

**IN THE UNITED STATES DISTRICT COURT
FOR THE EASTERN DISTRICT OF NORTH CAROLINA
SOUTHERN DIVISION
No. 7:23-CV-897**

IN RE:)	NOTICE OF CONTINUATION OF FILING
CAMP LEJEUNE WATER LITIGATION)	ADDITIONAL EXHIBITS REGARDING
This Document Relates To:)	UNITED STATES' MOTION TO EXCLUDE
ALL CASES)	PLAINTIFFS' PHASE I EXPERT
)	TESTIMONY IN SUPPORT OF USING
)	ATSDR'S WATER MODELS TO
)	DETERMINE EXPOSURE LEVELS FOR
)	INDIVIDUAL PLAINTIFFS

The United States files this Notice of Continuation of Filing Additional Exhibits in support of its Motion to Exclude Plaintiffs' Phase I Expert Testimony in Support of Using ATSDR's Water Models to Determinate Exposure Levels for Individual Plaintiffs and Memorandum in Support.

[Signature page to follow.]

Dated: April 29, 2025

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CERTIFICATE OF SERVICE

I hereby certify that on April 29, 2025, I electronically filed the foregoing using the Court's Electronic Case Filing system, which will send notice to all counsel of record.

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2	Feb. 13, 2025, Deposition Transcript of R. Jeffrey Davis
3	Jan. 16, 2013, Letter from ATSDR to Veterans Affairs
4	Aug. 3, 2015, Veteran Affairs Press Release
5	Expert Report of Morris Maslia
6	Rebuttal Report of Morris Maslia
7	March 28, 2005, ATSDR Expert Panel Transcript (Day 1)
8	March 29, 2005, ATSDR Expert Panel Transcript (Day 2)
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10	April 30, 2009, ATSDR Expert Panel Transcript (Day 2)
11	Expert Report of Mustafa Aral
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18	<i>The Handbook of Groundwater Engineering</i> , Chapter 20 on Groundwater Modeling by Leonard F. Konikow & Thomas E. Reilly
19	ATSDR “Chapter A: Summary of Findings” Report for Tarawa Terrace Model
20	Frank Bove, Morris Maslia et al., <i>Evaluation of exposure to contaminated drinking water and specific birth defects and childhood cancers at Marine Corps Base Camp Lejeune, North Carolina: a case-control study</i> 12 Env’t Health 104 (2013)
21	Jun. 19, 2008, Navy Letter to ATSDR
22	June 30, 2010, Deposition Transcript of Morris Maslia
23	March 10, 2009, ATSDR Response to Navy Letter
24	ATSDR Disclaimer for Tarawa Terrace Water Modeling
25	ATSDR “Chapter A: Summary of Findings” Report for Hadnot Point/Holcomb Boulevard Modeling
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35	Sept. 26, 2024, Deposition Transcript of Morris Maslia
36	Jan. 12, 2007, Email from Morris Maslia
37	Jan. 13, 2007, Email from Robert Faye

Exhibit	Description
38	Sept. 26, 2011 Email from Barbara Anderson

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Rebuttal Response to:
Reports of Alexandros Spiliotopoulos, Remy J.-C.
Hennet & Jay Brigham

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Glossary of Abbreviations and Acronyms

Definitions of terms and abbreviations used throughout this report are listed below.

A

AS Alexander Spiliotopoulos, Ph.D., DOJ Expert

ATSDR Agency for Toxic Substances and Disease Registry; codified under CERCLA, section 104(i), 42 U.S.C. §9604(i); <https://atsdr.cdc.gov>

B

BTEX Benzene, toluene, ethylbenzene, and xylenes

Bz Benzene

C

CERCLA The Comprehensive Environmental Response, Compensation, and Liability Act of 1980, also known as Superfund

CLW Camp Lejeune Water document

COC Contaminant or chemical of concern

D

DCE 1,1-dichloroethylene or 1,1-dichloroethene

1,2-tDCE *trans*-1,2-dichloroethylene or *trans*-1,2-dichloroethene

DON Department of the Navy

E

EDRP Exposure-Dose Reconstruction Program developed by ATSDR in 1993

EPA U.S. Environmental Protection Agency, <https://www.epa.gov>, also see USEPA

F

ft Foot or feet

ft³/d Cubic foot per day

G

Ga. Tech Georgia Institute of Technology, Atlanta, Georgia

g Grams

gpm Gallons per minute

H

HB Holcomb Boulevard

HBWTP Holcomb Boulevard water treatment plant

HP Hadnot Point

HPFF Hadnot Point fuel farm

HPIA Hadnot Point Industrial Area

HPLF Hadnot Point landfill

HPWTP Hadnot Point water treatment plant

I

J

JB Jay L. Bringham, Ph.D., DOJ Expert

L

LCM Linear control model; a model based on linear control theory methodology developed to reconstruct historical contaminant concentrations in water-supply wells

LHS Latin hypercube sampling

M

MODFLOW A family of three-dimensional groundwater-flow models, developed by the U.S. Geological Survey, <https://www.usgs.gov/mission-areas/water-resources/science/modflow-and-related-programs>

MT3DMS Three-dimensional mass transport, multispecies model developed on behalf of the U.S. Army Engineer Research and Development Center. MT3DMS-5.3 (Zheng and Wang 1999) is the specific version of MT3DMS code used for the Hadnot Point–Holcomb Boulevard study area analyses

MCL Maximum contaminant level

µg/L micrograms per liter; 1 part per billion

Model calibration The process of adjusting model input parameter values until reasonable agreement is achieved between model-predicted outputs or behavior and field observations

N

ND non-detect

NRC National Research Council

P

PCE Tetrachloroethene, tetrachloroethylene, 1,1,2,2-tetrachloroethylene, or perchloroethylene; also known as PERC® or PERK®

PDF Probability density function

R

RH Remmy J.-C. Hennet, Ph.D., DOJ Expert

ROD Record of Decision

S

SCADA Supervisory control and data acquisition

T

TCE 1,1,2-trichloroethene, or 1,1,2-trichloroethylene, or trichloroethylene

TechFlowMP A three-dimensional multispecies, multiphase mass transport model developed by the Multimedia Environmental Simulations Laboratory at the Georgia Institute of Technology, Atlanta, Georgia

TT Tarawa Terrace

TTWTP Tarawa Terrace water treatment plant

U

USMC U.S. Marine Corps

USMCB U.S. Marine Corp Base

UST Underground storage tank

V

VC Vinyl chloride

VOC Volatile organic compound

W

WDS Water-distribution system

WTP Water treatment plant

1.0 Introduction

I am Morris L. Maslia, P.E., a licensed Professional Engineer in the State of Georgia and a consulting engineer retained by the Camp Lejeune Plaintiffs' attorneys. On December 10, 2024, I was provided with electronic copies of the Expert Reports of Alexandros Spiliotopoulos (**AS**), Remy J.-C. Hennet (**RH**), and Jay L. Brigham (**JB**), who have been retained by the U. S. Department of Justice (DOJ). Their Expert Reports evaluate and review the Agency for Toxic Substances and Disease Registry's (ATSDR) water-modeling analyses and historical reconstruction conducted at U.S. Marine Corps Base (USMCB) Camp Lejeune, North Carolina, for the Tarawa Terrace (TT), Hadnot Point (HP), and Holcomb Boulevard (HB) water treatment plants (WTP), water-distribution systems (WDS), and associated service areas.

Purpose of Report

The purpose of this rebuttal report is to respond to certain positions as set out by the DOJ Expert Reports (authored by AS, RH, and JB), dated December 9, 2024 (Spiliotopoulos 2024, Hennet 2024, Brigham 2024). My responses are grouped by major topical areas discussed and presented in the DOJ Expert Reports and listed below (Section 4.0 of this report). This report is organized as follows:

- **Section 1.0:** Introduction
- **Section 2.0:** Purpose of Rebuttal Report
- **Section 3.0:** Agreed Upon Concepts and Facts
- **Section 4.0:** Response to Department of Justice (DOJ) Expert Reports
 - **Section 4.1:** Start Dates for Sources of Contamination
 - **Section 4.2:** Water-Supply Well Operations
 - **Section 4.3:** Volatilization of VOCs During Water Treatment Process
 - **Section 4.4:** Derivation and Computation of Sorption Parameter Values
 - **Section 4.5:** Model Calibration and Uncertainty Analysis
 - **Section 4.6:** Post-Audit of the ATSDR Tarawa Terrace Models
 - **Section 4.7:** Graphing and Visualization of Data and Model Results
 - **Section 4.8:** Non-Degraded and Degraded PCE Historical Reconstructions
 - **Section 4.9:** Additional Topics
- **Section 5.0:** Summary and Conclusions
- **Section 6.0:** References
- **Appendices A:** Volatilization Issues: Excerpts from ATSDR's Expert Panel Meetings, March 28, 2005 and April 30, 2009

3.0 Agreed Upon Concepts and Facts

Prior to providing responses to DOJ Expert Reports (Spiliotopoulos 2024, Hennet 2024, Brigham 2024), I set forth several fundamental concepts that are accepted as scientifically valid approaches and facts that can be agreed upon. These are listed below.

1. The Agency for Toxic Substances and Disease Registry (ATSDR) is a federal, non-regulatory public health agency codified in the Comprehensive Environmental Response, Compensation & Liability Act (CERCLA) of 1980, also known as Superfund (CERCLA 1980); 42 U.S.C. §9604(i).
2. ATSDR, overseen by the U.S. Department of Health and Human Services, is the lead federal public health agency for determining, preventing, and mitigating the human health effects of exposure to hazardous substances. It does this by responding to environmental health emergencies, investigating emerging environmental health threats, conducting research on health impacts of hazardous waste sites (public health assessments, epidemiological studies, and toxicological profiles), and building capabilities and providing actionable guidance to state and local health partners.
3. When data are limited or unavailable, ATSDR conducts exposure-dose reconstruction studies, which can include the use of environmental data, models (air, soil, water, and pharmacokinetic) or biomarkers to estimate and quantify environmental concentrations and exposures to toxic substances.
4. Historical reconstruction is an analysis and diagnostic method used to examine historical characteristics of groundwater flow, contaminant fate and transport, water-distribution systems, air dispersion, and exposure to contaminants (chemical and radiological) when data are limited or unavailable. It is an accepted method of analysis having been applied since the 1930s and described in many peer-reviewed publications (e.g., Costas et al. 2002, Grayman et al. 2004, Konikow and Thompson 1984), Maslia and Aral 2004, NRC 199), Rodenbeck and Masli, 1998, Rogers 1996, Samhel et al. 2010).
5. The mathematical, analytical, and numerical models (e.g., groundwater flow, contaminant fate and transport, and water-distribution system) used by ATSDR are accepted tools and practices among engineers, researchers, and scientists. These models approximate the physics of groundwater flow and contaminant fate and transport, which do not depend on professional judgment. The uncertainty in these models can be reasonably bounded and quantified to provide useful results of chemical exposure (EPA 1998).
6. The rationale and justification for using the historical reconstruction process, including models, at Camp Lejeune is precisely because historical data were limited and not available to ATSDR. As such, the models play an important role in providing insight, information, and quantitative estimates of environmental and exposure concentrations when data are missing, insufficient, or unavailable (Konikow and Thompson 1984, Maslia and Aral 2004).

4.0 Response to Department of Justice (DOJ) Expert Reports

In this section, I present rebuttal responses to DOJ Expert Reports by topical subject matter. The opinions in this report are based on my review of the DOJ Expert Reports, published literature, data

and documents made available to me while consulting on this case (e.g., Plaintiffs' and DOJ's Expert Reports) and my work and analysis during my work on the Camp Lejeune studies as an employee of ATSDR. I have reviewed and am relying upon the rebuttal expert reports of Dr. Leonard F. Konikow, Dr. Norman Jones/Mr. R. Jeffrey Davis, and Dr. David R. Sabatini. I hold the opinions expressed in this report to a reasonable degree of scientific and engineering certainty. I will produce a list of all materials I considered in reaching these opinions within seven days of service of this report. Many of the materials, documents, and data are also listed in the publicly available ATSDR reports on Tarawa Terrace (Maslia et al. 2007) and Hadnot Point-Holcomb Boulevard (Maslia et al. 2013, Appendix A2).

4.1 Start Dates for Sources of Contamination

4.1.1 ABC One-Hour Cleaners

The ATSDR Tarawa Terrace (TT) fate and transport modeling analysis applied a 1,200 gram/day (g/d) tetrachloroethylene (PCE) mass loading rate as the contaminant source at ABC One-Hour Cleaners. ATSDR used a contaminant (source) release date of January 1953. DOJ Experts (AS, RH, and JB) posit that July 1954 is a more appropriate start date for releases of PCE at ABC One-Hour Cleaners (Spiliotopoulos 2024, Section 4.1.2.1; Hennessey 2024, Opinion 3; Brigham 2024, Section IV.B). ATSDR relied upon the deposition (sworn testimony) of Victor Melts (owner of ABC One-Hour Cleaners) who testified on April 12, 2001 that he started ABC One-Hour Cleaners in 1953 and that he operated the company in the same location since 1953 (Melts 2001, p.6–7)¹. Additionally, in remedial investigation reports of the ABC One-Hour Cleaners site by Roy F. Weston, Inc. (1992, 1994)² a specific date for start of operations is not provided; rather, these documents indicate that ABC One-Hour Cleaners is a North Carolina corporation registered with the Secretary of State as of March 4, 1958. The U.S. Environmental Protection Agency's (EPA) Record of Decision (ROD) for the ABC One-Hour Cleaners Site (Section 2.1 Facility Operations and History)³ also does not provide a specific date for start of operations—it also indicates that ABC One-Hour Cleaners is a North Carolina corporation registered with the Secretary of State as of March 4, 1958. Without documented information and data as to the specific date for start of operations at ABC One-Hour Cleaners, ATSDR relied upon the sworn testimony of Victor Melts (Melts 2001, p. 6-7).

To test the effect of varying the start date for operations at ABC One-Hour Cleaners on reconstructed PCE concentrations, Plaintiffs' experts conducted a sensitivity analysis using the calibrated (and published) ATSDR Tarawa Terrace MODFLOW and MT3DMS input files (Maslia et al., 2007, provided on DVD). The sensitivity analysis consists of applying the following start date of operations (source release dates) at ABC One-Hour Cleaners:

- January 1953 (ATSDR calibrated model start date used in Faye 2008)
- January 1954 (+1 year from calibrated model start date)
- July 1954 (+1.5 years from calibrated model start date posited by DOJ Experts AS, RH, and JB)

¹ CLJA document 00897_PLG_0000067569 – 00897_PLG_0000067570.

² CLJA_WATERMODELING_09-0000083841; CLJA_WATERMODELING_09-0000084255.

³ CLJA_EPA01-0000383135 – CLJA_EPA01-0000383136.

- January 1955 (+2 years from the calibrated model start date)

Results of varying the start dates of operations at ABC One-Hour Cleaners (source release date) are shown in Figures 4.1A and 4.1B for reconstructed PCE concentrations at water-supply well TT-26 and the Tarawa Terrace water treatment plant (TTWTP), respectively. These results show that the calibrated TT modeled PCE concentrations are insensitive to these variations in source release date throughout much of the exposure period since these variations make a negligible difference in PCE concentrations from the calibrated reconstructed concentrations for the duration of the epidemiological study (1968-1985)⁴, as listed in Table 4.1. Additionally, the dates that the maximum contaminant level (MCL) for PCE of 5 ug/L is exceeded at water-supply well TT-26 and at the TTWTP, the duration of exceedance (in months), and the maximum reconstructed concentrations are listed in Table 4.2. Note the negligible changes from the calibrated ATSDR model results due to the variable start dates (Maslia et al. 2007; Faye 2008). Based on this sensitivity analysis, I conclude that the ATSDR calibrated models for reconstructing PCE concentrations are not sensitive to the start date of operations (source release date) at ABC One-Hour Cleaners. I stand by the ATSDR start of operations at ABC One-Hour Cleaners of January 1953, as documented in the sworn testimony of Victor Melts (2001) and applied by Faye (2008) as a more reliable start date.⁵

⁴ Reconstructed concentrations are shown for the start of the epidemiological study of January 1968 and the last in-service date of TT-26.

⁵ The evidence for ABC One-Hour Cleaners opening in 1954 as presented by Dr. Jay Brigham is circumstantial. Advertisements are subject to a lag in publication so that they may come out well after things have changed on the ground. Similarly, grand openings often occur well after a business has opened, when operations are more fully established. The sworn testimony of Mr. Melts is more reliable than the information provided by Dr. Brigham.

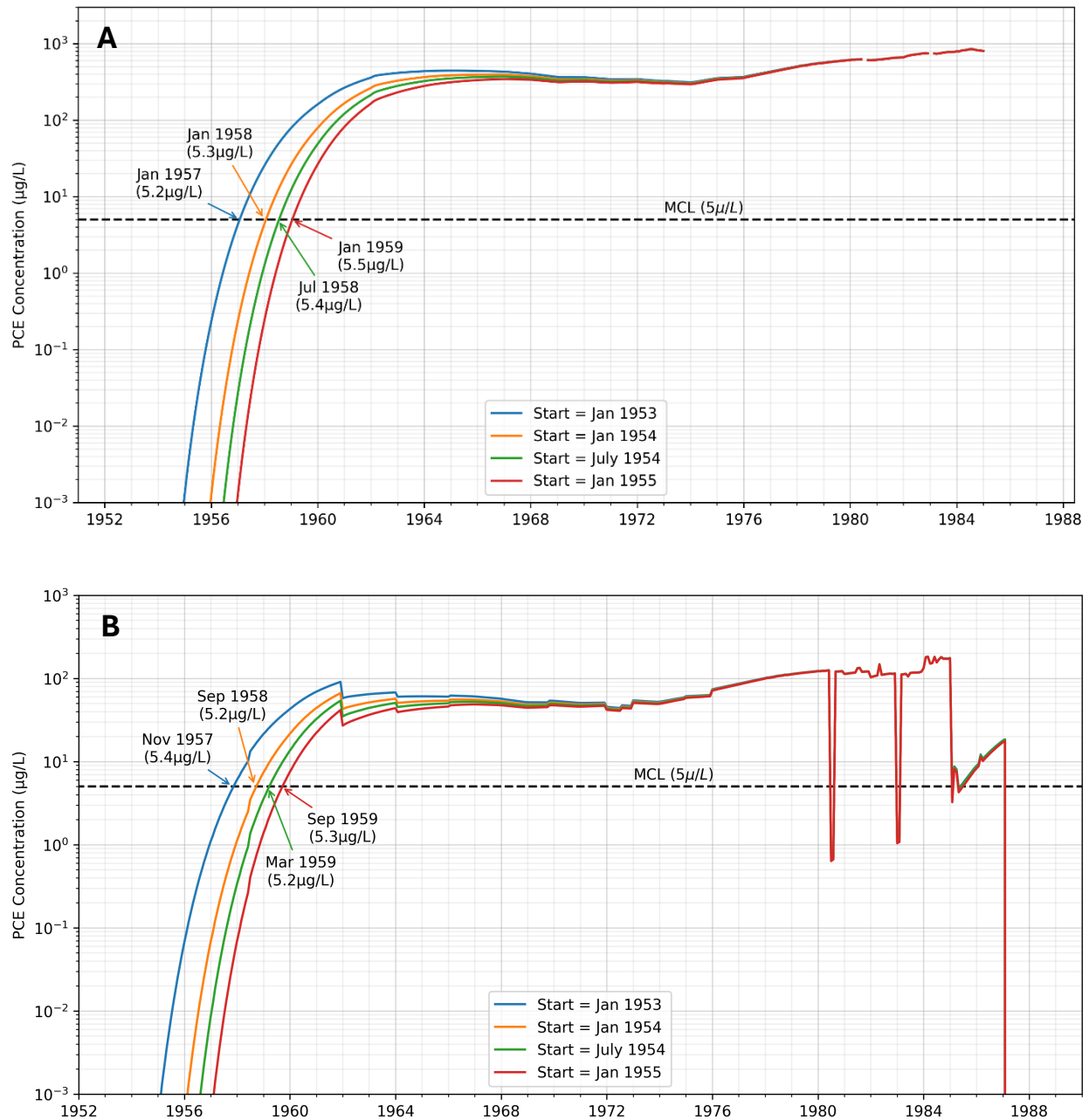


Figure 4.1. Plot of Modeled Concentration of tetrachloroethylene (PCE) with source release date variation: A, water-supply well TT-26 and B, Tarawa Terrace water treatment plant (TTWTP)

Table 4.1. Reconstructed PCE concentrations for variations in source release date at water-supply well TT-26 and the Tarawa Terrace water treatment plant (TTWTP)*

[µg/L, micrograms per liter, PCE, tetrachloroethylene]

Date*	January 1953 ⁺	January 1954	July 1954	January 1955
Water-supply well TT-26				
January 1968	402	373	356	336
January 1985	804	802	801	800
Tarawa Terrace water treatment plant (TTWTP)				
January 1968	57	53	51	48
January 1985	176	176	175	175

*Using calibrated ATSDR model parameter values and published model input files (Maslia et al. 2007)

*January 1968 is start of ATSDR's epidemiological study; January 1985 is last operating month for well TT-26

Table 4.2. Date reconstructed PCE concentration exceeds the MCL (5 µg/L), duration of exceedance, and date of maximum concentration for variations in source release date, at water-supply well TT-26 and at Tarawa Terrace water treatment plant (TTWTP)*

[MCL, maximum contaminant level; µg/L, micrograms per liter; PCE, tetrachloroethylene]

Source release date	Date exceeding MCL (5 µg/L)	Duration exceeding MCL, in months	Maximum PCE, in µg/L (date of occurrence)
Water-supply well TT-26			
Jan 1953 ⁺	Jan 1957	361	851 (Jul 1984)
Jan 1954	Jan 1958	349	849 (Jul 1984)
Jul 1954	Jul 1958	343	849 (Jul 1984)
Jan 1955	Jan 1959	337	847 (Jul 1984)
Tarawa Terrace water treatment plant (TTWTP)			
Jan 1953 ⁺	Nov 1957	351	183 (Feb 1984)
Jan 1954	Sept 1958	341	183 (Feb 1984)
Jul 1954	Mar 1959	335	182 (Feb 1984)
Jan 1955	Sept 1959	329	182 (Feb 1984)

*Using calibrated ATSDR model parameter values and published model input files (Maslia et al. 2007)

4.1.2 Hadnot Point Industrial Area and Landfill

In Section 4.2.3.2 (Spiliotopoulos, 2024, pp. 78-79), AS notes that ATSDR recognizes the lack of explicit data defining source locations and mass loadings but criticizes ATSDR for “arbitrarily assigning these quantities to the model to fit the limited water-quality data available starting in 1982.” However, AS's critique goes to the heart of the model calibration, history matching, and parameter estimation processes used in groundwater modeling. In these processes, parameter values are adjusted (either manually or automatically) to improve the fit (Hill and Tiedeman, 2007).

Furthermore, ATSDR conducted meticulous and detailed source characterization analyses, as documented in Maslia et al. (2013, Tables A6, A7, and A8). Table A8, shown below as Table 4.3 of this report, provides specific information relevant to documented source areas, timelines, primary contaminants, and locations of major dissolved sources for the HPIA and HPLF areas.

Table 4.3. Maslia et al. (2013), Table 8.

Table A8. Identification of documented source areas, timelines, primary contaminants, and location of major dissolved-phase sources, Hadnot Point–Holcomb Boulevard study area, U.S. Marine Corps Base Camp Lejeune, North Carolina.		
[HPFF, Hadnot Point fuel farm; UST, underground storage tank; AS/SVE, air sparging/soil vapor extraction; MW, monitor well; µg/L, microgram per liter; gal, gallon; LUST, leaking underground storage tank; CERCLA, Comprehensive Environmental Response, Compensation, and Liability Act of 1980; TCE, trichloroethylene; PCE, tetrachloroethylene]		
Source-area timeline [reference documents]	Primary contaminant; number of major sources	Location of major dissolved-phase sources
Hadnot Point Industrial Area (see Figure A13)		
Hadnot Point fuel farm events	Benzene; three sources	HPFF/Building 1115/Building 1101 free product footprint Building 1613 free product footprint Building 1601 locations of maximum measured benzene in groundwater (78-GW75-1 and 78-GW74) and former location of USTs and dispenser island at southeast corner of building; MW 78-GW75-1 (5,500 µg/L in 2003; 3,200 µg/L in 2004); MW 78-GW74 (3,200 µg/L in 2004) (See Figure A9 for building and monitor well [MW] locations)
1941 , HPFF USTs installed [UST #669, UST #670]		
1942 , Building 1115 USTs installed [UST #670]		
1993 January , HPFF and Building 1115 USTs removed [UST #1186, UST #670]		
2000 December , Piping removal (extensive) at HPFF/Building 1115 [UST #417]		
Building 1613 events	TCE; two sources	Building 1601 locations of maximum measured TCE in groundwater (MW 78-GW09-1 (old) and (new)) and former location of 1,500-gal waste UST on north side of building; MW 78-GW09-1 (old) (5,000–14,000 µg/L during 1987–1991); MW 78-GW09-1 (new) (at/above 1,000 µg/L during 1993–1996) Building 901/902/903 locations of max measured TCE in groundwater (MW 78-GW23; 13,000 µg/L in 1987), maximum measured vinyl chloride in groundwater (MW 78-GW44; 1,600–6,700 µg/L during 2000–2004), and former locations of USTs containing TCE/solvent waste at Building 901 and between Buildings 902/903. (See Figure A9 for building and monitor well [MW] locations)
1950s , USTs installed [UST #548, UST #546]		
1995 January , USTs and contaminated soil removed [UST #535, UST #548]		
1998–2004 , AS/SVE remediation system operated		
Building 1601 events		
1940s , Building 1601 built [UST #172, UST #195] UST removal date unknown	PCE and TCE; one source	Location of maximum measured concentration of TCE and PCE in groundwater (MW 06-GW01D) TCE ranged from 6,400 to 180,000 µg/L during 1992–2004; PCE ranged from 210 to 6,500 µg/L during 1992–2004 (See Figure A10 for monitor well [MW] locations)
Building 1601 events		
1940s , Building 1601 built [UST #172, UST #195]		
1942 , 1,500-gal UST install date listed in LUST study completed in 1990 by Geraghty and Miller [UST #504, UST #507]		
1993 June 29 , UST excavated/removed [UST #624]		
Building 901/902/903 events	PCE and TCE; one source	Location of maximum measured concentration of TCE and PCE in groundwater (MW 06-GW01D) TCE ranged from 6,400 to 180,000 µg/L during 1992–2004; PCE ranged from 210 to 6,500 µg/L during 1992–2004 (See Figure A10 for monitor well [MW] locations)
1948 , Buildings 900, 901, 902, 903 constructed [CERCLA #258, p. 149]		
TCE UST installation date unknown; removal/abandonment date unknown, but probably occurred prior to onset of remediation efforts around January 1995 [Sovereign Consulting, Inc. 2007]		
Landfill		
1940s , reportedly used as a waste disposal area (Site 6 and Site 82; Figure A8) beginning in the 1940s		

¹ UST # refers to UST Web Management Portal file number (see References section of this report for complete details); CERCLA # refers to CERCLA Administrative Record file number (provided on digital video disc [DVD] in Maslia et al. 2007)

ATSDR does indeed discuss the lack of data to define the source loading terms for the model in the Hadnot Point Industrial Area (HPIA) and Hadnot Point landfill (HPLF) areas. However, as Dr. Konikow (2025) notes and I agree, there is no doubt that these chemical contaminants (including TCE and PCE) were present in the groundwater at toxic concentrations (substantially exceeding the MCLs⁶) in these areas, and that they were pumped out of the aquifer by several operating water-supply wells shown in Maslia et al. (2013, Figures A9 and A10) and provided below as Figures 4.2 and 4.3.

In AS's summary for his Opinion 14 (Spiliotopoulos, 2024, p. 79), ATSDR is criticized for having “assumed constant mass loading of the same magnitude at all sources for more than 40 years,” which he believes is “highly uncertain, if not impossible.” I disagree. ATSDR applied an average rate over the critical period because there was no basis for determining how the loading might have varied over time. This approach aligns with accepted groundwater flow and contaminant fate and transport modeling best practices. The fact that the model with a constant mass loading adequately reproduced observed concentrations supports ATSDR's method for modeling the sources at Hadnot Point Industrial Area and Hadnot Point landfill. (Konikow 2025)

Finally, ATSDR reviewed an EPA study (USEPA 1986, 1986) of 12,444 leak incident reports to estimate the timing of UST releases at Hadnot Point. This is certainly not “arbitrary and uncertain.” Reliance upon such a comprehensive study is an accepted methodology; it is not “arbitrary.” In summary, ATSDR based parameter values on the best data it had available, including site-specific and published data. ATSDR also made appropriate adjustments to parameters to fit site-specific conditions.

⁶ MCL, maximum contaminant level; 5 µg/L for PCE and 5 µg/L for TCE.

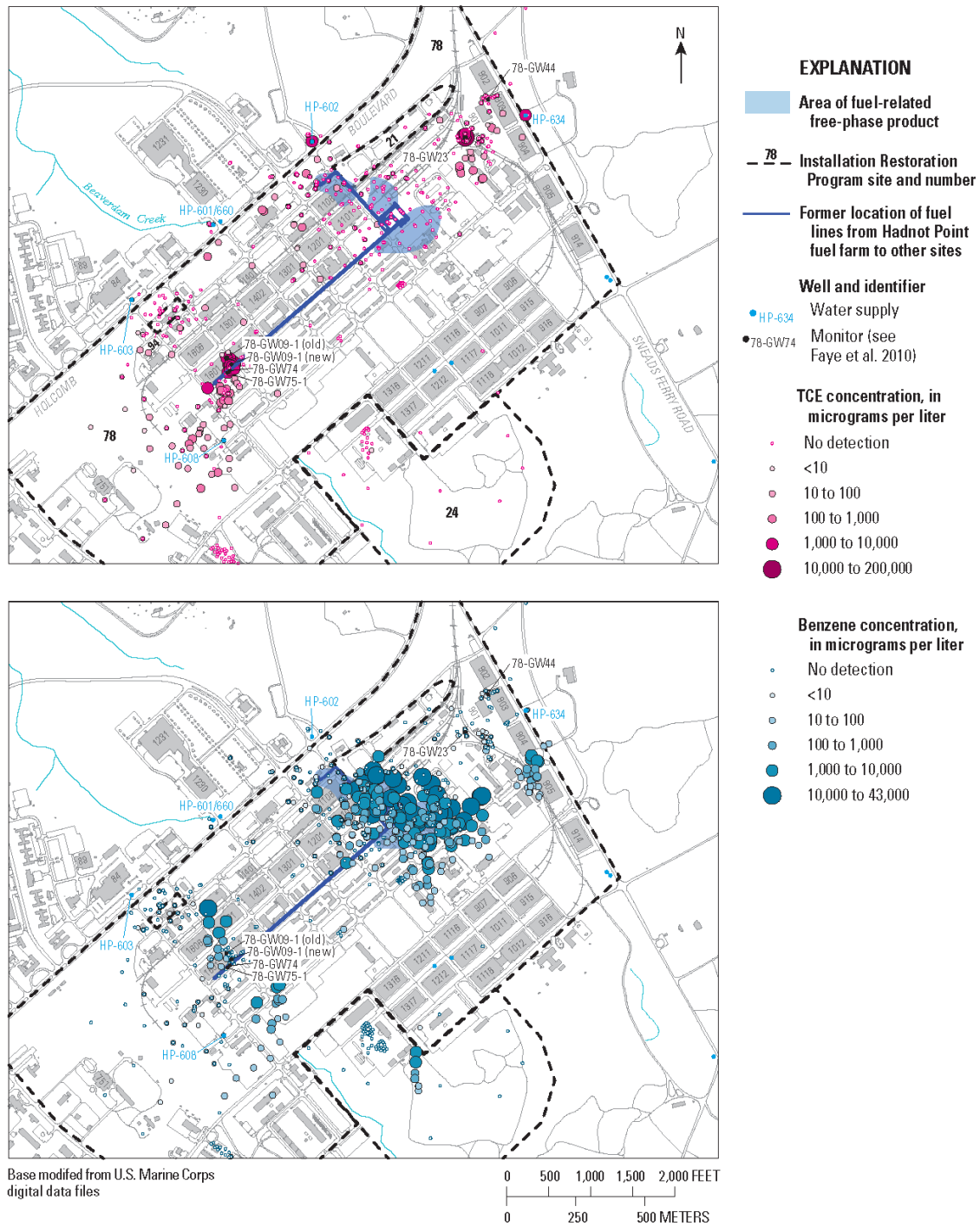


Figure A9. Sampling data for trichloroethylene (TCE), benzene, and fuel-related free product in groundwater for the Hadnot Point Industrial Area, Hadnot Point–Holcomb Boulevard study area, U.S. Marine Corps Base Camp Lejeune, North Carolina. (See Figure A8 for location and Figure A13 for selected building numbers.)

Figure 4.2. From Maslia et al. (2013), Figure A9

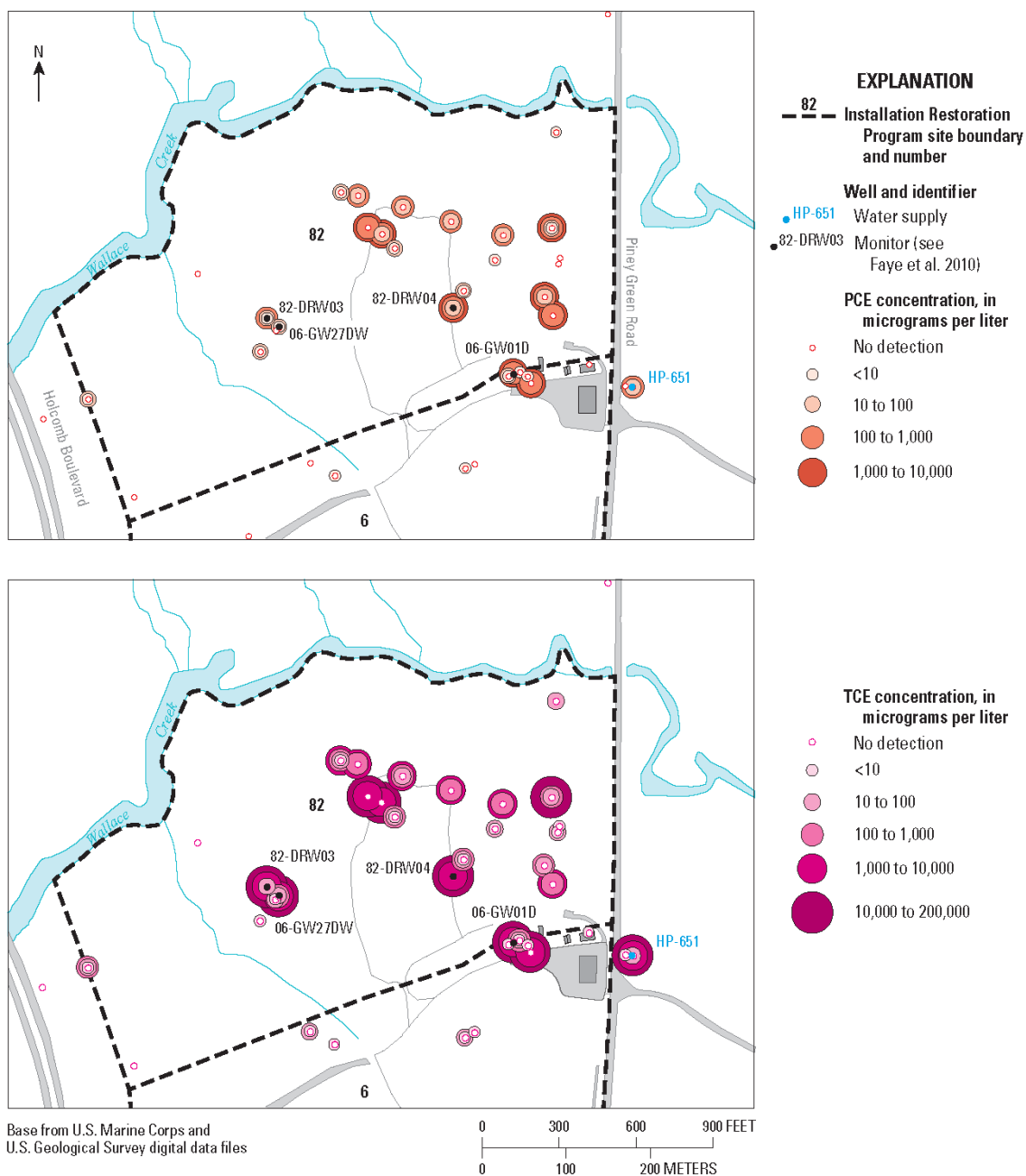


Figure A10. Sampling data for tetrachloroethylene (PCE) and trichloroethylene (TCE) in groundwater for the Hadnot Point landfill area, Hadnot Point–Holcomb Boulevard study area, U.S. Marine Corps Base Camp Lejeune, North Carolina. (See Figure A8 for location.)

Figure 4.3. From Maslia et al. (2013), Figure A10

4.2 Water-Supply Well Operations

4.2.1 Tarawa Terrace

In his opinion 5, Spiliotopoulos (2024, Section 4.1.2.6) posits that the ATSDR groundwater model for TT resulted in “biased-high estimates of monthly contaminant concentrations” at water supply well TT-23. (his Section 4.1.2.6). I concur with Dr. Konikow’s assessment of opinion 5:

Section 4.1.2.6 (p. 42) offers no clear evidence that the discrepancy at this one well (out of many) has a substantial impact on the overall results. Based on ATSDR Table E2, of the nine unique sampling dates for this well, six had an observed level of PCE or TCE above the MCL. Furthermore, with respect to the overall effect on concentrations estimated at the WTPs, it is important to note that TT-23 was operational for only about 9 months or less, starting in 1984, and had the shortest operational (pumping) period of any of the 16 pumping wells operating in the TT area (see Table H3 in Chapter H of the TT series of reports). When it was pumping, the contribution from this well provided only a small fraction of the total groundwater inflow to the WTP with concentrations far less than well TT-26 (with its modeled concentrations likely being underestimated). Thus, if indeed the estimates for this well were too high (by less than two times), the effect on calculated concentrations in the WTP would be minimal both in magnitude and in duration.

(Konikow 2025).

With respect to calibrated ATSDR models being “biased high” as posited by DOJ experts, the opposite is true. For example, Figure 4.4 from Faye (2008, Figure F16)⁷ shows a plot of observed data (5 of the 6 samples were obtained within a week’s time) and reconstructed PCE concentrations for water-supply well TT-26. Note that the highest and first sample was taken during the period when this well was in service, as compared to the remaining samples when this well was out of service. If anything, it could be argued that the model is under-predicting the concentrations. Furthermore, note that reconstructed PCE concentrations fell almost exactly at the midpoint of the range of observed values (about 800 ug/L)—countering the claim of being biased high and confirming the adequateness and acceptability of the calibrated ATSDR models including the reconstructed supply-well operations. As with well TT-23 discussed above, the first sample from well TT-26 was taken when it was operating, and the remainder of the samples were taken after well TT-26 was permanently removed from service.

⁷ CLJA_WATERMODELING_01-0000488379.

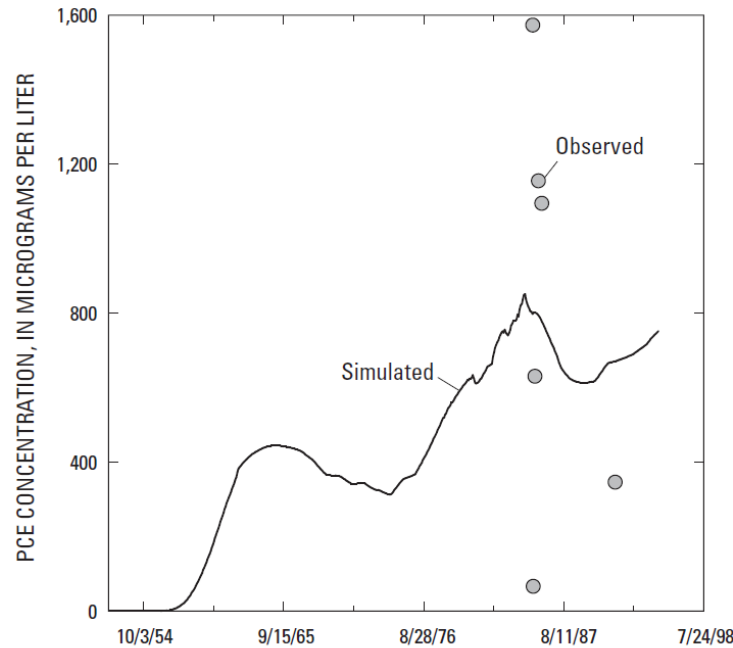


Figure F16. Simulated and observed tetrachloroethylene (PCE) concentrations at water-supply well TT-26, Tarawa Terrace, U.S. Marine Corps Base Camp Lejeune, North Carolina, January 1952–December 1994 (see Figure F6 for location).

Figure 4.4. From Faye (2008), Figure F16.

4.2.2 Hadnot Point

In Section 4.2.2 (Spiliotopoulos, 2024, p. 72), the claim is made that ATSDR “made arbitrary assumptions to reconstruct pumping history...” I agree with Dr. Konikow who, after reviewing the ATSDR’s historical reconstruction, concluded:

In my opinion, the assumptions were not arbitrary, but rather were well-informed, well-reasoned, and carefully documented. Assumptions had to be made about the pumping history, and they were made, but they were not arbitrary. For example, Dr. Spiliotopoulos notes that “Yearly volumes are available for some years prior to 1980. A trendline was used to estimate raw-water flows for years prior to 1980 when no data exist.” This appears to be a sound statistical approach, and the use of a trend line is certainly not arbitrary.

In Section 4.2.2 (p. 72-73) Dr. Spiliotopoulos offers a further criticism that “it was assumed that a well would be operated in the historical period based on a pattern similar to the more recent ‘training period,’ with further adjustments to account for information on the varying capacity of wells, where available.” Dr. Spiliotopoulos’ statement actually

contradicts his assertion that estimates were arbitrary. Here he describes a reasoned and reasonable approach to estimating a pattern of past water use (well pumpage)—an approach that is not “arbitrary.”

In several additional paragraphs on p. 73 (as well as elsewhere), he repeats the claim that pumping rates were based on arbitrary assumptions. ATSDR uses sound statistical methods (such as regression and correlation) to estimate pumpage. This is neither arbitrary nor unreasonable.”

(Konikow 2025)

ATSDR developed and applied a sophisticated and novel pumping schedule algorithm for the nearly 100 water-supply wells serving Hadnot Point and Holcomb Boulevard. They did this by using a “training period” when pumping data are known (typically, present-day) and a “predictive period” when pumping data were unknown. Details of this methodology are provided in Telci et al. (2013)⁸ and are the basis for the pumping schedules assigned to wells supplying the HP-HB service areas. Similar wells managed by the same operating authority (e.g., the Camp Lejeune Water Utilities Department) are likely to have been operated in a similar manner—however, in the early years of operations they simply were not required to maintain as detailed records (e.g., SCADA data) as would be expected today. AS does not offer a better or more reasonable approach than the one used by ATSDR.

4.2.2.1 HP-634

In Section 4.2.3 (Spiliotopoulos 2024, p. 77), AS states that model calibration was “improperly influenced” by “erroneous concentrations reported for well HP-634 ... while non-detections were ignored.” Documentation and discussion below provide evidence that the concentration in well HP-634 (sampled on 1/16/1985) of 1,300 µg/L of TCE was not an erroneous concentration. Furthermore, non-detections were not ignored. They are clearly listed and labelled in many tables presented in the ATSDR reports (e.g., Maslia et al. 2013, Table A4) and in many other places in ATSDR reports (Faye et al. 2008; Faye et al. 2012).

There are certain documents that show that well HP- 634 was (temporarily) shut down on 12/10/84 when methylene chloride was found in the sample; however, the documents below demonstrate that well HP-634 was operating until early February 1985.

The first document is cited in RH’s footnote 111 (Hennet 2024, p. 5-31, footnote 111).⁹ In the callout of the wells out of service on 1/16/1985, HP-634 is not among those listed, suggesting that the well was still in service on this date. January 16th is when the 1,300 µg/L sample was taken at HP-634.

⁸ CLJA_WATERMODELING_05-00001005675 – 05_00001005810.

⁹ CLJA_CLW00000004559

WELLS SHOWING NO DETECTABLE CONCENTRATIONS, ASSUMING A DETECTION LIMIT OF 10 UG/L:

606 632 640
609 633 641
611 635 642
613 636 652
614 638 653
616 639-D 655
620 639-N LCH 4007
621
627

WELLS OUT OF SERVICE AND COULD NOT BE SAMPLED ON 16 JAN 1985:

610
615
654
LCH 4006

*LEGEND

a = Trichloroethylene	g = toluene
b = 1,2-trans-dichloroethylene	h = 1,1-dichloroethane
c = chloroform	i = tetrachloroethylene
d = benzene	
e = bromodichloromethane	
f = methylene chloride	

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- **Event #1:** Well HP-634 is tested with other wells on 12/10/1984.
- **Event #2:** Test samples from 12/10/84 are back with "Wells 634 and 637, previously showing nothing, showed significant levels of Methylene Chloride (MC). 634 and 637 were shut down."
- **Event #3:** This is a key statement: On Jan. 16, 1985, "Sampled all operating wells for HP and Holcomb Blvd Water Plant (HB). 37 wells". The key being all **operating** wells.

Further documentation that supports the fact that HP-634 was operating on 1/16/1985 when the sample was taken is provided in CLW4546,¹⁰ which is a chronological listing of events from 11/30/1984 to 2/25/1985. A portion of that document covering 12/10/84 to 1/16/85 is shown below.

1

10 Dec Sampled HP treated water, plus Wells 601, 602, 608, 634, 637 and 642

13 Dec Took Quality Control (QC) samples of 602, split three ways.

13-19 Dec Took daily samples of HP raw water.

2

14 Dec Received results of 10 Dec 84 sampling (Table [2]). Treated water levels dropped. Wells 634 and 637, previously showing nothing, showed significant levels of Methylene Chloride(MC). 634 and 637 were shut down.

19 Dec Took a distribution sample from HP. Location was FC-540, far point from plant.

21 Dec Received results of daily HP samples (Table [3]), plus JTCs QC sample and FC-540. The QC samples from JTC and Grainger (received later) confirmed the presence of TCE and DCE.

3

16 Jan 85 Sampled all operating wells for HP and Holcomb Blvd Water Plant (HB). 37 wells.

On page 6 of the same document (Table [5])¹¹ the 37 wells tested on 1/16/85 are listed and HP-634 is on the list, and shows a sampled concentration for TCE of 1,300 µg/L.

Table [5]

LAB: JTC Sampled: 16 January 1985 Detection Limit: 10ppb

Well	DCE	TCE	PCE	VC	11D
1 601	8.8	26	ND	ND	ND
2 634	700	1300	10	6.8	ND
3 651	3400	3200	386	655	187
4 652	ND	9.0	ND	ND	ND
5 653	ND	5.5	ND	ND	ND

None Detected:	6 603	16 632	26 642	Broken Samples:	35 602
	7 606	17 633	27 643		36 608
	8 609	18 635	28 644		37 645
	9 611	19 636	29 646		651
	10 613	20 637	30 647		
	11 614	21 638	31 648		
	12 616	22 639(OLD)	32 650		
	13 620	23 639(NEW)	33 655		
	14 621	24 640	34 LCH 4007		
	15 627	25 641			

See Note 3.

¹¹ CLJA_WATERMODELING_09-0000424938

Further support for the fact that HP-634 was only temporarily closed comes from an email dated 4/11/1989 (Bates CLJ16100/CLW1818) from the Supervisory Chemist to the Director of the Natural Resources and Environmental Affairs Division with the subject "WATER MONITORING RELATED TO THE INSTALLATION RESTORATION (IR) PROGRAM".

On page 2 of the document (CLJ161101/CLW1819) bullet 6 states certain wells were tested on 12/4/1984 including HP-634:

6. On 4 Dec 84, the Hadnot Point Water Treatment Plant's raw and treated water was sampled as well as any drinking water wells within a mile of the Hadnot Point Fuel Farm or Bldg 602. The Bldg numbers sampled were:

601 603 608 634 642

Bullet 8 on the same page states that methylene chloride was found in wells 634 and 637 during a 2nd sampling on 12/10/1984. "The wells were temporarily closed until it was determined that the methylene chloride was probably a laboratory contaminant."

8. From 10-31 Dec 84, duplicate and quality control samples were run to confirm the presence of TCE, DCE and PCE in the wells. Wells 634 and 637, on the second sampling showed Methylene chloride. The wells were temporarily closed until it was determined that the methylene chloride was probably a laboratory contaminant. It was determined that all drinking water wells would be analyzed for volatile organic chemicals (VOCs) to start in January 1985.

CLW

0000001819

Bullet 9 (CLJ611102/CLW1820) states 37 wells serving HP and HB were tested on 1/16/1985.

9. 16 Jan 85. 37 wells serving the Hadnot Point and Holcomb Blvd water plants were sampled.

Bullet 13 on the same page states “On 1 Feb 85, the 31 Jan 85 samples showed that there was still a contaminated well operating in the Hadnot Point system. The results of the 16 Jan 85 sampling were phoned into Natural Resources and showed high levels of TCE in 651.” At the end of the bullet text it states, “Well 634 showed TCE also and was shut down”.

13. On 1 Feb 85, the 31 Jan 85 samples showed that there was still a contaminated well operating in the Hadnot Point system. The results of the 16 Jan 85 sampling were phoned into Natural Resources and showed high levels of TCE in 651.
Well 651 is located on the back side of DRMO's disposal storage lot. It was not initially sampled as being in proximity to a NACIP site. It had the highest levels of TCE found. The concentration was in the 17,000 to 18,000 ppb range. Well 651 was shut down. Well 634 showed TCE also and was shut down.

This statement supports the facts that HP-634 was “temporarily closed”, as stated in bullet 8, and that the well was shut down for TCE - not methylene chloride.

Therefore, based on the documentation regarding water-supply well HP-634, the claims made by the DOJ Experts (Spiliotopoulos 2024, Hennem 2024) are incorrect. HP-634 was operating on the date it was sampled on Jan. 16, 1985; the result was 1,300 µg/L of TCE; and the well was shut down due to this high TCE concentration.

4.2.2.2 HP-651

RH (Hennem 2024, p. 5-28 and 5-29) posits that well data covering 11/28/1984 to 2/5/1985 (CLJA_CLW00000006590 – 6593) should be used as the basis for determining HP-651's contribution to the HPWTP finished water concentrations from 1972 to 1985. The paragraph below summarizes RH's position:

“The average concentration measured for TCE in HP-WTP over the period January 21 to February 5, 1985, is 582 µg/L. During this period it is known that HP-651 was being pumped (RH, p. 4-19, Exhibit I-9). Considering that HP-651 was being pumped 39% of the time (0.39 frequency of pumping; Exhibit I-9) yields a TCE long-time average concentration of 227 µg/L for HP-WTP supplied water.

$$0.39 \times 582 \text{ (}\mu\text{g/L)} = 227 \text{ (}\mu\text{g/L).”}$$

RH presents a table that represents the data in CLJA_CLW00000006590 – 6593 in an Excel™ spreadsheet. Using these data he determines that over the 69 days covered, well HP-651 only was operating 39% of the time so this is the value that should be used over the entire life of well HP-651, which is from 7/72 to 2/85 or 12.6 years. In doing so RH either fails to realize or does not disclose that these two months of well operation from 11/28/1984 to 2/7/1985 are anything but ordinary and therefore, should not be used as the basis for any long-term forecasting of pumping schedules. Below I discuss the reasons why the 69-day period selected by RH is not reliable and should be disregarded.

- **Point 1:**

The 11/28/1984 to 2/5/1985 period should be broken into months and not as a 69-day pumping period. The ATSDR pumping schedules are based on months as their base unit. If this is done for well HP-651 the results for days of operations and percentage of time operating are as listed in Table 4.4.

Table 4.4. Monthly pumping schedule for well HP-651, December 1984 – and January 1985.

Month	Days of Operation	Percentage on
December 1984	2	6%
January 1985	18	58%

These results should make the modeler question whether there is an explanation for the HP-651's low operation in December. The most logical explanation involves wells New 623, New 622, New 629, New 661 and New 662. These 5 wells were new wells brought online from 6/1984 to 10/1984 and represent over 1,200 (gallons per minute (gpm) of combined capacity. The frequency with which they were in operation ranged from a low of 61% to a high of 94% (Table 4.5). Certainly, the addition of these 5 new wells had an effect on the pumping schedule at HPWTP.

Table 4.5. Characteristics of New Hadnot Point Wells, June–October 1984.

[DOB, construction completion date; gpm, gallons per minute; HP, Hadnot Point; %, percent]

HP Well ID	Other Name	Well DOB	Original Capacity, in gpm	Dec 84 — Jan 85 Capacity, in gpm	Well age as of 2/85	December 84 Operating Days	%	Jan 85 Operating Days	%	Total Days	% On
611	(New 623)	8/1/1984	360	242 (9/85)	0.5	27	87%	30	97%	61	87%
614	(New 622)	6/1/1984	323	320 (9/85)	0.7	23	74%	30	97%	57	81%
621	(New 629)	10/1/1984	NA	NA	0.3	26	84%	16	52%	43	61%
627	(New 661)	8/1/1984	192	280 (10/84)	0.5	28	90%	31	100%	66	94%
639 (New)	(New 662)	10/1/1984	146	146 (10/83)	0.3	26	84%	26	84%	59	84%

- **Point 2:**

The lack of use of well HP-651 in December 1984 had nothing to do with the well's capacity as demonstrated by its capacity tests. Well HP-651 Capacity Data listed on page S1.71 of the HPHB Chapter A–Supplement 1 (Sautner et al. 2013)¹² Descriptions and Characterizations of Data Pertinent to Water-Supply Well Capacities, Histories, and Operations show the last capacity test

¹² CLJA_WATERMODELING_05-0000826112, found in CLJW_WATERMODELING_05-0000826036 – 05-0000826153

was 10/29/1984 and the well operated at 242 gpm—which ranks in the Top 10 highest capacity wells at the time.

Table 4.6. Sautner et al. (2013), p. S.71.

Well HP-651			
[gpm, gallon per minute; —, no data; VOC, volatile organic compound; USGS, U.S. Geological Survey]			
Date	Capacity, in gpm	Operational status	Data source
12/30/1971	200	Construction completed	Driller ¹
7/1/1972	—	In service	Estimated date
1/1976	—	In service	CLW-4039
3/31/1977	190	In service	Well capacity test
1/1978	—	In service	Operation records
1/10/1979	167	In service	Well capacity test
2/13/1980	178	In service	Well capacity test
7/26/1981	232	In service	Well capacity test
1/1982	—	In service	Operation records
9/14/1983	239	In service	Well capacity test
10/29/1984	242	In service	Well capacity test
1/1985	—	In service	Operation records
2/1985	—	“Contaminated”	Operation records
2/4/1985	—	Out of service	CLW-4913 ²
2/4/1985	—	Service terminated	CLW-4913 ²
6/1994	—	Abandonment	AH Environmental Consultants ³
¹ Corbin Construction Company, written communication, December 30, 1971			
² Well secured due to VOC contamination			
³ AH Environmental Consultants, Inc., electronic communication, September 3, 2004			
Data sources:			
CLW, Camp Lejeune Water Documents 3559–3561, 3573–3575, 3585–3587, 3588–3590, 3641–3643, 3644–3646, 3772–3774, 3775–3777, 3996–3997, 3998–4000, 4044–4046, and 4047–4049			
USGS, operation records, written communication, March 2004			

- **Point 3:**

When compared to other wells that were supplying raw water during that time, well HP-651’s age is also not a reason for its lack of operation in December 1984. Well HP-651’s completed construction date (a/k/a/ DOB) was 7/1/1972 making it only 12.6 years old as of 2/1/1985. In comparison, well HP-616 operated at 57% in December 1984 and its DOB is 1/1/1943 making it 42.1 years old on 2/1/1985. Its last capacity test placed it at 210 gpm—still substantial, especially considering its age. The same holds true for well HP-632. In December 1984 it operated at 64% at an age of 27.7 years (DOB 5/27/1957). When tested on 10/1984 its capacity was 201 gpm.

- **Point 4:**

The fact that well HP-651 only operated at 6% could also be attributed to the pumping schedule being used at the time. As outlined extensively in ATSDR's reports (Telci et al. 2013),¹³ ATSDR used current (2008) pumping data as a "training period" to reconstruct well operations during the historical period ("predictive period"). On those wells that were shut down due to contamination, "surrogate wells" were used for the "training period" (Telci et al. 2013, Table S2.2)¹⁴. HP-651 was shut down in February 1985 so well HP-633 was used as its surrogate. If we look at the historic pumping schedule that was created for HP-651 based on HP-633 we see there is a cycle:

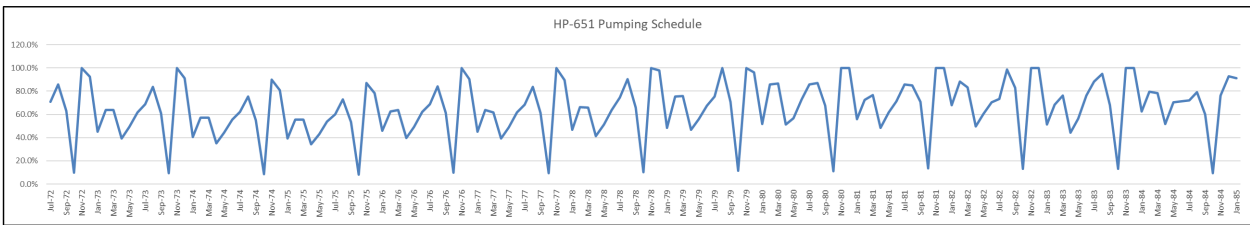


Figure 4.5. Reconstructed historical pumping operations for well HP-651 (from Telci et al. 2013)

In the reconstructed pumping operations cycle, well HP-651 drops below 10% every October. This cycling was common for several reasons, including substantial reductions in consumption and demand owing to deployment of troops and climatic conditions where October and generally Fall to early Winter are "wet months." It is very possible that the actual low-cycle month for HP-651 was December and not October, which would explain the 6% value of operation time for December of 1984.

In addition to those points outlined above there are other reasons why this period should not be used to represent normal operation of not only HP-651 but the well field in general.

- **Reason 1**

The first and foremost reason why this is not a representative time period is because November 30, 1984 marked the start of the investigation into the sources of contamination at HP. Well HP-602 was shut down on 11/30/1984. Additional testing on 12/4/1984 and 12/10/1984 resulted in well HP-608 being shut down permanently on 12/6/1984 and wells HP-634 and HP-637 being shut down temporarily on 12/14/1984. This disruption is not a normal occurrence and therefore adds to the reasons why this period of time should not be used to determine historic pumping schedules for any wells.

- **Reason 2**

As outlined in my Expert Report (Maslia 2024) the HBWTP had to be shut down from 1/27/84 to 2/7/85 due to a fuel line contaminating the HB water supply. During this time HPWTP had to supply

¹³ CLJA_WATERMODELING_05-00001005675 – 05-00001005810.

¹⁴ CLJA_WATERMODELING_05-00001005695.

all finished water for the HB area, in addition to its own, which is not representative of normal operation.

- **Reason 3**

Based on ATSDR's research into Camp Lejeune's water treatment plant's operations, it became apparent that the WTP operators would not cease operating a 12.6-year-old well (HP-651) that at 12 years of age is still producing more than 240 gpm. In July 1972, well HP-651 would have been operated very similar to that of the new wells discussed previously—wells New 623, New 622, New 629, New 661 and New 662, which were operated at 70% – 100% capacity.

- **Reason 4**

Camp Lejeune is a military base. Therefore, production and consumption of water are determined by demands for: (a) fire protection, (b) housing, facilities, and recreation, (c) utility requirements (steam and heat production), (d) troop deployments, (e) leave for rest and relaxation, and (f) a combination of (a)-(e) above. ATSDR staff observed an example of the impact of troop deployment on production and consumption of water supplies during the conduct of a field test of the HPWTP service area during May 2004 (Sautner et al. 2005). During this field test, ATSDR requested that Camp Lejeune water utility operators increase normal water production of the HPWTP from about 1,600 gpm to about 2,100 gpm so ATSDR could conduct tracer tests. On the final day of the test, water utility staff told ATSDR that they would need to reduce production back to the 1,600 gpm at the HPWTP because they were “spilling water from the elevated storage tanks.” Camp Lejeune water utility staff indicated that a substantial reduction in demand was being observed because of troop deployments.

RH's position on well HP-651 is an attempt to lower concentrations that occurred at Camp Lejeune during 1953 – 1987 using incorrect and/or select, non-representative data. RH's contentions regarding HP-634 are incorrect and the same holds true for HP-651. Supply well HP-651 was a major contributor to the raw water supply from June 1972 – February 1985, and the ATSDR reconstructed pumping schedule accurately reflects well HP-651's overall operation. RH's claim of 39% lifetime operation is made without a thorough review of the documents he is relying on to support his position.

4.3 Volatilization of VOCs During Water Treatment Process

DOJ expert (RH) posits that a substantial portion of chemicals of concern in the raw water was unavoidably lost during subsequent storage, treatment, and distribution (Hennet 2024, Section 5, Opinion 2). His report goes through numerous calculations that he claims show substantial percentages of VOCs volatilizing off during the water treatment and storage process at the WTPs (Tarawa Terrace and Hadnot Point).¹⁵ For example, in Hennet's Exhibits 2-4 and 2-5 (2024, p. 5-6 – 5-11) he computes an “Overall Evaporative Removal” of VOCs of concern at the HPWTP as: 18.34% (PCE), 17.07% (TCE), 22.41% (1,2-tDCE), 32.48% (VC), and 15.12% (Benzene). For the TTWTP, Hennet computes the “Overall Evaporative Removal” of VOCs of concern as 18.84% (PCE), 17.63% (TCE), 23.23% (1,2-tDCE), 33.41% (VC), and 15.68% (Benzene). These calculations

¹⁵ The Holcomb Boulevard WTP (HBWTP) was never supplied with contaminated raw water.

substantially exceed values of volatilization computed by the consultant to the U.S. Marine Corps (USMC), AH Environmental Consultants in its December 2004 report on Estimation of VOC Removal (AH Consultants 2004).¹⁶ Specifically, Section 5 (Summary) of the AH Consultants report states:

“The calculations revealed that VOC removal due to volatilization from quiescent basins was negligible at MCB Camp Lejeune. The only significant VOC removals must have occurred at the spiractor effluent pipe, where the falling water undergoes some aeration. Considering the uncertainty in the estimates for the fall height over the weir formed by the pipe, the removals for TCE and PCE were likely to be less than 15%.”¹⁷

Earlier in its report, AH Environmental Consultants (2004, (pages 4-1 – 4-2) found that “volatilization due to aeration at the spiractor effluent pipe resulted in TCE and PCE removals of 6.1% and 7.7% at the design flow rate 700 gpm, respectively. ... A sensitivity analysis showed that the fall height has the largest effect on VOC removal at a weir.” This sensitivity analysis conducted by AH Environmental Consultants (2004) found that removal of PCE and TCE is nearly proportional to the fall height from the spiractor. AH Environmental Consultants (2004) went on to explain that the fall height at Hadnot Point was only 1 foot but at Holcomb Blvd it was 2 feet. It was this uncertainty along with “additional uncertainties ... introduced by varying head losses in the pipes caused by calcium carbonate scale build-up and manual cleaning” that led AH Environmental Consultants (2004) to state at page 4-4 that “it is estimated that PCE and TCE removals due to aeration at the spiractor effluent pipes are likely to be *no larger than* 15%.”

To assess the DOJ expert’s (RH) calculations and conclusions, Dr. David R. Sabatini conducted a detailed analysis of the volatilization of VOCs for the Camp Lejeune WTPs including volatilization from mobile water units (a/k/a water buffaloes¹⁸), and this analysis is adopted and incorporated by reference into this report. Results of this analysis are summarized by Sabatini (2025, Section 5.1.4) for the TTWTP and HPWTP are listed Table 4.7 (Sabatini (2025, Table 5.3).

Table 4.7. From Sabatini (2025), Table 5.3.

Source	TCE (%)	PCE (%)	1,2-tDCE (%)	VC (%)	Bz (%)
Spiractor (Sec 5.1.1)	5.2	6.2	5.9	9.9	4.3
Storage tanks (Sec 5.1.2)	<1	<1	<1	<1	<1
Other losses (Sec 5.1.3)	<1	<1	<1	<1	<1
My Estimate - overall losses	<7.2	<8.2	<7.9	<11.9	<6.3
AH Environmental (2004), p.5-1	<15	<15	-	-	-
Hennet (2024) Exhibit 2-6, p.5.14	17	18	22	32	15

¹⁶ CLJA_WATERMODELING_01-0000334594 – 01-0000334660.

¹⁷ CLJ_WATERMODELING_01-0000334634.

¹⁸ Detailed analyses and discussions of the water buffalo types used at Camp Lejeune and the filling process during the historical period of VOC exposure are provided in Appendix A to Dr. Sabatini’s report and are not discussed in this report.

As Sabatini (2025) states in his report, “As such, I conclude that Hennes (2024) overestimated the potential losses in the water treatment processes. The actual loss values, in my opinion, were less than 6 to 12% for the VOCs of interest versus 15% to 32% as suggested by Hennes (2024).”

For the mobile water units (water buffaloes), Sabatini (2005, Section 5.3) concludes:

“Hennes’s calculations overestimated the VOC losses during filling of the water buffaloes; he estimated 41% to 61% for the range of VOCs while I estimate much lower (15 to 22% through filler pipe/strainer and 4.2 to 6.7% through the manhole, including daily use not accounted for by Hennes) for the range of VOCs, I thus conclude that the water buffalo water was only mildly to moderately lower in VOCs, not substantially lower as Hennes (2024) states.”

Sabatini’s (2025), Table 5.7, provided in this report as Table 4.8, lists a summary of the overall VOC losses in water buffaloes based on Hennes’s (2024) calculations and Sabatini’s (2025) estimates for filling the water buffaloes from the filler tank and from the manhole cover.

Table 4.8. From Sabatini (2025), Table 5.7.

[My estimate refers to Sabatini (2025)]

Source	TCE (%)	PCE (%)	1,2-tDCE (%)	VC (%)	Bz (%)
(1) Hennes – filler pipe/strainer - Overall loss (see Table 5-6, Row 2))	41	44	54	61	45
(2) My estimate – filler pipe/strainer overall filling losses (see Table 5.6, Row 3)	14	15	18	20	15
(3) My estimate – filled by standpipe through manhole cover – 5.6% of Hennes’s Row 1 values in Table 5.6	3.0	3.2	4.0	4.5	3.3
(4) My estimated losses during daily use of water buffaloes (Exhibit C.4)	1.2	1.0	1.9	2.2	1.2
(5) My estimate – overall losses – filler pipe strainer plus daily use (Row 2+4)	15	16	20	22	16
(6) My estimate – overall losses – standpipe filling through manhole plus daily use (Row 3+4)	4.2	4.2	5.9	6.7	4.5

In summary, the detailed calculations of both AH Environmental Consultants (2004) and Dr. Sabatini (2025) demonstrate that the DOJ expert (RH) has vastly overestimated alleged VOC losses

during storage, treatment and distribution. In addition, RH's assertion that ATSDR did not account for such VOC losses (Hennet 2004, Opinion 10, p. 5-36) is incorrect. First, ATSDR analyzed sampling data of water from both pretreatment and post treatment. Table 4.9 lists sampling data for the HPWTP including sampling status (treated or untreated) where known. Out of the 20 water samples taken at the HPWTP, 7 were from treated (finished) water, 4 were from untreated, and 9 had unknown treatment status. Furthermore, for TCE samples taken on 7/27/1982, results show that the concentration for untreated water was 19 µg/L and for treated water was 21 µg/L. Allowing for measurement error, these data indicate no losses to volatilization of TCE during the treatment process.

Table 4.9. Treatment status of water samples from the Hadnot Point water treatment plant

Date	Measured in µg/L	Treatment Status	Reference or Citation	Bates Identification
Tetrachloroethylene (PCE)				
5/27/1982	15	Unknown	CLW 0606	CLJA_USMCGEN_0000003332
7/27/1982	100	Unknown	CLW 0606	CLJA_USMCGEN_0000003332
12/4/1984	3.9J	Treated	CLW 5632	CLJA_USMCGEN_0000009913
2/5/1985	7.5J	Treated	CLW 5509	CLJA_USMCGEN_0000005529
Trichloroethylene (TCE)				
5/27/1982	1400	Unknown	CLW 0606	CLJA_USMCGEN_0000003332
7/27/1982	19	Untreated	CLW 0606	CLJA_USMCGEN_0000003332
7/27/1982	21	Treated	CLW 0606	CLJA_USMCGEN_0000003332
12/4/1984	46	Untreated	CLW 5632	CLJA_USMCGEN_0000009914
12/4/1984	200	Treated	CLW 5632	CLJA_USMCGEN_0000009913
12/12/1984	2.3J	Treated	CLW 5644	CLJA_USMCGEN_0000003979
12/19/1984	1.2	Untreated	CLW 4546	ATSDR_WATERMODELING_01-0000886764
2/5/1985	429	Unknown	CLW 5509	CLJA_USMCGEN_0000005529
Trans-1,2 Dichloroethylene (1.2-tDCE)				
12/4/1984	83	Treated	CLW 5632	CLJA_USMCGEN_0000009913
12/4/1984	15	Untreated	CLW 5632	CLJA_USMCGEN_0000009914
12/12/1984	2.3J	Treated	CLW 4546	ATSDR_WATERMODELING_01-0000886764
2/5/1985	150	Unknown	CLW 5509	CLJA_USMCGEN_0000005529
Vinyl Chloride (VC)				
2/5/1985	2.9J	Unknown	CLW 5509	CLJA_USMCGEN_0000005529
Benzene				
11/19/1985	2500	Unknown	CLW 1355	CLJA_USMCGEN_0000007001
12/10/1985	3	Unknown	CLW 1355	CLJA_USMCGEN_0000007001
12/18/1985	1	Unknown	CLW 1355	CLJA_USMCGEN_0000007001
Note 1: J = Estimated				
Note 2: Data from Faye et al. (2010, Tables C11 and C12); Maslia et al. (2013, Table A18)				

At the TTWTP a triplet of measured water samples obtained on 7/28/1982 show results as follows: 104 µg/L in “finished water”, 76 µg/L in “untreated water”, and 82 µg/L in “treated water”,¹⁹ indicating no PCE loss to volatilization during the treatment process.

Additionally, in contrast to RH’s contention that ATSDR ignored or did not account for VOC losses during storage, treatment and distribution, this issue (including the results of the AH Environmental Consultants report [2004]) was discussed in detail with the Expert Panels convened by ATSDR in 2005 and 2009 (Maslia, 2005, 2009). During the first day of the meeting in 2005 (March 28) panel members Dr. Tom Walski (Bentley Systems) and Dr. Peter Pommerenk (AH Consultants and consultant to the USMC) responded to a question from panel member Dr. James Uber (University of Cincinnati) to Morris Maslia about whether there are any potential chemical biological processes taking place in the distribution system.²⁰ Additional discussion occurred during the 2009 Expert Panel meeting (April 30) by Dr. Pommerenk.²¹ Excerpts from the verbatim transcript are provided in Appendix A. The consensus was that there was negligible volatilization (at most 10% from the spiractors). “So although we said it’s probably negligible, and I agree with Tom’s number here. At 90 percent, what’s going in is coming out on the other end.” (see Appendix A). In light of the conclusions of AH Environmental Consultants (2004) and the recommendations of its Expert Panels, ATSDR made the decision to consider any potential VOC losses from storage, treatment and distribution as negligible.

Additional support for this decision comes from the eight-day period, January 28-February 8, 1984, when the HBWTP was shut down and not operating. At that time, the HPWTP provided finished (and contaminated) water to the HB water-distribution system by operating booster pump 742 and opening the Marston Pavilion valve (Maslia et al. 2013, p. A2, p. A65). Water samples taken on January 31, 1985, indicated TCE concentrations ranged from 24.1 mg/L to 1,148.4 mg/L, with a sample taken at the HPWTP (Building 20, treatment status unknown) having a TCE concentration of 900 mg/L.²² Although not a direct indication of negligible TCE loss to volatilization during the treatment process at the HPWTP, these samples, taken from the HB water-distribution system (supplied by contaminated HPWTP finished water), suggest that any loss of VOCs owing to volatilization in the treatment process were consistent with the advice of the ATSDR Expert Panels (Appendix A) and the findings of AH Environmental Consultants (2004) and Sabatini (2025).

4.4 Derivation and Computation of Sorption Parameter Values

DOJ experts AS and RH posit that selected geochemical parameters (sorption parameters) were incorrect (Spiliotopoulos 2024, Section 4.1.2.2) and that ATSDR failed to consider site data to parameterize models (Hennet 2024, Opinion 12). Both opinions are incorrect. A detailed response pertinent to sorption parameters for the TT analyses is presented below and is also provided in Konikow (2025).

ATSDR applied and calibrated the MT3DMS model to evaluate the occurrence and migration of contaminated groundwater at TT. MT3DMS, a multi-species, mass transport model, is a widely

¹⁹ CLJA_USMCGEN_0000009869.

²⁰ CLJA_WATERMODELING_01-0000942379 – 01_0000942381.

²¹ CLJA_WATERMODELING_02-0001111469 – 01-0001111472.

²² CLW 4552, CLJA_WATERMODELING_09-0000424939.

used public domain model code used to simulate the migration of solutes/contaminants in groundwater (Zheng and Wang, 1996; Zheng 2010).

To account for sorption, MT3DMS computes a retardation factor (R_f), which, in turn, requires the selection of an equilibrium isotherm. A linear equilibrium isotherm was selected for the TT MT3DMS model. The retardation factor and the linear equilibrium isotherm are related by the following formula:

$$R_f = 1 + (K_D \times \rho_b)/n_e \quad (1)$$

where

R_f = the retardation factor, dimensionless

K_D = the distribution coefficient, in L^3/M

ρ_b = the bulk density, in M/L^3

n_e = the effective porosity of the porous media, dimensionless

(M =mass; L =length))

The K_D is a parameter that accounts for adsorption to mineral and/or organic material in the soil. While a chemical is adsorbed to soil, it does not move with the groundwater, so that the chemical migrates through the subsurface more slowly than the average groundwater velocity. This slower chemical velocity is quantified by the retardation factor, which is the ratio of the average water velocity to the chemical velocity. A R_f of 2, for example, indicates that the chemical moves at half the average groundwater velocity because of adsorption.

As seen in Equation (1) above, the R_f depends on the product of the ρ_b (bulk density) and K_D . Different combinations of K_D and ρ_b (and effective porosity, n_e) can thus result in the same retardation factor and will calibrate a model equally well. For example, a K_D value of 0.5 and a ρ_b of 2.0 would result in the same R_f as a K_D value of 0.6 and a ρ_b of 1.67, because $0.5 \times 2.0 = 1$, and 0.6×1.67 also equal 1. Because contaminant movement in groundwater depends on the R_f , an erroneous ρ_b and an erroneous K_D can compensate for each other because they are multiplied together, resulting in a R_f that best calibrates a model even though the individual ρ_b and K_D are not correct or are unknown.

During model calibration, the ρ_b and n_e were held constant while K_D was varied (i.e., K_D is a model calibration parameter). This approach was largely dictated not only by the several divergent methodologies used to determine K_D , generally batch and column experiments, but also by the high uncertainty and variability of reported K_D values, regardless of methodology. The EPA in its Volume II of *Understanding Variation in Partition Coefficient, K_D , Values* (USEPA 1999, Volume II, p 3.4) states “*The K_D values reported in the literature for any given contaminant may vary by as much as 6 orders of magnitude.*” Similarly, Spiliotopoulos (2024, Appendix A) tabulates site-specific K_D values for total organic carbon (TOC) at Camp Lejeune that vary by at least 3 orders of magnitude.

The initial K_D values used during calibration of the Tarawa Terrace MT3DMS model were derived largely from Hoffman (1995) and were determined from column experiments performed on sediment samples collected from 240 boreholes drilled into a plume contaminated with PCE and trichloroethylene (TCE). Borehole samples were composed largely of sand, silt and gravel, similar to the subsurface at Tarawa Terrace. Borehole sediments also contained low concentrations of total organic carbon. The K_D values for PCE reported by Hoffman (1995) related to silt and sand ranged from about 0.20 to 0.80 milliliters per gram (ml/g) and averaged 0.40 and 0.39 ml/g, respectively. The K_D determined from the completion of MT3DMS model calibration was 0.14 ml/g and was somewhat less than values determined by Hoffman (1995). The retardation factor (R_f) determined from MT3DMS calibration was 2.93 (Faye 2008) and is very close to other values reported in the literature for similar geologic materials (e.g., Rogers 1992).

In his report, Konikow (2025) also discusses Hennet's (2024, Opinion 11) criticism of ATSDR for having failed to consider available site-specific data for f_{oc} (fraction of organic content) to estimate K_D . However, as Konikow (2025) points out:

"Rogers (1992, p. 51) in discussing the K_d parameter says "Numerous researchers have used theoretical methods correlating the organic carbon content (OCC) of the subsurface material and the K_d (Karickhoff, 1984). Others have used the partitioning between octanol and water to predict the K_d (Kenega, 1980). **These methods are not considered appropriate where the OCC is less than approximately 0.1%.**" OCC is equivalent to TOC, and 0.1% is equivalent to a fraction of 0.001. Hennet's Expert report lists (Exhibit 3-2, and p. D-11 to D-12) 21 Camp Lejeune samples where f_{oc} is given. The median value is 0.0013, barely above the indicated limit, and 9 samples (43% of the samples) have values <0.001, indicating that the use of f_{oc} to estimate K_d is not appropriate. If ATSDR had used this approach, it would have introduced additional errors and sources of uncertainty."

Following calibration of the Tarawa Terrace MT3DMS model and the subsequent peer reviews and publication of model results, a member of the 2009 ATSDR Expert Panel (April 29–30) indicated in his pre-meeting comments on published ATSDR analyses that a wet rather than a correct dry bulk density was input to MT3DMS (Maslia 2009, p. 117)²³. Because transport models depend on the retardation factor which, in turn, is determined by the product of K_D and bulk density (Equation 1), the erroneously high bulk density implied that the value of K_D was too low. Accordingly, project staff resumed calibration of the Tarawa Terrace MT3DMS model by assigning a corrected bulk density (ρ_b) of 1.65 g/ml (46,725 g/ft³) to MT3DMS and testing simulated results by varying K_D values ranging from 0.20 to 0.40 g/ml (Hoffman, 1995). Test simulations were determined to be relatively insensitive to changes in K_D ; however, K_D values near the low part of the range (0.20 ml/g) were determined most comparable to best calibration. Finally, a corrected TT MT3DMS model was achieved using a dry bulk density of 1.65 g/ml and applying Equation (1) to compute a paired K_D value of 0.23 ml/g, thus maintaining the calibrated retardation factor (R) of 2.93 and model results as published (Faye 2008). Thus, the initial erroneous bulk density value had no effect on the final model calibration, which depended only on the product of K_D and ρ_b through the R_f . Note, the K_D value of 0.23 ml/g input to the corrected MT3DMS model is within the lower part of the range for this value applicable for PCE published by Hoffman (1995).

²³ CLJA_UST02-0000059851

By comparison, and as Dr. Konikow discusses in his report (Konikow 2025), “Kret et al. (2015) studied a Quaternary sandy aquifer to estimate sorption coefficients for PCE fate and transport modeling. They estimated K_D from both batch and column experiments and concluded that reasonable values for R_f for PCE are typically between 1.1 and 3.6.” The ATSDR calibrated value of 2.93 is very near the mean of this range. As Dr. Konikow points out, Rogers (1992) also supports the ATSDR’s calibrated value. There, a groundwater transport model was developed for the Lawrence Livermore National Laboratory (LLNL) site in California, which includes “several hundred feet of complexly interbedded, unconsolidated alluvial sediments” with an upper boundary represented by an unconfined water table condition. Their calibration and history matching resulted in reasonable matches for R_f values between 1.0 and 3.0, with their conclusion that “a spatially averaged retardation factor of approximately 3 is recommended...”.

The values used by Spiliotopoulos (2024) for ρ_b (1.65 g/cm³) and for K_D (0.30 and 0.40 mL/g) result in R_f values of 3.48 and 4.30, respectively, which are on the high-side of many literature-reported values and the calibrated value of 2.93. Using the Spiliotopoulos (2024) values in effect slows the movement of PCE through the aquifer and increases the time at which PCE-contaminated groundwater arrives at water-supply wells and the TTWTP (Spiliotopoulos 2024, Figures 7 and 8). Spiliotopoulos (2024, p. 37-38) also posits a R_f of 6.44 but provides no supporting evidence or reference for this value. What Spiliotopoulos has done is in essence conduct a sensitivity analysis using R_f as the varied parameter. However, Dr. Spiliotopoulos did not adjust ρ_b and/or n_e to best calibrate the model using his higher K_D values. The higher R_f based on Dr. Spiliotopoulos’ larger K_D values do not calibrate the model as well as the R_f used by the ATSDR team. In addition, as shown in Faye (2008), the calibrated TT fate and transport model is relatively insensitive to changes in R_f (K_D being the varied parameter in R_f). Instead, the model is substantially more sensitive to changes in mass loading rate and pumping variation.

ATSDR documented the above modifications to ρ_b and K_D in an email (and attachment) dated February 28, 2011.²⁴ ATSDR had planned to issue an errata pertinent to the updated ρ_b (dry) and K_D as a forthcoming TT Chapter K report (mentioned in the Foreword Section of all published TT reports). Agency budgetary and project completion time constraints prevented the errata and any supplemental information from being formally published and publicly released as the TT Chapter K report.

To test the effect that variations in R_f have on PCE concentrations at water-supply well TT-26 and the TTWTP, a series of simulations were conducted wherein the calibrated retardation factor of 2.93 (Faye 2008) was increased to 3.48 and 4.3 as speculated by AS and RH. As these sensitivity analyses (variations in retardation factor) demonstrate in Figure 4.6 below, the model is insensitive to changes (increases) in the retardation factor. After 1960, simulated results show PCE concentrations at TT-26 and at the TTWTP more than the MCL for PCE of 5 µg/L.

²⁴ ATSDR_WATERMODELING_01-0000887322 and 01-0000887324.

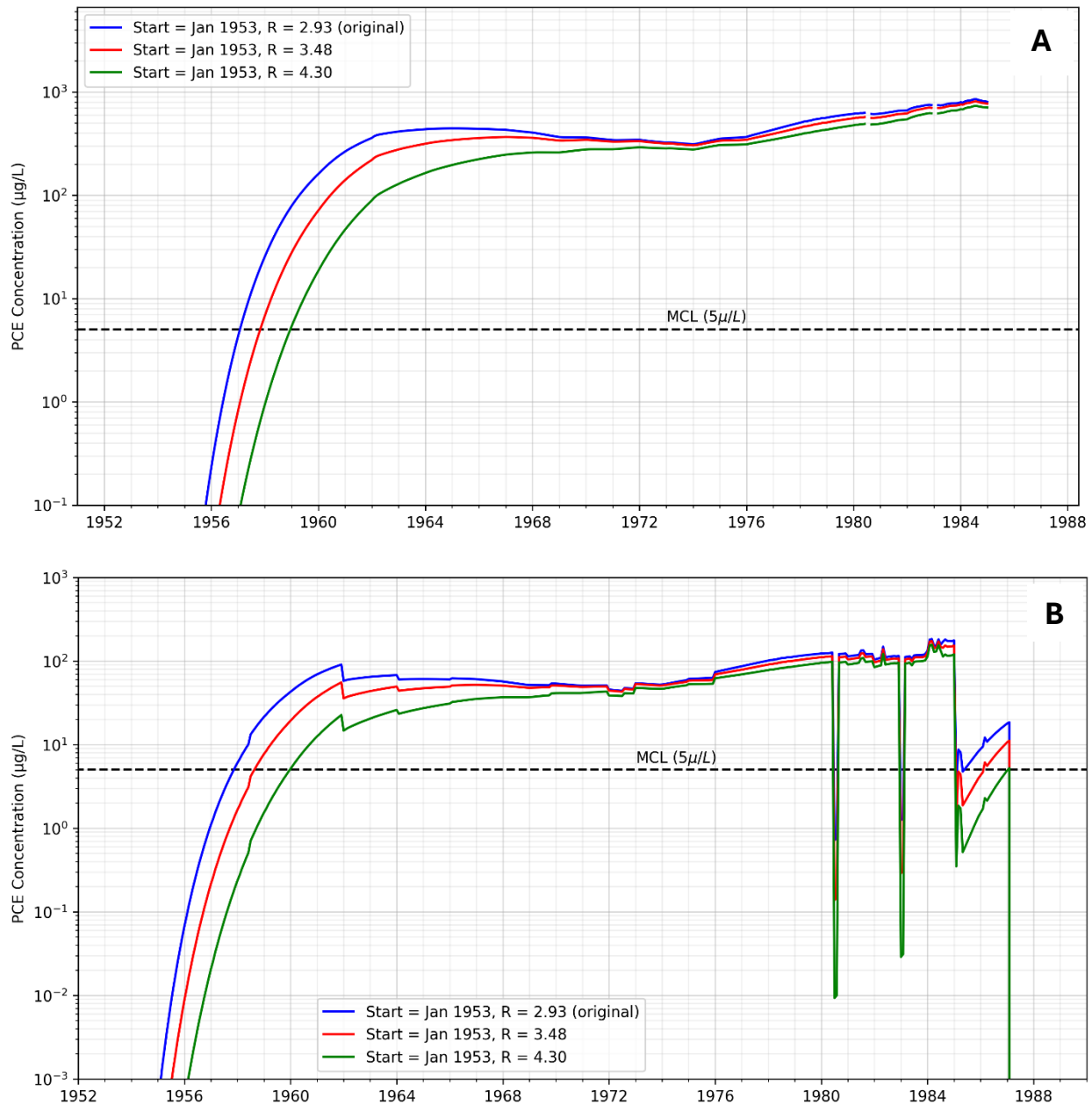


Figure 4.6. Comparison of tetrachloroethylene (PCE) reconstructed concentrations for variations in retardation factor for: (A) water-supply well TT-26, and (B) Tarawa Terrace water treatment plant (TTWTP). Note: R = 2.93 is calibrated retardation factor from Faye (2008).

4.5 Model Calibration and Uncertainty Analysis

Rebuttal responses to criticisms related to model calibration and uncertainty analysis raised by AS (2024) and RH (2024) are provided below.

4.5.1 Model Calibration

In Opinion 1, AS posits that the ATSDR models were not “calibrated to observed data for the first 30 years of simulation” (Spiliotopoulos, 2024, p. 30). However, it is crucial to understand that concentration data for that period do not exist, which is exactly why reconstruction was performed. The ATSDR models were designed to estimate those concentrations in a state-of-the-art manner, consistent with principles of groundwater flow and fate and transport processes. These models did not generate arbitrary random numbers; rather, the results are reasonable and realistic. The presence of error bands or uncertainty ranges around the estimates is to be expected and is readily acknowledged (Konikow 2025).

In his Opinion 2, AS (2024, p. 33) reproduces ATSDR’s Figure F16 (Faye 2008)²⁵ of TT historical reconstruction results at water supply well TT-26, and states that ATSDR’s work resulted in “biased high estimates.” As Dr. Konikow notes, Figure F16 (provided in this report as Figure 4.4 in Section 4.2.1) illustrates the opposite and instead “shows 5 measured PCE concentrations in samples from well TT-26 collected within weeks of each other in early 1985. Over this relatively short time span, the concentrations varied greatly (bracketed between a high of 1,580 µg/L on 01/16/1985 to a low of 3.8 µg/L on 02/12/1985)—a rate of change that cannot be replicated in a model using monthly time steps. Most importantly, the plot shows that the model results fell almost exactly at the midpoint of the range of observed values (about 800 ug/L)—countering the claim of being biased high.” (Konikow 2025)

The plot shown in Spiliotopoulos (2024, Figure 13) is discussed in AS’s Section 4.1.3.2 (p. 50, paragraph 8). It is noted that the results of the calibrated model, as AS states, “sits at the upper bound of the retardation-factor uncertainty range.” However, as Dr. Konikow notes and I agree, “that is not true for the majority of the simulation period. It is close to the middle of the range during the period of 1962 through the end (around Dec. 1987). And prior to 1962, it still lies within the uncertainty bounds, which is acceptable and not indicative of bias.” (Konikow 2025). Furthermore, calibrated model results do not always lie at the center of the uncertainty band because the response of the model to some parameters can be non-linear, and a model can be insensitive to changes in a model parameter at either high or low extremes.

For water-supply well HP-651, ATSDR applied the Linear Control Model (LCM) to reconstruct concentrations of TCE, PCE, and PCE degradation products (TCE, 1,2-tDCE, and VC). In Opinion 16 (Spiliotopoulos 2024, Section 4.2.4, p. 82-83) AS argues that the model for volatile organic compound (VOC) degradation products was based on limited data, and ATSDR’s historical reconstruction prior to December 1984 “cannot be verified.”

²⁵ Figure 4.4 of this report, previously discussed in Section 4.2.1

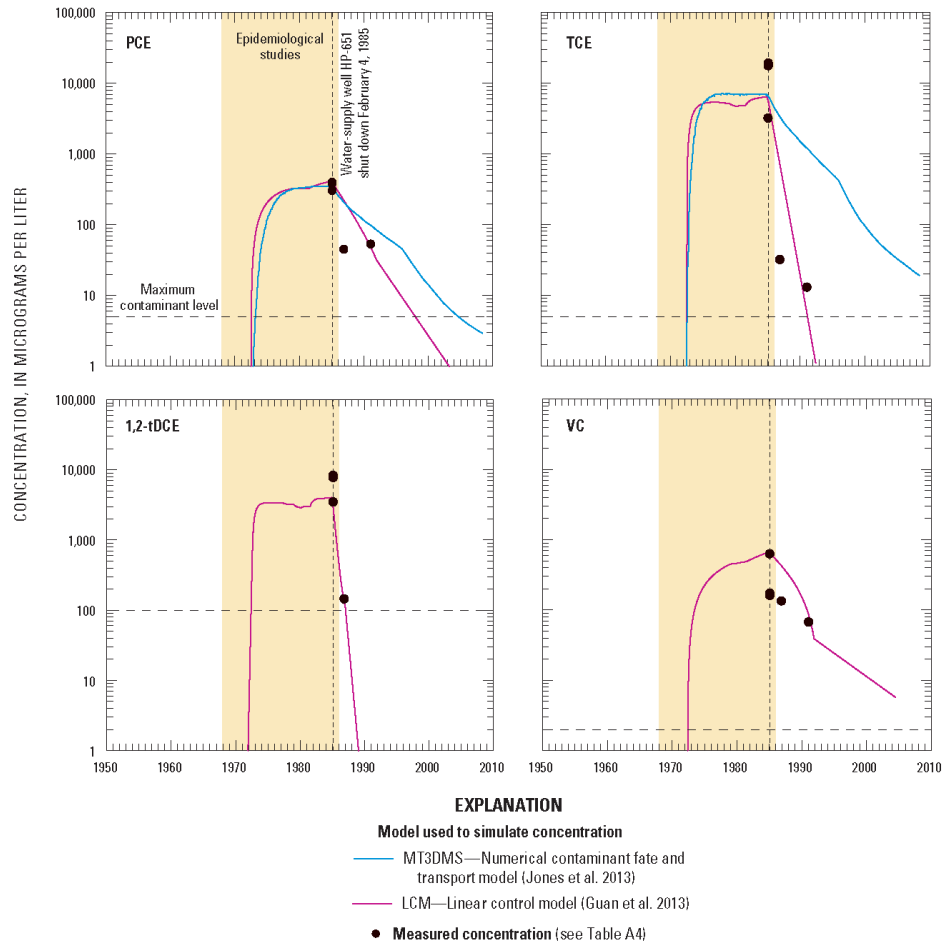


Figure A25. Reconstructed (simulated) concentrations of tetrachloroethylene (PCE), trichloroethylene (TCE), *trans*-1,2-dichloroethylene (1,2-tDCE), and vinyl chloride (VC) at water-supply well HP-651 using numerical (MT3DMS) and linear control methodology (TechControl) models, Hadnot Point–Holcomb Boulevard study area, U.S. Marine Corps Base Camp Lejeune, North Carolina. (See Figure A14 for well location.)

Figure 4.7. From Maslia et al. (2013), Figure A25.

In section 4.2.4 (p. 82-83), AS states that “As illustrated in Figure 33 [ATSDR Figure A25], the historical reconstruction prior to 1985 cannot be verified, due to lack of observed data for the period.” As I have stated previously, and as Dr. Konikow also opines, this is the reason why a simulation model was needed and was developed. For the four contaminants shown in Figure 4.7 the agreement between simulated values and observed data where data was available is excellent in all four plots. If anything, the model results for TCE and 1,2-tDCE are below the peak sampled data points, again suggesting that the model is under-predicting these concentrations. “This close agreement when observations are available builds confidence in the reliability of the model and its predictions,” including for the historical reconstruction results for times prior to 1985. (Konikow 2025). The objective was to use a technically sound model that would be calibrated to available data in and after 1985, and to estimate the values during the 15 or so years prior to that calibration period to inform the epidemiological studies.

The objective was to use a technically sound model that could be calibrated to available data in and after 1985 and to estimate the values during the 15 or so years prior to that calibration period to inform the epidemiological studies. As Konikow (2025) observes, for PCE and TCE, the fit with the LCM model was slightly better than with the MT3DMS model, which was not designed to simulate degradation products. The excellent quality of the fit is illustrated in Figure 4.7.

4.5.2 Uncertainty Analysis

ATSDR is transparent in its analyses and publications that uncertainty exists about conditions during both the historical reconstruction and calibration period. Results include assessments of uncertainty (Maslia et al. 2007, p. A52; Maslia et al. 2013, p. A92), including an entire Chapter Report (Chapter I) in the Tarawa Terrace report series (Maslia et al. 2009). In fact, the EPA in its Superfund Exposure Assessment Manual (1988, Section 4.4), discusses “Approaches for Dealing with Uncertainty” and the use and application of sensitivity analysis and Monte-Carlo (MC) simulation.

In his Opinion 8 (Section 4.1.3.2, p. 50, paragraph 3), AS criticizes the Monte Carlo (MC) simulation approach used by ATSDR “... because ATSDR implemented a ‘probability distribution function’ ... to describe how values closer to the mean value of the range are more probable than those away from the mean.” This is not a problem or issue as posited by AS, but rather, this is one of several accepted methods “for random sampling of parameter values for a MC analysis when information or theory indicates that a parameter has a statistically normal or log-normal distribution.” (Konikow 2025). Tung and Yen (2005, Section 6.1, p. 213) state, “. . . due to the complexity of physical systems and mathematical functions, derivation of the exact solution for the probabilistic characteristics of the system response is difficult, if not impossible. In such cases, Monte Carlo simulation is a viable tool to provide numerical estimations of the stochastic features of the system response.” Additionally, Bobba et al. (1995) state, “A Monte Carlo model is basically constituted by a deterministic portion (the deterministic model), of variable complexity, that is used to represent mathematically the system under observation, and a probabilistic portion, constituted by the probability distributions of both the parameters of the deterministic model (if available) and the observed variables (conditions).”

In Section 4, Basis for Opinions (p. 29), AS quotes Dr. T.P. Clement’s comments about ATSDR’s uncertainty analysis (Clement, 2011): “The figure also shows that closer to the initial starting point, the confidence band is almost 100%, implying that our knowledge of initial conditions, initial source loadings, and initial stresses is almost exact.” Contrary to Dr. Clement’s observations, both Dr. Konikow and I are confident that there was no (or negligible) PCE in the groundwater from ABC One-Hour Cleaners (or any other source) prior to January 1953, and likely very little for several months thereafter. (see Konikow 2025)

Additionally, uncertainty analysis is a process associated with simulations (Bobb et al. 1995). One cannot produce an uncertainty band at the start of simulations. If there is no simulation, there is no uncertainty. Thus, uncertainty at the start is zero when there is no simulation, and it expands as the computation process progresses forward. ATSDR did not consider uncertainty at the start of our source characterization. Instead, ATSDR assumed that prior to the start of operations at ABC One-Hour Cleaners, the concentration of PCE in groundwater was perfectly known, and it was 0 µg/L.

Another point to be made is that the graph in question in AS's critique (Maslia et al. 2007, Figure A26)²⁶ is the concentration time history at the TTWTP. This plot was created using a mass balance equation:

$$C_{TTWTP} = \frac{\sum_{i=1}^{NW} C_i Q_i}{\sum_{i=1}^{NW} Q_i} \quad (2)$$

where C_{TTWTP} is the concentration of water at the TTWTP for a specific month, NW is the number of operating wells for a specific month, C_i is the concentration of well i for a specific month, and Q_i is the pumping rate of well i for a specific month, featuring water pumped from a variety of supply wells. Most of the PCE comes from Well TT-26. All these wells are down-gradient from the source at ABC One-Hour Cleaners. While the fringe of the plume with very low concentrations arrives fairly soon, it takes several years for the bulk of the plume to arrive. Consequently, the parameter variations in the model instances within the MC simulation will lead to variations in the PCE plume. However, these variations do not manifest at the TTWTP for several years. Therefore, a narrow band early in the TTWTP timeline is expected. Even with the application of source concentration variations by ATSDR, the uncertainty band at the TTWTP would remain relatively narrow in the initial years.

In summary, ATSDR used and applied an accepted methodology for conducting an uncertainty analysis—Monte Carlo simulation using probability distribution functions. This method is described in several references including EPA's Superfund Exposure Assessment Manual (1988, Section 4.4), Tung and Yen (2005), and Zheng and Bennet (2002, p. 353). ATSDR provided specific details on how it carried out its uncertainty analysis with respect to both groundwater-flow model and contaminant fate and transport model parameters (and assigned probability distributions) in the Tarawa Terrace Chapter I report (Maslia et al. 2009, p. 130).²⁷ I agree with Dr. Konikow's assessment of the ATSDR uncertainty analysis where he states:

"I do not see a problem here as this is an option within standard practice for random sampling of parameter values for a MC analysis when information or theory indicates that a parameter has a statistically normal or log-normal distribution. Zheng & Bennett (2002, p. 353) say "The Monte Carlo method is by far the most commonly used method for analysis of uncertainty associated with complex numerical methods." They further state (p. 356) "The heart of the Monte Carlo method is the generation of multiple realizations (or samples) of input parameters that are considered to be random variables. Each random variable is assumed to follow a certain probabilistic model characterized by its probability density function (PDF). The probability distributions commonly used in hydrogeologic studies include *normal*, *lognormal*, *exponential*, *uniform*, *triangular*, *Poisson*, and *beta* distributions." It is worth noting that when this book was published, co-author Bennett was an employee of SSP&A and first author Zheng was a former employee and affiliate of SSP&A" (Konikow 2025).

²⁶ ATSDR_WATERMODELING_01-0000909018.

²⁷ CLJA_WATERMODELING_01-0000772752.

4.6 Post-Audit of the ATSDR Tarawa Terrace Models

Jones and Davis (2024) conducted a post-audit of the Tarawa Terrace groundwater flow and contaminant fate and transport models by extending the TT simulations from 1995–2008 using additional ABC One-Hour Cleaners site data that had become available after ATSDR published results for TT in July 2007 (Maslia et al. 2007). Jones and Davis (2024, Executive Summary) state,

“In summary, this post-audit found that the original Tarawa Terrace groundwater flow and transport models were developed using sound methodology and continue to provide reliable insights into the migration of PCE contamination. Despite the inherent challenges in simulating complex subsurface conditions and dealing with incomplete data, the model effectively simulates long-term trends in contaminant migration. Based on this post-audit, we can find no significant evidence that would invalidate the analyses performed by ATSDR with the original model.”

In his Opinion 13, AS states “Prior to offering opinions as experts in this litigation, Mr. Maslia and Dr. Aral should have used the data that Dr. Jones and Mr. Davis used to conduct the Tarawa Terrace Flow and Transport Model Post-Audit to update the calibration of the dose reconstruction groundwater model.” (Spiliotopoulos 2024, p. 3).

There are few post-audits for calibrated contaminant fate and transport models to compare approaches with the Tarawa Terrace post-audit (e.g., Person and Konikow, 1986). Most post-audits have been conducted for calibrated groundwater-flow models. The literature on post-audits of groundwater and hydrological model predictions remains limited (Kidmose et al., 2023). Anderson and Woessner (1992) reviewed five post-audits from the 1990s and concluded that original model failures were primarily due to errors in conceptual models or defining future stress (such as pumping).

In reviewing the literature on post-audits (Alley and Emery, 1986; Konikow, 1986; Kidmose et al., 2023), the outcomes are generally used to identify where additional data are required and to enhance the understanding of hydrogeology and transport phenomena (conceptual model improvement). Post-audits are not necessarily conducted, as AS posits in his Opinion 13, to re-calibrate or update a calibrated model based on additional (and future) data.

Alley and Emery (1986) provide general perspectives on groundwater modeling gained from post-audit analysis, noting that “post-audit analysis of groundwater modeling studies is a valuable exercise, particularly considering that historically groundwater modeling studies have not included a strong model verification stage.” In conducting a post-audit of a solute-transport model, Person and Konikow (1986) concluded that “the nature of the errors indicated a need to incorporate an additional process into the model (salt transport through the unsaturated zone).”

In extending ATSDR’s original TT groundwater-flow and contaminant fate and transport model, Jones and Davis used additional site data such as recovery-well locations and operations, additional monitor-well locations, changes in recharge during the post-audit period (1995–2008), and observed PCE concentration data. Re-calibration of the TT models was not an objective and would not have yielded substantive changes to the original ATSDR results and conclusions because no conceptual model flaws (groundwater flow and contaminate fate and transport) were noted. Thus, AS’s Opinion 13 is a moot point.

Finally, it needs to be noted that after the publication of ATSDR's TT Models in 2007 (Maslia et al. 2007)²⁸, ATSDR modeling staff recognized the value of conducting a post-audit of the TT models and they communicated this to ATSDR Senior Management and representatives of EPA Region IV. The extension of the TT models from 1994–2007 would have required additional agency resources, modeling time, and coordination with the EPA (Region IV) to obtain all the additional data required for the post-audit.²⁹

4.7 Graphing and Visualization of Data and Model Results

Konikow (2025) discusses AS's position that the presentation of results of the uncertainty analysis conducted by ATSDR for the TT model is "visually misleading" (Spiliotopoulos, 2024, Section 4.1.3.1). I agree with Dr. Konikow. The cited reason is that "they used a logarithmic scale, which visually compresses the uncertainty range around their calibrated model [results]." However, as Dr. Konikow notes, using a logarithmic scale is an accepted and common approach in engineering and scientific studies, and it is not considered misleading by scientists and engineers. Concentration data often vary over many orders of magnitude, which is why it is frequently presented using a log scale.

Furthermore, AS notes that the plot ranges over six orders of magnitude on the axis for PCE concentration, yet the width of the uncertainty bands does not span an equally wide range. Again, I concur with Dr. Konikow: "When values span such a large range, it is normal and standard to use a log plot. Using just an arithmetic scale would effectively hide all the changes in the lower part of the scale." (Konikow 2025)

AS also states (p. 46, para. 4) that "the difference between the high and low values in his Figure 11 (Maslia et al., 2009, Figure I29) is not significant enough to justify the use of a logarithmic scale." However, because the observed values span more than two orders of magnitude (excluding non-detects) and the simulated values span more than five orders of magnitude, plotting these data and results using a logarithmic scale is reasonable and informative. It is the only way to portray the early time results of the simulation in the same graphic (Konikow 2025).

4.8 Non-Degraded and Degraded PCE Historical Reconstructions

In his Summary of Opinions 10 and 11, Spiliotopoulos (2024, Section 4.1.4, p. 58) states,

"ATSDR applied two different numerical codes for modeling dose reconstruction. The results of the two codes are not in agreement. This is due, in part, to inconsistent application of contaminant source terms in the two models. Neither ATSDR, Mr. Maslia, nor Dr. Aral, provided sufficient scientific justification for selecting the higher estimated monthly contaminant concentrations for their dose reconstruction".

ATSDR has been open and transparent about the application of different models to reconstruct historical concentrations of PCE and PCE degradation products (TCE, 1,2-tDCE, and VC). All models are approximations of the real world and site-specific conditions, and modeling objectives determine the simplicity or complexity of a model to be used. Models that include different

²⁸ Results of the Tarawa Terrace models were publicly release during July 2007.

²⁹ CLJA_WATERMODELING_01-0000840256 – 01-0000840257; CLJA_WATERMODELING_01-0000070593, 01-0000070594, 01-0000065999, 01-0000021042, 01-0000837170 – 01-0000837172; CLJA_WATERMODELLING_01-0000837170 – 01-0000837171.

physical processes will naturally produce different results. This is an accepted modeling approach practiced by groundwater modelers. In the TT Chapter A report, Summary and Conclusions section (Maslia et al. 2007, p. A70)³⁰, both the non-degraded analysis for PCE (MODFLOW/MTDMS) and the degraded analysis for PCE (TechFlowMP) are discussed and summarized. ATSDR did not, as AS states “select[ing] the higher estimated monthly contaminant concentrations for their dose reconstruction” (Spiliotopoulos 2024). The water-modeling staff, being blinded to the epidemiological study through the entire water-modeling process, provided both the non-degraded (MODFLOW/MT3DMS) and degraded (TechFLOWMP) historical reconstruction results to the ATSDR health studies staff.

For the Tarawa Terrace historical reconstruction analysis, ATSDR applied a simplification of the biochemical processes such as volatilization and biodegradation taking place in the subsurface and used a model (MODFLOW/MT3DMS) that does not consider the biodegradation of PCE. ATSDR’s philosophy was to “start simple” to try to understand aquifer and transport characteristics before attempting a more complex modeling effort that included biochemical processes such as volatilization and biodegradation of PCE. Again, this is a common and accepted modeling approach. Using a four-stage, hierarchical calibration approach, ATSDR achieved acceptable or better calibrations for predevelopment and transient groundwater flow, contaminant fate and transport (using MT3DMS), and the simple mixing model, as evidenced by the comparison of reconstructed and observed PCE concentrations at the TTWTP (Maslia et al., 2007, Figure A39; Fay 2008, Table F14 and Figure F27). Table 4.10 of this report, which is taken from Faye (2008, Table F14), shows that the model achieves acceptable matches between reconstructed and observed PCE concentrations at the TTWTP. In fact, even for observed non-detections, most reconstructed PCE concentrations are within the published detection limits (a non-detect does not imply zero concentration, but that the sampling and testing methodologies were not sensitive enough to detect concentrations). At the TTWTP storage tank (STT-39), the reconstructed PCE concentration was 176 µg/L compared to an observed PCE concentration of 215 µg/L—quite an impressive match for water-quality data—resulting in a geometric model bias of solely 1.5 (Maslia et al. 2007).³¹

³⁰ ATSDR_WATERMODELING_01-0000909028.

³¹ ATSDR_WATERMODELING_01-0000908983 – 01-0000908984.

Table 4.10. From Faye (2008). Table F.14.**Table F14.** Computed and observed tetrachloroethylene (PCE) concentrations in water samples collected at the Tarawa Terrace water treatment plant and calibration target range, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[µg/L, microgram per liter; TTWTP, Tarawa Terrace water treatment plant; ND, not detected]

Date	PCE concentration, in µg/L		Calibration target range, in µg/L
	Computed ¹	Observed	
²TTWTP Building TT-38			
5/27/1982	148	180	25–253
7/28/1982	112	³104	33–329
7/28/1982	112	³76	24–240
7/28/1982	112	³82	26–259
2/5/1985	176	³⁴80	25–253
2/13/1985	3.6	⁵ND	0–10
2/19/1985	3.6	⁶ND	0–2
2/22/1985	3.6	⁵ND	0–10
3/11/1985	8.7	⁶ND	0–2
3/12/1985	8.7	⁶,⁷6.6	2.1–21
3/12/1985	8.7	⁶,⁸21.3	6.7–67
4/22/1985	8.1	⁵1	0.3–3.2
4/23/1985	8.1	⁵ND	0–10
4/29/1985	8.1	⁵3.7	1.2–11.7
5/15/1985	4.8	⁵ND	0–10
7/1/1985	5.5	⁵ND	0–10
7/8/1985	5.5	⁵ND	0–10
7/23/1985	5.5	⁵ND	0–10
7/31/1985	5.5	⁵ND	0–10
8/19/1985	6.0	⁵ND	0–10
9/11/1985	6.0	⁵ND	0–10
9/17/1985	6.0	⁵ND	0–10
9/24/1985	6.0	⁵ND	0–10
10/29/1985	6.0	⁵ND	0–10
²TTWTP Tank STT-39			
2/11/1985	176	⁵215	0–10

¹Weighted-average computation

²See Plate 1, Chapter A report, for location (Maslia et al. 2007)

³Detection limit is unknown

⁴Analysis of tap water sample for Tarawa Terrace, address unknown

⁵Detection limit = 10 µg/L

⁶Detection limit = 2 µg/L

⁷Sample collected downstream of TTWTP reservoir after operating well TT-23 for 24 hours

⁸Sample collected upstream of TTWTP reservoir after operating well TT-23 for 22 hours

Next, ATSDR set out to apply a more complex and more sophisticated approximation of transport in the subsurface by using a model that would degrade PCE into TCE, 1,2-tDCE, and VC. As PCE migrates in the subsurface it continues to undergo transformation through physical and biochemical processes such as volatilization and biodegradation. To quantify historical concentrations of PCE degradation by-products observed in groundwater samples reported in Faye and Green, Jr. (2007, Figures E1-E14) and in soil (vapor phase) requires a model capable of simulating multiphase flow and multispecies mass transport such as TechFlowMP (Jang and Aral 2008). ATSDR summarized the second and more complex modeling approach in Maslia et al. (2007, p. A41) and described the detailed development and application of the TechFlowMP model at Tarawa Terrace in Jang and Aral (2008). MT3DMS and TechFlowMP use two entirely different numerical schemes. MT3DMS uses a finite difference scheme to approximate the partial differential equations of saturated groundwater flow and contaminant fate and transport. TechFlowMP uses a Galerkin finite-element based approach with upstream weighting and mass lumping of the time derivative matrices to simulate multiphase flow and multispecies mass transport in the vadose zone and saturated zone.

To simulate groundwater flow conditions at TT, TechflowMP applied the calibrated hydraulic and aquifer properties from MODFLOW, reported in Maslia et al. (2007, Table A11). A correlation between geologic and hydrologic units and the MODFLOW/MTD3DMS and TechflowMP models is provided in Jang and Aral (Table G1), with the main difference between the two modeling approaches being that TechFlowMP has 5 layers assigned to the variably saturated zone. For predevelopment and transient groundwater flow, TechFlowMP applied the same initial and boundary conditions and pumping schedules used in MODFLOW reported in Faye and Valenzuela (2007). Comparisons of simulated groundwater heads between the TechFlowMP and MODFLOW-96 models show good agreement, and comparisons between the two modeling approaches are shown in Jang and Aral (2008, Figure G3) for model layers 1, 3, and 5 (main water-bearing units). Slight differences between groundwater-head simulations obtained using the two models were most likely due to the different numerical methods used by the two models to approximate the equations of groundwater flow. Recall that TechFlowMP uses a finite-element technique, whereas MODFLOW uses a finite-difference technique.

As discussed above, the TechFlowMP model uses a more complex approach for simulating fate and transport of biochemical processes such as volatilization and biodegradation taking place in the subsurface. Additional chemical and physical properties required by TechFlowMP for PCE and its degradation products (TCE, 1,2-tDCE, and VC) are listed in Jang and Aral (2008, Table G2). Other fate and transport properties used for the MT3DMS simulation are listed in Maslia et al. (2007, Table A11). For the source concentration (PCE) at ABC One-Hour Cleaners, MT3DMS applied a mass-loading rate of 1,200 g/d (calibrated) to the saturated zone (MODFLOW/MT3DMS model Layer 1). At ABC One-Hour Cleaners the altitude of the source ranges from 0 to 13 ft, which implies that in TechFlowMP the source PCE was partially released into the unsaturated zone and partially released into the saturated zone.

PCE concentrations simulated by TechFlowMP are less than those using MT3DMS (Maslia et al. 2007, Appendix A2; Expert Report of M. Maslia (2024, Appendix H1). This is partially due to TechFlowMP simulating (1) the release of PCE from the subsurface (groundwater) to the atmosphere, (2) PCE partitioning from the water phase to the soil vapor phase, and (3) the

placement of the contaminant source at the ABC One-Hour Cleaners site in the unsaturated and saturated zones. The difference between MT3DMS and TechFlowMP in simulating PCE transport at Tarawa Terrace and vicinity is (1) TechFlowMP considers PCE in both water and gas phases while MT3DMS considers PCE only in the water phase and (2) in MT3DMS the source concentration is released solely to the saturated zone. In MT3DMS simulations (Faye 2008), there is no PCE transfer into the gas phase. In TechFlowMP simulations, however, because PCE could be present in the gas phase, a portion of PCE in the gas phase could be released from the subsurface into the atmosphere through the ground surface. This results in the reduction of PCE concentration in the subsurface. The differences in simulated PCE concentrations at Tarawa Terrace were clearly and transparently presented by ATSDR in Appendix A2 (Maslia et al. 2007) and in the Expert Report of Maslia (2024, Appendix H1). In these appendices, column 3 represents the MODFLOW/MT3DMS simulation of PCE whereas column 4 represents the TechFlowMP simulation of PCE (the same simple mixing model was applied to both simulation methods to obtain PCE concentrations at the TTWTP).

Based on the explanations given above for simulated PCE differences between MODFLOW/MT3DMS and TechFlowMP, it is not clear, evident, or apparent what issue Spiliotopoulos (2024, p. 55) has with simulating different concentrations of PCE using the two different modeling methods. The simulated PCE concentrations using MODFLOW/MT3DMS and TechFlowMP must be different and the PCE concentrations simulated by TechFlowMP should be (and were) less than those simulated by MODFLOW/MT3DMS.

4.9 Additional Topics

Below I briefly respond to several additional topics raised in the Expert reports of AS (Spiliotopoulos 2024) and RH (Hennet 2024).

4.9.1 Benzene Contamination

RH posits in his Opinion 4 that the TTWTP was likely not contaminated with benzene (Hennet 2024, p. 5-22). I agree with that opinion because ATSDR analyses indicated that benzene was not detected or detected at trace levels at the TTWTP.

RH posits incorrectly in his Opinion 6 (Hennet 2024, p. 5-32) that the HPWTP was likely not contaminated with benzene. He bases this opinion on a flawed and erroneous assumption that water-supply well HP-602 was operated solely 39% of the time (frequency of use of 0.39). This is the same flawed reasoning that RH used for water-supply well HP-651 and which I conclusively discredit (see Section 4.2.2.4 in my report).

Well HP-602's operational log demonstrates the well's long-term operation; even with short-term operation and repairs, it was kept as part of the group of operating wells, even though it was not a high-volume producing well (Sautner et al., 2013, p. S1.17).³² The last three capacity tests for well HP-602, however, indicated capacities of 130 gpm (8/17/1983), 100 gpm (6/20/1984), and 154 gpm (10/24/1984).

³² CLJA_WATERMODELING_05-0000826058.

RH's claim that benzene is a recent short-term event does not consider the expansive remediation effort that has taken place at the HPIA and HPFF (Faye et al. 2010, p. C26)³³ and the volumes of estimated benzene in the subsurface as discussed below.

Measured concentrations of benzene have been documented. HPHB Chapter C (Faye et al. 2013), Figure C34³⁴ shows substantial benzene concentrations from samples within the HPIA. Table C80 (Faye et al 2013)³⁵ shows substantive benzene concentrations at IRP Sites: 6 (32J µg/L), 22 (29,000 µg/L), 78 (HPIA, 5,500 µg/L), 84 (3,800 µg/L), and 94 (17,300 µg/L). In addition the model TechNAPLVol (Jang et al. 2013)³⁶ confirmed previous LNAPL (floating benzene) volumes using the SpillCAD™ model (Engineering Science & Technology 1993) and Order of Magnitude analysis (CH2M HILL 2001). Additionally, Faye et al. (2013, Table D10)³⁷ summarize BTEX contaminants at selected RCRA investigations sites and occurrences of BTEX in nearby supply wells for the HP-HB area—HP-608 (Buildings 1502 and 1601), and HP-602 (HPFF, Building 1115, and Michael Road Fuel Farm). Three samples at the HPWTP, collected after all contaminated water-supply wells had been removed from service show the following benzene concentrations: 11/19/1985 (2,500 µg/L), 12/10/1985 (38 µg/L), and 12/18/1985 (1.0 µg/L). These data in addition to the erroneous assumption of a 39% operational frequency for well HP-602 demonstrate the flaw in RH's logic and reasoning that the HPWTP was likely not contaminated with benzene.

4.9.2 Site-Specific Data

Both RH and AS posit that ATSDR did not consider site-specific data to parametrize models (RH Opinion #11, page 5-37). Their *only* example of this is ATSDR not using site-specific f_{oc} data, and that has been rebutted above in the section on Derivation and Computation of Sorption Parameter Values. ATSDR provided a long and comprehensive list of documents and data that it used for the historical reconstruction analysis (Maslia et al. 2013, Appendix A2)³⁸, whose title is "Information sources used to extract model-specific data for historical reconstruction analysis." Examples of the site-specific data sources include water-quality laboratory analyses by Granger laboratory, JTC environmental laboratories, the CERCLA Administrative Record files, solid waste management unit reports, installation restoration program site reports, as well as hundreds of consulting reports providing site-specific data (e.g., AH Environmental Consultants, Baker Environmental, CH2HILL). The claim by AS and RH that ATSDR did not use site-specific data is simply false.

4.9.3 Travel Time for PCE to Reach TT-26

RH posits that travel time to TT-26 is in the range of 15-25 years (RH 2024, p. 5-15, 5-16, 5-22, and his Attachment D). Konikow (2025) provides a detailed discussion and response to RH, with which I agree and provide below:

"Dr. Hennet estimates a range of values for travel times of PCE between ABC Cleaners and TT-26 that are stated to be "in the 15 to 25 years range", based on three assumed

³³ CLJA_WATERMODELING_05-0000777129.

³⁴ CLJA_WATERMODELING_05-0000777170.

³⁵ CLJA_WATERMODELING_05-0000777384.

³⁶ CLJA_WATERMODELING_05-0001005553.

³⁷ CLJA_WATERMODELING_05-0001004009.

³⁸ CLJA_WATERMODELING_05-0000777681 – 05-0000777688.

“representative” flow paths, indicating the arrival didn’t occur until the 1970s. He presents supporting material and calculations in his Attachment D. Dr. Hennem assumes the horizontal travel distance in the shallow aquifer is either (1) 200 ft in the shallow aquifer and 800 ft in the pumped aquifer, (2) 500 ft in the shallow aquifer and 500 ft in the pumped aquifer, or (3) 800 ft in the shallow aquifer and 200 ft in the pumped aquifer. He further assumes that the hydraulic gradient in the layer 2 confining unit is the same in all cases (i.e., at three different distances from the pumping well). This is not a reasonable assumption (for example, see TT Figs. C19 & C21). In the pumped aquifer, a cone of depression will form with lowest heads adjacent to the well and higher heads further from the well. In the shallow aquifer, the heads will not change much due to pumping in the deeper aquifer. This drawdown effect is strongest near the well, and results in a greater hydraulic gradient (and faster velocity) across the confining layer closer to the well.

Pumping also results in a steeper horizontal gradient (and faster velocity) closer to the well in model layer 3, and a shallower gradient further from the well. Dr. Hennem’s calculations assume the same horizontal velocity in the pumped aquifer regardless of the distance from the pumped well, which is not a valid assumption.

Examining the heads for model layers 1 and 3 as shown in TT Figs. C18 and C19, and looking at a point about halfway between ABC Cleaners and TT-26 and at a point very close to TT-26, the head difference between the two layers (across the confining bed) is about $10' - 9' = 1$ ft at the halfway location and about $5' - 2' = 3$ ft at a location close to TT-26. Therefore, the hydraulic gradient potentially driving downward flow is about 3 times greater close to the well than it is halfway between the well and the contaminant source. So this large spatial change in vertical hydraulic gradient must be accounted for, and the assumption that it is the same at all locations cannot be supported. Dr. Hennem does not account for the steeper vertical gradient in layer 2 for the path closer to the pumped well, nor does he account for the faster velocity in layer 3 when the travel distance is only 200 ft.

It is more likely that the travel distance in the shallower aquifer for much of the contaminated shallow groundwater would be more than 800 ft and the corresponding travel distance in the pumped aquifer would be less than 200 ft because (1) the vertically downward transport is more likely to occur where the vertical gradient is the strongest in the confining layer, which is closest to the pumping well, (2) the downward velocity would be fastest where the gradient is steeper close to TT-26, and (3) according to Dr. Hennem’s calculations, the downward flux is only about 5% of the horizontal flux in the shallow aquifer, so that even if some contaminant leaked downward at further upgradient distances from TT-26, much would remain in the shallow aquifer to migrate to locations closer to, or even adjacent to, TT-26, where downward leakage would be the fastest. Thus, Dr. Hennem’s three “representative” flow paths did not include a more critical flow path in which travel in the shallower aquifer is close to 1,000 ft. For this critical flow path, the travel time would be much less than 15 years—on the order of 3.5 to 5 years. For these several reasons, Dr. Hennem’s estimates of travel times from ABC to TT-26 are erroneous, misleading, biased-high, and based on unreliable assumptions.” (Konikow 2025).

Based on my and Dr. Konikow’s analysis, a summary of my response to RH is as follows:

- **Travel Time Estimates:** RH estimates a 15–25-year range for PCE travel time between ABC Cleaners and TT-26, but his calculations show a 14.9-19.7-year range.
- **Retardation Factor:** RH uses a retardation factor of 3.5, whereas the calibrated value for the TT model is 2.9, overestimating travel times by 20%.
- **Horizontal Travel Distance:** RH assumes horizontal travel distances of either 500 ft in both the shallow and pumped aquifers or 800 ft in the shallow aquifer and 200 ft in the pumped aquifer.
- **Hydraulic Gradient Assumptions:** RH incorrectly assumes consistent hydraulic gradients in layer 2's confining unit at both distances from the pumping well.
- **Cone of Depression:** In the pumped aquifer, a cone of depression forms with the lowest heads near the well and higher heads farther away.
- **Shallow Aquifer Heads:** Heads remain relatively unchanged in the shallow aquifer, affecting horizontal gradients.
- **Gradient Variation:** The hydraulic gradient near the well is three times greater than halfway between the well and the contaminant-source.
- **Gradient and Velocity:** RH does not account for the steeper vertical gradient closer to the pumped well or the higher velocity in layer 3 over a 200 ft travel distance.
- **Travel Distance Plausibility:** It's more likely that the travel distance in the shallow aquifer exceeds 800 ft, with a shorter distance in the pumped aquifer, due to the concentration of vertical downward transport and gradients near the pumping well.
- **Downward Flux:** RH's calculations indicate that downward flux is only about 5% of the horizontal flux in the shallow aquifer.
- **Misguided Assumptions:** RH's estimates are based on an overly simplistic and unreliable methodology.

4.9.4 Purpose of ATSDR Modeling

AS claims that the ATSDR models cannot be used for the purpose of estimating Plaintiffs' exposures because that was not the stated purpose of the model (Spiliotopoulos 2024, p. 18). This is a flawed rationale because the stated purpose of a model does not limit or determine the value and use of the model and its results.

ATSDR is a Public Health Agency. Therefore, reports reflect (and state) the ATSDR policy that analyses were not being conducted or extrapolated by ATSDR to individuals. This agency policy is not an indication or determination as to the applicability of the model and historical reconstruction results to individuals.

The methodology used by ATSDR was appropriate and reasonable to provide mean monthly contaminant concentrations in finished water. These model results may be used by health professionals for an epidemiology study and/or to estimate past exposures of residents on an "as likely as not" or "more likely than not" basis. The methods used were rigorous and scientifically sound. ATSDR appropriately told the public that "ATSDR's exposure estimates cannot be used *alone* to determine whether you, or your family, suffered any health effects as a result of past exposure to TCE-contaminated drinking water at USMCB Camp Lejeune." A determination of health effects requires interpretation of the exposure and dose data by a health professional.

5.0 Summary and Conclusions

I have provided detailed responses to eight topical areas addressed in DOJ's Expert Reports (Brigham 2024, Hennet 2024, Spiliotopoulos 2024). None of the opinions found in the DOJ Expert Reports would substantively or even moderately change any of the conclusions from ATSDR's historical reconstruction and water-modeling analyses reported in Maslia et al. (2007, 2013, and other supporting reports and documents), or the opinions in my October 2024 expert report. In summary, in response to DOJ's expert reports, I offer the following opinions and conclusions within reasonable scientific certainty:

- ATSDR calibrated its models using a four-stage, hierarchical calibration process. Results of the model-calibration process indicated excellent model and observed data comparisons in finished water at the WTPs, which resulted in geometric model biases of solely 1.5 (TTWTP) and 2.3 (HPWTP). This provides confidence that model behavior (i.e., results) for all four calibration stages provide reasonable accuracy and concordance with system behavior. Neither RH (2024) nor AS (2024) address the merits of the four-stage calibration process in their reports.
- AS (2024) repeatedly accuses ATSDR of making “arbitrary” assumptions and of not basing parameter values on site-specific data. Neither accusation has merit. For example, AS (2024) takes the position that adjusting a model parameter value (e.g., mass loading) to fit water quality data, which are of course site-specific data, is an “arbitrary” decision. (For example, AS Report, pages 78-79.) This is not true. Making such an adjustment is an accepted and best-practices part of the methodology of model calibration. As another example, AS asserts (at page 84) that the use of a U.S. EPA study (USEPA 1986, 1987) of 12,444 leak incident reports to estimate the timing of UST releases at Hadnot Point is “arbitrary and uncertain.” Again, this is not true. Reliance upon such a comprehensive study is an accepted methodology; it is not “arbitrary.” In summary, ATSDR based parameter values on the best data it had available, including site-specific and published data. ATSDR also made appropriate adjustments to parameters to fit site-specific conditions.
- It is precisely because there was limited data prior to 1980 that ATSDR applied the historical reconstruction process, which included information gathering, data analyses, and model simulation to reconstruct historical concentrations of finished water delivered to the residents of Camp Lejeune. Models play an important role in providing insight and information when data are missing, insufficient, or unavailable. Historical reconstruction has been utilized since the 1930s, is a widely accepted analysis method, and has been applied to other high-profile public sites (Konikow 1977, Konikow and Thompson 1984, Rogers 1992, NRC, 1996). This method has also been reviewed extensively by Samhel et al. (2010) and others.
- Owing to the four-stage, hierarchical calibration process that ATSDR used in calibrating its models, the presentations in Tarawa Terrace Chapter A (Maslia et al. 2007) and Chapter F (Faye 2008) reports comparing computed and observed PCE concentrations at the TTWTP

comprise a major part of TT model calibration. Such comparisons indicate that, regardless of simulated concentrations at individual supply wells, the calibrated Tarawa Terrace MT3DMS model delivered a reasonably accurate total PCE mass to the TTWTP during the 1980's.

- ATSDR applied models that have been tested and verified, and that are available in the public domain, as part of its historical reconstruction process for Camp Lejeune. These models approximate the physics of groundwater flow and chemical transport and are not “professional judgment.” Professional judgment and experience were used when selecting values for model parameters, but those values were based on both field and literature sources and were adjusted over reasonable ranges during calibration to best replicate the observed data, which is the generally accepted methodology in the hydrogeology and modeling fields.
- Selecting model parameters based on professional judgment is a normal, standard, and accepted practice. Data are always limited, requiring professional judgment to determine how to handle this paucity of data and how much weight to assign to the limited number of measurements. Groundwater modelers always wish for more data, but the reality is that there is never enough data available to avoid relying on professional judgment.

6.0 References

- AH Environmental Consultants, 2004. ATSDR Support—Estimation of VOC Removal, Marine Corps Base Camp Lejeune, North Carolina, Prepared for: Environmental Management Division, Camp Lejeune, NC 28542-004, Contract No.: DACW56-03-R-1013, December 2004.
- Alley, W.M., and Emery, P.A., **1986**. Groundwater Model of the Blue River Basin, Nebraska—Twenty Years Later. *Journal of Hydrology*, vol. 85, pp. 225-249.
- Anderson, M.P., and Woessner, W.W. **1992**. The role of the post audit in model validation. *Advances in Water Resources*, vol. 15, pp. 167-173.
- ATSDR (Agency for Toxic Substances and Disease Registry), **1980**. Codified under section 104(i) of CERCLA, 42 U.S.C. §9604(i).
- Bobba, A.G., Singh, V.P., and Bengtsson, L., **1995**. Application of uncertainty analysis to groundwater pollution modeling. *Environmental Geology*, 1995, v. 26, pp. 89-96.
- Brigham, J.L., **2024**. Expert Report of Jay L. Brigham, Ph.D., in the United States Eastern District of North Carolina, No. 7:23-cv-897, Camp Lejeune Water Litigation, Morgan, Angel, Brigham, and Associates, LLC, December 9, 2024.
- CH2M HILL,, Inc., **2001**. Hadnot Point Fuel FARM/Building 1101, Remediation Assessment Report, Marine Corps Base Camp Lejeune, North Carolina; 2001. Contract No.: N62470-95-D-6007 (UST Management Web Portal File #670).
- Clement, T.P., **2011**. Complexities in Hindcasting Models – When should we Say Enough is Enough. *Groundwater*, v. 49, no. 5, pp. 620-629.
- Environmental Systems & Technologies, **1993**. SpillCAD User and Technical Guide, ES&T Software, LTD. Blacksburg, VA; ES&T; 1993.
- Faye, R.E., **2008**. Analyses of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Drinking Water at Tarawa Terrace and Vicinity, U.S. Marine Corps Base Camp Lejeune, North Carolina: Historical Reconstruction and Present-Day Conditions—**Chapter F**: Simulation of the Fate and Transport of Tetrachloroethylene (PCE). Atlanta, GA: Agency for Toxic Substances and Disease Registry; 2008.
- Faye, R.E., and Green, J.W., Jr., **2007**. Analyses of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Drinking Water at Tarawa Terrace and Vicinity, U.S. Marine Corps Base Camp Lejeune, North Carolina: Historical Reconstruction and Present-Day Conditions—**Chapter E**: Occurrence of Contaminants in Groundwater. Atlanta, GA: Agency for Toxic Substances and Disease Registry; In press 2007.

- Faye, R.E., and Valenzuela, C., **2007**. Analyses of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Drinking Water at Tarawa Terrace and Vicinity, U.S. Marine Corps Base Camp Lejeune, North Carolina: Historical Reconstruction and Present-Day Conditions—**Chapter C: Simulation of Groundwater Flow**. Atlanta, GA: Agency for Toxic Substances and Disease Registry; 2007.
- Faye, R.E.; Anderson, B.A.; Suárez-Soto, R.J.; Sautner, J.B., **2010**. Analyses and Historical Reconstruction of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Drinking Water within the Service Areas of the Hadnot Point and Holcomb Boulevard Water Treatment Plants and Vicinities, U.S. Marine Corps Base Camp Lejeune, North Carolina—**Chapter C: Occurrence of Selected Contaminants in Groundwater at Installation Restoration Program Sites**; Agency for Toxic Substances and Disease Registry: Atlanta, GA, USA, October 2010.
- Hennet, J.-C., **2024**. Expert Report of Remy J.-C. Hennet, in the United States Eastern District of North Carolina, No. 7:23-cv-897, Camp Lejeune Water Litigation, S. S. Papadopoulos & Associates, December 9, 2024.
- Hill, M.C., and Tiedeman, C.R., **2007**. Effective Groundwater Model Calibration; John Wiley & Sons, Inc.: Hoboken, NJ, USA, 2007.
- Hoffman, F., **1995**. Retardation of Volatile Organic Compounds in Ground Water in Low Organic Carbon Sediments: Interim Report. Lawrence Livermore National Laboratory, U.S. Department of Energy, 1995 April, Report No.: UCRL-ID-1204711995.
- Jang, W., and Aral, M.M., **2008**. Analyses of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Drinking Water at Tarawa Terrace and Vicinity, U.S. Marine Corps Base Camp Lejeune, North Carolina: Historical Reconstruction and Present-Day Conditions—**Chapter G: Simulation of Three-Dimensional Multispecies, Multiphase Mass Transport of Tetrachloroethylene (PCE) and Associated Degradation By-Products**. Atlanta, GA: Agency for Toxic Substances and Disease Registry; 2008.
- Jang W., Anderson B.A., Suárez-Soto R.J., Aral M.M., and Maslia M.L., **2013**. Source Characterization and Simulation of the Migration of Light Nonaqueous Phase Liquids (LNAPLs) in the Vicinity of the Hadnot Point Industrial Area—Supplement 7. In: Analyses and Historical Reconstruction of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Drinking Water Within the Service Areas of the Hadnot Point and Holcomb Boulevard Water Treatment Plants and Vicinities, U.S. Marine Corps Base Camp Lejeune, North Carolina—Chapter A: Summary and Findings. Atlanta, GA: Agency for Toxic Substances and Disease Registry; 2013.
- Jones, N.L. and Davis, R.J., 2024. Tarawa Terrace Flow and Transport Model Post-Audit, Integral Consulting, Inc., October 25, 2024.
- Jones, N.L. and Davis, R.J., **2025**. Expert Rebuttal Report of N. L. Jones, Ph.D., and R. J. Davis, Camp Lejeune Water Litigation, January 14, 2025.

- Konikow, L.F., **1986**. Predictive Accuracy of a Ground-Water Model — Lessons from a Postaudit. *Ground Water*, vol. 24, no. 2, pp. 173–184.
- Konikow, L.F., **2025**. Rebuttal to Reports of Dr. Alex Spiliotopoulos and Dr. Remy J.-C. Hennet. Camp Lejeune Water Litigation, January 13, 2025.
- Konikow, L.F., and Thompson, D.W., **1984**, Groundwater contamination and aquifer reclamation at the Rocky Mountain Arsenal, Colorado: *in* Groundwater Contamination, National Academy Press, Washington, D.C., p. 93-103.
- Kidmose, J., Trolborg, L., and Refsgaard, J.C., **2023**. Post Audit of Groundwater Model Predictions under Changing Conditions. *Water*, vol. 15, 22 p.
- Maslia, M.L., and Aral, M.M., **2004**. ACTS—Analytical Contaminant Transport Analysis System (ACTS)—Multimedia Environmental Fate and Transport. *ASCE Practice Periodical of Hazardous, Toxic, and Radioactive Waste Management*, 2004, v. 8, no. 3, pp.181-198.
- Maslia, M.L., editor, **2005**. Expert Peer Review Panel Evaluating ATSDR’s Water-Modeling Activities in Support of the Current Study of Childhood Birth Defects and Cancer at U.S. Marine Corps Base Camp Lejeune, North Carolina: Atlanta, GA: Agency for Toxic Substances and Disease Registry; 2005.
- Maslia, M.L., Sautner J.B., Faye R.E., Suárez-Soto R.J., Aral M.M., Grayman W.M., Jang W., Wang J., Bove F.J., Ruckart P.Z., Valenzuela C., Green J.W. Jr., and Krueger A.L., **2007**. Analyses of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Drinking Water at Tarawa Terrace and Vicinity, U.S. Marine Corps Base Camp Lejeune, North Carolina: Historical Reconstruction and Present-Day Conditions—**Chapter A**: Summary of Findings. Atlanta, GA: Agency for Toxic Substances and Disease Registry; July 2007.
- Maslia, M.L., editor, **2009**. Expert Panel Assessing Methods and Analyses for Historical Reconstruction of Groundwater Resources and Distribution of Drinking Water at Hadnot Point, Holcomb Boulevard, and Vicinity, U.S. Marine Corps Base Camp Lejeune, North Carolina, April 29–30, 2009; *Prepared by* Eastern Research Group, Inc., Atlanta, GA; *Prepared for* Agency for Toxic Substances and Disease Registry (ATSDR), Atlanta, GA, 149 p.
- Maslia, M.L., Suárez-Soto, R.J., Wang J., Aral M.M., Faye, R.E., Sautner J.B., Valenzuela C., and Grayman, W.M., **2009**. Analyses of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Drinking Water at Tarawa Terrace and Vicinity, U.S. Marine Corps Base Camp Lejeune, North Carolina: Historical Reconstruction and Present-Day Conditions—**Chapter I**: Parameter Sensitivity, Uncertainty, and Variability Associated with Model Simulations of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Drinking Water. Atlanta, GA: Agency for Toxic Substances and Disease Registry; February 2009.
- Maslia, M.L., Aral, M.M., Faye, R.E., Grayman, W.M., Suárez-Soto, R.J., Anderson, B.A., Bove, F.J., Ruckart, P.Z., and Moore, S.M. **2012**. **Comment on**: “Complexities in Hindcasting Models—When Should We Say Enough Is Enough,” by T. Prabhakar Clement, v. 49, no. 5, 620–629: *Ground Water*, v. 50, no. 1, 10–16.

Maslia, M.L., Suárez-Soto R.J., Sautner J.B., Anderson, B.A., Jones, L.E., Faye, R.E., Aral, M.M, Guan, J., Telci, I.T., Grayman, W.M., Bove, F.J., Ruckart, P.Z., and Moore, S.M., **2013**. Analyses and Historical Reconstruction of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Drinking Water Within the Service Areas of the Hadnot Point and Holcomb Boulevard Water Treatment Plants and Vicinities, U.S. Marine Corps Base Camp Lejeune, North Carolina—**Chapter A: Summary and Findings**. Atlanta, GA: Agency for Toxic Substances and Disease Registry; February 2013.

Maslia, M.L., **2024**. Expert Report of Morris L. Maslia, P.E., D.WRE, DEE, Fellow EWRI. Camp Lejeune Water Litigation, October 25, 2024.

Melts, V.J., 2001. Deposition, in the General Court of Justice, Superior Court Division; April 12, 2001. Report No.: 01-CVS-566.

NRC (National Research Council), **1996**. *The Waste Isolation Pilot Plant--A Potential Solution for the Disposal of Transuranic Waste*. National Academy Press, Washington, D.C., 169 p.

Person, M., and Konikow, L.F., **1986**. Recalibration and Predictive Reliability of a Solute-Transport Model of an Irrigated Stream-Aquifer System. *Journal of Hydrology*, vol. 87, pp. 145–165.

Rogers, L. **1992**. History matching to determine the retardation of PCE in ground water. *Groundwater*, **vol. 30**, no. 1, p. 50–60.

Roy F. Weston, Inc., **1992**. Remedial Investigation Report, ABC One-Hour Cleaners, Jacksonville, North Carolina: Roy F. Weston, Inc.; 1992.

Roy F. Weston, Inc., **1994**. Remedial Investigation, ABC One-Hour Cleaners, Operable Unit 2, Jacksonville, North Carolina: Roy F. Weston, Inc.; 1994.

Samhel, J.; Devlin, D.; Paustenbach, D.; Hollins, D.; Gaffney, S., **2010**. The Role of Exposure Reconstruction in Occupational Human Health Risk Assessment: Current Methods and a Recommended Framework. *Critical Reviews in Toxicology*. 2010, *40*, 799–843.

Sabatini, D.R., **2025**. Expert Rebuttal Report of David Sabatini, Ph.D., PE, BCEE,. Camp Lejeune Water Litigation, January 14, 2025.

Sautner JB, Maslia ML, Valenzuela C, Grayman WM, Aral MM, and Green JW Jr., **2005**. Field Testing of Water-Distribution Systems at the U.S. Marine Corps Base Camp Lejeune, North Carolina, in Support of an Epidemiologic Study. Proceedings: World Environmental and Water Resources Congress; 2005 May 15–19, Anchorage, AK.

Sautner, J.B., Anderson, B.A., Suárez-Soto, R.J., and Maslia, M.L., **2013**. Descriptions and Characterizations of Data Pertinent to Water-Supply Well Capacities, Histories, and Operations—**Supplement 1**. In: Maslia ML, Suárez-Soto RJ, Sautner JB, Anderson BA, Jones LE, Faye RE, Aral MM, Guan J, Jang W, Telci IT, Grayman WM, Bove FJ, Ruckart PZ, and Moore SM. Analyses and Historical Reconstruction of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Drinking Water Within the Service Areas of the Hadnot Point and Holcomb Boulevard Water Treatment Plants and Vicinities, U.S. Marine Corps Base Camp Lejeune, North Carolina—Chapter A: Summary and Findings. Atlanta, GA: Agency for Toxic Substances and Disease Registry; 2013.

Spiliotopoulos, A., **2024**. Expert Report of Alexandros Spiliotopoulos, Ph.D., in the United States Eastern District of North Carolina, No. 7:23-cv-897, Camp Lejeune Water Litigation, S. S. Papadopoulos & Associates, December 9, 2024.

Wilcox, D.A, Thompson, T.A., Booth, R.K., and Nicholas, J.R., **2007**. Lake-level variability and water availability in the Great Lakes: U.S. Geological Survey Circular 1311, 25 p.

Tung, Y-K., and Yen, B-C., 2005. Hydrosystems Engineering Uncertainty Analysis, McGraw-Hill, 273 p.

USEPA (U.S. Environmental Protection Agency), **1986**. Underground Motor Fuel Storage Tanks: A National Survey. Washington, DC: U.S. Environmental Protection Agency; 1986. Report No.: EPA-560/5-86-013.

USEPA , **1988**. Superfund Exposure Assessment Manual. Washington, DC: U.S. Environmental Protection Agency, April 1988. Report No. EPA/540/1-88/001.

USEPA, **1987**. Causes of Release From UST Systems. Washington, DC: U.S. Environmental Protection Agency; 1987. Report No.: EPA 510-R-92-702.

USEPA, **1999**. Understanding Variation in Partition Coefficient, K_d , Values, Volume II. Washington, DC: United States Environmental Protection Agency, 1999 August. Report No.: EPA 402-R-99-004B.

Zheng C., **2010**. MT3DMS v5.3 Supplemental User's Guide. Technical Report to the U.S. Army Engineer Research and Development Center. Tuscaloosa, AL: Department of Geological Sciences, University of Alabama; 2010.

Zheng C., and Bennet, G.D., **2002**. Applied Contaminant Transport Modeling, Second Edition. John Wiley and Sons, Inc., New York, 621 p.

Zheng C., and Wang P.P., **1999**. MT3DMS: A Modular Three-Dimensional Multi-Species Model for Simulation of Advection, Dispersion, and Chemical Reactions of Contaminants in Groundwater Systems: Documentation and User's Guide. Vicksburg, MS: U.S. Army Engineer Research and Development Center; 1999. Report No.: SERDP-99.

Appendix A — Volatilization Issues: Excerpts From the ATSDR Expert Panel Meetings of March 28, 2005 and April 30, 2009

2005-03-28 Panel Meeting Transcript at 55:2-57:14

Panel members Thomas Walski and Peter Pommerenk (AH Environmental consultant) respond to a question from Dr. James Uber to Morris Maslia about whether there are any potential chemical biological processes taking place in the distribution system.

Dr. Thomas Walski, 55:2-56:1: “To give you a little answer to your question, Jim, on the processes, most of the things that happen to the VOCs in pipes don't really -- I mean, there's not much that can happen to them. I mean, in pipes, the only place where you could have much of a process affecting them is usually in tanks where you have a free water surface and they can volatilize. But when Ben and I did the work in Phoenix/Scottsdale, we looked at that, then went back to Henry's Law and looked at stuff like that. And we did -- you know, since you don't really -- it's hard to measure these kind of things, and there's not a lot of literature on Henry's Law in a perfectly still tank. Usually, if it's for stripping towers and stuff like that, you have a lot of literature data.

But going back and trying to reconstruct this, we estimated 97 percent of what went into a tank came out. Very little is really lost through the surface, and that's about the only process that you lose VOCs is through the surface of the tank. So basically, assuming that it's -- what goes in the system goes to the tap is probably, you know, a reasonable assumption if there's not processes occurring. At least, we couldn't figure out any processes that would knock down the concentration significantly.”

Dr. Pommerenk, 56:2-57:14: “Yeah. I have some supporting information on that. Because that question was asked by Camp Lejeune to us as their consultants, we looked into literature and tried to come up with a rough estimate of would there be any removal within the treatment plant. And since, you know, we had to review all of the drawings of the existing plants, we knew the surface areas that are available. We made certain assumptions: You know, is the water quiescent in that tank, or, you know, is there any agitation anywhere?

In all the tanks that we looked in -- and some of the tanks are newer. There's more surface area available today than there used to be early in the seventies. But removal due to volatilization was negligible. I mean, it was less than a tenth of percent. The only location where there would be some removal was in the spiractors that were operated in all these Hadnot Point, Holcomb Boulevard, and Tarawa Terrace plants. And even there, there was a certain uncertainty, depending on they had conditions downstream you would get some agitation at the effluent pipe. So although we said it's probably negligible, and I agree with Tom's number here. At 90 percent, what's going in is coming out on the other end.”

2009-04-30 Panel Meeting Transcript

Dr. Pommerenk, 178:18-181:19: “ . . .there's a big five treatment plant in between, between the groundwater collection system and the distribution system.

It consists -- and correct me if I'm wrong -- of a [ground storage --ed.] tank. I don't remember what the size is, but it's probably a million gallon or larger. The Hadnot Point plant has a pump station that pumps water from that water collection tank into what are called catalytic softening units or [spiractor --ed.] cones to which [lime --ed.] is injected to facilitate softening and it overflows into a central pipe.

It goes from there through a rectangular basin that used to be a re-carbonation base, and I'll get back to that. And from there into gravity filters and you know after chlorination and fluorination into a finished water clear well.

Obviously, in this facility there's several quiescent or not so quiescent surfaces from which volatile – ed.] organic compounds can escape. And that kind of depends on the physical properties of these compounds, PCE more so than TCE and so on. We made an estimate a few years ago, a rough estimate, that probably PCE and TCE, we didn't look at BTEX, removal would be incidental, minor, probably. The tanks are covered so there's no way effluents could stir up things.

However, what was not looked at that was, because of lack of information is the re- carbonation basin. The re-carbonation basin serves to, it's typically a small, flow-through basin to which you inject carbon dioxide that is generated from a propane generator or from gas bottles. And carbon dioxide is an [acid –ed.] in water and [decreases –ed.] the pH which has been pretty high prior to, because of lime addition.

So that's how this whole softening process works. You bring the pH up you're still going to have calcium carbonate. Bring the pH back down within the allowable limits. So as far as I know, and as far as I can recall, I've never seen this basin in operation. It was just water flowing through. However, it was put in for a purpose originally some time in the '40s, and nobody can tell me exactly if it ever has been operated and how long it has been operated. Because if it has been operated, it could have [caused –ed.] substantial removal of PCE and TCE. It would have been in the 90 percent removal.

And it kind of depends on the gas flow rates. It kind of depends on the turbulence that got generated. So there's a variety of factors that would have presented. But it could have affected removal of these compounds in the plant. And again, we just looked at PCE and TCE as from volatilization from the basins that are there, not [re-carbonation –ed.] because we didn't have any additional information.

But it might be worth looking into BTEX volatilization from the basins, you know, whether that as a source is uncertainty again. And I'm not trying to get exact numbers or anything, but it's another source of uncertainty for the exposure calculations for what could potentially be the removal of these compounds from the plant, A. And B, finding out whether this has ever been online, this re-carbonization basin

EXHIBIT 7

**THE U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
PUBLIC HEALTH SERVICE
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY**

convenes the

**EXPERT PEER REVIEW PANEL
ATSDR'S HISTORICAL RECONSTRUCTION ANALYSIS
CAMP LEJEUNE, NORTH CAROLINA**

VOLUME I

The verbatim transcript of the meeting of the Peer Review Panel, held at 1825 Century Boulevard, Room 1A/B, Atlanta, Georgia, on Monday, March 28, 2005, taken by Diane Gaffoglio, Certified Merit Court Reporter.

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Volume I
March 28, 2005

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Legend of the transcript:

[sic]	Exactly as said
[phonetic]	Exact spelling unknown
--	Break in speech continuity
...	Trailing speech or omission when reading written material
[inaudible]	Mechanical or speaker failure
[microphone]	Speaker is off microphone

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P R O C E E D I N G S

8:38 a.m.

MR. MASLIA: Good morning. Welcome, everybody, to our expert panel meeting. We're going to wait a few minutes for some other people to arrive that are part of the program this morning. But in the meantime, I thought I would go through some housekeeping rules, if that's okay with everybody. And just to our panel members and everybody else that had to fly in, either yesterday or this morning, through the weather, thank you for making the effort. We appreciate it.

And -- so real briefly, for those not familiar with ATSDR campus, we're right over here. And there's a cafeteria here and down here as well is the restaurant in the Century Center hotel plus some other restaurants around. And so, on campus, there's two cafeterias and the restaurant. There will be two buses for lunch from the hotel. We've made arrangements to eat at the restaurant or the dining area at the Century Center hotel.

And I'm going to ask for those other guests, the nonpanelists, to allow the panelists to take the first bus -- it holds 12 -- so they can get to the business of eating and getting back. And then there's a second bus that will take anyone else to that, or you're free to go any place off-campus. There's a variety of foods and

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1 other establishments.

2 Located on the first floor behind the guard station
3 through the metal detector that you passed through are
4 restrooms and candy machines and Coke machines, if the
5 bottled water or the candy that Ann brought will not
6 suffice.

7 Messages will be at a board near the registration
8 desk, if you need someone to -- if you've got messages.
9 And there's also a telephone out in the outer alcove for
10 you to use. And any copying, faxing, or other needs, Ann
11 Walker, who's staying by the door right there, and Joann
12 -- I don't see Joann. She's out in the hallway -- Joann
13 Flesner have been very gracious to stand by at a moment's
14 notice and at the panel's needs to do anything you need.

15 And you are being recorded, audiotaped. So we ask
16 you to speak into the microphones, primarily for the
17 purpose so ATSDR can have a transcript and a report of
18 your comments so we can deal with them directly after the
19 meeting. There will be a report published of this
20 meeting; not the transcript, but a summary report that
21 will be available to everybody. And we're asking you to
22 silence your cell phones. If you can, just turn them off,
23 which would be our preference. If you have it on vibrate
24 and you're at a microphone, everyone will hear the
25 vibration go off. And for those in the audience, the

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1 microphones and the court reporter can pick up your side
2 conversation, even though you're not on mike. So I'll
3 just remind you of that, that it will be picked up.

4 And with that, that's -- any other questions or
5 housekeeping issues? If not, Dr. Sinks, are you prepared?
6 It's my pleasure to introduce Dr. Tom Sinks, who is our
7 director of science and acting administrator for ATSDR.

8 DR. SINKS: Thanks, Morris. Well, good morning to
9 all of you. It's a pleasure to be here. As Morris
10 indicated, I'm the acting director for both ATSDR and the
11 National Center for Environmental Health, a title I've
12 been -- I've had for all of three weeks. And as actings
13 go, that may be a record. Who knows? It could be two
14 more days; it could be two more months. But it's actually
15 -- it's been thrilling, embarrassing, exciting. It's been
16 -- it's been a good ride so far in three weeks.

17 This is a -- this is a great opportunity for us to, I
18 think, do what ATSDR wants to be doing in these very
19 complex sites that we deal with. And the three things, I
20 think, we really want to accomplish here is to make sure
21 that we challenge ourselves to do the best science that we
22 can in what, in this particular example, is a very
23 complex, difficult study that we're trying to conduct.

24 And in this case, it's the modeling of drinking water
25 supplied to people who were living at Camp Lejeune many,

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1 many years ago and trying to recreate exposure scenarios,
2 which have occurred pretty far in the past; to do it in a
3 scientifically credible way; and make it as valid as we
4 can. And reconstructing these types of scenarios are
5 quite difficult, and we do need help in trying to do that.

6 So the first thing is the best science. The second
7 thing is trying to do this in a fairly transparent
8 process, to be open to criticism, constructive comments,
9 to let people know what it is that we are trying to
10 accomplish, and to give them that idea upfront so that
11 when we arrive at our conclusions, people have a good
12 understanding of what we were doing and how we were trying
13 to do it. And this panel is helping to play a role for us
14 and when -- to challenge ourselves to the best job that we
15 can.

16 The panel members here are nationally and
17 internationally recognized experts in the areas of
18 groundwater hydraulics, fate and transport analyses,
19 water-distribution systems, numerical-modeling techniques.
20 And we're delighted to have you-all here.

21 Again, our objectives are to secure from the panel
22 members, who are not ATSDR employees but are people from
23 outside of ATSDR, your critiques and your approaches and
24 your recommendations for what we're about to do. This
25 information will be made public.

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1 Morris, will we put it on the Web site? Is that --
2 will the report be on the Web site?

3 MR. MASLIA: It's our intent to.

4 DR. SINKS: Okay. So it will also be open to the
5 public just beyond this meeting. And I presume we'll put
6 a response to the recommendations on there as well, how
7 we're going to handle that.

8 My next challenge is to introduce Dr. Barry Johnson.
9 Barry is sitting at the head of the table. He looks
10 younger every time I see him. I think it's because he
11 doesn't have to be the assistant administrator of ATSDR,
12 and I think a great weight has probably come off of his
13 shoulders. He's smiling. It's the first time I've seen
14 him smiling in years. I tend to be chasing Barry around.

15 Barry -- I've known of Barry since 1985 when I became
16 an EIS officer assigned to NIOSH. As soon as I arrived to
17 NIOSH, Barry took off. He left NIOSH, and he went to
18 ATSDR where he effectively really became the first
19 assistant administrator of ATSDR, pulling it away from
20 CDC, creating a separate agency and really building it to
21 what it is today. Barry retired in 1986 -- no. That's
22 the wrong date; 1999.

23 DR. JOHNSON: It depends on how you interpret
24 retirement (laughter).

25 DR. SINKS: Barry left ATSDR in --

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1 DR. JOHNSON: 1999.

2 DR. SINKS: -- 1999 and has joined the Rollins School
3 of Public Health over on Clifton Road as an adjunct
4 professor there. He's currently working on a lot of
5 editorial boards. He's writing books. He has one in
6 publication right now, and it's his job to give you-all a
7 charge for this conference and to lead this throughout the
8 next couple of days. I do plan to stop in from time to
9 time during the course of the next two days. I won't be
10 able to attend the entire meeting, but I wish you-all
11 success in a fairly difficult and complex situation.

12 So thanks a lot and, Barry, I think it's all yours.

13 DR. JOHNSON: Thank you, Dr. Sinks, for those kind
14 remarks and sage advice to the panel. We have a full
15 agenda ahead of us over the next two days, building upon
16 the direction that Dr. Sinks has provided to us. As you
17 all know, I'm sort of a last-second fill-in for someone
18 else, and I certainly look forward to trying to be as
19 helpful as I can.

20 When Mr. Maslia called me about a week ago and said
21 he needed a Chair, I listened. And I then reminded him of
22 my retired status, my membership as a senior citizen, and
23 so forth and so on. I said, "Morris, I'm willing to
24 consider this, but there are many personal sacrifices I
25 have to bring to your attention and -- for example,

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1 foregoing my morning, afternoon, and early evening naps;
2 my shawl; my warm cocoa; and, of course, the prune juice."

3 And he said, "Johnson, these sound more like excuses
4 than sacrifices." And with that unassailable logic, I
5 signed on. So I look forward to working with you over the
6 next couple of days. Perhaps, we can get it done in a
7 little bit less time.

8 The agency has asked me to present both a statement
9 from the Chair as well as the charge to the panel. I'm
10 assuming that you have the charge to the panel, but, I
11 will nonetheless go through it shortly. With regard to
12 the purpose and scope of this expert peer review panel, it
13 is to assess ATSDR's efforts to model groundwater and
14 water-distribution systems at the U.S. Marine Corps Base,
15 Camp Lejeune, North Carolina.

16 This work includes data-collection activities, field
17 investigations, and water-modeling activities that were
18 performed through -- from March through December 2004.
19 The panel is specifically charged with considering the
20 appropriateness of ATSDR's approach, methods, and time
21 requirements related to water-modeling activities. It is
22 important to understand that the water-modeling activities
23 are in the early stages of analysis; hence, the data and
24 interpretations are subject to modifications based in part
25 on information provided by members of this expert panel.

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1 ATSDR expresses a commitment to weigh questions from
2 the public and to respond to public comments and
3 suggestions in a timely fashion. However, in order for
4 this panel to complete its work, it must focus exclusively
5 on water-modeling issues. Therefore, the panel will
6 address questions and comments that pertain to the water-
7 modeling effort. All other questions and statements will
8 be referred to ATSDR staff for consideration and response.

9 In particular are -- the ATSDR contact for nonwater-
10 modeling questions is Dr. Frank Bove and -- who will
11 handle questions related in particular to the
12 epidemiological work, and Mr. Morris Maslia and associates
13 will handle the water modeling and other water-related
14 questions.

15 Any reactions from the panel? Tread on any toes?
16 You okay with that?

17 (No audible response)

18 DR. JOHNSON: I think the bottom-line message here is
19 that this is a meeting for the next two days that's going
20 to be focused on the water-modeling activities. I
21 understand there have been other meetings that have
22 focused on other things and so forth. Do you each have a
23 copy of the charge to the panel?

24 (No audible response)

25 DR. JOHNSON: I will read most of that for -- just to

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1 be sure that it's in the record and it's put before the
2 public and would suggest that you follow along as I go
3 through this.

4 The Agency for Toxic Substances and Disease Registry,
5 ATSDR, is requesting the panel's opinion with respect to
6 the following questions. ATSDR is seeking a majority
7 opinion with opposing views. First, will ATSDR's approach
8 of using "50-foot cell sizes" for groundwater modeling and
9 all pipes, networks for water-distribution system models
10 provide sufficient detail required by the epidemiological
11 case control study? Should coarser, variable-spacing
12 groundwater-model grids or skeletonized-pipe networks for
13 water-distribution system models be considered in an
14 effort to reduce the length or duration of modeling
15 activities?

16 Two, is the ATSDR approach of simulating monthly
17 conditions using water-distribution system models sound,
18 or should ATSDR consider using a continuous simulation for
19 the historical period; i.e., 1968 through 1985? If
20 continuous simulation should be used, does this approach,
21 A, increase or decrease the work effort with respect to
22 modeling activities? B, increase or decrease the level of
23 uncertainty and variability of simulated results?

24 Three, based on information provided by ATSDR to the
25 panel, are there modifications or changes that ATSDR

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1 should consider making in its approach to modeling, A,
2 groundwater resources at Camp Lejeune; B, present day;
3 i.e., 2004, and historical reconstruction of water-
4 distribution systems serving Camp Lejeune? If, in the
5 panel's majority opinion, ATSDR should consider changes in
6 its approach, what specific changes does the panel
7 suggest?

8 And fourth, compared with other publicly documented
9 historical-reconstruction analyses, is the three-year
10 project schedule for completing all historical-
11 reconstruction modeling activities appropriate and
12 realistic for the amount of work and level of detail
13 required by the epi study? If, in the panel's majority
14 opinion, ATSDR should modify the project schedule, what
15 specific actions and activities does the panel suggest
16 ATSDR take to modify the project schedule?

17 That is the charge to the panel as developed by
18 ATSDR. Any questions or reactions at this time to either
19 the statement or the charge to the panel? It is the
20 Chair's intent on Day 2 to go through each of these four
21 charges, beginning at the "working lunch" on Tuesday. And
22 at minimum, I anticipate providing your reactions, your
23 advice to the first two charges at the working lunch.

24 If we work in, perhaps, an exceptionally, efficiently
25 way, then we might try to go through Charges 3 and 4. But

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1 at least we'll do the first two charges tomorrow at lunch.
2 Charges 3 and 4, if they remain unaddressed, will be
3 subject to our discussion at the 2:30 period.

4 The take-home message to the expert panel is that we
5 will provide answers to our -- the best of our ability to
6 each of these four charges. Is that okay with the panel?

7 (No audible response)

8 DR. JOHNSON: At this time, I'd like to ask each of
9 the panel members -- and as Dr. Sinks said, it's truly an
10 internationally distinguished panel, and we welcome you to
11 Atlanta. Sorry the weather wasn't a bit better, but it's
12 that time of the year, folks, in Atlanta; pop-up storms.

13 I'd like to ask each of you to introduce yourself,
14 your affiliation, experiences related to this panel's
15 work. And I think I'll ask each of you, as you go through
16 your introductions, to give an initial but pithy, succinct
17 reaction to what you have read, the information that was
18 provided to you. I'm not asking you to pass judgment at
19 this time. That's going to be the product of our
20 deliberations, your deliberations in particular, but just
21 an initial reaction to what you have received. Okay.

22 Let's start to my right, if we could, with Dr.
23 Walski.

24 DR. WALSKI: Okay. My name is Tom Walski. I'm with
25 the Haestad Methods Group within Bentley Systems. I've

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1 been doing water-distribution analysis work since the
2 seventies and have worked on systems ranging from
3 outhouses at rec areas to the New York City water-supply
4 system. I've done some reconstruction of water quality,
5 in one case with Ben Harding, who's showing up later on.
6 So I have some experience in doing this kind of
7 reconstructive work as well. And my initial pithy
8 reaction is: Gee, I wish I had the budget that these guys
9 had when I was doing my work.

10 DR. JOHNSON: Thank you. Dr. Singh.

11 DR. SINGH: Yes. My name is Vijay Singh. I am a
12 faculty member at Louisiana State University. I have been
13 involved for many, many years in hydrologic modeling, both
14 in surface water as well as groundwater modeling. I have
15 also been involved in this kind of analysis as well as
16 stochastic modeling, which has involved some
17 reconstruction work, more specifically in the area of
18 groundwater, particularly the area of surface water as
19 reconstruction codes.

20 My reaction, based on reading the reams of papers and
21 reports that we were supplied, is a very positive one. I
22 was much impressed with the level of effort and the
23 scientific rigor with which the work has been done.

24 DR. JOHNSON: Thank you. Please.

25 DR. POMMERENK: My name is Peter Pommerenk. I'm with

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1 AH Environmental Consultants. We specialize in water
2 resources, water treatment, water distribution. In such,
3 we are involved in water master planning and treatment
4 studies and treatability studies. We also do some water-
5 distribution system modeling, although we don't use
6 Haestad methods at this time.

7 My particular expertise for this panel is that AH
8 Environmental Consultants has been consulting with Camp
9 Lejeune for several years in the water resources and
10 treatment-distribution system arena. And we have also as
11 such supported the Marine Corps in their efforts to
12 collect data for this ATSDR study.

13 My initial reaction, when I got first involved in
14 this project -- as I said, this is a huge effort. And
15 what has been collected today is really impressive. Thank
16 you.

17 DR. JOHNSON: Thank you. Let's just continue.

18 DR. CLARK: My name's Robert Clark. I spent 41 years
19 with the federal government in the U.S. Public Health
20 Service in the U.S. EPA as a public health service officer
21 for 30 years. And during that time, I was director of the
22 drinking-water research division -- water-resources
23 research division for EPA for about 14 years and then for
24 three years as a senior scientist in the agency and then
25 retired in -- about three to four years ago. And since

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1 that time, I've been consulting and am an adjunct
2 professor at the university, which is keeping me busy as
3 well.

4 Very impressive. I had a chance to work with Morris
5 early on when he was working on the Toms River project.
6 They've come a long ways; very impressive technical
7 effort. I think the questions are even more challenging
8 in terms of how can you extend this now to exposure
9 epidemiology.

10 DR. DOUGHERTY: My name is Dave Dougherty. I'm from
11 Subterranean Research in Massachusetts. I spent 15 years
12 as a faculty member in civil and environmental engineering
13 in California and Vermont. My background started in
14 groundwater and moved to modeling and moved to
15 optimization and more -- slightly more on the IT side now.

16 I think the things that I bring to this particular
17 table are the integration of groundwater modeling and
18 optimization kind of activities, experience with a lot of
19 models in the past, and the most interesting connection is
20 when Roger Page and I, in 1985, I think, built the first
21 3-D model for Toms River; so just trying to connect the
22 loop.

23 My reaction is there's been a lot of -- there's been
24 a lot of good work here. It is in many ways, in many
25 ways, very far advanced in particular narrow areas for the

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1 project. As a whole, I think we have a lot of
2 opportunities to make contributions to the directions that
3 need adjustment, and I'm looking forward to it.

4 DR. JOHNSON: Thank you.

5 DR. UBER: My name is Jim Uber. I'm an associate
6 professor at the University of Cincinnati in the
7 department of civil and environmental engineering. I'm an
8 environmental engineer. My research area is water-
9 distribution systems analysis. I've been working in that
10 area for about 15 years and have, kind of like David,
11 focused to some degree on optimization studies and
12 calibration techniques for models, particularly on water-
13 quality models for water-distribution systems and as well
14 as doing some fieldwork and tracer tests.

15 And my initial reaction is that I thought that the
16 data that was provided was very comprehensive and in
17 particular on the water-distribution systems' side. The
18 -- for example, the fieldwork is certainly very much state
19 of the art in that area, and I think a central question
20 for me is exactly how that fieldwork and those data link
21 back to the needs of the epidemiological study and how
22 they connect up in a logical way with the historic data
23 that is or is not available for what happened some years
24 ago.

25 DR. JOHNSON: Thank you.

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1 DR. KONIKOW: My name is Lenny Konikow. I'm a
2 research hydrologist with the U.S. Geological Survey.
3 I've worked for them for over 30 years; to a large extent,
4 working on the development and application of solute-
5 transport models, contaminant transport models for
6 groundwater systems. One of the first applications I was
7 involved in was reconstructing the history of groundwater
8 contamination at the Rocky Mountain Arsenal in Colorado,
9 which was kind of the forerunner of the whole installation
10 and restoration program in the Department of Defense.

11 One of my concerns, reading through all the
12 documentations and thinking about this, is the lack of
13 historical data from the fifties, sixties, on into the
14 seventies. And I see that as presenting a very difficult
15 hurdle to overcome in trying to develop the quantitative
16 models. There's going to be invariably a lot of
17 uncertainty associated with the results of the very
18 quantitative models.

19 And as Jim said, I'm also a little concerned that I
20 don't have a firm feeling yet -- and I hope I get it today
21 -- for what -- how the models will be put to use. What is
22 needed by the epidemiological studies to come out of the
23 models? And for us to evaluate the models and the
24 approach to modeling, I think we need a clearer -- or at
25 least I need a clearer understanding of how the models are

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1 going to be used in terms of the epidemiological studies.

2 DR. JOHNSON: Thank you. We have two other panelists
3 who will be arriving a little bit later: Mr. Harding and
4 Dr. LaBolle. Did I pronounce that correctly? We look
5 forward to their joining us. Any questions across the
6 table to each other?

7 (No audible response)

8 DR. JOHNSON: My hope is that this is truly an
9 interactive panel, and I encourage dialogue, questions
10 back and forth across the table amongst the panelists.
11 And to the extent that I can help clarify, I will try to
12 do that. But this is your panel, and this is your
13 opportunity, as we've already heard, to have some concerns
14 and some really important questions placed on the table
15 already. So keep that up.

16 I think, at this time, there's going to be an
17 introduction of the epi team and the water-modeling teams,
18 Dr. Bove, and Mr. Maslia.

19 DR. RUCKART: Good morning. I'm not Dr. Bove, by the
20 way. I'm going to be discussing a summary of ATSDR
21 activities at Camp Lejeune and hopefully answering your
22 question of how the water-modeling component will fit in
23 with epi study.

24 DR. JOHNSON: Would you introduce yourself, please.

25 DR. RUCKART: Yep; next slide.

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1 DR. JOHNSON: We'd love to know who you are.

2 DR. RUCKART: My name's right there. I'm Perri
3 Ruckart. I'm the principal investigator of the epi study,
4 and my other team members include Dr. Frank Bove, Miss
5 Shannon Rossiter, and Dr. Morris Maslia, who I believe
6 everyone knows.

7 Next slide, please.

8 The base began operations at Camp Lejeune in the
9 1940s. Currently, there's a population of about 150,000
10 living or working on the base, including active military
11 personnel, their dependents, retired population, and
12 civilian employees. Almost two-thirds of the active
13 military personnel and their dependents are under age 25.

14 Next slide.

15 Because this is a military base, there has been
16 considerable in-and-out migration. It is estimated that
17 about one-third of the mothers receiving prenatal care at
18 the base hospital during the 1970s and '80s were
19 transferred off base before delivery, and the average
20 duration in base-family housing is two years. There are
21 15 different base-housing areas. And there are three
22 water-distribution systems serving the base-family housing
23 area: Hadnot Point, Tarawa Terrace, and Holcomb Boulevard.
24 And the dates they were constructed are shown here on this
25 slide.

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1 Underground storage tanks were installed during the
2 1940s and '50s, which contaminated the Hadnot Point wells,
3 primarily, with TCE. And ABC One-Hour Cleaners began
4 operations on the base in 1954, and the cleaners were near
5 the supply wells for Tarawa Terrace, and that water system
6 was primarily contaminated with PCE.

7 ATSDR published a public health assessment for Camp
8 Lejeune in 1997. Because of the limited information in
9 the scientific literature on how chlorinated solvents in
10 drinking water might affect a fetus or a child, the public
11 health assessment recommended that we conduct an
12 epidemiologic study to evaluate whether maternal exposure
13 was associated with the higher risk of having an adverse
14 birth outcome or whether maternal or infant exposure was
15 associated with a childhood cancer.

16 As a first step in following up the public health
17 assessment recommendation, ATSDR published a study in 1998
18 which evaluated potential maternal exposure to drinking-
19 water contaminants on base and preterm birth, small for
20 gestational age, and mean birth-weight deficit. Only
21 available databases were used, such as electronic birth
22 certificates, which were available beginning in 1968, and
23 base family-housing records.

24 There was insufficient data available for the 1998
25 study to evaluate fetal deaths. The study did find an

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1 elevated risk for SGA, small for gestational age, only
2 among male infants exposed to Hadnot Point water, which
3 was primarily contaminated with TCE. And the study also
4 found an elevated risk for SGA among infants born to
5 mothers who were greater than 35 years of age and mothers
6 with two or more prior fetal losses who were exposed to
7 Tarawa Terrace water, which is primarily contaminated with
8 PCE.

9 Because the 1998 study could not evaluate birth
10 defects or childhood cancers, the current study will look
11 at these outcomes, using a case control approach. It is a
12 multistep process, and the first step involved a review of
13 the scientific literature to identify specific birth
14 defects and childhood cancers that were associated with
15 drinking water contaminated with VOCs.

16 Next slide, please.

17 And this slide shows the outcome selected for further
18 study based mainly on evidence from the epi studies of
19 VOC-contaminated drinking water.

20 The second step in this process was to conduct a
21 telephone survey to identify the potential cases of the
22 selected birth defects and childhood cancers occurring to
23 mothers who were pregnant at any time during their
24 pregnancy and living at Camp Lejeune during 1968 to 1985.
25 And the survey needed to address the questions shown here.

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1 Can you go back for a second. Okay.

2 And as part of the telephone survey, ATSDR surveyed
3 parents of 12,598 children. This is an overall
4 participation rate of approximately 74 to 80 percent. And
5 the survey identified sufficient numbers of neural tube
6 defects, oral clefts, and childhood cancers. 106 cases
7 were reported, including 35 neural tube defects, 42 oral
8 cleft defects, and 29 childhood cancers. And the
9 childhood cancers include leukemia and non-Hodgkin's
10 lymphoma.

11 Next slide, please.

12 The third step is to verify the diagnoses of the
13 reported cases. To date, 24 reported cases have been
14 confirmed as not having the condition of interest or being
15 ineligible or refused. That leaves us with 82 children
16 with pending or confirmed conditions. And by pending, I
17 mean we are still looking for evidence to verify they have
18 their condition. That includes, for the neural tube
19 defects, 15 confirmed as having that condition. Thirteen
20 are still pending. For the oral clefts, 20 confirmed as
21 having that condition and 16 still pending. And for the
22 childhood cancers, 14 confirmed as having that condition
23 and four still pending.

24 The study will include 818 controls, who were sampled
25 from the original survey population. This is a ratio of

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1 about ten controls to cases. Interviews will begin in the
2 spring and continue through the summer of this year. And
3 they will be administered to parents of the cases and
4 controls to obtain information on maternal water-
5 consumption habits, residential history, and parental risk
6 factors. We anticipate a 90 percent participation rate
7 based on previous contact with this population and the
8 interest that they've shown in our work.

9 An important part of the current epi study is the
10 water-modeling component. There's a lack of historical
11 contaminant-specific data at Camp Lejeune. To provide a
12 quantitative estimate of exposure, a historical-
13 reconstruction approach is needed, consisting of modeling
14 the groundwater flow and present-day distribution systems
15 at Camp Lejeune and extrapolating backwards in time. The
16 water-modeling component needs to address the following
17 questions shown on this slide.

18 Next slide. Oh, go back. Can you go back, please.

19 DR. KONIKOW: Do you define "exposure" as just being
20 the presence or absence of a contaminant, or are you
21 interested in knowing the concentration of the
22 contaminant?

23 DR. RUCKART: We would like to know the
24 concentration, and our hope would be to group them into
25 some kind of high, medium, low exposure. But it's going

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1 to be dependent on what is available. That's our ultimate
2 goal.

3 And the goals of the water-modeling component are to
4 determine when the contamination arrived at the wells and
5 the spatial and temporal distribution of the contaminants
6 by housing location. And I'd like to conclude with the
7 study time line.

8 Are there any questions? We'll be here throughout
9 the panel if things should come up.

10 DR. JOHNSON: Could you go back, please, to the
11 couple of slides previous; one more; stop. Thank you.
12 No; the one that says "Current ATSDR Epi Study; that one;
13 try again; stop. Thank you.

14 My question, I guess, is to Mr. Maslia. Are these
15 questions to be addressed in the water-modeling component
16 part of what has been put before this panel? Or are these
17 questions that are, maybe, new?

18 MR. MASLIA: Part of the -- some of the questions are
19 to be addressed by this panel. We've -- you want me to
20 speak into the microphone, I guess. Let me just come over
21 here and sit down.

22 Some of the questions have been put forth in the
23 discussion, for example, at Tarawa Terrace where the
24 source is located, the strength of the contaminant source.
25 Others, for example, like at the Hadnot Point, we

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1 obviously have not addressed that issue at this point in
2 time. And that's an issue for us to discuss and to
3 address, both with information that we may present or
4 elucidate to the panel now in some of the complexities at
5 Hadnot Point, as opposed to Tarawa Terrace.

6 Which chemical compounds were supplied? Again, at
7 Tarawa Terrace, it is our intention -- and the data that
8 we have presented has at this point indicated that PCE,
9 PERC, is the primary contaminant, and that's what the
10 modeling to date has been done on. We have not looked at
11 modeling-degradation products, say, TCE to DCE and TCE.

12 Hadnot Point, again, presents a much more complex
13 issue because, as Perri has alluded to, it's primarily
14 TCE, but there was underground-storage tanks as well. And
15 we just have not -- I'll get into -- actually, when I give
16 an overview of the water-modeling activities as to our
17 rationale for going in one direction right now. But we
18 have not addressed that issue.

19 How was the contaminated water distributed is a main
20 focus of our investigation. And we start out -- our
21 approach is to try to understand what's going on today
22 simply because of the lack of historical data, and I will
23 get into a little bit later on our approach for
24 deconstructing the system, if that's the way, actually, we
25 proceed. That is, indeed, a required step that we go.

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1 Lenny, did you have a question? Yes.

2 DR. KONIKOW: In terms of the water distribution and
3 the goals of that modeling, are you aiming to actually get
4 exposure down to the household level?

5 MR. MASLIA: We're aiming to get it down to the
6 street level. Now, at Camp Lejeune, it so happens -- and
7 we'll get into this -- the distribution is built such that
8 it's a looped system so that each house is serviced by a
9 pipe, as opposed to, say, an area like Dekalb County or
10 even Toms River, where maybe there was a 4-inch main
11 running down the street and we did not model any of the
12 attached or smaller diameter pipes.

13 But the way the distribution system is constructed at
14 Toms -- I mean, at Camp Lejeune, you really have a 2-inch
15 pipe going from the street to the house. So in essence,
16 by default, you've got houses attached or implied in your
17 distribution-system modeling.

18 However, I think it's important also to tell the
19 panel as well as the public is -- as with other
20 contamination sites that we have looked at, we are
21 actually blinded to the cases and controls at the site.
22 ATSDR people modeling the groundwater and distribution
23 system, we haven't been provided nor are we asking for any
24 specific information as to who resides, who's included in
25 the cases and controls so that it is our approach that any

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1 models that we develop or any analyses -- let's make it
2 more general -- should be robust enough that if you say
3 you want Location XYZ, you should have as much confidence
4 in the results that we give you for Location XYZ as
5 Location ABC. And that is our approach, but we are
6 blinded. So hopefully, that's addressed your question.

7 DR. BOVE: I just want to say one more thing that one
8 of the questions earlier was: How are we going to
9 categorize exposure? And as it was done in Toms River and
10 Woburn, where they just focused on the percent of the
11 water coming from a contaminated well during a month and
12 then averaging over that for the exposure window, we'll be
13 doing something like that. They had three categories in
14 the Toms River study. Woburn was ever-never, and then
15 they did have three categories, again, of exposure, the
16 high one being the upper tenth percentile, if I remember
17 right.

18 But the numbers get small when you start doing that.
19 And I have some tables, and we can discuss the impacts of
20 exposure misclassification bias and some of that during
21 the panel discussion at some point during the day, if you
22 want.

23 DR. JOHNSON: Yes.

24 DR. WALSKI: I think just to put things in
25 perspective, you said there were about 80-some cases of

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1 illnesses that are -- were determined in the study group.
2 About what would the number of illnesses be out of the --
3 like, an average population? Would it be, like, many
4 times above what we would expect? Or is it only
5 marginally, or what's the perspective?

6 DR. BOVE: Well, part of the problem here is the way
7 we had to ascertain cases. Ideally, you would like to
8 have a cancer registry, or you would like to do your case
9 ascertainment through hospital records. We had to do it
10 through a survey. So this is not the most optimal way,
11 but it was the only way to do ascertainment of cases.
12 That being said -- and all the comparison data is based on
13 medical records data or cancer registries, like the Sierra
14 Cancer Registry, or birth defect registries, like the one
15 in Atlanta.

16 It's hard to really compare the two. But if you
17 want, these are -- what we've -- both the reported
18 positive ones that we verified and the ones we're still
19 working on, if you combine those two, we have slight
20 elevations here in the -- I would say the realm of two
21 times what we might expect for some of the end points.

22 But, again, there are problems with that. Not
23 everybody was exposed at Camp Lejeune either. And the way
24 we ascertained them was different than the databases we
25 would compare them to.

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1 DR. JOHNSON: Other questions? Dr. Singh.

2 DR. SINGH: So here the assumption was that the
3 increase was attributed to the water contamination?

4 DR. BOVE: No. We didn't want to do that. We wanted
5 to use the survey to ascertain cases and do the study with
6 the modeling that Morris -- and you're going to be
7 commenting on. We did not want to say straight off
8 whether the -- it was an excess, number one, because we
9 wanted to verify the cases. At the time of the survey,
10 it's only self-reporting -- or parent-reported cases. And
11 so we wanted to verify those cases.

12 And secondly, because of all the problems with the
13 water information, new information we've been getting over
14 the -- well, not so new actually, over the last few years
15 that things we thought we knew about the water system,
16 information we got about the water system was not quite
17 correct and that, in fact, the study that Perri mentioned
18 that we completed in '98 probably needs to be revisited.

19 Most definitely, it needs to be revisited because
20 assumptions made in that based on that information at the
21 time, but we find it was incorrect. So we didn't want to
22 do anything until the modeling was done, and we -- and
23 base whatever we do on better information.

24 DR. CLARK: Are we going to have a chance to look at
25 other compounding effects?

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1 DR. BOVE: We -- well, as Perri pointed out, we're
2 doing an interview of the cases and controls. That's one
3 of the nice things about doing a case-control sample. You
4 have a small enough group so you can do extensive
5 interviewing and go over all the other risk factors that
6 are either suspected or known for these outcomes.

7 DR. JOHNSON: Do the members know the essentials of a
8 case-control epi study? Are you-all real comfortable with
9 that?

10 DR. BOVE: Well, we can -- we -- again, that's
11 something we can go into in-depth at any point during the
12 day.

13 DR. JOHNSON: Could you give us about two minutes
14 now?

15 DR. BOVE: Okay; two minutes? Okay. Well, I mean,
16 you have -- we're not sure how many pregnancies occurred
17 at the base between 1968 and '85 because many were
18 transferred. We had to guesstimate that about a third of
19 the people who were pregnant there migrated off-site --
20 transferred basically off-site before they delivered. So
21 we knew how many births on base. That was about 12,400
22 and some. And we assumed another 3,000 or so were
23 transferred off base and delivered elsewhere, so roughly
24 around 16,000.

25 Now, you have 16,000. You can't interview them all;

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1 right? That would be an incredible undertaking. That's
2 one approach. Another approach is to take a random
3 sample. But when we have rare diseases, that's not a good
4 approach because you take a random sample and may not get
5 any of the cases in that random sample of 16,000. So the
6 approach you take within a disease that's rare, like this
7 situation, is what we call case-control sample.

8 DR. JOHNSON: You're speaking of birth defects;
9 correct?

10 DR. BOVE: We're talking about birth defects. We're
11 talking about, in particular, neural tube defects, which
12 is spina bifida and anencephaly. We're talking about oral
13 clefts, which is cleft lip and cleft pallet. And we're
14 talking about childhood leukemia and childhood non-
15 Hodgkin's lymphoma. And those are all rare events, those
16 diseases that we're focusing on.

17 And so the approach has been to gather all the cases
18 from that population at Camp Lejeune, keeping in mind that
19 the population at Camp Lejeune of births, both born on
20 site and born off site, some were exposed; some were not
21 exposed; right. That's the question we're going to be
22 asking you is hopefully is will the modeling be able to
23 tell us with some assurance who's exposed at least and who
24 wasn't exposed. If we can get that, that's one step.

25 And then, of course, we'd like to have -- be able to

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1 define it better than that. But that's the first
2 consideration. So we have a population here, some of whom
3 are exposed, some of whom are not exposed during their
4 pregnancy. And we take -- we get all the cases from that
5 population, and then we take a random sample of that
6 population to give us a control series. And that's the
7 case-control series.

8 Now, in some methodologies, you sample your control
9 series irrespective of whether they were -- what their
10 disease status was. That's one approach. A lot -- most
11 often, though, you sample the nondisease, those people in
12 the population that did not have the case -- the diseases
13 you're focusing on. So that's basically what we're
14 talking about: a case-control sample, the most effective
15 way of doing these kinds of studies. It was also the
16 approach taken in Woburn, the approach taken at Toms
17 River.

18 DR. SINGH: So why do you have some people not
19 exposed if they were living on Camp Lejeune?

20 DR. BOVE: Well, we're -- see, that's the question.
21 We -- in the previous study, we thought that about half of
22 the births were unexposed because they were getting water
23 from the Holcomb Boulevard system. And at that time, we
24 assumed that the Holcomb Boulevard system was clean.
25 Okay? So that study, half -- about half the births were

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1 unexposed.

2 Now we're not sure about anything, or at least I'm
3 not. I'm waiting to hear from the discussion. There may
4 be interconnections between Holcomb and Tarawa Terrace.
5 The -- before '73, the people who -- the residences that
6 got Holcomb Boulevard water got Hadnot Point before that.
7 And so we thought that they -- for some reason, we didn't
8 know what their exposure was. We assumed they were
9 unexposed. That was a bad assumption probably.

10 So we don't know the percent unexposed. I mean,
11 that's what the modeling effort's going to have to tell
12 us. That's why we have to revisit those previous -- that
13 previous study.

14 DR. RUCKART: There's another piece about those also
15 when during the pregnancy that the mother was exposed.
16 And we're hoping to have that information as well if they
17 were exposed in the first trimester or later. It depends
18 on when they were actually residing at Camp Lejeune.

19 DR. JOHNSON: David, you had a question.

20 DR. DOUGHERTY: It actually follows on that one, and
21 it is: You addressed the issue of the spatial resolution
22 desired. What temporal resolution of exposure is desired
23 from these studies?

24 DR. BOVE: Well, for neural tube defects and oral
25 clefts, the window of exposures is the first trimester.

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1 And actually, for neural tube defects, it's Day 20 to 24,
2 roughly. So we're not asking for day. But we are asking
3 for a trimester with the idea that, you know, that the
4 exposure windows for neural tube defects and oral clefts
5 is quite small. Okay.

6 Now, childhood leukemia and childhood non-Hodgkin's
7 lymphoma, we are not sure. We -- from the studies I've
8 seen, the initial cause for the disease appears to be
9 prenatal. So again, we're interested in most often --
10 mostly in prenatal exposures for this study as a whole for
11 all the outcomes.

12 DR. JOHNSON: Other questions? Yes, please.

13 DR. UBER: Just to -- I think I know the answer to
14 this, but just to clarify. The study is not concerned
15 with any fetuses that would not have made it to a live
16 birth that might have had a cause from contamination?

17 DR. RUCKART: Right; because it's difficult to
18 ascertain that. If we could, that would be ideal. But
19 it's just not really possible here.

20 DR. JOHNSON: Yes.

21 MR. MASLIA: Just to help everybody get oriented, I
22 think during a subsequent presentation, I've got some maps
23 and some slides, so we're all calling the same parts of
24 the base the same names and things like that. And we'll
25 define that for everybody, so...

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1 DR. JOHNSON: Thank you. Any more questions to Dr.
2 Ruckart or Dr. Bove? I have one last question to PI.
3 This isn't a question but a comment. The question will
4 follow. It looks like these five questions in the main
5 are -- have been in some way put before the panel. Do you
6 feel that that's true? I mean, are you okay?

7 MR. MASLIA: Absolutely.

8 DR. JOHNSON: Okay. I would --

9 DR. RUCKART: We work together.

10 MR. MASLIA: We even talk with each other.

11 DR. JOHNSON: Lord, the agency has indeed changed
12 since I left (laughter). I'm so glad I'm sitting down. I
13 would invite the epi team, starting with this principal
14 investigator, to place before this panel at any time
15 questions that you feel have not been addressed or have
16 not been addressed to your satisfaction because this work
17 in terms of the water modeling absolutely has to be vital
18 in support of your work. And now is an excellent time to
19 get things, you know, you always wanted to ask. Put it in
20 front of this group, and you will have profound answers.

21 Now my question: You mentioned work that's upcoming
22 in the spring of 2005. Has that work begun?

23 DR. RUCKART: We are actually traveling up to
24 Maryland this weekend to be part of the training for the
25 interviewers, and interviews are scheduled to begin Monday

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1 night or Tuesday morning by the latest. That will be next
2 Monday and Tuesday.

3 DR. JOHNSON: Do you foresee anything that this panel
4 will do over the next two days as having impact for the
5 spring work?

6 DR. RUCKART: I don't believe so.

7 DR. JOHNSON: Okay. Well, thank you very much for
8 your presentation. Mr. Maslia, a summary of water-
9 modeling activities.

10 MR. MASLIA: Let me get the summary of water-modeling
11 activities. Actually -- no. Let's go to project staff
12 first; yes. Thank you. I've got it. I've got it.

13 DR. JOHNSON: And there are handouts here for the
14 panel.

15 MR. MASLIA: The panel, yes. Some of the handouts
16 are copies of this slide, and if any of the slides that we
17 show that you would like copies of, please let me know or
18 let Ann Walker know, and we'll try to provide those for
19 you.

20 DR. JOHNSON: Are these available to the public
21 outside?

22 MR. MASLIA: Some of them are. The ones that contain
23 actual model simulation and data are not because they have
24 not been cleared by the agency and subject, obviously, to
25 panel deliberations. And so those are not available to

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1 the public. But we do have posters and maps, showing some
2 information that everyone's free to look at and peruse,
3 and we'll be pointing to.

4 Let me officially, I suppose, introduce myself. My
5 name's Morris Maslia. I'm a project officer of the
6 Exposure Dose Reconstruction Program at ATSDR. And I was
7 approached by Dr. Bove and his predecessor to take part in
8 the Camp Lejeune epidemiologic study and looking at some
9 of the techniques that we used for the Dover Township
10 analyses and seeing if those, in fact, could be used or
11 something similar to that could be used.

12 I've introduced myself. Also from ATSDR is Jason
13 Sautner over here. Jason did the bulk of the modeling
14 work at Dover Township and had his intentions on doing the
15 modeling here. But as things progressed, Jason has really
16 helped us developing some of the field approaches and
17 field protocols for the tracer tests on the water-
18 distribution system modeling and setting those up, setting
19 up the field type of analyses and data gathering. And so
20 he's been more involved in that respect up until this
21 point.

22 We also have -- we used the Oak Ridge Institute for
23 Science and Education to get postgraduate research fellows
24 to assist us. Claudia Valenzuela has unfortunately been
25 relegated to helping us with logistics on the slide screen

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1 back there. I don't mean to point the laser at you,
2 Claudia. It's like *Star Wars*.

3 But Claudia has really done the lion's share of the
4 water-distribution system analyses that were presented in
5 the notebooks and also has done a tremendous job in
6 investigation in trying to figure out this issue of
7 classification of different types of consumption and
8 demand. We'll get into that. Obviously, being a military
9 reservation, we may not have a simple case of residential,
10 urban, industrial-type classifications.

11 Also just joining us this past October is Joe Green,
12 and Joe's background is in medical geography. And all of
13 the nice posters and the spatial analysis work, Joe has
14 helped us out. He goes back and forth between the
15 distribution-modeling results and the groundwater-modeling
16 results, helping us put together and pull different
17 aspects of the data.

18 And as far as groundwater modeling and fate and
19 transport modeling, we have Robert Faye, who is sitting
20 over there. And Bob spent -- and I had my notes. It's
21 probably on another slide here but -- I believe, 27-1/2
22 years in U.S. Geological Survey; 12-1/2 or so, he was the
23 regional groundwater specialist for the southeast region
24 at USGS. And he has been doing the groundwater -- not
25 only groundwater modeling, but the geohydrologic

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1 framework, culling through the data files for the
2 groundwater aspect of the analyses.

3 And then finally, we also have Dr. Mustafa Aral, who
4 is sitting right at this table. And we have a cooperative
5 agreement with the multimedia environmental simulations
6 lab at Georgia Tech. They assisted us with our Dover
7 Township work and are involved -- I expect to be even more
8 involved when we start tackling this issues of uncertainty
9 modeling, operational cycles, and things of that nature.

10 And finally, not present -- and I'm not sure why Dr.
11 Grayman decided that he'd rather be on the beach at St.
12 Maarten than here -- but Walter Grayman, whose background
13 is in water-distribution system modeling, has been an
14 advisor to us, helping plan the tracer tests on the water-
15 distribution side as well as water-distribution system
16 modeling. And as I said, he's an advisor to ATSDR.

17 So that is the project team. I would like to just --
18 and we can revisit this, but I was -- in going through
19 some of the premeeting comments, which we really do
20 appreciate. It helped us focus more on the direction we
21 needed to go and some of the answers we're going to try to
22 at least provide you in a general sense at this meeting
23 and something to work on, obviously, after the meeting.

24 But a couple of questions came up with respect to the
25 charge on the work effort. Obviously, everyone's admitted

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1 thus far this is not a small undertaking. And so I put
2 together a couple of slides just very quickly, and you
3 have -- there's a -- should be a packet. If not, we can
4 provide you these in your handout.

5 But this slide sort of shows -- the red bar is the
6 total work effort, the percent of effort. You see, for
7 example, groundwater, we're estimating thus far has taken
8 about 35 percent of the total effort. Water-distribution
9 system modeling is about 40, primarily because of the
10 field and us having to go out in the field and that
11 nature. Data discovery -- this is anything from going
12 through the Marine Corps base facility that they call "the
13 vault" to look through data to other -- finding other
14 sources of information. And then communication, whether
15 that's preparing reports for this meeting, preparing
16 presentations, or ultimately preparing final reports or
17 protocols as to what we did.

18 And just within each subject I subdivided. For
19 example, in groundwater modeling, you've got a data
20 discovery component and you've got a data-analysis
21 component, which would be both geohydrologic and modeling
22 and so forth.

23 You can see that in the water-distribution side,
24 we've got an extremely driving up until this part is the,
25 I believe, that's the data discovery. No. That's the

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1 spatial analysis. I'm sorry; spatial analysis. And that
2 is the cause of the complexity, both present day as well
3 as historically, of exactly having documentation of where
4 the pipes were, which treatment plants were operating.

5 A lot of this information originally was on paper
6 copies, and we had to geocode it and all that sort of
7 stuff. Even conducting field tests, locating hydrants,
8 many, if not most, of the hydrants on base are not
9 numbered. And we had to physically send people out there
10 to actually locate and two different people locate two
11 different hydrants and things of that nature. So that's
12 what's driving that.

13 The final slide is more of a budgeting in terms of
14 staff. If you add up all the red bars, it adds up to
15 about four and a half equivalents, full-time equivalents.
16 And so within that, again, you can see the present day.
17 This refers to the present-day water-distribution system
18 modeling. It is really driving the time-consuming and
19 manpower-intensive aspect of the project. So that's just
20 a very quick overview of our staffing from the water-
21 modeling side.

22 And I believe that's all the project staff comments I
23 have, unless someone has any specific questions on those.
24 If not, I think next on is a summary of water-modeling
25 activities. Claudia, if you will -- and I think that's

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1 number four; number four -- no. It's number five. Yeah,
2 yeah; right there. That's it. Okay.

3 I'm going to just give a very brief overview of
4 modeling activities, so hopefully you get -- if the
5 written documentation you were providing was confusing
6 enough and voluminous enough to sort of simplify it. And
7 you can go on -- I've got it right here. Okay.

8 Obviously, we're in coastal North Carolina, and we've
9 got some maps here, some aerial photographs. But as Frank
10 mentioned, there are actually seven water-distribution
11 systems. And historically, there have been eight
12 different water-distribution systems at Camp Lejeune. And
13 we are actually concentrating the discussion today in our
14 charge are the ones down in this area right over here.

15 So the ones, for example, at the air base, which is
16 over here, and Onslow Beach, while they have and we may
17 have information on them, they are not part of the
18 analysis that we are undertaking. Basically, Perri
19 reported this information; population of active duty,
20 100,000; and seven water systems supply groundwater at
21 Camp Lejeune.

22 Here are the names of the different systems, and as I
23 said, we're dealing with the Tarawa Terfrace, Holcomb
24 Boulevard, and Hadnot Point systems. And in the next
25 slide, what I would like to do -- and we have the posters

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1 up, that one over there, and I think if you want to move
2 the second poster. Okay.

3 We have sort of a nomenclature issue. As anybody
4 who's done any groundwater investigation or other
5 investigations, as you get later and later time away from
6 either when the wells were installed or the systems
7 operated, names change.

8 So this is the nomenclature that we are using for the
9 present discussion and for the present-day system. At
10 present, there are two operating water-treatment plants.
11 Water-treatment plants service areas that we are
12 analyzing. And these are the Hadnot Point, which is down
13 to the south here. And we're referring to that as the
14 Hadnot Point water-treatment plant service area. And then
15 there's the Holcomb Boulevard water-treatment plant
16 service area, which is this area.

17 Basically, there are two sets of shut-off valves
18 right along the Wallace Creek here that at present day
19 separates the two systems completely. They're shut off.
20 In terms of actual water-distribution systems, there are
21 three water-distribution systems within the two water-
22 treatment plant service areas. Hadnot -- could you back
23 up? Okay.

24 Hadnot Point happens to service the Hadnot Point
25 water-distribution system area. So it's coincident. The

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1 treatment plant services the water-distribution system.
2 However, in this northern area, the Holcomb Boulevard
3 actually services two different distribution systems. One
4 is to the northwest here, the Tarawa Terrace water-
5 distribution system, which presently is combined with
6 service to Camp Johnson.

7 Historically, there was another treatment plant here,
8 which I'll get to in a minute, and then also the
9 distribution system at Holcomb Boulevard area. There is
10 one pipeline here that, once the water is treated at the
11 treatment plant, sends water to an underground reservoir
12 at Tarawa Terrace and based on demand and tank levels
13 would then distribute water just to the Tarawa Terrace
14 area.

15 So are there any questions with respect to
16 nomenclature that we're going to use for the balance of
17 the panel meeting at this point?

18 (No audible response)

19 MR. MASLIA: I'll get to a very brief chronology.
20 We've got some larger boards here. And as Frank said,
21 this chronology has been sort of at times chasing a moving
22 target. And so it remains sort of changing in flux even
23 as we speak. As we get new information or as we get
24 conflicting information, we start changing.

25 But very briefly, the Hadnot -- this is actually as

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1 -- I put this together last week, so it's the most current
2 that we have. '43, Hadnot Point was the first
3 distribution system and first treatment plant on base.
4 And then in '51 to '52, the Tarawa Terrace treatment plant
5 was constructed. That's about the time that they also
6 built the housing complex at Tarawa Terrace. And then at
7 '50 -- in '57 was the Montford Point. And the Montford
8 Point actually serviced the Camp Johnson, which is the
9 northwestern-most part of the distribution system.

10 Then we have a big question, which we have not
11 resolved to date yet. We cannot get a month or year as to
12 when Holcomb Boulevard began operating. They've got a
13 picture on the wall that says '73. You know, one of those
14 architectural pictures that -- and we do have an accounts
15 book that we just received a couple of weeks ago that
16 lists when the information is filed into their system.
17 That sort of lists '73 as well. However, documentation
18 that we have just -- that we've just recently received
19 says '71, and that can be a very critical issue.

20 So all I can say is I'm at the panel's mercy. That
21 is a major issue, and, in fact, I think -- and I hope the
22 panel doesn't mind me mentioning names, if you've made
23 some comments. But Tom made a comment about putting some
24 effort into data discovery. I'll call it that. And that
25 still is ongoing and needs to be refined. We're planning

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1 to do that some more, but we're going to have to obviously
2 get detailed into the files to figure that out. So I'll
3 just put that up there. We're not sure when in that time
4 frame. And obviously, if the epidemiologic study is
5 looking at months, that becomes an issue.

6 Tarawa Terrace -- when the water-treatment plant was
7 closed, again, we think March. We think 1987. It started
8 back in '85. We just recently obtained some information,
9 a report, that I'm asking for some more background on --
10 that I've asked the Marine Corps for some background on
11 that was written in '91 that makes a statement in there
12 that, "Two years prior," which would be at -- in '89,
13 "that Tarawa Terrace" -- and I'm quoting --- "supplied
14 water to Holcomb Boulevard." That, again, so -- and
15 that's in a consulting report. There may be other
16 information as well, but that's some of the issues we're
17 still dealing with.

18 And finally, in '87, again, we have some
19 documentation that says all the remaining wells were
20 closed. So we -- the issue is we are still in the midst
21 of this data discovery and coming up with a finalized or a
22 time line that, if you want to say, is cast in concrete or
23 stone that's fixed. We're not satisfied with some of the
24 components of the time line at this time. Okay.

25 Goals and objectives of the modeling. These were the

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1 goals discussed with the epidemiologists when we first met
2 as to what they needed for the epidemiologic study;
3 arrival of contaminants at the well. And obviously, that
4 also means concentration values or ranges, not just when
5 they first arrived at the wells.

6 From the distribution side, the distribution of
7 contaminants by housing location. We've sort of -- and
8 housing location is taken to mean, like, Tarawa Terrace,
9 Holcomb Boulevard; not necessarily House, you know, 2103.
10 That's my interpretation, but as I said, the piping-system
11 network does go down to the street level.

12 And it's always been our intent to address
13 uncertainties. We understand their impact and the impact
14 they can have, especially on interpreting results from the
15 epidemiologic point of view and what sort of confidence.
16 Just as an example, when we were doing our Dover Township
17 work, the epidemiologist came back to us and asked, "Well,
18 now that you've given us that House A receives 10 percent
19 of the water, does that mean it's 10 percent plus or minus
20 50 percent, or is it 10 percent plus or minus 2 or 3
21 percent?" We had -- I don't know if it's luxury or
22 opportunity there to tell them, "No. It's 10 percent plus
23 or minus about 3 to 4 percent." We were able to reduce
24 that out by running different scenarios for them.

25 Whether that proves -- or whether we have the ability

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1 to do that here based on data, we're still looking into
2 it. That's what we're looking for some of the input from
3 this panel to tell us. And so -- and we've got the
4 uncertainties on all sides: the groundwater analyses as
5 well as the distribution side.

6 So to finish up, again, and this, I suppose, is more
7 so for our public that's here but to go over a generalized
8 approach. We've got our site, Camp Lejeune, here. And on
9 the groundwater side, we're using the Modflow or one of
10 its derivatives, which will become eventually coupled with
11 a fate and transport analysis.

12 You have only been provided -- the panel -- with an
13 advective part up until this point in time. But it's been
14 our intent all along to go to the full-blown look at the
15 dispersive issues as well and then, on the distribution
16 side, an EPANET-type or its equivalent too. Again, we've
17 used EPANET and its equivalent for our present-day
18 analyses; actually to help us, guide us, in preparing some
19 of the field studies.

20 And I believe that's all on the overview of the -- of
21 the types of models. One point I wanted to make on the
22 report that the panelists were given -- I'm calling it a
23 report, and that's probably a misnomer. It's more
24 probably a collection of data collection efforts and some
25 background information.

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1 And if we -- or if I implied that it was intended as
2 a final or finished product, that was probably a
3 miscommunication on my part. It was really meant to be a
4 working document, hopefully presented in some intelligent
5 form, that you could make sense out of it. So this is not
6 an intent for you necessarily to review that document as a
7 report but as the data contained in it.

8 And I believe that's it for the overview of the
9 modeling. At this point, Dr. Johnson, we've got two
10 options. I've got a brief overview on the groundwater and
11 then leading into detailed discussions and analyses with
12 Bob Faye. Or we had prepared some general responses to
13 some of the premeeting comments. I didn't know if that
14 was the opportunity -- if this was when you wanted me to
15 just give an overview of those.

16 DR. JOHNSON: No.

17 MR. MASLIA: Okay.

18 DR. JOHNSON: I think it is, though, the time and
19 opportunity to ask questions on what we've heard thus far.
20 Yes.

21 DR. UBER: Morris, this might not be the best time to
22 ask this question. So I don't -- I cannot speak myself
23 authoritatively at all on chemical or biological processes
24 affecting any of these contaminants, and so this question
25 also maybe then goes to some of the panelists who can.

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1 But do you know: Right now, do any of those potential
2 chemical biological processes act in the distribution
3 system? And if so, are their kinetics effective over
4 residence time scales that are typical of distribution
5 systems?

6 MR. MASLIA: I have to plead ignorance to that. I
7 don't know if that's a question that Frank -- as far as
8 biologic processes with respect to the epi part of things.
9 I know that question came in other studies of biologic
10 plausibility, the fact that you can make an association,
11 say, between contamination of a water resource and an
12 apparent disease. Is there, in fact, a biologic
13 plausibility for that?

14 DR. BOVE: Oh, I didn't know -- I thought the
15 question was more on processes.

16 MR. MASLIA: Oh, was it? Okay. I think I can --

17 DR. BOVE: Yeah; because I can answer that one.

18 DR. UBER: I think I can -- I was probably too wordy.
19 I just want -- I'm basically asking: Does the team feel
20 right now that for purposes of transport in the
21 distribution system that they can model these contaminants
22 as tracers?

23 MR. MASLIA: Based on what we've seen with the
24 responses to the present-day system -- and that's all we
25 have right now -- the answer is yes. In fact, we've made

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1 some, I think, some interesting, if not eye-opening,
2 observations based on how the present-day system is
3 operating. And from what we have been told to date, that
4 is a typical operation over the last 20 or 30 years with,
5 of course, obviously, changes in hydraulic and
6 infrastructure, removing treatment plants, starting up the
7 Holcomb Boulevard treatment plant, things of that nature.

8 But based on the preliminary tests that we've done to
9 date, we have been able to, I believe, do some acceptable
10 -- not maybe final, but acceptable model simulations.
11 And, in fact, it was the model simulations that led us --
12 and we'll get into this probably later this afternoon and
13 tomorrow -- that led us to suggest to the utilities' folks
14 at Lejeune that they, in fact, perhaps had some closed
15 valves while we were doing it, relying on some -- and it
16 turned out that that was correct.

17 So I believe -- to answer your question in a short
18 manner, I believe the models will -- based on what we've
19 seen to date will provide us the ability to provide some
20 answers on that. As far as the level of variability or
21 uncertainty, I think that's where we need to get back with
22 the epidemiologists and really sit down and see what level
23 they're willing to accept or can accept for their
24 analysis. And that, I can't answer you at this point in
25 time.

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1 DR. UBER: Oh, okay.

2 DR. WALSKI: To give you a little answer to your
3 question, Jim, on the processes, most of the things that
4 happen to the VOCs in pipes don't really -- I mean,
5 there's not much that can happen to them. I mean, in
6 pipes, the only place where you could have much of a
7 process affecting them is usually in tanks where you have
8 a free water surface and they can volatize.

9 But when Ben and I did the work in
10 Phoenix/Scottsdale, we looked at that, then went back to
11 Henry's Law and looked at stuff like that. And we did --
12 you know, since you don't really -- it's hard to measure
13 these kind of things, and there's not a lot of literature
14 on Henry's Law in a perfectly still tank. Usually, if
15 it's for stripping towers and stuff like that, you have a
16 lot of literature data.

17 But going back and trying to reconstruct this, we
18 estimated 97 percent of what went into a tank came out.
19 Very little is really lost through the surface, and that's
20 about the only process that you lose VOCs is through the
21 surface of the tank.

22 So basically, assuming that it's -- what goes in the
23 system goes to the tap is probably, you know, a reasonable
24 assumption if there's not processes occurring. At least,
25 we couldn't figure out any processes that would knock down

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1 the concentration significantly.

2 DR. POMMERENK: Yeah. I have some supporting
3 information on that. Because that question was asked by
4 Camp Lejeune to us as their consultants, we looked into
5 literature and tried to come up with a rough estimate of
6 would there be any removal within the treatment plant.
7 And since, you know, we had to review all of the drawings
8 of the existing plants, we knew the surface areas that are
9 available. We made certain assumptions: You know, is the
10 water quiescent in that tank, or, you know, is there any
11 agitation anywhere?

12 In all the tanks that we looked in -- and some of the
13 tanks are newer. There's more surface area available
14 today than there used to be early in the seventies. But
15 removal due to volatization was negligible. I mean, it
16 was less than a tenth of percent. The only location where
17 there would be some removal was in the spiractors that
18 were operated in all these Hadnot Point, Holcomb
19 Boulevard, and Tarawa Terrace plants.

20 And even there, there was a certain uncertainty,
21 depending on they had conditions downstream you would get
22 some agitation at the effluent pipe. So although we said
23 it's probably negligible, and I agree with Tom's number
24 here. At 90 percent, what's going in is coming out on the
25 other end.

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1 One thing that had to be -- we were not able to
2 address. I believe the Hadnot Point plant used to have a
3 carbon dioxide contact basin. We could not find out when
4 this contact basin was operated because, obviously, that
5 process would agitate the water significantly. It was
6 also open to the atmosphere. It was not in a closed
7 building. And there could have been some significant
8 removal, but we were not able to be certain when this --
9 they ceased the operation of that unit at Hadnot Point a
10 long time ago. And even some of the older operators that
11 we talked to were not able to tell us when that was. But,
12 again, you know, what Tom said is probably accurate, that
13 you can probably use PCE and TCE as a tracer distribution
14 system.

15 DR. WALSKI: Which leads to the question, though, on
16 the measurements we have. We have only a handful of
17 measurements of VOCs in the system. Were these taken
18 before treatment or after treatment? When were they
19 taken?

20 MR. MASLIA: There are some -- from the health
21 assessment, there's some tap samples. So that obviously
22 would be after treatment. We've got some groundwater
23 wells with PCE and PCE measurements, so that's obviously
24 before treatment.

25 DR. CLARK: But there's a third class that's on the

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1 schedule that says water-distribution system.

2 DR. JOHNSON: Step up to the microphone, please.

3 DR. CLARK: I'm sorry. The time line also has water-
4 distribution systems from neither tap nor well. And
5 that's what, I think, the question is.

6 MR. MASLIA: It's somewhere -- tap is at the
7 household.

8 DR. CLARK: No. Let me quote from it. It says,
9 "water-distribution system tested."

10 MR. MASLIA: Right.

11 DR. CLARK: Was that -- at which side of the
12 distribution system? I mean, at the tap?

13 MR. MASLIA: Oh, I see what you're saying.

14 MR. FAYE: I think that was on the treatment side.

15 COURT REPORTER: Excuse me. I can't hear you.

16 MR. FAYE: I believe it was on the treatment side.

17 DR. CLARK: Post-treatment.

18 MR. MASLIA: Post-treatment; post-treatment side.

19 DR. POMMERENK: Can I add to that? Thank you. As
20 far as I'm aware of -- and you, Morris, you probably
21 remember that too. The contamination of the drinking
22 water was first discovered -- there was -- a portion of it
23 was discovered in the early eighties when the -- after the
24 promulgation of the THM rule, the trihalomethane rule. So
25 these samples were taken in the distributions system at

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1 consumers' taps, and I think in the course of the
2 analysis, the laboratory that analyzed had problems
3 resolving the peaks from, you know, from the THM compounds
4 because I believe TCE or PCE was masking those other peaks
5 on their chromatograms. So these early data may have been
6 actually tap samples in the distribution system.

7 MR. MASLIA: Yes. We've actually got documents with
8 the lab notation on there, specifically addressing that
9 particular issue.

10 DR. JOHNSON: I have a question. With regard to the
11 models, you indicated, I think, that they're both EPA
12 models?

13 MR. MASLIA: No. No, sir. Modflow was originally
14 developed in the middle to late eighties -- correct me,
15 Lenny, if I'm wrong -- by the U.S. Geological Survey.
16 It's a public-domain model. And now, of course, there are
17 any number of proprietary codes that use it as the engine,
18 more or less, with the data sets. Basically, if they say
19 they're Modflow compatible, then you can run them with a
20 plain vanilla code, which is publicly available from the
21 USGS Web site, and we have done that.

22 EPANET is the same issue. That was developed by --
23 can I say this? -- your shop, Bob Clark's shop, when he
24 was at EPA, by Lou Rossman. We've worked with it from
25 Dover Township days, and again, a lot of the commercial

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1 codes for the water-distribution models use the EPANET
2 engine. We are actually using both a commercial or
3 proprietary code and EPANET. Some of the commercial
4 codes, as they do have nicer bells and whistles on the
5 front-end to make data input a little easier and things
6 like that. So there are two publicly available model
7 codes that have been vigorously and publicly tested.

8 DR. JOHNSON: What do we know about their validity?

9 MR. MASLIA: There -- we're convinced of their
10 validity. There's documentation. In fact, EPA has a
11 documentation ad for specific problems to test for
12 Modflow. And that's, again, available on the EPA Web
13 site, that if you want to -- if you make a modification,
14 if you will -- we have not made any modifications to the
15 models, by the way.

16 But if you do and you want to test its verification
17 or validity, then you can run those sets of problems.
18 EPANET 2 obviously is a second-generation version of EPA,
19 and it has gone through robust testing. And most of the
20 commercial codes, again, will carry the -- EPANET has a
21 set of problems that you can test your adaptation of it
22 against those benchmark -- if you want to call it those
23 benchmark problems.

24 DR. JOHNSON: Okay. Thank you. Why don't you
25 continue with the other material, please.

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1 MR. MASLIA: Okay. Thank you. At this point, what I
2 want to do is give a very brief overview, more of a
3 generalized overview, of this morning's -- the rest of
4 this morning's session will be on groundwater. And then
5 throw it over to Bob Faye to really address step-by-step
6 technical issues.

7 So, Claudia, if you'll get the groundwater slide --
8 groundwater overview. Okay. There you go. Is that the
9 first slide? No. I need -- back up one. Okay; one more.
10 Okay. I've probably got them X'd out. Okay. I'll make
11 it short and sweet then. Okay. Okay. There you go.

12 Sources of contamination, we've -- as we spoke about
13 Hadnot Point being the first one leaking underground-
14 storage tanks and spills and other waste disposal and then
15 Tarawa Terrace, which is the dry-cleaning source. And
16 that's really why in discussions with Bob Faye and myself
17 and with some input from the epidemiologic side is where
18 should we attack first.

19 In other words, we were more sure or more positive of
20 Tarawa Terrace being as close to a single source as
21 possible, an identifiable source. And so we decided from
22 a project-management standpoint as well as initial results
23 to show the applicability of what we were doing to go
24 after Tarawa Terrace. So -- and that just gives you the
25 dates. And the Well 26, which you'll probably hear a lot

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1 about and it is on our time chronology, is about 900 feet
2 from the dry cleaners. And that was the well -- one of
3 the wells that became contaminated at Tarawa Terrace.

4 And so the approach to modeling groundwater was to
5 assess Tarawa Terrace as a single source and a known
6 location, known location for the source and to develop a
7 geohydrologic framework. There have been some previous
8 work done -- Bob Faye will get into the details of that --
9 both from the U.S. Geological Survey in the middle to late
10 eighties being on site at Camp Lejeune as well as some
11 private consulting firms doing some work; construct the
12 three-dimensional Modflow model; calibrate the model for
13 study state or predevelopment; and then look at transient
14 conditions; and then conduct fate and transport. As of
15 today, we have done all but -- with Tarawa Terrace --
16 except the fate part. We've done the advective transport.

17 And that's really all -- I just wanted to give a
18 complete overview from the groundwater side to any members
19 of the public who are here or who want to see the big
20 picture. So that's the big picture on the groundwater
21 side. And at this point, again, I'd like to introduce Bob
22 Faye, who will give you the details of our groundwater-
23 modeling analyses.

24 DR. JOHNSON: Any questions to Mr. Maslia with regard
25 to the groundwater presentation?

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1 DR. POMMERENK: I have one question.

2 MR. MASLIA: Oh, sure.

3 DR. POMMERENK: Morris, don't quote me on this. I
4 don't remember quite -- in one of the public health
5 assessments, I seem to remember there was another
6 dry-cleaning business to the east of ABC. Can you just
7 briefly state why this is not included in your talk?

8 MR. FAYE: Yeah. Is this on? Peter, I can address
9 that. The initial study that was done in 1985 by Shiver,
10 I think it's called Globa-something or other --

11 MR. ENSMINGER: Globarama.

12 MR. FAYE: Globarama; right; Globarama Dry Cleaning.
13 The initial study that was done by NCDEM by Shiver in
14 1985, he looked at that -- at that facility in detail and
15 decided that not only did their operations -- it was a
16 closed operation, apparently, where they completely
17 recycled their waste and handled their waste in a
18 responsible way by hiring a waste management -- a concern
19 to move the waste away from the site.

20 Also, there were groundwater samples taken near the
21 site, as I recall, and it showed that there was no real
22 opportunity at that site for groundwater contamination.
23 For example, I think the observation well that they
24 drilled right in front of the ABC facility, the
25 concentration in September of '85 was about 12,000

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1 micrograms per liter of PCE. And the contamination at the
2 Globarama facility was minimal, was no comparison, if any.
3 Did that answer your question?

4 DR. POMMERENK: Yes.

5 MR. FAYE: Was that -- okay. And that has been
6 described and discussed in detail, not only in Shivers'
7 report, but also in the EPA Operable Unit 1 and Operable
8 Unit 2 reports that Weston --

9 DR. POMMERENK: Okay.

10 MR. FAYE: -- the Weston folks put together back in
11 the early nineties.

12 DR. POMMERENK: Thank you.

13 DR. JOHNSON: Okay. Any other questions?

14 MR. FAYE: Okay. My name is Bob Faye. I'm a
15 contract employee with the Eastern Research Group. And as
16 Morris said, my responsibilities for the most part have
17 been to construct and calibrate the groundwater-flow model
18 to date.

19 Dr. Johnson, am I allowed to suggest that if the
20 panel members have questions that they could just freely
21 interrupt me at any time?

22 DR. JOHNSON: Oh, absolutely.

23 MR. FAYE: Okay; great. Please do.

24 DR. JOHNSON: About how long is your presentation?

25 MR. FAYE: I think probably -- well, depending on

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1 questions, to complete the framework and the contaminant
2 description as well as the flow-model description,
3 probably on the order of 90 minutes or so.

4 COURT REPORTER: I'm going to need to take a computer
5 break before then.

6 DR. JOHNSON: 90 minutes?

7 MR. FAYE: 90; as in 80, 90, 100.

8 DR. JOHNSON: Morris, we have a 10:30 panel
9 discussion and answers to questions. This appears -- a
10 90-minute presentation would appear to be a serious
11 overlap.

12 MR. MASLIA: Yes. Part of the answer to the question
13 is we were going to direct feedback.

14 COURT REPORTER: Excuse me. Please get a microphone.

15 MR. MASLIA: Our intent was, I guess, with direct
16 feedback during Bob's presentation, to start addressing
17 some of those questions and perhaps hopefully -- not
18 eliminate them, but have some discussion on specific --
19 those specific questions. Unless -- and the other
20 suggestion -- not that that shortens the length, but I
21 didn't know if you wanted to take the 15-minute break now
22 and go through the entire presentation and go forth,
23 rather than breaking it up for the scheduled break.

24 DR. JOHNSON: What does the panel wish to do? Take a
25 break now?

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1 (Audible responses)

2 DR. JOHNSON: Okay. We'll take about a 15-minute
3 break and --

4 MR. FAYE: How do we resolve this, Dr. Johnson? Do
5 you want me to just describe the groundwater-modeling
6 effort? What does the panel -- well, I'm happy to
7 accommodate whatever the wishes are or try to accommodate.

8 DR. JOHNSON: What I heard Mr. Maslia say that the
9 idea here is to have the panel address some of the, what I
10 call, the eight questions that the agency has put forth on
11 groundwater and to try to integrate those into your
12 presentation. And that leads to them asking questions
13 during your presentation, and that seems to me to be quite
14 a good process. So does that answer your question?

15 MR. FAYE: Right. Well, I'll just -- then I'll just
16 continue with Plan A, and if somewhere in the interim we
17 need to switch, we'll go to Plan B and Plan C.

18 DR. JOHNSON: Okay. I will say that 11:45 we're out
19 of here as a stampede toward the lunch. So why don't we
20 take a 15-minute break? Be back at 10:30, please.

21 (Whereupon, a recess of approximately 17 minutes was
22 taken.)

23 DR. JOHNSON: Okay. Let's resume.

24 Let me suggest to the panel that you ask questions
25 during Mr. Faye's presentation, and I think it would be

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1 useful if you could relate some of your questions to the
2 questions that have been provided by ATSDR that pertain to
3 groundwater. And specifically, these are some eight
4 questions that were provided to you in advance.

5 I know you also provided premeeting comments, and at
6 some point, Mr. Maslia is going to provide kind of an
7 overarching response to that. But feel free to blend in
8 your premeeting questions and comments during the
9 presentation here by Mr. Faye.

10 We will continue the groundwater discussion after
11 lunch to some degree, to the point where we feel satisfied
12 with it. And if we finish a bit early, then I'm going to
13 push up the water-distribution systems questions to later
14 in the day.

15 So I need, also, as a matter of courtesy and respect
16 to introduce Dr. LaBolle. Would you introduce yourself,
17 your affiliation, and I asked each of the other panelists
18 to give kind of an initial reaction to the materials that
19 you received.

20 DR. LABOLLE: Yes. I'm Dr. LaBolle from University
21 of California, Davis, department of hydrologic sciences.
22 And my initial reaction: I was quite pleased with the
23 level of detail and work that's being done with the
24 distribution system. My expertise is in groundwater, but
25 I have some experience with distribution-system modeling,

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1 in particular, models that are similar in construction
2 with this groundwater linkage to the distribution-system
3 model with the fate and transport involved as well.

4 And my greater concern is with the variability and
5 uncertainty in the groundwater system, and I'll be posing
6 some questions with regards to that.

7 DR. JOHNSON: We look forward to those questions.

8 DR. LABOLLE: Thank you.

9 DR. JOHNSON: And welcome to the panel. Okay.

10 MR. FAYE: You ready?

11 DR. JOHNSON: Yes.

12 MR. FAYE: Okay. Just to start out, I want to
13 clarify one thing. You may hear me -- and I know in my --
14 in my papers that I wrote for the document, I use the term
15 "Montford Point," but that's equivalent to Morris' Camp
16 Johnson. Okay? So if I say -- if I slip and say
17 "Montford Point," just think Camp Johnson.

18 The rest of the areas, he's already talked
19 about: Tarawa Terrace area and the Holcomb Boulevard area.
20 And those are the three areas that feature in the
21 framework discussion. The Tarawa Terrace area features
22 exclusively in the model discussion and in the description
23 of contamination.

24 The purpose of the framework was to describe and
25 quantify the geometry, hydraulic characteristics, and

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1 potentiometric levels of the aquifers and confining units
2 at Tarawa Terrace and vicinity at a scale and level of
3 detail suitable for application to groundwater flow and
4 contaminant fate and transport models.

5 As far as data are concerned, these -- this is
6 inclusive of the Camp Johnson area, Tarawa Terrace area,
7 and the Holcomb Boulevard area. Elogs, that stands for
8 electric logs. We have a -- we have a poster with the --
9 with several examples of electric logs for your benefit.

10 There's two parts to an electric log: the resistivity
11 side, the spontaneous potential side. Both are important
12 and useful in terms of defining the various layers that we
13 -- that we're dealing with in terms of the framework.

14 There were 100 boring logs that were available to us
15 from a variety of sources. There were -- there are two
16 reports that address -- or three reports, actually, that
17 address the contamination relative to ABC One-Hour
18 Cleaners. There were -- and then -- many, many boring
19 logs associated with those reports. There's also a large
20 number of boring logs associated with RI/FS investigations
21 that are ongoing in the Tarawa Terrace area.

22 Claudia, could you move back to the previous slide;
23 and the next one, please.

24 These boring logs, unfortunately, are not spatially
25 well distributed in the study area. The boring logs

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1 almost exclusively refer to -- I'm sorry, almost
2 exclusively refer to RI/FS studies that are ongoing in
3 this very southern part of Tarawa Terrace and, of course,
4 in this northern area, just north and south of Lejeune
5 Boulevard, between ABC One-Hour Cleaners and Supply Wells
6 TT-26 and TT-25. And we'll be talking about those in just
7 a second.

8 That's a picture of a typical Elog that we have to
9 deal with. The spontaneous potential curve, which is the
10 left-hand -- the left-hand curve, is not very useful at
11 Camp Lejeune because it's a -- it's, more or less, an
12 industrial area. You've got a lot of ground currents, a
13 lot of current loss in the subsurface, which causes
14 reversals of the spontaneous potential curve.

15 Also, you have cycling going on; 60 cycles per second
16 in the subsurface. You have bleeding out of the -- out of
17 the electrical conduits that are buried, which also
18 confuse the resistivity side. But for the most part, all
19 of these analyses were based on areas or zones of low and
20 high resistivity and not related back to the spontaneous
21 potential.

22 This is typical of a boring log, one of the hundred.
23 I think this extends to a depth of about 20 feet or less.
24 Just a couple of points: This is the detail. These are
25 mostly logs from augering, hollow-stem augering. So you

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1 have a lot of smearing in the lithologic descriptions
2 going on, probably plus or minus half of a logger stem,
3 which is typically 5 feet. So any of these depths that
4 you identify as perhaps a top of an aquifer or a top of a
5 confining unit have to be identified in that context, that
6 we're looking at something that might be accurate to only
7 within plus or minus several feet.

8 A number of the boring logs were created using split-
9 spoon samples at different intervals. Those, of course,
10 are accurate to the identified depth, and they're very
11 accurate. Many of the logs -- many of the boring logs in
12 the Tarawa Terrace area, the northern part of Tarawa
13 Terrace area, the ABC Cleaners' area, identified a feature
14 called "running sands." And this -- this was -- shows
15 universally as the top of the Tarawa Terrace or the -- top
16 of the upper Castle Hayne aquifer. And I can tell you --
17 I can explain the rationale for that at some time later.

18 This is typical of the drillers' logs that we had
19 available to us. In fact, that's quite a good one
20 compared to many. That's the kind of detail that we
21 looked at; the lithologic descriptions. Most of the time,
22 I use the drillers' logs just to identify the occurrence
23 of what was called limestone or Copena.

24 There was a major, major problem in locating
25 accurately the various points of well-data collection, of

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1 monitoring wells, particularly for the many RI/FS studies
2 that were -- that were conducted there relative ABC
3 Cleaners and these other places. That was the 100 boring
4 logs that we -- that I discussed.

5 Virtually, the reports did not -- we used the state
6 plain coordinate system for North Carolina in 1983,
7 9-AD -- NAD. Virtually, none of the reports use that
8 system, so we had to convert the coordinates that were
9 available to us. Many of the coordinates in the report --
10 in some of the reports were not correct. They were --
11 even on their own system -- whatever arbitrary system they
12 devised.

13 So basically, what we did was just go back to the
14 old-fashioned way of measuring distances on the maps that
15 were provided. And we were able to identify -- you'll see
16 this -- the little building there, TT-47. We would take
17 intersections of roads or identified buildings or whatever
18 and use that as the -- we would find the state plain
19 coordinates for those places and then extrapolate those
20 coordinates to the rest of the map, basically just using
21 hand measurements. So you need to keep that in mind as
22 well as you think about the accuracy of the location data.

23 Finally, the end product of the geohydrologic
24 framework analysis was the development of 11 or 12 --
25 actually 11 -- 11 units as part of the framework, aquifers

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1 and confining units. Now, as far as the Tarawa Terrace
2 area is concerned, the Brewster Boulevard aquifer and the
3 Brewster Boulevard confining unit do not occur at Tarawa
4 Terrace except perhaps as a -- just a thin mantle of
5 sediments at the surface that are -- that are smeared with
6 every -- with everything else and really not of use to be
7 identified or not even -- they're unsaturated almost
8 always. And they're not dealt with in the Tarawa Terrace
9 area.

10 I might say two things about the correlation effort.
11 The U.S. Geological Survey produced two reports exclusive
12 to the Marine Corps base Camp Lejeune back in the late
13 eighties. And both of these reports had long, detailed
14 sections, using various Elogs and drillers' logs and
15 whatever; published these sections.

16 They identified a number of units that they would
17 track on these sections across almost the whole entire
18 base from well to well or Elog to Elog. And essentially,
19 below the Tarawa Terrace confining unit, our geohydrologic
20 framework conforms very, very closely with a few
21 exceptions here and there to the framework analysis that
22 was -- that was performed by the U.S. Geological Survey.

23 Relative to the Tarawa Terrace aquifer, Tarawa
24 Terrace confining unit, and the Brewster Boulevard and
25 Brewster Boulevard confining unit, we sort of did that on

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1 our own. And some of our results at certain places differ
2 from the USGS interpretations regarding these two
3 aquifers.

4 One thing that I -- one thing that I like to do when
5 I develop a conceptual framework like this is to constrain
6 my results using chronostratigraphic boundaries. That --
7 that would be like actual geologic unit times.
8 Unfortunately, for this particular study, that type of
9 information was very limited. But I did use the
10 distribution of the top of the Castle Hayne formation,
11 which I identified with the top of what I call the local
12 confining unit. That is the top of the Eocene. And I
13 identified also the top of the Beaufort confining unit,
14 which the US -- USGS has identified as the top of
15 Paleocene.

16 And what you do essentially is you look at the -- you
17 look at the strike, the distribution of those particular
18 units. That helps you to understand the depositional
19 cycles that occurred, that you're trying to identify as
20 aquifers or confining units. That helps you identify the
21 depositional cycles that occurred within that particular
22 time frame.

23 And that's important because if you're just
24 correlating a clay to a clay from Well A to Well B, you
25 could just very easily be missing a facies change;

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1 whereas, if you can -- if you can correlate it as well
2 with a chronostratigraphic line, you have some confidence
3 that you're looking at a spatially continuous unit in the
4 subsurface. And we did that. We did that as well as we
5 could with the limited amount of chronostratigraphic
6 information that we had.

7 And then there's just a whole series of maps that you
8 have in your report. This is the top of the upper Castle
9 Hayne aquifer. This is one of the time units that I just
10 spoke about that I used to sort of keep me on track in
11 terms of the spatial distribution; orientation to the
12 north, south, east, or west; dip and strike that I would
13 apply to units below that and also actually to the River
14 Bend unit, which was above it. And there's the thickness
15 of the upper Castle Hayne.

16 Almost all of these surfaces that I've identified as
17 either the top of a confining unit or the top of an
18 aquifer are erosional surfaces. Okay? So you would
19 expect some degree of irregularity in the -- in the
20 altitudes at the top as well in the thickness and
21 formation. And I wasn't disappointed at all in that
22 regard.

23 Another feature of the geohydrologic framework
24 analysis was the -- was the computation, the analysis of
25 aquifer-test data. We probably had -- between Camp

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1 Johnson, Tarawa Terrace, and Holcomb Boulevard areas, we
2 probably had close to five dozen aquifer tests. Almost
3 all of these invariably were single well tests, and almost
4 all of the single well tests were step-drawdown tests.

5 And what I used -- what I used in for almost all
6 these analysis is the public domain U.S. Geological Survey
7 aquifer test analyses worksheets, Excel worksheets. And
8 the real advantage to those is one -- it has one of the
9 best approaches and methods to analyzing step-drawdown
10 data, which was the majority of my data. And this is just
11 an example of one of the output sheets.

12 Now, there was a question -- somebody addressed the
13 notion of preferential zones of high permeability within
14 the -- within the various units -- within the various
15 identified aquifer units. We had no opportunity to do
16 that except in the context of the resistivity curves on
17 the electric logs. We could identify, perhaps, where
18 there may have been a relatively thin lensoidal clay
19 within the overall sand that we identified as an aquifer.
20 But there was no way to, in my opinion -- and if folks
21 here on the panel have some suggestions, I'd be happy to
22 hear it. But we did attempt to quantify. That was just
23 strictly a -- that would be strictly just a qualitative
24 analysis, and frankly, it didn't really occur that much.

25 Another feature of the -- of the geohydrologic

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1 framework analysis was the spatial mapping of the
2 horizontal hydraulic-conductivity data that we determined
3 from the aquifer-test analyses. That's the -- such as it
4 is, that's the spatial distribution of the data for wells
5 that were open to the upper and middle Castle Hayne
6 aquifers.

7 The last thing that we did with respect to the
8 geohydrologic-framework analysis was try to -- try to
9 create a picture of what the prepumping conditions or
10 predevelopment conditions were in the -- in our areas of
11 interest, which were Camp Johnson, Tarawa Terrace, and the
12 Holcomb Boulevard area.

13 And the way we did this was to identify the -- at a
14 particular well site -- excuse me, was to identify the
15 earliest measurement that we had available to us in terms
16 of a water level. And in particular, in the Holcomb
17 Boulevard area, we were quite fortunate to have a lot of
18 -- quite a good number of measurements that were -- that
19 were obtained in the early 1940s when the first supply
20 wells were drilled.

21 We either chose the earliest measurement at a site,
22 or we took the highest measurement at a site. If we were
23 fortunate enough in a very few cases to actually have
24 multiple measurements, multiple water level measurements,
25 at a site, it was -- I could probably count those on one

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1 hand -- but except for the Tarawa Terrace supply wells.
2 But we chose either the highest measurement or the
3 earliest measurement, and we just spatially plotted those
4 data. And the data almost completely refer to either the
5 upper Castle Hayne aquifer or the -- and the middle Castle
6 Hayne aquifer.

7 But the notion here was just to look at possible
8 boundaries that might be indicated as a predevelopment
9 condition as well as flow directions. And what we find is
10 that -- what we find is, as expected, Northeast Creek is
11 an obvious boundary at least as far as these aquifers
12 where the water-level information was obtained is
13 concerned. And we have flow directions in Tarawa Terrace,
14 generally either east or south, toward Northeast Creek.
15 And in the Holcomb Boulevard area, we have flow directions
16 north, west, and somewhat northwest, toward Northeast
17 Creek.

18 And what this tells us is that, at least as far as
19 those upper four aquifers or so are concerned, Northeast
20 Creek is probably a major flow boundary. What this does
21 as well -- and we have one site just north of Wallace
22 Creek, I believe, right in this area here where there is a
23 -- there's one -- there's a cluster site.

24 There's a series of wells there that are open to
25 several of the units that we identified as aquifers here.

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1 In particular, there's a well open to the Tarawa Terrace
2 aquifer and intermediate to the middle Castle Hayne and
3 also to the lower Castle Hayne. And that's just north of
4 Wallace Creek.

5 And interestingly there, there's only about a 2-foot
6 head difference between the head in the lower Castle Hayne
7 aquifer and in the -- and the Tarawa Terrace aquifer. And
8 I know that's not a lot to go on, but, as far as the
9 conceptual model, which we'll talk in terms -- we'll talk
10 in a minute about in terms of the model.

11 The conceptual model that we developed for guiding
12 our approach to the flow-model analysis is that the
13 predevelopment of potentiometric surfaces in all of the
14 aquifers were relatively similar, in fact, very highly
15 similar, so that, as far as the River Bend unit and as far
16 as the lower Castle Hayne aquifer, the flow directions and
17 the distribution of head in the aquifers was highly
18 similar. And that tells us that Northeast Creek, indeed,
19 would have been -- well, it is a boundary for flow for all
20 of the aquifers that we're dealing with.

21 And I'll just take a minute to explain the reasoning
22 there. You have groundwater flow -- pick your aquifer:
23 River Bend unit or Tarawa Terrace aquifer, whatever. You
24 have groundwater flow heading down gradient toward
25 Northeast Creek from Tarawa Terrace, and that's heading

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1 generally south. You have groundwater flow heading east
2 and north in the Holcomb Boulevard -- Holcomb Boulevard
3 area toward Northeast Creek. Well, this flow has to meet
4 in the middle somewhere at Northeast Creek. And at that
5 point, you have vertical upward flow in the vicinity of
6 the creek. And that was the rationale behind us selecting
7 the midline of Northeast Creek -- the midchannel line as a
8 flow boundary -- as a no-flow boundary for the
9 groundwater-flow model.

10 Also, in these USGS reports that I mentioned earlier,
11 there were some seismic studies that were conducted in the
12 water of New River and Northeast Creek, right around this
13 Paradise Point area. And what they -- what they
14 discovered was that there were buried subsurface channels
15 that were relic -- relic river channels that were now
16 under water. And probably, these relic channels manifest
17 themselves inland as well as zones of relatively high
18 hydraulic conductivity.

19 But our -- the distribution, the spatial
20 distribution, of our well data are not sufficient that we
21 can actually identify what that old relic channel would
22 have -- where it is and what it would have been. And that
23 may be one of the reasons that we have some irregularities
24 in our -- in our surface well data as well as in our
25 thickness data and also in our hydraulic-conductivity data

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1 where, just by chance, one of these wells may have been
2 developed in part or all of an old river channel, which
3 would have been now filled with sand and would be an area
4 of relatively high hydraulic conductivity.

5 DR. KONIKOW: Bob, what was the -- what's the
6 rationale for the northern limit of your contouring on all
7 of these maps?

8 MR. FAYE: We have a -- we have digital elevation
9 models, Lenny, of this larger area. Let me show you. We
10 have digital elevation models of this whole large area
11 here. Actually, I think, probably of most of Camp
12 Lejeune, but I was just looking at this. And that is
13 interpolated to 2-foot contour intervals. And so using
14 the -- using that, I identified the divide that ended up
15 as the northern boundary, the no-flow boundary, in the
16 groundwater flow-model.

17 I identified that as a hydraulic divide that
18 generally sweeps up like this and down like that, and
19 that's a hydraulic -- that's a topographic divide that is
20 translated to a hydraulic divide in the groundwater-flow
21 model. As I said -- and, of course, those are 2-foot
22 contour intervals on the DEM, and they're interpolated as
23 well. But that's the best information that we have.
24 Okay?

25 DR. KONIKOW: Okay. I was looking at the topo maps.

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1 It looked like there were -- I mean, I couldn't see the
2 divide that close.

3 MR. FAYE: No, you can't. You can't, Lenny. There's
4 a -- I can show you later, when we get into this, a much
5 larger map specifically of the Tarawa Terrace area.
6 There's -- you might have noticed that just north of this
7 road that runs parallel to Lejeune Boulevard, there's a --
8 there is a closed 35-foot contour right north of that
9 road, and that sits on that -- that sits on that divide.
10 That is mapped on the topographic map. And that coincides
11 with -- that coincides with that -- with the divide, as
12 recognized on the digital-elevation models.

13 DR. LABOLLE: Are you going to -- this is Eric
14 LaBolle here. Are you going to get more into the
15 simulation of the predevelopment heads?

16 MR. FAYE: Yeah.

17 DR. LABOLLE: Okay.

18 MR. FAYE: Yes. This is just the framework.

19 DR. LABOLLE: Okay.

20 MR. FAYE: It'll show up very well, Morris, in the
21 next couple of slides. Okay. Claudia, let's go to the
22 description of the PCE contamination at Tarawa Terrace.
23 There we go.

24 Okay. The next major area of responsibility that I
25 had was a description of just what is this PCE

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1 contamination at Tarawa Terrace. Where is it relative to
2 the source area? Where is it relative to the supply
3 wells? How deep within the subsurface does it go? What
4 are the quantities; i.e., concentrations in the water?
5 What are the concentrations in the unsaturated materials?
6 So let's try to address that.

7 The purpose of the study, again, for the record, is
8 describe the occurrence and distribution of PCE and
9 related contaminants within the Tarawa Terrace and upper
10 Castle Hayne aquifers at and in the vicinity of Tarawa
11 Terrace housing area, Marine Corps base, Camp Lejeune.

12 And a number of comments in the premeeting notes were
13 related to degradation products of PCE, and, yes, to the
14 best of our ability -- and we're severely limited by the
15 data here. But to the best of our ability, we did -- we
16 addressed trichloroethylene, which is the immediate
17 degradation product of PCE, as well as dichloroethylene,
18 the immediate degradation product of TCE,
19 trichloroethylene. We addressed all of that as well as we
20 could, but the data are very limited; very, very limited.

21 Okay. Here's a map. Maybe we can see that 35-foot
22 contour. There you go. Can you go back, Claudia. There
23 you go, Lenny; right here.

24 COURT REPORTER: Please get on your microphone.

25 MR. FAYE: Thank you. There you go, Lenny. That's

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1 that -- that's the contour I was talking about right
2 there. And that's right on the line as shown on the DEM
3 and comes down to -- it splits the difference between one
4 of these two little tributaries right in here, I think. I
5 think it's that one. It could be that one.

6 DR. KONIKOW: You also have a 35-foot contour a
7 little further north.

8 MR. FAYE: Yeah; right; right. And there are
9 differences between the DEM and the topo map, as you would
10 expect. Actually, some of that is fairly significant,
11 substantial. The differences are somewhat substantial. I
12 can't recall now exactly what -- what's going on up here
13 with respect to the DEM. But I looked for the major
14 divide between here and there, northeast and southwest,
15 and selected it.

16 Now, that may not be the -- from a groundwater
17 modeling point of view, that may -- and particularly a
18 fate and transport point of view, that may not be the best
19 -- the best boundary. But, really, if we try to extend
20 that north beyond the hydraulic divide, then we're stuck
21 with a general head boundary, probably, for all of the
22 units that we're modeling. And it just seems to me that
23 would introduce more uncertainty into the -- into the
24 analysis than selecting the hydraulic divide as the
25 topographic divide. But let's -- let's -- go ahead.

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1 DR. KONIKOW: I'm not convinced of that. Plus
2 another problem is that during pumping conditions that
3 predevelopment divide -- if that's really where it is and
4 I'm not convinced of that either -- that the divide is
5 going to migrate under pumping conditions.

6 MR. FAYE: It will. I don't think -- I don't think
7 the -- at least as far as -- we don't really know. We
8 have no data at all, field data, relative to -- relative
9 to any kind of notion of radius of influence of the supply
10 wells; no data whatsoever, so --

11 DR. KONIKOW: That could be computed --

12 MR. FAYE: We did.

13 DR. KONIKOW: -- more accurately than a lot of the
14 other things.

15 MR. FAYE: Yeah. We looked at that. It just depends
16 on where you want to go with the minimum drawdown out at
17 some radius that you're looking at, whether it's .01 feet
18 or .1 feet or something like that. I mean, that bounces
19 your radius of influence all over the place. And right
20 now, I'm fairly comfortable with the notion of using that
21 hydraulic divide not only as far as the predevelopment
22 situation is concerned, but as far as the transient.

23 But I would certainly welcome any kind of
24 qualification or criticisms, comments of that notion. I
25 mean, we're open to all that, absolutely. But I wanted

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1 you just to be aware of my reasoning, you know, as far as
2 the decision was concerned to identify it as such.

3 DR. JOHNSON: David, you have a comment?

4 DR. DOUGHERTY: No. I think we can proceed.

5 DR. LABOLLE: Well, I have a question here, actually,
6 regarding the -- not the hydraulic divide. But since
7 we're on the subject of boundary conditions here --

8 MR. FAYE: If we could -- if we could just be patient
9 just for a minute and let me get through the
10 contamination, then we'll be into the heart of the
11 groundwater model. Okay?

12 DR. LABOLLE: Okay.

13 MR. FAYE: And that might be the best place to
14 discuss that. I didn't mean to --

15 DR. LABOLLE: No. That's just fine.

16 MR. FAYE: Okay.

17 DR. LABOLLE: That's probably an appropriate
18 opportunity.

19 MR. FAYE: This slide just identifies all of the
20 Tarawa Terrace supply wells that we know of. There
21 actually may be several more that we don't have knowledge
22 of, but this is all of them from the beginning of time,
23 which is -- it'd be about 1952 up to the time in 1987 when
24 all the wells were shut down. And, of course -- and, of
25 course, some of these were taken out of service long

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1 before 1987. And as part of our plans, we have identified
2 various data reports that we plan to produce.

3 And, of course, in the final report, there will be
4 data reports, and all of these data will be tabulated and
5 identified in terms of well-construction information, when
6 the wells were placed in service and removed from
7 services, et cetera, et cetera. We do have that
8 information for most of these wells. We have good
9 information regarding that, not only from our own data
10 discovery, but the AH people have been very forthcoming
11 and helpful in that regard.

12 Claudia, I'm going to go one more slide, just to
13 orient myself here; just a second.

14 All right. Let me talk a little bit -- and I think
15 this is very important to understand. Let me -- even
16 though we're a little pressed for time. But let me talk a
17 little bit about the contaminant data collection at ABC
18 Cleaners and vicinity as well as the Tarawa Terrace supply
19 wells that were affected in terms of timing, in terms of
20 concentrations, in terms of quality of information.

21 What this slide represents is a summary of several
22 series of data that were collected between 1991 and 1993.
23 And I went into some detail in this in the report, but I
24 want to say it here as well for the record.

25 The vast majority of these data that you see

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1 portrayed here -- summarized here actually -- relate to
2 DPT data, hydrocone data, direct push technologies. We
3 all familiar with that? You know what I'm talking about?
4 Okay. There were probably like 40-some -- almost 50 of
5 these DPT points where data were collected at -- in an
6 upper zone, generally between about 15 and 25 feet, and
7 at the same site in a lower zone, generally between 35 and
8 45 feet.

9 And what you see here is a -- is the -- if it happens
10 to be one of those dual sites, this is the highest
11 concentration that occurred at that site, whether it was
12 the upper shell or the lower shell, the upper zone or the
13 lower zone. Several comments about those data: There was
14 an analysis done from a field mass spec operation at the
15 site when the DPT operation was ongoing, and there were
16 results obtained from that.

17 The -- Weston, the folks that conducted that site,
18 also collected a number of duplicate samples and sent
19 these off to a qualified laboratory for analysis. The end
20 result of that was that there was very poor agreement
21 between the laboratory analyses and the on-site analyses
22 for a particular bore hole or whatever. So we have that
23 particular problem. By the way, the points that were used
24 to construct this map were all the laboratory analyses
25 where they were available. Where they were not, we used

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1 the field -- the field site data.

2 Several -- okay. Let's look at -- here's ABC
3 Cleaners. A point that I'll make later in our advective
4 transport analysis when I describe that -- and, again, I
5 apologize. I'm talking about a model here. But it'll be
6 clear in a minute. The Well TT-26 is right here, and at
7 least as far as our model is concerned now, under normal
8 operation, the operation of TT-26 would capture every bit
9 of the PCE that was introduced into the subsurface and
10 into groundwater at ABC Cleaners.

11 But we have fairly large concentrations of PCE north
12 and west of ABC Cleaners. And in addition, we have
13 respectable concentrations of PCE south of -- south of the
14 well here, TT-26. And this is near another supply well,
15 TT-23. But as you can see, PCE values or concentrations
16 values at this time, now 1991 to 1993 -- you have to
17 remember this is four to five years after the Tarawa
18 Terrace wells were shut down -- there's zero
19 concentrations here. And these points I'm making now
20 because they'll occur prominently in the discussion of the
21 groundwater-flow model.

22 Okay. We had these data, as I mentioned, of the PCE
23 concentrations and other contaminant concentrations that
24 we could assign to an upper shell and a lower shell. So
25 given that, we created -- is that it? I'm going to go for

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1 this now. We created a map. Thanks, Claudia.

2 We created an average or a midconcentration map,
3 using the aerial distribution, the spatial distribution
4 from the upper shell and from the lower shell. With that
5 midconcentration shell, we also computed the volume of
6 aquifer material between the two shells. And in doing
7 that, the DPT data we actually used the depth they
8 identified. If it happened to be a well, we used the
9 midpoint of the screen interval to put a limit on the
10 volume -- on the depth.

11 We computed the area-weighted PCE concentration
12 between the average shell-concentration contours. That,
13 in a sense because it's the midconcentration shell, is the
14 volume-weighted PCE concentration. Once we had that, we
15 multiplied that by the volume adjusted by effective
16 porosity. And we ended up with a PCE mass of about 2500
17 pounds between those two shells or 185 gallons of PCE.
18 And this analyses, I think, is described in pretty good
19 detail in the report.

20 DR. KONIKOW: Bob, why do you use effective porosity
21 rather than total porosity?

22 MR. FAYE: Yeah. Well, if you recall, Lenny, there
23 was a -- there was also a description in the report of the
24 movement of the mass of concentration, the center of mass
25 of the PCE concentration, from the doorstep of ABC

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1 Cleaners, in '85, down to some point midway between ABC
2 Cleaners and TT -- Well TT-26.

3 Well, the reasoning there was that that movement had
4 to occur through connected interstices in the porous
5 media. And where it ended up in 1991 to '93, the volume
6 that that PCE was occupying was only connected
7 interstices, not the -- not the total interstices in the
8 porous media. So as a consequence, we used effective
9 porosity.

10 DR. KONIKOW: Well, you know, I think if you have the
11 contaminant in the connected interstices, it's going to be
12 in the -- I don't see any way to have uncontaminated water
13 adjacent to it in the disconnected pores, even if there
14 are. And I find it hard to believe there are disconnected
15 pores there. You used a specific yield value of 20
16 percent, I believe.

17 MR. FAYE: In Layer 1 in the Tarawa Terrace aquifer,
18 that's right. The rest of -- the rest of the layers --
19 like, the River Bend unit is 15 percent, and that's where
20 the vast majority of the contaminant is. Now, we don't
21 have any measurements of effective porosity. We don't
22 have any point measurements.

23 Two of the studies that -- the Weston study and, I
24 believe, the Bragg's report as well, used effective
25 porosity depending on the on the unit they were -- of 15

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1 percent and 10 percent. And I kind of qualitatively
2 looked at the lithologies and assigned a slightly higher
3 effective porosity to the Tarawa Terrace aquifer.

4 It looked to me like that was a cleaner, sandier
5 unit. The 15 percent, I accepted for the River Bend unit.
6 And I really couldn't see a whole lot of difference in the
7 lithologies between that unit and the other aquifer, so I
8 assigned a 15 percent effective porosity to the -- to the
9 rest.

10 But the one point would be that, you know, this is
11 just a preliminary calibration. Okay? We really haven't
12 -- we really haven't had an opportunity to do all of the
13 tests and provide all of the simulation results that we
14 want to, so...

15 DR. KONIKOW: It's in my comments. But I looked at
16 -- there was one part in your report where you say the
17 center of mass migrated at about .3 feet per day.

18 MR. FAYE: That would have been an average, yeah,
19 given the distance.

20 DR. KONIKOW: But if you used that information,
21 together with the other information, you would estimate an
22 effective porosity of about 28 percent.

23 MR. FAYE: At a retardation factor of one.

24 DR. KONIKOW: If there's no retardation.

25 MR. FAYE: Yeah. And if there is retardation, which

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1 I do believe there is, your effective porosity then would
2 -- to maintain that same average velocity, your effective
3 porosity would have to decrease from that number. And
4 really, I think the way to address that, Lenny, is to, you
5 know, take your comment and the notion of the analysis,
6 which I thought was really on target, and just do a range
7 of computations and look at -- look at the various
8 alternatives. And that's what -- we'll definitely do
9 that.

10 DR. DOUGHERTY: Is there information from the
11 split-spoon samples that you referred to earlier that
12 gives total porosities that would provide some boundary
13 information on where we are with respect to those?

14 MR. FAYE: You know, I won't say no. If there -- if
15 there are, they would be -- there would be very, very few.
16 And they would be probably only related to the Tarawa
17 Terrace aquifer or the River Bend unit. Okay?

18 DR. DOUGHERTY: Okay.

19 MR. FAYE: Okay.

20 DR. LABOLLE: Can you define how you're using
21 effective porosity in this context?

22 MR. FAYE: Only in terms of the advective transport.

23 DR. LABOLLE: That's not what I mean. I mean, are we
24 talking about effective porosity at the pore scale, or are
25 we talking about some macroscopic effective porosity to

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1 scale the velocities in the contaminant transport model?

2 MR. FAYE: Yeah. Well, the correct answer to that is
3 yes (laughter). And I'm not trying to be a smart-ass.
4 I'm just saying that, you know, we're sort of stuck with
5 -- when you do the advective transport modeling,
6 obviously, it's a macro-scale condition. Okay? But if we
7 have any data at all, it would be -- it would be data only
8 on a -- it would be like a laboratory test that you could
9 probably relate to the pore scale itself. Conceptually,
10 we're dealing with the pore-scale concept. Okay? But in
11 practical application, it's a macro scale. Okay?

12 DR. LABOLLE: Okay.

13 MR. FAYE: And let me go back now. We'll look at
14 some temporal -- are there any questions at all about the
15 PCE mass? I want to make one other comment about that
16 computation. Pankow and Cherry, not only in their text
17 but also in at least one journal article, they address
18 this particular methodology. And they have some comments
19 about the results.

20 One comment that they -- that they make is the fact
21 that that particular result of 185 gallons -- actually,
22 they give several examples, like seven or ten examples in
23 their work. It sort of fits midway into their -- into
24 their volumes that they've computed for -- at various --
25 various places and various studies. Also, they make the

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1 point that this is very likely just a very small
2 percentage of the total PCE that's actually out there in
3 residence in the aquifers themselves, and we believe that
4 as well.

5 MR. MASLIA: Am I on here? I believe -- and Bob
6 brought this to my attention -- there, either through
7 some verbal information or a report that quantified that,
8 they estimated that the ABC Cleaners were using
9 approximately 100 gallons a month of PCE historically in
10 their dry-cleaning process. So again, the 185 is an
11 extremely small --

12 MR. FAYE: Yeah.

13 MR. MASLIA: -- percentage of what potentially could
14 be out there.

15 MR. FAYE: Yeah. I hate to waste 60 seconds on an
16 anecdote, but I am because it gives you a -- just
17 clarifies the kind of things that we're dealing with.
18 Wouldn't you believe that if someone is conducting an
19 RI/FS investigation twice relative to ABC Cleaners that
20 one of the things they would at least do would be to ask
21 those folks how much PCE they're actually using during
22 their operations or did use during their operations? No.
23 Nowhere in the RI/FS reports, the detailed technical
24 investigation reports, nowhere do you find any kind of
25 reference at all as to what was happening at the source in

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1 terms of PCE use.

2 The report Morris referred to is something I ran
3 across fairly recently. It was a report from the National
4 Oceanic and Atmospheric Administration, who were looking
5 at the impact of this PCE loss into the groundwater on
6 wildlife and wildlife habitat in Northeast Creek. And
7 those folks actually had enough sense to go and talk to
8 the ABC Cleaners and ask them, "How much PCE do you folks
9 actually use a month in your operations?" And it turned
10 out to be about 380 liters or 100 gallons a month.

11 MR. MASLIA: Dr. Johnson, there's a question from the
12 public.

13 DR. JOHNSON: Please. Go ahead. State your name,
14 please.

15 MR. ENSMINGER: (Off microphone) My name's Jerry
16 Ensminger. I was a resident there.

17 COURT REPORTER: Can you state your name again,
18 please.

19 MR. ENSMINGER: Yes. My name's Jerry Ensminger. I
20 was a resident there. I lost my daughter to leukemia.
21 When you're talking about historical data, and especially
22 ABC Dry Cleaners, there are a lot of variables in that
23 site that need to be considered. And one thing is the
24 historical information: What took place between 1965 and
25 1970 which involved the Marine Corps and increased the

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1 population of the Marine Corps almost two-fold, and that
2 was Vietnam.

3 From 1965 to 1972, that was the heyday for dry
4 cleaners in Jacksonville. Did anybody get the tax records
5 from these people because PCE would have been an expense
6 which would have shown how much they actually used? And
7 knowing the amount of people -- every Marine that went in
8 the Marine Corps east of the Mississippi River ended up at
9 Camp Lejeune to go to their infantry training school at
10 Camp Geiger.

11 These dry-cleaning services had trucks that went
12 aboard base, collected these kids' uniforms at the chow
13 halls in the morning and brought them back that night or
14 the next morning. They picked them up. But every Marine
15 east of the Mississippi went through Camp Lejeune. These
16 people made a fortune during those years, and the PCE use
17 was elevated. Thank you.

18 DR. JOHNSON: Thank you. Thank you for your comment;
19 absolutely.

20 MR. FAYE: Claudia, could we go back a few slides to
21 the -- there we go. Keep going and maybe one or two more;
22 one more. All right.

23 These slides represent what we have at the wellheads
24 in terms of contaminant concentration through time.
25 Beginning in late '84 or early '85, these are our data

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1 points that we have. This is Well TT-26. This is
2 probably the main culprit in terms of providing PCE to the
3 water-distribution system, far and away, probably. But
4 you can see the poor distribution of data.

5 Now, enter -- let's go -- let me see what we have
6 here. That was PCE. This is the daughter product, TCE.
7 Virtually, the analyses are for the same time. And you
8 can see there was -- you can make a pretty good case there
9 that biodegradation of the PCE product was going on.

10 DR. JOHNSON: And what's the source of these data?

11 MR. FAYE: Who asked that?

12 MR. MASLIA: Dr. Johnson.

13 DR. JOHNSON: What's the source of the data?

14 MR. FAYE: Dr. Johnson, there are a variety of
15 sources. Some of it came from LANTDIV, the Marine -- the
16 Navy lab. Some of it came from EPA. Some of it came from
17 the North Carolina EPA equivalent.

18 DR. DOUGHERTY: Do we have any information on
19 sampling protocols?

20 MR. FAYE: Only in the -- only in the latter reports,
21 the latter analyses, which would be in 1991. We think --
22 have to assume that if NCDEM, North Carolina Department of
23 Environmental Management, did the analyses or the LANTDIV
24 people did the analyses that it probably was a respectable
25 representation of the protocols at that time. And they've

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1 changed a lot. The protocols have changed a heck of a lot
2 in the last 20 years, so...

3 DR. DOUGHERTY: Just to clarify, at that point in
4 time, there were pumps still in these wells?

5 MR. FAYE: Oh, yeah. Yeah. The wells were actually
6 abandoned formally; and that is, grouted up, pumps
7 removed, everything like that in 1991.

8 MR. MASLIA: David, I have a document, again, just
9 received. I hate to keep saying "just received," but you
10 know the story. And, in fact, it lists many of the TT
11 wells, and it will say "Well closed but pump still
12 installed in the well," and TT-26, TT-23, and so on. And
13 this is a nine -- I believe it's a '91. I believe I left
14 it on the desk there; a '91, '92 report. It's handwritten
15 notes. It's a document released by the Marine Corps to
16 us. But it does indicate whether the well can be operated
17 and whether it still has a pump or the well does not have
18 a pump and can be operated.

19 MR. FAYE: You know, and that was a note from the --
20 from the folks at the facilities -- in charge of
21 facilities at Camp Lejeune to the EPA contractor, who was
22 inquiring whether or not these wells were sampleable. And
23 almost immediately, as far as I can tell, after this
24 contractor obtained those July 1991 analyses, those wells
25 were history. They were grouted up. They were done.

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1 Now, also, recently -- we keep referring to these
2 recent revelations that we get. We have -- actually down
3 to the -- down to report numbers, dates, sample numbers,
4 the whole thing. We have information regarding monthly
5 samples at Well TT-25, which was not -- which was actually
6 right about here. And this -- in July of 1991, there was
7 an indication that Well TT-25 was beginning to show
8 contamination in its discharge.

9 And North Carolina DEM recommended that monthly
10 samples at TT-25 be collected over the period April --
11 actually until the well was shut down. But the samples
12 were collected from April of '86 to April of '87. And
13 we're making major, major efforts now to obtain the
14 results of those analyses. The Marine Corps doesn't seem
15 to know anything about them. But we know -- we know the
16 samples were collected. We know the analyses were made.
17 We have sample numbers and report numbers. So we're
18 trying to -- and that will fill in some of that, some of
19 that gap.

20 Yeah. Also at the -- in the same documents, there
21 were weekly samples taken on the downstream end of the
22 Tarawa Terrace WTP at the same time, which would -- which
23 would help Morris' efforts to -- and the network
24 simulation efforts immensely. Again, we're trying to find
25 those data. We know they exist, but no one seems to know

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1 where.

2 MR. MASLIA: Let me just qualify. Those data were --
3 there was a panel in September or October, convened by the
4 commandant of the Marine Corps, and it's a published
5 report. It's on the Marine Corps. And in Appendix or
6 Attachment K, they list some of those data. The issue
7 that both Bob and I have with that is that the Marine
8 Corps commandant's panel left out -- and I'm not sure why
9 -- any qualifiers on the data and any of the nondetects
10 based on their interpretation.

11 I have requested that, and there was a letter from
12 the U.S. Navy to U.S. EPA Region IV, transmitting the data
13 weekly for a various number of wells with these
14 attachments. EPA doesn't have that -- the attachments,
15 and apparently, my last communication with headquarters
16 Marine is they're working on finding the attachments. But
17 that would, again, supply us with what appears to be, on
18 the surface, very needed information because it goes from,
19 I believe, the first week in December of '84 through about
20 '86.

21 DR. JOHNSON: Bob, if I could go back to your
22 contamination --

23 MR. FAYE: Oh, yes, sir.

24 DR. JOHNSON: -- data. I didn't see any error bars
25 for each of the data points. And is that not done for

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1 this kind of data? If it were a tox study, you would
2 expect to find it.

3 MR. FAYE: When you say "error bars," you're --

4 DR. JOHNSON: Standard errors, standard deviation;
5 some sense of variability at each data point.

6 MR. FAYE: Well, at the very -- at the very most, Dr.
7 Johnson, except for those supply wells that we have, that
8 I showed you through time, the spatial maps like that at
9 the very, very most, we have only two samples.

10 DR. JOHNSON: Okay.

11 MR. FAYE: And those are for different levels.
12 Remember, I talked about the upper shell and the lower
13 shell, and that's all we have there. There were -- we
14 could do some sort of cursory analyses like that for the
15 half a dozen samples that we have at a single site like --
16 but that's so dynamic, you've got biodegradation going on.

17 DR. JOHNSON: I understand.

18 MR. FAYE: I don't know what that would show.

19 DR. LABOLLE: How do you explain the region between
20 the two plumes with the zero concentration? What's your
21 interpretation of that?

22 MR. FAYE: That, I'll talk about in the model. Okay?

23 DR. LABOLLE: Yeah.

24 MR. FAYE: Yeah. That's after a lot of aspirin,
25 believe me. Okay. We've got a few minutes left to talk

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1 about the model. Let's get going. I'm not going deal
2 with the introductory material. Let's do the purpose of
3 study.

4 Construct and calibrate a groundwater-flow model
5 sufficiently representative of the geohydrologic framework
6 and groundwater-flow conditions at Tarawa Terrace and
7 vicinity to support fate and transport simulations.
8 You've already seen the well locations. You know what the
9 aquifers are and confining units.

10 Let's describe the model grid very briefly: 270
11 columns, 200 rows. That's the complete model domain.
12 That's the inactive and active areas, 24,000 active cells.
13 All of the active domains are spatially equivalent. The
14 cell dimensions are 50 feet by 50 feet.

15 There's nine layers, and they correspond exactly to
16 the geometries of the aquifers and confining units that
17 we've identified. Frenchman's Creek -- could we -- could
18 we go back to that; Frenchman -- Frenchman's Creek is a --
19 sorry. Frenchman's Creek is a small drain in the western
20 part of Tarawa Terrace, and that's -- that's accommodated
21 in the model as a drain in Layer 1, which is the Tarawa
22 Terrace aquifer.

23 Northeast Creek, the whole area -- sorry, Claudia.
24 Northeast Creek, this -- the whole area down to the
25 midchannel line, which is our no-flow boundary, is a

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1 specified head boundary, zero altitude, in Layer 1. In
2 the other -- in the other eight layers, it's just an
3 active layer or an active part of it -- of the model.

4 DR. KONIKOW: Is that salt water at Northeast Creek?

5 MR. FAYE: Yes. Yes. It's not seawater, Lenny, but
6 it's tidal. And it's definitely -- it's definitely --
7 it's definitely saline. Okay? Whatever that boundary is
8 in terms of TDS or whatever you want to call salt water, I
9 don't think it -- I don't think it quite meets that. But
10 it's definitely saline.

11 DR. LABOLLE: I had noticed that the previous map
12 you'd put up with hydraulic-head measurements, the
13 hydraulic heads along Northeast Creek that have been
14 measured -- or on boundaries of it --

15 MR. FAYE: Mm-hmm.

16 DR. LABOLLE: -- range from 14 to about 4 feet. And
17 now you're putting the boundary condition on the creek of
18 a zero head in Layer 1. How -- what kind of
19 correspondence does that have to the elevation mapping
20 along the Northeast Creek as far as the actual heads in --
21 on the creek itself, and how is that influencing the flow
22 model?

23 MR. FAYE: Okay. Let me try to understand your
24 question, which I don't completely. Are you asking: Do we
25 actually have measurements within the various aquifers

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1 within the Northeast Creek area or on shore at wells that
2 were --

3 DR. LABOLLE: Either.

4 MR. FAYE: We don't have any measurements in that --
5 within the creek area itself.

6 DR. LABOLLE: I'm referring to a map you showed in
7 the previous presentation where we were looking at
8 hydraulic heads that shows them from --

9 MR. FAYE: Yeah. The estimated potentiometric
10 surface?

11 DR. LABOLLE: Exactly.

12 MR. FAYE: Yeah. Okay.

13 DR. LABOLLE: And I'm looking at a contour map here
14 in one of the reports that shows a predevelopment
15 simulation, and now I'm hearing you describe this boundary
16 condition of a zero head along the creek. And I'm asking
17 how does that boundary condition influence the model
18 because there appears to be some potential inconsistency
19 there between the 14- to 4-foot head difference along
20 Northeast Creek in the measured potentiometric heads. And
21 I say along Northeast Creek --

22 MR. FAYE: Mm-hmm.

23 DR. LABOLLE: -- I mean, they're interpolated from
24 measured heads --

25 MR. FAYE: Mm-hmm.

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1 DR. LABOLLE: -- taken at wells, you know --

2 MR. FAYE: Mm-hmm; right.

3 DR. LABOLLE: -- in the land nearby and the heads
4 plotted, for example, in the potentiometric contours in
5 one of these predevelopment simulations. And this refers
6 directly to the boundary that you just discussed, the --

7 MR. FAYE: Right; right.

8 DR. LABOLLE: -- zero-head boundary.

9 MR. FAYE: Right. The -- I think the map you're
10 referring to, the actual loop contour is 4-feet upstream
11 of -- that shows flow toward Northeast Creek. The actual
12 loop contour is a 4-foot contour, not a 14-foot contour.
13 And then there's -- you're going to have to remember now,
14 this is an interpolation, so --

15 DR. LABOLLE: Well, I think it was four on the
16 downstream and then --

17 MR. FAYE: That's right.

18 DR. LABOLLE: -- 14 feet if you go up the creek, I
19 think, if you go to the far end of the creek. Is that --
20 am I correct, or...

21 MR. FAYE: Well, that -- yeah. That's an
22 interpolation from a point onshore at Tarawa Terrace to a
23 further point, further offshore -- onshore at Holcomb
24 Boulevard. So --

25 DR. LABOLLE: Okay.

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1 MR. FAYE: -- this is just an estimated -- remember,
2 I said this was a map that we were --

3 DR. LABOLLE: There we go.

4 MR. FAYE: -- we would try to put in the highest
5 water level so that we could just kind of define for our
6 own purposes what we thought the major flow directions
7 were in the system as well as what the major boundaries
8 were.

9 DR. LABOLLE: I can see these Xs on here are --
10 or the plus signs are the actual data points used in
11 creating --

12 MR. FAYE: Yes.

13 DR. LABOLLE: -- this map.

14 MR. FAYE: Yes.

15 DR. LABOLLE: So effectively, what I'm hearing is
16 that you don't -- actually, you don't have enough data
17 near the creek to --

18 MR. FAYE: No.

19 DR. LABOLLE: -- just to --

20 MR. FAYE: No. No.

21 DR. LABOLLE: Okay.

22 MR. FAYE: This was -- this was a kriging exercise.

23 DR. LABOLLE: Which explains the inconsistently.

24 MR. FAYE: Yeah. Yeah.

25 DR. LABOLLE: Okay. Thank you.

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1 MR. FAYE: We were just there trying to -- well, for
2 example, this shows up very nicely here; this Loop 4, I
3 mean. It definitely shows that you're looking at -- as
4 far as the extant data are concerned and as far as this
5 particular interpolation is concerned, you definitely
6 have, you know, a gaining stream. And you have --
7 definitely have a flow toward it from the north to the
8 south and the south to the north.

9 And there's, you know, an inconsistent -- this is --
10 this shows the inconsistency between -- you know, caused
11 by interpolation very well. You've got, you know, this
12 data point here. Obviously, this contour in the real
13 world doesn't cross the river like that. But this is all
14 of our dirty laundry, you know, that we're laying out
15 there, I mean. And this is just for estimating and
16 interpretive purposes. This is nothing that we would put
17 forth as a real potentiometric surface map.

18 Okay, Claudia, let's go to the modeling.

19 DR. JOHNSON: Bob, take about five minutes, and then
20 we will adjourn for lunch and come back and continue with
21 what you are presenting.

22 MR. FAYE: Okay. I'll try to finish as much of it as
23 I can in that five minutes, Dr. Johnson. Thank you.

24 That's a picture of our grid. That's the active
25 model domain. This is the now infamous northern boundary

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1 that we talked about earlier. This is Layer 1 -- yeah,
2 Layer 1. This is Frenchman's Creek. And that's an old --
3 this is an old map, by the way. This was before I filled
4 in the rest of Northeast Creek as a -- as a specified head
5 boundary.

6 There's your -- I forgot I had the map with me here.
7 There you go -- layer tops or cell-by-cell arrays that
8 equate directly to the corresponding geohydrologic unit
9 arrays. And I just showed some examples that we've
10 already seen. We're not going to repeat that.

11 I did play around with the horizontal hydraulic-
12 conductivity distributions a little bit and try to
13 differentiate a hydraulic-conductivity array for the
14 Tarawa Terrace aquifer and then possibly -- and the River
15 Bend unit and then possibly a different array for the
16 middle Castle Hayne aquifer. But you can -- you can take
17 your pick. It's, basically, I think, if you used all the
18 data and assigned it to all the layers as far as the
19 aquifers were concerned, you probably would not be far
20 off.

21 Let's see. The horizontal hydraulic conductivity of
22 Layer 9, I reduced strictly to 5 feet per day. And that
23 was just based on a qualitative evaluation of the few
24 descriptions of lithology of that unit that I had. I
25 assigned a hydraulic conductivity of .2 feet per day to

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1 all of the confining units, and that was somewhat
2 arbitrary but not completely.

3 I had a -- I had a -- one aquifer test, a good
4 aquifer test actually using an observation well. Where
5 the observation well was -- actually both the observation
6 and pumping were partly screened across the Tarawa Terrace
7 confining unit. And it came out to be a very low
8 horizontal hydraulic conductivity, and so -- I think of
9 like 2 feet per day. So I just took an order of magnitude
10 less than that and assigned it.

11 And I want to make a comment, too, about the model
12 that I hope you'll keep in mind through the rest of the
13 discussion. This is just -- this is a preliminary
14 calibration that we got to where we thought we were
15 actually getting some reasonable results.

16 We haven't really been able to completely test the
17 flow model or for sensitivity or the advection transport
18 model for all the results that were -- that we'd really be
19 interested in. You could look at it on the other side.
20 There's not a lot of sense spending time on that if we
21 have a fatally failed model, so that will -- hopefully,
22 we'll find things like that out from your panel comments.

23 And I think the vertical anisotropy of -- was 10
24 percent that I assigned to all layers. The specific yield
25 of the Tarawa Terrace aquifer, I assigned as .2. The rest

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1 were -- was point -- well, the rest doesn't -- don't
2 count. That's the only unconfined aquifer.

3 The storativity of the model, Layers 2 to 9, I
4 assigned as five times ten to the minus four. I have no
5 storage coefficient data for any of the aquifers, okay,
6 with the possible exception of one or two measurements
7 that I kind of wonder about in the Tarawa Terrace aquifer.

8 But as far as the -- as far as the other layers are
9 concerned, two to nine, the storativity is constant at
10 .0005. The specific storage of all the model layers is
11 simply the thickness determined from the layer geometry
12 divided into that number, and that's our specific storage
13 that we assigned to the model in a cell-by-cell array.

14 Okay. The calibration strategy. Dr. Johnson, you
15 ready?

16 DR. JOHNSON: Let's stop right here.

17 MR. FAYE: Okay.

18 DR. JOHNSON: And we will resume with your
19 presentation because it's really important that we
20 understand what it is that's been done and what you're
21 proposing to do. Also, Mr. Maslia has prepared some
22 responses to your premeeting comments. And following
23 Bob's presentation, Morris, I'd like for you to put that
24 in front of us.

25 Following that, we will then begin discussing -- and

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1 it may be simply something that reflects my own
2 personality. But they gave us eight questions to answer,
3 and I propose to drag us through one by one because they
4 took the time to prepare them. And they really need your
5 advice and insight on many of those questions, it seems to
6 me.

7 So that's kind of how I see -- how we proceed after
8 lunch. Does anyone want to do it differently, or...

9 (No audible response)

10 DR. JOHNSON: Okay. Well, be back here promptly at
11 one o'clock because that's when we will resume. And,
12 Morris, any questions, any announcement about the lunch
13 arrangements?

14 MR. MASLIA: Again, if you want to eat at the Century
15 Center motel or hotel where you're staying -- I've eaten
16 there before. It's fine. I'm still around. The bus is
17 there. I would ask that the panel members get the first
18 bus out there because the bus seats 12. We're going to
19 make two trips and then anyone else. Or there are other
20 establishments around here. But we've allotted 11:45 to
21 one -- an hour and 15 minutes or so.

22 Obviously, I know Dr. Johnson would prefer to get out
23 by five today. Today's not as critical as I'm sure people
24 who are catching a plane tomorrow afternoon, so we'll just
25 play it by ear then. But do try to get back as promptly

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1 as we can.

2 (Whereupon, a recess of approximately 73 minutes was
3 taken.)

4 MR. FAYE: All right. Let's continue with the
5 discussion where we left it off. Let's talk about the
6 model-calibration strategy, if we could, for just a
7 minute. The first -- the first effort was to develop a
8 conceptual model of groundwater flow. Then we wanted to
9 define a predevelopment condition as well as we could,
10 knowing that it was, at best, an estimate of
11 predevelopment conditions -- and when I say
12 "predevelopment," that's prepumping -- and simulate that
13 as well as we could, but knowing that we would have to
14 iterate back and forth between a transient simulation and
15 a predevelopment simulation in terms of changing arrays
16 and whatever; but any -- to see if the simulations that we
17 -- that we obtained for the prepumping condition would
18 generally support the conceptual model and then attempt to
19 do the same thing basically with transient simulations.

20 And we would have to choose the period of interest
21 for the transient simulations as a period when we had as
22 many water-level data as we possibly could to give us some
23 insight into how good or how poor our transient
24 simulations were or are. And essentially, that's -- with
25 a few sort of rather cursory advective transport

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1 simulations, that's -- that is where we are now in the
2 modeling effort, groundwater-flow modeling effort.

3 The conceptual model that we came up with -- and I've
4 already alluded to all of -- to most of this. Your
5 groundwater flow occurs as -- groundwater recharge occurs
6 in the highland areas and flows down gradient toward
7 Northeast Creek and Frenchman's Creek and New River. The
8 long-term average annual recharge is 12 inches, and that
9 is -- that's borrowed strictly from several North Carolina
10 State and USGS reports. That seems to be the favorite
11 number that folks -- that folks apply to this part of the
12 North Carolina coastal plain in terms -- could you go
13 back, Claudia -- in terms of recharge to the water table.

14 The Tarawa Terrace area is not dissected to a large
15 degree with drainage, with streams. Frenchman Creek is
16 essentially the only prominent creek in the area. And my
17 particular feeling is that recharge could probably range
18 from 12 -- net recharge could probably range from 12 to 16
19 inches per year in that area. If you look at the maps of
20 long-term average annual rainfall and potential
21 evapotranspiration for this part of Onslow County in North
22 Carolina, you're looking at a difference between the two
23 numbers of about 16 inches.

24 So somewhere between 12 and 16 inches per year is the
25 number that we'll probably end up with as an estimate of

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1 long-term average annual recharge, and that's one of the
2 things that we want to continue to -- one of the issues
3 that we need to continue to address in the modeling that
4 we haven't done yet.

5 And the other third element of the conceptual model
6 is -- and I've already suggested that previously -- that
7 the potentiometric surfaces in all of the aquifers are
8 relatively similar. And if you'll recall, that large area
9 map that I showed earlier that we had some discussion
10 about here, if we just take the piece out of that that
11 reflects Tarawa Terrace, you can see the data points. You
12 can see the contours, and now these represent -- these are
13 data points that represent the highest water levels at a
14 particular point or the oldest. And for the most part,
15 they're the highest.

16 Okay. All of these points here in the western part
17 of the study area, these relate to us; fairly coarse and
18 crude studies of underground-storage tank removals. And
19 we selected these water levels regardless of season,
20 regardless of -- regardless of season. There's probably
21 some fairly inherent inaccuracies in there because of the
22 lack of data that we had at a particular point. But to be
23 honest with you, I was just so happy to have a data point
24 in a particular place, I just -- I selected it and just
25 kept in mind the caveats regarding the accuracy of the

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1 point.

2 But that's the map in detail for Tarawa Terrace that
3 we generated, our estimate of the prepumping
4 potentiometric surface. And if you recall, I mentioned
5 earlier in the context of the framework discussion, that
6 the monitor wells and bore hole logs that we had were
7 concentrated in the southern part of the Tarawa Terrace
8 area. That's actually in a shopping center area there
9 where there's a -- probably a half a dozen or so RI/FS
10 operations going on. And then here, of course, are the
11 monitor-well data and -- related to the ABC problem.

12 So that's our conceptual model, the hydraulic
13 characteristic data that we described earlier, and the
14 arrays and whatever. We applied that to Modflow, Modflow
15 2000. We have the drain -- is that the upper Castle
16 Hayne? That is -- that's either -- well, that could be
17 the River Bend unit or the lower unit. It's probably the
18 River Bend unit. There's our simulation. You'll recall
19 now that -- darn it. Claudia, can we go back, please;
20 forward one. There we go.

21 Recall that in the uppermost layer that Northeast
22 Creek out to the midchannel section is all a specified
23 head of zero elevation. You can see that, for the most
24 part, at 12 inches a year recharge, with Frenchman's Creek
25 in there as a drain -- and this is -- this is three or

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1 four layers below the Layer 1. You can see that the
2 discharge to Frenchman Creek is still occurring. It's
3 well defined. You can see that the -- that the head
4 declines from the highland areas toward Northeast Creek
5 and toward New River, toward Frenchman's Creek.

6 The flow lines are just as we had hoped in the
7 conceptual model down toward the southeast and the south
8 toward Northeast Creek. So for all intents and purposes,
9 given the sort of cursory data and approach that we used,
10 the simulation of the prepumping conditions, I think,
11 supported our conceptual model quite well, and we were
12 satisfied with that.

13 So let's take another look. No. That's the
14 simulated potentiometric surface in the lower Castle Hayne
15 aquifer. So we've essentially gone from Layer 1 to Layer
16 9. And as you can see, just as the conceptual model
17 indicated, we're dealing with a very similar -- very
18 similar directions in terms of flow lines and a relatively
19 similar potentiometric contours and slightly higher heads;
20 slightly lower heads in the highland areas; slightly
21 higher heads in the discharge areas.

22 This is a scatter diagram of those data points that I
23 just told you about, wherein -- which we used to construct
24 our prepumping surface. This is just a direct one-to-one
25 comparison between the simulated head and the observed

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1 head with -- and the observed heads, as I said, they have
2 some bit of baggage associated with them. But it's not --
3 I think that's quite good actually. The variance on this,
4 I think, was slightly less than one; the comparison
5 between the observed and the simulated heads, .96.

6 There we are. Okay. There's our simulated
7 predevelopment budget, the recharge -- Claudia, please.
8 Thank you. She's getting used to me.

9 The recharge was 1.9 CFS, and if you want to
10 distribute that to the 1400 acres for a year, you'll find
11 that you've got 12 inches a year. Discharge to Frenchman
12 -- we want to distribute that then as discharge.
13 Discharge to Frenchman's Creek was .6 CFS, and discharge
14 to Northeast Creek was 1.3 CFS. And this is nice and easy
15 in the model. It tells you what you're discharging to
16 drains, and it tells you what you're discharging to
17 specified heads. So it's sort of a no-brainer after the
18 computation is done.

19 All right. We'll talk about the transient
20 simulation. I went into some discussion in the report
21 regarding the quality of head data that we were dealing
22 with, with respect to creating a transient simulation,
23 developing a transient simulation. The vast, vast, vast
24 majority of those head data occur between 1978 and 1985.
25 And as best as I can understand it -- and I would be the

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1 first to admit I don't completely understand where the
2 head data come from or how they were measured, I guess, is
3 a better way to say it -- these are air line measurements.

4 And there was apparently a monthly requirement at
5 Camp Lejeune to obtain what they called a static level and
6 a pumping level at each of their supply wells. And we
7 have data, as I said, from Tarawa -- for Tarawa Terrace
8 for almost all of the supply wells. There's data gaps,
9 but all of the supply wells are in the mix from January of
10 1978 to about April of 1986.

11 And -- so we used the static-water levels as a
12 calibration standard, and we didn't try to adjust them.
13 We just took them as they were. And you'll see in a slide
14 here that, basically, these levels -- you know, for static
15 levels, they're sort of all over the landscape. We don't
16 have any notion of the accuracy of the gauges that they
17 used. I made some -- I made some estimates of that in the
18 report. We don't have any notion of the accuracy of the
19 gauges that were used to obtain these measurements.

20 We do know that the gauges were calibrated to the
21 depth of the air line in the well. We don't know if there
22 was a standard. For example, when you obtain a water-
23 level measurement, you repeat the measurement until you
24 get a consistent result within some predetermined error.
25 We don't know if that was done. We don't know whether

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1 this measurement was just a one-time shot. We don't know
2 how much time elapsed between turning. If it was indeed a
3 static measurement, we don't know how much time elapsed
4 between terminating the pumping at the well and collecting
5 the so-called static level. We don't know any of this.

6 We're on track to answer some of those questions when
7 we have some discussions with the folks at Camp Lejeune.
8 But I just want to outline the uncertainties related to
9 these data. So -- and we selected -- because Morris and
10 Mr. Bove are -- you've already heard this morning of the
11 time reference that they're interested in, we selected
12 one-month periods as stress periods.

13 So between -- and we extended the transient
14 simulation through 1994 because, in '91, '92, '93, and
15 '94, we had several dozen accurate water-level
16 measurements that were obtained throughout the Tarawa
17 Terrace area in various monitoring wells that were related
18 to several RI/FS investigations, ongoing investigations.
19 So rather than stop the transient analysis at, like, when
20 the wells shut down in 1987, we extended the analysis
21 without pumping at Tarawa Terrace up through the end of
22 1994 to take advantage of those additional measurements.

23 Let's go through a number of details. So that
24 results in 204 monthly stress periods. Because I think
25 the 12-inch standard -- the recharge of 12 inches per year

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1 is somewhat on the low side -- I had some difficulties
2 with cells drying up in the upper two layers of the model,
3 and this caused some convergence problems during the
4 transient simulations.

5 So I just tweaked the recharge for that particular
6 stress period; just would start it at 12, and I'd increase
7 it to 13 inches a year, maybe 14 inches a year to maintain
8 a continuance convergence for each stress period. And I
9 had, ultimately, a range of recharge rates between 12 and
10 16 inches per year that I ended up using for a month.
11 Those were monthly rates. I think the average recharge
12 that I ended up with between -- for the period January '78
13 to March -- or December of '86 was like 12.7 inches per
14 year.

15 We had data from a consultant's report that listed
16 the well capacities, the active supply wells, in 1979.
17 And those are the capacities that we identified and used
18 throughout the transient analysis. We also had annual --
19 annual average daily pumpage rates. Actually, these were
20 -- these were treated-water rates from the Tarawa Terrace
21 WTP on an annual basis, so -- that were reported by the
22 USGS in one of their reports.

23 So, for example, in 1982, for example, we would --
24 we had a number of, like -- I don't know. I'll shoot at
25 it -- maybe, like .93 MGD. So for the whole year, 1982,

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1 the average pumping rate was like .92, .93 MGD. So we had
2 that number, and we had well capacities.

3 We also had a crude idea of how Tarawa Terrace
4 operates their well systems. It's called a rotating
5 system. They would -- at a particular well, they might
6 pump for eight hours a day, and the well then would be on
7 standby for like 16 hours a day. And they would rotate
8 that type of a schedule through their whole active supply
9 well network. And, of course, we don't have -- we have no
10 data indicating the period of pumping for any particular
11 well for any particular day.

12 So -- but I did know -- I did -- unless these
13 operational records that had -- that we have copies of
14 that include these static water-level measurements.
15 Unless they indicated that, say, for example, Well TT-26
16 pumped all month or Well TT-52 was down for two months for
17 maintenance or something like that, I made sure that the
18 actual rate that I used for simulation in the model was
19 less than the capacity and also that all of the wells
20 pumped for a particular stress period for a particular
21 year equaled the rate -- the average daily rate reported
22 by the USGS. Those were the only two constraints that I
23 had.

24 And a secondary constraint were the operational
25 records. So if a -- if the records told me that a

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1 particular well did not pump for a certain three months in
2 1984, I honored that. I took that pump off-line. I
3 didn't -- that well off-line. There was no water
4 discharge for that.

5 So those are basically the three constraints that I
6 used to put together a pumping schedule for 1978 through
7 1986. And then, of course, when the wells were all shut
8 down in March of '87, then all the wells were turned off.
9 And the Tarawa Terrace -- then the aquifer basically
10 recovered to pretty much its simulated predevelopment
11 condition in a very short period of time.

12 Okay. I think that covers that all.

13 DR. WALSKI: I have a question.

14 MR. FAYE: Sure.

15 DR. WALSKI: On the monthly recharge rates, did you
16 take into account anything about whether it was a wet
17 month? dry month? Like, some --

18 MR. FAYE: No.

19 DR. WALSKI: -- months you had hurricanes hitting
20 with --

21 MR. FAYE: No.

22 DR. WALSKI: -- huge flows --

23 MR. FAYE: No.

24 DR. WALSKI: -- and some with none.

25 MR. FAYE: That's a great question, Tom. No. We

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1 haven't had time to do that. We're in the process of
2 having discussions, actually. And that's something that
3 we would very much like to hear from you -- from you-all,
4 from the panel. What we have in terms of meteorological
5 data: We have pan evaporation data so -- and on a monthly
6 basis. We have rainfall data on a monthly basis for our
7 whole period of interest, basically from 1950 to 1995,
8 something like that, as much as we want. Okay?

9 So we have that all on a monthly basis. And once we
10 can make a decision about a long-term average rainfall --
11 rather long-term average recharge, whether it's 14 inches
12 or 13-1/2 or 15 or whatever it is, we're trying to devise
13 a scheme to use this meteorologic record to adjust our
14 recharge on a monthly basis. That's clearly, clearly on
15 the radar screen, but as I said earlier, these simulations
16 were pretty basic. I mean, we're just trying to get a
17 handle on things, and we haven't done that. Okay?

18 And that's kind of why I felt free to just kind of
19 tweak recharge during a stress period when I had a
20 convergence problem, just boost it a little bit to a
21 particular higher rate -- a little higher rate and achieve
22 convergence and go on because I wanted to see what the end
23 product was. Okay?

24 DR. KONIKOW: Did you give any thought to the
25 possibility that recharge may be greater than the natural

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1 recharge in urban areas where you have lawn watering
2 and --

3 MR. FAYE: Yeah.

4 DR. KONIKOW: -- leaks and --

5 MR. FAYE: Leaky pipes --

6 DR. KONIKOW: -- car washing and --

7 MR. FAYE: Yeah, we have; we have. And any comments
8 that you-all have about how to deal with that -- there's a
9 really good paper -- I can't quote it right now to you --
10 that really goes into a tremendous amount of detail on
11 this and using GIS to look at the lawn areas and the paved
12 areas and everything else and --

13 DR. KONIKOW: Are they on septic tanks, all the
14 houses --

15 MR. FAYE: They were.

16 DR. KONIKOW: -- housing developments?

17 MR. FAYE: They were originally on septic tanks.

18 DR. KONIKOW: That's a source of recharge.

19 MR. FAYE: Oh, absolutely; for quite a while. And
20 they're on a collection system now, but for --

21 DR. KONIKOW: A leaky collection system, no doubt.

22 MR. FAYE: Probably; yeah. And the water supply, the
23 pressurized pipes are probably leaking as well in
24 different places. Yeah. Yeah. Yeah. We've thought
25 about all of that. We haven't really acted on it. We're

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1 in the process of trying to find -- figure out how to act
2 on it.

3 DR. KONIKOW: Now, you have a lot of cells going dry,
4 I saw, in your simulation --

5 MR. FAYE: In the -- in the -- yeah --

6 DR. KONIKOW: -- if you're concerned about that.

7 MR. FAYE: In the -- in Layer 1 and Layer 2 in the
8 highland areas; yes. And that -- and I know for a fact
9 that that actually is true in the real world. These --
10 those cells would only be wet, seasonally wet. Okay?

11 DR. KONIKOW: Yeah.

12 MR. FAYE: The water table --

13 DR. KONIKOW: Did you -- did you run Modflow with the
14 rewetting?

15 MR. FAYE: I did, and it just caused a tremendous
16 amount of convergence problems. I'm going to revisit that
17 again.

18 DR. KONIKOW: Have you thought -- you were using
19 monthly stress periods, but I believe you're also using
20 monthly time steps. Have you thought of cranking down
21 your time-step size?

22 MR. FAYE: Oh, to a smaller size?

23 DR. KONIKOW: Yeah. In other words --

24 MR. FAYE: Yeah.

25 DR. KONIKOW: -- you could have monthly stress

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1 periods but --

2 MR. FAYE: I did that. I did that. I did that when
3 I rewet it, when I played around with the rewetting
4 feature. And it just -- I was not -- I spent a lot of
5 time. I was not successful. I'm hoping -- I'm hoping --
6 well, I very strongly believe that the baseline recharge
7 that we come up with, this long-term average annual, is
8 going to be somewhere probably around 14 inches or so.
9 I'm hoping that when we're dealing with that extra
10 recharge plus, you know, we'll be starting out as a
11 prepumping condition. So we'll have antecedent conditions
12 taken care of pretty well, right from the get-go, in early
13 1950s.

14 I am hoping that we -- we're still going to have dry
15 cells. I'm hoping it's not going to be a big issue. And
16 I hope, maybe, we can try to do some rewetting in that
17 context, but the rewetting was not at all successful, not
18 at all.

19 DR. KONIKOW: Maybe, with smaller time steps, it
20 would work better.

21 MR. FAYE: It could. It may. I definitely did try
22 that, but I'll definitely try it again.

23 DR. KONIKOW: Yeah.

24 MR. FAYE: I'm open for any -- I'd like to have that
25 rewetted. I really would.

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1 DR. LABOLLE: My experience has been, like Lenny's
2 suggesting, decreasing the time step --

3 MR. FAYE: Right.

4 DR. LABOLLE: -- but you can also -- if you want to
5 get that to converge, another helpful item is to use a
6 solver with a dual-convergence criteria. So in other
7 words, you'll have convergence criteria for the outer,
8 nonlinear loop, in which things are --

9 MR. FAYE: That's the PCG solver.

10 DR. LABOLLE: -- which you can -- which you can --
11 no; not the PCG. It will be the -- actually, it will be
12 one of the latest solvers that Mary Hill released. I
13 forgot which one it was. It's the only one with the dual-
14 convergence criteria.

15 MR. FAYE: Okay.

16 DR. LABOLLE: I can send you one for the PCG if you
17 want. I have one.

18 MR. FAYE: Oh, that'd be great.

19 DR. LABOLLE: But the nonlinear loop, you set its
20 loose convergence criteria, and you can set the linear
21 solver. You know, it's a very strict convergence
22 criteria, and the combination of the two allows you to --

23 MR. FAYE: To rewet?

24 DR. LABOLLE: No. What it allows you to do is to
25 solve a confined flow problem as an approximation

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1 essentially is what you end up doing because really you're
2 solving a confined flow problem --

3 MR. FAYE: Mm-hmm.

4 DR. LABOLLE: -- at some point in time. And you're
5 looping nonlinearly, but you --

6 MR. FAYE: Mm-hmm.

7 DR. LABOLLE: -- at every point, you're making a
8 confined approximation, essentially. Anyway, that allows
9 you to converge. That's one issue. And another comment I
10 have is on your calibration, recognizing that it's
11 preliminary, but I noticed that if I were to probably fit
12 a line through the scatter points there that it would
13 probably have showed less of a gradient. And I think
14 that --

15 MR. FAYE: You mean the scatter line?

16 DR. LABOLLE: Yeah; exactly --

17 MR. FAYE: Yeah.

18 DR. LABOLLE: -- and then the one-to-one.

19 MR. FAYE: It would --

20 DR. LABOLLE: And so the implication being that your
21 heads up here --

22 MR. FAYE: Mm-hmm -- are too low?

23 DR. LABOLLE: -- out in front are lower than --

24 MR. FAYE: Yeah.

25 DR. LABOLLE: -- you expect, and --

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1 MR. FAYE: Yeah; yeah.

2 DR. LABOLLE: -- bringing them up --

3 MR. FAYE: Yeah.

4 DR. LABOLLE: -- relates to this --

5 MR. FAYE: And that's the --

6 DR. LABOLLE: -- wetting and drying --

7 MR. FAYE: And that's the recharge problem too.

8 DR. LABOLLE: Exactly.

9 MR. FAYE: That -- I know that, and I'm hoping,
10 again, like I say, that the baseline recharge, whatever we
11 actually end up with is going to be more than 12. And
12 it'll take -- and you'll see on the -- you'll see on the
13 scatter diagram for the transient analysis the same kind
14 of thing, I believe, although it's only the latter part of
15 it up toward the top where we have some really decent data
16 that it shows up. But I'll point that out.

17 Here's the capacity data that we used. This is from
18 the consultant's report, that I mentioned, in 1979. And I
19 violated this with respect to one well. After like 1980
20 or something like that, I violated that with respect to
21 TT-53 or 52, I believe -- it's in the report -- just
22 because I couldn't find any water anywhere else. I needed
23 water to match the USGS criteria.

24 It was one of those several periods -- several month
25 periods where several well -- two wells were down. And I

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1 just needed that extra water to match that annual rate,
2 and so I violated that criteria at that time for Well
3 TT-53, I believe it was, or 52. But that was the only
4 time.

5 All the other times, those capacities were honored to
6 the limit. In other words, unless I had a note that the
7 well was being pumped for 24 hours, all of the capacities
8 that I used in the model to pump were less than those
9 recorded there and in many cases substantially less.

10 DR. POMMERENK: Bob?

11 MR. FAYE: Yes.

12 DR. POMMERENK: The map shows a lot more wells than
13 you indicate here.

14 MR. FAYE: Yes.

15 DR. POMMERENK: Do you have the data for the other
16 wells as well?

17 MR. FAYE: A lot of them we do, Peter.

18 Can we go back to that one, Claudia. Is it in -- is
19 it in this module where I showed the -- yes. Keep going.
20 There it is.

21 Yeah. Yes. Yes, Peter. These TT-45, TT-29, TT-28,
22 2-A, TT-55, TT-27 were all out of the -- out of operation
23 by 1978. Okay? These are some of the original wells
24 along with TT-26 that originally supplied the Tarawa
25 Terrace network water supply treatment plant: TT-27,

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1 TT-55, 2-A, 28, 29, and 45. And in the very beginning of
2 Tarawa Terrace, from about 1952 to 1961, there were
3 actually two wells, and Tarawa Terrace call -- or Camp
4 Lejeune called them six and seven that were off the
5 reservation. They were off-campus. They were about a
6 mile and a half or so up Bell Forks [sic] Road.

7 And what the operation was there, I have no idea how
8 the water was actually connected to the network at Tarawa
9 Terrace. I don't know. But they're officially listed as
10 Tarawa Terrace supply wells in the records, numbers six
11 and seven. And they're actually located on Bell Forks
12 Road, and I have a crude map showing where they were
13 located.

14 So there's another actual two wells that actually
15 don't show up here for the very early supplies. Now, you
16 have to remember those -- all of these wells were off --
17 out of the system by about 1961 -- those ones. Except for
18 TT-26, all of those wells were out of the system by 1961
19 or '62. Okay?

20 DR. KONIKOW: Why were they out of the system?

21 MR. FAYE: Pardon?

22 DR. KONIKOW: Why were they taken out?

23 MR. FAYE: The early wells, Lenny, the way they were
24 constructed had a tendency to sand up. The maintenance
25 was a horrible situation. They had that, plus, I believe,

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1 there were some network problems because of the lack of
2 proximity to the wells, to the WTP. The WTP is located
3 about right there.

4 And so they just -- they took those wells out of the
5 system. They were low producers. I have records in 1959,
6 indicating that they were very low producers and -- except
7 for TT-26. And so in '61, they came in and put in a
8 number of additional supply wells and took those all
9 off-line, abandoned them.

10 Thank you, Claudia.

11 DR. POMMERENK: I have another question on that table
12 that you showed earlier.

13 MR. FAYE: The Von Oesen table?

14 DR. POMMERENK: No; the capacity table.

15 MR. FAYE: Yeah. Could you go back.

16 DR. POMMERENK: According to those numbers, they
17 would have to meet their one MGD daily demand to
18 operate --

19 MR. FAYE: Easily; easily.

20 DR. POMMERENK: -- three wells for 24 hours?

21 MR. FAYE: Mm-hmm; easy.

22 DR. POMMERENK: Or let's say six wells for 12
23 hours --

24 MR. FAYE: Yeah.

25 DR. POMMERENK: -- because the state of North

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1 Carolina doesn't allow you to run your --

2 MR. FAYE: Right.

3 DR. POMMERENK: -- wells 24 hours a day.

4 MR. FAYE: Right. Well --

5 DR. POMMERENK: So how did you determine in your
6 model which out of those seven wells -- did you just have
7 them all run at a, you know, prorated capacity?

8 MR. FAYE: No. What we had, Peter -- we actually had
9 copies of tables from Camp Lejeune of their operational
10 records. Okay? And the various columns of these records
11 would show a pumping level, a static level, a pumping
12 rate, operational notes about the well, whether the well
13 was down, whether the well was -- where the pump was being
14 replaced, things like that. And we have those on a
15 monthly basis from January '78 through March of 19 -- or
16 April of 1986.

17 So the pumping schedule that is used in the model for
18 each of the 204 stress periods honors those operational
19 records 100 percent in terms of what wells were operating,
20 what wells were not. I could see that what I just said is
21 bothering you. What is that?

22 DR. POMMERENK: No. I'm just wondering. So that's
23 in the simulation. And I'm not a groundwater modeling
24 person, but the simulations of those wells that you
25 determined according to that operating schedules were

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1 operated --

2 MR. FAYE: Mm-hmm; at that month.

3 DR. POMMERENK: -- for the whole month.

4 MR. FAYE: Yeah. I had to. Yeah.

5 DR. POMMERENK: Okay.

6 MR. FAYE: That's our -- that's our minimum --

7 DR. POMMERENK: And at that capacity?

8 MR. FAYE: No, no, no, no; because, I just said, the
9 wells rotated. They were, like, on-line eight hours a day
10 and off like 16. So if you -- if you use that capacity --

11 DR. POMMERENK: You were just --

12 MR. FAYE: -- you're assuming a 24-hour pumping
13 period.

14 DR. POMMERENK: No. It's understood. Thank you.

15 MR. FAYE: Okay. Okay. So that's what I said. The
16 pumping schedules in the model honor those capacities,
17 such that the rate was always less --

18 DR. POMMERENK: Okay.

19 MR. FAYE: -- than that capacity.

20 DR. POMMERENK: It's understood. Thank you.

21 MR. FAYE: Okay. And I mentioned that the USGS gave
22 us average daily rates for various years. And the -- our
23 -- the pumping schedule, Peter, also honors those rates
24 from 1978 to '86. And then '87, you know, everything went
25 to hell, and they shut it down.

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1 And I mentioned the static water-level data. This is
2 -- this is Well TT-26. This is what these data look like.
3 These are the static measurements, unvarnished. That's
4 what they are, and that's typical of all of the so-called
5 static measurements for all of the supply wells.

6 Okay. Given the schedules, given the data that I've
7 talked about, that's the scatter diagram for the transient
8 analysis. And these data here -- oh, why do I do that?
9 Thank you, Claudia.

10 These data here are -- for the most part, a lot of
11 these or the majority of these are the monitor-well data
12 that we had for the early nineties in various parts of the
13 -- of Tarawa Terrace. Almost -- and these are all of
14 these so-called static water levels that we just
15 discussed.

16 These are the accurate measurements here. And we
17 have a situation where, for example -- and I don't
18 understand this at all. Like, for example, like, at
19 TT-30, which is near TT-26 and TT-25, all of a sudden in,
20 like, about 1980, the static water levels just go up and
21 stay there. And the well is running. The well is
22 operating, and I don't know what happens. Then it just --
23 water levels rise, and it stays there. Not only is that
24 pump -- is that well operating, but it's near two other
25 operating wells. And yet -- but those numbers are in

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1 there. We didn't -- I didn't selectively disregard any of
2 the data at all. It's all there.

3 DR. JOHNSON: Bob, you need to kind of wrap this up,
4 please.

5 MR. FAYE: Okay. We're almost done. And I'll just
6 show you a couple of the results. This is TT-26. That's
7 the observed -- so-called observed static and the
8 simulated. There's TT-31, -52, -67. And there's the
9 stress period '84, when TT-23 was operating and just very
10 rapidly that -- and we've just done some very preliminary
11 advective transport simulations. And let me go through
12 that.

13 There's our water budget for the stress period '84.
14 There's our recharge. It was 12.8 inches a year, what
15 went into storage. That's induced recharge from Northeast
16 Creek, which would have been brackish water; our well
17 pumpage, and that honors the USGS rate for 1984; the
18 discharge of Northeast Creek; discharge of Frenchman's
19 Creek; and change in storage.

20 Advective transport, I just basically did several
21 things. We -- I seeded the cells or one or two cells
22 right next to ABC One-Hour Cleaners to see where they
23 would end up. Because of the -- because of the
24 contaminant extent that went north and west of ABC
25 Cleaners that we saw on the maps before lunch, I put

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1 particles in 600 feet west of ABC Cleaners along Lejeune
2 Boulevard. That's State Route 24, and I looked at the
3 time of travel to the Tarawa Terrace supply wells of
4 interest. And I came up with an explanation for the
5 occurrence of PCE at Well TT-23, which is that isolated
6 section to the south that we looked at in the maps
7 earlier.

8 When we seeded the particles right in the immediate
9 vicinity of Tarawa Terrace -- of the ABC One-Hour
10 Cleaners, all of them were captured at TT-26; everything.
11 The -- none of the other supply wells captured anything
12 for this particular stress period '84, which relates to
13 December of 1984. When we went a little bit west of ABC
14 One-Hour Cleaners -- and this is after 10,000 days, by the
15 way -- indeed, TT-23 captured particles that were seeded
16 west of the ABC Cleaners.

17 DR. LABOLLE: Bob, are you running the hydraulic
18 static then? Because you keep mentioning the stress
19 period in '84, but then you run it for 10,000 days.

20 MR. FAYE: Yeah.

21 DR. LABOLLE: Can you elaborate? So steady-state
22 hydraulics, transient?

23 MR. FAYE: The gradients, velocities, and whatever
24 relate to that one stress period, stress period '84.

25 DR. LABOLLE: That would explain probably the sole

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1 capture of contaminants in a single well.

2 MR. FAYE: Well, actually --

3 DR. LABOLLE: If you consider all the pumpage, you
4 tend to have things --

5 MR. FAYE: Yeah. It could bounce around. Yes, it
6 could; in reality, yeah. I also did it for other stress
7 periods, but I came up with slightly different
8 configurations in terms of drawdown from the, you know, in
9 the system. And TT-26 captured everything, always
10 captured everything when -- but, again, that's a simulated
11 of continuous pumping. But it captured everything that I
12 put in right in the immediate vicinity of ABC Cleaners.
13 It captured everything. It always went there.

14 DR. DOUGHERTY: Were these all seeded in the top
15 layer?

16 MR. FAYE: Some of them were. One experiment seeded
17 Layer 3, which is the River Bend unit. And that's where a
18 lot of the contaminant was -- has been observed. And I
19 also seeded Layer 5, which is the lower unit of the upper
20 Castle Hayne aquifer. And there was a little bit of
21 contamination observed in that layer as well from the
22 field data. So I seeded both layers.

23 DR. KONIKOW: Why didn't you seed layer -- the top of
24 Layer 1? That's where the contaminants reached the water
25 table.

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1 MR. FAYE: Yeah. The -- that's a good question. The
2 -- at that time, the Tarawa Terrace, when the data were
3 collected, all of the -- all of the contaminant was below
4 that particular layer. And that was -- that was when I
5 was having problems with the cells drying out too, Lenny,
6 in Layer 1. And that's up in the highland areas with
7 Layer 1 and Layer 2. So I ended up -- I ended up seeding
8 Layer 3.

9 DR. WALSKI: The fraction of the time was 26 on? Is
10 it run like 80 percent of the time, or did it run 70
11 percent of time on average?

12 MR. FAYE: That, I really don't know, Tom. All I
13 know that it probably rotated --

14 DR. WALSKI: Okay. So --

15 MR. FAYE: And so didn't run 100 percent of the time.

16 DR. WALSKI: So therefore, you can explain possibly
17 some of this water getting past it by the fact that, if
18 you took real, like, hourly time steps for a change, the
19 hydraulics would then shoot past it and --

20 MR. FAYE: And that's right; that's right. That's
21 right. And there's even a better explanation, I think.
22 Okay? And that's this right here. If you seed -- there's
23 another well down here, TT-54, right here. And TT-23 is
24 actually right here, and if you look at the capture zones
25 of TT-26 and TT-54, you can see right in this area that

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1 they're very close to one another. So when the well --
2 when TT-26 is shut down for any reasonable period of time,
3 probably the capture zone for TT-54 moves over into part
4 of the capture zone for TT-26.

5 Also, this is a highly contaminated area right in
6 here. This is a much less contaminated area here. So
7 even if this situation here persisted through time
8 constantly, I think you may also have had some exchange of
9 mass along concentration gradients from the highly
10 contaminated area to a lesser contaminated area. And it
11 would end up in the capture zone of TT-54.

12 Now, you say, how did well -- well, this -- you have
13 to understand that TT-23, at best, only operated for about
14 a year. And TT-23 is right here. And in the DPT analyses
15 that we have, there was a low-level PCE contamination
16 throughout all of this area here.

17 So my conclusion was that one possible explanation
18 for the occurrence of PCE at TT-23 was not that TT-23
19 pumped for six months and was able to capture PCE that was
20 in the general vicinity of ABC Cleaners, but rather over a
21 period of time -- TT-54 began operation in 1961. But
22 rather over a period of time, you had intermittent capture
23 of PCE by TT-54 that ended up creating this low-level
24 contamination in this particular area of the Tarawa
25 Terrace campus or housing area.

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1 And then in 1984 when TT-23 was actually turned on
2 for a short period of time, there was a resident PCE in
3 the aquifer that was induced into the well. That's one --
4 that's my explanation, and I'm sure there's others. But
5 that's my explanation for the occurrence of PCE in Well
6 TT-23.

7 DR. DOUGHERTY: Quick question. In terms of -- I
8 want to connect this one to the pumping capacity chart
9 from Van Oesen. Looking at those capacities for the late
10 seventies, it appeared that if I summed up the capacities
11 for the TT-26 area, there are the three wells up there --

12 MR. FAYE: Mm-hmm.

13 DR. DOUGHERTY: -- and then for the cluster that's
14 down in the development that there was a significantly
15 larger net capacity for the southern cluster than the
16 northern cluster --

17 MR. FAYE: No.

18 DR. DOUGHERTY: -- is that accurate? I mean, it was a
19 partial record.

20 MR. FAYE: It's as accurate as I know it.

21 DR. DOUGHERTY: No. What I'm saying is my
22 assessment, since I only saw this table rather than the
23 entire simulation set of data. In terms of what you
24 simulated, did you actually have twice as much pumping
25 from the southern cluster of wells than from the northern

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1 cluster? Is that roughly the division?

2 MR. FAYE: Oh, I see; because of the -- because of
3 variations that I made in the pumping schedule to honor
4 those two criteria that we talked about; yeah.

5 DR. DOUGHERTY: Because of capacity --

6 MR. FAYE: Yeah. Mm-hmm. And -- but, again, now,
7 Dave, you have to understand that there would be months
8 when these -- some wells were out of --

9 DR. DOUGHERTY: Sure.

10 MR. FAYE: -- operation. So I had to increase the
11 pumpage at other wells to make sure I could maintain that
12 rate.

13 DR. DOUGHERTY: No. I understand. I've got that
14 right. I got how it worked.

15 MR. FAYE: Great; okay.

16 DR. DOUGHERTY: But I'm just trying to get a sense
17 for -- a simplified sense because there's an awful lot of
18 material here.

19 MR. FAYE: Okay.

20 DR. DOUGHERTY: Basically, you're pumping twice as
21 much down here, generally speaking --

22 MR. FAYE: Right.

23 DR. DOUGHERTY: -- than up there?

24 MR. FAYE: Right. But if you -- and I -- what I also
25 looked at the simulated capture zones for all of those

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1 wells. And they're all deflected up to the northwest
2 except for TT-54. Okay? These wells down in this,
3 they're all deflected up here --

4 DR. DOUGHERTY: Mm-hmm.

5 MR. FAYE: -- rather than giving any competition to
6 TT-54 or TT-26 up there.

7 DR. DOUGHERTY: Mm-hmm.

8 DR. LABOLLE: Did you look at the sensitivity of the
9 simulated capture to vertical hydraulic conductivity at
10 all?

11 MR. FAYE: No; haven't done that at all. It's on the
12 radar screen; just there's all kinds of sensitivities that
13 we need to deal with.

14 DR. LABOLLE: Yeah. It's been my experience in
15 situations like this that it tends to be highly sensitive
16 because what will happen is that if your source is seeded
17 in Layer 1 and your vertical hydraulic conductivity is
18 decreased, then the contaminant's going to migrate along
19 more -- not in the ambient gradient, but more of an
20 ambient gradient --

21 MR. FAYE: Right.

22 DR. LABOLLE: -- than is affected by the --

23 MR. FAYE: Right.

24 DR. LABOLLE: -- by the actual pumpage in the deeper
25 layers, assuming these wells are screening deeper.

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1 MR. FAYE: Right. Well, also, too, we're dealing
2 with, in the real world, a heck of a contrast in
3 densities. I mean, 1 to 1.6 and that -- none of this
4 shows up in any of that simulation there. I mean, that's
5 just strictly advective transport.

6 Thank you very much. And I'm sorry that -- oh.
7 Okay.

8 DR. KONIKOW: When you talk about a density contrast,
9 you're talking about --

10 COURT REPORTER: Please get on your mike.

11 DR. KONIKOW: When you're talking about a density
12 contrast, you're talking about pure phase?

13 MR. FAYE: Yeah; absolutely; yeah.

14 DR. KONIKOW: But we're not looking at the movement
15 of the pure phase, are we?

16 MR. FAYE: No. No. But, I mean, that's just -- I
17 know it's a DNAPL. Okay? And that's what -- that's what
18 the -- that's what it is: 1.6 in the laboratory.

19 DR. LABOLLE: But not at these concentrations.

20 MR. FAYE: No.

21 DR. DOUGHERTY: I wonder if the hydrodynamics will
22 drive it.

23 DR. LABOLLE: Only near the source --

24 MR. FAYE: Right.

25 DR. LABOLLE: -- might we have some kind of density

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1 effects.

2 MR. FAYE: And most of that is actually in the -- I
3 mean, there is no -- the almost free product stuff is in
4 the unsaturated zone at the source. And there's a map in
5 your report that shows that.

6 DR. JOHNSON: Well, thank you very much for your
7 presentation, and --

8 MR. FAYE: Well, thanks for your forbearance.

9 DR. JOHNSON: -- also thanks to the questions from
10 the panel. Let's proceed. Morris, you had prepared some
11 responses. Yes, please.

12 DR. CLARK: I had one question.

13 DR. JOHNSON: Of course.

14 DR. CLARK: We had a side conversation before,
15 earlier today, about the other sources of groundwater
16 contamination that existed in the Camp Lejeune area, and I
17 thought it might be useful for the panel to hear about
18 some of that.

19 MR. FAYE: You mean, like, in the Hadnot Point area?

20 DR. CLARK: Well, in the Hadnot Point area.

21 MR. FAYE: Am I going to steal your thunder on that,
22 Morris?

23 MR. MASLIA: No; no.

24 MR. FAYE: Okay. Yeah. I'd be happy to as long as
25 -- the -- as Morris mentioned this morning when we first

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1 started the program, we deliberately chose Tarawa Terrace
2 because, believe it or not, it's the simplest system that
3 we had to deal. Okay? As he said, there's one source,
4 and it's an identified source as far as the contamination
5 of the groundwater is concerned.

6 If you go south to the Hadnot Point area, you're
7 dealing with dozens and dozens of sources of
8 contamination, some relatively small, some off the radar
9 screen, that have contaminated groundwater in a big way.
10 A number of these sites have RI/FS operations ongoing
11 right now in terms of remediation. We're looking at a lot
12 of TCE, a lot of BTEX. It's kind of a mess. Okay?
13 You're looking at -- you're looking at surface sources.
14 You're looking at buried sources.

15 You face the possibility of -- you face the
16 possibility of a particular supply well capture zone
17 collecting contaminants from several sources very easily.
18 So that's an exceedingly complex condition to try to do
19 what we're trying to do. And you sort of have to crawl
20 before you can walk. And our thought was if we can be
21 reasonably successful, create a technically defensive --
22 defensible product at -- ah, a Freudian slip -- product
23 for Tarawa Terrace, then we may have a shot at doing
24 something similar for the Hadnot Point area. Does that --
25 does that cover --

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1 DR. CLARK: But the chances of actually being able to
2 do that, I gather, are marginal at best; right?

3 MR. FAYE: I really -- I don't know one way or the
4 other on that. I would just -- in fact, I don't even know
5 how we would approach that, maybe just a single supply
6 well at a time. Okay? I don't know. It's just -- we're
7 just going to have to deal with that when the time comes.

8 MR. MASLIA: Let me, if I might, qualify that because
9 when Bob and I got together, again, we made the decision
10 based on, you know, consulting work, the USGS work, and
11 all that, that we had the best chance from -- for
12 developing a framework and either before you even get to
13 the modeling at Tarawa Terrace. And so that's some of the
14 -- I guess one of the questions we've posed is: Do we
15 extend that? And, again, it means going back to
16 developing the geohydrologic framework again for Hadnot
17 Point, which we -- I don't believe we've done at this
18 point --

19 MR. FAYE: No; just for Holcomb Boulevard.

20 MR. MASLIA: -- at this point yet. And so that's one
21 of the issues we really want to discuss. Or is it just
22 going to be so completely uncertain and variable that we
23 may not be able to narrow any of the uncertainties, stuff
24 like that? So Tarawa Terrace, we felt, was our best shot,
25 given the time frame, given agency constraints, budgets,

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1 and time lines for the epi study. Dr. Bove can address
2 the study time frame and some of the pressures associated
3 with that to try to get some answers in a reasonable
4 amount of time.

5 Am I on?

6 DR. JOHNSON: Yes, you are.

7 MR. MASLIA: Okay. Okay. I'm a little shorter than
8 Bob. It's happened all my life. I even have to look up
9 to my son, so...

10 In reviewing the premeeting comments and, of course,
11 I've had a few days to look through them and hit more of
12 the salient points. And they do bring up some gaps, if
13 you will, that we need to address. But I wanted to give
14 the panel a sort of a feeling that, again, we take these
15 very seriously. Some of them may, in fact, change our
16 approach or change our direction.

17 So I wanted to try to see what general areas the
18 comments from the panel got into and, you know, what our
19 response -- obviously, in a generalized, given the time
20 frame that we've put these in. So I will go through here,
21 and I'm not sure if I've included that in your handouts or
22 not, in your packets. If not, we can get the panel a copy
23 of our generalized responses.

24 But from the groundwater side, and, Doctor, did you
25 just want me to end on the -- for the groundwater for this

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1 morning and then --

2 DR. JOHNSON: Yes.

3 MR. MASLIA: -- tomorrow we can or --

4 DR. JOHNSON: Yes.

5 MR. MASLIA: Okay. On the groundwater, a lot of
6 comments resided in the area of uncertainty of geologic
7 and aquifer parameters as we've discussed thus far and
8 what -- it looks like some mention of probabilistic
9 methods, such as Monte Carlo, looking at realizations.
10 And I know Dr. LaBolle has a lot of expertise in that area
11 and has worked on some sites for ATSDR in that area.

12 And that is something, I think, would be the next
13 step. The question, I think, for the panel would be: In
14 taking that as the next step, should that be the next step
15 prior to doing any more refinement of the Tarawa Terrace
16 model? Should we jump into probabilistic uncertainty
17 methods now, rather than doing any more refinement on the
18 Tarawa Terrace model?

19 Secondly, some parameter estimation methods to look
20 at sensitivities like vertical hydraulic conductivity
21 relative to other parameters. Again, that is a direction
22 we definitely need to go in and anticipate going in. As
23 far as modeling boundaries and sources, source conditions,
24 I think the best way may be to look at use of sensitivity
25 analysis to assess the nearness or the impact of moving

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1 that northern boundary further away from the source and
2 seeing how much change it provides to the model, adjusting
3 the boundary.

4 Again, we have the contradiction, if you will, that
5 you've got the DEM that I didn't get to mention. The DEM
6 data that was contoured for us -- actually, North Carolina
7 district office is who we sent it up to, to pull it off
8 the DEM site and provided us with the 2-foot contours,
9 but, again, based on that and the topo maps. But I think
10 that would be an area of -- that we could at least try to
11 address and looking at the sensitivity of the northern
12 boundary with relation to what impact it may provide on
13 the model.

14 And the one question is: Would we see a bigger impact
15 or a more pronounced impact if we go to the full fate and
16 transport as opposed to just looking at the advective
17 flow, which we're doing right now? In other words, you
18 may find a changed impact when you go to the full fate and
19 transport where you're looking at dispersive properties
20 and start moving boundaries away from the ABC Cleaners'
21 source.

22 The other approach -- and I think this comes into if
23 you want to put in the area of sensitivity analysis -- is
24 we do have techniques. Actually, there have been some
25 papers on that, developed out of the multienvironmental

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1 media simulations lab at Georgia Tech, but they -- where
2 they have taken observed concentration values and backed
3 out source locations through use of genetic algorithms.

4 And that's, again, maybe an avenue to explore, taking
5 some of the observed values that we have, historical in
6 nature, and seeing if, in fact, it backs out the source
7 location that we are assuming to ABC Cleaners. And I
8 don't know -- I don't want to put Dr. Aral on the spot
9 there. But we've had some preliminary discussions on
10 that. And as I said, that's another area that we may --
11 that perhaps, we should explore is using the observed
12 data --

13 (Projection screens withdrew to the ceiling.)

14 MR. MASLIA: I didn't -- is it time? You may have to
15 touch the touch screen, Claudia. The touch screen may
16 have timed out (laughter). Either that, or it didn't like
17 the answer I gave. Okay. I don't know. Okay. You may
18 have to hit "dual projector" to do that. And if not, I
19 don't know if Ann Walker or somebody out in the hallway
20 can hear us. They may have to call somebody to come get
21 us. But I'll proceed in talking as we go on.

22 So those two areas of doing -- I'm not sure --
23 inverse modeling is not the correct nomenclature, but
24 reverse modeling of going from the source, observed
25 source, backing out. And that may also give us an

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1 indication if, in fact, that source -- where we think ABC
2 is too close to a boundary.

3 The next groundwater, I've got fate and transport
4 issues. And I know, Lenny, you brought that out that we
5 mentioned fate and transport only provided advective, and
6 it's been our intent all along to do a full fate and
7 transport. And again, in the Tarawa Terrace area being
8 PCE is the only known source that would give us a single
9 constituent model. So we are -- definitely, that's on the
10 plans. That's always been on the plans to do that.

11 One of the issues I want to bring up -- and Bob
12 mentioned -- some of the data that we get in pieces as far
13 as production and things like that, although we've been at
14 this for over a year, I think, more or less. For example,
15 last week, I just got a pile of information: month-by-
16 month, raw water, finished water, production data from
17 Camp Lejeune from 19 -- what was it?

18 MR. ASHTON: 1980.

19 MR. MASLIA: 1980 through 1986.

20 MR. ASHTON: '84.

21 MR. MASLIA: '84; month by month. And, of course,
22 we've been asking for all data, so I'm saying it's slowly
23 filtering in. It may take a more direct involvement of,
24 you know, giving ATSDR staff or whatever to going into the
25 vault, locating contract numbers, and things like that.

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1 But this is new data that we just were provided with from
2 the folks at Camp Lejeune. So again, that's in that
3 critical period. What we really still need is the prior
4 to the '78 information; '68 to '78. We're still looking
5 for that.

6 Let's see. So again, the advective transport were
7 viewed as preliminary estimates; get the model working;
8 any issues with -- as far as not model code, but
9 implementation of the code that we could take care of at
10 this end and then taking comments, feedback, from the
11 panel. Again, at least we've got some basic parameters
12 and basic numbers to then go into uncertainty areas, go
13 into other more refinements of the model.

14 So that's really the groundwater issues; a quick
15 preliminary perusal from your comments that I saw, and
16 that's the direction we're going in. And we will try to
17 answer, you know, anything else.

18 DR. JOHNSON: Did anything you just heard raise
19 concerns, or is there anything that you heard for which
20 you would give a strong endorsement? What I've heard from
21 Mr. Maslia is a series of considerations, and all that's
22 good. But is it something that really that you've heard
23 you'd say, "This really ought to be something you pursue,"
24 based upon his responses?

25 DR. DOUGHERTY: I think you should move the northern

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1 boundary and skip the sensitivity.

2 MR. MASLIA: Okay.

3 DR. DOUGHERTY: Just do it. Topography does not
4 define hydraulics, unfortunately.

5 MR. MASLIA: And would you then just use a
6 generalized, head-type boundary or inflow boundary
7 since --

8 DR. DOUGHERTY: I'd have to look further north than
9 the maps that I have here show me --

10 MR. MASLIA: Okay.

11 DR. DOUGHERTY: -- so I can't answer it really.

12 MR. MASLIA: Okay.

13 DR. WALSKI: Are there municipal wells, other things
14 up north?

15 MR. MASLIA: Oh, yeah. There's the city of
16 Jacksonville is, you know, pumps the wazoo out of
17 groundwater. And I think we uncovered some -- did we not
18 uncover some documents when we first went to Raleigh about
19 discussions back and forth between Camp Lejeune and the
20 city of Jacksonville about --

21 MR. FAYE: For the period of time that we're
22 interested in, the pumping at the city of Jacksonville is
23 not an issue. They have for decades pumped from the
24 Cretaceous aquifer system, which is well below the Castle
25 Hayne units that we're talking about here and with no

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1 effect on the Castle Hayne.

2 Just most recently, they've applied for permits
3 within the last year or so to develop wells in the Castle
4 Hayne. But for the period of time we're involved in,
5 Jacksonville pumping would not be an issue.

6 What would be an issue would be a lot of older
7 subdivisions and industrial areas and business areas north
8 of there that back in the fifties and sixties and
9 seventies, the period of time that we're interested in,
10 would have been self-supplied. And I don't -- it would be
11 just -- we could certainly look, but I wouldn't be too
12 hopeful of determining or of finding out what kind of --
13 we would know less about those situations than we would
14 about the Camp Lejeune pumpage.

15 So that's the situation there in terms of the -- and
16 that self-supplied pumping was almost invariably from the
17 same aquifers that we're dealing with because they were
18 shallower and they were good. They yielded good water to
19 wells, and, of course, the businesses and the residences
20 and everything loved that because it was much cheaper than
21 going deeper. So that's what we're dealing with.

22 MR. MASLIA: I've got half a screen -- half a room
23 screen working, and we've got a number for the room
24 operator. So we're trying to...

25 DR. JOHNSON: Based on what's on the screen, we've

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1 had one comment from David in terms of his view and strong
2 recommendation. Does the panel have other recommendations
3 based on what's on the screen or what you have heard?

4 DR. KONIKOW: Well, I would look again closer at the
5 vertical hydraulic conductivity, its relation to the
6 horizontal, and also the hydraulic conductivity of the
7 clay layers of the confining units. The values that you
8 or Bob gave earlier just seem a little too high, relative
9 -- you were talking about .2 feet per day, as opposed to,
10 you know, maybe 10 or 15 in the aquifer.

11 That -- for a clay confining layer, that just seems
12 too high. And one of the things that might -- what you
13 might find is that, as you make the vertical hydraulic
14 conductivity lower and the hydraulic conductivity of the
15 confining layers lower, your cell drying problem may go
16 away.

17 MR. FAYE: Yeah. That's a good point, and you easily
18 could be right. But the fly in the ointment there, Lenny,
19 two things: The, admittedly, very limited lithologic --
20 good lithologic descriptions that we have of these
21 confining units, yeah. They're clay, but they are very,
22 very sandy. They are definitely sandy. And they're not
23 real competent clays there, texturally.

24 I mean, when you look at the drilling times and the
25 drilling records, pha-phooonk, I mean, it's -- you know,

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1 there's no -- there's no slowing down at one -- at a clay.
2 So they're leaky. They are very definitely leaky. We
3 haven't done any kind of sensitivity analysis at all on
4 the anisotropy or the horizontal hydraulic conductivity.
5 But this is not, you know, this is not a -- these are not
6 real competent confining units at all. Okay?

7 MR. MASLIA: I, actually -- and this is part of our
8 question, so I don't know if you want me to pose that now.
9 Dr. Johnson, I'll let you go down the list. But I'll just
10 throw it out there, and then you can decide. I'm not
11 usurping your power as the Chair.

12 DR. JOHNSON: I have no power as the Chair, nor do I
13 want any. But I am fully committed at some point today to
14 start down this list of questions, and we will do that in
15 the not-too-distant future. Are there any other points
16 here of emphasis from the panel on Morris' presentation?
17 Yes, Vijay.

18 DR. SINGH: I think it was pointed in prepanel
19 meeting discussion as well as during the presentation. I
20 think that there has to be a better accounting of
21 recharge, especially when you are doing the transient
22 groundwater modeling because recharge constitutes the
23 input. And if your input is not properly accounted for, I
24 don't think -- I don't think you will be able to do as
25 good a job in groundwater modeling. And I think that may

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1 also partly explain the problems that you're encountering
2 in the convergence.

3 Dr. FAYE: You're exactly right. I mean, we have
4 recognized that, and I know it sounds kind of lame. But
5 the actual truth is that we just haven't had a chance to
6 really address that issue in a lot of detail, but I fully
7 agree with you. And hopefully, that will solve a lot of
8 these problems.

9 DR. SINGH: And the other point that I think it will
10 be important to also evaluate the reliability of the model
11 results, and this is particularly useful from the
12 standpoint of giving the information to the public.

13 MR. FAYE: The reliability of what, sir?

14 DR. SINGH: The reliability of your model result, how
15 -- what level of credence can you really put, given all
16 the uncertainty associated with your hydrogeologic
17 description, your parameter estimation, you know,
18 groundwater conceptual assumptions, and a whole host of
19 other things. I think it's very important to --

20 MR. FAYE: To qualify.

21 DR. SINGH: -- give the level of confidence --

22 MR. FAYE: Right.

23 DR. SINGH: -- or the confidence bends to the model
24 results so that -- so that the public can have some
25 confidence --

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1 MR. FAYE: Absolutely.

2 DR. SINGH: -- in the results that you are giving.

3 MR. FAYE: And that should not be a qualitative
4 assessment. That should be a quantitative assessment as
5 much as we can do, and I fully agree with you.

6 DR. JOHNSON: In that same vein, I asked a question
7 earlier about validity of the EPA models, and to my
8 knowledge, they're quite good. So I'm not -- I don't have
9 any agenda here other than the fact to say to you that the
10 National Academy of Sciences has begun a very serious
11 study of the EPA system of modeling and validity of
12 specific models. Now, I do not know how far into that
13 study they have gotten, but I surely do know that they are
14 doing that at the request of EPA, which is quite
15 commendable.

16 MR. FAYE: Well, let me just say that, first of all,
17 the USGS, the mother and daughter of Modflow here, which
18 is our simulator, they have exceedingly rigorous standards
19 for qualifying their codes, number one. And typically,
20 Dr. Johnson, the way this is done, they -- you recognize a
21 standard groundwater problem that can be solved
22 analytically. And then you pose that problem to the
23 numerical code and see -- and compare that result against
24 the analytical results. And I can tell you that that was
25 done with a great deal of rigor by the USGS, and the

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1 results were highly successful.

2 DR. JOHNSON: I have a couple of administrative
3 questions, Morris.

4 MR. MASLIA: Yes.

5 DR. JOHNSON: The panelists have provided a set of
6 written comments, premeeting comments. My question is:
7 Will these be made part of the public record?

8 MR. MASLIA: They will be in the -- in a refined --
9 and when I say "refined" -- grammar and otherwise --- as
10 part of the report -- the report about the meeting
11 summary. Our past experience has been, like in Dover
12 Township, they were included as an appendix to the report.

13 DR. JOHNSON: This is going back to Dr. Singh's
14 comment this morning about the transparency of all of this
15 effort. It would seem quite meritorious to have these
16 part of the public record, whether it's the record of this
17 meeting or some other source. Does any panelist object to
18 having his comments made part of that record? Do you want
19 time to "correct your premeeting comments," knowing now
20 that it looks like they'll be in the public record? You
21 should be given that privilege.

22 DR. DOUGHERTY: I'd like the opportunity to go back
23 and just check. I don't have a problem with the
24 principle.

25 DR. JOHNSON: Okay.

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1 MR. MASLIA: Well, what will happen, based on our
2 modus operandi from the past is that a draft meeting
3 summary report will come out with your comments in the
4 appendix. And each panelist will be given a copy of that
5 draft meeting summary to correct their comments, see if
6 it's misquoted, or anything else through our contractor,
7 Eastern Research Group. And then once they hear back from
8 you -- yea or nay or change page so-and-so -- then that
9 will become a final meeting summary report. And that will
10 be published and, as Dr. Singh's asked, put on the Web as
11 well.

12 DR. JOHNSON: Does ATSDR plan to provide an answer to
13 each of these questions?

14 MR. MASLIA: As closely as we can. In other words,
15 some of the questions were -- the same questions were
16 asked by multiple panelists. That's what I'm trying to
17 say. I have not thought out yet -- if you're asking me
18 going down each comment, you know, Panelist No. 1, you
19 know, has ten questions. Do we answer those specifically,
20 then go to Panelist No. 2, even though there's a
21 repetition -- may be a repetition.

22 DR. JOHNSON: All right. That's just an
23 administrative detail, you know. It's called "ditto" or
24 something like that.

25 MR. MASLIA: Right.

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1 DR. JOHNSON: But do the panelists feel the need for
2 having an agency response to what would strike me as
3 rather seriously thought-through questions? What are your
4 expectations? I don't want to push something forward
5 that's not palpable.

6 DR. POMMERENK: For me, personally, if I see that my
7 comment has been addressed in a follow-up report -- you
8 know, this is obviously a draft. If the final has those
9 questions addressed because, you know, some of the
10 questions were simply due because I could not find the
11 answer immediately. If they were addressed now, for
12 example, that would be fine, but if it's something else,
13 or...

14 DR. JOHNSON: But there's another group of people who
15 might profit from a reply, and that's the public.

16 DR. POMMERENK: Yeah.

17 DR. JOHNSON: I mean, here's a serious question from
18 Dr. Clark. Number 5, what kind of errors might be
19 inherent in these assumptions? Should that be answered
20 and made part of the public record?

21 DR. WALSKI: I think that as long as they have
22 addressed the substance of the comments, I don't think
23 it's really a good use of resources to be going through
24 question by question. It seems like that's excessive. As
25 long as they substantially respond, I think, and

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1 incorporate it in the report, that would be satisfying to
2 me.

3 DR. JOHNSON: Okay.

4 DR. DOUGHERTY: For myself, they weren't -- were not
5 prepared for the expectation of a point-by-point response
6 because they were prepared to inform the agency about some
7 of the issues that were on my mind that would be useful to
8 hear about here. They were to prompt discussion as
9 opposed to elicit responses. There are some that,
10 certainly, are in that other category, but I think we've
11 heard many responses; not all, but many.

12 DR. JOHNSON: I would offer the opportunity at 2:30
13 when the public addresses us to make comments on that same
14 subject. But I think you have a sense from the panel that
15 it might be -- it might be an overreach to provide a kind
16 of point-by-point response to their premeeting questions.

17 MR. MASLIA: I thank the panel for clarifying that.
18 Tom, your point is well taken about agency resources in
19 general, but I think there are some points specific, like
20 the boundary issue. I think that's a specific answer or
21 approach that we've discussed here. But others will be
22 generalized, and as Peter said, if he sees it in the final
23 report --

24 DR. POMMERENK: Yeah. I'll --

25 MR. MASLIA: That's sort of the approach that we used

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1 in Dover Township. We used a similar set-up with several
2 panels. And the final report did either allude directly
3 to some issues that were brought up.

4 DR. POMMERENK: Yeah. Many of my questions were --
5 they're clarifications questions --

6 MR. MASLIA: Right.

7 DR. POMMERENK: -- where I was not clear --

8 MR. MASLIA: Right.

9 DR. POMMERENK: -- and you --

10 MR. MASLIA: We appreciate -- I appreciate another
11 set of eyes or ten sets of eyes looking over our shoulders
12 to help us see the light of day.

13 DR. JOHNSON: Well, thank you. Let's take a 15-
14 minute break, and when we return, we will start with the
15 specific issues and questions for discussion.

16 (Whereupon, a recess of approximately 11 minutes was
17 taken.)

18 MR. MASLIA: One issue: For our working lunch
19 tomorrow and -- we're going to this place called -- or not
20 going to, but we're going to order several platters of
21 Roly Poly sandwiches, which include anything from monster
22 veggie, California turkey, roast chicken, and all that
23 sort of stuff; a variety of that. And so what the ladies
24 up -- well, there's Ann right there -- need to know by the
25 end of this afternoon is how many people want to

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1 participate in that. It's a volume thing. And the price
2 is based on the volume of whatever we order so -- and then
3 they'll -- based on that, then tomorrow morning, they'll
4 pass around envelopes to everybody, and you can put your,
5 you know, five or six bucks in there.

6 DR. DOUGHERTY: When we do that, do you want us to
7 raise our -- just raise our hands and get a head count
8 now?

9 MR. MASLIA: Well, this afternoon, maybe, sometimes
10 -- I don't know if we're taking another quickie break or
11 whatever at some point. Ann.

12 MISS WALKER: Tell me if you're not going to do it.

13 MR. MASLIA: Oh, well, that's -- who doesn't want to
14 do it? And that includes any people in the audience and
15 public as well.

16 DR. JOHNSON: Thank you.

17 MR. MASLIA: Okay?

18 MISS WALKER: Okay.

19 MR. MASLIA: Okay.

20 MISS WALKER: I don't see any no's, so we'll just
21 count. And then tomorrow morning, you can see Joann and
22 give her some money.

23 MR. MASLIA: Okay. It's all yours, Dr. Johnson.

24 DR. JOHNSON: Well, let's turn to the questions that
25 the agency posed that are specific to the groundwater

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1 presentation. As I count them, there are eight questions,
2 and there may be others that arise during the course of a
3 discussion.

4 First of all, based on groundwater-modeling results
5 presented, what modifications, if any, should ATSDR make?
6 Who wants to take the lead on answering that, as I look
7 around the panel? Let me warn you, I teach, so I know how
8 to pick them (laughter).

9 DR. DOUGHERTY: I'm in the front row.

10 DR. JOHNSON: I know when I see people hunkering
11 over. Robert.

12 DR. CLARK: Okay. I guess one of the -- one of the
13 questions I had goes back to the relative importance of
14 the work that's being done now versus the other
15 contamination sources in the system. And would it be
16 better to devote some resources to understand the relative
17 impact of that, particularly on the epidemiologic results,
18 as opposed to spending a lot more resources in refining
19 the existing model? And I'm not clear on that. I don't
20 have a clear feeling. It's a very impressive technical
21 effort, but I'm not sure that it gets us very far as far
22 as understanding what the other sources might be and what
23 the impact might be.

24 DR. JOHNSON: Eric.

25 DR. LABOLLE: Yeah. I would like to add to that.

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1 it's not clear to me yet the role of the groundwater model
2 in the whole simulation process. And what I mean by that
3 is some of the discussions we've been having over lunch
4 and such and looking at this time-line chronology that's
5 presented here and I'm looking at when the Tarawa Terrace
6 wastewater treatment plant came on-line and when it was
7 closed down.

8 And it looks like, you know, the contamination from
9 the various wells is mixed at a single point, and it would
10 be useful, actually, to have some kind of discussion at
11 some point -- maybe perhaps tomorrow or something -- on
12 the ranges of concentrations within these different wells
13 and how much we really gain with additional detail in the
14 groundwater model.

15 So I think -- I think any recommendations should be
16 preceded with some further understanding of its role and
17 how much is going to be garnered from additional work in
18 that regard.

19 DR. CLARK: Another variation on that, too, is the
20 amount of resources that are available to do the study and
21 how does it take away from other type -- other parts of
22 the study, which might actually have more impact, more
23 importance.

24 DR. JOHNSON: Morris; Bob; whomever.

25 MR. FAYE: The objective of the groundwater model --

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1 flow model is to form the basis of a fate and transport
2 analysis using numerical models that will ultimately
3 result in a monthly value of concentration of contaminant;
4 i.e., PCE at certain wellheads. I mean, that's from --
5 for the period -- was it 1968 to '85? That's the
6 objective. I think that was clearly stated several times.
7 Now, if that's not a tenable objective, it would be nice
8 to know that in your opinion. But that is the objective.

9 DR. KONIKOW: Based on your groundwater modeling so
10 far, you're really starting in 1978 or '79 --

11 MR. FAYE: Right.

12 DR. KONIKOW: -- and so what's -- how do you hope to
13 cover the period back through 1968 or so --

14 MR. FAYE: Good --

15 DR. KONIKOW: -- when the epidemiological data is
16 starting?

17 MR. FAYE: Good question. The reason we did the '78
18 to '94, as I said, was because that's when we had some
19 water-level data that we could actually pay attention to.
20 Probably between 1952 and 1978, we may have a grand total
21 of two or three dozen water-level measurements in
22 comparison. Okay?

23 We also only have discrete -- a discrete window for
24 about, oh, six or seven years, periodic nonconsecutive
25 years; a discrete window in terms of a published value of

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1 the -- of the quantity of water, the total quantity of
2 water treated. We have another half a dozen references
3 for different years in that interim, relating to well
4 capacities and what wells were operational. The well
5 capacities do change with time.

6 The flip side of that is that for most of that period
7 -- and certainly the USGS data there for the -- for the
8 pumping information from '75 to '86 indicate that within
9 plus or minus 10 percent of about -- of .95 MGD that the
10 average annual rate doesn't change that much. And that's
11 because Tarawa Terrace, the housing units, were occupied
12 just about 100 percent all of the time, 90 to 100 percent
13 all the time. So we shouldn't be looking for a lot of
14 variation.

15 We do have enough data now with the additional
16 information that Morris discussed a few minutes ago. We
17 do have enough data now, I believe, to make some sense out
18 of monthly variations and pumping over a long period. And
19 we can apply that information backwards in time as well.
20 And that's kind of the summary of the suite of information
21 that we have available to us, Lenny.

22 DR. KONIKOW: As far as exposure goes, though,
23 there's no --

24 MR. FAYE: No. That -- that's historical
25 reconstruction. I mean, that's -- we do know -- we do

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1 know the -- within a year of the beginning of operations
2 of ABC Cleaners, we know that they used only PCE during
3 their whole period of operation. That's it.

4 MR. MASLIA: Based on suggestions also -- and this
5 gets into, I think, Bob's question about resources and
6 staffing. But, actually, I think another part of our
7 effort or a more intense effort will be on data discovery.
8 That appears to be a key factor, and I think going back
9 to, like, tax records, maybe trying to refine the actual
10 use of the PCE at ABC Cleaners.

11 And that calls into, as far as an answer in terms of
12 agency resources, that's a two-part answer, and I think
13 you can appreciate this being a former government employee
14 yourself. As far as the, how shall I say, funding-part
15 issue, I believe the funds are there. Okay. They've been
16 there this past year while we've been doing fieldwork and
17 that. The other side of the equation is the staff of
18 personnel. That is not there. Issues of do we have
19 enough staff -- and let me get into that.

20 As we discussed at lunch, unlike with other state
21 programs that ATSDR has, we have no cooperative agreement
22 with the state of North Carolina. We used that very
23 heavily in Dover Township, New Jersey being a state. So
24 that alleviated the need if we needed people to go and do
25 some historical record search or do some detailed sitting

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1 on site, so to speak. We actually had a field office over
2 there.

3 So that assisted us. We don't have that option in
4 this situation. So that means if I want to spend the next
5 month, which maybe I'm just taking a month out of my hat,
6 and doing "data discovery," going into the files at Camp
7 Lejeune or something, somehow our project has to come up
8 with a warm body to do that.

9 So while the funding may be there, the people are not
10 there. And that's a consideration, I think, with
11 recommendations, obviously, from the technical staff that
12 management may need to look at that. If we say it appears
13 to be a consensus of the panel -- I haven't taken a vote.
14 That's -- Dr. Johnson probably will try to do that later
15 on.

16 But if data discovery, refining our chronology, our
17 operational history, and things of that nature to pinpoint
18 specific lack of information that we have now is a --
19 should be a focus of our continued effort, then that's
20 something we have to address, I think, as a division, as
21 an agency. So hopefully, that's addressed your question.
22 Is there a follow-up, or is there...

23 DR. JOHNSON: Well, what I hear is a strong
24 commitment on the part of the agency to continue the
25 groundwater modeling and activities associated with that

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1 effort. I also am hearing from the panel some concern as
2 to whether that, perhaps, the depth of that should be
3 pursued. Am I misstating the case here? Please, Tom.

4 DR. WALSKI: What I would want to do as a starting
5 point would just sort of do an overall classification of
6 which areas we know were contaminated with this chemical,
7 which ones we know were safe, and then which ones were --
8 and those you just sort of say, you know, these people
9 were exposed, period, and these people were not exposed,
10 and concentrate the modeling on areas that we're gray on.
11 Do we have a marker for this easel here?

12 MR. MASLIA: I've got -- these are drawing markers,
13 but you can --

14 DR. WALSKI: Here. Oh, here's one. Okay. How am I
15 going to operate this thing? Okay. There we go.

16 (Drawing) It's sort of a thing like this with, you
17 know, Terrace, Hadnot, Holcomb, 1952, 1972. You know, I
18 have separate rows. 1971, 1987, and just draw these in.
19 This one here is a -- this area where we know was bad
20 here, we know it's cleaned up here because they shut the
21 plant down, and we know that ABC Cleaners wasn't in
22 existence before some date, possibly. So this we know,
23 and we just want to focus the modeling in here to areas
24 we're not sure.

25 And like, Holcomb, we knew was pretty good most of

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1 its life, but there are some periods where we were
2 uncertain of. And this might be where you'd look at some
3 modeling where it was unsure. And Hadnot, we know was
4 pretty bad throughout all time and you know, until they
5 went to some type of -- what ended the -- they put some
6 more treatment in, right, some pump and treat?

7 MR. FAYE: No, they didn't. They just took the wells
8 off-line.

9 DR. WALSKI: They took the bad wells off-line at some
10 point. So we know that after this point you're okay. But
11 here we were in pretty bad shape. And then just focus in
12 on the places where the models could tell you, you know,
13 where it's critical because here you knew there was
14 exposure. So you might want to do some kind of matrix
15 like this as the next step before you got into, you know,
16 doing -- just trying to model every single month of this
17 thing where you know there's contamination in some of
18 these areas. So why bother beating that when -- or you
19 know that some of these weren't contaminated at that time,
20 so why bother modeling those periods?

21 MR. MASLIA: My -- I guess, at least, my experience
22 and knowledge would be in a numerical model, such as
23 Modflow or any of its varieties. We have to step through
24 time. So we're going to have to time step whether we --
25 whether we use the information or not, we're still going

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1 to have to time step it to get to the period of interest.
2 Is that --

3 MR. FAYE: And also, in terms of the periods of time
4 when no exposure was occurring, your point's well taken.
5 But it would be so much more convenient -- say, for
6 example, we know that Tarawa Terrace -- I mean, the ABC
7 Cleaners, for example, they probably started operations
8 around 1955. We know that. And the Tarawa Terrace wells
9 went on-line in 1952. From a modeling standpoint, it
10 would be so much better to start your -- to start your
11 simulation in 1952 because you're starting out from a
12 prepumping condition, rather than begin things in 1955 and
13 try to guess at what the antecedent conditions were.

14 So, you know, that's a decent trade-off. Three years
15 is not a big deal. And we wouldn't have to do that, say,
16 for example, on a monthly basis; those three years. So I
17 think -- in certain context, I think your comments have a
18 lot of merit. In that particular case, I'm not sure.

19 DR. UBER: I think that I'm taking Tom's comments as
20 more metaphorically, maybe, not exactly literally, on that
21 -- on that matrix. Just to -- what I hear some of the
22 panel saying is that we might like to hear the objectives
23 of the groundwater modeling explained more in the context
24 of the ultimate goal of the investigation, meaning the
25 epidemiological study and the needs for that.

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1 So, for example, if you knew that these nine wells --
2 I'm not saying this is the case. But if you knew that
3 these nine wells were all blended together and served
4 Tarawa Terrace residents during a certain period, then
5 that means that the groundwater model is really predicting
6 the blended sum of those waters from those nine wells.
7 And the -- and if you do sensitivity analysis, such that
8 it doesn't really affect very much the blended water over
9 time from those wells, then you -- you know, if that's the
10 case, if that's insensitive to those assumptions, then
11 those assumptions are not necessary to nail down any
12 further.

13 Whereas, those same assumptions might have impacted
14 significantly the individual arrival times at certain
15 wells or individual captures zones. So, I mean, that's
16 just an example. I'm not saying -- you don't need to
17 comment on that particularly. But if that were the case,
18 then that would be one example of making the objectives of
19 the groundwater modeling, in my mind, closer to the needs
20 of the epidemiological study because it brings it into the
21 context of the exposure. Does that make any sense? I'm
22 thinking not.

23 MR. FAYE: Yes, it does. The fly -- well, yes, your
24 comments do make a lot of sense. The situation as it
25 exists is that the results of the groundwater-flow model,

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1 which would provide monthly concentrations at the
2 wellheads -- those are one step removed from the exposure
3 at a street or a house in the -- in Tarawa Terrace because
4 that -- those results are linked to the network, to
5 EPANET, to the network model, which provide the exposures
6 at the individual residences or streets or whatever.

7 DR. UBER: Mm-hmm.

8 MR. FAYE: So the results of the groundwater flow
9 model are one step removed from where you're getting to.
10 But that's the linkage that the network -- the network
11 analysis is the linkage.

12 DR. LABOLLE: So expanding on that -- Eric LaBolle
13 here -- if one looks at the groundwater model and its
14 results today, even though they're still in preliminary
15 stages, can you make an assessment that some of these
16 wells saw contamination for all time, for all the entire
17 study period?

18 MR. FAYE: That's a really good point, and I was
19 hoping somebody would ask that. My gut feeling right now
20 -- and I could be wrong. But my gut feeling right now is
21 that TT-26 is the major player in the whole -- in the
22 whole event from the time that there was a breakthrough at
23 TT-26 of the PCE from ABC Cleaners until the times that
24 the wells were shut down. I think most of the PCE
25 produced at ABC was captured at -- only at TT-26 with

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1 maybe some residual amounts at TT-25.

2 There were -- we have that migration to the
3 northwest. That was probably caused by local pumping
4 there that we know nothing about as well as dispersion.
5 But for all intents and purposes, the capture of PCE
6 occurred at TT-26, and I think, you know, that that's
7 going to be the end result.

8 DR. LABOLLE: And is it -- can you state an opinion
9 at this point in time as to a range of times that you
10 think the contamination might have arrived at TT-26? Not
11 to pin you down, but my point here is this. My point is:
12 If you're dealing with a study period in which TT-26 saw
13 contamination during the whole time, that might change the
14 role of the groundwater model versus a study period in
15 which the groundwater model is expected to predict an
16 arrival curve to TT-26. The level of detail necessary to
17 predict an arrival curve would be significantly different
18 than one needed to predict, say, maybe just a boundary
19 range of concentrations --

20 MR. FAYE: Yep.

21 DR. LABOLLE: -- in which assumes --

22 MR. FAYE: Yes. That's good.

23 DR. LABOLLE: -- inherent uncertainty.

24 MR. FAYE: Yeah. That's very good. You have -- you
25 have several issues to address, okay, in that whole

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1 context. If you have the arrival time -- I made an
2 estimate with the advective transport simulation. It
3 occurred about -- in about three years. Okay. So if we
4 assume that PCE entered the -- got -- was actually being
5 discharged to the septic tank at ABC Cleaners some time in
6 1955, probably made it to the water table maybe a few
7 months or a year later, you're looking at something around
8 1959 when PCE started to -- and that's not accounting for
9 dispersion. It might have gotten there earlier when
10 dispersion effects are taken into account.

11 Now, having said that, you have these other issues of
12 retardation, biodegradation, and whatever that are going
13 on in that interim -- in that whole period of time, say,
14 from 1959 or whenever up to 1985 when that particular well
15 was shut down and taken off the -- taken out of the
16 network.

17 So what the model would be attempting to do, okay,
18 would be to address those issues of retardation,
19 dispersion, biodegradation, whatever, decay; and in that
20 interim period of time for that particular -- for that
21 interval.

22 DR. LABOLLE: The sense that I'm getting then is that
23 the 15 years roughly -- or, say, 10 to 15 years that have
24 elapsed there between the introduction of a source to the
25 system and/or probable introduction of a source to the

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1 system and the beginning of the study period sounds like
2 sufficient time for the contamination to have arrived --

3 MR. FAYE: Oh, yeah.

4 DR. LABOLLE: -- at TT-26.

5 MR. FAYE: Oh, yeah; absolutely; absolutely. We
6 would not begin -- or at least I would not think it would
7 be appropriate to begin the model simulation -- the
8 groundwater flow and fate and transport simulations in
9 1965, which is the beginning of the period of interest to
10 the epi study. We would want to be there before. We
11 would be simulating conditions before that and then all
12 the way through it.

13 MR. MASLIA: One other issue because Bob and I have
14 discussed this, and that's the issue of Well TT-23. And
15 that, again, I think this is where the model can help
16 refine our understanding. Well TT-23 was drilled after
17 the shutdown or in anticipation of the shutdown of TT-26.

18 MR. FAYE: No. It was '84. Well TT -- we have a --
19 we have an actual step-drawdown test for TT-23. I think
20 it was in March of '83. So TT-23 was sitting there
21 available. That was part of Tarawa Terrace's routine
22 operation of bringing a new well on-line and probably
23 taking an older well that had reduced yield off of line.

24 And then all of a sudden, when they did the sampling
25 while TT -- there was PCE that showed up in TT-23. So PCE

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1 -- TT-23 never got a chance to be in operation probably
2 for more than a year. But -- and frankly, I don't know
3 how much importance the contribution of TT-23 had to the
4 -- to exposure because it was only operated for such a
5 short period of time.

6 But I will say that it's been on everybody's radar
7 screen as a point of interest, and I do believe that the
8 only way you're really going to understand whatever the
9 contribution was from TT-23, if it remains a major point
10 of interest as it seems to be, would be through a --
11 through numerical simulation.

12 DR. JOHNSON: Well, I think we've had a good
13 discussion and some suggestions as to how the modeling
14 work might be modified. It's certainly for the agency's
15 consideration and final determination. But some
16 interesting ideas were placed on the table, and we would
17 ask that they be seriously considered by the agency.

18 As an aside, I have not forgotten about the public
19 session, and I plan to do that at 3:30. So those of you
20 who wish to speak at 3:30, be prepared to do so. We will
21 need your name, et cetera. To the extent possible, focus
22 on what we're discussing today: the water-modeling issues.
23 But anyway, at 3:30, we will do that.

24 Let's continue on to Question 2, and, again, we can
25 come back to any of these questions. I'm just trying to

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1 get us through these series of significant issues. Number
2 2: Should ATSDR use the same level of detail; i.e.,
3 50-foot cells and expand the groundwater model to include
4 the Holcomb Boulevard and the Hadnot Point areas? If so,
5 what level of increase in effort does the panel envision
6 for this effort? Lenny, please.

7 DR. KONIKOW: Well, a 50-foot grid spacing seems, you
8 know, reasonable, but I think the approach that, you know,
9 I would recommend and probably other people would
10 recommend is do some grid-sensitivity testing. I heard
11 someone mention that this morning. Try a 100-foot cell,
12 and see if there's any difference. Try a 25-foot cell
13 spacing, and see if there's any difference. If it doesn't
14 make any difference, stick with the 100 foot.

15 UNIDENTIFIED SPEAKER: Right.

16 DR. KONIKOW: If it makes a difference, depending on
17 the nature of the difference, you probably want to go to
18 the finer grid spacing. So it's hard to say if 50-foot
19 spacing is the right one without looking at some
20 sensitivity tests. So somewhere along the line -- and,
21 again, this is one of the nice things about a graphical
22 preprocessor based on a GIS-type system is that you can
23 very easily change your grid spacing. And that's one of
24 the things we'd certainly recommend doing.

25 As far as expanding it to the Holcomb Boulevard and

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1 Hadnot Point areas, I think it depends do you want to
2 apply a transport model there or not. Do you want to, you
3 know, look at the -- I mean, you're starting in just the
4 Tarawa Terrace because that's simpler. So if you can't
5 succeed there, then maybe there's no point going to the
6 other systems.

7 MR. FAYE: And that's -- that was the whole idea.

8 DR. KONIKOW: Yeah. So I think you have to kind of
9 see what the results are after a little more time.

10 MR. FAYE: Good. Thank you.

11 DR. JOHNSON: Other comments on this question?
12 Vijay.

13 DR. SINGH: I think you may also want to look at
14 variable grid size. You may want to consider finer grids
15 near the source and coarser away from the source.

16 MR. FAYE: Yeah. That's clearly -- that's clearly
17 something that we intend to do. And as Lenny said, when
18 you're using a GIS conditioner for your input arrays, why,
19 it's really easy to do. It's not a problem, and that's
20 something that we very definitely would look at or intend
21 to look at.

22 DR. JOHNSON: Any sense on what extra level of effort
23 would be required?

24 MR. FAYE: Not a whole lot.

25 DR. JOHNSON: I'm not sure -- I'm not sure that's the

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1 kind of thing a panel is equipped to come to grips with,
2 but I speak only for myself. I haven't a clue as to how
3 efficiently you work and other -- what equipment you have.

4 MR. FAYE: My response was just to the specific
5 notion of changing the grid dimensions. Okay? I mean, I
6 didn't know you were touching on the overall issue.

7 DR. JOHNSON: It's part of the question.

8 MR. MASLIA: Let me just address this. The reason
9 that question came up is looking at the, I guess,
10 experience and expertise and different type of analyses
11 that some of the panel members have been involved, I
12 suppose we were looking at it based on their experience of
13 saying, "Oh, no. That's going to take a completely
14 separate project team. You know, that's going to take
15 another three years, five years, or whatever based on our
16 experience."

17 And that's something -- an input that we need and to
18 discuss with the epidemiologists as whether that increase
19 in effort is warranted for the type of results that we may
20 obtain. It clearly has been referred to on a number of
21 occasions now. If, in fact, we're having some difficulty,
22 although maybe success, in Tarawa Terrace in this level of
23 effort now, expanding that difficulty at least an order of
24 magnitude because of uncertainty and unknown in Hadnot
25 Point and the variety of nonpoint specific sources, that

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1 may be an area that we may say that the level of effort
2 will not warrant the refinement in the answers that we
3 need for Hadnot Point area. And that's really why that
4 was posed, not looking for a specific person number or
5 hour -- labor hours or anything like that.

6 MR. FAYE: Could I say something?

7 MR. MASLIA: Yes.

8 MR. FAYE: With regard to the additional complexity
9 that we're fairly certain that we would see at Hadnot
10 Point, perhaps, an intermediate step or even a final step
11 to simulating various concentrations at a great number of
12 wells with numerous source areas would be analytical,
13 rather than numerical, which would greatly simplify the
14 situation in terms of analysis. But what would also be
15 somewhat limiting in terms of the results that we would
16 provide -- be able to provide for the epidemiological
17 study. But it may be a very useful intermediate step.

18 DR. JOHNSON: Yes.

19 DR. CLARK: The answer -- it seems like the answer to
20 this question somewhat answers the concerns I had on the
21 first question. In effect, what you're doing with Tarawa
22 Terrace, that's basically a pilot study to validate,
23 develop groundwater-transport model; right?

24 MR. FAYE: It's -- I would say it's perhaps a little
25 further than a pilot study. We know that these things

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1 have been done before. There's not a lot of mystery about
2 it. More the issue is, yeah, we can do it, and we can
3 give you an answer, but just how damn good is the answer?
4 Okay?

5 DR. CLARK: And so if you have success at Tarawa
6 Terrace, then the potential for applying it to other areas
7 increases, I suppose, significantly.

8 MR. FAYE: Yes; sure.

9 DR. CLARK: And so that basically is kind of the
10 reason that you're taking that approach on the project.

11 DR. JOHNSON: Yes, please.

12 DR. UBER: Could I just follow up on that real quick?
13 Could you clarify for me: Is the proposal -- I know we're
14 talking about just the groundwater analysis now. But is
15 the proposal to use Tarawa Terrace really, truly as an
16 advanced pilot study but moving it from the groundwater to
17 the water distribution through to the epidemiological
18 conclusions prior to moving significantly or changing
19 directions drastically for some of the other areas?

20 MR. FAYE: That's yours, Ace.

21 MR. MASLIA: That is -- our intent is to hopefully --
22 I don't want to say wrap it up -- but put some finality on
23 our state of knowledge and conclusions we can make from
24 the effort at Tarawa Terrace in terms of the groundwater
25 fate and transport and the distribution side. That is the

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1 -- as we've alluded to, we know we've got one primary
2 well, TT-26. We've got some data gaps in historical or
3 chronology.

4 But as far as the hydrogeologic framework, we've
5 defined that as far as modeling. When I say "boundaries,"
6 not the physical model of the boundaries, but where we
7 should start our timing, stuff like that. We've got --
8 we're getting more well-production records. As I said, we
9 just got some more in the middle eighties to fill in some
10 gaps. So that's pretty much further along. I can't speak
11 as far as the cases and controls. Dr. Bove can probably
12 speak more on that if he thinks it's appropriate to
13 discuss that issue.

14 MR. FAYE: And there's also another major issue
15 implicit in that -- in that question. And that is the
16 actual linkage between the models. The results of the
17 groundwater flow model I used as input into EPANET or some
18 similar thing. And we want that to be as transparent and
19 as fluid as -- no pun intended -- as fluid as possible.
20 We don't want that to be a stop-and-start, really hard-
21 nose mechanical-type of operation. And so there's some
22 issues there to be dealt with in terms of refining that.

23 DR. UBER: So that's good. That actually reinforces
24 the point, perhaps, of making a decision to try to do it
25 all with Tarawa Terrace. It sounds to me like maybe the

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1 team is not quite committed to doing that because there's
2 some, maybe, uncertainty, reasonably, about the time
3 frames of the, you know, getting all the control group
4 together and doing all of that work.

5 But I -- personally, I would be very much in favor of
6 that approach, if it is feasible at all, because I think,
7 you know, well, you always learn from doing it. And I
8 think bringing this -- bringing that study to the end
9 conclusion, even on a first-order basis -- end, meaning to
10 some kind of integration with the epidemiological
11 conclusions -- would be a good thing to add going into the
12 other areas.

13 MR. MASLIA: The other thing, if I might just jump
14 the gun for either this afternoon or tomorrow's
15 presentation on the water-distribution side, I alluded to
16 earlier in my opening remarks that we do have an analysis.
17 Claudia did a very good analysis on building use and
18 building type and, you know, whether it's residential,
19 family housing, industrial, car wash, and so on. And I'll
20 show that later on either tomorrow or this afternoon,
21 depending on the time.

22 But what you will notice is obviously Tarawa Terrace
23 is 90-plus percent family housing. Holcomb Boulevard is
24 90-plus percent family housing with elementary schools and
25 high schools. When you get down to Hadnot Point, it's

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1 just the opposite. It's 90 percent plus industrial and
2 other things and bachelor housing with maybe 5 percent
3 family housing. Would that be about right, Claudia,
4 somewhere around that?

5 MISS VALENZUELA: Yeah.

6 MR. MASLIA: Yeah; about like that. So that's the
7 other -- we haven't gotten into that, but you'll see some
8 maps on that. So that's the other consideration really
9 from our standpoint.

10 DR. WALSKI: When the distribution system
11 measurements for PCE were made in Tarawa Terrace, what was
12 the range of values at the tap?

13 MR. MASLIA: PCE or TCE?

14 DR. WALSKI: PCE at Tarawa Terrace, like, the range.
15 Was it a huge range? Did it show tremendous variability,
16 or was it basically, once you got it, you got it?

17 MR. MASLIA: We've got a map with the chronology on
18 them.

19 MR. FAYE: Yeah.

20 MR. MASLIA: Here. We've got a chronology here.
21 Here we go. Actually --

22 MR. FAYE: The concentrations at the tap were
23 probably somewhat less to greatly less variable than the
24 concentrations that we observed at the wellheads.

25 DR. WALSKI: Because everything gets blended, and

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1 so --

2 MR. FAYE: Right.

3 DR. WALSKI: -- it seems like, basically, once the
4 system gets contaminated water in it, the people get
5 contaminated water, and, you know, the amount that the
6 model is going to tell you is, well, maybe they got 52
7 instead of 54. But the fact is that once the plume hits
8 the wells and they use the wells, everybody got the same
9 thing in that system. That, you know, I'm just
10 questioning how much more you're going to get by really
11 refining the models.

12 MR. FAYE: Don't know; don't know. I can't -- I
13 couldn't -- I know that the concentrations at the
14 wellheads vary by orders of -- by an order of magnitude at
15 least. And I'm not -- I'm not sure that I'd be
16 comfortable in going into detail even about a cause and
17 effect of that. I don't know that. I haven't reasoned
18 that out that well. I just -- that's it. I -- you know,
19 that's the extent of the information.

20 DR. LABOLLE: Particularly with regards to the
21 distribution system model, I think that what's been raised
22 here is quite important. If you're putting in a source
23 and everybody has to drink that water because there's only
24 one source in the system, which is the wastewater
25 treatment plant, at least during a significant portion of

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1 the time, if not all the time in the study period, then
2 how does refining the model increase one's information on
3 exposure?

4 MR. FAYE: Well, for one thing, when we -- when we
5 finally get to the point where we're able to deal with
6 monthly recharge and we have some decent confidence that
7 we're doing a good job there, you're looking at -- you're
8 looking at orders of magnitude change and recharge from
9 month to month. Okay?

10 DR. LABOLLE: My question was with regards to the
11 distribution-system model though.

12 MR. FAYE: Oh, I'm sorry.

13 DR. LABOLLE: But I have one for the groundwater too.

14 MR. MASLIA: Let me -- if we assume that you've got
15 several wells and they're all blended in at the treatment
16 plant and then they go out into the distribution system
17 and are up in the tanks and equally mixed and all that,
18 then your point is everybody gets the same blended
19 concentration of water; no question about that.

20 We found a couple of things, and again, this is
21 probably something we'll get into tomorrow or this
22 afternoon. But we are finding, at least in the storage
23 tanks, that it's not a complete mixed situation. This is
24 based on some field testing that we did this past year.

25 We're not sure if you're seeing last-in/first-out or

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1 a compartmental-type issue in the tanks. We're testing
2 that out, doing some sensitivity runs right now, so that,
3 if you had in one given month one well running more than
4 the other, either contaminated or not contaminated, and
5 pushing that out through the treatment plant and then
6 stored up in the tanks or whatever, you may not
7 necessarily see that water coming out into the
8 distribution, depending what's going on in the mixing in
9 the tanks.

10 DR. LABOLLE: Then in that case then, the study, you
11 know, the detail would then focus on a very restricted
12 portion of the system, that being the tank and one of the
13 sources --

14 MR. MASLIA: Mm-hmm.

15 DR. LABOLLE: -- which wells the sources were coming
16 from?

17 MR. MASLIA: That's correct.

18 DR. LABOLLE: But then the rest of the distribution
19 system, the detail and the level of analysis would have
20 little effect then on exposure. Am I missing something in
21 that?

22 MR. MASLIA: Well, the only thing we're -- or we're
23 trying to understand right now is we're still in the
24 process, at least for present-day, trying to understand
25 exactly how the tanks are mixing. We've instrumented some

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1 tanks, and it's raised some additional questions. And I
2 really can't, at this point, answer: Can we make some
3 either simplifying assumptions or assume, given a certain
4 input from the treatment plant, that this portion of the
5 system received this slug of water or not?

6 I think, perhaps, maybe the panel will see some
7 insights from some of the data, more detail that we'll
8 present either this afternoon or later tomorrow. Those
9 are some good issues to bring up.

10 DR. CLARK: Depending upon the variability on the
11 input side, you could get blending in the system that
12 would cause different levels of exposure to individual
13 households too. So I guess it's those issues that you
14 have to resolve.

15 DR. LABOLLE: Yeah. Particularly if the treatment
16 plant doesn't. You know, the treatment plant is
17 delivering water out into various pipes into the system at
18 that point, then the detail -- I could see the
19 distribution system would become important.

20 MR. FAYE: On the groundwater side, you would have an
21 expectation of variability. We don't know how much.
22 Depending on your rainfall, which would translate -- the
23 way we're looking at recharge now would translate directly
24 to recharge. You would have periods of time when you'd
25 virtually have no recharge, probably extended periods of

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1 time. And then you'd have other times when you would have
2 just an excess of recharge.

3 How this affects the -- would affect the variability
4 of concentrations at the wellhead, we just don't know.
5 And it -- is that the reason of the order of magnitude
6 change in contaminant concentrations at the various wells?
7 We don't know. But we do know that there is a great deal
8 of variability in concentrations at the wellhead, just
9 based on observations.

10 DR. DOUGHERTY: I have one question for -- actually
11 your comment and Eric's. Since you're preparing, planning
12 to perform a fate and transport model --

13 MR. FAYE: Ultimately.

14 DR. DOUGHERTY: -- ultimately. And this is a
15 question about your preliminary thinking, and so it's
16 subject to draft and revision and all these things as the
17 project evolves. But the question is: How do you think
18 you're going to handle the source? How is it going to be
19 represented?

20 MR. FAYE: Well, as Morris said, one thing that we
21 have in the works is to use Dr. Aral's expertise at
22 Georgia Tech. Are you familiar with CXTFIT?

23 DR. DOUGHERTY: Sure.

24 MR. FAYE: Okay. It's kind of a simplistic notion,
25 but, you know, it's the same idea where you would actually

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1 look at your observed concentrations in a "plume" and then
2 be able to compute backwards and estimate a source
3 concentration for a limited period of time relative to
4 those observed conditions.

5 We have data in 1985 that probably -- early 1985,
6 that probably represents, goodness, for want of a better
7 term, routine operating conditions, okay, at the -- at ABC
8 Cleaners. And we're looking at 12,000 micrograms per
9 liter there. The gentleman earlier made the point that
10 there may have been a greatly increased rate of input into
11 the system during Vietnam.

12 And hopefully, hopefully, through the data discovery
13 that Morris was talking about with the tax returns and
14 whatever, we can get something of a handle on that.
15 Obviously, it goes without saying, I mean, the source term
16 is the -- is -- it's not all the eggs in the basket, but
17 it's a good number of them.

18 DR. DOUGHERTY: My question in particular was: Is it
19 going to be treated as a specified concentration, or is
20 there going to be -- or are you anticipating a process
21 model for --

22 MR. FAYE: No.

23 DR. DOUGHERTY: -- some dissolution process?

24 MR. FAYE: I -- that, we haven't thought of yet. My
25 -- right now, my thinking would be basically just a rate

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1 at a -- at some concentration. Okay?

2 DR. DOUGHERTY: Some of mass loadings?

3 MR. FAYE: Yeah; right.

4 DR. JOHNSON: Okay. Let's stop at that point. I
5 think we've -- the panel's given you some excellent advice
6 and some perhaps new directions to consider: grid
7 sensitivity, testing, et cetera, other ideas. Again, we
8 can always come back to any one of these questions.

9 The third question, before we have the questions from
10 the public: Rather than developing three distinct
11 groundwater-flow models, should ATSDR considering --
12 should consider developing one model?

13 DR. CLARK: It sounds like the answer to that has to
14 be no, given the complexity of trying to do that.

15 DR. JOHNSON: The answer is no.

16 UNIDENTIFIED SPEAKERS: It may be later.

17 DR. DOUGHERTY: And then you have the choice of
18 whether you do two and three or whether you expand one and
19 two or incorporate two and three or whether it's a similar
20 approach at that point.

21 DR. LABOLLE: Where does the third one come in?
22 That's actually where I'm confused. We have Tarawa
23 Terrace. We have Hadnot Point. It's my understanding
24 that the community in the middle wasn't receiving much
25 contamination; is that correct?

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1 MR. MASLIA: Actually, correct, unless we find any
2 other information to the contrary. That was probably a
3 rush to write questions down, but I suppose one -- when I
4 was thinking also of three models, one way I was thinking
5 back to my USGS days is where you have an overall model
6 and -- one model for the whole area, which may be a
7 coarser grid, or define some boundary flows or whatever
8 and then you have the two refined areas.

9 But from what our discussion this morning and this
10 afternoon is going is, I believe, we'll be doing good to
11 get at narrowing uncertainty or addressing uncertainty
12 with the Tarawa Terrace area. I mean, I think there's
13 some issues there that may, in fact, tell us, you know,
14 don't go down the direction of the numerical model to
15 Hadnot Point.

16 MR. FAYE: Accept no.

17 MR. MASLIA: What?

18 MR. FAYE: Accept no.

19 DR. JOHNSON: Okay. I think you got a clear
20 answer on that one. We need to take about a five-
21 minute pause or so, so that our recorder can
22 recalibrate her recording equipment. And then after
23 that, we look forward to comments from the public,
24 and then we'll resume with the rest of the questions.
25 So take a brief break of about five to ten minutes.

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1 (Whereupon, a recess of approximately seven minutes
2 was taken.)

3 DR. JOHNSON: We are at the point where we would be
4 pleased to hear comments or observations from the public,
5 and please come forward to the dais. Tell us your name.
6 To the extent possible, we would ask that you summarize
7 the significant points that you wish us to hear.

8 MR. ENSMINGER: Good afternoon.

9 DR. JOHNSON: Good afternoon.

10 MR. ENSMINGER: My name's Jerry Ensminger. I told
11 you who I was earlier. I lost a child due to this
12 contamination, and I have been deeply involved in this
13 since 1997. Likewise, a retired major, Thomas Townsend,
14 who I work very closely with and have worked with him for
15 many years on this, and this following statement is a --
16 and questions is a combined effort between Mr. Townsend
17 and I. And without further ado:

18 Construction of the Tarawa Terrace housing area
19 commenced in 1952 and, at that time, was owned by Spangler
20 Real Estate Company. My family lived at Tarawa Terrace,
21 3442 Hagaru Drive, from January 1955 to May of 1956, as
22 cited in CLW-2982. In 1958, TT-26, the first of eight
23 water supply wells, was constructed in Tarawa Terrace.
24 The year 1961 saw the construction of an additional three
25 wells: TT-52, 53, 54. Wells 27, 31, and 25 were

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1 constructed in 1972, 1973, and 1980, respectively.

2 Well 23 was constructed in 1984. However, this well
3 was never put on-line or in -- never put into production,
4 as PCE was discovered immediately following construction.
5 This well is also described as TT-NEW WELL in the same
6 documents.

7 I provided you with a list of the supporting
8 documents that support this statement. TT tap water was
9 tested 27 May 1982 from seven wells less TT-23. PCE was
10 found at 80 parts per billion and on 27 and 28 July '82
11 retested with PCE at 76 parts per billion, 82 parts per
12 billion, and 104 parts per billion. TT wells were sampled
13 in July of 1984; TT-23 at 37 parts per billion; TT-25,
14 trace amounts; and TT-26 had 3.9 parts per billion. No
15 TCE was detected.

16 Tap water in Tarawa Terrace was tested again on 5
17 February of 1985. The analysis indicated PCE at 80 parts
18 per billion, TCE at 8.1 parts per billion, and DCE at 12
19 parts per billion. All Tarawa Terrace wells were
20 disconnected from the water-distribution system on 8
21 February 1985, and Wells TT-23 and 26 were closed.

22 Four days later, on 12 February 1985, and again on 19
23 February of 1985, water from the TT system was tested and
24 determined to contain no VOCs. Unable to meet the
25 increasing water demand without these wells, the Tarawa

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1 Terrace water-distribution system was supposedly closed.
2 None of the TT well data, installation or operational
3 date, and contamination testing results can be confirmed
4 by this reporter since Marine Corps base Camp Lejeune has
5 not provided same after many FOIA requests submitted; no
6 responsive documents.

7 Question: If the TT water-distribution system was
8 closed in February of 1985, where did the potable water to
9 support some 1843 housing units and commercial
10 establishments come from to fill that void?

11 DR. POMMERENK: Can I answer that question? I
12 believe, in 1984, there was a pipeline constructed from
13 the Holcomb Boulevard treatment plant, and that pipeline
14 connected directly to the raw-water tank. So you received
15 treated water from the Holcomb Boulevard area.

16 MR. ENSMINGER: In 1984?

17 DR. POMMERENK: I believe so. I would have to check
18 the numbers, but that's the approximate time frame that I
19 recall from the...

20 DR. JOHNSON: Come to a microphone, please.

21 MR. FAYE: The records that I'm familiar with that
22 we've obtained from Camp Lejeune and other sources
23 indicate that only Wells TT-23 and TT-26 were taken
24 off-line in February of '85, that the other wells in the
25 system at that time continued to operate, probably,

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1 through all of '85. We know for sure that the water-
2 treatment plant was operating and processing water at
3 least up to March of 19 -- 1987. There's a real question
4 about 1986. My gut feeling is that the ex-TT-23 and
5 ex-TT-26 at the Tarawa Terrace wells probably operated all
6 through 1986 as well.

7 Just with some corrections here to what this
8 gentleman has said about TT-26, we have copies of notes
9 from Mr. - a Mr. R. E. Peterson, who was an employee of
10 the Lejeune facilities at that time in May of 1951, where
11 he describes the construction and -- the drilling and
12 construction of Well TT-26, TT-27 and 2-A. At that time,
13 they were called Number 1 and Number 2-A and 2-B; 2-B was
14 TT-27. So that's just a few comments there.

15 Thank you.

16 MR. ENSMINGER: And if you would, in your supporting
17 documentation that I've provided you, CLW No. 1129 through
18 1131 was an action brief prepared by the Chief of Staff of
19 Marine Corps base and is dated 1 March of 1985. That's
20 Colonel M. G. Lilley, who I have spoken with personally.
21 And he gave a -- his action brief was -- the subject was
22 "Alternatives for Providing Water to Tarawa Terrace Area."
23 So if a pipeline was installed in '84, why are they having
24 an action brief in '85?

25 DR. POMMERENK: That's a good question. I was just

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1 aware of the construction date of that pipeline.

2 Obviously, my conclusion was that there was water supplied
3 which may have not been started at that point.

4 MR. ENSMINGER: Well, while we're speaking about
5 that, the next part of the question: Action brief for the
6 commanding general of 1 March 1985, which I just referred
7 you to, had seven alternatives, ranging from hauling water
8 in tankers or construct a new 8-inch line from the Holcomb
9 Boulevard water-treatment plant, which was being upgraded
10 from 2 million gallons to a 5 million gallon per day
11 capacity, or turn on the contaminated wells that have been
12 shut down if required to maintain adequate water levels;
13 estimated cost: none. New water -- new line was
14 installed, temporary auxiliary line, in June of 1985 from
15 Holcomb Boulevard water-treatment plant to the TT
16 distribution center.

17 Question: Definitive criteria for describing --
18 describing operation of well status at Marine Corps base
19 is confusing by using active, inactive, closed, abandoned,
20 on-line, off-line, et cetera. CLW-2963, which you have
21 there in your references, wells are taken off-line or out
22 of service for short periods for maintenance; pumps are
23 replaced; screens are cleaned; new data loggers installed.

24 Too many reports from Marine Corps base will show X-
25 well closed in 1965, then in operation again in 1967, shut

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1 down in 1968, operational in 1969. Having run water
2 systems, I consider a sequential pattern: One, electricity
3 turned off, pump in well, et cetera, et cetera.

4 Wells are either on-line or off-line; active or
5 inactive; temporary nonfunctioning for service or long-
6 term nonfunctioning, which can show as permanent non-
7 serviceable; to be abandoned. Is there a sanctioned set
8 of rules -- state, federal, American Water Works -- that
9 can demystify this melange of terms, which are chaotic, at
10 Marine Corps base?

11 DR. JOHNSON: Does anyone know?

12 (No audible response)

13 DR. WALSKI: Well, unfortunately, I think the
14 terminology is whatever the person who wrote it down felt
15 like writing that day. That's unfortunately the case.

16 MR. ENSMINGER: And another thing is, especially over
17 in the Hadnot Point system, when you look at the Marine
18 Corps' chronology, you would find wells that were taken
19 off-line for contamination. And later on in the events,
20 you'll see that it was taken off-line again for
21 contamination, which tells me it was back on-line.

22 DR. POMMERENK: I guess the only state regulation,
23 current state regulation, in North Carolina that I recall
24 that would relate to that is that you have to, I think,
25 file a record of abandoning a well if you take it

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1 completely out of service. But otherwise, I wouldn't know
2 of any, you know, regulatory issues regarding this
3 terminology.

4 The other issue that you just addressed, and I'm just
5 -- one problem could be -- and we have observed it in Camp
6 Lejeune -- that sometimes a new well is drilled and it
7 receives the same well number as the old well. That may
8 have not happened in Tarawa Terrace, but I'm just throwing
9 this out as a thought.

10 MR. ENSMINGER: You said at Lejeune there were wells
11 -- new wells that were drilled that had the same number as
12 the old one?

13 DR. POMMERENK: Yes. This has happened.

14 MR. ENSMINGER: Where?

15 DR. POMMERENK: I can't cite the exact numbers.

16 MR. ENSMINGER: Which well numbers?

17 MR. FAYE: Peter, I think, you know, your statement
18 may be only partially correct. What happens in the --
19 when the contract -- at least as far as the documents that
20 we have, when Lejeune turns loose of a contract, either
21 for bidding or whatever, they'll -- there's a note on that
22 "Well Replaced." Okay? And the old well number goes in
23 there because there is no new well yet. Okay?

24 And so what happens then is the driller comes along
25 and creates that suite of documents, like the drillers'

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1 log or Elog or whatever. And they'll put in new HP-645 or
2 something like that or new HP-647, which is what you're
3 referring to. But that number, in my experience -- and
4 I've looked through dozens of these records -- that number
5 doesn't actually stay in the system. Okay? That new
6 something or other gets a new number. Okay? Ultimately,
7 as far as I can tell from the Camp Lejeune records, that
8 well gets a new number. It doesn't -- it doesn't stay the
9 old number very long.

10 DR. POMMERENK: Okay.

11 MR. FAYE: Okay?

12 DR. JOHNSON: Please proceed.

13 MR. ENSMINGER: When were the wells or the eight
14 wells at Tarawa Terrace taken 100 percent out of service
15 and abandoned? When were they taken out? When were they
16 absolutely abandoned, closed, pumps pulled?

17 MR. FAYE: May I address that?

18 DR. JOHNSON: Would you stay up there, please.

19 MR. FAYE: I think that's a really critical,
20 critical, critical question. The only -- what I can say
21 with relative certainty is that TT-26 and TT-23 were
22 removed completely from service in February of 1985. We
23 have records in January and February and March of 1987
24 that indicate that the Tarawa Terrace -- and also, I think
25 if you look at the plant capacities, you would really have

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1 some bit of difficulty believing that Holcomb Boulevard
2 could supply all of its needs, its original service area
3 needs, and Tarawa Terrace needs during 1985 and 1986.
4 Okay?

5 Maybe it could, but I think there would be some real
6 serious operational difficulties. Unfortunately, the
7 records that we have, like, for example, for monthly
8 discharge -- monthly water-treatment plant operational
9 records that give flows for a particular month that are
10 exceedingly complete from 1980 to 1984 and then again
11 exceedingly complete from 1987 to 1989. For some reason,
12 these records for 1985 and '86 have just up and
13 disappeared. No one seems to know what happened to them,
14 but I believe they certainly existed.

15 My own feeling, as I expressed a few minutes ago, is
16 that ex-TT-23 and ex-TT-26, the remaining wells at Tarawa
17 Terrace that were operational in 1984, probably continued
18 -- most of them -- in operation in 1985 and 1986. But we
19 really -- and we do know that something was going on at
20 the WTP in early 1987. But we really cannot say what was
21 going on with the wells, what the well operations were in
22 '85 or '86. The records for that period of time have just
23 fallen into a black hole somewhere.

24 DR. JOHNSON: Okay. Let's continue. I'm going to
25 ask ATSDR to provide answers expressly to each of these

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1 questions. I don't think that's an imposition on the
2 agency. To the extent that we can provide some feedback
3 today, we will try to do that. But if you're looking for
4 complete, satisfying answers, this isn't -- this isn't the
5 forum for that. But please continue.

6 MR. ENSMINGER: Well, in response to what Mr. Faye
7 just said, you have there in your package CLW-1914, which
8 is a handwritten memorandum and it's dated in 1991. And
9 it stated in this handwritten memorandum that TT-23,
10 TT-25, and 26 has pump, will run. However, the well was
11 closed. I mean, they weren't 100 percent decapitated.

12 MR. FAYE: That's a note from, I believe, Daniel
13 Sharp, from the facilities branch at Camp Lejeune. And
14 that was written in a -- in specific -- as a specific
15 response -- as a request from either EPA or Weston
16 Engineers as they were preparing the Operational Unit 1
17 project to study the contamination caused by ABC Cleaners.
18 That was a note to Camp Lejeune and a response, asking
19 which wells were operational so that they could prepare to
20 sample them.

21 MR. ENSMINGER: Well, there are means of pulling the
22 pumps and putting a -- and still taking samples.

23 UNIDENTIFIED SPEAKER: But it may be more convenient.

24 MR. ENSMINGER: Okay. All right. If the TT well
25 fields were not incapacitated in 1985 and an auxiliary

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1 line to Tarawa Terrace, back and forth from Tarawa Terrace
2 to Holcomb Boulevard, was in place in June of 1985, how do
3 we know if Holcomb Boulevard water-treatment plant did not
4 receive raw water from the Tarawa Terrace well fields?

5 MR. FAYE: We don't, and we actually have just the
6 opposite information, a report from Geophex -- was it
7 1991, Morris? There is a -- there is a consultant's
8 report that we have that we've recently referenced from a
9 firm called Geophex out of Raleigh, North Carolina, that
10 indicates just what Mr. Ensminger has said, that indeed,
11 perhaps in 1989, the Tarawa Terrace wells were used to
12 supplement the water supply to the Holcomb Boulevard
13 water-treatment plant and perhaps for even an extended
14 period of time in that -- within that year or maybe
15 several years.

16 DR. DOUGHERTY: Did you say '89?

17 MR. FAYE: Yeah.

18 DR. WALSKI: But wouldn't they have to construct
19 another line to go across, then, a raw-water line because
20 you can't send the raw water over and treated water back
21 in the same pipes. So they had to put in another line, so
22 there'd be some record of that.

23 MR. FAYE: Yeah. One of those -- the report
24 continues to say that whatever those operations were, Tom,
25 that they ended when the -- when a freeze occurred and the

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1 pipe collapsed into Northeast Creek. So whatever was
2 happening there, it ended when the pipe collapsed. Okay?
3 But I agree with you, and perhaps, there were dual pipes
4 there. But we don't have the details.

5 MR. MASLIA: Let me just, if I may, qualify that
6 again in terms of data discovery and all that. We just
7 came across this report, actually, a couple of weeks ago,
8 maybe less than that. It's a report that's dated 199 --
9 March of 1991. And on page 23 it makes the specific --
10 apparently the author of the report, who we're trying to
11 find out still who the author is, makes the statement
12 going over historical issues with different well fields,
13 and it talks about the Tarawa Terrace well field.

14 And it says two years ago, which would make it '89,
15 that the Tarawa Terrace wells supplied Holcomb Boulevard
16 with water. That's almost a verbatim quote. I've got the
17 report with me. I have called the Geophex office in
18 Raleigh. They are no longer doing environmental report,
19 and I'm on my third contact, trying to actually pinpoint -
20 - if I can pinpoint the author of the report, as well as
21 we've asked -- we do have a contract number, Camp Lejeune
22 contract number, for that particular report. And we have
23 asked and I think the folks from Camp Lejeune are
24 preparing some documents for us on the entire contract
25 that generated that report. So we may find out more

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1 details, but that's what we have that's come to our
2 attention within the last couple of weeks.

3 MR. ENSMINGER: If you'll take a look at the 1 March
4 1985 action brief by the Chief of Staff, Colonel Lilley,
5 go to the last page, which is 1131. Please note under
6 advantages, Item No. 5: Potential future use to return raw
7 water from Tarawa Terrace wells. And I'd like you to look
8 at Number 2 as well: Availability of water. Can draw from
9 Holcomb Boulevard and Hadnot Point system, which leads me
10 to believe that that interconnecting valve between the
11 Holcomb Boulevard system and the Hadnot Point system was
12 being opened, just by that statement in Item No. 2.

13 DR. JOHNSON: Any reaction, Bob or Morris?

14 MR. FAYE: That could easily be a --

15 MR. MASLIA: I'll only address one of the issues that
16 has been brought to our attention previously, and this is
17 by a different -- a congressionally mandated panel that
18 occurred what? In February, Frank? Yeah, in February.

19 And we were repeatedly -- I was repeatedly asked the
20 question: Would we and could we model the interconnection?
21 Because, again, the understanding or the statements have
22 been made previous to our investigation that the
23 interconnection was only for emergency purposes, meaning,
24 you know, neither short supply and by definition emergency
25 -- and we've had this discussion with the present-day

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1 operators of Camp Lejeune -- would be, you know, a day --
2 maybe a day or two if either something broke or needed
3 extra supply of water.

4 That panel specifically wanted to know if we could
5 model, you know, several weeks to several months at a time
6 of interconnection on that. And my answer to them, just
7 to complete the answer, would be that's where we would
8 need distribution-system models to model that
9 interconnection.

10 DR. CLARK: It sounds like Tom's point --

11 COURT REPORTER: Microphone, please.

12 DR. JOHNSON: Use the microphone, please.

13 DR. CLARK: I'm sorry. Could we turn -- it sounds
14 like this pipe was designed to do both things:
15 potentially, to return raw water from Tarawa Terrace as
16 well as provide treated water from Holcomb Boulevard and
17 Hadnot, which is very unusual to do that.

18 MR. FAYE: Don't forget now, you're dealing with two
19 pipes, okay, one connecting Tarawa Terrace and Holcomb
20 Boulevard and the other connecting Holcomb Boulevard and
21 Hadnot Point.

22 DR. CLARK: Yeah. But this talks out -- oh, I'm
23 sorry. Yeah. This talks about one pipe: construct 8-inch
24 line from Brewster Boulevard to Tarawa Terrace. And then
25 it has advantages, and I assume that refers to the --

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1 MR. FAYE: That's --

2 DR. CLARK: -- 8-inch line.

3 MR. FAYE: That's the one from -- that's the one that
4 apparently froze up and fell into Northeast Creek.

5 DR. CLARK: Okay.

6 MR. FAYE: If they actually built it, which we don't
7 know.

8 DR. CLARK: But they're talking about a potential use
9 of both supplying raw water as well as --

10 MR. FAYE: That refers to what Tom was talking about.

11 DR. CLARK: That was Tom's point.

12 COURT REPORTER: You need to be at the microphone.

13 UNIDENTIFIED SPEAKER: Sorry.

14 DR. JOHNSON: Okay. Shall we move along?

15 MR. ENSMINGER: All right. How do historical water-
16 system operations, assessment, monitoring, treating, and
17 distribution at Camp Lejeune relate to systems of
18 comparable size of population served during the same
19 general time frame from 1950 to 1985 in the United States'
20 civilian world? In other words, how does -- did the
21 operation of Camp Lejeune and presently how does it stack
22 up against its civilian counterparts?

23 MR. MASLIA: Could I give you a brief answer now, and
24 then, since we haven't got into the distribution side of

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1 things, give you a more detailed answer tomorrow? Because
2 I do want to answer that, so -- but I didn't want to go
3 off on a --

4 MR. ENSMINGER: No.

5 MR. MASLIA: -- tangent right now, if that's okay
6 with the Chair.

7 Briefly, based on our experience, it's -- and I'm
8 talking about Camp Lejeune, not other military
9 installations, but it's night and day. There's almost
10 basically an intent to make it demand independent; in
11 other words, so they maintain constant pressure, constant
12 level in the tanks.

13 They don't empty the tanks out, as opposed to, say,
14 our work where we saw in Dover Township where there's more
15 of a sinusoidal, a filling of a tank during periods of low
16 demand, you know, midnight through four a.m. and then
17 using that supply of water in the tanks and draining it
18 out as people take showers or restaurants come on.

19 At Camp Lejeune -- and I'll admit our understanding
20 still is not complete as total operation -- even for
21 present day, we still have questions. They basically
22 almost maintain a constant pressure, maintain a constant
23 level in the tanks with the exception of one controlling
24 tank per service area. And based on the water level in
25 that controlling tank, which, based on our present-day

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1 information, may only fluctuate from a -- from half a foot
2 to maybe 6 feet at most. It's in a paper we prepared.
3 That's the maximum fluctuation we have -- we have seen
4 based on data for present day.

5 Then trigger high-lift pumps to turn on, say, at
6 Tarawa Terrace to push water through the system. So it is
7 a totally different way of operating, and that's one of
8 the lacking pieces of information is specific diurnal
9 demand. You know, the military personnel, enlisted
10 people, you know, may get up at four or three a.m., and
11 that's when, maybe, your maximum use may be. And then it
12 may trail off six, seven a.m.; whereas in a more urban
13 setting, like Dover Township, you may not see a peak in
14 demand until eight -- seven or eight o'clock in the
15 morning. And then it levels off, and then another peak at
16 six p.m. when people come home. And we're still trying to
17 understand it, but typically it's a vastly different way
18 of operating.

19 DR. CLARK: But they do -- they do meet the
20 requirements of the Safe Drinking Water Act. I think
21 that's a commitment on the part of the military to do
22 that.

23 MR. MASLIA: Oh, I wasn't referring to Safe Drinking
24 Water Act.

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1 DR. CLARK: But in terms of treating water, they meet
2 the requirements of the Safe Drinking Water Act.

3 MR. MASLIA: Right.

4 DR. WALSKI: Yeah. I wouldn't say "night and day"
5 either. I mean, there's a wide range in the way systems
6 are operated around the country, and they're somewhere in
7 the band. You know, they're more conservative though.
8 From what I've been reading here, they're more
9 conservative. Like, they try to keep raw water in storage
10 for fires and emergencies than the average system, which
11 allows more fluctuation.

12 MR. MASLIA: Yes.

13 DR. WALSKI: But it's -- so they're a little more on
14 that side of the curve. But there's a wide range of
15 operations. If you go -- every time I say I've seen it
16 all, I go to the next water system. I see something
17 totally different.

18 DR. CLARK: That includes civilian water systems
19 too; right?

20 DR. WALSKI: Yeah; civilian and military.

21 MR. FAYE: I don't -- I don't mean to belabor the
22 situation, but it is really important. Going back to the
23 use of the wells at Tarawa Terrace during 1985 and '86, we
24 do know that from Naval records that water samples,
25 specifically to identify any contaminants, were collected

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1 at the water-treatment plant at Tarawa Terrace weekly from
2 March 1986 to March 1987, which certainly lends [sic] me
3 to believe that -- that the wells were operating during
4 that period.

5 And monthly samples were collected at TT-25 during
6 that same period, so there was this continuing concern on
7 the -- and these -- this sampling program was recommended
8 by North Carolina DEM and, I believe, implemented by the
9 Navy, by the Marine Corps.

10 So it just seems rather incongruous, if the wells
11 were not operating and if there was still a not a concern
12 about contamination, that none of this sampling program
13 would have been implemented. And that's the main reason
14 that I believe that the Tarawa Terrace supply Wells
15 ex-TT-23 and ex-TT-26 were operating during 1985 and 1986.

16 MR. ENSMINGER: I know that flow meters have been
17 installed during the conduct of this study. It's been
18 published in the newspapers down at Camp Lejeune. What
19 results can be made public at this time, and do they -- do
20 they match your expectations?

21 MR. MASLIA: Again, we'll get into the specifics this
22 afternoon and tomorrow, but basically, flow meters were
23 recommended -- or requested to be installed by ATSDR
24 because we could not just, based on system records

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1 available to us, get a handle on flow to different areas
2 and trying to establish a diurnal and demand pattern.

3 We located 16 areas -- or 16 points, not areas, 16
4 points where we wanted the flow meters installed. This
5 discussion took place initially with representatives from
6 environmental management division from headquarters,
7 Marine Corps and Camp Lejeune staff in July 28th -- on a
8 July 28th meeting at Camp Lejeune. And headquarters said
9 to proceed with that.

10 As of -- in January, towards the end of January, all
11 the flow meters were installed. It was ATSDR's technical
12 staff, meaning myself and my staff, that a performance-
13 based contract be used to install those; that is, install
14 one and see any issues that may arise with it, how useful
15 it may be. And then proceed to the next one or not
16 proceed, as the case may be.

17 We were in a position that to let a contract of that
18 size -- for ATSDR to let a contract would have required us
19 to, at the minimum, advertise in the *Business Commerce*
20 *Daily*, and you would have seen that taking six months or
21 longer -- eight months. So at the time, it was decided
22 that the Marine Corps would handle the procurement.

23 Apparently, they had a contract in place that would
24 not require such a long time to get the flow meters
25 installed for procurement. That was already in place,

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1 whereas ATSDR would've had to advertise to the world
2 basically on a size of that, 16 meters -- a contract
3 containing 16 meters.

4 So that's why. The Marine Corps offered, and we
5 accepted their offer for them to do the procurement and
6 installation. So we were in the recommendation stage. We
7 did recommend that it be performance based. All 16 were
8 purchased, and all 16 were installed.

9 As of this past March, while they are operating, they
10 are not calibrated. And we're still working on that. We
11 have submitted a report, a detailed report, on every flow
12 meter on what needs to be done to calibrate the flow
13 meters so we can get reliable information. So the short
14 answer to your question is: We have not obtained any
15 reliable or useful information to date from the flow
16 meters.

17 MR. ENSMINGER: What's the holdup with the
18 calibration?

19 MR. MASLIA: Some technical issues. Number one, in
20 the calibration process, certain valves have to be shut
21 off to zero the meters out. And on the other side is
22 ATSDR not having -- or I not having staff to actually --
23 as I alluded to, we don't have a field office there. So
24 when questions need to be answered, we are not on site to
25 specifically direct the work to do that.

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1 We are not on site there full-time, and so it's a
2 combination of installing field equipment and so us making
3 trips back and forth. We have been told on a number of
4 occasions that the flow meters have been calibrated. We
5 have made trips up there, and when we try to QAQC them,
6 they're not calibrated.

7 DR. JOHNSON: Let me digress and ask if anyone else
8 from the public plans to make a statement.

9 (No audible response)

10 DR. JOHNSON: Seeing no hands raised, please,
11 continue.

12 MR. ENSMINGER: Historical documentation: pumping
13 records as to quantity, quality, distribution-system
14 problems, well-field problems, infrastructure data on well
15 construction, depth output, locations are by necessity to
16 be furnished by the environmental management division of
17 Marine Corps base Camp Lejeune or by their utility
18 section.

19 Has ATSDR received all the materials it has specified
20 that it would require? And if not, what is the
21 explanation? And has ATSDR brought this matter of lack of
22 cooperation to a -- to the attention of anybody else, such
23 as headquarters of the Marine Corps?

24 MR. FAYE: Well, first of all, let's not make the
25 presumption that there's been a lack of cooperation

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1 because I wouldn't go that far. In a number of areas that
2 are very critical, the Marine Corps has been extremely
3 forthcoming and provided very useful information.

4 As far as the well data are concerned, between the
5 information that we have obtained from the Marine Corps
6 and from the U.S. Geological Survey, who, as I mentioned
7 earlier, did two very comprehensive studies there in the
8 late 1980s, we've got a -- we have -- ATSDR has a very --
9 what I would say a very substantially complete record of
10 all of the wells that have been drilled at either Holcomb
11 Boulevard, Hadnot Point, or Tarawa Terrace, or Camp
12 Johnson, starting back in the early 1940s up to about 1987
13 or '88.

14 We do have additional -- well, several additional
15 well records that have been completed at Camp Lejeune;
16 very extensive records with contract numbers and whatever.
17 Now, we have asked Camp Lejeune if -- we've asked them for
18 some location data and other information about these wells
19 that they've not provided yet. But in that regard, you
20 know, that's only a half a dozen records.

21 Another thing I'd like to point out is the records
22 provided to us relative to RI/FS studies and underground-
23 storage tank removal studies at Tarawa Terrace have been
24 very, very useful. And as far as I can tell, the records

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1 provided by Camp Lejeune, which are in the dozens --
2 dozens of reports, are complete.

3 We would really like to have a similar contribution
4 of those RI/FS and underground-storage tank removal
5 reports, et cetera, from the -- for the Holcomb Boulevard
6 area and the Hadnot Point area, and we've asked for that.
7 But that's a large volume of information, and we haven't
8 received it yet. But we hope we will in the future. In
9 fact, very soon, I hope.

10 But as far as the well data are concerned,
11 specifically, I think we have a very substantially
12 complete record of what's available, of the data
13 available.

14 MR. ENSMINGER: Listening earlier --

15 MR. FAYE: No. That doesn't -- that includes the
16 well data in terms of, like, construction. That does not
17 include operational information.

18 MR. ENSMINGER: Yeah. That's what I was just going
19 to ask because earlier you stated that you didn't have
20 near the information for, say, Hadnot Point that you did
21 for Tarawa Terrace. I mean, that's the same organization.
22 The same outfit that's running Tarawa Terrace is running
23 Hadnot Point. So if they had good records for Tarawa
24 Terrace, they should have good records for Hadnot Point
25 water system as well.

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1 MR. ASHTON: I'd like to --

2 COURT REPORTER: I need you to get to a microphone.
3 Please identify yourself.

4 MR. ASHTON: I'm Brynn Ashton, and I've been really
5 spearheading the effort from our environmental management
6 division to provide the information. And in all cases, I
7 think we've given -- we tried to provide you whatever we
8 have. Recordkeeping is not consistent across Camp
9 Lejeune. And there's been times where we might have some
10 information in certain plants. We might not have as good
11 information or organized as well in other plants.

12 So what we've tried to do is provide whatever we
13 have, and, you know, the Commandant has made it very clear
14 to us that we shall provide you with whatever information
15 we have in as timely a manner as possible. If, at any
16 time, it appears that we are not providing that
17 information, it's just because it's not available or it's
18 not organized. Or in some cases, we've scoured our
19 records. We've found records that we did not realize were
20 in existence. So in summary, we have the charge, we have
21 the mission, to provide as much information as you ask in
22 as timely a manner as possible.

23 MR. ENSMINGER: I have another question for you while
24 you're up here. If that's the case, the plant account
25 records --

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1 MR. ASHTON: Yes.

2 MR. ENSMINGER: -- I know that EMD has a listing of
3 all and has pulled all the well data and all of the water-
4 system data off the plant account records, all the
5 historical data. I know it exists because I used to call
6 Rick Raines and get certain information from him when he
7 was here. Why hasn't that been provided to them?

8 MR. ASHTON: Now, I think -- I think they will verify
9 that we've provided them what we have. The plant account
10 data is very minimal. It -- what it has is it has square
11 footage of the buildings. It has years of construction.
12 It has, you know, numbers of the facilities. It has
13 certain category codes, and that -- you now, that is
14 available through our plant account organization.

15 MR. ENSMINGER: I know.

16 MR. ASHTON: Some of it was not computerized. Some
17 of it's in hard copy.

18 MR. ENSMINGER: I know.

19 MR. ASHTON: I think we've provided you what you've
20 asked for on the plant account. And we've -- we actually
21 have a point of contact that runs that section, and what
22 we've done is we've provided the point of contact so you
23 can get whatever information they have.

24 Again, you know, I'm not always proud of their -- the
25 level of recordkeeping that we've done in the past. You

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1 know, we've already alluded to some gaps in the knowledge.
2 Whatever we have, whatever we can locate, we provide.
3 And, you know, that's our charter. That's our charge from
4 the highest level, from the Commandant, is that we be
5 fully cooperative, that we provide whatever information we
6 have. And we're routinely -- we're going through records
7 as we speak. We've got volumes of records.

8 Morris will verify to the facts that we have this
9 vault with, probably, 70,000 different drawings in it.
10 And the vault dates back from the forties because,
11 for example, Tarawa Terrace was built by a private
12 contractor --

13 MR. ENSMINGER: Mm-hmm.

14 MR. ASHTON: -- the records are very spotty because
15 we -- they weren't government records when the development
16 was initially constructed. The air station, for example
17 -- this isn't part of this study. But, you know, we had
18 virtually no construction drawings from the early fifties
19 from the air station. It was just discarded by somebody.
20 That's the unfortunate environment that we're working
21 with. But the one thing that, I guess, I'm here to say is
22 that whatever support we can provide, whatever information
23 we can provide, we try to provide that as soon as -- in as
24 timely a manner as possible.

25 MR. ENSMINGER: Thank you.

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1 DR. JOHNSON: Well, thank you for your comments. Do
2 you have one more question, Mr. Ensminger?

3 MR. ENSMINGER: No. I have some -- I have some
4 statements. The reason I am a bit skeptical of the Marine
5 Corps or their personnel, as far as their involvement in
6 this thing -- and you have to admit, Camp Lejeune, that --
7 or the people that represent Camp Lejeune now, today, what
8 was done in the past at Lejeune regarding this situation,
9 there's -- there have been some real atrocities committed
10 down there by some people that provided ATSDR with
11 incorrect water-system data, purposely. And when they
12 were told to correct it, they did not do it.

13 And there was a repeated request by headquarters
14 Marine Corps for you to correct it -- or not you, but your
15 predecessors: Mr. Neil Paul to be exact. And he did
16 nothing. And ATSDR went from 1993 to 2003 under the
17 assumption that the Holcomb Boulevard water system
18 provided water for all those housing areas on the main
19 part of the base for the entire study period, which was
20 '68 through '85 when, in fact, Hadnot Point provided that
21 water up until 1973, August of '73. And that's by
22 statement from Carl Baker from the plant account records.

23 So can you understand my skepticism? And you've got
24 to understand that I lost a child. And I wish -- there's
25 no way that I can relay to you what I feel and what my

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1 daughter went through. And damn it, I want to know, and
2 there's a lot of other people out there that want to know
3 what happened to their kids. I want to know why my
4 daughter went through the hell she went through. And if
5 there's anybody that's withholding information or not
6 providing correct information, I swear to God, if I find
7 out about it, I'll do everything that is possible to make
8 sure that they are dealt with.

9 DR. JOHNSON: We appreciate your comments, and we
10 offer, certainly, our condolences in the loss of a child.
11 We cannot fully appreciate your feelings, but we certainly
12 commiserate with you and offer you our sympathies.

13 I have asked your comments and those from Mr.
14 Townsend might be made part of this public meeting's
15 record. I have suggested, Dr. Cibulas, that the agency
16 provide a response to what are serious and important
17 questions. And I hope that you feel that you've had a
18 fair hearing and response to your questions today.

19 MR. ENSMINGER: Well, we'll see by the end of
20 tomorrow.

21 DR. JOHNSON: Okay.

22 MR. ENSMINGER: Thank you.

23 DR. JOHNSON: Thank you again. I'd like to return to
24 these eight questions and ask first of all, Mr. Maslia,
25 we've got four through eight. Is there any priority here

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1 in these -- priority of importance in these questions that
2 remain?

3 MR. MASLIA: Okay. Let me reorient myself here; not
4 really. They're of equal importance.

5 DR. JOHNSON: Okay. Let's turn to Question 4:
6 Should ATSDR consider using a parameter estimation
7 approach to assess parameter sensitivity? And I suggest
8 that you -- that we ignore the second part of that
9 question: when such a process should begin. Anyone want
10 to take a bite on parameter estimation? Eric.

11 DR. LABOLLE: Are we referring to the distribution
12 system model or the groundwater model at this point?

13 DR. JOHNSON: Groundwater.

14 MR. MASLIA: Groundwater.

15 DR. LABOLLE: Well, my primary concern would be with
16 dealing with the uncertainty and variability in the
17 subsurface with regards to parameter estimation. At this
18 point in time, there is some preliminary characterization
19 done and a model constructed. And the construction of the
20 model -- and I think I voiced some of this in my
21 premeeting comments -- kind of constrains one's
22 characterization of the subsurface, which is considerably
23 more variable. And the uncertainty in that is great. We
24 have samples at locations, wells, borings, and such, but

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1 no information between other than what we know of the
2 geology.

3 And so the parameter estimation that you do is going
4 to allow you to vary these parameters within the cells
5 based upon the constraints of the model. And my concern
6 -- not -- that's not a bad idea, but my concern would be
7 that the model response is still constrained by the
8 characterization that's in place and that there
9 potentially be, in addition to, depending on the role of
10 the groundwater model, of course, and the level of detail
11 that it requires in order to improve the answer.

12 But my concern would be that not only there would be
13 some parameter estimation, but also a way of addressing
14 the uncertainty and variability in the subsurface beyond
15 the constraints imposed by the current characterization,
16 if necessary.

17 And that's going to be driven by the epi model,
18 whether or not one needs to essentially get at multiple
19 exposure scenarios in order to tease out the dose
20 response. So if the epi model is very weak in a sense in
21 terms of its correlation, the actual dose response, then
22 one might need multiple exposure scenarios in order to
23 find that. There's my primary concern. But, certainly,
24 parameter estimation, I think, is a necessary step if,

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1 indeed, one needs to refine the arrival curves to these
2 wells.

3 MR. FAYE: I have no argument or really even any
4 comment to say except that I agree with you, and we've
5 always planned to use parameter estimation to the greatest
6 extent that we possibly could. We've only done it
7 recently -- or not recently. But with respect to the
8 prepumping model, I spent quite a bit of time using PEST
9 and UCODE to estimate -- to estimate that recharge rate.
10 And frankly, I didn't get any better answers than just
11 using the estimate that's published in several -- several
12 papers. So -- but it's something that we definitely plan
13 to deal with in the future.

14 DR. LABOLLE: There is one additional concern
15 actually with regards to parameter estimation that I've
16 been meaning to touch on at some point here which is: What
17 data do you calibrate to? And I've noted from some of the
18 slides you had up there that parameter estimation or the
19 focus on the calibration has been on the hydraulic model,
20 and that's used in the transport model. Now, to the
21 extent that the parameter estimation could be used in
22 combination for both the hydraulic and the transport
23 model, I think that's quite important.

24 And the more recent data that's available on
25 concentrations, unfortunately, probably doesn't overlap

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1 with the time frame of interest and the time frame in
2 which the model's been developed.

3 But if there was any plan to extend the model period
4 forward over the later periods over which you have better
5 information, there may be something to be gained from
6 calibrating the transport model to probably the better
7 data on concentrations in later time periods.

8 MR. FAYE: Oh, yeah. We would definitely be remiss
9 if we ended our calibration in 1985. We would extend the
10 calibration for the fate and transport to 1991, which is
11 the last period that we actually have contaminant
12 information at several supply wells. That's always been
13 on the books to do that. I had another comment. It
14 slipped my mind.

15 DR. LABOLLE: Is there --

16 MR. FAYE: The -- pardon?

17 DR. LABOLLE: Is there additional data after '91
18 also?

19 MR. FAYE: No; no; no. As Mr. Ensminger said and as
20 I reiterated later in some of my comments, apparently,
21 right after the wells were sampled during Operable Unit 1,
22 the Operable Unit 1 study at ABC Cleaners, the Marine
23 Corps destroyed the wells, literally. It grouted them up,
24 took the hardware out, pumps, and grouted them up.

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1 DR. LABOLLE: And there's no monitoring at the
2 monitoring wells after that time period? Or is there?

3 MR. FAYE: No; no. I think actually the monitoring
4 wells are gone as well.

5 DR. LABOLLE: Okay.

6 DR FAYE: Except for the immediate vicinity of ABC
7 Cleaners because they have to -- they have to have some
8 means of determining the efficiency of their remediation
9 activity there at ABC Cleaners. So that's pretty much it.
10 The -- as you saw, we would -- in order to -- in order to
11 do some parameter estimation during this transient period,
12 we would probably do some additional refinement on those
13 so-called static water levels.

14 You saw the shotgun scatter diagram there, so that
15 makes -- that makes the notion of parameter estimation a
16 little -- a little difficult when you're trying to match
17 that number of water levels plus that type of variability
18 in the water levels. But it's definitely something that
19 we -- that we'll deal with. And that was a good comment.
20 Thank you.

21 DR. JOHNSON: Any further comments on that question?

22 DR. CLARK: One comment.

23 DR. JOHNSON: Yes; please, Bob.

24 DR. CLARK: It seems to me that, in addition to
25 having data for parameter estimation, it would be nice to

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1 be able to create an independent data set for validation
2 of predictions. And I think that would be an essential
3 part of the protocol for doing the regression estimations.

4 MR. FAYE: The only -- the only way we could do that
5 would basically to be randomly select data from the --
6 from the -- from the total population of the database that
7 we've got. We could do that.

8 DR. SINGH: I would like -- since it says no linear
9 regression approach, you know, I think you should consider
10 using more efficient and powerful parameter estimation
11 techniques, such as GLUE, and especially in conjunction
12 with the generic programming, your load times. I think
13 that would be a better approach than only the regression
14 approach, especially when you have such limited data.

15 MR. FAYE: Thank you.

16 DR. DOUGHERTY: One other comment is that, at least
17 the way the language is usually used, parameter estimation
18 assumes a model. And it seems to me that the model
19 estimation, at least the submodel for source terms -- and
20 getting ahead of our current topic -- tanks is perhaps
21 more significant than some of the parameters that one
22 might first think of going off and estimating. And my
23 initial reaction is that the model estimation process,
24 particularly at the source term, is more significant.

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1 DR. JOHNSON: Okay. Let's move on to the next
2 question. Should ATSDR consider using probabilistic
3 analyses to assess the variability and uncertainty of
4 model parameters and variability and uncertainty of
5 contaminant concentrations at public supply wells? Are
6 there public domain codes available that the panel would
7 recommend using? Anyone want to bite on that one?
8 Please.

9 DR. CLARK: I'll take a shot at it. Yeah. I think
10 the idea of using probabilistic analysis and so forth is a
11 good idea, but I'm wondering: You're having enough trouble
12 dealing with just the -- with the deterministic model
13 you're working with is -- wouldn't that add a level of
14 complexity that goes way beyond where you could possibly
15 go at this point?

16 MR. FAYE: That was your question, Morris. You
17 answer it.

18 MR. MASLIA: Yes. Yes. That was a question posed in
19 the early stages of the formulation of this panel, and we
20 were trying to consider any and all topics that might be
21 brought to the table. And obviously, the panel has sort
22 of narrowed our focus into certain areas. And it may be
23 just more than we can bite off at the present time. And I
24 think, as David already appropriately pointed out, we may
25 be talking more into model estimation as opposed to

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1 parameter estimation, given the limited data that is
2 available, and really find out how our model -- the effect
3 on the performance of our model.

4 If I could just go back for a second when -- Eric,
5 you were speaking about calibration for -- from the water-
6 quality standpoint or from the transport standpoint in
7 addition to the hydraulic. And I think we've taken -- and
8 this gets into the distribution side.

9 But we've taken that approach, and that's one of the
10 ideas that has driven us on the water-distribution side --
11 once we saw some of the hydraulic parameters of the
12 distribution side -- to do tracer tests, realizing that if
13 we were going to ever calibrate a distribution model that
14 we would have to calibrate it to water-quality parameters,
15 rather than just on the hydraulic side.

16 We would probably end up, at best, with a nonunique
17 hydraulic solution; at the very best if we did not. So we
18 are aware of that. Your point is well taken. We're
19 probably at that step on the distribution side, and that's
20 a step we need to look at from the groundwater side.

21 DR. LABOLLE: I think it might be important here to
22 define what we mean by calibration to some extent because
23 the previous question was with regards to parameter
24 estimation for calibration. But in my mind, when I speak
25 of calibration, I think we're talking the big picture,

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1 including the source term, as David brought up, then
2 including the recharge and everything else --

3 MR. MASLIA: Oh, absolutely.

4 DR. LABOLLE: -- that comes into play here, so...

5 And with regards to the use of specific models, I'm
6 reluctant to advise ATSDR to necessarily embark on, for
7 example, a geostatistical approach to -- although that's
8 kind of what I was implying by my previous answer. I'm
9 reluctant to specifically recommend that at this point in
10 time until I understand more the role of the tanks, the
11 mixing, and the distribution-system model, the time frame
12 at which we know contamination was present at some of the
13 wells relative to, you know, some of the uncertainty, and
14 how much uncertainty can be tolerated in the epi model. I
15 think that's going to become apparent over the next day
16 and a half.

17 DR. WALSKI: Instead of using the word
18 "probabilistic" analysis, I would just think in -- more in
19 terms of sensitivity analysis. Find out what is the model
20 sensitive to and focus on that parameter and not try to
21 figure out every cell's hydraulic conductivity or anything
22 like that. And you know, focus on the one or two things
23 that really make a difference. And it's probably going to
24 be source.

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1 DR. DOUGHERTY: And the answer is -- focusing on the
2 last part of the question, rather than the first part, the
3 answer is yes. You should you use some probabilistic
4 analysis for the impact at the -- it's not clear yet
5 whether it's the individual wells or the blended well
6 concentrations but on that metric. Yes.

7 DR. LABOLLE: Yeah. The answer -- if I can elaborate
8 on what I said -- I was reluctant to provide
9 recommendations for using geostatistics but certainly some
10 sort of probabilistic analysis is going to have to be
11 employed to consider the uncertainty in these arrival
12 curves to the wells regardless of how well you know the
13 source because although the source terms -- and the
14 uncertainty in that is going to, you know, directly affect
15 the arrival to these wells and the concentrations at which
16 the PCE arrives.

17 The hydrogeologic uncertainty is an additional
18 component that will make that highly uncertain as well and
19 possibly on the order of a magnitude, an order of
20 magnitude or more, maybe even two orders of magnitude,
21 uncertainty in concentrations that arrive to these wells,
22 even from the hydrogeologic uncertainty. And so
23 constraining that, to the extent that you can, from the
24 models, I think, is important.

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1 DR. JOHNSON: Okay; moving on. How should ATSDR
2 address the issue of lack of observed water-level data
3 prior to 1974, reminding us that the epi study is from
4 1968 -- or covers 1968 through 1985?

5 MR. MASLIA: That should have been from '78. If
6 you've been following the discussion all day, we don't
7 have the data prior to '78.

8 MR. FAYE: Very few.

9 DR. JOHNSON: So that becomes a moot question.

10 MR. FAYE: No. But I think we've already addressed
11 it in terms of the uncertainty discussions and the
12 parameter estimation discussions. I think we just sort --
13 it would be a lot of repetition in response to that
14 question, but that's no reason not to respond.

15 DR. JOHNSON: If you're happy, I'm happy. Any
16 comments on --

17 MR. FAYE: Okay. I'm happy.

18 MR. MASLIA: The only comment I will -- I will make
19 and I've had this initial discussion with Frank Bove, and
20 he's actually prepared some, I guess, iterations or some
21 initial analyses. And the discussion went along the line
22 is: How much uncertainty or variability could the epi
23 study tolerate in terms of if our arrival times are plus
24 or minus a couple of months versus plus or minus six
25 months versus plus or minus a couple of years?

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1 And that's an issue. As I said, he's just prepared
2 some preliminary analysis on, but that's something we need
3 to sit down and discuss with them. That's the exact
4 issue. So the fact that we don't have very many data
5 prior to '78 brings that again to the forefront since
6 they're starting the study in '68.

7 DR. KONIKOW: Do you have pumpage data from prior to
8 1978?

9 MR. FAYE: Yeah, we do, Lenny. We have periodic
10 information for, perhaps -- well, not perhaps, for a
11 particular year. Maybe, I think we have data for '71. We
12 have data for '62. And, of course, the USGS, their data
13 go to '75. I think we also have some '68 data, but these
14 are just, you know, snapshots.

15 And -- but the point is -- and I think I made it
16 earlier -- that because of the -- because of the utility
17 of Tarawa Terrace, the housing was occupied 90 percent to
18 100 percent all the time. And that's borne out in the
19 USGS data as well. I mean, we're looking at point --
20 averages of .95 MGD plus or minus 10 percent for, you
21 know, well over a decade. And I think that was probably
22 the case, you know, from the get go.

23 DR. KONIKOW: So really what you're saying is that if
24 you can calibrate the model adequately for the times when
25 you have water-level data --

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1 MR. FAYE: Right. That's --

2 DR. KONIKOW: -- you could then run the model --

3 MR. FAYE: That's the whole plan.

4 DR. KONIKOW: -- impose the stresses --

5 MR. FAYE: Yep.

6 DR. KONIKOW: -- for the earlier time.

7 MR. FAYE: Right. That's the plan.

8 DR. KONIKOW: -- and that still leaves you with the
9 issue of concentrations though.

10 MR. FAYE: Exactly; exactly. And the thing that we
11 hope to be able to do is to have some good estimate of
12 mass loading through time. It should be fairly constant
13 except for the periods there that, like Mr. Ensminger was
14 discussing during Vietnam, when there was -- when it was
15 probably somewhat to greatly accelerated, the activities
16 at ABC Cleaners.

17 But for all intents and purposes, it is a single
18 source, and hopefully, maybe, perhaps from these tax
19 records or other information that we'll be able to
20 discover in the reasonably near future. We should be able
21 to -- or we'll hopefully be able to get or to obtain some
22 notion of the use at the source. That still doesn't
23 really address what the loss -- what the percentage of
24 loss was from their actual total use. So we'll just have
25 to start out, make some estimates, do alternative

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1 simulations, and hopefully arrive at a defensible,
2 reasonable answer.

3 DR. KONIKOW: Well, I think what you're going to come
4 up with is that there was some contamination there from
5 the beginning of this --

6 MR. FAYE: Right.

7 DR. KONIKOW: -- epidemiological study.

8 MR. FAYE: Oh, yes.

9 DR. KONIKOW: And --

10 MR. FAYE: No question.

11 DR. KONIKOW: -- you may not be able to refine it
12 down any more than we just said.

13 MR. FAYE: Maybe we can't; yeah. I don't know
14 whether that precludes the attempt or not. That's
15 hopefully what -- where we'll get -- gain some insights
16 from you-all.

17 DR. JOHNSON: Okay. How should ATSDR address the
18 issue of lack of monthly groundwater production data when
19 monthly data are required for the epi study?

20 MR. FAYE: Well, let me say a few words about that
21 too. We now have good monthly data back to 1980. All
22 right? And we have -- prior to 19 -- 1980, we probably
23 have, maybe, three, four, five snapshots in time of the
24 well capacities because the well capacities have changed
25 through time.

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1 So what we can ultimately do -- what we possibly
2 should be able to do, using the monthly data that we do
3 have now from 1980 through 1984 and the well capacity data
4 that we have for that time, possibly rate the -- that use
5 as a factor of -- as a factor of capacity. And then, as
6 the capacity changes back through the historical record,
7 adjust that on a monthly basis. And knowing what the
8 annual record is -- we know what monthly variability is
9 now from the -- from the detailed records that we have for
10 those four, five, six years -- develop a model of
11 activity. Okay?

12 MR. MASLIA: One of the pieces of information that
13 we've just recently obtained, which has been referred to,
14 is this plant accountability record. I actually have a
15 copy with it, and it goes from 1990 backwards 'til they
16 started keeping the records.

17 What's in it is it lists -- for example, it lists the
18 pump house or well house and treatment facility and
19 anything by all the different water-plant areas at Camp
20 Lejeune. It references a card number, which is my
21 understanding how records are referenced to or kept in the
22 vault at Camp Lejeune. That should -- at least, we'll
23 make the attempt at going back there and pulling whatever
24 information is in there.

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1 Up until we got that information telling us or
2 suggesting that we go into this storehouse of information
3 and start looking someplace, it was like looking for a
4 needle in a haystack. You don't know where to turn to
5 look. At least now we have some directed means. Whether
6 that yields useful information or not, I can't answer, but
7 that may -- in fact, just this last week -- I think it was
8 last Thursday or Friday -- I received from the EMD folks
9 at Camp Lejeune the -- was it from the '80 to '80 --

10 MR. ASHTON: '84.

11 MR. MASLIA: '80 through '84 monthly production
12 records by every water system. So this information is
13 still coming in. And as we have -- as we refine -- excuse
14 me -- our approach based on recommendations from this
15 panel -- also I think that goes hand-in-hand with
16 hopefully obtaining additional data we may find. In other
17 words, we have not given up on trying to locate the
18 earlier information.

19 DR. JOHNSON: Okay. Anything else? Lastly, Question
20 8: Is it sufficient to use an annual average recharge or
21 infiltration rate and assess climatic conditions to derive
22 monthly recharge rates? Are other methods or techniques
23 available to derive monthly recharge data? Does anyone
24 know?

25 DR. CLARK: [off microphone]

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1 COURT REPORTER: Sir, I need you to use the
2 microphone.

3 DR. CLARK: I'm sorry. Could one use some of the
4 meteorological data we discussed to get estimates?

5 MR. FAYE: Yes. That's our plan now. We have
6 monthly rainfall, pan evaporation records for the entire
7 period of interest, starting in the early fifties and
8 going up into the nineties. And once we can decide on
9 this baseline annual recharge, whatever it is -- 14
10 inches, 13 inches, 15, something like that.

11 Whatever that is, then we can use that -- and we
12 compare that then to the -- we have -- what we'll have
13 from that -- from that long period of meteorological
14 record, we'll have an -- a long-term average annual
15 rainfall as well. So we can equate that 14 inches of
16 recharge to the long-term average rainfall. And then,
17 using the monthly data, we can prorate that out.

18 We can say, well, for 1963 the recharge -- the annual
19 recharge was only 10 inches and prorate that out on a
20 monthly basis, using the meteorological record. 1975, it
21 was 16 inches and prorate that out, using the
22 meteorological record. And hopefully, we can develop a
23 recharge schedule for the various stress periods that way.
24 It's not -- it's not, you know, it's not rocket science,

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1 but it is somewhat practical and common-sensely and
2 straightforward. So hopefully, it might work.

3 DR. CLARK: Can you get an estimate for changes in
4 soil permeability over that period of time?

5 MR. FAYE: There may be some agricultural records at
6 an experiment station somewhere down there in the coastal
7 plain where they -- where they collect those -- that
8 information, I guess, almost daily, particularly during
9 dry periods. We haven't looked for it.

10 DR. DOUGHERTY: The only comment I have with respect
11 to using the preset and then generating the variations of
12 the record is that that may be excessively rough compared
13 to the infiltration function at -- as it accretes to the
14 groundwater system. So it may be useful to -- basically
15 the unsaturated zone acts as a buffer and --

16 MR. FAYE: Sure.

17 DR. DOUGHERTY: -- and a smoother, so it may be
18 useful to use a very simplistic, one-dimensional model,
19 representative of characteristic depths to groundwater --

20 MR. FAYE: Oh.

21 DR. DOUGHERTY: -- to reduce the roughness.

22 MR. FAYE: Mm-hmm. And then what would you -- you
23 would -- you would bleed off the rainfall with some
24 estimate of ET or loss, using, what, pan evaporation data
25 or something like that?

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1 DR. DOUGHERTY: That's one approach. The other
2 approach may be to do a simple, straightforward extension
3 of what you're doing now.

4 MR. FAYE: Oh, okay.

5 DR. DOUGHERTY: You have an average --

6 MR. FAYE: Okay.

7 DR. DOUGHERTY: -- from the average prorate. That's
8 the loading to the top of your reactor.

9 MR. FAYE: Right; right. And the advantage of what
10 you're saying just because we think we got 14 inches of
11 recharge or maybe the 1 inch of recharge during a
12 particular month -- because of the thickness of the
13 unsaturated zone, the water table may not see that for
14 another month or another two months.

15 DR. DOUGHERTY: Right. The unsaturated zone acts
16 as --

17 MR. FAYE: Yeah.

18 DR. DOUGHERTY: -- as bank storage.

19 MR. FAYE: Yeah. And the advantage of what you're
20 saying would allow us to look at that antecedent condition
21 pretty nicely.

22 DR. DOUGHERTY: Perhaps. The other advantage is that
23 it may smooth out some rewetting problems that you may
24 have because it's smoother rather than rougher.

25 MR. FAYE: Oh, yeah; right; okay.

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1 DR. LABOLLE: You might try -- with regards to that,
2 you might try the -- I think it's been released. But one
3 of the researchers in our office was developing --

4 COURT REPORTER: Can you get nearer your microphone,
5 please.

6 DR. LABOLLE: -- the sat/unsat package for Modflow.
7 And it's not a full unsaturated code, so it doesn't have
8 its complexities that you'd -- that you would normally
9 associate with that --

10 MR. FAYE: Well, that's good.

11 DR. LABOLLE: -- an enigmatic wave --

12 MR. FAYE: Okay.

13 DR. LABOLLE: -- approach.

14 MR. FAYE: Yeah.

15 DR. LABOLLE: And it will provide the buffering that
16 you're looking for. It's essentially, you know, a
17 modified recharge.

18 MR. FAYE: Oh, that would be nice. What's this
19 person's name?

20 DR. LABOLLE: That's the -- Dave Prudic is working on
21 that with Richard --

22 MR. FAYE: Oh, yeah, I know Dave.

23 MR. MASLIA: Oh, we know Dave.

24 MR. FAYE: He's a personal friend of mine.

25 COURT REPORTER: One at a time, please.

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1 DR. LABOLLE: Rich and Dave are the two --

2 MR. FAYE: Okay.

3 DR. LABOLLE: -- that have been developing that,
4 so --

5 MR. FAYE: Oh, okay.

6 DR. LABOLLE: I think it's either been released or
7 it's in testing, one or the other.

8 MR. FAYE: All right. Well, it's time to harass
9 Dave.

10 MR. MASLIA: Lenny, would you know anything -- would
11 you know anything about if that's been officially released
12 by the survey?

13 DR. KONIKOW: To the best of my knowledge, it's not
14 officially released yet.

15 MR. MASLIA: Okay.

16 DR. JOHNSON: Okay. We have plodded through these
17 eight questions, and I offer the panel the opportunity to
18 further elaborate on any point, something you, maybe, have
19 forgotten and wished you had brought up as an earlier
20 discussion. But this is going to be pretty much the
21 conclusion of comments on the groundwater modeling.
22 Anything that any panelist wishes? Please, James.

23 DR. UBER: Well, I just -- I'm no groundwater modeler
24 at all, but I've heard a few people talk about source
25 terms. And I just offer this as an idea for it to be shot

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1 down, I guess. I wonder whether some more time should be
2 spent on working your way back to the source, to your, you
3 know, your hardest number, which I guess is your estimate
4 of how much PERC they used on a monthly basis.

5 So in other words, I mean, I don't know how a dry-
6 cleaner operates and how much they lose --

7 MR. FAYE: Well, we don't either.

8 DR. UBER: -- and how much is diluted with other --
9 with water as it goes into the septic system and whatnot.
10 But should more effort be spent on modeling that process?

11 MR. MASLIA: I think -- if I can do that one.

12 MR. FAYE: Have at it.

13 MR. MASLIA: That's really -- and this may be an
14 inappropriate term, but I'm going to use it anyway. I can
15 get shot down. That's really a facilities management-type
16 question that you're asking. How was the facility
17 managed, and can we glean any information as far as how we
18 classify or quantify the source that goes into our
19 groundwater model?

20 In other words -- and that, I think, goes back to
21 this data-discovery issue. Can we pull tax records? Can
22 we perhaps find -- and I don't know the issue. But if you
23 look at deliveries, deliveries to the dry-cleaner on how
24 much they use, we should see an upswing during the Vietnam
25 period, obviously.

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1 And then perhaps through the -- there's a dry-cleaner
2 -- National Dry-Cleaners Association. Because my dry-
3 cleaners -- I asked him once about PERC, and he gave some
4 handout from them. So I know they have a national
5 organization. They may, in fact, have some information we
6 have not looked on on typical uses, historic uses. That's
7 an area, I agree, I think we need to really look at.

8 DR. WALSKI: So related to this, we're doing all this
9 sophisticated stuff, going back through tax records and
10 all that, why don't we just talk to the guy that ran ABC
11 Cleaners? I mean, get somebody who was the manager and
12 interview that person and find out what they did, I
13 mean --

14 UNIDENTIFIED SPEAKER: Because he's dead.

15 COURT REPORTER: Either at the mike, or (laughter)...

16 DR. WALSKI: If he's dead, then I think one of his
17 employees or somebody should know what went on there.
18 There should be somebody who worked there that's still
19 alive.

20 MR. FAYE: I think we're also dealing with, Tom,
21 something you pointed out a few minutes ago with regard to
22 the operation of these water-treatment plants. And that
23 is, you know, there's a broad spectrum of the way folks do
24 things, and I think -- and we had two -- we have two
25 examples right there.

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1 We have the ABC Cleaners, who were, obviously,
2 exceptionally sloppy, to put it kindly, and we have this
3 Globarama place, who was very -- they were very efficient
4 in their operations and how they -- how they tracked their
5 and collected their PCE waste. So, yeah, we need to try
6 to find out as much as we can about that. And all of that
7 affects the source term, and there's just no denying --
8 and we wouldn't that -- the source term is a critical,
9 critical, critical feature of the fate and transport
10 model.

11 DR. LABOLLE: You might want to look at one of these
12 other simple models for looking at a dissolving source
13 like that, you know, a DNAPL, like we're dealing with
14 here.

15 MR. FAYE: Mm-hmm.

16 DR. LABOLLE: And I've actually run some of these in
17 the past. I forgotten the names if it. Something called
18 3-D? Does that sound --

19 MR. FAYE: There's something called Fate 5. There's
20 a number of them out there.

21 DR. LABOLLE: And, you know, that may be helpful, I
22 think, in --

23 MR. FAYE: Mm-hmm.

24 DR. LABOLLE: -- because, you know, what's been
25 mentioned is one aspect, which is facilities operation.

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1 But then below that, you know, you've got the unsaturated
2 zone. You've got the source entering in there. And
3 you're looking at the saturated zone, not the unsaturated
4 zone.

5 MR. FAYE: Right.

6 DR. LABOLLE: So it might be useful in helping to
7 refine what the source may have looked like once you get a
8 handle on how much is entering the subsurface.

9 DR. JOHNSON: Mr. Ensminger.

10 MR. ENSMINGER: I just wanted to add one thing. I
11 know that depositions were taken prior to Mr. Meltz's
12 death by the EPA and some different law firms. And those
13 are available.

14 MR. FAYE: Do you know where?

15 MR. ENSMINGER: Yes. I'll tell you.

16 DR. JOHNSON: Okay. Thank you for your comment.
17 Anything else on groundwater?

18 (No audible response)

19 DR. JOHNSON: Looking at tomorrow, let me bring to
20 your attention that we begin at eight a.m., not 8:30. So
21 there's a time change, so be here a few minutes before
22 eight. We will begin, Morris, with your presentation on
23 the water-distribution system, an update on that work, and
24 then go from there into the set of questions that the
25 agency has brought forward.

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1 As a matter of, perhaps, a take-home assignment to
2 the panelists, we're going to be talking about these four
3 charges. And clearly, we've already discussed some of
4 this. And tomorrow at the working lunch, we need to begin
5 formulating some specific responses to these four charges.
6 And I would ask that you simply look at these four charges
7 tonight, maybe put a few notes in the margin. And that
8 will help us perhaps go through these in a more efficient
9 fashion tomorrow.

10 With regard to the hotel, is there transportation
11 provided this evening as well as tomorrow? It's a very
12 accommodating hotel.

13 MR. MASLIA: There probably is. If there's anyone
14 out in the lobby -- you mean going back to or going out to
15 a restaurant?

16 MR. MASLIA: Going --

17 DR. JOHNSON: All of the above; yes.

18 MR. MASLIA: The hotel is very accommodating, and I
19 will see if anyone's out in the hallway to answer that
20 question.

21 But if I -- if I might just -- about a 60-second
22 point here is, again, on behalf of the technical staff --
23 and I assume I won't get beat over the head by agency
24 management for speaking for the agency, although Bill's
25 backing his chair up right now, so maybe I shouldn't. We

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1 do very much appreciate your input. It's very useable.
2 It's from people who've seen a variety of cases, both
3 public and private contamination cases.

4 One of the things we take into consideration -- for
5 example, if we modify or go down a different path, taking
6 the information that you have provided us, we still need
7 to provide our other audience, the public and others, a
8 technical reason why we have chosen to change direction.
9 In other words, so that may still require us to say,
10 "Well, we did a cursory review of Hadnot Point, and, based
11 on recommendations from the panel and what we're seeing
12 right now, we're not going there any longer."

13 And that's just, for those who are not familiar with
14 the way ATSDR operates, we do have this other audience to,
15 at least, you know, address or at least acknowledge their
16 questions. So that's the other side to that. You're
17 obviously not charged with, but our mission is charged
18 with. So while some of these questions may seem like why
19 did they ask these questions or why are they posing it,
20 the answer may be obvious. We do -- we're posing them
21 because we have another audience to acknowledge and to
22 provide respectful answers for. So we do appreciate your
23 contributions and look forward to continuing down with the
24 distribution side tomorrow.

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1 DR. JOHNSON: May we leave our materials in this
2 room?

3 MR. MASLIA: Absolutely. It'll be locked up.

4 DR. JOHNSON: Okay. Anyone want to say anything?

5 (No audible response)

6 DR. JOHNSON: If not, thank you for a good day.

7 (Whereupon, the proceeding was adjourned at
8 approximately 5:08 p.m.)

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EXHIBIT 8

**THE U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
PUBLIC HEALTH SERVICE
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY**

convenes the

**EXPERT PEER REVIEW PANEL
ATSDR'S HISTORICAL RECONSTRUCTION ANALYSIS
CAMP LEJEUNE, NORTH CAROLINA**

VOLUME II

The verbatim transcript of the meeting of the Peer Review Panel, held at 1825 Century Boulevard, Room 1A/B, Atlanta, Georgia, on Tuesday, March 29, 2005, taken by Diane Gaffoglio, Certified Merit Court Reporter.

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C O N T E N T S

Volume II
March 29, 2005

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Legend of the transcript:

[sic]	Exactly as said
[phonetic]	Exact spelling unknown
--	Break in speech continuity
...	Trailing speech or omission when reading written material
[inaudible]	Mechanical or speaker failure
[microphone]	Speaker is off microphone

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P R O C E E D I N G S

8:07 a.m.

DR. JOHNSON: Good morning. Good morning, one and all, and I hope you all had a restful evening. Before we ask Mr. Maslia for any housekeeping kinds of things, let us welcome one of our panelists, Benjamin Harding, who had airplane difficulties that we've all encountered over our careers. But we welcome you and ask that you, for the record, identify yourself, your affiliation, and lastly to any overarching comments on the materials that you received from ATSDR.

MR. HARDING: I'm Benjamin Harding. I work for a firm called Hydrosphere Resource Consultants out in Boulder, Colorado. And I think, if I had to sum up what I thought in an overarching sense, I would say that the work that's been done here is impressive. One of the things I think that was identified by the other panelists as well is that we need to deal with the issue of uncertainty and try to deal with that in a quantitative way, I think.

DR. JOHNSON: Thank you. Do you know all the other panelists?

MR. HARDING: The ones -- I think I've met everybody at this point, and some of them I knew prior to this time, so...

DR. JOHNSON: Why don't we take a couple of minutes

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1 and just go around; name and affiliation, please.

2 DR. POMMERENK: My name is Peter Pommerenk. I'm with
3 AH Environmental Consultants.

4 DR. SINGH: I'm Vijay Singh from Louisiana State
5 University.

6 DR. WALSKI: Tom Walski, Bentley Systems.

7 DR. KONIKOW: Lenny Konikow, U.S. Geological Survey,
8 Reston, Virginia.

9 DR. UBER: Jim Uber, University of Cincinnati.

10 DR. DOUGHERTY: Dave Dougherty, Subterranean
11 Research.

12 DR. CLARK: Bob Clark, formerly with EPA and
13 currently a consultant.

14 DR. JOHNSON: And I'm Barry Johnson, School of Public
15 Health, Emory University.

16 Morris, do you have any housekeeping things before we
17 begin today's work?

18 MR. MASLIA: Just, again, to remind anyone if they've
19 got their cell phones on to silence them or turn them off,
20 whichever you prefer. And again, any of the audience in
21 the back here, your conversation can be picked up by the
22 mikes, even if you're turning to your partner.

23 And one last thing, more towards the -- for the
24 panelists, Dr. Johnson gave me a homework assignment last
25 night and to see if we could reduce or perhaps modify the

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1 questions and answers for the second day with respect to
2 the water-distribution systems, and I did some of that. I
3 handed Dr. Johnson a copy, and I will hand the panel out a
4 copy when we get to that time so we can go through them
5 and cover all of them in a little faster manner.

6 I've combined a couple of them as well. So other
7 than that, Dr. Johnson, that's it. Oh, the -- if you
8 haven't deposited your money -- I think it's \$5 for the
9 working lunch. Ann is taking the money outside. Just,
10 either at break, leave the money there, and they'll go out
11 and get the lunch. Thank you.

12 DR. JOHNSON: Okay. Thank you. My purpose in asking
13 Mr. Maslia to take another look at the list of questions
14 that bear on the water-distribution systems was that these
15 questions were prepared some time ago. And he and the
16 agency have received some information since the
17 preparation of these questions, and that led to, in my
18 mind, as to whether all of those questions were still of
19 importance to ATSDR, and so Morris has reduced the list in
20 response.

21 With regard to one housekeeping matter from the
22 Chair, today's agenda shows, at 2:30, us going somewhere
23 in executive session. And I gather that that was put in
24 as an opportunity for the panel to sort of closet itself
25 and say things, perhaps, in the absence of ATSDR staff.

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1 In fact, that would be the case, and we would have
2 ATSDR staff there initially to answer any early questions,
3 but I would then ask them to leave so that this would be a
4 totally candid kind of executive session amongst the
5 panelists. Do you want to maintain that or forego it and
6 simply continue all of our deliberations here in a public
7 forum? And it's -- really, it's up to the panel to
8 decide. If you feel that need, we'll certainly do it.
9 What is your preference?

10 DR. CLARK: I don't have any problem with continuing
11 in a public forum.

12 DR. JOHNSON: Is that all right with all of you?
13 Tom, is that all right?

14 DR. WALSKI: It's all right with me.

15 DR. JOHNSON: Okay. Then we'll just continue
16 everything here in public session. And the main thrust of
17 that executive session was to finish our response to the
18 four elements of our charge -- the first two, we will
19 address at the working lunch -- and also to craft some
20 kind of communique.

21 I asked Mr. Maslia last evening: What did they have
22 in mind as a communique? And his response was: answers to
23 the four charges -- and which we will be preparing as we
24 deliberate this morning and early this afternoon. It
25 seems like we can fill their desire for a communique and

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1 still doing it all in public session.

2 I also want to alert you that, at the end of our
3 deliberations and toward the end of the meeting, I'm going
4 to ask you the same kind of question I asked you at the
5 beginning, and that is: To what extent are you comfortable
6 with the, what I call, the protocols that are in play,
7 both for the groundwater modeling as well as what you're
8 going to hear today, the water-systems modeling? To what
9 extent are you comfortable? Are you -- do you have
10 something you'd like to sort of red letter as key advice
11 to the agency? But just where are you personally in
12 regard to what you have heard over these two days?

13 And I don't foresee us taking any kind of vote as a
14 panel. If you feel that that is a need, then let's
15 discuss it. But by voting as a panel, it seems to me to
16 put ATSDR in a bit of a bind and potentially in a bit of a
17 bind. But they will have the benefit of your advice and
18 your recommendations as individual panelists. Does anyone
19 have a problem with the panel, as a body, not taking some
20 kind of vote on whatever, but speaking as individual
21 panelists? Tom?

22 DR. WALSKI: I'd prefer it that way. It's pretty
23 hard to get this group to agree. I mean, Jim and I
24 probably agree only about 10 percent of the time. So, you
25 know, it'd be pretty hard to get a unanimity on the panel

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1 here, so...

2 DR. JOHNSON: Well, let the record note that Jim is
3 smiling (laughter).

4 DR. UBER: It's one of the 10 percent.

5 DR. JOHNSON: Which is part of the 10 percent. Well,
6 if the panel feels, during the course of the day, to
7 change some of these suggestions, put it on the table, and
8 we will -- you will debate it as a panel. Okay.

9 Having said that, Morris, are you ready to begin
10 updating us on the water -- water-distribution systems
11 work?

12 MR. MASLIA: I sure am. Good morning, everybody.
13 And, Claudia, if we can go ahead and get the overview. My
14 plan this morning is to give an overview of the approach
15 for the water-distribution systems analysis and then go
16 into the field testing that we've done to date on the
17 present-day water-distribution system.

18 And as Bob said yesterday, if you would like to
19 interrupt me or ask a specific question that's either
20 among the questions that are there or that comes to you as
21 you're sitting here, please, feel free to do so, and I
22 will try to answer it as best as I can.

23 We're all familiar with Camp Lejeune, hopefully,
24 since yesterday. And again, for the present-day system,
25 we've got two water-treatment plants and three water-

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1 distribution systems. Just for your information, our
2 piping network has been obtained from data from autoCAD
3 drawings, supplied by Camp Lejeune, as well as through
4 their contractor, AH Environmental, also provided update
5 on piping. And so it's a combination of information as
6 well as us being in the field and observing pipes or
7 asking questions and then defining or having updated
8 information.

9 This was three bullets of activities based on the
10 entire project, and we talked about, obviously, yesterday,
11 the groundwater issue and some uncertainty issues which
12 still apply to today's issues. But specifically, today
13 we'll look at the potential distribution of contaminants
14 and water-distribution system models.

15 And let me just add, as Dr. Johnson mentioned, I
16 updated the questions and answers that were prepared a
17 while back based on discussions yesterday. I have not
18 done that with the slide material. So some of the slide
19 material is presented, not in contradiction to your advice
20 or your recommendations, but that they were prepared a
21 while back. And I thought I would just go with what I had
22 prepared.

23 So again, the chronology, which we still need to
24 refine in some areas. The one point to make here: What is
25 called Montford Point is presently known as Camp Johnson

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1 and is not in existence. It's serviced by the Holcomb
2 Boulevard water-treatment plant. And the treated water
3 goes to Tarawa Terrace ground storage, and that's where it
4 gets its water from.

5 Basically, we were asked by the epidemiologists to
6 quantify historical exposures for the purpose of their
7 epidemiologic study. And so our understanding is that if
8 the systems are completely separated, completely isolated
9 so you've got three hypothetical systems, they may or may
10 not have any contamination in them. Then, of course,
11 there would be no need to reconstruct the actual
12 distribution system historically, but rather we could
13 assume everyone would receive the concentration based on
14 our groundwater modeling and the source concentration
15 there.

16 Based on information and talking to people to date,
17 we know at some point in time the distribution systems
18 have not been operated independently or they have been --
19 a better word is there's been interconnection. Exactly
20 how long that is -- we've heard information on two weeks.
21 We see other data that suggests maybe there were other
22 opportunities for the systems to be interconnected.

23 And so if that's the case, then we need to do some
24 amount of historical reconstruction to try to get a
25 distribution of contaminants within those systems. So, as

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1 we see it, there are two approaches that we can do the
2 historical reconstruction. One, we can use historical
3 water-distribution system data. This is data from the
4 operators of the system, cycling on and off of wells,
5 flows, demands.

6 And what we have at least found out, in looking for
7 information, is that the information is sporadic. We
8 talked about that yesterday. There may not be any record
9 specifically of cycling on and off pumps and wells, or it
10 may not be in existence. Bob, did you have a question?

11 DR. CLARK: Morris, yeah, I had a question on the
12 exposure assumptions. You're assuming that everybody who
13 lives in a system that's independently operated is
14 exposed. Is that --

15 MR. MASLIA: That would be the assumption.

16 DR. CLARK: Okay. But you're not taking into
17 consideration things like activity patterns --

18 MR. MASLIA: No, we're not.

19 DR. CLARK: -- water use by individual homes and
20 that sort of thing?

21 MR. MASLIA: No. If you wanted to take into account
22 water use, you would either have to have some measured and
23 demand-type consumption metered information. At a Marine
24 Corps base -- and I assume at military bases in general --
25 they do not meter household water. We'll actually address

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1 that issue a little later on.

2 And as such, they do have -- they've got a production
3 meter, obviously, that's going into the system. But
4 because in some of the areas you've got mixed use -- say
5 bachelor housing, industrial. In some of the areas, it's
6 more homogeneous: total family housing. We would have to
7 derive some estimates of that.

8 DR. CLARK: Right. To the degree that you can't do
9 that, then that constitutes the potential for error, I
10 guess, in the analysis.

11 MR. MASLIA: Yes.

12 DR. CLARK: I guess Frank's not here.

13 MR. MASLIA: Yes. Just as an example, when we were
14 doing the work in Dover Township, we had quarterly billing
15 records for about 18 or 24 months, and we -- I shouldn't
16 say "we." I should say Jason put those in about a month
17 at a time, putting them in by hand.

18 But they came out. Where we measured, I think it was
19 7.5 million gallons per day on a test. With the billing
20 records, we came out with 7.6 million gallons. It was
21 right on target. We don't have that here, and it's -- so
22 that's just not available.

23 DR. WALSKI: Okay. It did bring up the question of
24 historical data. One other source of data is the fact
25 that a lot of the engineering work of this in the past was

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1 done by the NAVFAC IINCOM LANDTIV up in Norfolk, and I
2 haven't heard them mentioned. Have you gone up through
3 their records? They may have some of the construction
4 drawings and such that, you know, they don't have on post.
5 Have you talked to --

6 MR. MASLIA: Let me talk about that now. We do have
7 historical maps as paper copies, for example, as housing
8 areas expanded. We've actually got maps that tell us how
9 many more housing units were added and which pipelines may
10 have been added. So from that standpoint, we do have that
11 information.

12 When we've requested, even on the present-day system,
13 say, for example the network drawings, if they haven't had
14 them at Camp Lejeune, they have provided it to us either
15 through their consultant. So I assume if they haven't had
16 it on base, they have gone up to the Navy facilities. We
17 are aware of that.

18 And, in fact, on the -- which I'll get to a little
19 bit later on. There was a conservation study done. Most
20 -- the Air Force and Navy developed this water-
21 conservation analysis, a software. And we requested it,
22 and I know they did go up to Norfolk to get a copy of
23 that, and actually, that has formed the basis for some of
24 our demand categorizations.

25 So I'll get into that, but we are aware of that, and

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1 when needed, we have requested. But we personally have
2 not gone up there, but we know someone has gone up there
3 because of the information that we've obtained. Were
4 there any more questions up to that?

5 The second approach then would be to -- in view of
6 the lack of historical system operation-type information
7 would be to develop a present-day system model; gather
8 information on that; and then to, what we're calling,
9 deconstruct the present-day system: removing pipes as they
10 were removed historically and using the assumption that
11 we've been told that they pretty much operated in a
12 similar manner; use that to do the historical
13 reconstruction or come up with historical systems.

14 Now, one of the differences we have found out, say,
15 from the Dover Township work, unlike in Dover Township
16 where the network changed at least every year, whether it
17 was addition of pipes, hydraulic devices, or anything,
18 there were just major -- major changes in only certain
19 years at Camp Lejeune, for example, the addition of the
20 Holcomb Boulevard plant.

21 From what we've been told and what we've been able to
22 find out, they were not adding sections of pipelines every
23 year. That sort of simplifies, at least from a simulation
24 standpoint, where we can make some larger assumptions. So
25 that we have found out, and that is why it's still very

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1 important on this chronology, especially with the Holcomb
2 Boulevard plant. If we can isolate that, the start-up, to
3 a month and year, it will really help us out.

4 And this is the approach up to this time that we have
5 been using to calibrate models for the present day; get a
6 description of the present-day system in terms of
7 operation, in terms of facilities; and then work backwards
8 in time. The information in front of you and what we've
9 been -- and what we'll discuss today, obviously, is just
10 for the present-day system, but hopefully, we can also get
11 some recommendations for the historical process.

12 And that's -- so the approach then would be to apply
13 the output from the groundwater model, and that's the
14 arrival of the concentration from the contamination. And
15 then either apply it to Approach A or B, and as I've
16 indicated, we have gone with Approach B because of the
17 lack of information from the historical standpoint.

18 And that's really a summary of just the approach and
19 what has prompted us to take the next step, which is the
20 field investigation and understanding the present-day
21 system. So at this point, are there any other specific
22 questions on the approach? Yes.

23 MR. HARDING: Morris, there's a high-level question
24 from the -- going up to 20,000 feet and looking at this
25 for a minute -- and this may have been answered yesterday

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1 since I wasn't here, so if it has, just somebody can take
2 me aside and tell me.

3 And that is, is that in the event that or in the case
4 where -- these systems were served by a single source
5 essentially. The wells were blended into a water-
6 treatment plant and then supplied to the distribution
7 system, and those systems weren't interconnected then.

8 MR. MASLIA: Did you say were or were not?

9 MR. HARDING: Were not.

10 MR. MASLIA: Okay.

11 MR. HARDING: So we have independent systems served
12 by a single point of supply. Then there's really no need
13 for any hydraulic modeling in my understanding of the kind
14 of etiology of disease that we're talking about. That is,
15 these are chronic, relatively chronic, exposures.

16 So we don't need to know, with a precision of hours
17 or even days, when a particular change in concentration
18 occurred. So the calculation -- essentially, everybody in
19 the system -- when you're averaging things out over a
20 period of days or weeks, even that level is going to get
21 the same exposure, the same concentration.

22 So it seems to me useful to divide this up into the
23 epochs, if you will, of the configuration and operation of
24 the system and decide, you know, what the benefit is of
25 doing the detailed hydraulic modeling and when that

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1 benefit's going to accrue because at some point -- at some
2 points, all of the uncertainty, all of the arithmetic
3 basically falls on the groundwater model. And at that
4 point, once you know the answer to groundwater model and
5 the dispatch of the wells -- if you've got innumerable
6 wells, you have to understand that. Once it gets into the
7 water-distribution system, it's no longer an issue.

8 MR. MASLIA: Right.

9 MR. HARDING: So we need to understand that to
10 evaluate when you need to do, if you need to do, the
11 detailed hydraulic modeling.

12 MR. MASLIA: Our assessment of the water-distribution
13 system, when we were first presented with the opportunity
14 to assist our division of health studies on the
15 epidemiologic study, was really twofold.

16 First -- and I am not an epidemiologist. I'm
17 probably stepping way off on the plank here. But my
18 understanding on some of the health outcomes, birth
19 defects, there -- they need some information in the first
20 trimester, and I think it's Days 21 through 28 or
21 something like that. So they had mentioned some daily
22 information to us, and Dr. Bove is not here. But David --

23 MR. HARDING: I probably can answer most of the
24 questions.

25 MR. MASLIA: Okay.

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1 COURT REPORTER: I need you to get to a mike then.

2 MR. MASLIA: Oh, okay. But that was our -- one of
3 the questions we had: Could we provide that kind or at
4 least on a monthly, looking at trimesters, monthly
5 information. Yes.

6 DR. CLARK: I wonder if everybody would be equally
7 exposed because you're talking about people that may --
8 you know, women who might be in the household, maybe, 18
9 hours, 16 hours a day with children as opposed to some of
10 the active-duty Marine Corps personnel who are off doing
11 something else.

12 And I wondered if maybe one way to deal with that is
13 sort of at least classify the percent of population who
14 falls into these different categories who would have
15 different kinds of exposures.

16 MR. MASLIA: We started down that road, and that's in
17 the next presentation or at least classifying building
18 types and the type of people that occupy those buildings,
19 and that's in the next presentation. And it significantly
20 varies by the different distribution systems, which I will
21 get into. Can I put that off until we get to that? Yes.

22 DR. UBER: A point of clarification on that, Morris:
23 You're only concerned with exposure of pregnant women.

24 MR. MASLIA: That's right.

25 DR. UBER: Okay.

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1 MR. MASLIA: That's right. Women who were living in
2 family housing, although they may have given birth off
3 base --

4 DR. UBER: Right.

5 MR. MASLIA: -- because of the movement of the
6 enlisted people, the enlisted men, as they took them off
7 base. Some of them may have been pregnant during the
8 period of exposure while on base, but then actually
9 delivered off base.

10 DR. UBER: Right. Understood. But the exposure
11 characteristics, the only ones that are of interest, are
12 the exposure characteristics of the women who had been on
13 base at some time during first trimester of pregnancy.

14 MR. MASLIA: Well, there's Dr. Bove. Let him --

15 DR. BOVE: What happened?

16 MR. MASLIA: The question was: We're interested in
17 exposure of women, pregnant women, who were on base during
18 only the first trimester.

19 DR. BOVE: No. That's for -- well, we have different
20 outcomes, end points. I know I have to get to the mike.

21 COURT REPORTER: You knew what was coming.

22 DR. BOVE: Right. We have different end points, and
23 for neural tube defects and oral clefts, it's the first
24 trimester. But we -- because there's some uncertainty as
25 to when the first trimester occurs, we asked for three

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1 months. We asked for the whole year before birth. And
2 we're looking at the first six months of that period:
3 three months before conception, three months after
4 conception because we don't know when conception really
5 is.

6 So we leave a wide window there to determine exposure
7 for oral clefts and neural tube defects. For childhood
8 leukemia, since we're not sure -- all the evidence seems
9 to indicate prenatal exposure, but we'll ask up to one
10 year of life for childhood leukemia and non-Hodgkin's
11 lymphoma.

12 DR. UBER: Okay. So you're interested in exposure of
13 women three months before pregnancy, three months --

14 DR. BOVE: Conception; yeah.

15 DR. UBER: -- three months before conception --

16 DR. BOVE: Yeah.

17 DR. UBER: And three months after conception and --

18 DR. BOVE: Because we're not sure when conception is.
19 Right.

20 DR. UBER: Right. And you're interested also in
21 exposure of infants.

22 DR. BOVE: For childhood leukemia --

23 DR. UBER: Childhood leukemia.

24 DR. BOVE: -- up to one year of life.

25 DR. UBER: But you're not concerned about exposure of

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1 active-duty military personnel who are -- I assume -- I
2 can't remember when that changed, but I assume at that
3 time they were all men.

4 DR. BOVE: Well, we're going to be asking in -- their
5 drinking-water exposure, no. No. We're concerned about
6 other exposures. We ask a wide range of questions in an
7 interview. Okay.

8 DR. UBER: But not for drinking water?

9 DR. BOVE: But not for drinking water, no. I think
10 -- we're really focused on that period of time. Okay.

11 MR. HARDING: Before you go --

12 DR. BOVE: Uh-huh.

13 MR. HARDING: Morris, let me just express --

14 DR. BOVE: I'm not going. I'll just sit there.

15 MR. HARDING: -- my understanding of how this system
16 worked and ask a question of both you and Dr. Bove, which
17 is if we go back to the case that I mentioned where we've
18 got a situation where the system operated independently
19 and was served by one water-treatment plant, then what
20 came out of that water-treatment plant was going to reach
21 a home in a matter of days or hours. It would stabilize,
22 given the operation of the tanks. But if we look at the
23 historical data we have a few snapshots here that Tarawa
24 Terrace -- Tarawa Terrace. How do you pronounce it?

25 MR. MASLIA: Tarawa.

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1 MR. HARDING: Tarawa was pretty stable. The
2 measurements that were made in the water-distribution
3 system were all within the factor of one and a half of
4 each other, it seems like. So my question here is that
5 when the wells -- the major influence then on the
6 concentrations in that system would be the cycling of the
7 wells if the wells in a well field had different
8 concentrations, which might occur three times a day, it
9 sounds like, something like that.

10 So for the question for the doctor, assuming that
11 that understanding is correct, then is: What is your time
12 resolution in terms of understanding? What kind of
13 averaging period is acceptable to you, and what kind of
14 precision on estimates of, ultimately, human intakes that
15 you're going to make as you assess this? What's your
16 level of precision both in terms of time and magnitude
17 that's -- that you need to have in order to make a
18 conclusion?

19 DR. BOVE: I mean, we're going to be looking at
20 monthly averages. So to do that, you know, at least
21 weekly levels. But beyond that, it's unclear. It depends
22 on how variable the data is, I guess. If there are spikes
23 during a particular time, we'd like to capture that. But
24 if there aren't, then, I guess, by week -- week by week.

25 COURT REPORTER: Can you go to the mike, please?

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1 DR. BOVE: Yeah. A week-by-week assessment might be
2 sufficient. You know, again, it depends on whether there
3 are peaks. If, in fact, the water that went in was also
4 the first water that came out and there are times when
5 there are slugs going out so that the tap-water sample
6 data that we have is not really reflective of what might
7 occur at the tap. In other words, you know, it may be
8 more closely related to that -- what's in that well
9 actually than -- so there would be, instead of 200 parts
10 that would bring us to the max, something like ten times
11 that much, we'd like to be able to capture that, I guess.

12 MR. HARDING: That's what my question is: Are we
13 dealing here -- orders of magnitude differences?

14 DR. BOVE: Well, that would be. Yeah.

15 MR. HARDING: Right. But, I mean, but you have to
16 answer this because you've expressed this desire to have a
17 six-month window of time. And the question is: Do you
18 need to know what happened in the third week of that six-
19 month window with a precision of two or ten or what? This
20 is what I'm getting at.

21 MR. MASLIA: Frank was asking me what we did in Dover
22 Township. And in Dover Township, they used the same
23 approach of going zero months, not knowing when
24 conception, to twelve months and the --

25 MR. HARDING: What was the resolution?

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1 MR. MASLIA: And the resolution -- the model was
2 obviously run on an hourly basis, and then we gave them an
3 average over a month period.

4 DR. BOVE: But we weren't -- we weren't -- we weren't
5 dealing with concentration at Toms River.

6 MR. MASLIA: No. No.

7 DR. BOVE: I mean, it's a tough question because
8 there's so much uncertainty. I'm more concerned about
9 being able to just determine whether people were exposed
10 or unexposed, given some of the things you'll probably
11 hear today about the confusion concerning interconnections
12 and so on.

13 But if we can get that straightened out, if I can be
14 confident that the people I'm calling unexposed are
15 unexposed and vice versa, which we -- I produced something
16 that -- yesterday that was handed out to you, which goes
17 over what happens when you can't -- when you have some
18 errors in just doing that and the impact on the odds
19 ratio. If we can get that far, then I can live with
20 weekly -- certainly, weekly estimates about resolution.

21 MR. HARDING: Well, but you're talking about were
22 they exposed in a given week or were they exposed in a
23 six-month period? Yes or no? What is it --

24 DR. BOVE: Oh, no. We -- there's two things here.

25 MR. HARDING: It's like two things here.

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1 DR. BOVE: I'm sorry. Well, I'd like to know on a
2 weekly basis whether they were exposed. Okay.

3 MR. HARDING: Whether they were exposed.

4 DR. BOVE: Yeah.

5 DR. LABOLLE: You mentioned at Toms River, you didn't
6 -- you weren't concerned with concentrations. Are you
7 concerned with concentrations here, or are you concerned
8 with mass?

9 MR. MASLIA: Let me explain here. It's not that --
10 that's probably a misstatement. It's not that we were not
11 concerned with concentrations at Toms River. We had an
12 alphabet soup of concentrations that we could not separate
13 out or get any definitive single contaminant like PCE
14 coming through there because of the way that the
15 contamination that was on hand.

16 So because of that -- and this, again, was part of
17 the epidemiologic protocol -- it was decided by the
18 epidemiologist to go after the proportionate amount and
19 look at comparative amounts of water that each of the
20 study cases received or did not receive from various well
21 fields.

22 DR. BOVE: What I meant was it wasn't part of the
23 analysis.

24 UNIDENTIFIED PANELIST: Okay.

25 DR. BOVE: It wasn't part of the exposure assessment.

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1 DR. CLARK: Morris, I had a question. This may be
2 going -- it may address this later on, but is -- have you
3 looked at degradation by-products in the distribution
4 system at all?

5 MR. MASLIA: No.

6 DR. CLARK: Okay. Because you've got a lot of cast
7 iron pipe that's going to build up a very heavy biofilm.
8 You've got lots of biological activity going on, and I'm
9 wondering, with the residence times that you have, if it
10 might not be something you might want to take a look at.
11 I assume when the analysis was done -- a lot of them were
12 done with just plain -- just the same volatile analysis
13 using GC, right, back in the early days when they were
14 looking for THMs primarily?

15 MR. MASLIA: That's what the lab notes indicate, and
16 that's what they indicate why they could not do it when
17 they saw the presence of the volatile or --

18 DR. CLARK: So there's no attempt to try to, say,
19 differentiate to see if vinyl chloride might be possibly
20 one of the by-products or not?

21 DR. BOVE: Well, they did later.

22 MR. MASLIA: Later on, they did.

23 DR. BOVE: Not during the THM -- not during the THM
24 analysis; no.

25 DR. CLARK: I know there's a period there when there

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1 were no methods, the standard EPA methods were volatile,
2 so...

3 DR. BOVE: The issue's about biofilms and residence
4 time.

5 MR. MASLIA: Not in Tarawa Terrace. It was --

6 DR. BOVE: Okay. So there's no dead-ends.

7 DR. CLARK: But there were -- do you know what --
8 well, you know what the residence times are in terms of
9 the system tanks and so forth; right?

10 MR. MASLIA: From what we found from our field
11 information -- and I'll present that --

12 DR. CLARK: Okay.

13 MR. MASLIA: -- the residence times may be forever.

14 DR. CLARK: Okay.

15 MR. MASLIA: And that's one of the issues that we
16 discovered -- or when I say we discovered, during our
17 field testing -- and I'll get to that. I'll just jump to
18 the punch real quick. Even though we allowed fluoride to
19 dilute over a two-week period down to .1 or .2 milligrams
20 per liter, the tanks are still showing one or a little bit
21 above after that.

22 DR. CLARK: So there is the potential then for very
23 long residence times, biological action, and --

24 UNIDENTIFIED PANELIST: (Off microphone)

25 MR. MASLIA: Not the -- I mean, it is.

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1 DR. WALSKI: Well, but just the opposite though.
2 When you had the tanks off-line, that means everybody gets
3 very fresh water. The water in the tank just sits there,
4 and so 99 percent of the people get water that goes
5 straight from the plant to their house, which means the
6 residence time on average is, you know, hours only in the
7 system, not days. And the water in the tank just sits
8 there.

9 MR. MASLIA: Right.

10 DR. WALSKI: It may dribble back in a little bit --

11 MR. MASLIA: Talking about in the tanks?

12 DR. WALSKI: Yeah, right; in the tanks. The tank
13 water doesn't get consumed. So therefore that water is
14 basically almost off-line except during a fire or
15 something is the only time that water gets drained out of
16 the system. So for the most part, the residence time on
17 average is extremely short in a system like this.

18 MR. MASLIA: Except we've seen both, both cases. And
19 I'll get into that now perhaps. But we've seen in a later
20 test the tanks filling and drawing, and I've got some data
21 to show that. So --

22 DR. CLARK: Well, I think it depends a lot on what
23 the record shows as far as tank operation is concerned.

24 MR. MASLIA: So that -- again, our attempt or our
25 concept was, if I can summarize this, is if we felt -- if

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1 we could really understand the present-day operation, that
2 would shed a lot of light on historical operations since
3 we were told they were operated in a similar manner or the
4 operation was in a similar manner, and that was our --

5 DR. CLARK: So it sounds like there were times when
6 the residents would get water that was fairly aged.

7 MR. MASLIA: There were times; yes.

8 DR. WALSKI: But it would be aged in tanks though,
9 not in pipes with contact with the biofilm that much. In
10 the tank, you don't have much contact with the wall.

11 MR. MASLIA: Right. But again, we've got data to
12 show both cases or at least our interpretation of it, that
13 it shows both cases.

14 DR. CLARK: You still have biological activity taking
15 place in the tank, too, as you know. So those are just
16 some issues I thought that you might want to at least kind
17 of chalk up and take a look at.

18 MR. MASLIA: We'll definitely note that down. And,
19 in fact, we're looking at different tank-mixing models,
20 just to let you know. Are there any other questions,
21 suggestions, comments, or -- because what I'd like to do
22 is get into the specificity of the present-day system and
23 the field testing that we've done and perhaps address some
24 of the issues that have been brought up this morning and
25 go from there. Is that okay with the panel?

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1 (No audible response)

2 MR. MASLIA: Okay. Present-day system. Okay. We
3 started preparing to do some field tests. Again, the
4 present-day information, we had some production
5 information from the utility operators, but specificity as
6 far as hydraulics in the present-day system were not
7 available, and we were, again, interested in ultimately
8 travel times of potential contaminants. So we developed a
9 field-testing program. And so we gathered information on
10 pipeline locations.

11 I've described how we have obtained that for the
12 present-day storage tank locations; high-lift pump data;
13 operational data -- I'll get into the controlling tanks in
14 a minute -- and production data; and what I'm referring to
15 housing data and facilities' use data, classifying the
16 different building types.

17 The approach was to construct present-day models, and
18 we've done that for the three different areas: for the
19 Tarawa Terrace, the Holcomb Boulevard distribution system,
20 and the Hadnot Point. And the data that we were
21 interested in gathering would be the hydraulic data,
22 pressure, C-factor data for pipeline characteristics,
23 operational data. This is including the controlling tanks
24 and the on-off cycling of pumps, pipe-flow data, and
25 travel-time data.

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1 Primarily, our thought behind the flow data was that
2 since we didn't have individual household meters and
3 household consumption, if we could get an aggregate of
4 small areas where the type of housing were homogeneous,
5 then we could get a present-day per capita use and per
6 diurnal type curves to service for that particular area,
7 and that was our thought behind the flow metering.

8 So as of right now, we've got three hydraulically
9 independent models. We're assuming here's where the
10 interconnection between Hadnot Point and Holcomb Boulevard
11 are. There are two sets of valves, one here and one here,
12 that are closed off. And so we've got a model for the
13 Tarawa Terrace-Camp Johnson area --

14 MR. HARDING: Morris, I got an ADH --

15 COURT REPORTER: Mike please. I didn't get it.

16 MR. HARDING: I'm color blind. I can't really make
17 out that pointer very well. Can you just linger a little
18 longer or point with your --

19 MR. MASLIA: Okay. Can I go over there and point to
20 it? Will that be okay?

21 MR. HARDING: That would be great. Just where the
22 valves are because that's a critical issue for me.

23 MR. MASLIA: Is there a pointer over here? How about
24 the pointer and that way?

25 MR. FAYE: Grab the radio mike.

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1 MR. MASLIA: Thank you.

2 COURT REPORTER: Now you're getting it (laughter).

3 MR. MASLIA: Is that on?

4 MR. FAYE: Yeah.

5 MR. MASLIA: Okay. This is the Hadnot Point area --

6 MR. HARDING: Right.

7 MR. MASLIA: -- to the south, and there's an
8 interconnection valve here and one over here or a set of
9 valves actually that they maintain closed for the present-
10 day system. This area up and to here is what we're
11 referring to as the Holcomb Boulevard water-distribution
12 system. And then this pipe right here from the treatment
13 plant provides water to the ground storage at Tarawa
14 Terrace. And then based on demands and the controlling
15 tank right here, that's how water is distributed within
16 the Tarawa Terrace area up north.

17 Previously, when we mentioned the Montford Point
18 here, that was in this area over there, which is present
19 day no longer in existence at that treatment plant.

20 MR. HARDING: So when Tarawa Terrace was isolated, it
21 was that pipe that crosses Northeast Creek there right by
22 the 30, TT-30?

23 MR. MASLIA: Right there. This pipeline comes over
24 there. And if you cross the bridge, you can actually see
25 the pipe tied or bolted underneath the bridge, the bridge

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1 there. And it comes into here. So what's left -- this is
2 where the original or the former Tarawa Terrace treatment
3 plant was. So the pump house is still there. They've got
4 four high-lift pumps there. And the reservoir,
5 underground storage tank, is still there. Just the
6 treatment facility is no longer there.

7 MR. HARDING: Now, if I recall from the materials,
8 there was a failure in that pipe due to freezing; is that
9 right?

10 MR. MASLIA: That, I believe -- we discussed this
11 yesterday. And I believe that's this pipe right here, and
12 that is information we're still trying to get some more
13 definitive documentation on. It's a report that was
14 written in 1991 by Geophex out of Raleigh, North Carolina.
15 We've got a contract number. We have no author that's on
16 it.

17 We're trying to really -- and it makes a statement
18 that two years prior, meaning about '89 or so, which is
19 outside the study period -- but that might be some
20 indication that there may have been other times that there
21 may have been some interconnections, but that's some of
22 the data discovery that we still need to figure out and
23 find a resolution on.

24 MR. HARDING: Well, there's valves on the pipe -- the
25 systems are isolated or were isolated by valves; right?

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1 MR. MASLIA: This system and this system were
2 isolated.

3 MR. HARDING: So the indication was that pipe was
4 only constructed after 1985, the one across Northeast
5 Creek?

6 MR. MASLIA: Yes. That would be correct.

7 MR. HARDING: Okay.

8 MR. MASLIA: Okay. In other words, because prior to
9 the closing of this treatment plant, this treatment plant
10 took care of this area here. So there would be no need
11 to --

12 MR. HARDING: But that can't be right because
13 originally Hadnot Point served the entire system; right?

14 MR. MASLIA: That was before Holcomb Boulevard plant
15 came into being.

16 MR. HARDING: So that pipe existed from the very
17 early days of Tarawa Terrace development.

18 MR. MASLIA: This pipe here?

19 MR. HARDING: Yeah. The pipe that crosses Northeast
20 Creek.

21 MR. MASLIA: That, I could not tell you. Joel, would
22 you know about that? Would that pipe have existed prior
23 to the -- no.

24 MR. HARTSOE: Excuse me. The -- what he's talking
25 about is the --

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1 COURT REPORTER: Excuse me. Microphone.

2 MR. HARTSOE: At one time, Hadnot Point served the
3 Midway Park area. That's up north, right there. And the
4 connection that he was talking about, there's two separate
5 connections between Hadnot Point and the Holcomb Boulevard
6 distribution system. But, at one time, when the Holcomb
7 Boulevard plant was not there, the Hadnot Point served
8 only up north at the Midway Park area. It did not serve
9 TT.

10 MR. HARDING: Okay. And so do we have a sense that
11 that pipe that crosses Northeast Creek was constructed
12 after 1985?

13 UNIDENTIFIED AUDIENCE MEMBER: (Off microphone)

14 MR. HARDING: Do you know when it was constructed?

15 MR. MASLIA: We've probably got that information in
16 our --

17 DR. POMMERENK: Like I indicated yesterday, there
18 seemed to be as-built drawings from 1984. And in
19 discussing a little more, there may have been a temporary
20 line for some time. But, you know, this is, like Morris
21 said, all not clear at this time, when this -- but it
22 probably wasn't -- hasn't gone on-line, you know, before
23 '84.

24 MR. FAYE: Is this on? The records that we have
25 indicate that that pipeline was constructed by June of

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1 1985 or in that fairly short time frame and it was
2 operating in June of 1985 or shortly thereafter.

3 DR. LABOLLE: Is it your understanding that it was
4 constructed to help mitigate the closure of --

5 MR. FAYE: Yeah.

6 DR. LABOLLE: -- Tarawa Terrace?

7 MR. FAYE: Yeah. There was a recognized -- they --
8 as I said yesterday, Wells TT-26 and TT-23 were shut down
9 in February of '85. That -- and Lejeune immediately
10 anticipated a water shortage for the Tarawa Terrace area,
11 up into the spring and summer months, because of that
12 shutdown.

13 So they expedited this construction of this pipeline,
14 to the best of my knowledge, so -- and it was -- to the
15 best of my knowledge, it was supplying water from Holcomb
16 Boulevard to Tarawa Terrace to supplement their existing
17 supply by the summer of 1985.

18 MR. HARDING: Okay. Morris, I have another question.

19 MR. MASLIA: Sure.

20 MR. HARDING: And so is the epidemiological study
21 driven by particular individuals or time frames, or are
22 you trying to establish the dose-response ratio? In other
23 words, could you -- after that pipeline is in place in the
24 situation in Tarawa Terrace, if the wells and the Holcomb
25 Boulevard supply both served the area -- it gets

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1 complicated.

2 But, prior to that time, it's not complicated at all.
3 The only complication is how they dispatched the wells and
4 the groundwater modeling. If I understand this correctly
5 -- anybody can jump in if they think I'm wrong here. But
6 prior to that time, you've got a much clearer picture.
7 It's not perfectly clear, but it's much clearer than it's
8 going to be after that pipeline opened.

9 MR. MASLIA: Yes. The epidemiologic study ends in
10 December of 1985.

11 UNIDENTIFIED AUDIENCE MEMBER: Last birth; yes.

12 MR. MASLIA: Yes. Last birth is December of 1985.

13 MR. HARDING: It's that last -- it's that period
14 from, potentially, 1984, some time in 1984, until December
15 of 1985 that's going to drive 90 percent or 95 percent of
16 your water-distribution effort.

17 MR. MASLIA: Plus we've got the potential issue,
18 which we've been asked on a couple of occasions now, about
19 the interconnection between Hadnot Point and Holcomb
20 Boulevard.

21 MR. HARDING: I understand. I'm just trying to get
22 one thing done first.

23 MR. MASLIA: Okay.

24 DR. WALSKI: But the point is, though, that if you
25 don't have enough information to know how to do things

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1 without the model, running this bad raw data through a
2 model isn't going to make it any better. You know,
3 because the boundary conditions are what's going to drive
4 the model. And so we're still in the -- you know, back to
5 the fundamental principle of modeling, which is: Garbage
6 in; garbage out.

7 And you don't know when those things are open or
8 closed. And you aren't ever going to know those things
9 because we can't go back in time and ask people or check
10 these things. So why model it?

11 I mean, basically, you have to say that in this
12 period we know they got contaminated water. At this
13 period, we know they didn't get it. And this period, we
14 just aren't sure and we just can't do it. And running a
15 model with wild guesses in it isn't going to make it any
16 better is the point, back to this chart here I did
17 yesterday.

18 DR. BOVE: I don't know if this is pertinent to
19 what's being raised here, but my main concern right now
20 and the problem with the previous study was that we called
21 some people, a lot of people, unexposed when they were
22 really exposed. Is that right? Yeah.

23 And if you look at the chart I produced, sensitivity,
24 which means correctly calling someone who is exposed --
25 who truly is exposed, exposed, and not calling them

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1 unexposed is a -- has a bigger impact than specificity of
2 exposure, correctly identifying the unexposed.

3 So I'm more concerned right now with being able to
4 say that these people -- certain proportion of the
5 population were unexposed and being confident of that
6 because that was the problem with the last study. And if
7 there are interconnections, we need to figure out how to
8 deal with that in our study. So, I mean, you know, I mean
9 the simplest analysis we can make in our study is simply,
10 as I said before, unexposed versus exposed and being
11 confident that we're identifying the people properly.
12 Okay.

13 Then, after that, we can talk about the level of
14 concentration and if we have the numbers. Part of the
15 constraints of our study is we have small numbers. You
16 saw the number of cases that we have to deal with. This
17 is not a large population.

18 In order to do a birth-defect study, I studied 80,000
19 births in northern New Jersey, and I still didn't have
20 enough really to -- I had small sample sizes when you
21 broke -- started breaking them down into exposure
22 categories. So this is -- you can't go too far in
23 categorizing the exposure before you really have very
24 unstable estimates for the relative risk or odds ratio.
25 So -- is this --

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1 DR. DOUGHERTY: So to summarize and prioritize, we
2 don't need to worry about the exposures at Tarawa Terrace
3 because we can pretty well guess they're all exposed.

4 DR. BOVE: Except for that period; right? The later
5 period? Right.

6 DR. DOUGHERTY: So we have -- I think we heard pretty
7 significant evidence that pumps were operating through the
8 entire study period out of Tarawa Terrace.

9 DR. WALSKI: Until they shut T-26 down.

10 MR. MASLIA: Yes.

11 DR. WALSKI: But until that date; yeah.

12 DR. DOUGHERTY: Possibly. We don't know the level of
13 concentrations at other wells. TT-25, for example, is
14 very close to TT-26, and it continued to operate, as I
15 understand, at least into '86 or '87. So what we're --
16 the real issue is worrying about the controls rather than
17 the cases. And that gets us out of Tarawa Terrace. Is
18 that fair?

19 DR. BOVE: Cases and controls is not the way that I
20 look at it. Exposed and unexposed -- we need to identify
21 who's exposed and not exposed.

22 DR. DOUGHERTY: Replace my language.

23 DR. BOVE: Right.

24 DR. DOUGHERTY: And then, is that a fair summary, a
25 first-order priority?

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1 MR. MASLIA: Yes. Yes.

2 DR. DOUGHERTY: Okay.

3 DR. LABOLLE: And that falls on -- on this connection
4 between Hadnot Point, I presume, and the Holcomb Boulevard
5 system, essentially, because the potential for an
6 unexposed population here is Berkeley Manor; is that
7 correct?

8 DR. DOUGHERTY: What's Berkeley Manor?

9 DR. LABOLLE: Well, I'm looking at this development
10 here, fed by the Holcomb Boulevard --

11 MR. MASLIA: Yeah. All the housing that would be
12 served by Holcomb Boulevard.

13 DR. DOUGHERTY: That's very helpful.

14 MR. HARDING: Now, let me just point out that on 5
15 February 1985, somebody sampled somewhere in the Tarawa
16 Terrace system and reports 80 parts per billion of PCE,
17 similar to the sampling that was done in 1982.

18 So, I mean, the whole system, if you just look at
19 these snapshots -- and we don't know what time of day,
20 what day of the week, what the circumstances were, which
21 wells were cycling. But it looks remarkably stable
22 through that period. It looks to me like even into 1985
23 you could -- it would be reasonable to think that the
24 people in Tarawa Terrace were all -- I want to make a
25 nomenclature suggestion here -- potentially exposed, in

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1 the sense that the concentrations were available at their
2 tap, should they choose to turn it on.

3 So it's a potential exposure. The actual exposure
4 occurs when they drink it, they take a shower, they bathe
5 in it. So they may have had personal habits that they
6 drank nothing but bottled water. They may have had --
7 they may have bathed rather than showered, which would
8 make a big difference in how much they actually -- how
9 much their intakes were. So we have to bear that in mind.

10 But the -- potentially, that population up there that
11 lived there, if they used the water somehow, then had an
12 exposure, had an intake. So in that whole area, up
13 through 19 -- through at least, it would seem, February of
14 1985.

15 MR. MASLIA: Would it be then your suggestion or
16 advice to just use that 80 parts per billion?

17 MR. HARDING: No. No. That would not be my advice.

18 MR. MASLIA: Okay. Then what -- then our question
19 would be --

20 MR. HARDING: I'm going to defer to the groundwater
21 people.

22 MR. MASLIA: -- is what number do we use?

23 MR. HARDING: But let me make -- the point is that
24 the water-distribution system is not a substantial factor
25 in what that concentration is. It's the groundwater.

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1 It's reconstructing the historical conditions in the
2 groundwater and then how the wells were cycled because if
3 you had a contaminated well that was used, you know, once
4 -- one day a month it's going to be real different than if
5 that well was running all the time. So you -- we have to
6 understand that. But the pipes, it seems to me, and --

7 MR. MASLIA: Would you not want -- let me -- let me
8 -- again, so I understand or at least your approach or
9 your understanding is, if we've got three, four wells, one
10 of them is contaminated or whatever and they're mixing.
11 Number one, you're suggesting that we use a simple mixing
12 model. In other words, you pump groundwater however,
13 assuming we get the information on how they're cycling.
14 Then they're -- you use a simple mixing model, and then
15 assume that that mixed mass was distributed equally to
16 everyone in Tarawa Terrace.

17 DR. LABOLLE: Yes. That's correct. During the time
18 when the systems were not connected.

19 DR. DOUGHERTY: Right. And to come back to the
20 question that you asked Ben and Ben deferred on, it
21 sounded like the first-order question was potentially
22 exposed or certainly not exposed and that we don't care
23 about concentrations for.

24 So the first priority out of that list that was given
25 to us by Dr. Bove checked off. The second one -- it seems

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1 to me -- to come back to the end of the day yesterday, all
2 of the focus should be on the source-release model.
3 That's where the focus has to be. And the attention to
4 how much at which well. That will fall out quite easily.

5 The hard part is the source term. And so you get the
6 source, and in a relatively simple mixing model, if we
7 need to get the second stage of concentrations, and the
8 first-order estimates based on observed data are that the
9 concentrations are stable, but that's only at the very
10 back of the -- at the very back of the study period. So
11 then we have to do the census work and precipitate perhaps
12 more -- careful analysis of precipitation-induced
13 accretion to get concentrations into the ground. But, you
14 know, it really -- the comments this morning were quite
15 helpful.

16 DR. LABOLLE: What source are you referring to?

17 DR. DOUGHERTY: ABC.

18 DR. LABOLLE: Okay. The ABC source itself.

19 DR. DOUGHERTY: For handling -- for handling the
20 Tarawa Terrace problem.

21 DR. LABOLLE: I think, also, as important, in my
22 experience, will be not just the source but the geologic
23 uncertainty. For a given source, different geologic
24 models can yield orders of magnitude, several orders of
25 magnitude difference in arrival concentrations to a well.

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1 And that's the kind of uncertainty that you'd be dealing
2 with there. I mean, granted, we see a few concentrations
3 here at points in time that make this system appear as if
4 it's stable. But then again, we've only got --

5 MR. HARDING: Two.

6 DR. LABOLLE: So, that -- there's, you know --

7 MR. HARDING: I understand.

8 DR. LABOLLE: -- there's not a lot to go with there
9 to assume stability in the concentration. My experience
10 has been that there's a lot of variability in the arrival
11 to wells based upon their cycling and how the systems are
12 run and variation in the source as David had mentioned,
13 so...

14 DR. KONIKOW: But the point -- one of the points is
15 that you really -- your study isn't starting until 1965 --

16 MR. MASLIA: '68.

17 DR. KONIKOW: '68. That gives you 14 years from the
18 time ABC Cleaner [sic] started. So the value in doing the
19 groundwater flow and transport model will be to, you know,
20 start the -- as best we know, they were introducing
21 contaminants into the soil, at least, through the septic
22 tanks very shortly after they started; maybe a year, maybe
23 instantly, maybe a year, maybe two years at most.

24 That gives you 12 years for it to reach the water
25 table and spread. The groundwater flow and transport

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1 models, accounting for uncertainty, heterogeneity, and so
2 on, will give you range of arrival times. But I'm
3 guessing that the bulk of your realizations will get
4 contaminant reaching the wells in that 14-year period.

5 MR. MASLIA: Oh, no question about it.

6 DR. KONIKOW: I think all of the uncertainty is going
7 to be the range --

8 MR. MASLIA: Right; range.

9 DR. KONIKOW: -- is going to be before your 1968
10 starting time. So it's worth doing those flow and
11 transport models just to demonstrate that, but I --

12 MR. MASLIA: Let me, again, and I'm not -- I don't
13 want this to come out right [sic] that I'm questioning the
14 panel. But I'm questioning you because we're, from what I
15 gather, at a critical juncture as to how we progress or
16 what direction we take. So I want to make sure, both for
17 the record and for my understanding, that -- and based on
18 what you said, Lenny, and some others.

19 It's your suggestion then that more of the effort now
20 be focused on understanding the groundwater flow and
21 transport, in fact, from the source characterization
22 through any unsaturated zone to get to arrive at a -- or a
23 reduced level of uncertainty for the concentration that
24 goes into the treatment plant. Is that --

25 DR. KONIKOW: Well, you have very limited data

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1 against which to calibrate your model. Okay. And you
2 know, in the period that you were collecting data, the
3 wells were contaminated. Okay. So if you're going to run
4 the groundwater model, it's a question of how do you get
5 from zero to that level of concentration that you're
6 calibrating. You start with an initial condition of no
7 PCE in 1954. Okay.

8 And then you start your model running. And there's
9 going to be speculation upon assumption built into that,
10 and you'll get a range of responses. My hypothesis or my
11 guess would be that all roads will lead to contamination
12 by 1968. You want to do the modeling to demonstrate it.
13 Maybe I'm wrong.

14 But you want -- the only possible outcome that would
15 differ would be a later arrival, and that may be the first
16 few years there's no exposure. I think that's unlikely,
17 but that's what you want to evaluate, and that's probably
18 the best you could hope from from all of these models.

19 MR. MASLIA: Would you look at then perhaps putting
20 some effort into different source characterization or
21 operation, a continuous source versus pulsing versus
22 operation five days a week versus seven days a week?

23 DR. KONIKOW: I don't see the point of doing that. I
24 mean, the only -- the only possible testing, in terms of
25 field testing, that might be worthwhile would be a tracer

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1 test to get a handle on travel time in this saturated
2 zone. But I would explore other -- apparently, there were
3 tracer tests done in the Tarawa Terrace area specifically
4 related to ABC Cleaners. And this comes out of a draft, a
5 National Research Council report that I saw.

6 And they say tracer tests were done there, interwell
7 tracer tests were done there. I don't know what distance
8 the wells were apart. And I don't exactly what the
9 purpose was, but there is some -- somewhere out there is
10 some information, and it would probably be useful to get
11 that. That might help pin down porosity, dispersivity,
12 and travel time.

13 MR. MASLIA: Okay. We'll look for that information.

14 DR. KONIKOW: But I'm guessing the outcome is still
15 going to be, from the start of your epidemiological study
16 to the end, Tarawa Terrace residents were exposed, which,
17 if you could support that, it kind of mediates the need
18 for more refined modeling because it's not going to yield
19 anything more than that.

20 MR. MASLIA: Then from a standpoint of being
21 conservative, from a public health standpoint, let's
22 assume we refine our groundwater understanding and we get
23 it -- get the simple mixing model and get it at whatever
24 concentration we happen to simulate going in. The fact
25 that we may or may not come out with the 80 parts per

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1 billion that was measured at the tap, is that immaterial
2 or is that of importance or should we go -- again,
3 supposing we come out with several hundred parts per
4 billion after that?

5 MR. HARDING: The 80 parts per billion, these are
6 five snapshots that we don't -- and first of all, we don't
7 know the sampling protocols, what time of day, what day of
8 the week, what the conditions were in the system. These
9 are just snapshots.

10 MR. MASLIA: Right.

11 MR. HARDING: So, I mean, in between those, it could
12 be 500; it could be two. You don't know. But the point
13 here is: After you've done the groundwater modeling,
14 you've got a one or a zero here on the breakthrough curve
15 having reached a particular well. You still have the
16 question -- and since I'm in the water-distribution
17 business, at least at this panel, I want to make sure we
18 still have a toehold on this; and that is, how the wells
19 were run.

20 You know, there's still this operational question of
21 how they cycled the wells. And if you had -- if I recall
22 correctly, there was a couple of these, two or three wells
23 -- groundwater people can may remember better -- that were
24 really contaminated at Tarawa Terrace. And then there
25 were several others that were still in operation. So

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1 they'd cycle through these.

2 So the concentrations were going to vary
3 considerably, depending on which well happened to be in
4 service at a particular point in time. And so personally,
5 right now, based on what I know, I would spend a lot of
6 time, in addition to dealing with the groundwater issue,
7 on trying to understand at least statistically how these
8 wells were operated, getting the statistics of those well
9 operations so you can -- you can do some kind of a
10 calculation of the probability that any particular person
11 was exposed at a particular time. And I have to say right
12 now that a weekly time resolution is probably
13 unreasonable.

14 You know, I just -- you know, the groundwater -- I
15 don't know. Once it's there, the well's going to be
16 contaminated, but how they ran the wells on a particular
17 day is unknown and probably will never be really known.

18 DR. BOVE: Right. And I was talking to Bob Faye just
19 a few minutes ago over there, and at the wellhead, we'll
20 have issues of seasonality; right? I mean, there will be
21 differences in recharge, so that I'd like to capture
22 because, you know, that will impact -- if we can
23 categorize exposure more than just yes/no, it will be
24 important to know whether the first trimester occurred at
25 a time of high recharge or low recharge. That would be

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1 important.

2 MR. HARDING: I don't think the recharge is going to
3 be as big an influence as to which switch on the wall has
4 been flipped.

5 DR. BOVE: No. There's two --

6 MR. HARDING: Well --

7 DR. BOVE: Right. There's two, you know, general
8 sources of uncertainty here, and I'm just focusing on --

9 MR. HARDING: You ought to pick the biggest one to
10 deal with. Spend most your effort on the biggest --

11 DR. BOVE: Well, we have a couple of issues here too
12 because we may have to do additional studies. Okay. So
13 we would like to know when that contamination actually got
14 to Tarawa Terrace. So that's why the modeling has to
15 happen, so that we know exactly when that water got there
16 because, if we have do to adult cancer study, for example
17 -- and that's probably going to be recommended -- that we
18 have a notion of how far back in time the exposure --

19 MR. HARDING: Prior to 1968?

20 DR. BOVE: Prior to 1968. Yes; absolutely. So
21 that's why it's important to do the groundwater modeling
22 and then determine that. But beyond that, as Bob was
23 telling me, there's variability at the wellhead, which we
24 have to capture. And then there's variability in the
25 system, which you're pointing out, which we have to

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1 capture.

2 Now, whether -- I just threw out weekly. I'm willing
3 to -- at this point, I'm willing to take what I can get.
4 That's what environmental epidemiologists do all the time.
5 So if monthly is the best resolution that makes any sense,
6 we can work with that.

7 DR. LABOLLE: When you refer to resolution monthly,
8 temporally, what if I told you that I can give you a range
9 of monthly concentrations and they vary over two orders of
10 magnitude?

11 DR. BOVE: It wouldn't be unusual.

12 UNIDENTIFIED PANELIST: For a medical epidemiologist.

13 MR. HARDING: Yeah; but neither is zero.

14 DR. WALSKI: The thing is you're going to know
15 they're exposed. In Tarawa Terrace, you know they're
16 going to be exposed from this time until they shut that
17 well off. And after that, they're not exposed.

18 The real hairy issue is the Hadnot Point to Holcomb
19 one. And I'm afraid there you're not going to get a: Yes,
20 they're exposed; no, they're not. You're going to get:
21 Yes, these people were exposed. No, those people were
22 not. And there's a big chunk of people that we think may
23 have not been, but there may have been a few days that
24 they got it. And that's going to be a chunk of your
25 population. You're not going to get a yes or no for those

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1 people because we just don't --

2 DR. BOVE: We have to whittle down that chunk because
3 we're going to run out of --

4 DR. WALSKI: But that's going to be archaeology and
5 not modeling. That's going to be finding out -- finding
6 those people who retired who operated the valves and
7 talking to them. And no amount of modeling is going to
8 make up for that type of uncertainty.

9 DR. LABOLLE: Have you run the binary analysis
10 already with the epi study? The one saying, you know,
11 under the assumption that Tarawa Terrace is exposed during
12 this --

13 DR. BOVE: That was the previous study. We said that
14 everyone at Tarawa Terrace was exposed.

15 DR. LABOLLE: Uh-huh.

16 DR. BOVE: And everyone at Holcomb Boulevard was
17 unexposed. And we left the Hadnot Point situation aside.
18 And we've been challenged, rightly, that the study had
19 exposure misclassification. The unexposed had a lot of
20 exposed people in them because during -- at least '68 to
21 '72, I don't know, they were getting Hadnot Point water,
22 so they were hardly unexposed. And that really attenuates
23 your odds ratio.

24 DR. LABOLLE: Couldn't you narrow that, your
25 unexposed population, to a different time frame when they

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1 actually were unexposed?

2 DR. BOVE: We could. We were going to revisit that
3 study after this effort was done. But we could do that,
4 sure.

5 DR. JOHNSON: Well, this has been really an
6 outstanding discussion, and at the risk of imposing upon
7 Mr. Maslia once again, I -- would you -- would you put in
8 a capsule statement what you think you've heard from the
9 panel?

10 MR. MASLIA: Basically, as I think said 15 or so
11 minutes ago, we need to -- my understanding is concentrate
12 on the groundwater issues. And I'll just put that in the
13 issues, including the modeling, the source, what I call
14 source characterization, a source understanding, trying to
15 either narrow or understand the uncertainties associated
16 with the groundwater parameters, infiltration, recharge,
17 things of that nature, well operation, cycling on and off
18 of the groundwater wells, and then assume a simple mixing
19 model at the plant and assume that's what the people in
20 Tarawa Terrace were exposed to.

21 DR. JOHNSON: Is that what the panel think that you
22 said?

23 DR. WALSKI: That's right for Tarawa Terrace.

24 MR. HARDING: In a summary, yes, for Tarawa Terrace.

25 DR. JOHNSON: Well, thank you. Let's move ahead.

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1 MR. MASLIA: Is there a need then to go over the
2 present-day system, or...

3 DR. JOHNSON: Yes.

4 MR. MASLIA: Okay. Okay.

5 MR. HARDING: I think -- let's get back to this
6 question here. We have an approach to establish an
7 exposed population and within some range of uncertainty
8 quantify those potential exposures and to calculate the
9 intakes that resulted from that once we know what people
10 did. That's the Tarawa Terrace area.

11 Now, I understand from the discussion that the second
12 need now is to find an unexposed -- populations unexposed
13 to the contaminants that had a similar lifestyle, you
14 know, geographic location. So we're trying to find
15 another population; right? That's our next -- that's our
16 second need here; am I correct?

17 DR. BOVE: On the base; yeah.

18 MR. HARDING: On the base being important because we
19 want them to have similar --

20 DR. BOVE: It's family housing, so they would be
21 similar. It won't differ by -- too much by housing, and
22 we can control for rank if necessary. We've done that
23 before in a previous study.

24 MR. HARDING: Right. The reason I made that point of
25 similar other exposures is we can't go off the base and

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1 find somebody -- some population. So we have to find some
2 place --

3 DR. BOVE: Not for this study. Not for this study,
4 we can't.

5 MR. HARDING: -- some place on that diagram, try to
6 find some place where you can be reasonably certain people
7 were not exposed for some certain period of time, right,
8 specified period of time?

9 MR. MASLIA: Yes. And I do have, I guess, just
10 another question to understand. Is it your suggestion or
11 understanding then, and going back to Tarawa Terrace, that
12 we would not need to know a diurnal pattern of any type
13 over a 24-hour period as far as to refine periods when
14 they did or did not most likely ingest water?

15 DR. CLARK: I think you would.

16 MR. MASLIA: We would need to?

17 DR. CLARK: That's my opinion. Yes.

18 MR. HARDING: You would only need it -- you would
19 only need it to try to go back and reconstruct the well
20 operation in my mind. Because once that water gets into
21 the pipe system, assuming there's only one source, it's
22 eventually going to reach every point in the system in a
23 matter of -- if the tanks are really irrelevant, in a
24 matter of hours. And the other -- most conditions. And
25 maybe, if there's dead-ends, it will take a little longer.

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1 But the important part of potentially understanding
2 water demand would be to go back and try to reconstruct
3 how they cycled the wells because they might bring more
4 wells on during the peak hours. They might not. If
5 they're not using the tanks, that's probably what they're
6 doing. I mean, there's only -- if they're not using the
7 tanks then they're matching their supply and their demand
8 quite well. Wouldn't you say, Tom? I mean, that's what
9 you got --

10 DR. CLARK: I thought they were using the tanks. I
11 thought that was part of what they found out from their
12 study.

13 MR. MASLIA: Yes. They found out both -- both in
14 different areas.

15 DR. WALSKI: We can't get rid of that uncertainty, so
16 why try to model it? You know, depending on -- you know,
17 Joe was operating the system in '91 and '92 and he did it
18 this way. And Johnny came in '93 and did it this way.
19 But back in '87, we had Frank did it and he did it this
20 way. And we can't -- we're not going to be able ever to
21 unravel that, I don't think.

22 MR. MASLIA: You're talking about operating the
23 distribution system?

24 DR. WALSKI: Yeah; operating the well pumps. You
25 know, we're not going to be able to unravel that it

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1 doesn't appear, other than saying on average from the
2 USGS data we know they pumped this much out that year of
3 the well. And that's about all -- that's the level of
4 resolution we're going to have. So talking about
5 hourly --

6 MR. HARDING: Monthly.

7 DR. WALSKI: Yeah. Okay. Monthly then. But
8 talking about hourly is just -- we just can't get down to
9 that resolution.

10 MR. HARDING: Do we have data for individual wells,
11 production data for individual wells?

12 DR. CLARK: Monthly, I think, isn't it?

13 DR. DOUGHERTY: I believe you said yesterday it was
14 monthly totals for the system.

15 MR. MASLIA: Yes.

16 DR. DOUGHERTY: And then we have snapshots in time of
17 the individual --

18 MR. MASLIA: Yes.

19 DR. DOUGHERTY: -- well capacities from the Tarawa
20 Terrace --

21 MR. MASLIA: We've got monthly totals.

22 DR. DOUGHERTY: -- capacities, not actual rates.

23 MR. MASLIA: We've got monthly production, raw-water
24 intake for each of the treatment plants in the eighties.
25 We're missing a couple of years.

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1 DR. LABOLLE: And some notes.

2 MR. MASLIA: And then we've got some notes on some
3 other --

4 DR. UBER: Well, you have an understanding of their
5 methodology of operation.

6 MR. MASLIA: Yes. Yes. We do have an understanding
7 with also the understanding, although it may be
8 qualitative, that they operated in a similar manner
9 historically.

10 MR. HARDING: I don't want to sound frivolous here,
11 but when going back and trying to figure out how people
12 have run things in the past, I tend to look at their
13 motivation individually. And in a public municipality
14 kind of situation, that typically is cost.

15 So they'll typically try to run their most efficient
16 resources first. They will get beat up by the city
17 council or the utilities director to try to cut back on
18 your costs. And I don't know what the motivating factors
19 for the operators here were. But you have to ask that
20 question if you're trying to go back and just come up with
21 some hypothesis about how they operated, which may be the
22 best you can do.

23 MR. MASLIA: Well, I can, perhaps, from what I've
24 observed, or we've observed, one motivation would be to
25 keep the tanks filled.

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1 MR. HARDING: Yeah. But at which wells would they --

2 MR. MASLIA: I'm saying --

3 MR. HARDING: You know, it may be that certain wells
4 were maintenance problems. So they would not run those as
5 often. It could be that they had a particular cycling
6 scheme to avoid biofouling. I don't know. But these are
7 the -- I'm not saying that we can determine that now.

8 But I'm just pointing out that when you go back
9 you're going to interview people about how they ran this
10 stuff. You're never going to know exactly. But you can
11 refine that a little bit by saying: Well, they typically
12 would run this well first because the switch was closer to
13 the -- to the office. I don't know. They didn't have to
14 walk as far. I mean, things like this happen.

15 DR. WALSKI: Well, we do have some evidence.
16 Somewhere I read here that they ran several -- they ran
17 each well several hours a day was their usual pattern. So
18 we have at least that guidance that it was fairly uniform,
19 that they didn't operate one for three months and then
20 shut it off for three months.

21 MR. HARDING: Right.

22 DR. WALSKI: It was more -- you know, several hour
23 cycles.

24 MR. HARDING: Right.

25 DR. WALSKI: So we know that the average, you know,

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1 contribution from each well over a day was fairly steady.
2 It wasn't changing.

3 MR. HARDING: And that would be, certainly, one model
4 to think about, you know, would be that they continued
5 that operation, one scenario.

6 DR. CLARK: But back to the 24-hour exposure, I think
7 you do. Particularly if you get into adult cancer studies
8 and other epidemiological studies, you're going to have to
9 have some sense of what people were exposed when. And it
10 seems to me the only way to do that is to come up with
11 some typical 24-hour cycles of exposure.

12 MR. MASLIA: That was our -- one of our motivations
13 in trying to understand or at least get some system flows,
14 present-day flows in the system. Now, that may or may not
15 be --

16 MR. HARDING: But it doesn't -- that doesn't -- what
17 matters is what goes into the system; that is, how they
18 operated the wells, the cycling of the wells. That's what
19 matters. Because once it gets into the system, that
20 defines what the profile of exposure is going to be over
21 the next several hours. If they're using the tanks, then
22 it's going to get dampened out some way.

23 MR. MASLIA: But are you saying we do not need to
24 know that -- and I'm just using throwing out numbers -- at
25 4 a.m. there's an upswing in demand? So obviously, on the

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1 Marine Corps base, perhaps, because they're showering at
2 4 a.m. And then it levels off, and then they come home,
3 you know, at 4 p.m., and the upswing goes up. Are you
4 saying -- it's my understanding that you're suggesting we
5 don't need to know that.

6 MR. HARDING: Let's separate the two issues here.
7 One is the behavior of the potential cases, the people
8 that were exposed, from the operation of the system. And
9 that information might be valuable in trying to figure out
10 how they cycled the wells. But I would -- I would not.
11 And I'm not an epidemiologist. But based on what work
12 I've done related to this, I would not try to infer what
13 people were doing from the water use of the entire system.

14 What I would do is try to look at the people, the
15 individuals, to the extent that you can interview them or
16 classify them, as to their behavior. And if you can't,
17 then use population-default probabilities that they would
18 shower at this time. If there's only one source, you're
19 never going to know. No matter what, you're never going
20 to know what happened at a particular hour. You won't.
21 You can't know that. You can --

22 MR. MASLIA: You don't think we can know that because
23 it's a specialized population on a military base?

24 MR. HARDING: I'm sorry. I was talking about the
25 water-distribution system.

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1 MR. MASLIA: That's what I'm saying. In other words,
2 when we've been on base anyway, at least our observation
3 is that, as we're conducting field tests at 6 a.m.,
4 they're all out jogging, doing exercises. Okay. So
5 they're out of the house or out of their quarters at
6 6 a.m.

7 If you look at some of our data, you see an upswing
8 in production or whatever at 4 a.m. Well, that would seem
9 to indicate somebody's using water from at 4 a.m. or using
10 more water. Let me qualify that.

11 MR. HARDING: Well, I would hope you'd see it at
12 about seven, you know --

13 MR. MASLIA: No.

14 MR. HARDING: -- when they come back from running.

15 MR. MASLIA: That's not what we've seen.

16 MR. HARDING: My point was that, in the water-
17 distribution system, you won't know the concentrations to
18 the hour. You just can't know that. The behavior of the
19 people, you know, you may be able to infer that from other
20 things you know. But I would not infer it from, at least
21 solely from, the water pattern of water use in the system.
22 That's all I'm saying.

23 DR. CLARK: But it's that combination of use and
24 concentration that's important in terms of exposure.

25 MR. HARDING: Right. The concentrations represent

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1 what I call the potential exposures.

2 DR. LABOLLE: Are the concentrations important, or is
3 it the total mass --

4 DR. CLARK I guess it depends on what you're looking
5 -- I guess if you're looking as adult cancer exposure, I
6 would think the concentrations would be important.

7 UNIDENTIFIED AUDIENCE MEMBER: We'd like to have
8 that.

9 DR. CLARK: Every epidemiologist would like to have
10 that, I would think.

11 MR. HARDING: Yeah. What Eric is saying is that it's
12 the actual mass that enters the body that matters
13 medically, and so it's a combination.

14 DR. DOUGHERTY: That depends upon the contaminant.

15 MR. HARDING: The drinking and the -- their behavior
16 because if the water is at the tap and they don't use it,
17 it doesn't --

18 MR. MASLIA: That's what I'm asking. Not to belabor
19 the point, but I'm trying to understand. If we're saying
20 we want to understand their behavior, short of having
21 activity patterns, would not a surrogate for that be the
22 development, based on data of diurnal patterns for
23 different locations within the base, knowing -- knowing
24 that they -- that you've got a specialized population
25 here. In other words, you've got --

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1 DR. KONIKOW: But is there any hope if you knew the
2 concentration at every well at all times, which you're not
3 going to? But if you did, even given that information, do
4 you know enough about when each well was pumped during the
5 day, how it connected to the distribution system, to the
6 treatment plant, to the tanks, that you could then predict
7 what the concentration distribution within the residential
8 area would be and how it varied with time on an hourly
9 basis? That's just --

10 MR. MASLIA: No. That, we do not have.

11 DR. KONIKOW: I mean, it just seems hopeless to try
12 to get hourly exposure data.

13 DR. CLARK: But you could get typical exposure
14 patterns.

15 DR. WALSKI: But they're getting the same
16 concentration every hour. So the pattern doesn't really
17 matter.

18 UNIDENTIFIED PANELIST: Right.

19 DR. CLARK: Well, it is important. I don't
20 understand your --

21 DR. WALSKI: If you're getting 80 in the morning or
22 80 at night, that's not the distribution system.

23 COURT REPORTER: I need you by the mike; one at a
24 time, by the mike.

25 DR. WALSKI: Okay. But that's not something you

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1 model. I mean, the model can -- let's say you get 80
2 during that day, and that's into the epidemiology whether
3 they drank it in the morning or drank it at night.

4 DR. CLARK: Well, it would depend on whether you're
5 using it -- you know, whether you're inhaling it, whether
6 you're ingesting it. I mean, those are very important.

7 DR. CLARK: Yeah, those are things are exposure
8 patterns and you have to be able to have that kind of
9 information. I think you could get that from a daily
10 exposure -- a daily cycle of concentration plus
11 superimposing upon that the pattern of activity.

12 DR. KONIKOW: Where are you going to get a daily
13 cycle of concentration from?

14 UNIDENTIFIED PANELIST: We're not going to get that.

15 DR. CLARK: I think you can get a typical daily
16 cycle.

17 UNIDENTIFIED PANELIST: I don't believe --

18 UNIDENTIFIED PANELIST: Where? Where would the
19 variation come from?

20 DR. CLARK: I believe you can.

21 UNIDENTIFIED PANELIST: But it goes through the same
22 place.

23 UNIDENTIFIED PANELIST: But you don't know that.

24 COURT REPORTER: Gentlemen (laughter).

25 UNIDENTIFIED PANELIST: Is she a Marine?

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1 COURT REPORTER: The record is suffering, and you're
2 not getting anything right now. This is for your advice.

3 DR. SINGH: I think we are playing a little bit of a
4 pundit here. I think the main issue is the water-
5 distribution modeling system here and how does it affect
6 the exposure. That is really the crux of the matter here.
7 That's what he's trying to get at. And as Ben pointed
8 out, as Tom pointed out, I don't think it is really going
9 to make a whole lot of difference so long as we know the
10 concentration and the depth because that is what is going
11 to determine the exposure of the people.

12 DR. CLARK: But you have to -- I think you have to
13 have the modeling to be able to predict what the
14 concentration of the tap is going to be.

15 DR. SINGH: Well, I'm not sure really if the water-
16 distribution modeling is going to make that much of a
17 difference to the concentration. I think what we need --
18 you know, what the groundwater model is giving, that is
19 really the crux of the matter. Once that -- that gives us
20 -- once it goes into the treatment plant, the water comes
21 into the pipes. I don't think the pipes are going to make
22 a great deal of difference unless, of course, as you
23 pointed out, unless we take care of the biology and the
24 chemistry, which they are not --

25 DR. LABOLLE: Well, that would be another issue.

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1 DR. SINGH: -- which they're not dealing with. Then
2 I'm not sure how it is going to really greatly impact the
3 pollutant concentration which the people will be exposed
4 to.

5 MR. MASLIA: The fact that -- given that we may not
6 be able to show a difference, you know, day to day or
7 whatever, but rather just come up with a typical day, do
8 we still need to be able to demonstrate that it is
9 insensitive in a formalized way, not just make a
10 statement, but demonstrate in a formalized, approved, or
11 acceptable method, i.e., some kind of model or something,
12 at least running it to some degree to show that this is
13 insensitive and that there's no need to refine it any
14 further?

15 DR. SINGH: Your snapshot data, on May 27th, 1982,
16 tap water at TT tested: PCE, 80 ppb. Then if you take in
17 the snapshot, February 5, 1985, TT tap water tested: PCB,
18 80 mpb. And in between, there is a little bit of
19 variation. It seems to me that really that it's not a
20 very wide range of PCE concentration in the water-
21 distribution system.

22 DR. LABOLLE: It's likely to vary more than, I think,
23 what's indicated by these two snapshots. That's just --

24 DR. BOVE: Probably an order of magnitude.

25 DR. LABOLLE: Maybe more; maybe less.

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1 DR. POMMERENK: It's just -- for example, wasn't
2 there a sample point that indicated 12,000 micrograms per
3 liter?

4 MR. MASLIA: At a well?

5 DR. POMMERENK: At a well.

6 MR. MASLIA: At a well, there was 1600 -- almost 1600
7 parts per billion.

8 DR. POMMERENK: So hypothetically --

9 MR. MASLIA: Was that Well 26?

10 UNIDENTIFIED AUDIENCE MEMBER: (Off microphone)

11 MR. MASLIA: Well 26 was almost 1600 parts per
12 billion?

13 UNIDENTIFIED AUDIENCE MEMBER: Uh-huh.

14 MR. MASLIA: Yeah; 1600 parts per billion.

15 DR. POMMERENK: Hypothetically, you know, the well
16 could have been turned on in the morning before any other
17 well was turned on, and that got into the tank. And let's
18 say we had some, you know, plug flow there. So the slug
19 of 16,000 -- 1600 micrograms per liter could have reached
20 some consumer within hours or a day. So there is a range
21 of, you know, a factor --

22 DR. DOUGHERTY: What if it proved less than that
23 because it takes multiple wells to fulfill the demand?
24 Right? Let's say --

25 DR. POMMERENK: Well, I mean if we assume --

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1 DR. DOUGHERTY: -- three, roughly three at a time, I
2 think, is what we discussed yesterday.

3 DR. POMMERENK: Well, if we assume that there's
4 always complete mixing and so on. And, of course, there
5 are reserves in the system. So they may draw some water
6 from tanks once in a while, and so...

7 DR. LABOLLE: But, certainly, that concentration in
8 that well, you know, although we see, you know, a point in
9 time 1600. It could have been 16,000, you know, the month
10 before.

11 DR. JOHNSON: Mr. Ensminger, do you wish to comment?

12 MR. ENSMINGER: Let me get up here before I get
13 yelled at (laughter).

14 There was one test at Tarawa Terrace that did show
15 215 parts per billion. And that was taken in February of
16 1985, just prior to the wells being closed down.

17 MR. HARDING: Was that a test at a well?

18 MR. ENSMINGER: Yes. And it's in the public health
19 assessment -- no; not at the well. That's at the tap.

20 MR. HARDING: What was that number again?

21 MR. ENSMINGER: 215. And it's in the public health
22 assessment.

23 DR. JOHNSON: I'd like to -- I've been getting sort
24 of a frantic message here from our recorder that she needs
25 to calibrate her recording equipment. So I'd like for us

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1 to take about a ten-minute break. We can return and
2 continue this discussion. And I would like to talk with
3 Mr. Maslia as to what you feel you need to present next,
4 if anything. Okay. So about a ten-minute break.

5 (Whereupon, a recess of approximately seven minutes
6 was taken.)

7 DR. JOHNSON: About how much time will you need,
8 Morris?

9 MR. MASLIA: Three years (laughter).

10 DR. JOHNSON: And more.

11 MR. MASLIA: No; probably 20 minutes, maybe. Is that
12 too much?

13 DR. JOHNSON: We'll give you 15 minutes. Okay?

14 MR. MASLIA: Okay. I'll --

15 DR. JOHNSON: So about ten after --

16 MR. MASLIA: Okay.

17 DR. JOHNSON: -- try to wrap it up. And then we can
18 turn to these questions.

19 MR. MASLIA: Okay.

20 DR. JOHNSON: I'm obsessed by these questions, as you
21 can tell.

22 MR. MASLIA: That's fine. I appreciate that. What
23 the presentation, continuing from this morning is intended
24 to be, is to go over what we understand about the present-
25 day system. So I'll proceed along that road.

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1 This is an example of the Hadnot Point water-
2 treatment plant. Does anybody mind if I stand out here?
3 Okay. But basically our approach is not to model anything
4 within the treatment plant but basically the flow or the
5 discharge coming out, the assumption being that nothing
6 significant would occur to the -- once the wells are mixed
7 to the concentrations within the treatment plant.

8 So what we have from a link and node point of view is
9 we're just supplying water at a node or at a point to the
10 distribution model and putting in demands and having our
11 tanks. That's the approach in all three models that we
12 have. And this information we obtained from the water
13 utility or from records that we have -- production records
14 that we have.

15 MR. HARDING: How complete are those?

16 MR. MASLIA: We have -- as Bob said yesterday, we've
17 got records in the eighties, except for a couple of years,
18 a couple of critical years. We've got sporadic
19 information, and then we also have some in the nineties.

20 This is monthly data for each of the -- it's
21 production for the total treatment plant, in other words,
22 not by well, but by what the -- the plant took in as raw
23 water and then produced and put out into the system and
24 then what we measured in the field.

25 Each system is operated -- each of the three systems

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1 is operated by using what's referred to as a controlling
2 tank. That's the one with the asterisk. And based on the
3 water level in that tank, that triggers high-lift pumps to
4 push water out into the system or fill the tanks.

5 We've done some C-factor tests. The -- this is an
6 average of all. We did eight C-factor tests. These are
7 the averages. The ones where it says "C-factor tests" is
8 an average of the tests for that particular pipe type. We
9 found that the cast iron pipes had a -- what we thought
10 indicated more of a smooth as opposed to more rough type
11 characteristic in them.

12 DR. WALSKI: Morris, roughly what percentage of the
13 pipe was cast iron versus PVC? I guess they're the two
14 main ones.

15 MR. MASLIA: I have that, and that's in the notes.

16 DR. WALSKI: Just approximately. Was it like half
17 was cast iron or 10 percent or...

18 MR. MASLIA: I want to say 60 percent, but I'm not --
19 it's in the report, and I don't have that off the top of
20 my head. But we've got a table. There was a table in the
21 report that listed it, but we can get you that number.

22 DR. WALSKI: Okay.

23 MR. MASLIA: Cast iron; yes. It's 34 percent cast
24 iron.

25 DR. WALSKI: Okay.

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1 MR. MASLIA: That's present day --

2 DR. WALSKI: Okay.

3 MR. MASLIA: -- present-day system. We've also
4 distributed or developed what we're calling demand groups,
5 and this is based on these group -- groupings are based on
6 nomenclature from a water-conservation analysis that was
7 done in 1999 for the Marine Corps at Camp Lejeune.

8 And we've got this unknown negligible group basically
9 because there was a large disparity between what could be
10 accounted for and what couldn't be. It's about 30 percent
11 difference.

12 Just to show you the distribution based on our
13 understanding. This is Hadnot Point, and you can see in
14 the Hadnot Point -- and I know -- I apologize, Ben, that
15 this is in color. So let me get a -- I'm trying to think
16 where I put the pointer now.

17 DR. JOHNSON: Use the microphone. I was referring to
18 Ben.

19 MR. HARDING: Sorry.

20 MR. MASLIA: Okay. Ben, Hadnot Point -- this is
21 really the only family housing right up in this area. The
22 area down in here is bachelor housing. And then the rest
23 would be more industrial and other offices and things like
24 that; whereas, in Holcomb Boulevard and Tarawa Terrace --
25 in Holcomb Boulevard, we've got all this area down here,

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1 down here, and down here. That's family housing. And, of
2 course, in Tarawa Terrace, we've got -- that's nearly 100
3 percent family housing with the exception of some shopping
4 centers.

5 The number of nodes that it's referring to in the
6 model is basically for in all pipes. These are all pipe
7 models, although we have also developed the network for
8 skeletonized ones as well. That is basically a short
9 description of the present-day distribution systems, and
10 now what I'll do is go through the field testing that
11 we've done.

12 DR. CLARK: One question is: Do you have a picture of
13 how pipe replacement took place over time? If it's 34
14 percent cast iron now, one of the issues is going to be, I
15 think, how much of it was cast iron under previous
16 scenarios, I guess?

17 MR. MASLIA: Here's a picture of how it took place.

18 DR. CLARK: Yeah. And do you know how much, for
19 example, in 1985, how much was cast iron?

20 MR. MASLIA: Not right offhand.

21 DR. CLARK: Okay.

22 MR. MASLIA: We don't. But we do know because right
23 now they're replacing -- substantially replacing. They've
24 got a building program, say, at Tarawa Terrace. And so
25 they're, as we speak, replacing -- replacing pipes with

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1 PVC. On the other hand, they replaced a pipe going up to
2 the Naval hospital. That's the asbestos cement pipe that
3 we did a test on, and for whatever reason, when they
4 replaced the pipe, they used asbestos cement not PVC.

5 So I'm -- for whatever reason, I don't know. I'm
6 assuming that's the way the contract -- whoever bid on the
7 contract replaced it with. Okay. Continuing on, we've
8 conducted -- we conducted a test at -- in the Hadnot Point
9 area from May 24th to 27th through monitored system
10 pressures. We retrieved storage-tank levels and we
11 conducted dual-tracer tests.

12 We injected calcium chloride, and then we also -- it
13 says injected sodium fluoride. We shut the fluoride off
14 to the -- we didn't shut it off. The utility people, at
15 our request, shut the fluoride off. And they used a
16 sodium fluoride gravity-feed system at both treatment
17 plants.

18 Just some equipment that we used to monitor: pressure
19 loggers. And these are the water-quality monitoring
20 systems. There's a dual-probe system that's ion specific.
21 In this case, it can measure fluoride and what we specify:
22 fluoride and chloride and then conductivity in the other
23 probe plus pH temperature. The single probe can measure
24 conductivity and -- but is not ion specific.

25 This is the way we attached it in the field, putting

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1 them in some plastic housing and then strapping it to the
2 hydrant and flowing the hydrant. And then we also
3 obtained grab samples as well and did some QAQC on site
4 as well as sending grab samples off to the federal
5 occupational health lab in Chicago.

6 This map here shows the monitoring locations, and
7 you've got that in the reports. We had 27 different
8 monitoring locations for the Hadnot Point. We had nine
9 pressure; nine dual-probe locations, where we did fluoride
10 and chloride; and then nine, just conductivity locations.

11 As I said, pressure ranges basically between about 55
12 and 65 PSI and fairly constant. And the topography is
13 fairly flat there as well, which gives you very small
14 hydraulic gradients. And realizing that, that was one of
15 the reasons behind us doing tracer tests, as we felt we
16 would not get any kind of unique calibration even on the
17 present day just looking at hydraulics.

18 This is some -- I'm just going to show you some data
19 from this test. This is injecting calcium chloride. This
20 is at location F-02. The red line is a model simulation,
21 and the -- or the solid line is a model simulation, and
22 the dots are the data recovered by the logger. Here is
23 an example -- this square box is the injection time and
24 at location F-01, which is -- let's see where is -- on
25 my map, it's at Hadnot Point, which is (off microphone) --

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1 COURT REPORTER: Microphone.

2 MR. MASLIA: Hadnot Point was located right over
3 here. That's F-02. And, of course, what we found out
4 that that's about a 20-hour lag and which greatly exceeded
5 what we predicted in the model even though the model
6 wasn't calibrated. And so we had thought there may have
7 been some closed valves, and post-test auditing by the
8 water utility, in fact, confirmed we had four closed
9 valves.

10 And you've also got this drawing in the notebook that
11 we gave you. But you can see right over here. Here was
12 the source at the treatment plant. So we've got down here
13 a couple of hour travel time, down in here, down to here
14 about nine hours; but all the way up to here, between 20
15 and 26 hours, right here. So that obviously shows the
16 effect of the closed valves and low demand as well. So it
17 just stayed in the system there.

18 This slide shows you the fluoride concentration in
19 the tanks. We had requested that the utility shut the
20 fluoride off on May 15th. The test took place the week of
21 May 24th. And, in fact, water samples, taken by the
22 utility within -- at the distribution-sampling point
23 showed concentrations of fluoride down around between .1
24 and .2, so it had diluted down.

25 But the concentrations in the tanks ranged between --

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1 almost averaged about one from these three tanks. This is
2 the controlling tank right down here. So, of course, it's
3 exchanging water back and forth. So it's getting the --
4 it's diluting; whereas, these tanks over here really did
5 not show much dilution.

6 This is an example of -- and it caught us by surprise
7 when we -- in the beginning since we didn't understand how
8 they were operating the tanks and that. Here is some grab
9 sample data of the fluoride, and this is a logger that was
10 near the French Creek tank, which is the controlling tank,
11 which was this tank right over here.

12 And unfortunately, we had to pull the logger for
13 technical reasons. But we still see the grab sample data
14 rising and chloride concentration indicating a slug coming
15 through here. And then 48 hours later, all of a sudden,
16 we see a slug of -- we reconnected the logger, and we see
17 a slug coming through.

18 And that is sort of what guided us and then in a
19 subsequent test in instrumenting the tanks, putting
20 loggers on the tanks and seeing that the water was not
21 mixing completely in the tanks.

22 DR. WALSKI: When you say putting a logger in a tank,
23 are you sampling the pipe going into the tank at ground
24 level or are you taking sample from inside the tank and --

25 MR. MASLIA: Not from inside. We're putting it on

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1 the pipe. And we can see -- and I've got some data to
2 show -- on a subsequent test, you can tell which is the
3 system fluoride and which is the tank fluoride --

4 DR. WALSKI: Okay.

5 MR. MASLIA: -- by the spiking, by the spiking of the
6 logger data, in other words, so you know what elsewhere in
7 the system, what the fluoride level is. And then all of a
8 sudden you see a high spike coming through the logger,
9 which is interpreted to be the tank releasing water to the
10 system. And that's when it's -- that's when you're
11 shutting off the fluoride.

12 Just the opposite is true when you're increasing the
13 fluoride in the system. You'll see low fluoride from the
14 tank now going in the logger as opposed to higher fluoride
15 from the system. And I'll show that in just a few
16 minutes.

17 Okay. We conducted the hydraulic test in the week of
18 August 25th. Again, this was to determine some C-factors,
19 and we used sort of an innovative fire-flow testing
20 technique where we opened up several -- several hydrants
21 at the -- at different times. We found eight. I think we
22 tested eight different sections of pipe. One of --
23 because of the piping construction and layout, we were
24 really trying to look at the -- get some information on
25 the Hadnot Point area. But it was just not possible to

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1 find, say, a thousand-foot long section of pipe with three
2 adjacent hydrants.

3 We scoured the maps and stuff and went out in the
4 field, and that just was not a possibility. So we did do
5 fire-flow tests in that area, but -- and for the C-factor
6 test, we used a diffuser, and then we also used a pitot
7 gauge for the fire-flow test in combination with this
8 diffuser.

9 And this is actually from the summary I showed you
10 before, the three C-factors. These are the actual values
11 that came out, and they were pretty much -- as I said, on
12 the average, they were within the literature published
13 about values. For the fire-flow tests, what we did: We
14 sort of modified the standard approach of putting a gauge
15 on one hydrant and flowing the other. What we did is we
16 used, in this case, two hydrants, flowing -- this is
17 flowing Hydrant 1 here and Hydrant 2 there.

18 So we would have a static pressure, which you can see
19 basically is about 50 to 53 psi on the observation
20 hydrants. Then we flowed Hydrant 1, which would be this
21 one, 773 gallons per minute. And you can see the pressure
22 drop across all the hydrants. Then we flowed Hydrants 1
23 and 2. So we'd flow this hydrant and that hydrant, and
24 you'd see a further pressure drop right there.

25 So that's the total flow coming out. It was about

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1 1300 gallons per minutes. And then, of course, we shut
2 off Hydrant 1 and only flowed Hydrant 2 and then go back
3 to the static case. So that one came out very well, and
4 that was to help us with calibration.

5 Finally, we conducted, based on our observation of
6 what we saw in May with the Hadnot Point with the
7 concentrations going -- or being delayed and coming in at
8 a later time than we expected at the tanks, we thought we
9 would instrument the controlling tanks.

10 So we had the water utility put some ports on the
11 pipes leading to the storage tanks, and in this case, we
12 had two controlling tanks. We had one at Paradise Point,
13 which would be right over here. That's controlling --
14 that's a controlling tank for the Hadnot Point water-
15 distribution system. And then the Camp Johnson tank,
16 which is the controlling tank for the Tarawa Terrace
17 distribution system.

18 So again, based on the water level in those tanks,
19 that's what triggers the high-lift pumps to turn on or not
20 turn on. And I just -- I showed you there. We monitored
21 the system. We used -- we've got nine of the loggers. So
22 we monitored the fluoride. We shut off the fluoride and
23 recorded as it was diluting.

24 And then we had the utility turn the fluoride back on
25 and record the increase in fluoride. We did not do any

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1 injection on this test. And so, Tom, you were asking
2 about the storage tanks. This is a picture of the
3 Paradise Point storage tank, the piping. And right over
4 here is piping going in and one coming out. And so our
5 loggers attached right here and on the outside of the
6 actual housing but -- so depending which way the water
7 would go, we would either get inflow or outflow and be
8 able to record the fluoride concentration in the logger.

9 DR. WALSKI: Is that one tap or two taps?

10 MR. MASLIA: That's two taps.

11 DR. WALSKI: It's two taps.

12 MR. MASLIA: Two taps.

13 COURT REPORTER: Microphone, please.

14 DR. WALSKI: Mike. Okay. It's two taps, but how do
15 you know that you're not getting the old -- the wrong
16 water, if you had two taps like that? That it's --

17 MR. MASLIA: If it's going -- if it's going in -- and
18 I'm trying to remember. I think it goes in --

19 DR. WALSKI: Usually, it fills through the smaller
20 one.

21 MR. MASLIA: Going in this way. Right. That's the
22 smaller pipe, going in this way. Then when it comes out,
23 it's going to come out that way.

24 DR. WALSKI: Okay. But some of the -- well, that's
25 okay. It's probably a very minor thing. Don't worry.

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1 MR. MASLIA: So here are a couple of loggers. F-01
2 is the source. That was put at the -- on the Venturi
3 meter or near the Venturi meter at Holcomb Boulevard
4 water-treatment plant. So that's essentially your source.

5 This dotted line here indicates when we shut the
6 fluoride off, which was at 1600 hours on September 22nd.
7 And then we turned it back on at 1200 hours on September
8 29th. And Logger No. 3 was located down here. So Logger
9 No. 1 is over here. Logger No. 3 is here. And you can
10 sort of see the time it takes between here and here. So
11 that's your -- you know, you could estimate an average
12 travel time from there.

13 This is the example of the loggers connected to the
14 controlling tanks. F-08 is the controlling tank at
15 Paradise Point, which is this one over here. And F-09 is
16 the Camp Johnson tank. That's basically the end of the
17 distribution system as it is today. So, for example,
18 right here, as the system water is being diluted, the
19 system water -- and that's -- our grab samples show that
20 too is down around .2.

21 So you've shut off the fluoride here, and by this
22 time the system water is down about .2, but you're getting
23 spikes of high -- high fluoride water, which is coming
24 from what's in the tanks. Okay. And then just the
25 opposite occurs when you're increasing the fluoride in the

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1 system. And, of course, this tank right here, being at
2 the end of the system, shows a much more attenuated
3 effect.

4 One of the issues we ran into and I believe we
5 resolved -- but this line down here is the flow of water
6 from the ground tank, the Tarawa Terrace ground tank. So
7 if Camp Johnson tank is the controlling tank, when the
8 Tarawa Terrace pumps come on and it's flowing water, we
9 should see changes in the water level in the Camp Johnson
10 tank. And the problem is, I believe, there was some SCADA
11 and/or telemetry issues because Camp Johnson tank is flat-
12 lining. If it's flat-lining, there should be no water
13 flowing from the Tarawa Terrace.

14 DR. WALSKI: That's not flat. That's about what
15 you'd --

16 DR. JOHNSON: Microphone. Mike; please.

17 DR. WALSKI: Okay. It's not going to drop
18 dramatically because it takes a long time. So it dropped
19 1 or 2 feet --

20 MR. MASLIA: Over here. This is flat. That's not
21 dropping.

22 DR. WALSKI: Okay. From there, it's --

23 MR. MASLIA: Yeah. Yeah. Yeah.

24 DR. WALSKI: There are -- it is --

25 MR. MASLIA: No. No. No. I'm talking about right

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1 here.

2 DR. WALSKI: But there's some issues with SCADA, in
3 that just the lag time that SCADA doesn't continuously
4 monitor and you may miss.

5 MR. MASLIA: Right.

6 DR. WALSKI: So it's not unlikely to happen, what you
7 see.

8 MR. MASLIA: Okay. Lack of -- lack of meter data.
9 We were going with the concept of a district metering
10 area. So, in other words, because we did not have -- or
11 we do not have household meters, we were going to meter
12 certain areas and then be able to come up with per capita
13 demand in that area. Sixteen meters have been installed.
14 And we've got eight in the Holcomb Boulevard and Tarawa
15 Terrace area.

16 So, for example, say, in Berkeley Manor, by knowing
17 the flows and from here, here, and here, we would be able
18 to come up with a per capita estimate or quantity. And
19 this, in fact, there's a paper that just came out in 2004,
20 talking about that. I've got the reference some place.
21 But basically, using this approach and then trying to
22 quantify the stochastic nature of the demand. And that's
23 in the Hadnot Point area, meters in the Hadnot Point area.
24 And that's it, I think. Oh, five minutes early.

25 DR. JOHNSON: Thank you. Tom.

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1 DR. WALSKI: Well, the question about the metering
2 now, you did full-pipe metering; right? You just tapped
3 whatever size pipe was there?

4 MR. MASLIA: Yes.

5 DR. WALSKI: Did you check the model to see what the
6 velocities were at those points?

7 MR. MASLIA: Actually, we've gotten into that issue,
8 and we have done that now. I mean, we have that now.
9 We've got an upflows. We've got flows. One of the issues
10 that's been run into -- let me just put this up.

11 One of the issues that we have run into with the flow
12 meters is the calibration process. And our understanding
13 is from the vendor -- of course, these meters are
14 Dynasonics, and they've got plus or minus 2 percent.

15 And the issue is at what magnitude -- if you
16 calibrate it for a higher flow and then you're actually
17 seeing a predominantly lower flow, you're going to have a
18 much larger error than that. And just the opposite: If
19 you're calibrating it for lower flow conditions and all of
20 a sudden you flow hydrants or whatever, it's not going --
21 so what we have done, we were just up there in March and
22 based on seeing the attempt for calibration and seeing
23 what we were running into -- and I can pass a couple of
24 these around and just -- if anybody wants a full copy,
25 then we'll just need to run it through our clearance

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1 people.

2 But this is meter by meter location. And we did use
3 the models as they are right now. They're not calibrated,
4 but we feel they're in the ballpark, in other words. And
5 we did both a table basically giving minimum, average, and
6 maximum simulated flows, pipe diameter and where they are,
7 as well as within each meter giving calibration
8 procedures. And then we also had graphs on some of them.
9 Where hydrants were available, we'd flow that hydrant to
10 change the flow, to check the calibration.

11 So we also did graphs. So when you go back out into
12 the field to calibrate them, we could know what ranges of
13 flows to expect. You know, basically whether you're
14 looking at flows below 100 gallons per minute or upwards
15 of 600 gallons per minute. So that's where we are with
16 that. We haven't gone back out in the field to do that,
17 but that's the next plan. I'll just pass one around.

18 (Passing document around)

19 MR. MASLIA: If the panel would actually like
20 copies --

21 COURT REPORTER: Mike.

22 MR. MASLIA: If the panel would like copies, let us
23 know and we'll run it off and get it to you.

24 DR. WALSKI: Okay. The issue I've run into in these
25 kind of meters is that, typically, the flows in the normal

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1 distribution system are very low because the pipes are
2 sized for fire flow and they're down less than a foot per
3 second and these meters are really lousy at a foot per
4 second.

5 I mean, no matter what you do, you're going to have a
6 really bad range. Almost -- usually for this type of
7 metering, you've got to go in with a smaller pipe; like if
8 you have a 12-inch line, you put in an 8-inch spool piece
9 or something like that to get the velocity higher so that
10 you get something in a range where it's sensitive because,
11 when you're down less than 1 foot per second, no matter
12 what you do for calibration, they're just lousy for those
13 ranges. So what velocities are you seeing in these pipes?

14 MR. MASLIA: Claudia, do we have those? We can get
15 those for you.

16 MS. VALENZUELA: (Off microphone)

17 MR. MASLIA: Yeah; yeah. If you don't mind showing
18 -- we'll pull that up for you, if that's okay.

19 DR. CLARK: We had some similar experiences in
20 Cincinnati when we tried.

21 MR. MASLIA: Are you saying so put them in smaller
22 diameter pipes or...

23 DR. WALSKI: Well, not so much putting them in
24 smaller diameter pipes, but make the pipe down. Like, if
25 you have a 12-inch pipe, you don't put in a -- just a

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1 12-inch meter. You put in an 8-inch meter so that the
2 velocity is higher for a little while and you have -- but
3 that's a lot more construction cost, unfortunately.

4 MR. MASLIA: Right.

5 DR. WALSKI: You want to just tap the pipe.

6 MR. MASLIA: Yes. They've just been tapped now, and
7 they've been tapped into a variety of diameter pipes.
8 I've got the diameters listed.

9 DR. WALSKI: Yeah. They range from 6 to 12. But in
10 a 12-inch pipe, to get more than 1 foot per second, you've
11 got to be really cranking the water through it.

12 MR. MASLIA: Yeah. In fact, we've got one -- well,
13 actually that one's not going to be used. We had one in
14 24-inch pipe, but that one's not being used. There's no
15 flow in that one. Basically, the majority of them are
16 12-inch pipes. We've got an 8-inch pipe and then a 16
17 inch and a 10 inch.

18 DR. WALSKI: So you need almost -- excuse me. You
19 need about 500 GPM in a 12-inch pipe to get sensible
20 velocity.

21 MR. MASLIA: Yes. Yes. Yes. And --

22 DR. WALSKI: And in most of the data, you don't have
23 that.

24 MR. MASLIA: And we've had to get that by flowing
25 hydrants.

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1 DR. WALSKI: But then when you measure it, though,
2 the actual flows you're measuring are going to be below --

3 MR. MASLIA: Right.

4 DR. WALSKI: -- the sensitivity of the gauge,
5 unfortunately. So it's going to be an issue. So -- it's
6 just going to be an issue when it comes up.

7 DR. JOHNSON: Please.

8 DR. UBER: Morris, I've just got a quick kind of a
9 boring clarification question here. I was just looking at
10 some of the hydraulic gradeline elevation in this Table 1.
11 And is this -- this is probably just a typo or something,
12 but the controlling tank in the Camp Johnson tank, which
13 is, I guess, the controlling tank for Tarawa Terrace,
14 that's indicated as having a hydraulic gradeline of 107,
15 roughly. Is that wrong, or...

16 MR. MASLIA: Which table are you looking at?

17 DR. UBER: Table 1 of -- in the present day, right
18 after the blue page in mine. The reason why I was asking
19 for -- because I was trying to look at hydraulic
20 gradelines between the different areas and that's -- you
21 know, the controlling tank in Hadnot Point is 160, and in
22 Holcomb Boulevard it's 151, and then this is 107. I can't
23 imagine there's that kind of losses.

24 MR. MASLIA: Oh, that one.

25 DR. UBER: I assume that it's a mistake.

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1 MR. MASLIA: No. No.

2 DR. UBER: No. I guess I just don't understand how
3 it operates then, but -- so -- well, if that's correct,
4 see, there's another. The other tank in Tarawa Terrace,
5 which is just, you know, a little ways away, has a
6 hydraulic gradeline of -- well, 142 plus 32. So, you
7 know, over 170 --

8 UNIDENTIFIED PANELIST: If you add that to that --

9 DR. UBER: We can't go from 170 to 107; can we?

10 DR. WALSKI: That's one of the things I pointed out
11 in my comments too.

12 DR. UBER: Oh, did you?

13 DR. WALSKI: It looked inconsistent to me.

14 DR. UBER: Oh, okay. The only reason why I was
15 asking is that -- I mean, if that were -- I was trying to
16 figure out whether there is any -- any infrastructure
17 information, having not been to this area or anything like
18 that, to indicate likelihood of, if there were
19 interconnections, what might be the possibilities of
20 shipping water between them, you know, sizes of pumps,
21 hydraulic gradeline, you know, that type of thing. And if
22 that were true, that that's a controlling tank, it would
23 seem to be hard to get water out of Tarawa Terrace --

24 MR. MASLIA: Is that just the tank level or the --

25 DR. UBER: Well, it's the hydraulic gradeline and the

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1 controlling "controlling tank."

2 MR. MASLIA: Joel, did you have or Brynn have any --

3 DR. JOHNSON: Come to a mike, please.

4 MR. ASHTON: Joel was just telling me -- that was our
5 operator -- that the elevation difference between Tarawa
6 Terrace and the Montford Point or Camp Johnson tank is
7 about 7 feet.

8 MR. MASLIA: Seven feet.

9 DR. UBER: Okay. So there's a mistake there.

10 MR. ASHTON: There must be a mistake there, but
11 there's about 7-foot elevation difference between the two.

12 DR. UBER: I don't want to belabor the point if it's
13 a mistake. I assumed that it was, but -- okay.

14 DR. JOHNSON: Well, thank you for the comment. Do
15 you have something else?

16 DR. WALSKI: Getting back to the graph that Claudia
17 put up on the screen, you're going to have problems with
18 that -- with these meters then. If the velocity is around
19 .1 to .2, you're really down at the very low range of
20 where that meter's good, unfortunately. If that's an
21 average day kind of condition that she's got there, that
22 doesn't bode well for accuracy, unfortunately.

23 DR. JOHNSON: Okay. Any further points?

24 DR. CLARK: Just a follow-up that we've even found
25 some cases where we've got negative velocities when we

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1 knew that wasn't the case. So -- yeah -- at those local
2 meters.

3 DR. JOHNSON: Morris, thank you for your
4 presentation. Why don't you have a seat there at the
5 table? And I would also ask Dr. Bove to join Mr. Maslia
6 at the table. Let us turn to the set of questions and
7 issues that the agency asked that you consider. And there
8 is a revision to this, but the revision is being passed
9 around.

10 The first question is -- and we've had some
11 substantive discussion on this already, but...

12 Are the distribution-system tests conducted to date
13 and the one planned for summer 2005 sufficient to provide
14 ATSDR with required data for reliable calibration of
15 present-day models?

16 Tom, would you like to take a lead on that?

17 DR. WALSKI: Yeah. It's outstanding. I mean, it's
18 the best data study I've ever seen, probably. And it's
19 probably more than they need for this study because you're
20 not really doing fire-flow analyses. So you don't really
21 need those high-flow tests. So, if anything, it's a
22 little bit of overkill. But they did a great job.

23 DR. JOHNSON: Other comments from the panel?

24 DR. CLARK: That was my reaction too, that they're
25 really kind of a state of the art of testing from what

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1 I've seen so far.

2 DR. JOHNSON: Turning to Question 2 then:

3 Considering the lack of household-consumption data and
4 diurnal-curve characteristics, will applying the "district
5 metering area approach," using the 16 system flow meters,
6 provide adequate and sufficient information to develop per
7 capita consumption data and diurnal-curve characteristics?
8 Are panel members aware of other approaches that could be
9 useful?

10 DR. WALSKI: Well, the more rudimentary way to do it
11 is just to do a mass balance on the system. You look at
12 flow in, plus or minus changing tank levels, on an hour by
13 hour basis. And that's usually good enough when you don't
14 have submetering because, unfortunately, as I was saying
15 here, the velocities are so low at those points that the
16 accuracy of these gauges aren't going to be that good at
17 those really low velocities. So just the mass-balance
18 approach may be adequate.

19 MR. MASLIA: Can I ask a qualifying question? Do you
20 not need to then have, you know, reliable SCADA
21 information for that?

22 DR. WALSKI: Right. Yes.

23 MR. MASLIA: Okay. And --

24 DR. WALSKI: And that's --

25 MR. MASLIA: At least we've been informed that, you

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1 know, the SCADA equipment is old at Camp Lejeune. And,
2 you know, at some points in time -- at least some times
3 when we were testing the test, there is some question as
4 to their reliability, that it doesn't have it. So that
5 was one of the issues we had discussed with the folks at
6 Lejeune is -- as to why we decided to go with a metering
7 approach. So -- but you would need the reliable SCADA
8 information then.

9 DR. WALSKI: Right. The question though is usually
10 it's a lot cheaper to recalibrate the SCADA system than it
11 is to put in all these meters and the vaults and all that.
12 But that's something where I don't know the details. So I
13 couldn't really say.

14 MR. MASLIA: Okay. I just wanted to clarify that.

15 MR. HARDING: I think we have to keep in mind the
16 purpose for the estimates of water use. And I'm not
17 completely clear on that. I think in Tarawa Terrace we've
18 decided we probably don't need it, other than to deal with
19 the well cycling. And in this particular circumstance, I
20 -- now, it's referring specifically to the work at Hadnot
21 Point; right?

22 It isn't clear to me that we're going to -- that a
23 model is required at Hadnot Point if our second objective
24 is to establish an unexposed population. So I think we
25 just need to keep that in mind. But get -- if we do want

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1 to establish hourly or subdaily water-use characteristics
2 at the water-treatment plant, then I think Tom's right,
3 that it's much easier to measure tank levels and flows at
4 the plant than it is out in the system.

5 DR. BOVE: Let me just say one thing. We do want to
6 know who was exposed to TCE. So we do want to know not
7 only who's unexposed but who -- how many were exposed to
8 Hadnot Point.

9 Originally, when we did the earlier study, we had a
10 very small group that we thought were exposed to Hadnot
11 Point. We found an odds ratio of 1.5 for small-for-
12 gestational age, if I remember right. But we would like
13 to also look at trichloroethylene if the numbers are
14 there. And the numbers would be there if we find that
15 some of the Hadnot Point water went to Holcomb Boulevard
16 for any length of time beyond '73 or whatever.

17 DR. WALSKI: Was there distribution -- or any kind of
18 distribution measurements of TCE at Hadnot Point, or is --
19 I mean, we talked to Jerry during the break and he says
20 there were well measurements, but were there any
21 distribution measurements of TCE?

22 DR. BOVE: At Hadnot Point?

23 UNIDENTIFIED PANELIST: Yeah; at Hadnot Point.

24 DR. WALSKI: Okay; because I wasn't seeing it in this
25 one list.

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1 DR. BOVE: In the old assessment, there were.

2 DR. WALSKI: Okay.

3 DR. DOUGHERTY: Let me go back -- the recorder has a
4 question.

5 COURT REPORTER: Well, the recorder didn't hear what
6 was coming from behind me, and I think it was the answer
7 to one of the questions. So it's not in the record. If
8 you want it in the record, please, identify yourself and
9 get to a microphone.

10 MS. HOSSOM: Okay.

11 COURT REPORTER: Thank you.

12 MS. HOSSOM: Hi, I'm Carole Hossom. I wrote the 1997
13 Public Health Assessment. And at Hadnot Point, I believe
14 the data shows -- excuse me -- 1400 parts per billion TCE
15 at Hadnot Point.

16 DR. BOVE: Tap sample?

17 MS. HOSSOM: Excuse me?

18 DR. BOVE: Tap sample?

19 MS. HOSSOM: Tap; drinking-water sample.

20 DR. WALSKI: Okay. Was that -- so there was one
21 measurement made there historically, or were there --

22 MS. HOSSOM: No. There were a few, but a handful.

23 DR. WALSKI: That was the range of numbers because it
24 wasn't on this summary sheet here, and that's why I was
25 asking if we had much.

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1 DR. LABOLLE: Okay. Was TCE the principal
2 contaminant there, or was there also PCE?

3 MS. HOSSOM: For Hadnot Point, TCE was the principle
4 contaminant and degradation products of TCE, not PCE.

5 MR. HARDING: Okay. While you're there, don't --
6 because if I recall correctly -- I don't have that open in
7 front me -- there was also an estimate of vinyl chloride.

8 MS. HOSSOM: Right.

9 MR. HARDING: Was that -- was that at any measurement
10 of that, or was that just a calculation based on assumed
11 degradation?

12 MS. HOSSOM: It was a -- because the laboratory-
13 detection limit was only ten parts per billion, the -- it
14 was estimated at below that to be eight. Although it was
15 not calibrated below ten, it was an estimated measured
16 value.

17 MR. HARDING: Okay. So it was detected.

18 MS. HOSSOM: It was detected.

19 MR. HARDING: But not quantifiable.

20 MS. HOSSOM: But not quantifiable.

21 DR. DOUGHERTY: So is that a quantitation limit,
22 you're talking about, and not a detection?

23 MS. HOSSOM: Correct. It was quantified, but it was
24 below the limit. So that's how it was reported as an
25 estimated detected value as opposed to not detected. Does

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1 that clarify that?

2 MR. HARDING: Uh-huh.

3 MS. HOSSOM: Okay. So Hadnot Point was TCE. Tarawa
4 Terrace was PCE; majority contaminants and then
5 degradation products.

6 DR. JOHNSON: Okay. Thanks.

7 MS. HOSSOM: Thank you.

8 DR. JOHNSON: So with regard to Question 2, Morris,
9 what do you think you have heard?

10 MR. MASLIA: I've forgot to give myself a copy.

11 MR. HARDING: Well, can I --

12 DR. JOHNSON: Please, Ben.

13 MR. HARDING: I'm still not sure we can answer
14 Question 2 yet because I'm confused again. And forgive
15 me, but, Dr. Bovey --

16 DR. BOVE: Bove.

17 MR. HARDING: Bove. Sorry. I understand now that,
18 okay, we're also interested in the TCE exposures in Hadnot
19 Point, and you talked about also looking for exposures in
20 Holcomb Boulevard. But it seems to me that -- let me just
21 see if I can frame this. And I apologize if I get this
22 garbled. But in doing this analysis, we're going to
23 compare the exposed populations to an unexposed -- I think
24 you guys call it -- case control or whatever.

25 DR. BOVE: Just keep with exposed and unexposed.

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1 MR. HARDING: Okay.

2 DR. BOVE: Because cases and controls are both
3 exposed and unexposed.

4 MR. HARDING: Okay. So we have to find -- ideally,
5 we'd like to find some populations on the base that were
6 exposed to TCE. We already have established that there's
7 a likelihood, high likelihood, that you can identify
8 populations that were exposed to PCE at Tarawa Terrace.
9 But then we also need to find a population that's
10 unexposed. So that population that's unexposed would
11 potentially be in Holcomb Boulevard during periods when
12 the two weren't interconnected.

13 DR. BOVE: Right.

14 MR. HARDING: Okay. Now --

15 DR. BOVE: But -- but there are interconnections.
16 And that's what I'm concerned about.

17 MR. HARDING: Well, representing those
18 interconnections is the complicated part of this. So the
19 question I have is -- is that: Can you select your
20 unexposed population from time periods where we're
21 reasonably certain there were no interconnections, where
22 Holcomb Boulevard operated independently of the other
23 water-distribution systems?

24 DR. BOVE: Well, that's the question, though, I
25 think; isn't it?

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1 MR. HARDING: Well, no. Is it adequate for your
2 purposes? is what I'm asking. You don't have to -- do you
3 have to -- do you have to have an unexposed population
4 that goes from 1968 to 1985, or can you pick a population
5 that, potentially, let's just say, from 1971 to 1981?

6 DR. BOVE: No. We have to be able to determine for
7 that whole period who was exposed and who was unexposed.
8 Okay. So -- and if we -- we can misclassify people as
9 exposed or unexposed, but we need to know that.

10 MR. HARDING: Okay. Well, can we have three groups:
11 exposed with some degree of certainty; unexposed with some
12 degree of certainty; and we don't know, which we put
13 aside? See what I'm saying?

14 DR. BOVE: See, the design of the study is that you
15 -- we use the whole time period as the -- I mean, the
16 population is all the births during that time period.
17 Okay. We take a sample of all the cases from that time
18 period, and we take a sample of controls. The controls
19 are supposed to give us some reflection of the exposure --
20 the proportion exposed in that population. That's the
21 purpose of a control series.

22 We're using that whole time period. So we have cases
23 during that whole time period. We'll have controls during
24 that whole time period. We need to assign exposure
25 properly to those cases and controls. So the -- in the

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1 previous study we didn't do a case-control sample. We can
2 do what you suggested because we can just -- we took
3 everybody. So we can decide, all right, we'll just take
4 this part of the population. But with a case-control
5 sample, you take a sample of that whole population. You
6 have to be able to assign exposure for that whole period
7 of time.

8 DR. DOUGHERTY: As I recall, the Holcomb Boulevard
9 came on-line in '73, the treatment plant. Is that --

10 MR. MASLIA: Between '71 and '73.

11 DR. DOUGHERTY: Somewhere in that time period.

12 MR. MASLIA: Yeah.

13 DR. DOUGHERTY: So -- and then the interconnection
14 was turned off.

15 MR. MASLIA: No. We don't know.

16 DR. DOUGHERTY: We don't know that for sure?

17 MR. MASLIA: We know --

18 DR. DOUGHERTY: And we know that --

19 MR. MASLIA: -- at certain times, we know the
20 interconnection between Hadnot Point and Holcomb
21 Boulevard. I believe it's January. There is a date on
22 the chronology. January of '85, we know there's a period
23 in there that there was an interconnection because of a
24 failure of a pump or whatever at Holcomb Boulevard. So
25 there was an interconnection.

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1 DR. DOUGHERTY: And at the other end, we know that
2 the connection at Tarawa Terrace came in somewhere in the
3 '85 and possibly '84 with a temporary line. Maybe even
4 '83, I think we heard, with a temporary line. So the
5 period prior to 1971, we can say pretty much with
6 certainty that Holcomb Boulevard people received water
7 from Hadnot Point, which makes the classification
8 straightforward. And let's see --

9 MR. HARDING: Well, you're a groundwater modeler, so
10 you shouldn't be saying that.

11 DR. DOUGHERTY: No. This is strictly about whether
12 there's a possibility as in a pipeline --

13 MR. HARDING: Yes.

14 DR. DOUGHERTY: -- that exists or doesn't exist. And
15 so we can take care of that much of the window. You can
16 fill in the rest of the blanks.

17 MR. HARDING: Well, but the reason -- I may be
18 belaboring this point. But the reason is is that I'm
19 trying to establish whether there's a way to avoid trying
20 to do the complex and the highly uncertain water-
21 distribution modeling, given the very sparse amount of
22 facts we have about it.

23 And if -- and I want to put this question to the
24 panel. Maybe you'll tell me to shut up about this. But
25 the level -- we don't need to know a lot about the diurnal

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1 patterns of demand, if we're going to use more of a mass-
2 balance approach to this. And so if we have this period
3 of time -- is it weeks? months? years? -- that we
4 absolutely must include to complete this study, that's a
5 different story than if we can pick the times when we have
6 reasonably good certainty.

7 If we have to include all of these periods, it's my
8 opinion that we have to be very honest about the very high
9 degree of uncertainty in the periods where we're doing
10 water distribution fate and transport model. So I don't
11 know. I'd like to hear what other people have to say
12 because I've beat this horse pretty hard.

13 MR. ASHTON: I would just like to clarify one thing.

14 DR. JOHNSON: Come on up.

15 MR. ASHTON: There's a little bit of confusion about
16 when the systems were interconnected. After this '72
17 plant was constructed, unfortunately, the two systems --
18 Hadnot Point and Holcomb -- they're at different
19 pressures. There are quite a bit of difference in the
20 elevation of the water tanks. So we keep, normally, those
21 belts closed.

22 The operational procedure now -- and I'm not sure how
23 long this dates back. But we contact the State when we
24 open those valves to get approval for interconnecting the
25 systems. We have two different operating permits for the

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1 systems. And so those systems are separate, and they're
2 kept separate.

3 The line that we were talking about yesterday between
4 the Holcomb system and the Tarawa Terrace system, that is
5 something that has been confused, and we're in the process
6 of clarifying it with both the construction drawings that
7 we have to install the lines and also the operators that
8 are familiar with the system. And we'll clarify that for
9 you very soon, and that's what we're working on right now.
10 But the people aren't here that have that information.
11 But we feel it's in our construction drawings.

12 DR. BOVE: Would there be a record of every time you
13 connected Holcomb Boulevard and Hadnot Point then?

14 MR. ASHTON: That's unfortunate. I don't believe
15 there is unless the State has --

16 DR. BOVE: But if you record -- that's what I mean.

17 MR. ASHTON: -- unless the State has a record, which
18 they might.

19 DR. BOVE: Okay.

20 MR. ASHTON: And I have no way of knowing what they
21 have. But we'll try to find that out. We've got a
22 request -- there's been some turnover at the State. We
23 have a request through the State to try to get -- see what
24 records they do and don't have, so...

25 MR. HARDING: Is there a distinct grade difference

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1 between the three systems, and if so, can you say
2 nominally what the -- what grades they were, what grades
3 they ran at?

4 MR. ASHTON: Yeah. I don't have the exact
5 information of the difference in the elevation between the
6 Hadnot Point and the Holcomb.

7 MR. HARDING: Which one was higher?

8 MR. ASHTON: Okay. I believe -- I believe the newer
9 system is higher, if I'm not mistaken.

10 MR. HARDING: The newer being Holcomb?

11 MR. ASHTON: Meaning the Holcomb system, I believe.
12 But I can verify that. The -- as Joel says, he wasn't
13 sure which system -- the tanks, of course, were not --
14 there were quite a bit of difference in the tank levels.
15 And, of course, we try to keep our tanks full for fire-
16 protection purposes, and that is the reason why that valve
17 is normally closed and we have two separate systems.

18 DR. UBER: Just on that point, the data in that same
19 Table 1 shows a 9-foot grade difference from -- actually,
20 contrary to what you said from Holcomb -- I'm sorry, from
21 Hadnot Point to Holcomb in that direction for the
22 controlling tanks.

23 MR. ASHTON: So you're saying that the Holcomb plant
24 is lower, you're saying?

25 DR. UBER: That's what -- just -- that's just what

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1 this data in the table shows --

2 MR. ASHTON: And I'll verify that.

3 DR. UBER: -- by 9 feet.

4 MR. ASHTON: That's -- that's -- we have records of
5 all the differences in elevations. The guys who -- the
6 guys that had that plan, he'd have it off the top of his
7 head, but I don't, unfortunately.

8 DR. UBER: Yeah. I mean, that would be -- that's, of
9 course, quite useful information to know in terms of
10 interconnectedness. So that would be -- that would be
11 good.

12 MR. ASHTON: The USGS has took with them all of the
13 elevations. So we have all that information.

14 MR. MASLIA: We have land-surface elevations at the
15 tanks.

16 DR. JOHNSON: Ben had put on the table sort of a
17 request for reaction to a proposal. I didn't hear much
18 reaction. Did I miss something?

19 DR. CLARK: I can give you my answer to Question 2,
20 and I think the answer's yes. I think it's probably the
21 best way you can go about it to develop diurnal patterns
22 using this district metering approach, given the fact that
23 you don't have other data available.

24 DR. JOHNSON: Okay. Let's move on to Question 3.

25 MR. MASLIA: Can I ask a question?

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1 DR. JOHNSON: Sure; of course.

2 MR. MASLIA: And it's sort of encompassing early --
3 both days, and it's more of a, I guess, philosophical one.
4 But I'll ask it anyway.

5 We acknowledge, both on the epidemiologic side as
6 well as the modeling side, that there's a great deal of
7 uncertainty. But what I'm hearing is -- or what I'm
8 interpreting is that perhaps we should just throw our
9 hands up even if we quantify it or make a gross
10 assumption, very simplifying assumption, and that is, not
11 degrading that approach. That may be a valid approach.
12 But then the agency still has other parties to answer to.

13 And so my question is: How does the agency go about
14 saying -- do we go about saying that this is the best we
15 can do and we can refine it no further, or do we -- that's
16 what I'm trying to clarify.

17 DR. WALSKI: Here's what I was going to suggest later
18 on --

19 MR. MASLIA: Yeah.

20 DR. WALSKI: -- but since you brought it up now, I
21 might as well talk about. It seems like -- my approach
22 would be is to take what you've got now and say, "Okay.
23 We know these people were exposed. We know these weren't.
24 We're not sure about these." And in about six months use
25 the model as best I can -- in about six months, study,

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1 write your report, and say that we could spend another two
2 or three years on this and we can refine the numbers a
3 little bit.

4 But, unless you have some hope that two or three
5 years of more work is really going to make the numbers
6 better, I think, you know, wrapping up the modeling part
7 of this in a short time and saying this is -- this is --
8 call it interim report to cover yourself. But say, "You
9 know, we can -- you know, in a couple of months we can
10 wrap this thing up, give you a good answer, and maybe we
11 can get it 2 percent better if we spend another three
12 years on it or something" is the way, I think, it's going
13 to all play out is my prediction. And I could be totally
14 wrong in it. You probably have some people...

15 DR. JOHNSON: And my opinion is: Someone who doesn't
16 know much about this whole area of work, they're -- one of
17 the parties you have to be concerned about is the
18 scientific community. And I always found it very useful
19 to try to anchor on those data that you had confidence in.
20 And things that might rise to the level of speculation you
21 discard, unless there's some really good reason for doing
22 otherwise.

23 And so your response to those other parties who may
24 want you to do God-awful things that may surpass your
25 ability to do, you simply have to say that that's not

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1 possible. The science just doesn't take us that far. And
2 we are going to base our work, whether it's in the area of
3 water modeling or epidemiology, on the most reliable data
4 in which we have confidence. And that's as far as we can
5 go. That's as far as the science will let us -- take us.

6 DR. BOVE: Well, I still think there's a lot of work
7 that could be done to get other data that's available,
8 both records from the state, if necessary, or other memos
9 and material that might give us a sense of how -- whether
10 these systems were in -- used in an interconnected
11 fashion.

12 And so I think that that's, more than modeling, is
13 what I would push for. It's a lot more of getting that
14 information from the vault that would help us clarify some
15 of these questions.

16 DR. JOHNSON: That may be true, but you have to ask
17 the question of: Well, what's it worth? And what am I
18 willing to invest to go beyond what I have now with which
19 I have some confidence? And as Tom characterized it
20 earlier this morning, you're getting into perhaps the area
21 of archaeology and that's -- may be quite appropriate. Do
22 you -- I think you have to do something akin to kind of a
23 cost-benefit effort to determine if it's worth it.

24 MR. HARDING: I would say that along those lines that
25 the question can be framed as: Where do you want to spend

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1 your resources? And let me first respond to Morris and
2 say, if you're interpreting what I was saying, I'm not
3 saying throw up your hands at all.

4 What I'm -- what I'm advising is essentially the same
5 thing here is that we ought to ask ourselves: Where can we
6 get the most bang for our buck? And if I had to say right
7 now where that is, it's in trying to refine the
8 understanding of when the contaminants reached the wells
9 at Tarawa Terrace and then -- I don't think we have much
10 of an understanding about what happened at the wells at
11 Hadnot Point if we're looking for exposures to TCE. So
12 those are two areas where more emphasis could be put than
13 on the water-distribution modeling.

14 And then when we get back to this issue of Holcomb
15 Boulevard, the purpose of the Holcomb Boulevard analysis
16 is to establish unexposed populations. And I think that
17 you have to ask yourself: If we've got these sporadic and
18 poorly defined periods where there was potentially some
19 contamination in that system, think about whether you can
20 exclude those periods from your analysis as a way of
21 saving a huge amount of effort that can be spent better,
22 to my way of thinking, in trying to reconstruct, for
23 example, what happened at Hadnot Point in the groundwater.

24 So that's my take on it, and that's why I've been
25 asking these questions now because I'm not sure that the

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1 -- if you want to do diurnal-demand reconstruction,
2 there's various ways to do it. But I'm not sure whether
3 you need to or not. That's my point. That's why I was
4 having trouble answering the question.

5 DR. WALSKI: The impact of your suggestion is (off
6 microphone).

7 DR. BOVE: We would lose some cases in a situation
8 where we already have a small number of cases, and we
9 would have to take a new sample of controls to fit the new
10 population we're talking about. We've already sampled
11 control, sent them to the vendor. We could -- and the
12 process of interviewing will start, as you heard, next
13 week. But that could be put on hold.

14 But my problem with this is that we don't know. I
15 mean, we can -- I guess we can -- I mean, we don't know
16 when the interconnections could have occurred, I mean, you
17 know, the water flowing back and forth. So when would you
18 say -- what groups of people, what periods of time should
19 we exclude from our study?

20 MR. HARDING: Well, let me put the question another
21 way. If you don't know when the interconnections
22 occurred, how are you going to model them? I think you
23 just have to bite this bullet. And you have to -- here is
24 our best determination of when these systems were -- you
25 have to do this no matter what. You have to say when were

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1 they connected and when were they unconnected. And what
2 I'm saying is: Once you've made that determination, don't
3 take the effort to model the interconnections.

4 DR. BOVE: No. Right. And I'd like to get these
5 records from the state, if they exist.

6 MR. HARDING: Well, I think that's -- I think that's
7 a good way to spend your money, and I think that doing the
8 archeology in a case like this may well be warranted to
9 figure out what happened. But once you've figured that
10 out, then -- then really you've got to ask the question:
11 Is it worth spending an enormous amount of energy to model
12 these relatively short periods at the expense of doing
13 what I think is more important?

14 And here, I'm speaking here as a ground -- or as a
15 water-distribution person. But I think that the
16 groundwater case at Hadnot Point is -- am I missing
17 something, or do we know anything about the historical
18 pattern of contamination at Hadnot Point?

19 DR. WALSKI: I think one of the things we talked
20 about yesterday was, it's so complex that we really can't
21 model it though. We kind of threw up our hands on that
22 one and said, "We know there was contamination, and we
23 know well-monitoring points, but there are so many sources
24 there --

25 UNIDENTIFIED PANELIST: Yeah. Didn't I hear

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1 160-something?

2 DR. WALSKI: -- but I can't tell exactly which source
3 went to which well.

4 DR. DOUGHERTY: That was the limit of information
5 that we've had to review. So the answer is: I don't know.
6 We may have some kind of generalizations.

7 DR. BOVE: I mean, we've been asked to determine when
8 contamination arrived at Hadnot Point too. I mean, this
9 is -- this was our charge early on. So forget the study
10 for a minute. We were asked that question. And there are
11 people out there who want to know the answer to that. And
12 I don't know if we can provide that, if that's what you're
13 saying, because of the multisources, and we don't have
14 that information on those sources.

15 DR. JOHNSON: I think Jerry has a point to share,
16 please.

17 MR. ENSMINGER: As far as the actual contamination of
18 the Hadnot Point water system, you have earlier recorded
19 data at the Hadnot Point system, actual analytical data,
20 than you do at the Tarawa Terrace system. You have a
21 report of October of 1980 from the Army hygienic team that
22 came in there to do the preliminary test for TTHMs that
23 identified chlorinated hydrocarbons in their water,
24 extremely high levels.

25 And behind that, in parenthesis, he wrote "solvents."

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1 And they had several tests. They didn't find the
2 hydrocarbons in Tarawa Terrace until 1982. But you do
3 have analytical data which shows the actual contamination
4 of the Hadnot Point system in 1980 prior to Tarawa
5 Terrace.

6 DR. BOVE: But we don't have it before that, and
7 that's --

8 DR. JOHNSON: Speak in the mike, please.

9 DR. BOVE: What we're trying to find out, though, is
10 when the contamination first arrived. I mean, that --
11 that's going to be the difficulty.

12 MR. ENSMINGER: Well, the hottest well in Tarawa --
13 or at Hadnot Point was Well 651. We do have the
14 historical data as to when that well was constructed, and
15 it was 1972. And it was constructed at the back corner
16 of the disposal lot, which had been in operation for some
17 30-odd years at that time. And when it was tested, it was
18 27,000 parts per billion of VOCs. I mean, it's not hard
19 to figure out that that well was contaminated the day it
20 was sunk.

21 DR. JOHNSON: Okay. Thank you very much.

22 DR. WALSKI: But you don't need a model to prove that
23 though. I think that's the point. We can do that without
24 doing sophisticated modeling for that.

25 DR. CLARK: Frank, what do you think the potential is

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1 for getting more data from the state that may be better to
2 find exposures in the system? Does anyone know that?
3 Does anyone know that?

4 MR. MASLIA: Early on, we -- Bob Faye and I went up
5 to Raleigh to look through the historical records, and in
6 the historical records, we found some information for the
7 forties, fifties, sixties, and then nothing after 1969
8 until the 1990s. There's not a single sheet anywhere.

9 DR. JOHNSON: Okay. I want to move on to Question 3.
10 Is ATSDR's approach of developing three water-distribution
11 system models appropriate to address answers needed for
12 the epi study?

13 DR. CLARK: I think it is.

14 DR. JOHNSON: Lord love you for that. Thank you for
15 that answer.

16 MR. HARDING: I don't think, based on what I know,
17 that it makes sense to develop models for these systems.
18 That's based on what I know right now is, that in the
19 sense of using a modeling code -- I mean, all of what
20 we're going to be doing is modeling. But a simple mixing
21 model, I think, is appropriate.

22 The time when you would need to do something more
23 sophisticated is during these periods of interconnection,
24 which we can't even define and potentially will never be
25 able to define. So based on that, I think that, yes,

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1 three models are appropriate. But they aren't -- they
2 don't need to be a fully sophisticated hydraulic water
3 distribution fate and transport model.

4 DR. JOHNSON: Well, that's a substantive comment.
5 How does the rest of the panel feel?

6 DR. LABOLLE: I thought I heard something previously
7 regarding the need to go back historically, in a related
8 study or as part of this study or an extended part of this
9 study, and look at cancer risks. And in that context, I
10 think, I see that the Hadnot Point was connected with the
11 Holcomb Boulevard system during the period that you had
12 mentioned.

13 And if that's the case, possibly in those -- you
14 know, those subtime periods there where there's the
15 interconnection is here, employing. But other than those
16 periods, I tend to concur from what I've heard here that
17 the sophistication in the models may be sufficient at this
18 point to answer some of the questions.

19 DR. CLARK: I think the sophistication should be at a
20 level that you can create some typical diurnal-exposure
21 curves. That's my opinion.

22 DR. WALSKI: Mine is that it's probably not worth the
23 effort, given the amount of data we have here. We'll
24 disagree to --

25 DR. CLARK: We'll disagree on that.

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1 DR. JOHNSON: James.

2 DR. UBER: I think that -- so first of all, the issue
3 of interconnectiveness is different from the issue of
4 understanding temporal -- or diurnal variation in
5 concentration. What I'm hearing and what I would agree
6 with is that more archaeology on the interconnectiveness
7 should precede further refinement of the water-
8 distribution system models.

9 I think that if you found through the archaeology
10 that the interconnections were frequent and of long
11 duration that that would be different from finding out
12 that, you know, there was never any period when Holcomb
13 was putting out less than one MGD. And therefore, from a
14 simple flow balance, you cannot have had significant
15 contribution of water in that area from another system,
16 you know.

17 So I think that -- I think that the effort needs to
18 be driven by those kinds of factors. I frankly don't
19 think that the information is on the table right now to
20 know -- to answer that question.

21 DR. KONIKOW: The distribution model -- in terms of
22 when the interconnection was opened, I'm assuming that
23 that connection was not the only source of water to
24 Holcomb Boulevard, or was it? Because if it wasn't, then
25 the distribution model could help refine which

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1 neighborhoods or sections received water from Hadnot Point
2 versus which did not. And that might be very useful.

3 MR. MASLIA: Right.

4 MR. HARDING: I might add that the point Jim made
5 earlier on the elevations of these tanks will prove to be
6 critical in that assessment because, if our goal is to
7 isolate the Holcomb Boulevard population, if that ran at a
8 higher grade than Hadnot Point, then we've got the answer.
9 But it isn't clear at this point.

10 DR. LABOLLE: I think, also, it's important to keep
11 in mind that when you're all done and you're refining, for
12 example, these diurnal curves that the source
13 concentrations to these systems are going to vary over
14 orders of magnitude potentially. And potentially -- and I
15 say "vary in time" -- the actual source may have.

16 And the uncertainty is potentially an order of
17 magnitude or more, two orders of magnitude, in these
18 concentrations at the wells. And that's due to both
19 geologic uncertainty and uncertainty in the source
20 concentrations, as David has brought up, so...

21 DR. JOHNSON: So what have you heard, sir?

22 MR. MASLIA: Well, I go on vacation in about six
23 months. No. The -- I mean, we're still -- we're still
24 talking about two major issues. One is data discovery,
25 and the other, again, is basically using simplified mixing

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1 models.

2 DR. JOHNSON: I heard a rather strong endorsement
3 that the "archaeology" should be, maybe, pushed before
4 other things -- pushed ahead before other things.

5 DR. CLARK: Is archaeology the same thing as data
6 discovery?

7 UNIDENTIFIED PANELIST: I would agree with that;
8 yeah.

9 DR. JOHNSON: Yes, I think it is. Turning to
10 Question 4: Based on information provided by ATSDR -- to
11 ATSDR by U.S. Marine Corps, pipelines connecting to Hadnot
12 Point water-treatment plant service area with the Holcomb
13 Boulevard water-treatment plant service area were opened
14 for emergency purposes only.

15 Does the panel agree with the ATSDR approach that,
16 because of this characteristic, these two areas can be and
17 should be modeled as two separate water-distribution
18 systems?

19 DR. UBER: The answer to that is easy. That's -- if
20 we answer yes to that, then -- then that -- then we don't
21 need to do the archaeology, and we probably don't need to
22 do the distribution-system modeling with -- you know, I
23 know that Bob feels differently. So I would say that --
24 I would say that the answer to that is that you have to do
25 -- I haven't seen the archeology to support saying yes to

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1 that.

2 MR. HARDING: The answer is: Challenge the predicate.

3 DR. UBER: Yeah.

4 DR. JOHNSON: Excuse me?

5 MR. HARDING: Challenge the predicate.

6 DR. JOHNSON: Challenge the predicate. Do others
7 wish to weigh in on this? Peter?

8 DR. POMMERENK: I can just agree with the previous
9 two speakers. If, for example, during main breaks, those
10 valves were open to supply, you know, a portion of either
11 system and we can -- certain windows occurred and how
12 long, you know, the question would be then: Is that of
13 significance for the epi study, if it's just a one-day
14 interconnection or not.

15 And, you know, if it's not, then, yeah, there is two
16 separate systems, and we -- I agree you won't need the
17 sophistication of the water-distribution system modeling
18 that is conducted right now.

19 DR. JOHNSON: Anyone else? I gather this is ATSDR's
20 preferred direction: to consider them as two separate
21 systems; is that right?

22 DR. BOVE: Not if it's not true, it isn't.

23 DR. JOHNSON: I don't think that was part of my
24 observation.

25 DR. BOVE: Sure, that would be the easiest thing.

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1 DR. JOHNSON: What will you need to know in order to
2 make that decision?

3 DR. BOVE: Well, if it was just one day, you know, we
4 probably wouldn't have to worry about it. But if it was
5 for months at a time that the water was flowing from
6 Hadnot Point to Holcomb Boulevard, then we need to know
7 that. I mean, I don't --

8 DR. JOHNSON: I understand. Okay. Question 6: An
9 innovative approach for fire-flow testing was employed at
10 Camp Lejeune, using continuous recording pressure monitors
11 simultaneously at several fire hydrants while different
12 combinations of hydrants were flowed. Is this approach
13 technically sound and beneficial? Ben.

14 MR. HARDING: It seems sound to me. It's better than
15 anything I've seen. So Tom's gone into a moment here.
16 But it's a really interesting approach, and it seemed to
17 work real well.

18 DR. POMMERENK: We've done a similar approach at a
19 different military base where we had continuous pressure
20 recorders, and it works very well. And I'm glad to see
21 that employed in this study as well.

22 MR. HARDING: I would make this point, that in terms
23 of calibrating the model you do need to have good data on
24 the tank elevations. And so if you've had doubt about the
25 SCADA system, those ought to be resolved because that's

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1 the other boundary condition you need.

2 DR. CLARK: Did you skip the question on: Should
3 ATSDR consider using probabilistic analyses deliberately,
4 or was that --

5 MR. MASLIA: I think -- I mean, we answered that. I
6 don't have an extra copy of the sheet I handed out, but is
7 that grayed out?

8 DR. JOHNSON: Oh, that was my oversight, to be
9 blatantly honest with you. And you can write that off to
10 early dementia. And we will return to that. I thank you
11 for making that observation. Eric, do you have a comment?

12 DR. LABOLLE: No. It was the same comment about the
13 earlier question.

14 DR. JOHNSON: Well, with my apologies, let us return
15 then to that previous question: Should ATSDR consider
16 using probabilistic analyses to assess the variability and
17 uncertainty of, one, water distribution-system model
18 parameters; two, nodal demands; and three, system
19 operations? If so, what specific methodologies would the
20 panel suggest or recommend?

21 MR. HARDING: Well, the answer in my mind is, to the
22 general question of using probabilistic analysis is, yes.
23 We had significant discussions about what needs to be
24 represented here in a simulation.

25 And -- but what does get represented should be

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1 represented as uncertain variables in a probabilistic
2 framework, and the most commonly accepted and readily
3 accessible technique for that is Monte Carlo simulation of
4 one sort or another.

5 So I think that ATSDR should not just consider using
6 probabilistic analysis. They should do that, and they
7 should frame the resulting intakes -- what I call intakes,
8 body intakes, of these materials in an empirical or
9 calculated set of credibility ranges based -- you know,
10 with probabilities assigned to them. That's my view.

11 DR. CLARK: I think that it would be great if they
12 can do that; yes. One technique that they might look at
13 is the PRP approach that Steve Buchberger is using at the
14 University of Cincinnati for individual household use and
15 -- which I think fits your -- within the framework that
16 you're talking about.

17 MR. MASLIA: Bob, would that not then require us to
18 have flow information?

19 DR. CLARK: You'd have to make some estimates about
20 individual household use; right. But you could aggregate
21 those into demands or metered demands.

22 MR. MASLIA: Well, I'm saying, but we would need some
23 metered information then.

24 DR. CLARK: If you had your -- going back to the idea
25 that you have the metered district approach.

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1 MR. MASLIA: Well, that's the question because at
2 least -- I may be jumping the gun, Dr. Johnson, as to what
3 I'm hearing. But I'll go ahead and take another
4 opportunity. What I'm hearing is that we should not
5 proceed any further with the flow meters because of
6 issues. Tom --

7 DR. CLARK: I think you should, so...

8 MR. MASLIA: Oh, okay. That's what -- I want to make
9 sure we get that out and get a clarification on that.
10 Could we have the panel address that issue? Just to give
11 you the status, they're in the ground. Okay. They're
12 operating. They're not calibrated, so...

13 DR. WALSKI: Well, I think the real source of
14 uncertainty though is the well data. So if I was going to
15 do a Monte Carlo simulation of this, I would not use
16 demands of the houses as my undetermined variable or my
17 C-factors at my variables that I would do statistics on.

18 I would use which wells are firing at which time.
19 That's the one that I would treat as the stochastic
20 variable because that's the one that's going to have the
21 greatest impact on it is which well.

22 So you say, "Okay. We roll the dice, and this is the
23 pattern of wells we're going operate, and we roll the dice
24 again and see this pattern." Because I think that's the
25 one that's going to cause the greatest variability in the

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1 results. We do have some data from the installation-
2 restoration reports and things like that as to well
3 concentrations.

4 You know, which wells were on at which time are going
5 to make the real issue and not which house showered at
6 this time versus which house flushed their toilet at that
7 time. It's not going to be what's going to drive TCE.

8 DR. UBER: I think that this question is connected,
9 in an obvious way, to all of the other ones, as far as I
10 can tell, that we've talked about. The only other comment
11 that I'd have to add is I would be -- I would be all for
12 doing things probabilistically, assuming that they can be
13 framed in a way that ends up being meaningful.

14 And my only problem with this is that I think it's
15 basically tantamount to rolling back stochastic hydrology
16 before it existed and just saying, "Should we invent this
17 over the next two years?"

18 And I don't -- I don't think that you're starting
19 from ground zero. I think you have things like, you know,
20 Buchberger's PRP model and stuff like that. But you have
21 really no -- you have no existing theory of any weight to
22 -- with which to say roughnesses are spatially correlated
23 or demands are -- how -- what their spatial, temporal
24 distribution looks like. And so I think that, you know,
25 you could get in trouble there by trying to do that.

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1 DR. LABOLLE: My experience has been that the
2 geologic uncertainty in the context of the Monte Carlo is
3 going to swamp out everything else. And that simply just
4 translates directly into the arrival curves at these
5 wells, which the sources to these systems. And as I've
6 mentioned several times, you know, can you tolerate a
7 couple of orders of magnitude, variability due to
8 uncertainty in those curves?

9 Because when you start Monte Carlo-ing geologic
10 uncertainty, that may be what you find out is the outcome.
11 And so in my experience, though, it's going to swamp out
12 other things. That may or may not be the case if you're
13 actually seeing the exposed and unexposed population
14 change based on roughness or something -- something of
15 that sort, depending upon where these interconnections
16 occur.

17 DR. BOVE: But -- see how I can phrase this. The
18 variability you're talking about, it's not a daily
19 variability. It's not a weekly variability. It's a much
20 larger time frame.

21 DR. LABOLLE: Well, we have -- you have two things:
22 variability and uncertainty. The variability in the
23 geology, it's spatial variability; and the geometry, the
24 hydraulic conductivities -- however you want to frame the
25 geologic characterization. But it's heterogeneity

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1 essentially.

2 Then we have uncertainty. What is that? All you
3 have are samples at a few points in space out there. And
4 in particular, this TT-26 at Tarawa Terrace, which appears
5 to be the main source of contamination potentially,
6 although that's uncertain too at this point. And the
7 source location are two points which have been
8 characterized somewhat, I guess, as the source by
9 monitoring well data in Tarawa Terrace by some log there.

10 But there's, for the most part, subsurface is not
11 sampled. And so all that -- all that material that fills
12 in these points, there's uncertainty there. And it's not
13 layer cake, as the models represented. At least, it's not
14 likely to be. Those are simplifications made for modeling
15 purposes, and that -- the uncertainty in that, if one were
16 to pursue modeling that, one would find, likely find, that
17 that uncertainty would translate to a great deal of
18 uncertainty in the arrival curves, and modeling that
19 uncertainty is a different level of modeling than what's
20 been proposed thus far, than what I've heard. It's not
21 simply twisting the parameters in the existing model.

22 It could be. I mean, you could approach it that way,
23 but there would also have to be a great deal of spatial
24 refinement in the vertical, potentially in the horizontal,
25 and then the way in which we change those parameters.

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1 We'd have to have some kind of geologic and context and
2 probabilistic context related to the geology and its
3 characterization.

4 MR. HARDING: I would like to really agree and
5 support the opinions of both Eric and Tom, that the
6 groundwater uncertainty is going to swamp everything else.
7 And then it's the well operation that determines the
8 introduction of the contaminants into the system. So it
9 seems to me these are the two most important factors and
10 that the -- we have to deal with the issue of
11 interconnection and whether you're going to address that,
12 but even so, those are the two most important things. And
13 those should -- and they're really uncertain, so they need
14 to be expressed in probabilistic terms.

15 DR. JOHNSON: Okay. Are there any other comments on
16 this? Let's finish with Question 7. Is it feasible or
17 necessary for ATSDR to simulate the complete 18-year
18 historical period on a continuous basis? And in red, pink
19 here, Ben, for your -- will monthly --

20 MR. HARDING: I can see it.

21 DR. JOHNSON: Just was trying to be helpful. So how
22 do we answer that? Tom.

23 DR. WALSKI: You don't need distribution modeling on
24 a continuous basis. I mean, it's nice if you want to do
25 it, but I just don't see it as being that important

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1 because essentially we don't have a good way to determine
2 which wells are operating at which times. So, you know,
3 why beat the -- this dislinear to death just because we
4 have nice models that'll solve it?

5 DR. CLARK: I agree with you, Tom (laughter).

6 DR. UBER: Our colleagues agree.

7 UNIDENTIFIED PANELIST: Even monthly simulations are
8 going to be tough, but I suspect that's what --

9 DR. LABOLLE: I would like to add something since I
10 had presented premeeting comments and suggested maybe
11 averaging exposure over the month would require continuous
12 modeling because that was my experience in another
13 modeling effort in which I was involved. But in that
14 modeling effort, we had multiple entries into the
15 distribution system, and at the time, I was thinking along
16 those lines. But this system with the single point of
17 entry during much of the time periods of interest here, I
18 don't think it's going to get you much.

19 MR. HARDING: I want to say that I think the ATSDR
20 should try to calculate the potential exposures on a
21 continuous time-series basis, whatever that time step is.
22 Now, as I've probably said a hundred times here, I don't
23 believe that in almost every case that requires water
24 distribution fate and transport modeling, but I think you
25 should try to reconstruct to your best estimate,

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1 basically, a set of probability, just empirical
2 probability distributions, for the breakthrough curves for
3 the model and for the contaminants that enter the system
4 so that you have a time series that you can then correlate
5 to the activities of the individuals. But that probably
6 doesn't require what we term water-distribution modeling.
7 It does require calculations that are really modeling, but
8 it isn't using a modeling code, continuously or otherwise.

9 DR. LABOLLE: I don't recommend monthly time stepping
10 in a fate and transport model for the groundwater as an
11 input to your system. I think that's going to end up
12 being a much smaller time scale than the information
13 that's available, simply due to constraints and the way in
14 which these models are run to get a numerically valid
15 result. And that's going to give you something, curves,
16 out of these models that are on a temporal scale, which is
17 much finer than a -- it's probably going to be fractions
18 of day, and that's the kind of output you're going to see
19 from there.

20 DR. JOHNSON: This completes these questions.
21 Morris, Frank, anything else you'd like to put before the
22 panel in the spirit of this kind of specific questioning?

23 MR. MASLIA: I'm still unclear on the flow-meter
24 issue. It's a critical issue for the agency and the
25 Marine Corps, and it may be that the panel has differences

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1 of opinion, which is fine. But I think for the record we
2 really need -- if there's any way --

3 DR. JOHNSON: You want some clarity as --

4 MR. MASLIA: Yes.

5 DR. JOHNSON: -- to position.

6 MR. MASLIA: Position; yes.

7 DR. JOHNSON: Tom, do you want to start?

8 DR. WALSKI: Well, if you've installed them already,
9 I would try and get them calibrated and see what I could
10 learn from them. But I wouldn't -- the ultimate impact of
11 that on the final bottom line of the study is going to be
12 really small. It's not -- you know, the fact is though
13 that, you know, it doesn't hurt to know that. But I
14 wouldn't really spend a huge amount of resources on it.
15 You know, try to get them calibrated because, looking at
16 what Peter just showed me, the threshold on those things
17 is like 2.2 feet per second. And most of the time, you're
18 below 2.2 feet per second, so it's questionable whether
19 you're going to get good data out of those things.

20 DR. JOHNSON: So why do it?

21 DR. WALSKI: Well, it's in there, so try it.

22 DR. JOHNSON: No. That's not a reason. Tom, that's
23 not a reason. Why do it if it's not going to give you
24 anything of use?

25 DR. CLARK: I think it -- I'm a little more

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1 optimistic than Tom in terms of what data you're going to
2 get out of it. I think that plus the flow balancing of
3 the tanks using SCADA data would probably give you a
4 pretty good estimate as to what the demands are in those
5 zones.

6 DR. JOHNSON: Peter, yes or no?

7 DR. POMMERENK: Well, I'm not quite sure whether, you
8 know, any background noise, electrical noise, at those low
9 flows will really be able to help us detect significant
10 flows in those oversized mains; that somebody indicated
11 earlier they're oversized for five of those. So, yeah,
12 the question is: Are we going to get any useful data out
13 of it? So if we have to open hydrants to perform the
14 calibration, that is -- it's fine, okay to calibrate it,
15 but in reality, this is not the flow that we usually see.
16 So my expectation is that there may be no useful data
17 coming out of that.

18 DR. JOHNSON: David, do you want to weigh in on this
19 issue?

20 DR. DOUGHERTY: No (laughter).

21 DR. JOHNSON: Okay. That's a very fair response.
22 Lenny.

23 DR. SINGH: I think it may be --

24 DR. JOHNSON: Please.

25 DR. SINGH: -- it may be opportunity to ask Morris as

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1 to his experience so far with regard to metering the flow.

2 MR. MASLIA: The -- it goes back -- one of -- the
3 concept of installing a flow-measuring device goes back
4 because of the inconsistency in the SCADA data originally
5 and trying to get at two things: getting a total flow,
6 which you can sum up from the different locations; and at
7 the same time, while you're getting a total flow, you can
8 also do the area, area-type analysis.

9 One of the issues we ran into is that we've got a
10 report, the conservation study, which admittedly is taken
11 from a water-budget standpoint -- but showed approximately
12 a 30 percent difference in water going in and coming out.
13 Of course, you can just allocate that. You know, one
14 method is just distribute that equally every place. That
15 may or may not be accurate.

16 So that was another factor, in that we've got a
17 documented approach that summed up water use and was plus
18 or minus 30 percent. From that standpoint -- that was not
19 acceptable from an epidemiologic standpoint. So those two
20 factors taken in combination led us to suggest that by
21 installing flow meters we could accomplish two things at
22 one time.

23 We would have -- we would be able to quantify by
24 summing up the various flow meters production versus flow,
25 and then really establish is that 30 percent difference

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1 reality, or was that just a method or a consequence of the
2 method that was used, the inaccuracy in that first method?
3 And at the second time -- at the second point also be able
4 to, at that point in time, determine areas, specifically
5 family-housing areas, due to the absence of individual
6 house meters.

7 At this point in time, as I said, the meters are in.
8 The modeling that we've done to date -- and I'm saying
9 this so you can understand because the comments about the
10 low flow are an issue. We had -- when we did the test
11 last May at Hadnot Point, we had -- I won't say
12 significantly -- we had larger, larger flows. And that
13 model to date, the present day, is probably the best of
14 all three.

15 The subsequent models for Holcomb Boulevard and
16 Tarawa Terrace, we've attempted to do the calibration
17 based on flow information in levels this fall and winter.
18 And that's, of course, when we've been trying to install
19 or calibrate these meters during a period, which
20 admittedly is a -- even based historically is extremely
21 low, low-demand conditions.

22 Our attempt or our plan was to have them calibrated
23 in sufficient time so for the peak-demand season, then you
24 would have the higher flows. We're still aiming for that,
25 and that's why I needed some feedback from the panel is

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1 that all our attempts to date have been trying to
2 calibrate them under exceedingly low-demand conditions.

3 DR. POMMERENK: One question: Have -- based on your
4 preliminary data collection, can you tell anything about
5 the accuracy of those meters, whatever you've measured so
6 far? Or have you collected any data and compared it with
7 -- you know, Claudia showed us that graph earlier about
8 one location. Could you compare, I mean, instantaneous
9 flow rates and maybe cumulative flow rates?

10 MR. MASLIA: Well, that's why we prepared the --

11 DR. POMMERENK: Okay. That was passed on.

12 MR. MASLIA: Yeah, it was passed on. But the concept
13 behind that -- so that when we're in the field, we
14 prepared a minimum, a maximum, and an average, then we
15 would be able to see immediately -- we have not had that
16 before -- you know, if the flow meters were somewhere in
17 between those range of flows. We'd be okay. We'd go
18 ahead with the calibration.

19 On one meter, as it turned out -- this was on the
20 24-inch pipe -- obviously, there's no flow. It turns out
21 to be a by-pass or a pipe to balance some tanks. And of
22 course, we're not -- you know, we're pulling the meter and
23 not using the meter there. As it turned out, that was not
24 a useful location.

25 But we do have some preliminary information based on

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1 the model simulation, which we're hoping would guide the
2 calibration process. However, what we -- what we have
3 seen is if you assume the meters have been calibrated and
4 we come up for QAQC, when we do flow a hydrant, you know,
5 increase the flow from up to, you know, 600, 800 gallons a
6 minute, there's a substantial difference in what the
7 meter's recording and what we're flowing.

8 What they have done for the calibration process, just
9 so everyone's clear, is they go down into the manhole and
10 strap an ultrasonic, a trans, which is plus or minus 1
11 percent. And then you read the Dynasonic, which is
12 supposed to be plus or minus 2 percent, so we figure, you
13 know, they should be within a few gallons per minute of
14 each other, and they're not.

15 DR. JOHNSON: Does anyone else wish to comment?
16 Peter.

17 DR. POMMERENK: Just one more question: You mentioned
18 the 30 percent difference between a water-conservation
19 study results and water-production records.

20 MR. MASLIA: That is -- that is correct. And that's
21 not a critique of the study. I'm just giving you --

22 DR. POMMERENK: No. I'm just wondering: What do you
23 attribute these 30 percent discrepancy to? Is that -- is
24 that mis -- over- or underestimating household demands or
25 commercial demands, or is that actually just an estimation

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1 issue so you're not assuming it's leakage, or --

2 MR. MASLIA: Well, no; no. I'm not assuming it's
3 leakage. It's both the -- what I attribute it to is that
4 methodology is a water budget, adding up, you know,
5 lavatory, sinks, showers, and things of that nature and
6 coming up that way. I don't believe -- it may be a small
7 amount of leakage, but I don't have any knowledge on that
8 so I attribute part of it, at least, to the -- to that
9 methodology.

10 I don't know if that's a standard, acceptable amount
11 of difference or not. And in the other -- and so what we
12 wanted to, again, determine with the flow meters is we've
13 got on one hand the total production or total delivered
14 water at the plant. Okay? So that's what -- and that was
15 our only other number. So even in the models that we have
16 right now -- for example, Hadnot Point or whatever, you've
17 still got this if you use the water-conservation study.

18 That's how we spatially distributed building use and
19 all that type of use per building and all that. And we've
20 got a 30 percent difference. We can evenly distribute it
21 or not, and that's another -- again, what we were hoping
22 to obtain with the flow-meter information is a more
23 quantifiable estimate or even areas where you have better
24 estimates than other areas.

25 DR. JOHNSON: Yes, Peter.

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1 DR. POMMERENK: I'll let Tom go ahead for a while.

2 DR. WALSKI: Well, first of all, I'm assuming that
3 when you measure the discrepancy the production was higher
4 than the estimated consumption; right? Your estimate was
5 production was up here and what the method says was down
6 here; right?

7 MR. MASLIA: Yes.

8 DR. WALSKI: So it was higher. The production was
9 higher. So, yeah, it is likely that there is leakage to
10 that extent. And also, they're thinking about these
11 methodologies that you're using that are based on typical,
12 average customers. And one thing that you learn is that
13 you never have a typical, average system. So that type of
14 discrepancy is not, you know, anything that would alarm
15 me.

16 You know, they say, "30 percent. My God. That's a
17 lot." But no. It's not really. It's not that bad.

18 DR. JOHNSON: Peter.

19 DR. POMMERENK: Yeah; just the other issue. You
20 mentioned you were waiting for higher demands during the
21 summer for doing additional validation of the metering
22 data or --

23 MR. MASLIA: What we were -- what we -- and we're
24 still anticipating to cal -- we're trying to calibrate the
25 meters during this period -- winter, early winter, fall,

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1 winter -- in anticipation of collecting about six months
2 of metering data to be able to capture the high-demand
3 period.

4 DR. POMMERENK: But have you -- has your review of
5 past production data indicated that there is substantial
6 -- a substantially higher demand during the summer months?

7 MR. MASLIA: Yes; yes. The USGS reports show that.

8 DR. POMMERENK: Okay. I'm just asking the question.
9 We have recently completed a related study, and my
10 recollection -- and I may be wrong -- we didn't really see
11 a pronounced summer. I'm willing to share that data with
12 you, so...

13 MR. FAYE: It's a difference of -- it's how you
14 define "substantial."

15 DR. POMMERENK: Okay.

16 MR. FAYE: But I'm looking -- I have the reports with
17 me; unfortunately, not exactly here in the room. But off
18 the top of my head, I'm looking at -- I'm thinking of
19 perhaps a 20, maybe 25 percent difference between, say, a
20 demand from January through March versus, say, June
21 through September.

22 DR. POMMERENK: Okay. I would think substantial is
23 if you're maxed is a factor of two or three over the
24 average annual demand, daily demand. So you don't quite
25 see --

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1 MR. FAYE: No.

2 DR. POMMERENK: -- those.

3 MR. FAYE: No.

4 DR. POMMERENK: Okay. With respect to the flow
5 metering, obviously, the increases in flow during the
6 summer are not expected to increase that much; right?

7 MR. FAYE: Maybe I can invent a different way of
8 saying it, but the average daily demand, for example,
9 during the period -- and this is basewide; basewide, not
10 selective to Holcomb Boulevard or Tarawa Terrace or
11 whatever. The average daily demand during July and August
12 would perhaps be 25 percent higher, greater, more than,
13 the average daily demand during January through February
14 -- January through March. Okay?

15 DR. POMMERENK: Thanks.

16 DR. JOHNSON: In summary then, is it fair to say that
17 there -- that some panelists have some concerns about the
18 flow-meter work and would suggest, given limited
19 resources, particularly personnel, that ATSDR look at this
20 in terms of, in effect, what the cost/benefit is? Is this
21 data worth what it's going to cost you to get? Is that a
22 fair statement? Should it be changed? Morris is looking,
23 I think, for a rather clear statement from the panel.

24 DR. CLARK: Well, given where you are in terms of
25 actually installing the meters, how much more effort would

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1 it take to actually do the next step?

2 MR. MASLIA: On our part, probably a couple of weeks
3 with a couple of people. That's basically the time to
4 calibrate the meters. And then, of course, on the Camp
5 Lejeune staff, because they assist us in collecting the
6 data, downloading the data -- it's going around to 16
7 meters once a month. They have the capability of storing
8 more but, say, once a month downloading the data.

9 So manpower-wise or labor-wise, I don't think it's --
10 it's the calibration process that's intensive, and it only
11 seems more so intensive because of the past attempts that,
12 obviously, we have made and have not been successful. But
13 now that we've got sort of a step-by-step how-to manual
14 and some estimates of what we expect to see the flows to
15 be based on our model simulation, we're hoping that it
16 will go much -- you know, on schedule. So basically,
17 you're talking about a two-week effort with a couple of
18 people from ATSDR.

19 DR. JOHNSON: Okay. Last comment from Tom.

20 DR. WALSKI: Okay. I've got more comments. This is
21 my last (laughter).

22 DR. JOHNSON: It's the last one on this issue.

23 DR. WALSKI: Okay. The -- to put this thing in
24 perspective, the calibration data is the calibration of
25 water -- calibrated water-distribution model, which we

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1 aren't sure we're going to need. So first of all, we have
2 that issue to get over.

3 But, in the meantime, since we have made this
4 investment, I think it's worth getting like a month's
5 worth of data and just looking at it and seeing what does
6 a month's worth of data say. And then we can decide if
7 it's worth doing several months; just for the background
8 information. It may be good for the utilities' people
9 just to have this data to help them manage this system
10 even if you don't use it for calibration.

11 So I'd say, you know, try it for a month. There's
12 going to be some places where you have shuttling between
13 the tanks where the velocities are going to be high, and
14 you are going to get good information. There are going to
15 be some dead-end areas where you're going to be below the
16 threshold half the time or so, and it's not going to be
17 very useful information.

18 But get a month's worth of data, and if it looks good
19 and the people from the utility think it's worth
20 collecting, then keep on collecting it. And then if you
21 do have to use it to -- if you decide to do a more
22 detailed model or a more detailed calibration, you'll have
23 it. So that's the way I would put it in perspective.

24 MR. MASLIA: One point, Dr. Johnson. Actually, it's
25 an answer to Peter that came to mind with respect to

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1 variation in production or flows. When we were doing our
2 testing in May of 2004 at Hadnot Point, we were seeing on
3 the average of about 2100 gallons per minute being
4 produced out of that plant during the week of our test,
5 more or less.

6 When we came back in August, although we were not
7 testing Hadnot Point, I just took the opportunity to go
8 over to the chart, and it was up at 3,000 gallons per
9 minute, so...

10 DR. POMMERENK: Okay.

11 DR. JOHNSON: Any more? Tom, anything else on this?

12 DR. WALSKI: Mm-mm.

13 DR. JOHNSON: Thank you. The panel, I think, has
14 done an extraordinarily excellent job of responding to
15 these questions and issues as well as those yesterday.
16 The work that remains for the panel is to respond to the
17 four specific charges, and we've talked about almost all
18 of them. And so that's the work that remains.

19 I foresee us being able to finish by around 1:30 and
20 such. That means that a public comment period needs to be
21 moved up, and I'd like to offer the opportunity now for
22 any comments from the public. Yes, Ben.

23 MR. HARDING: Can I just ask one --

24 DR. JOHNSON: Please; of course.

25 MR. HARDING: -- question before we do that?

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1 DR. JOHNSON: Yes.

2 MR. HARDING: We have this amended question, issues,
3 and discussions page, which has explicitly marked out
4 certain bullets. And then on the original sheet, there's
5 issues. On page 3, there was integration of groundwater
6 and water-distribution systems. Did we deal with that
7 yesterday? Was that -- or has that been implicitly X'd
8 out?

9 DR. POMMERENK: X'd out.

10 MR. HARDING: X'd out. Okay. It just --

11 MR. MASLIA: That was my -- that's why I didn't bring
12 it up. I didn't X it out, but, based on the discussion
13 that we've gone today, that becomes a moot point, at least
14 from my interpretation.

15 MR. HARDING: Okay. That was what I thought, but I
16 just wanted to make sure.

17 DR. JOHNSON: Okay. Comments from the public. Mr.
18 Ensminger.

19 COURT REPORTER: I need to go down.

20 DR. JOHNSON: Oh, excuse me. Let's take about a
21 ten-minute break.

22 COURT REPORTER: All I need is two minutes, if you
23 just want to continue.

24 DR. JOHNSON: No. I think the panel needs to have a
25 break. Let's break until lunch arrives.

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1 (Whereupon, a recess of approximately 28 minutes was
2 taken.)

3 DR. JOHNSON: Okay. The floor is open for comments
4 from the public. Mr. Ensminger.

5 MR. ENSMINGER: Not so much comments. I had a few
6 questions on some of the things that were brought up
7 during the discussion. It was brought up by one of the
8 members from the Camp Lejeune delegation that North
9 Carolina State requires separate permits for multiple
10 water systems, and I have a question is: How long has that
11 been -- requirement been in place?

12 MR. ASHTON: I'm not --

13 MR. ENSMINGER: Whenever you open and close a valve?
14 How long has that requirement been in place?

15 MR. ASHTON: I'm not sure how long, but I can try to
16 find that out there and also, you know, the -- I can
17 certainly find when we got those permits for the water
18 systems as well.

19 MR. ENSMINGER: And another thing about the Holcomb
20 Boulevard water system was that it seems that there were a
21 limited number of wells initially assigned to that water-
22 treatment plant. Were the wells that were assigned to
23 Holcomb Boulevard initially able to keep up with the
24 demand for the area that it serviced?

25 And the question of on the flow meters, there seemed

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1 to be a lot of dissension about that because of the
2 oversized pipes. Would the installation of choke points
3 -- somebody brought that up -- improve the accuracy and
4 the velocity? I know it would increase the velocity of
5 the water going through them. Would it increase the
6 accuracy of the data? I mean, you're talking about 16
7 flow meters. I don't know if all 16 are on 12-inch
8 oversized lines.

9 DR. JOHNSON: Tom or Peter or both?

10 DR. WALSKI: Well, to increase the accuracy, whether
11 or not we need it is still the question. So that's why
12 I'd say: Don't spend this money until we're sure we need
13 that extra quality of data would be the way that I would
14 leave it.

15 DR. JOHNSON: Peter?

16 DR. POMMERENK: I agree.

17 MR. ENSMINGER: And on the Hadnot Point water system,
18 the questions of historical data as far as contamination
19 of certain wells, the installation-restoration program has
20 the accurate data now for each well that was contaminated
21 in the Hadnot Point system. They have the actual
22 contaminants that were in those systems or in those wells,
23 and they know what the sources were. So as far as
24 reconstructing, you know, and doing the historical, there
25 would be some work involved in it, but that data is

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1 available.

2 DR. JOHNSON: Okay. As I commented before lunch, I
3 think we can certainly be through by 1:30. Some meetings
4 go quicker than anticipated. I have been in many meetings
5 where it's gone the other way and you reach 2:30 on the
6 third day and you realize you're not done. And so this is
7 quite to the contrary. And the preplanning done by ATSDR
8 was really very, very well done, and presenting the issues
9 and questions to the panel has helped us go through some
10 of these tough matters that the ATSDR is going to have to
11 deal with after we leave.

12 So my goal is to have us out of here around 1:30 or
13 so. I propose to provide a formal response to Questions 3
14 and 4 in the charge to the panel. I discussed with Mr.
15 Maslia before lunch if all four were still relevant, and
16 he indicated that we had really done a good job discussing
17 questions or Charges 1 and 2. But he asked that we do
18 provide a formal response to Charges 3 and 4. Charge 3 is
19 now on the screen, and so that spares me having to read it
20 to you now. How does the panel wish to react to this
21 third charge?

22 DR. CLARK: One area that it seems to me that ATSDR
23 might consider is looking at the degradation by-products
24 of some of these oxidated chemicals, and I think there's a
25 potential there that there might be things like vinyl

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1 chloride in the system, which I think would bias their
2 results. And I hadn't gotten a sense of how much of that
3 has actually been done.

4 DR. SINGH: Number 2 shows that we -- ATSDR already
5 has started with their groundwater modeling. One portends
6 to consent to the analysis, and the other one relates to
7 the accounting for the variability recharge. I think
8 those are the two issues that ATSDR should take into
9 consideration.

10 DR. JOHNSON: Other advice on this charge?

11 DR. KONIKOW: Well, the groundwater modeling that we
12 discussed -- and I think that's been focused on the Tarawa
13 Terrace area. And I guess maybe we should talk for a
14 minute about the need for looking at and modeling the
15 groundwater flow and contamination in the Hadnot Point
16 area or the Holcomb Boulevard area. Or do we just accept
17 that Hadnot Point wells are contaminated over the whole
18 time?

19 DR. LABOLLE: In addition, Lenny, you had mentioned
20 previously -- and I concur with the need to at least
21 demonstrate that contaminants arrive to TT-26 or
22 demonstrate that they may not, depending on the outcome of
23 the models within this for the 14-year time frame, for
24 example, and to the extent that the study period's going
25 to be pushed back further.

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1 In addition, somebody mentioned other periods of time
2 we might be looking at the cancer risk. You may want to
3 actually have a model that's useful for protecting the
4 uncertainty in the arrival curve itself. I'm not sure if
5 you're planning on going back before '68 at Tarawa
6 Terrace.

7 MR. FAYE: Our intention has always been -- largely
8 due to modeling considerations as well as others, but our
9 intention has always been to begin the groundwater flow
10 simulations at Tarawa Terrace with the beginning of
11 operations of the WTP and the well fields, which would be
12 like 1952, '53, and then simulate that forward to '94,
13 which is the end of our relevant water-level record.

14 DR. LABOLLE: But the question would be the period of
15 time from '54 through '68.

16 MR. FAYE: Yeah. To transport -- very definitely.
17 We would do the fate and transport simulations as well for
18 that period of time.

19 DR. LABOLLE: Well, but are they going to use it in
20 the epi study?

21 MR. FAYE: That, I don't know. But I would just feel
22 comfortable doing that. If we don't, there's always going
23 to be a question there: Did the contaminants arrive at the
24 wells in one month, six months, five years, or whatever?
25 And I think that's an important consideration.

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1 DR. LABOLLE: I'm not suggesting that it not be done.
2 Actually, I'm suggesting that the degree of effort put
3 into this will depend upon whether or not the epi studies
4 are in the future pushed back to earlier dates,
5 I think.

6 MR. FAYE: That, I don't know. But our -- as far as
7 the modeling is concerned, I can speak to that, and our
8 plans from Day 1 have been to provide those simulations
9 from the beginning of the WTP operation and the well-field
10 operation, which would be, as I said, 1952 or '53.

11 DR. KONIKOW: For all three areas?

12 MR. FAYE: Just for the Tarawa Terrace. Lenny, as we
13 said yesterday, we're using the Tarawa Terrace because it
14 is a "simpler system." But it is a little simpler. So
15 that's our -- what would you say? That's our prototype
16 effort, and if we think we're successful there, then we
17 can advance ourselves to -- if necessary.

18 I mean, if the epi -- epidemiological demands require
19 that, then we can advance to a more complex system where
20 we have this confidence that we've built on and attempt
21 that, which would be Hadnot Point.

22 DR. KONIKOW: So is the default option then in the
23 epidemiological study to assume that the Hadnot Point
24 system was contaminated over the whole period of time?

25 MR. FAYE: I don't know what their default position

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1 would be. But based on the data that I've seen and how
2 the wells are positioned with respect to obvious sources
3 of contamination and whatever, yeah, I would say that
4 there -- whoever said here today that when the particular
5 well was actually opened up and began to be used, it was
6 probably contaminated at that time. I would say that
7 that's an accurate statement with respect to perhaps a
8 number of wells, supply wells, at Hadnot Point.

9 And also through time -- I mean, the wells may have
10 been -- in 1941 when the wells were constructed, there
11 probably was no problem. And then over the years, as the
12 facility grew and different things were done land-use-
13 wise, why, yeah, they probably became contaminated.

14 MR. MASLIA: Two issues. If we go into Tarawa
15 Terrace, from a groundwater fate and transport standpoint,
16 if we don't start at predevelopment, then we have some
17 real issues to address with antecedent conditions, and
18 then we're going to have to do some more uncertainty
19 modeling as to the effect of not knowing the antecedent
20 conditions, which I think adds to our effort and, I think,
21 overpowers the amount of additional effort, just by
22 starting from before the -- from predevelopment and
23 running them out. My understanding is we can also -- we
24 can vary the step size in MODFLOW, can we not?

25 MR. FAYE: Oh, yes.

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1 MR. MASLIA: Yes. So we could use larger -- if we
2 see there's no contamination, you know, for a certain
3 number of years in the beginning after some trial runs, we
4 can make those larger, larger step size, and then when we
5 think it is down to a much smaller -- as you said 15 day
6 or less.

7 I've actually used even smaller time steps for that
8 previously and do that. And that would be, at least
9 initially, my approach is not to complicate our analyses
10 even more with trying to guess antecedent conditions but
11 let the model do the work; in other words, circuitous
12 development.

13 MR. FAYE: Yeah. At that -- yeah, the issue then
14 very rapidly moves from a code-capability issue to a
15 number-crunching issue, so that's where you're at there.

16 DR. LABOLLE: I wouldn't bother corseting the time
17 study, in my opinion, simply because, I mean, you're
18 probably not going to be constrained by the time it takes
19 to run this model. And what that would then do is lead to
20 possible numerical errors and a plume that doesn't look
21 like the plume that the model was intended to solve for.

22 So you might as well just leave them at the required
23 resolution to obtain a numerically valid solution. I'd be
24 more concerned about the assumptions in the model itself
25 than those kinds of issues and the underlying geologic

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1 characterization, which it looks like, you know, you've
2 done a good job approaching that.

3 But the -- it's the way in which one deals with the
4 uncertainty in there. And if I were to make any
5 recommendation, I would recommend an approach to dealing
6 with geologic uncertainty be incorporated into the
7 analysis so that one can examine the uncertainty in the
8 geology and its effect on arrival, potential arrival, to
9 these various wells in the vicinity of this ABC's Cleaner
10 there and of the -- some of the wells that are reported --
11 reportedly clean throughout the periods of interest may
12 have actually seen contamination because they simply
13 weren't sampled continuously.

14 MR. FAYE: Right. They're --

15 DR. LABOLLE: And others that -- I'm sorry. Excuse
16 me.

17 Others, you know, that have seen contamination, we
18 don't know when the contamination arrived. And to the
19 extent that maybe all of these are swamped out by
20 concentrations of TT-26 and the models begin to show that,
21 maybe you can lay these issues aside because the mixing
22 that appears to have been in this system. All wells are
23 mixing.

24 You may not need to pursue, you know, the groundwater
25 modeling past that point in terms of determining what

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1 arrived at these other wells. But there seems to be
2 another issue -- and I think that you and I discussed
3 during the break -- where if TT-26 is turned off and these
4 other wells have taken over --

5 MR. FAYE: Right.

6 DR. LABOLLE: -- and yet there may not be sampling at
7 these wells to assess whether there was contamination
8 arriving to them, and some of them are quite close to
9 TT-26 and appear to be very capable of intercepting the
10 plume.

11 MR. FAYE: That is a real issue; absolutely.

12 DR. LABOLLE: And so then you're left with modeling
13 to resolve that.

14 MR. FAYE: That's right.

15 DR. LABOLLE: And once again -- I don't mean to
16 belabor the point -- but I think it's geologic uncertainty
17 that is going to swamp out a lot of other uncertainties in
18 all of these modeling efforts of the water-distribution
19 system. And that's going to be one of the main players.
20 That and the source, as David will know.

21 MR. MASLIA: The other question or issue with respect
22 to the Hadnot Point -- as Bob said, we're using Tarawa
23 Terrace first. But if we assume or can assume that at
24 least some of the wells were sunk into an aquifer upon
25 production that was already contaminated, does that then

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1 not bring the problem in trying to simplify matters to a
2 materials mass balance where if we knew the cycling on and
3 off of wells we could calculate the concentration of the
4 mixture on there? And that might then alleviate also any
5 detailed numerical modeling of the Hadnot Point area with
6 the large and nonpoint specific sources.

7 DR. JOHNSON: Okay. Let's then turn to Charge No. 4.
8 And as that comes up on the screen, let me ask kind of a
9 housekeeping detail of Mr. Maslia. Are arrangements being
10 made for transportation to the airport? I mean...

11 MR. MASLIA: My understanding is some -- some people
12 have arranged with the hotel shuttle, and all that needs
13 to be done is to call the hotel shuttle when they are
14 ready to board that hotel shuttle. Ann Walker or Joann
15 can do that once we tell them we're -- we're finished.

16 DR. JOHNSON: Okay.

17 MR. MASLIA: If people want -- what?

18 DR. WALSKI: The shuttle doesn't bring us to the
19 airport, does it?

20 UNIDENTIFIED PANELIST: There is a shuttle.

21 MR. MASLIA: There is a shuttle.

22 DR. WALSKI: Yeah. But not the -- a different
23 shuttle; okay.

24 MR. MASLIA: Right.

25 DR. WALSKI: Okay.

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1 DR. CLARK: We're better off sharing taxis.

2 DR. WALSKI: Right. I think so; yeah.

3 DR. LABOLLE: Along the lines, yeah, I spoke with the
4 driver on the way here, and he mentioned that he's trying
5 to get us a large van to be able to go to the airport from
6 here. And I have to actually have them deliver my bags
7 here, and I mentioned that you --

8 DR. SINGH: Yeah. My bags are at the hotel.

9 (Whereupon, a conversation ensued off the record.)

10 DR. JOHNSON: Charge No. 4 gets under the matter of
11 the project schedule. It seems -- it seems, at least to
12 the Chair, that there have been a number of rather
13 significant suggestions as to perhaps how to reorder the
14 work that is anticipated. That makes it a little bit
15 unclear, at least in my mind, as to how that works out in
16 terms of a project schedule. But I would look forward to
17 the comments from the board -- from the panel.

18 DR. CLARK: Subject to the comments that have made by
19 the panel, it seems to me that the three-year planning
20 projected cycle is probably a reasonable one to work
21 towards.

22 DR. DOUGHERTY: Tom had suggested six months.

23 DR. WALSKI: Yeah. I can see you're getting to the
24 point of beating a dead horse after a while that possibly
25 you can do this in about six months unless you find that

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1 missing notebook. You know, the notebook that was on top
2 of the refrigerator back in '85 that fell behind the
3 refrigerator? And they move it, like, next year, and they
4 find this notebook with all the data in it or something.
5 Unless you find that kind of a notebook, I don't see three
6 years of work giving us a much better answer than we can
7 in probably about six months.

8 MR. MASLIA: Can I qualify that last charge so that
9 everyone's on the same playing field here?

10 MR. FAYE: Did you look behind the refrigerator?

11 MR. MASLIA: I've looked in at a lot of places,
12 including down a manhole. The three years was the total,
13 not three additional years. That was three years of
14 project length, and we have spent length approximately,
15 what, a year or more? Less. So we really are only
16 talking about another year and a half or so.

17 The initial schedule called to have some preliminary
18 fate and transport modeling results with Tarawa Terrace by
19 this September, which I believe we're on track for that.
20 The question is the additional work, taking the
21 suggestions of the panel. I've been trying to simplify
22 them on the Hadnot Point area, assessing some preliminary
23 flow data from the meters. Would, you know, the three
24 years be sufficient? And the one comment I would have,
25 given a perfect world where, even if you had to look for

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1 data, in six months would probably be acceptable.

2 Being -- doing the kind of detective work that we
3 have to do with historic data, I would say shortening --
4 my experience would be on this project that that would
5 really be constraining the agency to shorten it any more
6 than that, but I'm open to some concrete ideas where --
7 Bob wants to.

8 MR. FAYE: I don't know, Tom. Maybe there's some
9 pharmaceutical issues related to your comment there, but
10 there's just no way in the world (laughter).

11 DR. JOHNSON: I don't know what that means. I'll
12 speak. If no one else will speak, I'll speak. What are
13 the pharmaceutical issues?

14 MR. FAYE: There's no way that I can imagine or
15 devise or anticipate that we could -- we can fulfill the
16 requirements or the suggestions of the panel here with
17 respect to the groundwater-flow models and the fate and
18 transport simulations and provide a comprehensive,
19 complete, technically defensible written product in a
20 six-month time period from today. I think that's a very
21 unrealistic -- that would be a very unrealistic proposal
22 or recommendation. And that's based on 30-some years of
23 experience.

24 DR. WALSKI: But we have put those -- we've taken
25 out, pretty much, most of the distribution modeling, and

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1 we're taking a fairly major chunk of the scope of work
2 out --

3 MR. FAYE: Yeah, but the --

4 DR. WALSKI: -- and also cut out most of the modeling
5 at Hadnot Point, too, for groundwater. So we've --

6 MR. FAYE: No. Let me clarify that. First of all,
7 the -- there -- the -- as the time-line chart, I guess,
8 that you've been -- that you have -- the groundwater
9 modeling and the distribution modeling were parallel
10 efforts. Okay. They weren't -- they weren't a series
11 situation: One gets done and then the other. So those
12 were all parallel efforts.

13 And so, I mean, we planned to converge the completion
14 of the two efforts, at a point in time merge the results
15 and then go on from there. So I think, as far as that
16 parallel effort with respect to the groundwater-modeling
17 situation is concerned, we're right on the regional time
18 lines. I think we conformed to them very well.

19 And as Morris said, the -- we're having -- we're
20 planning to have some fate and transport simulation
21 results by the end of September, this fall. I think
22 that's -- with a bit of work, that's probably doable.
23 So -- and realistic. And so then I would anticipate
24 finishing that project completely: providing the written
25 report, the appropriate peer reviews, et cetera,

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1 et cetera, would still take most of the next year
2 after that. So --

3 DR. CLARK: Don't you also have to integrate the
4 epidemiological studies --

5 MR. FAYE: Exactly.

6 DR. CLARK: So you're talking, what, probably another
7 six months to a year?

8 MR. FAYE: Absolutely; yeah; yeah. So there's a --
9 even conforming exactly to what I've heard that you folks
10 will probably recommend, this three-year time interval
11 that we're looking at now with about a year and a half or
12 so left is still extremely ambitious. And I don't know.
13 I mean, maybe I'm just all wet, but I'd like to hear from
14 some of my groundwater colleagues on the panel to tell --
15 to say -- is that -- are you -- have you been smoking
16 something, too, Bob (laughter)?

17 DR. JOHNSON: Well, there's a clarification.

18 DR. DOUGHERTY: What is the terminus of the three
19 years? Is it the delivery of the water-modeling results,
20 or is it the delivery of the epi results?

21 MR. MASLIA: The original schedule was three total
22 years to deliver the final historical reconstruction to
23 the epi people.

24 MR. FAYE: With all of its elements.

25 MR. MASLIA: And that included another -- another

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1 peer panel to assess the historical or the final report,
2 as we did in Dover Township.

3 DR. DOUGHERTY: And the Hadnot and --

4 MR. MASLIA: Right.

5 DR. DOUGHERTY: -- Holcomb?

6 MR. MASLIA: That's -- that's correct. I will add --

7 DR. DOUGHERTY: Or whatever may be done with Hadnot?

8 MR. MASLIA: Right. I will add that Frank and I and
9 the epi team had discussed, in fact, with Marine Corps
10 headquarters, back in February that it was going to be a
11 challenge, an extreme challenge, if we were going to the
12 distribution-type stuff to even keep to that three-year
13 schedule; an extreme challenge.

14 I think based on some recommendations here that
15 three-year time frame becomes a more realistic and
16 attainable goal. And that's really -- but, again, there
17 are a number of, still, work efforts and implementing
18 recommendations that you have made even with the
19 simplifications.

20 DR. DOUGHERTY: My personal feeling is then that --
21 and take the comment with a grain of salt because I really
22 haven't seen the detail of the work plan for the other two
23 portions of the site in terms of groundwater modeling and
24 its impact. But I think the schedule is going to be
25 aggressive because of the additional emphasis on the

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1 archaeology, as we've been calling it, and that really
2 takes a lot of calendar time. It takes a lot of calendar
3 time.

4 MR. FAYE: Absolutely.

5 DR. KONIKOW: I think, also, if the goal is to do an
6 advective/dispersive transport model and that hasn't been
7 started yet, that takes time. And that's going to take
8 time.

9 MR. HARDING: If I might speak specifically about
10 this July schedule --

11 MR. MASLIA: This is July of? Is that in the July
12 book?

13 MR. HARDING: It's revised 13 July. It's the
14 current.

15 MR. MASLIA: Right. There's probably one in
16 September. I don't know if you've gotten it. We've
17 revised it somewhat for -- in September. But you can go
18 ahead. That's probably within a six- or eight-month
19 period.

20 MR. HARDING: So if you look at this, the
21 geohydrology of groundwater flow, fate and transport work
22 appears to end, roughly, the end of this fiscal year,
23 which is --

24 MR. MASLIA: Which is September 30th.

25 MR. HARDING: Of 2005?

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1 MR. MASLIA: Yeah; that's correct.

2 MR. HARDING: And then what extends beyond that is
3 water-distribution system historical models; actually,
4 water-distribution system present-day models. But we, I
5 think, suggested that you dramatically compress that --

6 MR. MASLIA: Yes; yes.

7 MR. HARDING: -- which, I think, may move that out of
8 what appears to be the critical path in this thing. Now,
9 I tend to disagree with Tom because I have been swearing
10 off all my pharmaceuticals recently.

11 But I think more time is necessary to characterize
12 the Hadnot Point situation, but I don't really know that
13 business. That's the groundwater people's business. But
14 I go down here to this methods' development -- and maybe
15 this was dealt with yesterday. But there's the GA
16 calibration methods, tank mixing, and dynamic linkage of
17 groundwater transport and water distribution models, which
18 I think can be eliminated.

19 And I think that uncertainty methods in groundwater
20 flow transport and also in terms of water distribution --
21 or if we want to say integration of exposures and intakes
22 and that stuff. Dealing with this in a -- dealing with
23 uncertainty and quantifying it can be expanded. But that
24 should not affect the overall length of the schedule. But
25 those bars down there on all those methods' developments

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1 are really driving the schedule out to the right, and
2 those should be essentially, I think, eliminated.

3 MR. MASLIA: Those were based, again, when -- were
4 based when the schedule was developed, based on our
5 previous experience, which they did drive the time frame.
6 Although they were -- or at least now we see them as
7 complementary, not driving the schedule.

8 And from the discussions that we've had here the last
9 couple of days what, again, I see driving the schedule are
10 two issues: the archaeology or data discovery. That is
11 very time-consuming and labor-intensive as well as the
12 methods to better understand the uncertainty with respect
13 to geologic issues at Tarawa Terrace and going to the
14 full-blown fate -- full blown as opposed to the effective
15 full fate and dispersive transport models.

16 MR. HARDING: Well, I want to emphasize that I think
17 that you can make a contribution, both to the
18 understanding of this situation but also to the practice,
19 if you would, instead of spending your resources on some
20 of these methods that relate to linking the models, if you
21 would spend more of your effort on quantifying and
22 propagating uncertainty through the methods.

23 That is going to contribute more to a realistic
24 assessment of the epidemiological situation in my view and
25 also to the practice here because this is something that

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1 has been an undercurrent in all the discussions. But the
2 practical matter of how you do this -- it's not like it's
3 unknown, but it's something that could use some effort.

4 It would be a good thing for you to shift resources
5 to that area, I think. That's my view, and I think that
6 helps both your schedule, and, also, it puts your
7 resources in a more appropriate area. And I agree with
8 you that the resources should be spent, understanding the
9 Hadnot Point geohydrology; is that right? Hydrogeology
10 transport.

11 DR. DOUGHERTY: In my premeeting notes, I had
12 compared the July version of the schedule with the version
13 of the schedule on a preceding page of the handout. And
14 even at that time, last summer, the areas in which the
15 greatest slippage had occurred appear to be in collecting
16 background information and then the development of the
17 historical network information.

18 I don't think that we've reduced or accelerated those
19 particular tasks in the last two days. And since those
20 seemed to have been the ones that already grew before we
21 had our two bits to say, they may slip further by as much
22 as the six months that Tom talked about; my gut feeling.

23 MR. HARDING: When you say "slip," you mean be
24 compressed?

25 DR. DOUGHERTY: No. I mean they've stretched out.

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1 They have been extended when you compare that page to the
2 previous page. And what we're hearing is there continues
3 to be data discovery that has some significance with
4 interconnects, monthly pumping rates that are not yet
5 complete. And their significance to the outcomes -- the
6 requirements for the outcomes seem significant enough that
7 they're going to stretch longer than I thought they would
8 when I walked in here yesterday morning.

9 DR. JOHNSON: Well, that would seem to conclude our
10 response to these Charges No. 3 and 4. My view of what
11 remains is to offer, indeed encourage, any kind of dialog
12 amongst the panelists on any issue that hasn't been
13 addressed to your satisfaction, any matter that you
14 brought up in your premeeting comments that has not been
15 addressed to your satisfaction, and any points that might
16 represent some differences of view within the panel. Put
17 those on the table to the extent you wish to discuss them.

18 Following that, it's kind of an open-discussion
19 opportunity. I'm going to conclude the meeting by asking
20 each of you as panelists what you would recommend the
21 agency do in regard to what you've heard about the
22 groundwater work as well as the water distribution work.

23 And I don't know that -- as I said earlier this
24 morning, that we want to take the individual advice and
25 recommendations and attempt to synthesize them into a

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1 panel product. I don't know that that's in ATSDR's best
2 interest because, to some extent, that may tie your hands.

3 But I think it is quite fair to ask each of you as
4 individuals your comments on what you would recommend for
5 the future. So with that on the table, what else do you
6 want to deal with as a panel? Open discussion on points
7 that haven't been addressed and then closing by asking you
8 your individual comments; vis-à-vis, advice;
9 recommendations; but not going that third step and
10 attempting to compile a panel body of recommendations.
11 How does that resonate with you, Morris? You're the
12 primary user of these deliberations.

13 MR. MASLIA: I actually would prefer not having a
14 vote, as you say, but rather having everyone's individual
15 opinion or summary of their understanding of what took
16 place today. I think that would be much more beneficial
17 to us.

18 DR. JOHNSON: Is it fair for the panel to say, as a
19 body, that we consider this work as extraordinarily
20 important for various reasons, certainly in support of an
21 epidemiological study, but for other reasons, as
22 articulated by Ben, as a study that will advance the
23 practice in the field as well? I'm paraphrasing. If I
24 misstate this, please correct me.

25 But is it fair for this body to go on record, saying

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1 this is pretty important stuff with the epi study and the
2 work that involves water protocol and that we would
3 encourage ATSDR, given the importance of this work, to
4 have resources that are commensurate with that importance?
5 Does anyone want to take issue with that? Are you
6 comfortable with saying that for the public record as a
7 body? Important stuff. Let's get the resources that
8 match the importance and urge ATSDR to provide those
9 resources.

10 DR. SINGH: I think so. I think this is a very
11 important study. This integrates hydrology, geology,
12 hydraulic engineering, and health sciences. So it's a
13 very important study, and it should be encouraged. And
14 obviously, we would like the agency to provide
15 commensurate resources.

16 DR. WALSKI: But we also have to be concerned that
17 the marginal benefits exceed the marginal costs. And some
18 of the things I'm still not convinced that they are from
19 my perspective. But, you know, I'm just one voice.

20 DR. JOHNSON: Does anyone else wish to speak to the
21 issue of importance of study and commensurate resources?

22 DR. CLARK: I think I would support all of your
23 characterization of the importance of the -- both as sort
24 of the movement for the state of the art, the idea of
25 integrating groundwater and surface water modeling

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1 activities and then tying together with epidemiology.

2 I think there's also -- I'm sure the study's going to
3 be scrutinized carefully by the public. And I guess what
4 I'm concerned about is that we appear to do a study that's
5 somewhat short of the best that we can do, then we could
6 be criticized for that, for not taking it seriously and
7 not understanding the public health implications of it
8 because they're very serious because there's a lot of
9 water systems that have similar kinds of problems.

10 And I can see that this could lead to, maybe, a
11 further study or a more in-depth study of better
12 understanding of what those exposures might be for other
13 water consumers. So it seems to me that you've got to
14 take it seriously and think of it as scientifically
15 defensible. And I say resources are there. Use the
16 resources to accomplish the end project -- the end goal of
17 the project.

18 DR. JOHNSON: Anyone else? Eric? Ben.

19 MR. HARDING: I want to build a little bit on what
20 Tom's saying because I started -- I think I -- I guess I
21 started this ball rolling a little bit. And I want to say
22 that just because something is possible doesn't mean it
23 should be done. And I think that we have to ask ATSDR to
24 really focus on important areas here. And this -- I think
25 this is what we're all going to address individually.

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1 But I think the study is important in the two ways
2 that you mentioned, and if ATSDR puts their emphasis on
3 the areas that will contribute to an understanding of this
4 situation and improving the practice, I think then it can
5 be a very important study. I just want to echo Tom that
6 it's important to make that and not take the resources and
7 use them in areas that are going to just be generating
8 friction.

9 So I'll make more specific comments, and I'm sure we
10 all will. But I would like to see particularly -- this
11 area of dealing with uncertainty quantitatively is an
12 important one that's moving more into the practice; out of
13 the universities and into practice. And I'd see some more
14 effort spent there.

15 DR. JOHNSON: Thank you. Eric LaBolle.

16 DR. LABOLLE: I think this -- it may come back to
17 something I touched on yesterday, which is: What is the
18 role of these models that are being developed? And I
19 think the answer at one point was, well, to provide
20 monthly or submonthly, you know, concentrations, for
21 example, with regards to the groundwater model and its
22 inputs to the distribution system model.

23 And that may not be the role of the groundwater
24 model. The groundwater model may play a role in simply
25 bracketing the uncertainty in those concentrations that

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1 arrived, and the groundwater model may not be used to even
2 predict the specific inputs used on any realization
3 because that could certainly -- may be so great that one
4 may just want to throw their shot at particular
5 concentration inputs over time.

6 It depends on how much detail is put into these
7 models and how much more effort is put into them. And I
8 think from what I've heard -- essentially, I think
9 everybody has a valid point hovering. And Tom,
10 essentially, you know, we need to -- they need to make the
11 best effort. You know, you certainly don't want to waste
12 resources. But I think that the role of these models is
13 really critical. You know, at what point do we say we're
14 just, you know, beating a dead horse here?

15 DR. JOHNSON: Yes, Lenny.

16 DR. KONIKOW: In terms of the epidemiological study,
17 is there a desire or a capability to look at the role of
18 all the various contaminants? I mean, we were talking
19 about PCE at the Tarawa Terrace. But there was also a
20 benzene pollutant, and there's some TCE and PCE and some
21 vinyl chloride at Hadnot Point and a longer list of
22 contaminants. I mean, is this -- is there enough
23 information to factor this into the epidemiological study?

24 DR. BOVE: Do you want me to answer?

25 DR. KONIKOW: I mean, this gets to, you know, what we

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1 might use the groundwater transport models to help define.

2 DR. BOVE: I mean, I don't think we have any
3 information as to when Hadnot Point had more TCE than
4 benzene. We don't have that data so that -- what we'll --
5 the way that we've characterized Hadnot Point exposure is
6 to a mixture of VOCs, TCE being the main component. But
7 if we're going to say -- if we're going to infer from that
8 -- if we see, for example, an elevated rate of childhood
9 leukemia or whatever, we will be able to say, at most,
10 that it's this mixture that caused the exposure, similar
11 to what we did at Toms River when we said that -- what was
12 the -- the Parkway well field, which consisted of TCE,
13 PCE, and this exotic chemical, styrene, acrylonitrile
14 trimer, and which one was it?

15 Well, they were all together. You know, or when I
16 studied trihalomethanes, well, which one caused the neural
17 tube defect increase? Was it the chloroform? Was it HX?
18 What -- what was it? That's how Hadnot Point looks to me.
19 It's a mixture with TCE being the main component, and to
20 make inferences, I would have to say that TCE is the main
21 component. But, just as you said, there's benzene.
22 There's all these other contaminants that could also cause
23 or be suspected of causing childhood leukemia.

24 DR. JOHNSON: Okay. The floor is open for things
25 that you think have been not addressed or not addressed

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1 adequately, things that you commented on in premeeting.
2 So let's put them on the table. David.

3 DR. DOUGHERTY: I'm just going to return to your
4 suggestion because the panel statement had, in terms of
5 advancing the state of the art, and just comment that what
6 it really looks like to me is the other bookend to Dover
7 Township that really is going to help define the
8 limitations of the methodology because there's such great
9 uncertainty here as compared to a very different case at
10 the other end.

11 DR. JOHNSON: Thank you. Ben, do you want to start?
12 Anything that's not been put on the table or put on the
13 table to your dissatisfaction?

14 MR. HARDING: I thought that's what we were doing
15 just now. Then we got interrupted to respond to your
16 charge.

17 COURT REPORTER: Microphone, please.

18 MR. HARDING: Again, the issue, monochloride, we've
19 raised it a couple of times, but I think it's something
20 that should not be neglected in our reconstructions.

21 DR. CLARK: I think that the issues have been
22 addressed pretty thoroughly in an open forum. I'm very
23 satisfied with the discussion.

24 DR. JOHNSON: David?

25 DR. DOUGHERTY: (Shakes head)

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1 DR. JOHNSON: James?

2 DR. UBER: Well, just a couple of very specific,
3 small questions.

4 DR. JOHNSON: I'm trying to make the point this is an
5 open discussion.

6 DR. UBER: Open discussion; okay. Just because I had
7 a couple of items here that I didn't have -- obviously, I
8 didn't think I had answers to, and I was just curious. In
9 the -- in the Hadnot Point area, what kind of plant
10 production data is available now and historically?

11 MR. MASLIA: Basically the same that we have on all
12 the plants. When we have asked for plant introductions,
13 the one that we have monthly data for -- well, it gives us
14 a chart, and it lists all the water-treatment plants.

15 DR. UBER: Okay. So nothing more than monthly?

16 MR. MASLIA: I haven't looked at the actual
17 individual well records at Hadnot Point, but for the
18 plant --

19 DR. UBER: The plant is monthly. So they didn't have
20 to report anything daily or didn't report daily water
21 production?

22 DR. POMMERENK: Actually, they do.

23 DR. UBER: They do?

24 DR. POMMERENK: I mean, in the recent past, I have
25 personally have data from 1998 on this daily production at

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1 each of the plants.

2 MR. MASLIA: But not for the present -- not for the
3 study period?

4 DR. POMMERENK: No; not for the study period. The
5 information was also for the current.

6 MR. FAYE: All of the data that I'm familiar with
7 from Hadnot Point, from the well-construction data to the
8 contaminant data to the supply data, you could probably
9 generally characterize that as at a higher level of
10 quality and number -- somewhat higher level of quality and
11 number than what is available or what was available for
12 Tarawa Terrace.

13 We can define the relevant issues that we've all
14 talked about in a well-production contamination, temporal
15 distribution of contaminants, spatial distributions, et
16 cetera. We can probably define that somewhat better at
17 Hadnot Point. Historical record: somewhat better at
18 Hadnot Point; not greatly record, but somewhat -- greatly
19 better, but somewhat better than we could at Tarawa
20 Terrace.

21 DR. UBER: But with regard to temporal resolution --

22 MR. FAYE: That too.

23 DR. UBER: Okay. So the subtext of that is that --
24 the only reason why I'm asking that is because I'm
25 thinking of the issue of interconnectiveness. And I'm

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1 thinking of just, in terms of the simplest model, if one
2 had daily water production and one had information on
3 base, then, you know, conceivably, you could look at a
4 statistical approach that would allow you to say, with
5 some degree of confidence, all of the water was -- all of
6 the water within this area was coming from this plant or,
7 no, there's definitely a shortfall. It had to come from
8 somewhere else. That's why I was asking that.

9 MR. FAYE: I don't think -- the folks from Camp
10 Lejeune can correct me. But I don't think the actual
11 amount of water available versus need at Hadnot Point is
12 not an issue. Where it was an issue was at Tarawa Terrace
13 for a couple of years.

14 DR. UBER: I was talking about the Holcomb area,
15 whether or not that ever got water from, you know, the
16 other two interconnects. So it was my recollection you
17 got about .8 MGD here and you got about three down here.
18 That's the data that I saw. And so I'm thinking, you
19 know, does it go down to .4 and go up to 3.4 on a
20 statistical basis? That's what I'm trying to think about.

21 MR. FAYE: Everything that I know regarding the
22 connection between Hadnot Point and Holcomb Boulevard is
23 that there -- over the years from 1973 to the present,
24 there were possibly some very short-term, intermittent
25 connections between the two systems; i.e., Hadnot Point to

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1 Holcomb Boulevard. Okay? That's that connection.

2 Between Holcomb Boulevard and Tarawa Terrace, there
3 was a supplemental connection, also possibly intermittent;
4 but a lot more continuous than the previous situation
5 between Hadnot Point and Holcomb Boulevard between 1985
6 and 1987 Holcomb Boulevard to Tarawa Terrace. Okay?

7 DR. UBER: Okay. Well, that's just -- that degree of
8 certainty that you just expressed is contrary to what I
9 heard before. I mean, that was our whole -- the whole
10 basis of our discussion of, you know, is Hadnot
11 distribution system a self-contained entity or is there
12 significant -- I'm sorry.

13 Is Holcomb a self-contained entity, or is there some
14 leakage from a contaminated area? That comment just
15 indicates that, no, or very, very intermittently. And so
16 I'm -- yeah; with the exception of those two years.
17 That's right; with the exception of those two years.

18 That was so -- we go back to the comments before that
19 was when we were saying, you know, we need to have some
20 archaeological investigation to look at this. So I'm,
21 frankly, uncertain about the degree of certainty, I guess.

22 MR. MASLIA: Yeah; yeah. We definitely agree with
23 that. And that's my take on the discussion this morning
24 would be to put some effort into trying to reduce the
25 uncertainty or refine the understanding on the

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1 interconnection issue.

2 DR. UBER: Okay.

3 DR. BOVE: It's very important because we're going to
4 be telling people and putting it on our Web site that if
5 you lived here at this particular time you were exposed or
6 not exposed. This is going to be information for
7 everybody -- anyone can see on the Web site, so we need to
8 nail this down.

9 DR. UBER: Okay. So that was my rationale for asking
10 those questions about the production -- production data.
11 The other thing that I was just curious about is I think
12 -- I guess I know the answer to this. But is there any
13 data at all on customer complaints (laughter)?

14 MR. MASLIA: Well, this past spring I was on the
15 airline, coming back to Atlanta, and one of the Marines
16 that was on there with me -- they knew that we were doing
17 some testing. And he says, "Well, the water tastes fine,
18 but I could use a hot shower."

19 DR. UBER: All right. You know the reason why I was
20 asking that is -- and I don't know anything about the -- I
21 don't know anything about taste and odor thresholds for
22 the levels of these contaminants. But if they had any
23 kind of record-keeping of complaint data or things or even
24 in terms of surveys of people. If anybody here knows
25 anything about taste and odor thresholds, it might be an

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1 interesting survey question. You know, did the water
2 smell like gasoline, that type thing.

3 DR. JOHNSON: Okay. Any unfinished business, Lenny?

4 DR. KONIKOW: Well, I think yesterday in the modeling
5 we had lots of specific comments and everything, and I'm
6 sure you'll consider them. I have just one residual
7 specific question, which I don't recall was addressed, and
8 it may have been.

9 But in advective transport, I think Bob said -- or at
10 least I remember reading in the report -- that he placed
11 or seeded particles 600 feet, I believe, east or west of
12 ABC Cleaners; west, I believe. And this somehow led to
13 the conclusion that the source of PCE in TT-23 was not the
14 ABC Cleaners. Am I remembering that right or wrong?

15 MR. FAYE: Well, you're -- you are remembering it
16 right, but the conclusion is wrong. It was just a poorly
17 written statement, Lenny. What I meant to say was that,
18 yeah, I think ultimately the PCE anywhere in that
19 vicinity, the source was ABC Cleaners.

20 DR. KONIKOW: Okay.

21 MR. FAYE: It's just that when the -- when TT-23 was
22 turned on, probably some time in the summer of 1984, and
23 only operated for, maybe, four or five months and in
24 January of 1995 all of a sudden here are these elevated
25 concentrations of PCE found in the well and you're 1600

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1 feet from ABC Cleaners, the conclusion that I was trying
2 to draw or make was that, obviously, whatever PCE entered
3 that well in that very short interval of pumping had to be
4 much nearer the well than ABC Cleaners.

5 And then I went on to the explanation of the
6 overlapping, contributing areas and suggested a
7 possibility for how that area north, immediately north, of
8 TT-23 had become somewhat contaminated with the PCE. So
9 you remembered it right, but I wrote it wrong.

10 DR. KONIKOW: That's okay. Thanks.

11 DR. JOHNSON: Tom, unfinished business?

12 DR. WALSKI: Okay. Well, since I've been accused of
13 being on hallucinogenics, I might as well continue
14 hallucinating here and make an observation that I think's
15 going to happen is: If we sat here today and figured out
16 about when the plume hit Well TT-26, we could probably --
17 with the data we have, including the model we've run, we
18 could probably say it's about the six-month window.

19 So what we're going to do is take another year and do
20 -- and possibly do a tremendous job. It's going to be an
21 outstanding modeling job and put all the uncertainty on,
22 and I'll bet the answer's going to be about the same
23 six-month window that we go today. That's my prediction
24 of probably what is going to come out of the results.

25 But having said that, I think, you know, the study

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1 team's outstanding. I have tremendous respect for the
2 ATSDR people: Bob and the others. I think they're doing
3 just a super job, and, you know, if anything, they're
4 probably doing a little too good of a job, but that's, you
5 know, not a bad criticism.

6 DR. JOHNSON: Okay. Thank you. Vijay, anything
7 that's not been addressed to this point that you'd like to
8 bring up?

9 DR. SINGH: No.

10 DR. JOHNSON: Peter?

11 DR. POMMERENK: I don't have anything either.

12 DR. JOHNSON: Eric?

13 DR. LABOLLE: I'm clean (laughter).

14 DR. JOHNSON: This is a government facility,
15 gentlemen. I don't know if there's anyone out there with
16 bottles waiting for us or not.

17 DR. LABOLLE: But I would like to comment on the
18 six-month factor. I really -- I think that that's -- not
19 the six-month factor, the six-month window of arrival time
20 here.

21 I think that that's a bit optimistic. Actually, my
22 experience has been if one were to really address the
23 level of uncertainty of the hydrogeology with a method
24 capable of doing that -- and at this point, I don't see
25 that that is in the cards for this, given the time frame

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1 in which they want to complete the job and the approach
2 that's been taken already. I think you're already down a
3 path that doesn't allow for the kind of thing I refer to.

4 But in that context, I think one would find that the
5 uncertainty in arrival would actually be much greater than
6 that, possibly. I mean, TT-26 may be close enough to the
7 source that that's narrowed down some of the six months
8 and is still kind of optimistic.

9 DR. WALSKI: So I'm even being too optimistic then.

10 DR. LABOLLE: But it may be -- it may be quite -- it
11 may become clear with a little more analysis that it
12 certainly did arrive prior to the study period beginning
13 in '68. And that's something, I think, that that's
14 another role for the groundwater model in this context.

15 DR. JOHNSON: Okay. Before I, starting with Eric,
16 ask for your individual recommendations and advice on the
17 groundwater work or the system distribution work, Morris
18 and Frank, are there things that are unfinished in your
19 minds? Are there things that you want the panel to
20 address now that haven't been addressed?

21 MR. MASLIA: No; only, Jim, you did ask about water
22 quality complaints, and Jerry just brought this document
23 here. Under Item No. 37, it says, "There have been
24 complaints concerning water quality residents aboard Camp
25 Lejeune." And that's dated -- I don't have the exact date

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1 on this, but it's one of the released Camp Lejeune
2 documents. So there apparently have been complaints. But
3 other than that -- '93. It's 1993.

4 Other than that, we've gotten -- or at least I've
5 gotten some clear indications and clear assessment of what
6 we've done and what we need to do. And I'd just like to
7 thank each one of the panel members. I think it's always
8 better to have internal discussions as opposed to, as
9 Frank said, putting it out on our Web site and then
10 hearing the discussions.

11 DR. JOHNSON: Don't be too conciliatory. You've not
12 heard their final recommendations. Frank, anything that's
13 not been discussed to your satisfaction?

14 DR. BOVE: Thank you very much.

15 DR. JOHNSON: Okay. Starting with Eric and then
16 working our way around, I'd ask for your individual
17 recommendations as to how ATSDR should proceed, given this
18 day and a half of discussions, and you can give that
19 advice, make those recommendations any way you wish:
20 specific to groundwater, specific to the water-
21 distribution systems, or both. So here's your -- at least
22 for this meeting of this expert panel. What are your
23 recommendations?

24 DR. LABOLLE: I suppose I'd begin with regards to the
25 water-distribution system, parsing out this chronology, as

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1 has been suggested by members of the panel, and focusing
2 on those times when we know there was contamination in the
3 system and there wasn't interconnection and assessing the
4 need for the water-distribution system during those times
5 -- the water-distribution system model during those times.

6 And I think the model itself that's been constructed
7 to date may be useful in this for showing that, you know,
8 what comes in this one line into the system reaches the
9 tap. It may be obvious to those of us sitting here, but
10 it may not be obvious to the public. And I think that I
11 would recommend at least demonstrating that to the effect
12 that it can be demonstrated and then identifying those
13 other areas where the water-distribution system model may
14 be important.

15 And I think if there's effort to be put into that
16 that's what I would focus on in terms of the water-
17 distribution system model. In terms of the groundwater
18 model, as I mentioned several times, you know, my
19 principal concern is with the geologic uncertainty and the
20 source terms to the system and how they're modeled and a
21 way to the uncertainty within the context of the model.

22 If there isn't the plan to do that in a realistic
23 way, a geologically realistic way, then one should
24 acknowledge, you know, the outcome of what they're seeing
25 and the uncertainty in the outcome with regards to the

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1 pre-existing characterization that kind of went into it
2 and the inability to modify that within the context and
3 the constraints of the modeling approach.

4 And I think that that's important because that's --
5 what it's going to do is constrain the model outcome to
6 kind of a precondition, you know, range of exposure
7 estimates that don't necessarily encompass the degree of
8 uncertainty that we really have about this system.

9 DR. JOHNSON: Thank you. Peter.

10 DR. POMMERENK: Yeah. My recommendations follow
11 almost exactly on that line. I think the focus on the
12 groundwater modeling should be on determining the range of
13 concentrations and times that the contaminants may have
14 arrived or may not have arrived at the wells. And as the
15 panel has, in my opinion, fully stated that's the driving
16 force for everything that is downstream of that.

17 So again, yeah, the focus should be -- you know,
18 several suggestions have been made, you know, for example,
19 Monte Carlo simulations and so on, to derive a measure of
20 the uncertainty of those values that come out of the
21 groundwater model.

22 With respect to the water-distribution modeling, if I
23 understand this correctly at this point, the main
24 uncertainty that we have right now left over is the degree
25 of interconnection between Holcomb Boulevard and Hadnot

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1 Point. Although we have heard -- we've heard two opinions
2 that think that these interconnections were only
3 intermittent and short-term connections. It would be good
4 to just be certain of this fact, if possible, and go from
5 there.

6 If, indeed, these interconnections don't have any
7 effect on the epidemiological study, then we can
8 essentially proceed and say, you know, whatever comes into
9 the plant goes out everywhere in the distribution system,
10 and that would essentially eliminate the need to, you
11 know, develop further sophisticated distribution-system
12 models.

13 My recommendation is not to continue on the field
14 efforts at this time until these issues have been
15 resolved. That's all I have.

16 DR. JOHNSON: Thank you. Vijay.

17 DR. SINGH: Essentially, I would just reiterate what
18 has already been said earlier as well as this morning and
19 yesterday. First of all, I would like to take this
20 opportunity to state on the record that the ATSDR group,
21 especially Morris Maslia and his group, have done really
22 an outstanding job, and I have nothing but admiration
23 for their work, both quality-wise as well as scientific
24 rigor-wise.

25 Having said that, coming back to the groundwater

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1 modeling area, as we have cited so many times, I think
2 it's important that there is a clear statement and a clear
3 discussion of the model assumptions, the hypotheses, as
4 well as the model limitations because no model is a
5 perfect model. That's why we call it as a model.

6 And from the standpoint of public, I think it's very
7 important to say very clearly what the assumptions are and
8 what the model limitations are and which model hypotheses
9 are, which directly would reflect on the quality and the
10 reliability of the model.

11 And then the issue of uncertainty and risk analysis
12 that we have been discussing since yesterday -- I think in
13 the groundwater modeling area -- this issue has to be
14 clearly, explicitly taken into consideration, and then
15 there has to be a better accounting of the recharge, which
16 really has not been done so far. Recharge has been taken
17 as an average value on a yearly basis, which in my view is
18 a very gross estimate of the rainfall water that goes into
19 the ground.

20 After all, it is the rainfall water which enters into
21 the ground which is responsible for transporting the
22 contaminants into the groundwater body. And so it is, to
23 me, of importance that the water percolation and the water
24 recharge are more accurately estimated and included in the
25 groundwater modeling area.

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1 In terms of the water-distribution network, I think
2 what Peter and Eric have said, I tend to concur with. The
3 original effort on water discovery, I think, will be well
4 worth the effort because there is no substitute for data,
5 for data is the only source through which we get the
6 information through which we communicate with nature. So
7 I would strongly suggest that they continue their effort
8 in terms of discovering or rediscovering the archaeology
9 of the data as far as they can go.

10 But I also tend to concur with Tom in terms of the
11 water-distribution modeling. I think the important point
12 here is once the groundwater model produces water
13 contamination through which we can quantify the water
14 contamination at the wellhead and we can also have some
15 data on the water contamination in terms of time and the
16 depth. I think that is what is essentially going to be
17 primarily responsible for determining the exposure from an
18 epidemiological viewpoint. And I think that, to me, is
19 essentially the central issue, which is what all this
20 interval is meant for.

21 And so I'm not quite certain if a very detailed
22 water-distribution modeling is really necessary. I think
23 a simpler one might suffice, but if they have already done
24 it and they're doing it, it certainly it's not going to
25 hurt.

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1 DR. JOHNSON: Thank you. Tom.

2 DR. WALSKI: Okay. Thanks. Yeah. I want to just
3 second, I guess, what other people have said, and we have
4 an excellent study team here, and they've done a very
5 high-quality job. And it's just really ironic to find
6 myself in the position of not selling modeling because
7 usually that's what I do for a living is sell models and
8 try to get people to use them. So I find myself, kind of,
9 in an odd position here of saying, "Don't put too much
10 emphasis on the models, but go for the real data."

11 And trying to -- I think, maybe, you might remember
12 things better if I could just tell a story here. There's
13 a guy walking down the street and sees another fellow on
14 the ground on his hands and knees, looking around. The
15 first guy -- he goes, "Well, what are you doing down
16 there?" And he goes, "Well, I lost a \$50 bill. I can't
17 find it.

18 So the second guy comes and helps the guy look for
19 the \$50 bill, and after about five minutes, he says,
20 "Well, how come you haven't found it? I mean, where did
21 you lose it?" And he goes, "Well, I lost it over there in
22 that vacant lot." And he goes, "Well, why aren't we over
23 there looking?" And he goes, "Well, it's dark over there,
24 and there's broken glass and rats and stuff. I don't want
25 to go over there."

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1 And I think that's kind of the position that the
2 study team is in. It's kind of nice to work with models,
3 but I think they're going to have to spend their time in
4 the archives with the rats and the broken bottles, looking
5 for data because that's where you're going to get the most
6 for your effort is not being under a light in a nice area,
7 but going to the archives and digging. And I think
8 they're a qualified team, and they're going to do a great
9 job with this.

10 DR. JOHNSON: Great. Thank you. Lenny.

11 DR. KONIKOW: Well, again, I second all the comments
12 that have been made up to now. I again just reiterate
13 with the groundwater modeling and the transport modeling
14 that ultimately we're limited in what we can do in terms
15 of the available data. I mean, you know, we don't have
16 concentration data before 1980 or '82. And so everything
17 we do for looking at distribution before then is going to
18 be a little fuzzy.

19 We'll do the best we can with the flow model. You'll
20 do the best you can with the flow model based on the
21 distribution of pumpage, and that may be about the best
22 you can do. In terms of, you know, the modeling approach
23 and sensitivity analyses, this is all stuff that should be
24 done. And one of the things to keep in mind is that your
25 hydraulic heads in your flow model may be relatively

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1 insensitive to certain things to which the concentration
2 distribution is highly sensitive.

3 And so there's not necessarily a direct transfer
4 value in terms of the sensitivity analysis and uncertainty
5 analysis between the flow and transport model. So it's
6 just something to be aware of.

7 DR. JOHNSON: Jim.

8 DR. UBER: I'll leave it to the groundwater
9 colleagues to talk about the -- what particular elements
10 to include any probabilistic analysis or whatever form
11 that may take, and I think that's clearly appropriate. My
12 only reason for mentioning that is that I would have a
13 suggestion that -- about the way the results of those
14 analysis be portrayed. And specifically, for me, I focus
15 on the precise connection between the groundwater resource
16 and the water-distribution system, which is this pipe
17 header that comes from the well field and goes into the
18 distribution system.

19 And I think that the results of that stochastic
20 analysis should be expressed in terms of the uncertainty
21 or some type of interesting plot of the variability or
22 uncertainty or both in that concentration that it is
23 delivered to the distribution system, considering not only
24 the uncertainty and the geohydrologic variables and the
25 model set-up, but also the uncertainty in how the wells

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1 are operated.

2 I believe that if the uncertainty in that quantity is
3 quantified within some bounds, then what we have been
4 talking about today, which is to, maybe, allow data
5 discovery to drive the train for a little while longer.
6 If we continued on data discovery and then you had the
7 results of that uncertainty analysis, then between those
8 two, I think it would become clear what to do, if
9 anything, more with the water-distribution system model.
10 And I would just leave it at that.

11 DR. JOHNSON: David.

12 DR. DOUGHERTY: Well, yeah, I think people have hit a
13 lot of the points, and we could repeat them several times,
14 as we have through the past couple of days. I think the
15 summary that I have is that the model complexity is too
16 far out in front of the data in the characterization of
17 the uncertainties. It's something that can be corrected,
18 I think, and reasonably without major correction. It's
19 just a correction.

20 The three issues that come to mind, and two of them
21 are on the groundwater side and one's a general, easy
22 observation about the archaeology, about interconnects.
23 And so that's number three, but the first two are about
24 the things that drive concentrations in the groundwater
25 delivered by the wells.

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1 There's the pumping schedules that, I think, keep
2 coming up, but I'm not sure we can do very much about
3 them. The things that we haven't characterized enough are
4 source, the mass loading, and the accretion; not just the
5 reinfiltration but the septic returns and making sure
6 we've got those in a time -- reasonably timed; very, very
7 consistent with the climate.

8 And finally, making any statements about the
9 groundwater issues for Hadnot, I don't feel comfortable
10 about it. I don't think we've had enough conversation or
11 information about that, and that may be something that you
12 may need your next panel to tend to.

13 DR. JOHNSON: Thank you. Robert.

14 DR. CLARK: Well, I don't think I'm going to say
15 anything new or original, but I am generally supportive of
16 the current plan. But I think with any project of this
17 complexity and magnitude, there always adjustments that
18 take place in the process. And it seems to me that a
19 couple of those are the re-emphasis on data discovery,
20 which I think is a very important issue.

21 But the uncertainty issues with regard to the model
22 parameters and the stochastic nature of demand and then
23 the consequences of those yield in terms of the output and
24 data reliability. It seems to me that the real issues
25 surrounding this study are really going to come in the

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1 public health and public policy area in terms of the
2 epidemiological results. Excuse me. That's going to be
3 the one that the public is going to look at, and the
4 public health community is going to look at very, very
5 carefully.

6 So I would suggest anything that needs to be done to
7 support effort to make it more scientifically defensible
8 is an important aspect to the project with the only
9 comments, which I've made before, that the issue of
10 transformation by-products is an important one to look at.

11 And also, what has actually been measured, I guess,
12 in terms of some of the samples that have been taken prior
13 to the establishment of the MCLs or vault organic
14 chemicals, and this concludes an excellent team. I'm more
15 impressed after listening to the presentation than I was
16 before when I read the background data.

17 DR. JOHNSON: Thank you. And Ben.

18 MR. HARDING: I want to thank Morris and ATSDR team
19 for the opportunity to sit in on this panel. I'm very
20 impressed with what you guys have done. It's an eye-
21 opener to see some of the kinds of efforts you guys have
22 made.

23 What I want to suggest is that now you sort of step
24 back and take a higher level look at this again. Take a
25 little break. Reassess the requirements, starting with

NANCY LEE & ASSOCIATES

1 the epidemiological study. Just say, "What is it that we
2 absolutely have to have and what are the things that are
3 just sort of nice?" And probably just toss the latter.
4 But certainly prioritize your requirements, and then make
5 a decision based on a prioritization how you want to use
6 your resources best.

7 With regard to the groundwater, which I can only
8 kibbutz about, but I think it seems clear that the Hadnot
9 Point situation requires some more understanding and
10 possibly some more quantitative work modeling simulation.

11 I think in support of that and in support of, also,
12 the water-distribution system, it's appropriate to do more
13 of what we've referred to as data archaeology and continue
14 in parallel while you're assessing your requirements. It
15 seems that the groundwater work should express the
16 uncertainty of, at least, the arrival time quantitatively
17 and in a probabilistic framework.

18 With regard to the water-distribution system, the big
19 issue here, it seems to me, is -- well, it may not be the
20 biggest issue, but it seems to be the most contentious --
21 is to understand these interconnections. And I would
22 suggest that if it turns out the systems are
23 interconnected and they're interconnected in such a way
24 that water flows from Hadnot Point into Holcomb Boulevard
25 based on the grades that you consider excluding those

NANCY LEE & ASSOCIATES

1 periods of time and those populations that are affected,
2 if you could possibly do that, rather than trying to model
3 that particular situation.

4 Otherwise, in the other periods where the systems can
5 be viewed as operating independently, I think the simple
6 mixing models are adequate. And there, the most important
7 issue, aside from the groundwater arrival time, is the
8 dispatch of the wells. And that might be supported by the
9 data archaeology.

10 And then, finally, and I think this would be a big
11 contribution to the practice. Again, I've said this over
12 and over and over again. But to apply methods of
13 propagating your uncertainty quantitatively. Typically,
14 Monte Carlo is the way people do that. It doesn't mean
15 you have to run your groundwater model in a Monte Carlo
16 framework. There's other ways to do.

17 I think it's practical, and I'd take a real hard look
18 at that because it's very clear from our discussions there
19 is a lot of uncertainty here. And again, thanks for the
20 opportunity. I've very much enjoyed this. I'm very
21 impressed with what you guys have accomplished.

22 DR. JOHNSON: Okay. Any reaction from the agency
23 representatives before we close?

24 MR. MASLIA: Only to thank everyone for spending the
25 time going through the material. Obviously, it was not a

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1 polished report by any means. But, again, to emphasize,
2 we do take your recommendations and suggestions very
3 seriously. It will, I believe, help guide us. We were at
4 a stage where we needed, at least, some external input and
5 guidance and just to thank everyone for their time and
6 effort.

7 DR. JOHNSON: And in closing, one observation from
8 the Chair. I've mentioned the term "cost benefit." And I
9 think, as Ben and others said, I think you -- there's time
10 now, and I think there's need now for the agency to step
11 back and reflect and digest what you've heard over the
12 past day and a half.

13 And I think you need to ask yourself, in the vain of
14 getting data in which you have confidence, what benefit is
15 it going to be toward that goal if other activities are
16 done or not done? What's going to be the cost of some of
17 these things you've put on the table? And perhaps, as a
18 result of the last day and a half, some suggestions have
19 been to perhaps reorder those activities? So take a hard
20 look at the cost of what you're proposing to do in the
21 future, factoring in the advice you've heard here from
22 this panel.

23 And with that, I'd like to close by thanking, as the
24 Chair, this panel. I've been in public health for about
25 40 years, and so I've attended lots and lots of meetings.

NANCY LEE & ASSOCIATES

1 I've been on lots and lots of committees. Some
2 committees, I've chaired. Some other committees, I simply
3 chewed on as a member. But this is, certainly, in my
4 experience, the most able and the most helpful committee
5 of which I've had the privilege of being associated. So
6 really, accolades to the panel.

7 I'd also like, on behalf of the panel, to thank the
8 agency representatives: Morris, Frank, Bob Faye, and
9 others who really in an exemplary way represented the
10 agency and interacted with this panel and with the public
11 representatives.

12 On behalf of the panel, I also would like to thank
13 the public input and the public representatives here. And
14 what was added was really important insights that we would
15 not have had otherwise brought forward and were very
16 valuable.

17 A special thanks to our reporter, who kept us all in
18 line, starting with the Chair. So many thanks for your
19 expert work. And lastly, many thanks to the
20 administrative staff, Ann Walker and her colleagues, who
21 have made much of what has been brought to you happen in
22 terms of materials, arrangements, et cetera, et cetera.

23 So with that, using the prerogative of the Chair, I
24 declare us adjourned. Thank you.

25 (Whereupon, the proceeding was adjourned at

NANCY LEE & ASSOCIATES

1 approximately 1:35 p.m.)

NANCY LEE & ASSOCIATES

EXHIBIT 9

THE U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

convenes the

EXPERT PANEL MEETING

Analysis and Historical Reconstruction of
Groundwater Resources and Distribution of
Drinking Water at Hadnot Point, Holcomb
Boulevard and Vicinity, U.S. Marine Corps
Base, Camp Lejeune, North Carolina

APRIL 29, 2009

The verbatim transcript of the Expert Panel Meeting
held at the ATSDR, Chamblee Building 106,
Conference Room A, Atlanta, Georgia, on Apr. 29,
2009.

ORIGINAL

STEVEN RAY GREEN AND ASSOCIATES
NATIONALLY CERTIFIED COURT REPORTING
404/733-6070

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April 29, 2009

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TRANSCRIPT LEGEND

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-- (sic) denotes an incorrect usage or pronunciation of a word which is transcribed in its original form as reported.

-- (phonetically) indicates a phonetic spelling of the word if no confirmation of the correct spelling is available.

-- "uh-huh" represents an affirmative response, and "uh-uh" represents a negative response.

-- "*" denotes a spelling based on phonetics, without reference available.

-- "^" represents inaudible or unintelligible speech or speaker failure, usually failure to use a microphone or multiple speakers speaking simultaneously; also telephonic failure.

-- “[-ed.]” represents a correction made by the editor

EXPERT PANEL

Analysis and Historical Reconstruction of
Groundwater Resources and Distribution of Drinking Water
at Hadnot Point and Holcomb Boulevard and Vicinity, U.S.
Marine Corps Base, Camp Lejeune, North Carolina.

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Glossary of Acronyms and Abbreviations

ASCE	American Society of Civil Engineers
AST	above ground storage tank
ATSDR	Agency for Toxic Substances and Disease Registry
AWWA	American Water Works Association
BTEX	benzene, toluene, ethylbenzene, and xylenes
CAP	community assistance panel
CD-ROM	compact disc, read-only-memory
CERCLA and Liability Act	Comprehensive Environmental Response, Compensation, and Liability Act
CI	cast iron
DCE	DCE: dichloroethylene
	1,1-
DCE:	1,1-dichloroethylene or 1,1-dichloroethene
	1,2-
DCE:	1,2-dichloroethylene or 1,2-dichloroethene
	1,2-
cDCE:	<i>cis</i> -1,2-dichloroethylene or <i>cis</i> -1,2-dichloroethene
	1,2-
tDCE:	<i>trans</i> -1,2-dichloroethylene or <i>trans</i> -1,2-dichloroethene
DHAC	Division of Health Assessment and Consultation, ATSDR
DOD	U.S. Department of Defense
DON	U.S. Department of Navy
EPANET or EPANET 2	a water-distribution system model developed by the EPA
ERG	Eastern Research Group, Inc.
gal	gallons
gpm	gallons per minute
HPIA	Hadnot Point Industrial Area
HUF	hydrologic unit flow
IRP	installation restoration program
LGR	local-grid refinement
MESL	Multimedia Environmental Simulations Laboratory, Georgia Institute of Technology
MGD	million gallons per day
µg/L	micrograms per liter
MODFLOW	a three-dimensional groundwater flow model developed by the U.S. Geological Survey
MODPATH	a particle-tracking model developed by the U.S. Geological Survey that computes three-dimensional pathlines and particle arrival times at pumping wells based on the advective flow output of MODFLOW
MT3DMS	a three-dimensional mass transport, multispecies model developed by C. Zheng and P. Wang on behalf of the

1		U.S. Army Engineer Research and Development Center,
2		Vicksburg, Mississippi
3	NAVFAC	Naval Facilities Engineering Command
4	NCEH	National Center for Environmental Health, U.S. Centers
5		for Disease Control and Prevention
6	NTD	neural tube defect
7	PCE	tetrachloroethylene, tetrachlorethene, PERC® or PERK®
8	PEST	a model-independent parameter estimation and
9		uncertainty analysis tool developed by Watermark
10		Numerical Computing
11	ppb	parts per billion
12	PVC	polyvinyl chloride
13	SGA	small for gestational age
14	Surfer®	a software program used for mapping contaminant
15	plumes in groundwater	
16	TCE	trichloroethylene, 1,1,2-trichloroethene, or 1,1,2-
17	trichloroethylene	
18	TechFlowMP	a three-dimensional multiphase multispecies contaminant
19		fate and transport analysis software for subsurface
20		systems developed at the Multimedia Environmental
21		Simulations Laboratory (MESL) Research Center at
22		Georgia Tech
23	TTHM	total trihalomethane
24	USEPA	U.S. Environmental Protection Agency
25	USMC	U.S. Marine Corps
26	USGS	U.S. Geological Survey
27	USPHS	U.S. Public Health Service
28	UST	underground storage tank
29	VC	vinyl chloride
30	VOC	volatile organic compound
31	WTP	water treatment plant
32		

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P R O C E E D I N G S

(8:15 a.m.)

HOUSEKEEPING RULES

MR. MASLIA: I'd like to welcome everybody and thank especially the experts on the panel for coming to this two-day panel meeting and providing input to the Agency and to those working on the Camp Lejeune Health Study. It means a lot of us for you to provide us with your time and input and appreciate your pre-meeting comments.

And I'll just go over some house rules. You came in at the Visitor's Center. This is for lack of a better word an official federal facility or compound. So you are prisoners of Building 106, and my name I think is on all of your visitors' badges. I'm not sure if you want to claim that or not, but if you walk outside the building I'm sure I'll hear about it. So with that we'd like to ask that all of your activities remain in Building 106 if at all possible.

There is a cafeteria. Some of you passed in front of it as you came in, and

1 there's lunch there. While we don't
2 officially have reserved tables, we have set
3 aside a row of about 25 or 30 seats that have
4 reserved signs for the expert panel at the end
5 of the cafeteria by the outside atrium as you
6 walk past the cashiers all the way to the end.
7 So if y'all want to sit together, that's fine.
8 We'll make that possible.

9 And also, there are vending machines
10 to my right outside the room here. Also, as I
11 said, due to security it's advisable not to
12 leave the building. We can't do it without
13 one of us or ATSDR person and but for this
14 evening or whatever, there's all sorts of fast
15 food, ethnic restaurants up and down Buford
16 Highway, which is a strip you came down, the
17 seven-lane strip you came down this morning if
18 you were awake to watch much of the scenery.
19 Snack rooms as I said. The restrooms are to
20 my left a couple of doors down.

21 We've got a number of people helping
22 us. I just want to -- I'm sure I've left
23 somebody off, so just let me know. But Liz
24 Burlsen* [Bertelsen -ed.], who is from ERG,
25 and has been in contact with most of our

1 expert panel members. Jerome Cater*, Chris
2 Fletcher*, Cathy Hemphill* in the back who
3 brought us some coffee, Rachel Rogers* and
4 Jane Tsu*. I don't think she's here.

5 Miscellaneous items: This is a sensor
6 mike system, so you push the red button twice,
7 and the red ring will come on around the top
8 of the mike, and please speak into the mike.
9 On the long tables here we've got four for
10 five people, so share. You on the short
11 table, y'all each have your own mike.

12 Please state your name for the first
13 time -- we've got a court reporter -- when you
14 speak into the mike or during the public
15 session, when people come up, please state
16 your name and affiliation.

17 This meeting is being audio taped,
18 streamed live to the web and videotaped. It
19 is a public meeting. As I said there's a
20 court reporter recording everything, and
21 that'll be part of the meeting report just
22 like -- for those of you who were in the first
23 expert panel meeting in 2005, the report that
24 came out had two CDs with the verbatim
25 transcripts. The same thing will happen here.

1 You'll, of course, get an opportunity to
2 correct that or see a draft report obviously
3 before it goes final to correct any
4 information.

5 Turn off your cell phones to silence
6 or vibrate and please no sidebars because it's
7 difficult for the court reporter to record
8 what you're speaking about on the side, and it
9 may prove very important to us at ATSDR for
10 those comments. So we'd like to hear it in
11 public.

12 And that is it for housekeeping rules.
13 Any questions?

14 (no response)

15 **MR. MASLIA:** At this time I'll bring up Dr.
16 Sinks.

17 **OPENING REMARKS AND INTRODUCTION OF CHAIR**

18 **DR. SINKS:** Good morning everybody. My name
19 is Tom Sinks. I'm the Deputy Director for
20 both the National Center for Environmental
21 Health and the Agency for Toxic Substances and
22 Disease Registries, a long title. And I just
23 wanted to welcome you here today. I am not an
24 engineer. I am not an engineer. I'm an
25 epidemiologist.

1 I have two of my mentors during my
2 graduate school were actually converted
3 engineers into epidemiologists of all things,
4 and it may be why I got into the Environmental
5 Health area. Because a lot of epidemiology is
6 focused on physicians who become
7 epidemiologists, the people from the health
8 side who then go on to look at health issues.

9 And it's very important, at least in
10 Environmental Epidemiology, for people on the
11 exposure side to become involved in
12 epidemiology because of an appreciation of how
13 important it is to get exposure right. And if
14 you have any appreciation for epidemiology,
15 misclassification of either exposure or
16 disease, is critical to the quality of your
17 work.

18 And in general, if it's unbiased
19 misclassification, it will always drive you
20 towards not finding associations. So we are
21 very, very concerned in Environmental
22 Epidemiology that we get exposure right;
23 hence, this is why we have you.

24 It's not unusual in situations where
25 you have Environmental Epidemiology you're

1 trying to look back over time that you have
2 precious little information about exposure.
3 And somehow you have to go back and try to
4 figure out as accurately as possible what
5 people were exposed to when you really don't
6 have the information you would like to have,
7 which is, gee, I wish I had some monitors on
8 the tap water -- in this case, Hadnot Point
9 from 1950 until 1985 -- so I knew exactly what
10 these people were, and, gee, I wish I knew
11 exactly how much they were drinking and how
12 often they were showering, da-da-da da-da.

13 We don't have that information. We'd
14 love to have it, but what we're going to do is
15 use fairly sophisticated techniques to try to
16 get back to the best information we can so we
17 can do a good job with our epidemiology.

18 A couple things I want to say to you.
19 First of all, I always appreciate Morris
20 because he does such a great job. He wrote my
21 opening remarks, and I'll pass these around
22 for you if you'd like to see them because I
23 don't plan to use them, but thank you, Morris.
24 I'm sure they would have come out much more
25 gracious than I will in person.

1 I want to make a couple of comments to
2 you. For us, Monday -- no, Tuesday through
3 Thursday is of all things a Camp Lejeune
4 marathon. Yesterday we had our community
5 advisory committee -- no, Community Assistance
6 Panel, thank you, our CAP. Some of those
7 members are here today. And the next two days
8 we have this panel.

9 And one thing that I am very pleased
10 with in terms of this project is the amount of
11 openness and transparency that we're trying to
12 put into this project. I think we can always
13 try to do more, and if there are ways we can
14 do more, we're interested in hearing that.
15 But that's something that I think is somewhat
16 unique about ATSDR. I'm very proud of it, and
17 I think we are trying to do the best job
18 possible on that.

19 Also, on this project and many of our
20 projects we're very interested in not doing
21 these solely intramurally. We're very
22 interested in critical comment. Not just
23 comment that says, hey, that's fine. Keep
24 going. But a critical comment that says this
25 is where I think you could do better.

1 Now in terms of being a scientist in
2 this program and a supervisor, our job is to
3 do exactly that with our staff. And we're not
4 doing that if our staff are not being critical
5 of ourselves all of the time. We should be
6 doing that. We're hoping you will be doing
7 that. You don't have to be too critical, but
8 that's an important role for us.

9 And in Camp Lejeune, at least since
10 I've been involved with this project, this is
11 the third expert panel that we've held on Camp
12 Lejeune. The first one had to do with seeking
13 some advice from outside experts on additional
14 epidemiologic studies. We had one similar to
15 this on Tarawa Terrace, and this one today on
16 Hadnot Point on exposure modeling.

17 And of all things, the National
18 Academy of Sciences is writing a very large
19 report we heard on Camp Lejeune. And we heard
20 yesterday that the report that was scheduled
21 to come out next week is now delayed again.
22 So that's another piece of this.

23 So we're getting quite a lot of that.
24 We will continue to get that. When we issue
25 our reports, we'll put them out as public

1 comment. We will get more comment then, but
2 that's part of the process.

3 In terms of this project, I think
4 you're probably very well aware of the charge.
5 And I'll just say maybe simply we want to get
6 the best information we can. Now, at the same
7 time I really don't want to spend five years
8 trying to figure out the best information we
9 can. I really want to make sure we're getting
10 the best information we can; we're doing it in
11 a timely way, and we're proceeding along to
12 get these projects finished.

13 Because, frankly, when I retire when
14 I'm 70 -- because my youngest is six years old
15 now -- when I retire when I'm 70, I hope I'm
16 no longer in the business of Camp Lejeune. I
17 know it will be something that has great
18 interest to many people, but I hope we can get
19 our projects finished, get the information out
20 that needs to get out and get things done that
21 need to be done at Camp Lejeune.

22 And so while you're looking at this,
23 and you're scrutinizing this, I hope you
24 recognize that this is not just an exercise in
25 excellence. It's an exercise in an applied

1 public health approach to an applied problem
2 that people need answers to, and we really
3 want to move ahead and get the best job we can
4 done.

5 So with that I'll just close, and I
6 hope you liked my opening comments whatever
7 they were. And with that, Morris.

8 **MR. MASLIA:** Introduction of panel members.

9 **DR. SINKS:** I didn't realize you wanted me
10 to do that, but you did give me this so I will
11 introduce this. Most importantly, Bob Clark
12 is from Cincinnati, Ohio, where I spent six
13 years working for the National Institute of
14 Occupational Safety and Health. I lived in
15 Hyde Park right next to Graeter's Ice Cream.
16 I could walk down there every afternoon, and I
17 gained five to ten pounds.

18 Bob is a registered engineer and, I
19 believe, a friend to epidemiologists.
20 Currently, an independent environmental
21 engineering and public health consultant. He
22 retired from EPA in 2001. He's worked as
23 environmental engineer at the --

24 You were a commissioned officer?

25 **DR. CLARK:** Right.

1 **DR. SINKS:** He was a commissioned officer
2 working in U.S. EPA, which is actually a
3 fairly rare thing. He was Director of the
4 Water Supply and Water Resources Division at
5 EPA from '85 to '99, and was appointed to a
6 senior expert position at the EPA. He's
7 authored or co-authored more than 350 papers
8 and published five books. And I guess I'm
9 going to turn this over to you.

10 **MR. MASLIA:** I was remiss in not stating,
11 and I apologize to the experts and the
12 audience. Those who have been in... We
13 originally had James Blumenstock as our Panel
14 Chair, which was on the original, and James,
15 working for ~~ASTO~~ [ASTHO -ed.], got called up
16 Monday morning to head their federal task
17 force on the swine flu.

18 And so on short notice, Bob Clark has
19 done a number of these panels, and I just want
20 to assure for the record, that neither ATSDR,
21 NCEH or CDC have any financial obligations or
22 association with Bob Clark, and there is no
23 conflict of interest, and we're appreciative
24 of Bob's effort to step in at a moment's
25 notice.

1 **OPENING STATEMENT AND PRESENTATION OF CHARGE**

2 **DR. CLARK:** Thank you, Morris, and thank
3 you, Tom.

4 When James couldn't do it, well, they
5 visually scraped the bottom of the barrel and
6 came up with what they could find, and so
7 that's me. So I will be the chairman this
8 morning.

9 As all of you have been with the
10 government or are with the government or
11 affiliated with the government, you know
12 there's a certain amount of bureaucracy that
13 goes on. And one of the things we have to do,
14 I have to read the charge so that we establish
15 the fact that this is an official government
16 meeting, so I'm going to do that.

17 This is the expert panel assessing
18 ATSDR's methods and analysis for historical
19 reconstruction of groundwater resources and
20 distribution of drinking water at Hadnot
21 Point, Holcomb Boulevard and vicinity, U.S.
22 Marine Corps Base, Camp Lejeune, North
23 Carolina. The purpose and scope of this
24 expert panel is to assess ATSDR's efforts to
25 model groundwater and water distribution

1 systems at the U.S. Marine Corps Base, Camp
2 Lejeune, North Carolina.

3 This work includes data discovery,
4 collection and analysis as well as water
5 modeling activities. To assist the panel
6 members with their assessment, they have been
7 provided with the methods used and results
8 obtained from ATSDR's previous modeling
9 efforts at Camp Lejeune which focus on the
10 area of Tarawa Terrace and vicinity. This
11 panel is specifically charged with considering
12 the appropriateness of ATSDR's approach,
13 methods and time requirements related to water
14 modeling activities.

15 It is important to understand that the
16 water modeling activities for Hadnot Point,
17 Holcomb Boulevard and vicinity are in the
18 early stages of analysis; hence, the data
19 interpretations and modeling methodology are
20 subject to modifications partly based on input
21 provided by members of this panel.

22 ATSDR expresses a commitment to weigh
23 questions from the public and to respond to
24 public comments and suggestions in a timely
25 fashion. However, in order for this panel to

1 complete its work, it must focus exclusively
2 on data discovery and analysis and water
3 modeling issues. Therefore, the panel will
4 only address questions or comments that
5 pertain to data discovery and analysis and
6 water modeling efforts.

7 For all non-water modeling questions
8 or statements, the public can contact the
9 ATSDR Camp Lejeune Information Hotline at
10 telephone ~~7-7-0-4-8-8-3-5-1-0~~ [770-488-3510 -
11 ed.] or e-mail atsdrcamplej@cdc.gov. So
12 that's the obligatory business that we have to
13 take care of this morning.

14 One thing I want to be sure is we have
15 a fair and open discussion. I certainly don't
16 want to cut off any discussions or the
17 opportunities for the experts to express their
18 opinions, especially this panel. But we do
19 have a very tight and specific agenda that
20 we're going to have to try to complete. And
21 so I'm going [to -ed.] hold fairly tightly to
22 this so I want to warn you now that if I
23 request that you terminate your discussion or
24 your questions, it's not because I don't want
25 to hear them; it's because we need to meet the

1 tightness of our deadline. So I'm going to
2 try to hold tightly to the agenda.

3 If there's additional comments, for
4 example, if the web people, web-streaming
5 people have comments, they can send e-mails
6 into ATSDR to get their questions answered.
7 Anybody here who has questions or feel like
8 there's an issue that has not been well
9 addressed can submit those questions or
10 comments in writing. I think Morris can give
11 you a contact point for that. We want to be
12 sure that we have the maximum input, but we
13 particularly, of course, want to hear from
14 this excellent expert panel.

15 **INTRODUCTION OF PANEL MEMBERS, AFFILIATIONS, AND**
16 **RELATED EXPERIENCES**

17 Just to give you a little more
18 background on my background, we'll go around
19 the table and introduce ourselves. I spent 41
20 years with the U.S. Public Health Service and
21 the U.S. EPA, 30 of those years were as a U.S.
22 Public Health Service commissioned officer.
23 So I'm very familiar with some of the uniforms
24 that I see in the room today.

25 I was detailed to the EPA when it was

1 created and ~~was~~, [-ed.]for 14 years of that
2 time, I was Director of the Water Supply and
3 Water Resources Division in Cincinnati. I was
4 actively involved in helping set the standards
5 and develop the technologies that are utilized
6 under the Safe Drinking Water Act for treating
7 the kinds of chemicals we're going to be
8 talking about today, so I'm very interested in
9 this area. I spent three years as a senior
10 scientist and since that time, I retired in
11 2002, I've been an independent consultant.

12 So let's go around the room. Randall.

13 **DR. ROSS:** My name is Randall Ross. I'm a
14 hydrogeologist at the Robert S. Kerr
15 Environmental Research Center, Ada, Oklahoma,
16 for the U.S. EPA. I've been with EPA 22
17 years, I guess, at Kerr Lab working for the,
18 what's now called the Applied Research and
19 Technical Support Branch, providing technical
20 assistance to EPA regional offices and
21 hazardous waste sites in all ten regions over
22 that time, mostly in hydrogeology, drilling
23 and groundwater modeling-related activities.

24 **DR. KONIKOW:** My name is Lenny Konikow. I'm
25 a research hydrologist, hydrogeologist with

1 the U.S. Geological Survey in Reston,
2 Virginia. I've been with the USGS for about
3 37 years, mostly in the research program and
4 have been involved in developing groundwater
5 flow and ~~solutransport~~ [solute-transport -ed.]
6 models and applying them to groundwater
7 contamination problems as well as water supply
8 problems.

9 **DR. GOVINDARAJU:** Hello, I am Rao
10 Govindaraju. I'm a professor in the School of
11 Civil Engineering at Purdue University. My
12 area of expertise is in surface and sub-
13 surface flows and contaminant transport. I've
14 been at Purdue for about 12 years now, and
15 before that I was a faculty member in Kansas
16 for five years.

17 **MR. HARDING:** I'm Ben Harding. I'm a civil
18 engineer with AMEC Earth and Environmental in
19 Boulder, Colorado, originally trained as what
20 was then called a sanitary engineer, worked in
21 advanced waste treatment for a number of years
22 and then started to practice warm water
23 resources and done a number of reconstructions
24 of fate and transport of contaminants in water
25 distribution systems. And I'm interested in

1 risk assessment and treatment of uncertainty.

2 **DR. CLAPP:** My name is Dick Clapp. I'm an
3 epidemiologist now at Boston University School
4 of Public Health where I've been on the
5 faculty for the last 18 years. Prior to that
6 I worked as Director of the Massachusetts
7 Cancer Registry and was deeply involved with
8 the Woburn Childhood Leukemia Cluster and the
9 water model that was created by a geologist at
10 the University of Massachusetts in Amherst,
11 named Peter Murphy.

12 And subsequently to that I worked in
13 the consulting company and was hired as a
14 consultant to the Ocean County Health
15 Department in New Jersey where they were
16 concerned about the Toms River exposures from
17 hazardous waste sites that may have affected
18 childhood cancer.

19 I'm currently a member of the CAP, and
20 I, as a result of that, get paid per diem by
21 ATSDR. I was here yesterday for the CAP
22 meeting, and I've been for the last three
23 years.

24 **DR. POMMERENK:** My name is Peter Pommerenk.
25 I'm an environmental engineer. I am currently

1 an independent consultant and used to consult
2 on various Marine Corps and Navy contracts
3 with Camp Lejeune, working on water treatment
4 projects and water distribution projects.

5 **DR. WARTENBERG:** I'm Dan Wartenberg, a
6 professor and Chief of the Division of
7 Environmental Epidemiology at Robert Wood
8 Johnson Medical School. And most of my
9 research is on spatial epidemiology and GIS
10 applications in epidemiology and also on
11 disease clusters. And in 2000 I wrote the
12 epidemiology section of EPA's reassessment of
13 TCE, which I guess is still to move forward in
14 terms of regulation.

15 **DR. BAIR:** My name is Edwin Scott Bair. I
16 go by Scott. I'm a faculty member at Ohio
17 State University in the Department of Earth
18 Sciences. I have experienced six years with
19 Stone and Webster Engineering Corporation. I
20 worked with the USGS 16 years as a part-time
21 employee.

22 And if I have a distinction at this
23 table, it's being the only one who's lived at
24 Camp Lejeune in 1952 when my father was called
25 back into the Marines. My interests are in

1 ground water hydrology, fate transport
2 modeling. And one of my Ph.D. students, Maura
3 Metheny, several years ago did a lot of work
4 on the cancer cluster up at Woburn,
5 Massachusetts.

6 **DR. ASCHENGRAU:** My name is Ann Aschengrau.
7 I'm an environmental epidemiologist at Boston
8 University School of Public Health. I'm a
9 classically trained epidemiologist, and the
10 area of research that I've been investigating
11 for probably about 15 years now is solvent-
12 contaminated drinking water. The research has
13 been done primarily in the Cape Cod area of
14 Massachusetts, which experienced exposure to
15 tetrachloroethylene through the drinking water
16 supply. I've also been investigating the
17 spatial epidemiology of cancer and other
18 diseases in the Cape Cod area, and happy to be
19 here today.

20 **DR. DOUGHERTY:** My name is Dave Dougherty.
21 I'm a consultant ~~on subterranean research~~ [at
22 Subterranean Research -ed.] in Duxbury,
23 Massachusetts. I'm trained as an engineer and
24 my expertise is in groundwater. My career arc
25 has gone from consulting to academia and back

1 to consulting. I was a faculty member at the
2 University of California Irvine and the
3 University of Vermont. Back to Toms River, my
4 first consulting gig was putting together a 3-
5 D flow and transport at Toms River 25 years
6 ago and has moved on to optimization perimeter
7 estimation and long-term monitoring.

8 **DR. HILL:** Hi, my name's Mary Hill. I am a
9 Research Hydrologist with the U.S. Geological
10 Survey and have my educational background is
11 geology and civil engineering. And I have
12 specialized in with groundwater models,
13 specifically integrating data and models,
14 essentially how to do that best, what the
15 uncertainty is, calibration methods,
16 sensitivity analysis methods. And my book,
17 actually a copy of my book is over there. It
18 came out a couple of years ago. And I also,
19 as part of that book, developed a set of
20 guidelines for model calibration. There's a
21 lot of talk about guidelines in this and what
22 to use. Also, some years ago for a
23 Proceedings article, I did a review of
24 existing guidelines for groundwater model
25 development and had submitted those. I don't

1 know if they're around, but there were some
2 questions about what guidelines might be
3 available so that might be useful. Thank you.

4 **DR. GRAYMAN:** Good morning. I'm Walter
5 Grayman. I'm an independent consulting
6 engineer in Cincinnati and have been for the
7 past 25 and-a-half years. My background is in
8 civil and environmental engineering, but for
9 the past, again, about 25 years I've been
10 working in modeling of water distribution
11 systems, hydraulic modeling and working with
12 Bob Clark early in terms of developing water
13 distribution system, water quality models. I
14 did serve as a consultant for ATSDR on the
15 Camp Lejeune work for a few years back when
16 they were first starting it in terms of the
17 field analysis modeling.

18 **DR. CLARK:** Well, thank you everybody. I'm
19 sure we have a very highly qualified panel,
20 and I'm looking forward to hearing everybody's
21 comments. I'm sure they're going to be quite
22 pertinent; it's going to be an interesting
23 session, I think.

24 Morris, you're up next with your
25 staff.

INTRODUCTION OF CAMP LEJEUNE**EPIDEMIOLOGICAL STUDY TEAM****INTRODUCTION OF STAKEHOLDERS**

1
2
3 **MR. MASLIA:** At this point Frank and I will
4 introduce the ATSDR Health Studies staff and
5 stakeholders as well.

6 Frank, I think you're up first so --

7 **DR. BOVE:** My name is Frank Bove. I'm a
8 Senior Epidemiologist in the Division of
9 Health Studies at ATSDR, been at ATSDR since
10 1991, before that with the New Jersey Health
11 Department. And I'm co-PI on this work.

12 Perri Ruckart is back there. She's
13 also co-PI, and she's an Epidemiologist in the
14 Division of Health Studies. And Carolyn
15 Harris, who's sick today, she's a Public
16 Health Analyst who works on our budgets and
17 contracts with contractors and so on. So
18 that's the epi side of the picture.

INTRODUCTION OF WATER MODELING TEAM

19
20 **MR. MASLIA:** From the water modeling side,
21 the study -- of course, I'm Morris Maslia.
22 I'm a Research Environmental Engineer, and
23 I've been with ATSDR and CDC since 1992, and I
24 also spent almost ten years with the U.S.
25 Geological Survey back in the days when we had

1 money to do lansa^ [RASA (Regional Aquifer
2 System Analysis) -ed.] studies and water
3 resource we talked about.

4 Since the first panel, is interesting.
5 We have the Agency has put resources in
6 obtaining additional full-time staff. For
7 those who were on the first panel, remember
8 Jason Sautner was the only other full-time
9 person with me, back there. Since then we've
10 added Barbara Anderson in the back row, and
11 Rene Suarez. And we also have Bob Faye, who's
12 with Eastern Research Group, who was also with
13 us for the first panel. And Dr. Mustafa Aral
14 from the Multi-media Environmental Simulations
15 Lab at Georgia Tech.

16 And at this point Frank and I would
17 also like to introduce stakeholders, and if we
18 miss anybody, please, if you want to stand up
19 and introduce yourselves, but we have from
20 Camp Lejeune and Marine Corps Headquarters, I
21 see Scott Williams, who has been our point of
22 contact both previously at Camp Lejeune and
23 now at Headquarters. We've got Dan Waddill
24 from the Navy. I see Joel Hartsoe from Camp
25 Lejeune and Brynn Ashton, also, Thomas Burton.

1 And are there other people from the --

2 **MR. GAMACHE:** Chris Gamache.

3 **MR. MASLIA:** Chris Gamache, I know I'd miss
4 somebody, welcome.

5 Then on the CAP -- oh, I'm sorry, I
6 forgot Mary Ann Simmons, forgive me.

7 **DR. BOVE:** Mary Ann's also the DOD
8 representative on the Community Assistance
9 Panel. And Mike Partain, back there, is also
10 a community member on the Community Assistance
11 Panel. And Jerry Ensminger walked out just
12 now, but he'll be back, is also on the
13 Community Assistance Panel.

14 **MR. MASLIA:** Is there anybody else who -- I
15 know we have a representative from EPA from
16 Cincinnati.

17 **MR. BELGIN** [Beljin -ed.]: Milovan ~~Belgin~~
18 [Beljin -ed.] ^ ~~geologist~~ [hydrogeologist -
19 ed.].

20 **MR. MASLIA:** And I've corresponded with him
21 along with Dr. Ross for the expert panel. So
22 welcome everybody. And at this point we're a
23 little ahead of schedule which is good.

24 **SUMMARY OF CURRENT HEALTH STUDY**

25 Frank, let me pull up your and Perri's

1 presentation, and we'll proceed with the
2 current health study, big picture, from Frank
3 and Perri.

4 **MS. RUCKART:** Good morning, Perri Ruckart,
5 ATSDR. Frank and I are just going to briefly
6 describe our current health study at Camp
7 Lejeune for you. We already introduced the
8 project team.

9 Now, ATSDR has conducted or is in the
10 process of conducting several health studies
11 at the base, and we started by looking at the
12 health effects on children or fetuses because
13 they were seen to be the most vulnerable
14 population on chemical exposures. In 1998 we
15 published a study on adverse pregnancy
16 outcomes. We evaluated potential maternal
17 exposure to drinking water contaminants and
18 the following outcomes: pre-term births,
19 small for gestational age and mean birth
20 weight deficit.

21 At that time we were only able to use
22 available databases. There was no water
23 modeling. We used electronic birth
24 certificates beginning in 1968, and during
25 1968 to 1985, when most of the contamination

1 ended, there were 12,493 singleton live births
2 on the base.

3 And to assign the exposure we looked
4 at base family housing records and linked
5 those to the mother's address at delivery and
6 usually the father's name. But we could not
7 evaluate birth defects and childhood cancers
8 because we're just relying on information from
9 the birth certificates.

10 The results of this study showed that
11 exposure to Tarawa Terrace water, which was
12 contaminated with PCE, there was an elevated
13 risk for small for gestational age among
14 infants born to mothers greater than 35 years
15 and mothers with two or more previous fetal
16 losses. As far as the exposure to Hadnot
17 Point water and TCE, there was an elevated
18 risk for SGA only among male infants.

19 However, going through this water
20 modeling process we discovered new data -- I'm
21 sorry, we discovered that there was exposure
22 misclassification because an area that was
23 previously categorized as unexposed is going
24 to be exposed. So once we have the water
25 modeling results, we're going to go back and

1 re-analyze the results from the 1998 study.

2 Now we also have a current case-
3 control study, and I want to point out to you
4 that here at ATSDR we do have peer review of
5 our study protocols and the final study
6 reports. I just want to mention that all of
7 our work here has been peer reviewed.

8 So the current study is exposure to
9 VOCs in drinking water and specific birth
10 defects and childhood outcomes. This was a
11 multi-step process. It involved reviewing the
12 scientific literature to identify which
13 defects and childhood cancers were potentially
14 associated with the contaminants and that we
15 could possibly pursue.

16 Because at that time period that we're
17 looking at there were no registries, we
18 conducted a telephone survey to ascertain the
19 potential cases. It was very important to us
20 to verify the diagnoses because we were using
21 self reports. We did want to obtain medical
22 records to verify what was self reported. And
23 then using that information we're in the
24 process of conducting a case-control study.

25 So this slide shows the outcomes that

1 we chose to further study in the telephone
2 survey. We were asking about neural tube
3 defects, oral cleft defects, the following
4 conotruncal heart defects, choanal atresia,
5 childhood leukemia and non-Hodgkin's lymphoma.

6 So through the telephone survey to
7 identify potential cases of those outcomes
8 among the births occurring during 1968 to 1985
9 to mothers who resided on base at any time
10 during their pregnancies, that would be they
11 delivered on base or they delivered off base
12 but the pregnancy was carried on base, we
13 identified about -- we estimated, I'm sorry,
14 about 16 to 17,000 births, and the parents of
15 12,598 eligible children were surveyed.

16 That's an overall participation rate
17 of 74-to-80 percent depending on which range
18 you use for the estimated births. Because
19 there is not a really clear handle on the
20 births that were delivered off base, we have
21 some best guess from the Naval hospital.
22 That's why it's an estimate of how many
23 pregnancies there were on base.

24 So through our telephone survey we
25 were able to capture a sufficient number of

1 neural tube defects, oral clefts and childhood
2 cancers to proceed further with the study of
3 those outcomes. There were 106 reported cases
4 broken down as 35 neural tube defects, 42 oral
5 cleft defects and 29 childhood hematopoietic
6 cancers. And as I mentioned before, it's very
7 important for us to verify, get medical
8 confirmation of those cases. And that process
9 has been completed.

10 So the way that shaped up was 52
11 confirmed cases out of the 106 we were able to
12 get medical records confirmation for 52 of
13 them, and 51 of those parents were
14 interviewed. That's 15 neural tube defects,
15 24 oral clefts, and 13 hematopoietic cancers.
16 Thirty-two of those 106 were confirmed not to
17 have the reported condition. Eight refused to
18 participate. We could not get, one way or the
19 other, whether they have ^ [the reported
20 condition -ed.] or not, they refused. Seven
21 could not be verified or there was no medical
22 record.

23 And believe me we tried. We took
24 extensive measures. For those cases that were
25 reported to have an oral cleft or a neural

1 tube defect we offered them a visit with a
2 doctor today for an oral cleft dentist so they
3 could say with their evidence of an oral cleft
4 if there was no medical record for the time or
5 the same thing for the neural tube defect.
6 But still, unfortunately, seven cases could
7 not be verified one way or the other, and
8 seven were determined to be ineligible. That
9 could be because it turns out that the
10 pregnancy did not actually occur on base or
11 they were born outside of the timeframe and
12 things like that.

13 So, as I mentioned, we conducted
14 parental interviews and also included
15 interviews of 548 controls. These interviews
16 were conducted in the spring of 2005, and we
17 wanted to get information on the maternal
18 water consumption habits, the residential
19 history on the base and up through the first
20 year of life, maternal exposures during
21 pregnancy and other parental risk factors.

22 And we conducted an extensive review
23 of the base family housing records to verify
24 the dates and location of where the mother was
25 reported to have lived on base. We also used

1 birth certificates and other information
2 that's available to try to determine where
3 exactly the mother was on base.

4 And Frank's going to discuss the data
5 analysis.

6
7 **USE OF WATER-MODELING RESULTS IN THE**
8 **EPIDEMIOLOGICAL STUDY**

9 DR. BOVE: I'm going to present what we
10 propose for the data analysis. First of all,
11 we're going to do separate analyses of each of
12 these birth defects and so we'll focus on
13 neural tube defects separately, oral clefts
14 separately, and then we'll split it up between
15 cleft lip and cleft palate and then look at
16 childhood leukemia and non-Hodgkin's lymphoma
17 together because of the small numbers of non-
18 Hodgkin's lymphoma.

19 It may be difficult to also split
20 cleft lip and cleft palate because there are
21 11 cleft palates roughly, and I think there's
22 13 or so cleft lips. So we're talking about
23 small numbers throughout. So this is going to
24 be the difficulty of this study because these
25 are rare events, and doing a survey, phone
survey, is not the best way to ascertain birth

1 defects or childhood cancer, but it was the
2 only way to do it at Camp Lejeune.

3 So next we'll evaluate the ~~contaminate~~
4 [contaminant -ed.] levels both as continuous
5 variables and as categorical variables. We'll
6 attempt to use smoothing methods to give us
7 cut points for the categorical variables;
8 however, again, because of the small numbers
9 of cases, we may end up with ^, no medium and
10 high for the categorical variable cut points.

11 Each contaminant will be analyzed
12 separately. That assumes that there's one
13 contaminant that's causing the problem, not a
14 mixture that's causing the problem, and then
15 we'll look at joint effects of mixtures.

16 So for neural tube defects first we'll
17 focus on the confirmed cases and look at
18 average and maximum contaminant level over the
19 first trimester, over the period three months
20 prior to conception to conception -- so that
21 period as well -- and the average level in the
22 first month of pregnancy since that's when the
23 neural tube is closing.

24 For clefts we'll again be looking at
25 average and maximum contaminant level in the

1 first trimester. Again, looking at the period
2 three months prior to conception to
3 conception. Again, some of these are
4 difficult to precisely or accurately define
5 because we know when the birth occurs. We
6 have some idea what the gestational age is and
7 so on.

8 And then we're going to look at the
9 second month of pregnancy because that's when
10 the cleft lip and cleft palate are forming and
11 are vulnerable to exposures. Although it may
12 shade into the early part of the third month,
13 so we may combine the second and third month
14 as well.

15 And then for childhood leukemia and
16 non-Hodgkin's lymphoma we'll look at each
17 trimester separately. Then we'll look at the
18 entire pregnancy. That's not on the slide.
19 We'll look at the entire pregnancy, look at
20 the average and maximum of the entire
21 pregnancy.

22 Then we'll look at the first year of
23 child's life. We only got information of the
24 first year of child's life on residents, so we
25 don't have information beyond the first year

1 of the child's life although it may be
2 possible to reconstruct that from housing
3 records and not from the survey information if
4 that is a recommendation. But we only have
5 information on the first year of the child's
6 life from the interviews of the cases of
7 controls.

8 And we'll also look at, again, the
9 three months prior to the date of conception
10 to conception. Again, we're not sure when
11 during pregnancy before the first year of life
12 when the child is most vulnerable to these
13 exposures that might cause leukemia or non-
14 Hodgkin's lymphoma. And then finally, we'll
15 look at the cumulative exposure over the
16 pregnancy and first year of the child's life.

17 I thought you might like to see some
18 real data. This is, we don't have Hadnot
19 Point data, but this is Tarawa Terrace, those
20 exposed who lived in the Tarawa Terrace
21 housing areas. And you can see why we need
22 monthly estimates because there is
23 variability, quite a bit.

24 Some people move in and out.
25 Sometimes the wells are shut, the main well at

1 Tarawa Terrace is shut down so that these
2 months there's very little exposure to these
3 months, very high exposure and so on. So I
4 want to reemphasize why we need monthly
5 exposure levels.

6 Now, we're planning two future
7 studies, one on mortality, one a health
8 survey. And for that monthly levels of
9 exposure contaminant levels aren't as
10 important as for this study. And we can talk
11 about this future ~~studies~~ [study -ed.] if you
12 want.

13 Data analysis, the typical way to
14 analyze these data is using logistic
15 regression. Again, I'll emphasize that the
16 data is sparse for the cases so we may explore
17 using conditional or exact methods. But
18 again, with sparse data no matter what you do,
19 you're limited by the sparseness of the data.

20 For confounders we'll use the ten
21 percent rule including confounders in the
22 model if they affect the ^dration by more than
23 ten percent. And we're trying to keep the
24 models as simple as possible given the sparse
25 data. And then we'll explore the information

1 we got from the survey on water consumption.

2 Now, I've never found this information
3 that useful especially when people have to
4 remember many, many years in the past, but
5 we'll look at it anyway and see if it sheds
6 any light on the situation.

7 Last slide we're going to talk, we're
8 going to conduct sensitivity analyses to look
9 at exposure misclassification varying
10 sensitivity and specificity of our
11 classification of exposure to see how that
12 might affect the results especially with
13 sparse data. They probably were affected
14 quite a bit so we have to examine that.

15 Additional analyses, we have some
16 cases and controls with a very poor
17 residential history. This is another problem
18 with the survey, people trying to remember
19 their residences 20-, 30-some years ago or
20 whatever. They forget. They're inaccurate.
21 We have housing records that help to confirm
22 some of that, but some people may have crashed
23 with other people.

24 There are all kinds of housing
25 arrangements that may have occurred on base,

1 and so the housing records only go so far.
2 They tell you where the sponsor lived, but not
3 necessarily where the spouse and the rest of
4 the family might have lived. And so we'll try
5 to work with residential histories just to
6 make sure all the cases that we interviewed
7 and confirmed get into the analysis.

8 But we might also include some that
9 haven't been confirmed yet and probably never
10 will be confirmed because we just can't get
11 the medical records for them. There's about
12 seven of those pending that will never
13 probably just determine whether they had the
14 disease or not. We did an extensive effort to
15 do that.

16 For clefts, for example, we actually
17 paid for people to go to the dentist to get a
18 confirmation that they had surgery for a
19 cleft. And we tried everything to get the
20 records for anencephaly, which is difficult,
21 and spina bifida and for childhood leukemia
22 we, again, made a big effort to confirm them.
23 But again, seven cases that were reported in
24 the survey we couldn't confirm yet. So we may
25 include them in a secondary analysis.

1 Finally, we don't base our
2 interpretations on P values. That's my
3 thinking. We use these kinds of criteria. We
4 can have a discussion of that if you want, but
5 that's how we analyzed it and interpreted it.
6 So, any questions for Perri and myself?

7 **MR. HARDING:** Ben Harding. If we go back to
8 the table of the real data example for Tarawa
9 Terrace, I'm not an epidemiologist, and I'm
10 afraid that this might cause you a headache.
11 But a question I have is, how could you use a
12 table like this instead of having, for
13 example, for child number one, I guess that's
14 minus three months.

15 **DR. BOVE:** Yes, minus three months from date
16 of conception all the way to the third month
17 of gestation.

18 **MR. HARDING:** If those cells were, instead
19 of having a single number in there, had either
20 a range or an empirical CDF of values that
21 were generated by a more probabilistic
22 analysis of an exposure, how would that, would
23 that make your analysis impractical,
24 impossible, what?

25 **DR. BOVE:** Yeah, the relative position of

1 each case and control wouldn't change with
2 that so in one sense, no. The difference
3 would be if we tried to make an inference as
4 to at what level we see effect and what level
5 we don't. And I think that this data is not
6 good enough both on the water side or the epi
7 side to make that assessment. Right now in
8 this situation with environmental epidemiology
9 and drinking water epidemiology, we still are
10 not sure about the effects of these
11 contaminants on these outcomes.

12 We have one New Jersey study looking
13 at birth defects and we have a few studies
14 looking at childhood leukemia like Woburn, for
15 example, and then that New Jersey study that
16 was looking at all ages but found an effect
17 with childhood leukemia with TCE. So we're
18 still in the early stages of trying to make
19 the associations, not trying to define exactly
20 what level of TCE or PCE we might see an
21 effect.

22 So in other words, yes, we can plug
23 almost anything in there, and it won't change
24 the relative position of the cases and
25 controls, and it will still be able to

1 determine whether relatively higher levels
2 seems to be associated versus relatively lower
3 levels. Does that answer?

4 **MR. HARDING:** Yeah, thanks.

5 **DR. HILL:** Two things. I'm kind of
6 uncomfortable with having numbers like this
7 reported with three significant digits.

8 **DR. BOVE:** Right, I'm sorry.

9 **DR. HILL:** So just a general comment there.

10 **DR. BOVE:** Actually -- Morris, correct me if
11 I'm wrong -- but I think we have more than
12 three significant digits in the table and on
13 the website, don't we? Right. So I actually
14 reduced the number of digits.

15 But, yeah, I mean, again, it doesn't
16 affect the relative positions.

17 **DR. HILL:** Right, it just affects the
18 appearance of ~~decision~~ [precision -ed].

19 **DR. BOVE:** Well, for 118, what would you
20 put, 120 or...

21 **DR. HILL:** I would tend to round.

22 **DR. BOVE:** Round? Okay.

23 **DR. HILL:** I would tend to round. Mostly,
24 it's conveying to people the precision of the
25 number to my mind.

1 Okay, and then I had a question
2 earlier on when Perri was talking. I thought
3 what I understood was that in your initial
4 assessment, you didn't have the results of the
5 groundwater model so you were using some other
6 estimate of concentrations at the wells to
7 get, and then you used the groundwater model
8 to refine that? Is that --

9 **MS. RUCKART:** You're talking about the 1998
10 study?

11 **DR. HILL:** Yes.

12 **MS. RUCKART:** Well, that was actually just
13 based on crude exposure, whether they lived in
14 an exposed area or not so at that time it was
15 believed that one area was unexposed, and we
16 got some new information that that area was
17 exposed. So it was just based on yes, no, you
18 were in an exposed area or not to take into
19 account the water modeling at all.

20 So now, first of all, we found out
21 about this error and then we are going to have
22 more specific information from the water
23 modeling. So it seems like a good idea just
24 to redo that analysis.

25 **DR. BOVE:** For example, I think that there

1 were 31 births we thought were exposed to
2 trichloroethylene at Hadnot Point because
3 that's the only area we thought. And that was
4 because we thought that Holcomb Boulevard
5 treatment plant was online before June '72.
6 In fact, we thought it was online at the start
7 of the study, which is '68. Of course, that
8 wasn't the case.

9 So if you now understand that Hadnot
10 Point served that housing up until June of
11 '72, there's more than a thousand births and
12 that changes things quite drastically for that
13 study. And we didn't have this kind of data
14 or the Hadnot Point data that we will have.
15 So we want to go back and reanalyze it.

16 **DR. HILL:** And was the problem that you were
17 using Holcomb Boulevard as your --

18 **DR. BOVE:** Unexposed group.

19 **DR. HILL:** -- as an unexposed group and now
20 it's exposed. So, you could now -- I don't
21 know if you can. I don't know how to do this
22 exactly. But I assume you need to identify
23 some other group as your unexposed group
24 because you need a control group in your
25 experiment?

1 **DR. BOVE:** No, the problem --

2 **MS. RUCKART:** Well, first of all, there's
3 still going to be unexposed because people
4 would have been exposed at different time
5 periods, and there'll still be unexposed --

6 **DR. BOVE:** ^

7 **MS. RUCKART:** There are still unexposed.
8 They'll just be less than there was like
9 before there was 5,000 unexposed. There'll
10 just be less, but there still will be
11 unexposed from that study. But we don't have
12 to collect any more data. We still have it.

13 **DR. HILL:** But the unexposed are amongst the
14 housing units in the same area, but they're --

15 **DR. BOVE:** From '68 to '72, June '72, any
16 part of the pregnancy that's within that area,
17 all we have are people exposed to either
18 Tarawa Terrace or Hadnot Point. Now, Hadnot
19 Point, so for that period of time will have
20 different levels of contamination but no
21 births that are totally unexposed.

22 From '72 on Holcomb Boulevard is free
23 of contamination except -- and we'll discuss
24 this later -- for an interconnection that's
25 used during the summer months. But we can

1 take that into account. We'll take that into
2 account in the current study, too. So from
3 '72 onwards we'll certainly have unexposed to
4 work from.

5 It's the before '72 that will be a
6 little bit difficult unless part of -- but
7 still, part of the pregnancy may have been off
8 base. These people move in and move out. For
9 that study they had to be born on base, but
10 they could have moved on base in the seventh
11 month of pregnancy, eighth month of pregnancy,
12 so they're unexposed before that. So there'll
13 still be some unexposed people even for the
14 '68 to '72 time period, just not as many as
15 before. Follow me?

16 **DR. HILL:** Yeah.

17 **DR. BOVE:** Let me take each period, '68 to
18 '72 you have two water supplies, Hadnot Point
19 and Tarawa Terrace, right?

20 **DR. HILL:** I understand that.

21 **DR. BOVE:** We don't know what the Hadnot
22 Point levels are from '68 to '72. An
23 important well comes online, what, '71, right?

24 **DR. HILL:** But the exposures are just based
25 on where the people had residence, right?

1 **DR. BOVE:** Right.

2 **DR. HILL:** But they live in this community.
3 They don't stay home all the time.

4 **DR. BOVE:** That's right. That's right. So
5 we're looking at, we're emphasizing
6 residential exposures. We don't have much
7 information. I mean, people may wander all
8 over base, that's true. We don't have an
9 outside comparison group, outside of Camp
10 Lejeune.

11 **DR. HILL:** And that's what I was curious
12 about.

13 **DR. BOVE:** We will. We will for the
14 mortality study and the health survey that
15 we're doing next. And the reason -- well, two
16 reasons why we didn't do it before. We
17 thought there was a clean, unexposed group.
18 So that study, but we can't really redo that
19 study other than take into account we could
20 take into account secondary exposure on base
21 and call the people who were completely
22 unexposed, those people who don't live on base
23 until they -- during the period when they
24 don't live on base.

25 For the future studies we're including

1 a comparison population from Camp Pendleton.
2 Now, Camp Pendleton is similar in many ways to
3 Camp Lejeune and unsimilar in other ways, but
4 they both have hazardous waste sites on base,
5 and the main difference is they don't have
6 contaminated drinking water, at least as far
7 as we know at Camp Pendleton. So that will be
8 an outside comparison group for the future
9 studies.

10 **DR. HILL:** Thank you.

11 **DR. ASCHENGRAU:** I just wanted to ask some
12 more questions about the residential history.
13 So did the people have to remember like a
14 street address? What did they have to
15 remember?

16 **MS. RUCKART:** Well, for the current case-
17 control study, we had some information from
18 this previous 1998 study as well as the
19 housing records. So we would like give them a
20 trigger. According to our records you lived
21 at whatever, and we would just say the housing
22 area. You lived at Tarawa Terrace during this
23 time. Is this correct? And then they could
24 say yes or no. And then that usually did not
25 cover the entire period that we're interested

1 in, three months prior to conception to first
2 year of life. So then we would use that as
3 our starting point and then ask them, well,
4 what about before that. Where did you live,
5 and then go back as far as we needed to and
6 then up in time. And so, as Frank was saying,
7 it's pretty hard to remember where you lived
8 20, 30, 40 years ago so then we did cross-
9 reference that with the housing records, and
10 then made adjustments. And then also with
11 birth certificates or just any other
12 information that we were able to process.

13 **DR. ASCHENGRAU:** So it's not like I lived at
14 371 --

15 **MS. RUCKART:** No, no, there's some --

16 **DR. ASCHENGRAU:** -- they don't have to
17 remember that.

18 **MS. RUCKART:** No, the housing records would
19 have information that was that specific, but
20 we were just asking about the broad housing
21 area. Our records show you lived at Tarawa
22 Terrace or Hadnot Point or Hospital Point.

23 **DR. ASCHENGRAU:** So everyone living in that
24 area gets assigned, or in a particular month,
25 gets assigned the same value for their

1 exposure?

2 **MS. RUCKART:** Yeah, we're not getting it
3 down to the street level or anything like
4 that.

5 **DR. BOVE:** But we did get, I mean, during
6 the survey we did get the street name and
7 sometimes street number from people. And from
8 that we realized that there was another part
9 of Jacksonville, North Carolina, that was
10 called Midway Park. Midway Park is a housing
11 area at Camp Lejeune, but actually, there's a
12 housing area outside the base that's also
13 called Midway Park.

14 And we found out that some of the
15 people we thought were eligible, were actually
16 living at the wrong Midway Park. So the
17 survey helped, and they weren't in the housing
18 records. That's why that triggered it to some
19 extent. I mean, we had no record of these
20 people living on base. So that was helpful
21 because the survey clarified that.

22 **DR. ASCHENGRAU:** And then the last menstrual
23 period, is that from like the birth records to
24 estimate the conception or do you use the
25 birth date and gestation to estimate the

1 conception?

2 **MS. RUCKART:** We don't have information as
3 part of the survey on ~~OMP~~ [LMP -ed.], or we
4 don't have birth certificates for everybody.
5 So that is why it's kind of, we don't exactly
6 know the three months before. That's why we
7 have those several different time periods
8 we're going to look at, you know, minus three,
9 date of conception to date of ~~conception~~
10 [conception -ed.], and it's not exact. We
11 really just have when they're born.

12 **DR. ASCHENGRAU:** So you're estimating it
13 when they're born, and then you're subtracting
14 --

15 **MS. RUCKART:** Yeah, we can't figure it out
16 gestationally or ^ [date of last menstrual
17 period -ed.].

18 **DR. GRAYMAN:** Walter Grayman. Just to
19 clarify, you seem to indicate that you weren't
20 looking at the addresses within the areas. Is
21 that correct?

22 **MS. RUCKART:** Yes, when we assign the
23 exposure, we're just going to do it on the
24 broad level, Tarawa Terrace, Hadnot Point, the
25 various places they lived on base. However,

1 as Frank was saying, as part of the survey
2 they could report a specific address and then
3 we can cross-reference that street to get the
4 housing area. But we're not expecting people
5 to be able to tell us the exact street. They
6 could just say, oh, yeah, I lived in Midway
7 Park or I lived in Knox Trailer Park.

8 **DR. GRAYMAN:** My concern really comes when
9 you go onto the Holcomb Boulevard where we
10 probably are talking about variation in terms
11 of the concentration of the contaminants
12 within Holcomb Boulevard which is different
13 from the other two areas.

14 **MS. RUCKART:** Yeah, there is still different
15 complexes or different housing areas within
16 Holcomb Boulevard like Berkeley Manor or
17 something like that. So we're not asking them
18 were you served by Holcomb Boulevard. We'll
19 be asking them for the specific, did you live
20 in Berkeley Manor. Did you live in Hospital
21 Point? Did you live in, you know, other areas
22 served by Holcomb Boulevard.

23 **DR. GRAYMAN:** Thank you.

24 **DR. BOVE:** Yeah, we can distinguish the
25 different housing.

1 **DR. GRAYMAN:** One other quick question on
2 that. You brought up other activities besides
3 residence. Did you look into work activities
4 or is this not a very big issue back at that
5 time?

6 **MS. RUCKART:** We did ask about that and can
7 factor it in if we have enough information.
8 And as Frank was mentioning, you know, the ten
9 percent rule for affecting the model under
10 estimate.

11 **DR. BOVE:** But very, very, very few of cases
12 work controls had a job that involved
13 solvents.

14 **DR. BAIR:** I guess my question follows with
15 --

16 **DR. HILL:** What's the ten percent rule?

17 **MS. RUCKART:** Well, it's just kind of a rule
18 of thumb, I guess, that epidemiologists use.
19 So you have your crude model which would just
20 be your outcome and your exposure. And you
21 get a, let's say it just gives an odds ratio
22 or a risk ratio. And let's say you get 1.5
23 just crudely looking at exposure and your
24 outcome. Are these associated?

25 Then as you start adding in some other

1 variables like did you work with solvents or
2 something like that, then if you add that
3 variable also in with your exposures, you just
4 would have let's say in this case three
5 variables: your outcome, your exposure and
6 your potential confounder, did you work with
7 this chemical.

8 And if you just run that model, and
9 you were to get an estimate that differed
10 from, in my example 1.5, of more than ten
11 percent, you would include it. But if not,
12 you'd say, well, it's not really impacting our
13 measure here so we're not going to add that.
14 Because when you start getting too many
15 variables it can make your model not run if
16 you have sparse data. It doesn't really help
17 you.

18 **DR. BOVE:** But some people use P values to
19 determine whether you include a variable or
20 not, and that would be really problematic in
21 this study with low statistical power. So we
22 try to make sure we capture as much of the
23 confounding bias that we can given that there
24 is also mis-measurement out of these factors
25 as well most likely because of recall

1 problems. But still we would have a better
2 chance of including the confounder in the
3 model that uses ten percent than if we use P
4 values or some other rule.

5 **DR. BAIR:** I guess the question I have
6 follows on one of Walter's earlier ones. Was
7 there any assessment of exposure at mess halls
8 or at daycare centers? Were all the residents
9 cooking in their own residence or were there
10 communal meals at some locations?

11 **MS. RUCKART:** All these things you mentioned
12 could affect exposures, but we just don't have
13 information on that. I guess we're going to
14 assume like non-differential --

15 **DR. BAIR:** Well, did the mess halls have
16 different water supplies than some of the
17 residences?

18 **DR. BOVE:** Okay, the mess halls, we're
19 talking now about the barracks then if you're
20 talking about the mess halls, and you're
21 talking about -- correct me if I'm wrong --
22 and so you're talking about bachelors'
23 quarters, not family housing.

24 **DR. BAIR:** So families all ate in the
25 individual residences because knowing my

1 mother that would not be the case.

2 **DR. BOVE:** I can't say that they didn't go
3 out and get a McDonald's or something during -
4 - I don't think McDonald's was around back
5 then -- but we're assuming that the major part
6 of their exposure is in the home from
7 consuming the drinking water and showering,
8 which gives you an important exposure and a
9 dermal exposure. So we're going to assume
10 that.

11 I mean, there's not that much
12 variability. We've looked at the data for
13 showering and consumption of water. There
14 really isn't much variability and they can't
15 remember anyway, but I think that we're in
16 good shape doing it this way. This is what
17 we'd normally do in these studies. We really
18 can't, I mean, you'd have to have a diary in
19 order to determine all those different ways of
20 exposure, and we just didn't do that.

21 **DR. WARTENBERG:** I assume you also do some
22 sensitivity analyses so that if there, if
23 there was an exposure estimates, you'll see
24 what the impact would be on the --

25 **DR. BOVE:** That's right, we talked, yeah,

1 yeah.

2 **DR. CLARK:** Any more questions from the
3 panel?

4 (no response)

5 **DR. CLARK:** Any questions from the audience?
6 (no response)

7 **DR. CLARK:** Morris, do you want to go ahead
8 with the program?

9 **SUMMARY OF WATER-MODELING ACTIVITIES**

10 **MR. MASLIA:** Our schedule, which is good,
11 which will leave lots of room for discussion
12 and questions. And just back to a couple of
13 housekeeping notes. I assume all the panel
14 members see the booklet of slides that we
15 prepared. I forgot to mention that. We do
16 have some extra ones if people in the audience
17 want to peruse them. We've got them in the
18 cart here.

19 We also have the notebook that we gave
20 out to the panel members if anyone in the
21 audience would like to just peruse a copy. We
22 do ask that you return it and keep it here
23 because it is draft material, but Barbara may
24 pass out a couple of copies if the audience
25 would like to see it.

1 What I'm going to do is just give a
2 general overview of the entire water modeling
3 activities. I'm going to start very briefly
4 on what we've done with Tarawa Terrace just so
5 we're all on the same page for those who,
6 panel members and members of the audience, who
7 have not been with us since then. And then go
8 into Hadnot Point very briefly. We have
9 subsequent presentations and staff that will
10 actually present very detailed information on
11 Hadnot Point.

12 Throughout the water modeling
13 activities, the epidemiological study came to
14 us and gave us four goals and objectives to
15 meet. And this is by order of preference, if
16 you will. If all we could do was give them
17 certain information, and at least wanted to
18 know the dates of the contaminants that
19 arrived at the wells.

20 If we were able to provide that
21 information, then they would like to have the
22 distribution of contaminants by housing
23 location. That is, was it served by the
24 Tarawa Terrace water treatment plant? Was it
25 served by the Hadnot Point water treatment

1 plant or the Holcomb Boulevard water treatment
2 plant? Having that distribution they would
3 like to have monthly mean concentrations, and
4 I believe that's the numbers that Frank and
5 Perri showed up on that table.

6 Is that correct, Frank? Those were
7 the mean values. We obviously, if you see any
8 of the reports we have ranges associated with
9 those. I think Frank just showed mean values
10 for an illustrated example.

11 And then, of course, we get into the
12 subject of reliability, confidence, how
13 confident are we, that is on the water
14 modeling side, and the values that we are
15 giving the epidemiologists. And just as an
16 example, if you look at some of the supply
17 well data from Tarawa Terrace of the wells, it
18 may range from non-detect all the way up to
19 1500 parts micrograms per liter. And so the
20 question is how reliable, when we give them a
21 number, does it range that much or does it not
22 range that much.

23 So getting back to this, and this will
24 help, I think, clear up a little. We've got
25 three housing areas, Tarawa Terrace and Knox

1 Trailer Park someone mentioned, served by both
2 Camp Johnson and Tarawa Terrace. What's
3 referred to as Holcomb Boulevard, and there's
4 the Holcomb Boulevard water treatment plant,
5 and the Hadnot Point area right here.

6 Initially, we assumed that Tarawa
7 Terrace was completely exposed or continuously
8 exposed I should say for the study period.
9 And we assumed that the Hadnot Point area was
10 continuously exposed for the study period. We
11 also then assumed -- and I say we, that was
12 the information that the epi study talked
13 about, that Holcomb Boulevard was completely
14 unexposed.

15 Based on some information and digging
16 around, newspaper articles, some transfer of
17 property documents that were provided by the
18 Marine Corps, we estimated actually that
19 Holcomb Boulevard really did not come online
20 until June of 1972. Just for your edification
21 that's based on one nice big picture in a
22 newspaper showing a grand opening of the plant
23 in August '72, and also U.S. government
24 property transfer to the tune of \$700,000
25 occurring in June of '72 which would be the

1 treatment plant, meaning it was completed and
2 online.

3 So that's our best estimate as to when
4 Holcomb Boulevard, so that's the difference in
5 time from '68 to '72. Obviously, Hadnot Point
6 did supply contaminated water or water with
7 varying concentrations of contaminants to
8 Holcomb Boulevard.

9 **DR. GRAYMAN:** Morris, what is French's
10 Creek? Why is that designated differently?

11 **MR. MASLIA:** It's just an area that's
12 referred to at Camp Lejeune as French's Creek.
13 It's on the same water distribution system.

14 **DR. GRAYMAN:** As Hadnot Point?

15 **MR. MASLIA:** Hadnot Point, but it's referred
16 to as French's Creek, and we just, but it's
17 the same distribution system.

18 We also have, and we met this past
19 November, I believe, with former and current
20 operators. You have a question?

21 **MR. PARTAIN:** Just [to -ed.] elaborate on
22 Dr. Bair's question about the housing. My
23 parents -- I'm one of the [Lejeune babies -
24 ed]. I was born in January of '68. My
25 parents lived in Tarawa Terrace, and the

1 housing units there are self contained. It's
2 like a neighborhood. You've got your kitchen,
3 everything you need is there. The base is a
4 self-contained unit.

5 My mother is French-Canadian, and at
6 the time English was her second language. She
7 didn't leave the base. Everything she needed
8 was on the base, PX. The PX was located at
9 Hadnot Point, the main side. All of her
10 OB/GYN appointments were on the main side at
11 the Naval hospital. The O Club, where my
12 parents would go for their recreation, was on
13 main side.

14 So we were exposed to both Tarawa
15 Terrace water, which provided our family
16 housing, and also Hadnot Point water, which
17 provided the water for the O Club, the Naval
18 hospital where I was born, and any activities
19 they did on there. So these houses are just
20 like you would go drive through a subdivision.
21 It's not like a barrack or anything like that
22 but family housing. Of course, when you're
23 dealing with barracks, it's a totally
24 different issue. I hope I clarified your
25 question there.

1 **DR. BAIR:** Thank you.

2 **MR. MASLIA:** There's an interconnection
3 valve here and a booster pump right here. And
4 when Frank mentioned previously about
5 intermittent mixing or interconnection, we had
6 a meeting with former and current operators,
7 ATSDR did, I think last November, and we also
8 have some logbooks that have some entries into
9 them.

10 And what it turns out as a general
11 rule of thumb is that during the spring, which
12 is dry in April, May, June, everybody's
13 filling up the kiddie pools, sprinkling a golf
14 course up here, and someone, they may need
15 some additional water at Holcomb Boulevard.
16 So they would turn on a 700-gallon-per-minute
17 pump. At some point they switched that out to
18 a 300-gallon-per-minute pump, and there's
19 entries into the logbooks when they did that.

20 At the same time if this did not
21 provide sufficient water, then they could go
22 and open up this interconnection, which is
23 referred to as the Wallace Creek valve, and
24 water would flow that way as well into that
25 site. So that's how you would get mixing of

1 water, contaminated water, even after '72 in
2 this area during April, May or June in that
3 time period. And Jason Sautner will speak
4 more about this on the second day about that.

5 And so that's a big difference than
6 Tarawa Terrace for the question that we have
7 posed because at Tarawa Terrace the last panel
8 recommended -- and rightfully so because we
9 didn't the testing because all the supply
10 wells fed into a central water treatment
11 plant, we could use a simple mixing model and
12 mix, and assume, which we did, that the
13 finished water concentration at the treatment
14 plant was the same water that residents
15 received from the treatment plant. So that's
16 what's different about this situation.

17 **MR. HARDING:** Morris?

18 **MR. MASLIA:** Yes.

19 **MR. HARDING:** Ben Harding. If you go back
20 to that slide, it doesn't make complete sense
21 that you'd be able to do both things in a
22 water distribution system, open the valve and
23 use the booster pump. The use of the booster
24 pump implies that the Holcomb Boulevard system
25 was running at a higher grade level than the

1 Hadnot Point. And if you open the valve, if
2 that were the case, then you'd expect water
3 just to flow back into Hadnot Point. So I
4 just want to put that question on the table,
5 and maybe Jason or somebody later can address
6 that.

7 **MR. MASLIA:** There's also Joe [Joel -ed.]
8 Hartsoe here who probably has more expertise
9 since he operated the system there that could
10 answer us. Our understanding was -- and, Joe,
11 please correct me. As I stated if there was
12 insufficient supply from the booster pump,
13 they would turn on, open up the valve.

14 **MR. HARTSOE:** The valve you're talking about
15 ^ [is Marston Pavilion. -ed.] I don't ever
16 remember opening that valve because of the
17 watering of the golf course. It was always
18 the booster pump. Then interconnections would
19 only be opened if, that interconnection would
20 only be opened if there was a major water
21 break or anything like that. I don't ever
22 remember opening that valve just to furnish
23 water for the golf course area.

24 **MR. MASLIA:** There's also a two-week period
25 in January of '85 when there was a fuel line

1 break at the water treatment plant here, and
2 BTEX compounds got into the supply here. So
3 then they used the Hadnot Point water supply
4 for about a two-week period. And there's
5 actually some fairly detailed measurement,
6 concentration data throughout the distribution
7 system that we have. That's the other point
8 to remember. Did that answer the question?

9 **MR. HARDING:** Yeah, it sounds like that
10 valve was only opened under very rare
11 circumstances.

12 **MR. MASLIA:** It is noted in the logbooks
13 that we have when it, at least on there is
14 notation that they opened up the valve, the
15 Wallace Creek valve.

16 **DR. HILL:** So are you saying that the
17 records you're seeing contradict what was
18 said?

19 **MR. MASLIA:** No, not at all. I'm just
20 saying when we have information or data, we
21 prefer to refer to the logbooks. The logbooks
22 specifically provide an incident that the
23 Wallace Creek valve was open.

24 **DR. HILL:** And as far as you know, is that
25 because some major main break or you just

1 don't know?

2 **MR. MASLIA:** Oh, we don't know. It does not
3 necessarily give those other details. We've
4 actually transcribed the logbooks. Actually,
5 the logbooks are on the DVDs for Chapter A,
6 that three DVD set. They actually, if you're
7 interested, we can point you to which files so
8 you don't have to look through 20 gigabytes to
9 find it.

10 But that's what we have gone through
11 those, and that's one of the purposes when we
12 had the meeting with the former operators so
13 we could understand clearly because we did see
14 entries mentioning a booster pump. We saw
15 another entry mentioning a valve. And for
16 awhile there we were not quite clear on the
17 understanding of that. So I believe we're on
18 the same page now, and we understand the
19 operations we have seen.

20 **DR. GRAYMAN:** It would be interesting to
21 maybe have a chart which would show on a
22 month-by-month basis the number of hours that
23 the booster pump was on and the number of
24 hours that the valve was open on Wallace
25 Creek.

1 **MR. MASLIA:** Jason does in his presentation
2 tomorrow have a chart showing from the pump
3 side the hours and so on, and he will present
4 that.

5 **DR. HILL:** So there was this period of time
6 where along Holcomb Boulevard there was this
7 spill, and so they shut that water off. They
8 brought water in from Holcomb Point, and
9 during that time they did detailed monitoring
10 of the quality of the water being delivered?

11 **MR. MASLIA:** Yes. I believe the state came
12 in also and took some samples.

13 Is that right, Scott?

14 Yes, the State of North Carolina came
15 in and there's actually sampling throughout
16 the distribution system.

17 **DR. HILL:** I hadn't heard of that occurring,
18 and it seems like that's a really nice
19 opportunity.

20 **MR. FAYE:** That's discussed in detail in
21 your three-ring binder report there. I think
22 it's actually Table 12 or 13 of the
23 Contaminant Data Report shows the analyses,
24 the time of analyses, the location of the
25 analyses. And there was the actual what we

1 would call detailed sampling only occurred for
2 probably a couple days, but then there was
3 periodic sampling at a smaller number of
4 locations for actually about two weeks.

5 And all of the data that we have
6 regarding that incident and the sampling and
7 et cetera, is on, like I said, Table 12 or
8 Table 13, and actually may not have been
9 printed out, but it's on the CD that was
10 provided with the binder.

11 **MR. MASLIA:** I can pull that up. If you'd
12 like me to pull that up right now, I can.

13 **DR. HILL:** Oh, no. I would suggest going on
14 with your presentation. I went through most
15 of those tables and marked them so let me look
16 at those, but I didn't understand the
17 significance of them.

18 **DR. KONIKOW:** Just one question on those
19 detail [detailed -ed.] datasets. Could that
20 provide an opportunity to test or calibrate
21 your water distribution model?

22 **MR. MASLIA:** Absolutely.

23 **DR. KONIKOW:** Okay, absolutely.

24 **MR. MASLIA:** Yes, that's at least one
25 thought that we have, but that kind of data we

1 don't have otherwise. So, yes, Lenny, that's
2 the lines, at least right now, that we're
3 thinking along.

4 **MR. PARTAIN:** One important thing to note, I
5 don't know if you pulled that dataset for the
6 North Carolina testing in January of '85.

7 **MR. MASLIA:** Let's see if I can.

8 **MR. FAYE:** If you go to my hard drive --

9 **MR. MASLIA:** What table was that, Bob?

10 **MR. FAYE:** There you go. Go down to the
11 tables.

12 **MR. MASLIA:** What table?

13 **MR. FAYE:** I think it's 12 or 13.

14 **DR. HILL:** It's 13.

15 **MR. MASLIA:** You want Figure 13?

16 **MR. PARTAIN:** Okay, that's it. Now, what I
17 want to point out, these are different sample
18 points along Holcomb Boulevard and Hadnot
19 Point. The January leak that they're
20 referring to that this dataset came from was
21 the result, was taken after the Holcomb
22 Boulevard plant had supposedly been cleaned
23 because of a fuel spill.

24 Now, at this point in time, there was
25 only one contaminated well operating that

1 produced these results. The other ten, I
2 believe it was ten contaminated wells had
3 already been taken offline at the time of this
4 reading. So you have one well producing those
5 results all along different points of the
6 distribution system within Holcomb Boulevard.

7 **MR. FAYE:** That's all discussed I think
8 pretty thoroughly in the text of that report
9 that discusses this incident and that was Well
10 HP-651 that the gentleman was referring to.

11 **DR. GRAYMAN:** And that time period was when
12 it was being supplied from Hadnot Point still?

13 **MR. FAYE:** Yes. And the issue there was
14 that earlier during December of '84, I believe
15 it was December 16th of '84, Camp Lejeune did a
16 major effort of sampling all of their active
17 supply wells because of their alert that they
18 had, that there was several of the wells had
19 been contaminated. And obviously, they were
20 on a mission to find out which ones.

21 Unfortunately, part of that sampling
22 effort, I believe, there were four of the
23 bottles that were broken at the time. And one
24 of those bottles was 651, so it was never
25 recognized by anyone that that particular well

1 was contaminated until these data came along.
2 And then that was the last contaminated well
3 that they removed from service.

4 **MR. MASLIA:** Yes.

5 **DR. ASCHENGRAU:** We just noticed that one of
6 the sampling sites was the Berkeley Manor
7 School, and that the TCE concentration's very
8 high there. So I'm just wondering is it
9 possible that some of the children in the
10 study went to school there? 1985.

11 **MR. MASLIA:** Frank says that's a future
12 study. The study goes from '68 to '85.

13 **MS. RUCKART:** The children in our study
14 report, they're carried in utero, so they
15 would not be at school. I suppose if the
16 mother was a teacher at the school.

17 **DR. ASCHENGRAU:** What year was it? Aren't
18 you going back to '68?

19 **MS. RUCKART:** Well, if the births occurred
20 during '68 to '85, it's possible that the
21 children did attend the school, but that would
22 not be included in our study because we're
23 just looking at exposures up to the first year
24 of life. We are doing some future studies,
25 and that will include as part of our health

1 survey, dependents.

2 **DR. ASCHENGRAU:** Okay, but maybe we'll
3 recommend that you go beyond the first year of
4 life for the cancer outcomes.

5 **MR. PARTAIN:** You'll notice, too, that the
6 hospital is in that dataset. I think it's 900
7 parts per billion or something like that.

8 **MR. FAYE:** And I think the relevance of this
9 is that, as the gentleman pointed out, this
10 was just one well that was pumping at the
11 time. There were many other wells that were
12 providing water to Hadnot Point by WTP at the
13 time, and so the actual concentrations from
14 651 were substantially diluted, and you still
15 got these concentrations.

16 And the point is -- I think I pointed
17 that out as well in the text there of the
18 report -- that you have as long as these
19 contaminated wells were operated routinely,
20 you obviously had contaminants routinely
21 delivered to the WTP and this just happens to
22 be the best example of that that we have.

23 **DR. BOVE:** One other point about this is
24 that, yeah, the high reading at the school,
25 but this was a two-week period. The school

1 was free of contamination most of the rest of
2 the time. But there are schools in Tarawa
3 Terrace, and they got contaminated water as
4 well so the child would have residential and
5 school exposure. And we're going to be trying
6 to capture this in the health survey, the
7 diseases that developed after as they got
8 older.

9 **DR. HILL:** But the school would also have
10 been contaminated perhaps during those April
11 through June time periods?

12 **DR. BOVE:** Right, we don't know. It depends
13 on, yeah, this is Berkeley, yeah. We're not
14 sure yet what parts of Holcomb Boulevard
15 housing got the full brunt of that when they
16 turned on the valve, and what parts didn't get
17 the full brunt if they're going to be diluted
18 of course. So these are questions we'll have
19 to resolve.

20 **MR. MASLIA:** Scott.

21 **MR. WILLIAMS:** You may have to present to
22 the panel that you have the well-cycling chart
23 for that time period, so there's a lot of
24 unknowns there. Morris has a well-cycling
25 chart when all that sampling was going on, so

1 you can actually see exactly which wells were
2 on what days. We don't have the resolution
3 for ^ (off microphone).

4 **MR. FAYE:** Morris, I think this highlights
5 the, probably the principal challenge from the
6 ground up on this is to understand this may
7 affect the groundwater as well, how these
8 wells were operated. This is the same thing
9 with Tarawa Terrace. This is a huge challenge
10 in reconstructing that, and I think we ought
11 to spend some time talking about how that was
12 done for Tarawa Terrace. How it might be done
13 for Hadnot Point.

14 **MR. MASLIA:** And I've actually got some
15 Tarawa Terrace slides so maybe I should
16 proceed to those and maybe we can --

17 **MR. FAYE:** Can I address that, Morris?

18 **MR. MASLIA:** Yes.

19 **MR. FAYE:** First of all at Tarawa Terrace
20 our main, we didn't have a lot of specialized
21 data in terms of the operations of the wells
22 at Tarawa Terrace. We do have those kind of
23 data for this particular aspect of the study
24 for this study, and I'll detail that in my
25 talk. But the point to be made a Tarawa

1 Terrace was our main approach was to make sure
2 that we removed an appropriate volume of water
3 from the aquifer at a particular time and for
4 a particular time.

5 And the well capacities were just used
6 to distribute that volume of water. We can
7 actually do various tests and Peter Pommerenk
8 has come up with a, described a whole series
9 of concerns and tests that he would recommend
10 for this particular study. And we actually
11 have the data that we can accomplish that, and
12 I'll talk about that in my presentation
13 specifically related to well operations.

14 **MR. MASLIA:** So for overview, again, wanted
15 to just make sure we were all on the same page
16 and understanding that exposure, exposed, non-
17 exposed and the time frame of each in which
18 you have the valve and booster pump.

19 I thought it would be interesting just
20 to give a generalized timeline so, again,
21 everybody understands the relationship of
22 different, the study, different occurrences of
23 treatment plants or supplies coming online.
24 And, of course, here's our current health
25 study going from '68 to '85. Hadnot Point was

1 the original water supply system on base. The
2 base started around 1941, and it's presently
3 still operating.

4 Tarawa Terrace based on information in
5 the work details of the Tarawa Terrace
6 reports, online from '52 to '87, and, of
7 course, that was shut off after February of
8 '87 due to contamination. And Holcomb
9 Boulevard, as we said, came online in June of
10 '72 and it's currently still operating.

11 It's interesting that the documented
12 VOC contamination, that's where we have
13 sampled data strictly from '82 through '87.
14 That's all to our knowledge that exists in
15 terms of specific contaminants such as TCE,
16 PCE, degradation products. And so that is
17 now, there's post-remediation or remediation
18 data as they were doing RIFS reports.

19 But in terms of the water supply,
20 that's what I'm referring to here, that's all
21 we have. The historical reconstruction for
22 Tarawa Terrace indicated that concentrations
23 above the MCL, which is five parts per
24 billion, for PCE in November of '57. And, of
25 course, the water treatment plant was shut

1 down during February of '87.

2 And at Hadnot Point, which is why
3 we're all here today, again, this is what this
4 meeting is all about, but again, the
5 contaminated wells were shut down by '87. So,
6 obviously, sometimes in this time frame it
7 became contaminated. Lenny?

8 **DR. KONIKOW:** With the documented VOC
9 contamination, was that in all three, from all
10 three water treatment plants and all three
11 supply systems?

12 **MR. MASLIA:** In '82 they not necessarily
13 went to the treatment plants, probably in late
14 '84, early '85 is when they actually started
15 going to the wells and the treatment plant
16 getting half singles, if you will. There's
17 actually some inferences because of THM
18 readings being affected by VOCs or chlorinated
19 solvents in '81 and '80, but that is from '85
20 forward that that's at the treatment plants.
21 I don't believe we have any supply wells prior
22 to '84.

23 Is that correct, Bob?

24 **MR. FAYE:** Well, the question was related
25 first to the WTPs. There's two tables in the

1 report, I think six or seven or something like
2 that, that actually show the, actually list
3 the contaminant information that we have for
4 both WTPs.

5 And I think to answer you question
6 directly, Lenny, I'm not really positive there
7 was VOC contamination noted through samplings
8 at the Holcomb Boulevard plant during this
9 time.

10 And, Morris, what was the question
11 about the wells, the supply wells? What was
12 that about?

13 **MR. MASLIA:** During this period, the
14 sampling.

15 **MR. FAYE:** Yeah, that's all in the report as
16 well. There's a large table in there showing
17 the BTEX contamination and the PCE, TCE and
18 derivative contamination at the supply wells
19 and it covers this period. And I think that
20 might be, I don't know. You'll have to look
21 at the list of tables, somewhere between six
22 and ten, something like that.

23 **DR. HILL:** The earliest year is '84.

24 **MR. MASLIA:** Yeah, the earliest year is '84.

25 **MR. FAYE:** For the supply wells, yeah,

1 absolutely, yeah. The earliest is July,
2 actually of '84, July 7th of '84, I think is
3 the earliest data that we have and then
4 there's the '82 data relate to sampling
5 locations within the Hadnot Point distribution
6 system.

7 **DR. KONIKOW:** The Tarawa Terrace with the
8 first arrival in November '57, if that was
9 actually several years later, maybe even four
10 or five years later, would that have any
11 effect on the health study since the health
12 study is '68 to '85? In other words would any
13 inaccuracy in that first arrival --

14 **MR. MASLIA:** We actually did, Mustafa Aral
15 did some well scheduling optimization and did
16 different scenarios with different wells other
17 than the ones that we calibrated for the
18 model. And you could shift the time from '57
19 to '60, but during the course of the study it
20 did not significantly affect at all the higher
21 concentrations.

22 They all tended towards that level of
23 that chart, the graph that shows in the
24 finished water that all it shifted was, other
25 than if you shut down, for example, TT-26. If

1 you shut down TT-26, both the data and the
2 model would show that your finished water went
3 down to practically no contamination at Tarawa
4 Terrace. But if you shifted the cycling so
5 that it didn't hit or arrive or pass the MCL,
6 say, as you said, 59, 60, 61, whatever, did
7 not significantly affect the higher
8 concentrations in the finished water.

9 **DR. DOUGHERTY:** Just to continue on that,
10 was there sensitivity to the contaminant mass
11 loading date as opposed to the water
12 production schedule?

13 **MR. MASLIA:** The actual date of the
14 introduction of the contaminant to the system
15 at Tarawa Terrace?

16 **DR. DOUGHERTY:** Yes.

17 **MR. MASLIA:** No, there was not. That was --
18 and I guess I'll refer to Bob, but that was
19 derived based on the deposition of the owners
20 as to when they began operating the dry
21 cleaner.

22 But, Bob, if you want to follow up on
23 that.

24 **MR. FAYE:** Yeah, there was a legal, a
25 deposition obtained from the owners, the Metts

1 (ph), the Metts family I believe is the name
2 that owned ABC Cleaners at the time. They
3 described the onset of their operations. They
4 indicated that they used PCE from the
5 beginning of their operations and so we had a
6 date, I think, of 1953 or '54, something like
7 that, when the PCE was initially loaded to the
8 subsurface as far as the modeling is
9 concerned.

10 **MR. MASLIA:** We also had information just to
11 bracket the actual value as to how much the
12 Metts estimated they used during their
13 process.

14 **MR. FAYE:** Yeah, they indicated that they
15 continuously for the years of interest to this
16 study anyway, continuously used between two
17 and three 55-gallon drums of PCE every month.

18 **DR. HILL:** Mary Hill. So I understand how
19 that the rest of the modeling concentrations
20 would change as that beginning date changed,
21 but in terms of the epidemiology study, and
22 their efforts to try to get time connections,
23 are their results impacted by that?

24 **MR. MASLIA:** No.

25 **DR. HILL:** I thought not. I just wanted to

1 verify that.

2 **MR. MASLIA:** No, they would not be.

3 **MR. FAYE:** There's another question.

4 **DR. BAIR:** Yeah, it might be more
5 appropriate for later on, but in terms of
6 amount of contaminants going to the water
7 treatment plants coming from the wells. The
8 wells are constructed in a manner that
9 commingles water between different aquifers?

10 **MR. FAYE:** Correct.

11 **DR. BAIR:** And I'm wondering in the Tarawa
12 Terrace as well as the future modeling being
13 done at Hadnot, how the quantity coming from
14 each aquifer is apportioned relative to the
15 total pump from the well because that makes a
16 huge difference as to what's going to go to
17 the water treatment plant. I mean, if you
18 brought up 651, which was the worst well,
19 that's open to three aquifers and there are
20 screen blanks across two confining beds. So
21 in terms, let's say it pumped 100 gallons a
22 minute just for sake of discussion, did 70
23 percent come from one zone based on its
24 permeability and thickness and 20 percent from
25 another and ten from another? Because that's

1 really going to impact what goes to the
2 loading to the water treatment plant. So if
3 that's in the mix, you know, I'll wait to hear
4 it then.

5 **MR. FAYE:** Well, the concentration at the
6 well is a concentration of the mass of the
7 water and the mass of the contaminant from all
8 of the contributing units. So it's a, we
9 could break out the individual contributions
10 from the individual aquifers, but I fail to
11 see how useful that information that would be
12 --

13 **DR. BAIR:** Well, you have to assign a
14 pumping rate to each zone in the well, don't
15 you?

16 **MR. FAYE:** ^ is the concentration ^ (off
17 microphone).

18 **DR. BAIR:** But in the flow model, the flow
19 and transport model, if those are not
20 apportioned properly, then you're going to get
21 a different velocity distribution coming to
22 one zone and another. And the velocity
23 distribution affects the concentration.

24 **MR. FAYE:** Well, like I said, we could break
25 out the individual contributions, but it's

1 entirely mixed compute with the end
2 concentration that the well delivers to the
3 WTP, so I fail to see, yeah, we can do it just
4 for academic purposes.

5 **DR. BAIR:** No, this is not an academic.

6 **DR. KONIKOW:** This is, you're using the
7 models to compute the concentration coming out
8 of the wells, and how you treat the wells in
9 the model makes a difference is what Scott's
10 saying. So the question is, how did you
11 represent the pumpage in the model? Did you
12 use the well package of ~~mod-flow~~ [MODFLOW -
13 ed.]?

14 **MR. FAYE:** I see.

15 **DR. KONIKOW:** In other words you have data
16 that you used to estimate the monthly pumpage
17 --

18 **MR. FAYE:** Right.

19 **DR. KONIKOW:** -- from each well. Some of
20 that comes from the shallow system. Some
21 comes from the deeper system. The
22 concentration of those two units are not the
23 same.

24 **MR. FAYE:** Where the well was in two
25 aquifers in Tarawa Terrace which was basically

1 what we had to deal with there was just two
2 aquifers, I'm trying to recall. I think for
3 the most part I just subdivided the assigned
4 pumpage equally. I had no basis for doing it
5 any differently.

6 **DR. KONIKOW:** What are you going to do in
7 the new models for Holcomb Boulevard and
8 Hadnot Point?

9 **MR. FAYE:** We would have to look at it in
10 terms of the, like the Trans-Pacific
11 [transmissivity -ed.] and American [word
12 incorrect, correct word unknown -ed.] are
13 different units, and try to apportion it as
14 appropriately as we can. I, frankly, haven't
15 thought about it a whole lot.

16 **DR. KONIKOW:** Because this, as Scott says
17 and I agree with Scott, this could make a big
18 difference in how you, how much pumpage you --

19 **MR. FAYE:** I agree if contaminant is
20 isolated to one unit, and that unit is poorly
21 pumped or vigorously pumped obviously, yeah,
22 it's going to make a big difference. I agree.

23 **DR. KONIKOW:** Have you thought of using the
24 multi-node well ~~passage~~ [package -ed.] because
25 that will do a lot of that automatically for

1 you.

2 **MR. FAYE:** Yeah, we have thought of that,
3 and I think that's registered somewhere in the
4 text there.

5 **DR. GOVINDARAJU:** Well, I just wanted to
6 follow up on that but some of this was brought
7 up at the discussion. Eventually, whatever
8 the model does, what is ^ established in the
9 well. So in the well water when it comes in
10 from whichever aquifer, it gets mixed up. So
11 the measured concentration is always a
12 particularly average value.

13 **MR. MASLIA:** But basically, we've hit on
14 Tarawa Terrace back and forth, which is fine.
15 I thought I would just get back to the expert
16 panel, the previous expert panel's, most
17 people here were on there, and go over. There
18 were five generalized recommendations. Some
19 had sub-recommendations obviously for
20 obtaining the groundwater modeling and sub-
21 recommendations of doing sensitivity analyses,
22 and dispersion fate and transport and so on.

23 But what I put together is just a
24 table in Chapter A, which I believe was sent
25 to you and it's on line and all that where we

1 applied the recommendation and wrote the
2 report in the manner so that anyone could
3 pull, go to the expert panel report and see
4 what the recommendation was and find a section
5 in the report. If anyone wants a hard copy of
6 this table, I could make that available.

7 But that's basically the approach, and
8 hopefully, the approach coming out of this
9 meeting is we'll have similar recommendations.
10 When I say similar, probably more, but of that
11 type that we can go down, and then the agency
12 will implement as needed appropriately.

13 I thought I'd summarize the Tarawa
14 Terrace -- and feel free to ask more detailed
15 questions -- but in three major categories
16 that the Agency feels that we achieved. And
17 one was the understanding that the calibrated
18 models for Tarawa Terrace are useful for the
19 epidemiological study. Second, the
20 concentrations that were measured in the
21 1980s, represent the high concentrations.
22 There are no higher concentrations based on
23 data and that was experienced over many years.

24 And finally, that using the models we
25 would not be able to conclude when the

1 contaminated water reached certain values,
2 such as arriving at the MCL, arriving at the
3 water treatment plant and water concentrations
4 people were exposed to on a monthly basis for
5 use with the epidemiological study.

6 **DR. HILL:** I agree with this, but one thing
7 I've thought about is the fact that the
8 concentrations are not higher in previous
9 years. Isn't that partly because of how the
10 source is represented in the model? And are
11 there situations such as high recharge events
12 or something, was it ever investigated as to
13 whether there might be circumstances that
14 weren't represented explicitly in the model
15 because it's an averaged, kind of a long-term
16 thing but that might be more smaller scale
17 events that could increase concentration?

18 **MR. MASLIA:** We did assume for the
19 deterministic approach that we had a
20 concentration. I believe it was 1,200 --

21 **MR. FAYE:** Mass loading ranges.

22 **MR. MASLIA:** -- mass loading ranges --

23 **MR. FAYE:** -- concentration varied over
24 time.

25 **MR. MASLIA:** -- yeah, mass loading range was

1 1,200 --

2 **MR. FAYE:** But to address Mary's question I
3 think, yeah, they have Δ [massive -ed.]
4 hurricanes there so you would get a dilution
5 for a short period of time, but on the flip
6 side, you get droughts that would increase
7 concentrations for a relatively short period
8 of time. So I don't know that we ever tried
9 to address those kinds of cause and effect
10 relationships in any of our modeling.

11 **DR. HILL:** And the one I was thinking of was
12 that hurricanes might produce greater transfer
13 of contaminants from the unsaturated zone into
14 the saturated zone and which might show a \wedge
15 [relationship -ed.] of such.

16 **MR. MASLIA:** We did not address events such
17 as those.

18 **MR. FAYE:** There was no continuous data to
19 see if there were pulses or anything like
20 that. We just didn't have that.

21 **DR. HILL:** I understand.

22 **DR. KONIKOW:** Just to follow up on that.
23 Those high, rare, let's say, uncommon high
24 recharge events might not lead to dilution,
25 might actually lead to peak concentrations

1 because it would have the opposite effect of
2 what you would want. Because some of the
3 contaminant is hung up as a separate phase in
4 some of it, and so the faster it flowed
5 through a water during high recharge events
6 could dissolve a lot more, just bring a lot
7 more solute.

8 Because one of the things that I
9 noticed in the analysis of it is that the
10 problem with mass loading rate is when you
11 match that with the fluid recharge rate that
12 you use, you wind up with source
13 concentrations in the liquid phase that would
14 be perhaps ten times above the solubility
15 limit. So there's an inconsistency there the
16 way the contaminant is loaded into the model
17 at least by using the mass loading. Or maybe
18 that's too much detail.

19 **DR. CLARK:** ~~Over here~~ [Dr. Bair. -ed.].

20 **DR. BAIR:** Yes, I was going to ask if in the
21 future model you're going to put together
22 that's transient, would there be spatial and
23 temporal changes in recharge that can account
24 for droughts and flood events and was that
25 used in the Tarawa Terrace model, transient

1 recharge, accounting for droughts?

2 **MR. FAYE:** We varied recharge only on an
3 annual basis. That was our estimate. But to
4 determine -- and we couldn't compute monthly
5 hydrologic budgets. We just did not have raw
6 data or examine the transporation date or
7 anything like that. But what we did do was,
8 we computed what we call a quasi or a gross
9 hydrologic budget on a monthly basis for the
10 period of interest using the climatological
11 data that we had.

12 For example, we had pan evaporation
13 data. We had rainfall data. So to estimate a
14 month, this was an experiment just to test the
15 sensitivity of the model to recharge. So what
16 we would do, we would subtract the evaporation
17 from rainfall and the difference we would
18 assign as effective recharge. If it was
19 negative, we would say recharge was zero for
20 that month. Then we ran the model for all 528
21 stress periods with an array like that.

22 And then we compared the end-of-year
23 changes in water levels using that approach
24 versus the approach that was used in the
25 calibrated model. And we found, and we did

1 that in the western part of the domain where
2 there was very little or no influence of
3 pumping so it would be just a natural
4 ~~relationships~~ [relationship -ed.]. And we
5 found that there was very little difference in
6 the year-to-year changes using one method
7 versus the other. And that's described in
8 Chapter C in detail, the whole approach.

9 **DR. BAIR:** Did you look at changes in
10 velocities? Because there's a difference
11 between focusing on water level changes during
12 that and looking at velocities during that.
13 And it's the velocities that are going to
14 drive the contaminants whether they slow up
15 during a drought, but during a drought you're
16 probably pumping more water, groundwater or
17 during a flood or hurricane event or a really
18 wet year.

19 **MR. FAYE:** The pumping rates didn't change
20 using the [recharge rates -ed.], from the
21 calibrated model. Pumping rates didn't change
22 using the quasi recharge rates, and we did
23 look at velocities throughout the model. But
24 basically that was just an effort to find out
25 where we possibly were violating the ^

1 [Courant -ed.] condition, not for the
2 possibility you were talking about.

3 **DR. ROSS:** I've got a quick question that
4 has to do, I guess, with recharge as well.
5 ABC Systems or ABC Cleaners discharged via
6 septic system. This answer may be in the
7 documentation, but was the base plumbed on a
8 waste water treatment system or was there a
9 septic system associated with each house at
10 any period of time or how did they treat their
11 waste water?

12 **MR. FAYE:** How did ABC specifically treat --

13 **DR. ROSS:** Not ABC, but the base.

14 **MR. FAYE:** Oh, the Tarawa Terrace. That was
15 a sewerage system. Yes, septic tanks as an
16 issue of recharge, I don't think that that was
17 anything to deal with.

18 **MR. MASLIA:** We're about five minutes from a
19 break. And as I told Bob, the reason the
20 breaks are so ^ [critical -ed.] and they might
21 want to have one is because of the video
22 streaming. They have pre-programmed certain
23 breaks in. So if we can go another few
24 minutes and take a break and then just pick
25 up, we can continue.

1 But while we're talking on it, this,
2 of course, appeared in the Chapter A report.
3 This is from the deterministic calibration
4 that we did at TT-26, the primary. And as you
5 see, as we have noted, when that shut down for
6 maintenance here, of course, the finished
7 water concentration, the water coming from the
8 WTP, mixed with the WTP, also dropped.

9 And, of course, this was the
10 probabilistic, we had two probabilistic
11 analyses. The blue line here represents the
12 calibrated finished water. This is just
13 finished water concentration that I just
14 showed you previously.

15 We ran one scenario where we used the
16 calibrated pumping schedule that Bob talked
17 about in the calibrated model unadjusted but
18 then assigned probability distributions to all
19 the other parameters as noted in the Chapter
20 I, hydraulic conductivity and infiltration and
21 there's contaminant parameters as well and
22 that's the yellow band from here to here.

23 And then the pink band we tried to
24 assign a statistical or an uncertainty
25 property to the pumping so that it varied

1 continuously, and that's detailed in the
2 Chapter I report, Uncertainty, and that's the
3 band, the pink band.

4 And I suppose what we observed is that
5 the data, the measured data that we have,
6 which obviously is in the late '80s, did fall
7 in the confidence bands and was in the, for
8 the water treatment plant, was in the
9 calibration target, so I'm sure we'll talk a
10 lot about calibration targets. There've been
11 some good discussions in the pre-meeting notes
12 about that.

13 But what I'd like to do --

14 And, Barbara, if you can get, I think
15 it's the third or fourth poster. What I did I
16 took this to the water treatment plant for
17 both scenarios. And rather than calibration
18 targets, I plotted it in terms of the 95
19 percent of the Monte Carlo simulations. So
20 that's your confidence, the pink line going
21 down there.

22 That's all the data that we have.
23 This is all the data that's above non-detect.
24 All these are detect measurements below
25 detection limit either indicated as non-

1 detects with no symbol or in this case for
2 example, we've got a below detection limit
3 with a value of I think about six micrograms
4 per liter.

5 And here the actual measured data --
6 well, that's the 95 percent of the Monte Carlo
7 simulation for those particular runs with
8 scenario one where pumping was not varied from
9 the calibrated and scenario two where pumping
10 was varied from calibrated value assigned a
11 statistical value properties.

12 **MR. HARDING:** Morris, if you could go back.

13 **MR. MASLIA:** Okay, let me back up here.

14 **MR. HARDING:** I just want to give you an
15 impression. And my impression in looking at
16 this was these seem too narrow. I would
17 expect to see a lot more uncertainty. That's
18 just, I want to give you my impression. I
19 have some specific questions related to the
20 sensitivity analyses, and they're things we
21 can talk about later, but just...

22 **DR. HILL:** Mary Hill. They do look a little
23 more reasonable on an ~~arid landscape~~
24 [arithmetic scale - ed.].

25 **MR. HARDING:** Yeah, but looking at just the

1 arrival times, for example, very narrow.

2 **DR. KONIKOW:** Well, I think these are
3 confidence bands assessed with a given
4 conceptual model, with a given numerical model
5 to look at the effects of uncertainty in just
6 a few selected parameters. I agree. They're
7 way too narrow in terms of what real
8 uncertainty is.

9 **DR. CLARK:** I'm going to use my prerogative
10 here as Chairman to say that we're going to
11 take a break.

12 (Whereupon, a break was taken between 10:15
13 a.m. and 10:30 a.m.)

14 **MR. MASLIA:** Y'all get an A-plus for using a
15 microphone except the people in the audience,
16 the court reporter cannot hear you sometimes.
17 So wait until you get the mike in your hand
18 before speaking.

19 Bob, are we ready to begin?

20 **DR. CLARK:** Let's roll.

21 **MR. MASLIA:** We'll pick up where we left
22 off, and I think just two comments I got
23 cleared up. I guess the first one is there
24 appeared to be some confusion about the valve
25 and the booster pump. Let me bring the slide

1 up. The booster pump is right here. That's
2 the 700-gallon-per-minute or 300-gallon-per-
3 minute pump that I said was noted in the logs.
4 And it ran intermittently April, May or June.
5 And Jason will also have some information on
6 that when he makes his presentation from
7 hourly information.

8 The shut-off valve, and I believe we
9 refer so there's less confusion, as Marston
10 Pavilion that's close to Wallace Creek 'cause
11 this is all Wallace Creek. And that's where
12 they had to actually go in by hand -- if you
13 can travel the bridge here, you'll see it's
14 down below -- and actually open it up by hand.
15 So there are two different hydraulic devices
16 so to speak. And that's where Joel said he
17 did not remember opening it up once.

18 I think we've seen -- correct me --
19 once or twice in the logbooks, Jason, that
20 they said they opened up the valve?

21 **MR. SAUTNER:** It really depends if you want
22 to count the period in January to February of
23 '85. It was open for a nine- or ten-day
24 period there. Besides that it was opened
25 maybe five times between 1978 and 1986.

1 **MR. MASLIA:** So just wanted to make sure we
2 were all, understood that if there was any
3 confusion. And then during the discussion as
4 to apportioning over at Tarawa Terrace where
5 wells may have been open to different zones at
6 Tarawa Terrace as Bob Faye pointed out, were
7 only open to two aquifers, and ~~tran-~~positivities
8 [transmissivities -ed.] were approximately the
9 same for each. Obviously, that will be
10 different for Hadnot Point. That will be
11 taken into account. We do have the multi-node
12 well package to use.

13 And then finally, Lenny, for my own
14 edification, when we get here to make it clear
15 that we did use the same conceptual model in
16 running the two uncertainty analyses. In
17 other words we did not change the conceptual
18 model or change boundary conditions or
19 anything of that nature or change how the
20 contaminant source was applied to the model, a
21 constant source versus a injection-type
22 source. Just wanted to clarify, just make
23 sure. I think that was Lenny's point.

24 **HADNOT POINT/HOLCOMB BOULEVARD PRESENTATIONS**

25 **AND PANEL DISCUSSION**

 So we will continue on over at Hadnot

1 Point. I'm, again, very briefly just going to
2 show where we currently are from a project
3 standpoint, and then we have follow-up
4 presentations and discussions.

5 We're basically 95 percent complete
6 with data analyses, the data that we have.
7 That was the data that was presented in the
8 notebook.

9 We're not 95 percent complete?

10 **MR. FAYE:** Yeah, for the IRP sites.

11 **MR. MASLIA:** Good, that's what I'm reporting
12 on.

13 **MR. FAYE:** Good, say the IRP sites.

14 **MR. MASLIA:** The IRP sites.

15 **DR. GRAYMAN:** What are IRP and what are UST?

16 **MR. MASLIA:** The UST are underground storage
17 tanks.

18 **DR. GRAYMAN:** And the IRP?

19 **MR. MASLIA:** IRP are the --

20 **MR. FAYE:** Installation Restoration Program
21 sites and that terminology may not be exactly
22 correct. Perhaps the folks from Camp Lejeune
23 or the Navy can clarify that. But just for
24 our own purposes of organization, that's how
25 we've subdivided up the general data that we

1 find.

2 **MR. MASLIA:** The data report, again, the
3 draft is what we provided you. When I say 95
4 percent complete, it's not going through
5 review or anything like that, but in terms of
6 compiling the tables, things like that, state
7 properties, statistical analyses 95 percent
8 complete.

9 Groundwater flow and transport
10 modeling, obviously, we have not gone very far
11 on there for a number of reasons. One is we
12 want feedback from this panel. We have to
13 provide you with some guidance as to the
14 direction we were heading, and we tried to do
15 that, but not yet commit a whole lot of time
16 and resource.

17 Number one, we needed the data
18 analyses to be complete. And then also,
19 again, obviously, we need input from this
20 panel. And the water distribution system
21 modeling, we do have calibrated all pipes
22 modeled for both Hadnot Point and Holcomb
23 Boulevard that is based on field work that we
24 did in 2004.

25 We conducted some initial simulations,

1 what were referred to as interconnection
2 scenarios. That's where we turned that
3 booster pump on and off, the 700-gallon-per-
4 minute, and Jason will report on that tomorrow
5 and that.

6 As Bob indicated, this refers to the
7 IRP sites. We have since March, we know we
8 have at least 100 more reports containing some
9 form of information, and we can discuss that.
10 We have a session on the second day to deal
11 specifically with the concept of, I guess,
12 more information. You have an expanding
13 universe or a universe with no bounds with
14 information. Some of it's usable; some of
15 it's not.

16 And the question is, is where do you
17 put the bounds on that to complete, as Dr.
18 Sinks said, to complete the study in some
19 amount of time frame. Perhaps there's an
20 opportunity to use the data from here, what
21 data is there as a second set of data,
22 calibrate or get some initial estimates from a
23 model, and then test it against the second set
24 of information.

25 This is an opportunity we did not have

1 at Tarawa Terrace, so that may lend itself to
2 addressing some of the issues as far as
3 testing the model against a second set of
4 information. And we have allotted some time
5 tomorrow, but we can obviously discuss it now.

6 **DR. BAIR:** Hi, Morris, with respect to the
7 data you have here, this doesn't include the
8 well packets. The three-ring notebook makes a
9 point of showing, I think it's an example of
10 Well 663, HP-663?

11 **MR. MASLIA:** No, I know what you're talking
12 about. We received ten years of, the most
13 recent ten years of, we refer to them as well
14 packets. Those are handwritten notes that
15 have been scanned in. And we are, this summer
16 I've got a --

17 **DR. BAIR:** Intern.

18 **MR. MASLIA:** Yeah, with the last name of
19 Maslia that's not busy for a month or two
20 during the summer who will be putting them in
21 into Excel. We've got the Excel templates set
22 up and they go from '98 to 2008.

23 **DR. BAIR:** I mean, one of the things I was
24 scrambling to find in all the information and
25 on the CD was the depth of the well screens,

1 the length of the well screens, the pumping
2 rates of the well. Is there a central
3 database that has that in it? That shows what
4 formation each screen is in? the diameter? the
5 length?

6 **MR. FAYE:** Well, I guess you just didn't
7 scramble enough because there's definitely a
8 lengthy table in the, on the CD. I don't know
9 whether it was printed out in hard copy or
10 not, but was it Table 5 that gives a complete
11 description of the well, the well
12 construction, the contributing aquifers, land
13 surface elevation, the names, the a/k/a names.
14 I think it's a fairly complete listing of the
15 supply wells, the irrigation wells at Camp
16 Lejeune.

17 **DR. BAIR:** I found that. What I couldn't
18 find to tie into that was the pumping rate of
19 that well or the pump capacity.

20 **MR. FAYE:** That's the capacity history
21 information and that is in a separate package.
22 I'm not sure if that was on the CD or not.
23 But all the well screens and the other
24 parameters that you mentioned were in that
25 table.

1 **MR. MASLIA:** We can provide, as a member of
2 the expert panel, a draft copy of that for you
3 if that assists you with doing that.

4 **DR. BAIR:** I mean, so one of the questions I
5 have, and I guess I'm just lumping it under
6 data analysis, is there was, taking HP-651 as
7 an example, they in another part listed a
8 sampling depth in that well as minus 98 feet,
9 and then listed TCE concentrations of 3,200,
10 17,006, 18,009. Was that a packed off
11 interval so it just measured the UCHRBU unit
12 or was that a vertically integrated sample?

13 **MR. FAYE:** No, all the samples were
14 vertically integrated. I'm not sure where you
15 -- we'll have to talk about that. That minus
16 98, that intrigues me. I'm not sure where
17 that came from.

18 **DR. BAIR:** It's the middle of the upper
19 screen of the three screens so it gets back to
20 my comments about this vertical mixing and
21 assigning appropriate pumping rates to each
22 one of those in the model, but we can come
23 back.

24 **MR. MASLIA:** Dave.

25 **DR. DOUGHERTY:** The one thing that was

1 missing in the well construction table, which
2 is C-3, are the details of it. Is it sand
3 pack all the way up? Are there ~~definite~~
4 [bentonite -ed.] seals or a similar type of
5 seals at certain depths? Or are these just
6 conduits from shallow depth to the screens?

7 The other related thing was the cross-
8 sections that were shown in the same Chapter C
9 from the IRP investigations show much
10 shallower depths than the screens. Are we
11 going to see some information that shows
12 additional geology for particularly the 651
13 area? That was the one that caught my
14 attention.

15 **MR. FAYE:** Of the approximately 100 supply
16 wells, I would say upwards of 90 percent of
17 those we probably have the detailed
18 construction information that you're talking
19 about in terms of the gravel packing, the sand
20 packing intervals, depth to ground, stub
21 index, the whole thing.

22 We have that information. It was just
23 a matter of, in terms of creating a table
24 picking the, what I thought was the most
25 salient information and including that. We

1 can generate all of that information. That's
2 not an issue at all. And if it turns out that
3 that's critical, we can just add another table
4 to include.

5 **DR. DOUGHERTY:** But the ~~ground~~ [grout -ed.]
6 interval I think is a significant one because
7 that [[^] - ed.transmission zone, if you will,
8 we don't know whether they're isolated by
9 zones or if there's connectivity --

10 **MR. FAYE:** Almost all of those wells are
11 constructed in terms of transecting the
12 individual confined units. If they're deep
13 enough, they're probably gravel packed across
14 the confining unit. The confining unit is
15 breached, and they're gravel packed across
16 that or sand packed.

17 **DR. DOUGHERTY:** And the grouting was this
18 ~~official~~ [surficial -ed.] --

19 **MR. FAYE:** Yes, this just on the supply
20 wells, typical 30 feet, 50 feet, whatever.

21 **DR. DOUGHERTY:** So they are open, basically,
22 gravel tubes all the way from 30 to 50 feet of
23 depth down to the bottom of the hole?

24 **MR. FAYE:** That's right, and even at Tarawa
25 Terrace, I think there were two wells, two of

1 the older wells, where the bore hole was
2 actually drilled substantially deeper than the
3 finished well. And they filled the bore hole
4 with pea gravel, the uncompleted bore hole
5 with pea gravel. So, yeah, there are those
6 construction issues. Like I say, we can
7 generate all that.

8 **DR. DOUGHERTY:** That's the one that's
9 pertinent to this and needs to be there.

10 **MR. MASLIA:** That's not a problem. That's a
11 good question.

12 I think I've just got one more slide.
13 This is just to give you really a sense of the
14 magnitude and I think complexity. When we
15 compare it side-by-side to Tarawa Terrace in
16 terms of data availability -- we'll get into
17 the model. The model is 25 times bigger --
18 but it's on the order of a magnitude more in
19 terms of amount of data.

20 And right here I think the interesting
21 is we've had our discussion, and as Bob has
22 pointed out, we actually have supply well
23 tests for Hadnot Point. We had none for
24 Tarawa Terrace. So that just lists to give
25 you sort of an idea of the volume of

1 information that we've gone through thus far
2 and gathered as well as some of the
3 complicating issues up here with a model that
4 large. Rene will be getting into that. And
5 that's it.

6 The follow-up presentations, and
7 actually I think we start with Bob, actually
8 provide much more detail. If y'all want to
9 proceed with that. I think we're just about
10 right on schedule or I can answer some
11 additional questions.

12 **DR. CLARK:** Morris, I have a question that
13 has to do with the distribution system
14 modeling the, you know, we discussed this
15 issue of potential contamination of THM
16 samples by VOCs. And it struck me that where
17 you had that interconnection problem, where
18 you actually had measured samples in the
19 Holcomb Boulevard area from the Hadnot Point
20 area, if you had comparable THM values, we
21 could compare against those. Then you get a
22 good comparison to see whether that
23 relationship is valid or not.

24 **MR. MASLIA:** That's a good point. I
25 mentioned that also if we could do that, then

1 we could go back to the Tarawa Terrace early
2 times where we have no VOC readings but we've
3 got the THMs. And we see the THMs
4 dramatically rising for a couple of years and
5 at least give some additional confidence about
6 that bound.

7 **DR. CLARK:** It should be possible to do
8 that.

9 **MR. FAYE:** That might be very useful in the
10 early parts of the period when we began
11 actually to obtain data in the early '80s, so
12 that might be a surrogate for that period.

13 **DR. CLARK:** And you should see the THM
14 levels then go back down again as they take
15 those wells offline so it would give a pretty
16 good, it might track. It might or might not,
17 but it might track pretty well.

18 **MR. FAYE:** The good part about that is that
19 those data are fairly numerous, and they do
20 span 1980 to well into the upper '80s period
21 in time.

22 **DR. CLARK:** Well, they probably started
23 collecting, I assume, on the base maybe about
24 1976? That's when the break, I think the
25 requirements went into effect.

1 DR. DOUGHERTY: Nineteen eighty.

2 DR. CLARK: Thank you, Dave.

3 MR. MASLIA: That's something I think we
4 want to go back and do not only at TT but also
5 for Hadnot Point where, again, actual measured
6 samples that we see are --

7 DR. HILL: Can I ask you a question? Are
8 there any records, what are the records on the
9 population of the base over the, from the
10 '40s? How variable is that?

11 MR. FAYE: Table 2. Table 2 in the report.

12 DR. HILL: I'm sorry?

13 MR. FAYE: Table 2, Table 3, Table 4,
14 something like that in the report. It gives
15 the --

16 DR. HILL: The electronic table?

17 MR. FAYE: Yeah.

18 DR. HILL: Not this one. This one's --

19 MR. FAYE: It's one of the early tables in
20 the, in your report there. It was probably on
21 the CD, but it --

22 DR. HILL: Table 2 is Average Annual Rate of
23 Treated Potable Water --

24 DR. CLARK: That's a different chapter.

25 MR. FAYE: No, it's in the background

1 section. It's in the housing area where I
2 discuss the population over, there's several
3 intervals of time there that I discuss the
4 population at the different base housing
5 units.

6 **DR. HILL:** If you can't remember, we can't
7 either.

8 **MR. FAYE:** It is the report that's in the
9 three-ring binder. It's the Contaminant Data
10 report.

11 **DR. HILL:** I was saying I was interested in
12 dates, the table reference provides the
13 resident population of the different housing
14 areas, but I was interested in base population
15 because some of the contaminant sources we're
16 talking about, the activity level at those
17 sources I would think would be proportional to
18 base population. And in this site like the
19 industrial area, for example, or some of the
20 carpal areas in Tarawa Terrace, they are
21 clean. But here there are different things
22 that you would expect the activity level to be
23 proportional, I would think, to base
24 population. So just if that seems --

25 **MR. MASLIA:** Frank, was not the base

1 population the assumption for the epi study
2 that was constant over most of the time?

3 **DR. BOVE:** For Tarawa Terrace we have
4 housing records and we can make some estimates
5 as to the population there based on that.
6 Now, the units, we don't ^ [know the number of
7 -ed.] people in those units. The same with
8 Holcomb Boulevard. We know when the housing
9 units are built, so we can do that. But the
10 problem is main side ^ Hadnot Point. We have
11 barracks, and we don't know how many people
12 went in and out ^ barracks ^ [during -ed.]
13 ~~Viet Nam~~ [Vietnam -ed.]. We do have ^
14 [information -ed.] from the '70s on based on
15 computerized data, but before that we just
16 don't know. And the barracks are --

17 **DR. HILL:** But you don't have sort of
18 population values for --

19 **DR. BOVE:** The health assessment that we
20 just went through has estimates of what the
21 population ^ is today and the recent past. We
22 don't know how many people went through those
23 barracks during the ~~Viet Nam~~ [Vietnam -ed.]
24 era and before.

25 We have computerized data -- and

1 Scott, correct me if I'm wrong -- We have
2 computerized data from '71 on although from
3 '71 to '75 we don't have their unit code so
4 we're not sure who was at the base even then.
5 From '75 onward we know how many people were
6 at the base but we have family housing. So we
7 have some information for -- we have Tarawa
8 Terrace and Holcomb Boulevard were pretty, we
9 can have good estimates. It's the barracks.
10 It's the barracks that have trouble before
11 '75.

12 **MR. WILLIAMS:** There are certain ways we can
13 estimate it, but, no, we don't, we didn't do
14 base ^ [census -ed.] or anything like that.
15 There was a base master plan that came out
16 like '87 that has 1983 data. Morris has all
17 those where they actually did go to each water
18 system to estimate how many people were served
19 by that water system. It was very, they don't
20 reveal the method they used, but you can tell
21 by ^ [? -ed.]22,223 [? -ed.] people on this
22 water system, and you can use that to
23 estimate. You can say if there was this many
24 people on these water systems and project that
25 before '87 back to '57, you can get a crude

1 estimate of how many people were served. And
2 then you can assume the military persons would
3 have had a two-year residency on average.
4 Sometimes it was higher than that; sometimes
5 it was lower than that. You can really get a
6 crude estimate of the population. And that's
7 how we came up with approximately 500,000, and
8 that's probably conservatively high.

9 **DR. CLARK:** Let's move on at this point.
10 I've got two more questions and then I want to
11 move on to Bob's presentation.

12 **DR. KONIKOW:** Morris, on your last slide, on
13 the availability of data I have two comments
14 and/or questions or one comment and one
15 question. One is that you're showing there's
16 a lot more data available for the Hadnot Point
17 area.

18 **MR. MASLIA:** We've got a hundred USD [UST -
19 ed.] reports.

20 **DR. KONIKOW:** Well, you show there's more
21 wells, more water levels.

22 **MR. MASLIA:** Oh, yes, yes.

23 **DR. KONIKOW:** So in terms of the, let's say,
24 practicality of doing the detailed,
25 deterministic models, I wanted to point out

1 that if you look at the density of the data,
2 it's actually much better in the Tarawa
3 Terrace. It's about 105 wells per square mile
4 in that area. Whereas, if you go to the
5 Hadnot Point, it's only about 17 wells per
6 square mile. So even though there's more
7 data, it's more spread out, and that just
8 makes it much more difficult to do the
9 modeling and get the resolution that you need.

10 **MR. MASLIA:** Are you speaking from a
11 deterministic standpoint?

12 **DR. KONIKOW:** From the deterministic
13 groundwater model.

14 **MR. MASLIA:** Right, we'll address that.
15 Rene will, but I would say probably 90-to-95
16 percent before we made up our minds to go with
17 ^.

18 **DR. KONIKOW:** The other comment I have is
19 that you're showing quite a few well tests,
20 pump tests in the Hadnot Point area, and I'm
21 assuming that these give estimates of
22 transmissivity or something that correlates
23 with transmissivity. And yet in the model, at
24 least in the first steady state model, you're
25 assuming each aquifer is homogeneous.

1 Can these data and all these tests be
2 used to look at spatial variations in
3 transmissivity and try to incorporate that
4 information into the model to get better
5 resolution and better matches on the head
6 distributions?

7 **MR. MASLIA:** Yes.

8 **MR. FAYE:** Do you want me to answer that?

9 **MR. MASLIA:** Yes, go right ahead.

10 **MR. FAYE:** Yes, but the vast majority of
11 those aquifer tests, Lenny, are for the
12 Brewster Boulevard aquifer. So, yeah, which
13 was obviously the, that's the aquifer that
14 receives the contamination. So for that
15 particular layer, probably for the layer
16 representing layers, the layer representing
17 the Tarawa Terrace aquifer, there may be
18 enough data out there to provide some kind of
19 gross detail resolution of the hydraulic
20 characteristics.

21 **DR. KONIKOW:** Are you planning to do that?

22 **MR. FAYE:** Yeah.

23 **DR. CLARK:** One more question right here.

24 **DR. ROSS:** This relates to, I guess,
25 variability in source streams. Perhaps it

1 also relates to population changes over time.
2 I expect during the ramp up to the Viet-Nam
3 [Vietnam -ed.] War there'd be more Marines
4 passing through the base; therefore, ABC
5 Cleaners would be cranking through probably
6 more than two or three drums of perc
7 [perchloroethylene or PCE-ed.] per month. Was
8 there any consideration about that?

9 **MR. FAYE:** That doesn't seem to be the case.
10 I mean, that was specifically addressed in the
11 interrogatories during the interviews of the
12 family and the owners. They had hands-on. I
13 mean, that was their business. And you have
14 to remember, too, now that there was a
15 laundry, a major laundry, at the base itself.
16 So they were possibly or probably dividing up
17 the available work between them. So, but Mr.
18 Metts was very specific, and he was asked that
19 question specifically, and it was two-to-three
20 55-gallon drums of perc every month.

21 **DR. ROSS:** Did the base want them to use
22 perc and what did they do with that?

23 **MR. FAYE:** They used barsaf* [Varsol -ed.]
24 up to the early 1970s and then they used perc.
25 And we do not have any records of their rate

1 of use. At least we don't at the present
2 time.

3 **MR. PARTAIN:** ^ [Where is the base laundry?
4 -ed.] (off microphone).

5 **MR. FAYE:** Site 88, Building 25.

6 **MR. PARTAIN:** And there is a PCE ^ [plume -
7 ed.] there.

8 **MR. FAYE:** Yeah, oh, big time plume.

9 **DATA ANALYSES -- GROUNDWATER**

10 **DATA SUMMARY AND AVAILABILITY**

11 My name's Robert Faye. I work for the
12 Eastern Research Group and I support the Camp
13 Lejeune Project here. For the Hadnot Point
14 and vicinity project my basic responsibilities
15 have been locating data, recognizing data that
16 will be useful to the project, processing that
17 data, creating databases, writing one of the
18 reports that was in the three-ring binder
19 there that you all received, The Soil and
20 Groundwater Contamination Report. I apologize
21 it wasn't completed, but it was 95 percent
22 completed and there's only so many hours in a
23 day.

24 This is a summary of available pumpage
25 data that we have, daily operation schedules
for Hadnot Point WTP individual supply wells.

1 We have daily operation schedules from
2 November 28th, 1984, to February 4th, '85.
3 Scott alluded to those data earlier when we
4 were talking about the BTEX spill at Holcomb
5 Boulevard.

6 As far as our corresponding pumping
7 rates for both the Hadnot Point and the
8 Holcomb Boulevard WTP individual supply wells,
9 we have that data for a several month period
10 here, from October of '88 to March of '89.
11 Total gallons pumped, average pumping rate,
12 average daily withdrawal and percent of time
13 inactive for HP and HB WTP. The supply wells
14 1993, we have that data from that year. And
15 as Morris was alluding to earlier, we have
16 daily logs for wells pumped indicating
17 operational status on and off for individual
18 supply wells at both Hadnot Point and Holcomb
19 Boulevard from January 1998 to June of 2000.

20 And these data to a large degree will
21 allow us to address a number of the questions
22 in terms of accommodating actual well
23 operation scheduling in the HP/HB model that
24 we're contemplating that you folks are
25 commenting on here today. Peter Pommerenk in

1 his notes address those issues in good detail,
2 and I think these data will allow us to
3 accommodate a lot of that, a lot of his
4 concerns.

5 These are data that we have relative
6 to either supply of water, water delivered or
7 both for the WTPs. The first two lines there,
8 Annual Delivery Rates, those are tables in the
9 three-ring binder and the Soil and Groundwater
10 Contamination Report that I wrote in Tables 3
11 and 4. I can't remember the names now, but
12 they're all listed in there. Delivery rates
13 from Hadnot Point, '42 to '98; Holcomb
14 Boulevard, '75 to '98.

15 And then we have monthly rates of well
16 water supplied or and/or treated by the WTPs,
17 September '55-January '57. January '80 to
18 December of '84, we have some overlap here;
19 January of '82 to December of '93; January of
20 '87 -- and these data do not all agree for the
21 same months so we have to reconcile that.

22 And then we actually have daily rates
23 of well water supply treated by the WTPs for
24 this period, January '95 to May '99; January
25 2000 to December 2005. So you can see we

1 have, at least as far as an annual situation,
2 we're in pretty good shape. And through the
3 whole period of interest that we would want to
4 accommodate. And as far as the monthly rates
5 not too bad either. And daily rates strictly
6 for more modern times.

7 **DR. KONIKOW:** Bob, on the previous slide I'm
8 still not sure. In your model you probably
9 are going to go with a monthly stress period,
10 right?

11 **MR. FAYE:** Yeah.

12 **DR. KONIKOW:** But with this kind of annual
13 data how are you going to reconstruct monthly
14 withdrawals from the wells to plug into the
15 model?

16 **MR. FAYE:** Well, we actually have monthly
17 rates of, we actually have several periods of
18 time here, Lenny, where we have hours pumped,
19 corresponding pumping rates --

20 **DR. KONIKOW:** That's all pretty recent.
21 What about prior to 1984?

22 **MR. FAYE:** We'll probably use the same
23 approach we did there in Tarawa Terrace where
24 we apportioned a monthly rate according to the
25 percentage of total well capacity. And that's

1 exactly what we did at Tarawa Terrace.

2 The objective there, as it should be
3 here, is to remove a specified volume of water
4 from the system. So in that case the actual
5 capacity, the actual pumping rate becomes just
6 a surrogate for apportioning based on a total
7 percentage basis. But we can also, using
8 these data, address a lot of the operational
9 concerns and interests that several folks have
10 addressed in your notes including Peter, who
11 really got into it in detail.

12 We can actually run tests and change
13 our stress periods to 12 hours and run for
14 specified periods of time where we actually
15 have data to allow us to do that, to tell us
16 to do that, and check the differences in water
17 levels over a month to see what those effects
18 would be. And by extension also into the fate
19 and transport models, see how it affects the
20 simulated concentrations.

21 **DR. GRAYMAN:** But if you go to the next
22 slide, I mean, it looks like there's that 23-
23 year period where you have absolutely nothing
24 finer than annual, and that's the major era,
25 major period.

1 **MR. FAYE:** Yes, and that was similar to the
2 same situation we had at Tarawa Terrace. We
3 didn't really pick up on monthly WTP
4 deliveries or supply water until 1975, I
5 believe. So we went from '52, '53 to '75.
6 And what we did, we took like a ten-year
7 period where we had, where we actually had
8 those data, took an average, and then assigned
9 that as a monthly rate back in time. We
10 considered that was the best average that we
11 had.

12 **DR. GRAYMAN:** Was there, I mean, to go back
13 to Mary's question if there was any kind of a
14 population or census data at least you could
15 use that as a surrogate for water --

16 **MR. FAYE:** Well, we did. We, in an
17 anecdotal way we did because it was Tarawa
18 Terrace. There was a finite number of houses,
19 and we understood that that housing was full
20 almost all the time. There was a demand for
21 that housing almost all the time for our
22 period of interest. And it was subdivided
23 into two bedroom, four bedroom, whatever they
24 were, and that was a consistent thing for the
25 period of time.

1 **DR. DOUGHERTY:** So one way of apportioning
2 the stress is based on their portion of the
3 capacity, but is there a portion of the record
4 that's sufficient where you could look at the
5 behavior of the operators in terms of how they
6 operated the system rather than how the well
7 screens had the capacity and use that as a
8 surrogate rather than --

9 **MR. FAYE:** Yes, as Peter pointed out most of
10 these wells were probably operated, well, he
11 says 12-to-16 hours a day, which is fine. We
12 can simulate that kind of a condition, not for
13 our whole 1942-to-2005 period of interest or
14 anything like that. But once we have a model
15 that we have confidence in in terms of close
16 calibration, quasi calibration, however you
17 want to term, however you want to categorize
18 it, we can run then these tests.

19 We actually have data that can assist
20 us in understanding how the system was working
21 operationally for individual wells. We can
22 run specific wells for specific periods of
23 time based on the data that we do have. We
24 can turn other wells on, turn other wells off,
25 that kind of thing, and actually test on an

1 end-of-month basis how it affects, what
2 differences there would be just using a
3 monthly stress period or a 12-hour stress
4 period, et cetera, et cetera. And that's
5 fully reasonable, and we intend to do that.

6 **DR. GRAYMAN:** Bob, could you put up a figure
7 if you have it, a figure of what the annual
8 delivery rates were over those periods? Is
9 there one?

10 **MR. FAYE:** I'm sorry, Walter, there is not,
11 but there is in the -- I keep alluding to that
12 report. There is a, there are two tables in
13 that report, one for the Holcomb Boulevard
14 plant and one for the Hadnot Point plant that
15 shows the annual delivery rates for those
16 periods that are up there.

17 **DR. HILL:** That's not one of the tables on
18 the -- is it a table or a figure?

19 **MR. FAYE:** It's a table.

20 **DR. HILL:** And it's not the table on the --

21 **MR. FAYE:** It's like C-2 or C-3 or something
22 like that.

23 **MR. HARDING:** They're Table C-2 and C-4.

24 **MR. FAYE:** Okay, there you go.

25 **DR. HILL:** A lot of years say N/A.

1 **MR. FAYE:** No, that's not true. There's
2 only a couple years that say N/A.

3 **DR. HILL:** In the C-2 there's one, two,
4 three, four, five, six, seven, eight, nine,
5 ten, 11, 12, 13. And then 69 and 70.

6 **DR. DOUGHERTY:** You can ^ [estimate -ed.]
7 from the neighbors unless there was some
8 significant population change, you can ^
9 [estimate -ed.] because it's ^ [stable -ed.].
10 In the study period it's the first, before the
11 first five years.

12 **MR. FAYE:** Okay.

13 **MR. HARDING:** If you look, it's reasonably
14 stable and reflects the change that was made
15 in, what was it, 1972, when Holcomb Boulevard
16 came on line.

17 **MR. FAYE:** That's right.

18 **MR. HARDING:** If you take that into account
19 it's really fairly stable.

20 **DR. BAIR:** And I think the first two years
21 of Holcomb Boulevard we don't have any of
22 that.

23 **MR. HARDING:** Just as a placeholder because
24 it's way more important -- well, maybe I
25 shouldn't say that. I'll leave the

1 groundwater people to say how important the
2 allocation of pumping to the different wells
3 is. But I think when you start looking at the
4 concentrations in the finished water, this
5 becomes critically important on a fairly short
6 time frame because we have a precision that's
7 required here, the trimester, for some of this
8 causation or whatever the epidemiologist calls
9 this.

10 I'm trying to think of it.
11 Association, there you go. And how the
12 operators ran these wells is going to become
13 really important. And so I'd like to have
14 more discussion about that when we get to the
15 water -- I think it's appropriate in the water
16 distribution side of this discussion.

17 **DR. BAIR:** And that in turn is dependent on
18 how the pumping rate is apportioned to each
19 one of the lenses or layers that the well
20 screens are across from, which in turn, is
21 dependent on the confining beds in between
22 them that are all given the same value of
23 hydraulic conductivity ^ [in feet -ed.] per
24 day.

25 **MR. HARDING:** Well, that will be physics

1 down in the well hole, and then above the well
2 hole there's a guy that flips a switch that
3 turns on a particular well. And the way they
4 make that decision is what, once we've figured
5 out the physics of what brings us to an
6 average concentration at the well head, it's
7 that flipping of the switch that's going to
8 determine what the concentration is
9 essentially for the most part that gets to
10 people's homes, and that's the part I'm
11 talking about.

12 **DR. BAIR:** It's defining the relative
13 permeabilities in the sediments that
14 determines which plume, whether it's at this
15 level or this level or this level contributes
16 what rate and what concentration to the well
17 bore.

18 **MR. HARDING:** I understand, and the
19 interface between the water distribution
20 modeler and the groundwater modeler, we just
21 refer to wellhead concentrations in the above
22 ground part of it. So once you guys have
23 figured out the wellhead concentrations which
24 relates to all the physics that takes place in
25 the bore hole, there's another question which

1 is when did the operator turn on the well and
2 for how long? That's my issue.

3 **MR. FAYE:** Actually, it's even more
4 complicated than that because there's --

5 **DR. BAIR:** Mary mentioned the three
6 significant digits on that table earlier, too.

7 **MR. FAYE:** There's a routine operation that
8 Peter constantly refers to, and correctly so.
9 And then there's sort of an exceptional type
10 of operation, and that's, and one example of
11 that is this period of time in late January
12 and early February of 1985 when a lot of the
13 wells that were contaminated were taken off
14 line. All of a sudden Holcomb Boulevard
15 couldn't be used any more.

16 All of the water supply to that part
17 of the base had to come from Hadnot Point, and
18 they just turned those wells on and let them
19 fly. So you have -- and so you have a
20 situation where these wells were being pumped
21 24 hours a day, day after day. I don't know
22 how frequently that kind of a situation
23 occurred, probably not a lot.

24 But ancillary to that situation is for
25 whatever reason most of these supply wells end

1 up on somewhat removed from the center of mass
2 of the plumes that were recognized in the
3 middle '80s, middle '90s, whatever at a lot of
4 these sites. So what happens is if you turn
5 the well on for 12 hours and sample it, you'll
6 get one concentration of a contaminant. If
7 you turn the well on for 24 hours for eight
8 days and sample it, you've moved a lot more of
9 that mass from the center, mass of contaminant
10 from the center of the plume toward the well,
11 and you'll get a much higher concentration.

12 And, indeed, we see that in the data,
13 and that's exactly what happens. So there's a
14 matter of routine operation, and then there's
15 a matter of exceptional operation so that adds
16 another level of complexity to the argument.

17 **DR. POMMERENK:** I want to chime in on this.
18 Just like you said, it makes a big difference
19 for the contaminant movement of whether you
20 operate a well like for a month continuously
21 at a reduced flow rate or whether you operate
22 it at a designed rate for 12 hours a day.

23 **MR. FAYE:** Right.

24 **DR. POMMERENK:** I think that the uncertainty
25 associated with this needs to be worked out

1 somehow and ^ [reflected in -ed.] the results.

2 **MR. FAYE:** Well, we have probably, what, two
3 or three individual cases where we can
4 actually test, use the model at some point
5 when we have confidence in the calibration.
6 At some point we can actually test that
7 against actual field data for several wells
8 which will give us some insight how the
9 model's actually responding to that kind of
10 condition. Right now that kind of a test and
11 maybe some hypothetical tests would be
12 perfectly feasible as far as I'm concerned.

13 **DR. POMMERENK:** I think at this point, I
14 think in the near future you would have to
15 develop at least some, a pilot study to just
16 demonstrate what the potential uncertainties
17 are, you know, operating in an idealized
18 fashion versus what I perceive is more the
19 realistic way of things, how things were done.

20 Another complicating factor is, of
21 course, the fact that the total well capacity
22 ^ [of the -ed.] well fields exceeded the
23 required capacity for water demands that were
24 at times 100 percent or even larger. So there
25 were many more wells available than needed for

1 day-to-day average operation. In fact, the
2 State of North Carolina currently requires
3 your water demand can be met with 12 hours of
4 pumping, and I don't know how far back this
5 regulation goes.

6 But so the result of this is that the
7 operator has twice as many wells available as
8 actually needed. So given the right
9 permutation for those times, we don't know
10 which wells were actually being used to meet
11 the demands introducing additional
12 uncertainty. Because you could have, you
13 know, on any random day or even if you go into
14 further larger periods, a set of wells that
15 were less contaminated than in other weeks a
16 set of wells was used that were more
17 contaminated. So I don't know how you're
18 going to address this kind of uncertainty.

19 **MR. FAYE:** I think we can get a large
20 handle, our arms around that issue, not
21 perhaps easily, but I think we have the
22 information to do that, Peter, right here with
23 this set of data. We have actually daily
24 operations on and off for dozens and dozens of
25 the supply wells that were active at this time

1 during January '98 to ^ [2008 for -ed.] ten
2 years. So there's a lot of statistical
3 inferences in terms of operations. This
4 10,000 pages of data so that we can, there's a
5 lot of statistical inferences that we can
6 glean from that data.

7 And the good thing about this in
8 addition, is that a lot of the wells that were
9 active at this time replaced previously active
10 wells going back 20, 25 years. So the
11 inferences that we glean from this set of
12 information, we can actually extend back in
13 time to the early '70s, perhaps even late '60s
14 and then maybe even beyond that if it turns
15 out that there's some degree of consistency
16 that we find to the way wells were operated
17 back in the '50s or whatever with the other
18 data that we have. So I think we can get our
19 arms around that anyway from about 1970 up to
20 the present time without a whole lot of
21 trouble. I shouldn't say that. We can get
22 our arms around that. It'll be a pain in the
23 rear, but we'll get our arms around it.

24 **DR. KONIKOW:** Can you briefly describe how
25 the well capacity data were derived? In other

1 words you, basically, you assumed that the
2 pumping rate was the well capacity
3 information. And what I remember from one of
4 the tables is that for an individual well for
5 month to month it looked like the indicated
6 well capacity could vary 20, 25 percent.

7 **MR. FAYE:** Yeah, and particularly over time
8 because these wells, well, some of these wells
9 were used for three and four decades. Now
10 they were periodically reconditioned and
11 whatever, you know, pumps repaired, bearings
12 replaced, et cetera, et cetera, of course.
13 But you do have a deterioration in, expected
14 deterioration in the well capacity over a
15 period of time.

16 And we have a lot of data indicating
17 what that is. What that deterioration was and
18 then as some operational thing occurred, what
19 pump replaced, whatever, and the capacity goes
20 up. To answer your question more specifically
21 with respect to the well capacity test,
22 typically, what you and I would call these
23 tests would be a crude step drawdown test.

24 And basically they vary the head that
25 the well is pumping against by discharge and

1 check that pressure just to make sure that the
2 well can meet its expected operational ranges.
3 And that's essentially what they are.

4 They're step drawdown tests, and then
5 typically, after the test there'll be a little
6 note at the bottom of the test page that'll
7 say left pressure at 100 psi or whatever it
8 is. And that 100 psi then refers directly to
9 a discharge that was used during the test, and
10 that's the discharge that would show up in the
11 Capacity Use Table that you're referring to at
12 a particular, you know, October of 1978 or
13 whatever it happened to be.

14 **DR. DOUGHERTY:** Just to go back to the
15 operational uncertainty and how to reconstruct
16 that, there's a marked change in data density
17 in '98. And I assume a bunch of sensors went
18 into the system. Was there a change in the
19 operations going through a programmable
20 controller or anything at that point which
21 would suggest a difference in operation prior
22 to those data?

23 **MR. FAYE:** I don't think so. They've been
24 using a SCADA system over there for many years
25 for better or for worse, but I don't know of

1 anything that demark -- delimited 1998 in
2 particular as an effort.

3 **DR. CLARK:** We're going to have to move on.
4 We've got a lot of other material to present,
5 so...

6 **MR. MASLIA:** Bob, can I just answer that?

7 **DR. CLARK:** Okay.

8 **MR. MASLIA:** The reason there appears, I say
9 there appears to be more data density is
10 because after ten years or ten years worth of
11 records, the records are destroyed. So in
12 other words '98 to 2008 represents the most
13 recent ten years of records that are kept.

14 **MR. WILLIAMS:** The State of North Carolina
15 requires you to maintain ten years of the
16 data, and so I don't know that they're
17 necessarily destroyed. They're just not kept
18 after, when it turns into the eleventh year.
19 So that's why we have --

20 **MR. FAYE:** That's your answer. Is that
21 good? Okay, let's go on.

22 This is the slide that Morris stole
23 from me, and I'll try to make him regret that.
24 He's wrong here in terms of the slide, and
25 where supply well tests at Tarawa Terrace.

1 And, Lenny, most of these were just
2 exactly what I was talking about. These
3 represent those step drawdown efforts that
4 were made during the capacity use tests.

5 Let's see, what else do we have?
6 Well, this is just, as Morris pointed out,
7 this points out the great difference in the
8 numbers of data that are available in this
9 study. And as we just briefly discussed
10 earlier, this represents what we call IRP
11 data. This slide sort of resembles a credit
12 card application. There's little, fine print
13 down here talking about these LUST reports
14 that have just recently come to light.

15 Timing was good on that because we
16 were just about finishing up the IRP data. We
17 couldn't have dealt with any more data if we
18 tried. But anyway these represent the numbers
19 of data that we have for the Hadnot Point and
20 Vicinity Study.

21 And, Lenny, I would quibble a little
22 bit with your density numbers. What you
23 should really do is pick out two or four
24 square mile areas where we have data, where
25 the data actually occur at Hadnot Point, and

1 you'll see tremendous differences in density
2 in the areas that count. And I'll talk about
3 that in a minute relative to Tarawa Terrace.

4 **DR. BAIR:** Bob, could you keep that on for
5 just a second?

6 **MR. FAYE:** Sure.

7 **DR. BAIR:** Thank you. You mentioned that
8 most of the 69 supply wells and 132 pump and
9 aquifer tests are really these step drawdown-
10 type tests?

11 **MR. FAYE:** No, not for these.

12 **DR. BAIR:** Not for the 132?

13 **MR. FAYE:** No, those probably represent
14 completion tests by [the driller -ed.]^. It
15 would still be, to a large degree they would
16 still be step drawdown tests, but they would
17 be a lot more detailed than a capacity use
18 test.

19 **DR. BAIR:** So my question is are there or
20 how many tests are there that are a bona fide
21 aquifer test where you have an observation
22 well, and we can extract from it a horizontal
23 hydraulic conductivity from a specific zone, a
24 ratio, perhaps an anisotropy within that zone
25 so that it gives you some guidance for what to

1 use as hydraulic conductivity distributions at
2 each one of the layers. And where did you get
3 values for the confining beds? Are those part
4 of that set, too?

5 **MR. FAYE:** No, no, these would all be the
6 permeable units. These would all be what we
7 would call the aquifer layers in the model,
8 virtually no data. We have a little bit of
9 data at one site at Tarawa Terrace that we
10 could refer possibly to, a confining unit, and
11 I think that was like a half a foot per day or
12 something like that horizontal.

13 But let me see. As far as the supply
14 wells, you can forget anisotropy. Maybe ten
15 percent of those had a single observation well
16 so you can compute storativity from that,
17 maybe ten percent of those. Now, the monitor
18 well tests are a lot different. There are
19 multiple, multiple observation wells for the
20 most part, but the pumping rates are so low
21 because it's contaminated water, and they're
22 trying to deal with it as a disposal issue.

23 So the pumping rates are so low that
24 the best information you can get from most of
25 the monitor well data would be like a distance

1 drawdown [curve -ed.]^ . You don't get a lot
2 of intervening time result at the observation
3 wells.

4 Now, to flip that around there's
5 probably several sites, I would say two or
6 three where I was actually able to apply a
7 ^[aquifer-test ed.] analyses, and actually
8 compute a leakage for the intervening
9 confining units. Also, there's quite a bit,
10 in the supply wells there's a fair number of
11 analyses that would lend themselves to like a
12 Cooper-Jacob analyses, so it wouldn't be
13 strictly a step drawdown.

14 **DR. BAIR:** Are those values, the variants
15 there, put into the steady state model? Or is
16 it still kind of a layered system with uniform
17 values going across all the layers?

18 **MR. FAYE:** I didn't construct, I wasn't
19 directly involved in the steady state model.
20 Rene is going to address that. But I do
21 believe that he interpolated the point data to
22 the layer for that domain. The confining
23 units are a whole 'nother story. They're sort
24 of an arbitrary assignment right now. And
25 one-tenth of the standard kind of heuristic

1 type approach and one-tenth of the permeable
2 unit value. But I think that'll be refined
3 later on.

4 **DR. BAIR:** I'm feeling really confident
5 about those three significant digits the more
6 we talk. It's getting --

7 **MR. FAYE:** All right, I'm glad of that.

8 **DR. BAIR:** How about slug tests? Did they
9 do slug tests in any well?

10 **MR. FAYE:** Ton, tons of slug tests. And --

11 **DR. BAIR:** Have those been processed?

12 **MR. FAYE:** -- here, you can see.

13 **DR. BAIR:** Sixty slug tests.

14 **MR. FAYE:** Sixty slug tests, yeah. We have
15 processed those now. This probably means that
16 there were originally somewhere between 150
17 and 180 slug tests.

18 **DR. BAIR:** You didn't believe?

19 **MR. FAYE:** I didn't believe them so I got it
20 down. Sixty I can believe.

21 **DR. BAIR:** Thank you.

22 **DR. DOUGHERTY:** Bob, one quick question on
23 the confining units. Are there data from the
24 IRP program whether direct sampling of the
25 fine grain materials or grain size analysis?

1 **MR. FAYE:** Lots of grain size analysis,
2 yeah, many, many. And a lot of those were
3 converted into a hydraulic conductivity value,
4 but I didn't use those.

5 **DR. DOUGHERTY:** For fine grain materials --

6 **MR. FAYE:** For whatever that permeable unit
7 happened to be.

8 **DR. DOUGHERTY:** Got it. Thank you.

9 **MR. FAYE:** But I'm very dubious of those, of
10 that methodology, and I didn't use any of that
11 here.

12 **DR. HILL:** You may not have used the values,
13 but did you use the trends? Are there any
14 trends evident?

15 **MR. FAYE:** I didn't look at trends in terms
16 of percent fines at a particular point,
17 percent coarse at a particular point. Haven't
18 got to that point yet, but we can easily do
19 that. My hunch is that on a macro scale it's
20 probably not going to be much.

21 The trends are, these aquifers in
22 terms of their hydraulic characteristics and
23 in terms of their lithologies appear to be
24 highly consistent until you get down to the
25 what I call the middle Castle Hayne aquifer.

1 And then the lower Castle Hayne aquifer is a
2 big jump downward in terms of the horizontal
3 hydraulic conductivity. It's much smaller
4 than the younger units.

5 DR. HILL: This is a report that I'm sure
6 you've seen. It's the Cardinale.

7 MR. FAYE: Cardinale Report, yeah.

8 DR. HILL: One of the figures would suggest
9 some trends. I mean, if you take out the
10 highs and lows and kind of look at the trends
11 so I was surprised to hear you say not.

12 MR. FAYE: I didn't say there weren't any
13 trends. I'm just saying I haven't gotten to a
14 point where I could investigate that situation
15 yet. There may be a trend out there. I have
16 to say though that I'm surprised that there
17 would be based on what I know about the
18 lithologies, but it easily could be. It could
19 be.

20 DR. HILL: Well, okay, now, I'm surprised to
21 hear you say that because one would think that
22 there would be archaic channels that came
23 through and that you would expect to see --

24 MR. FAYE: Are you saying trans-vertically
25 or within a layer?

1 **DR. HILL:** It could be either, but I was
2 thinking horizontally at the moment, but it
3 could be both.

4 **MR. FAYE:** Yeah, there are, these layers,
5 many of them have been, they were erosional
6 surfaces. They were transgressed by streams.
7 And then those channels were later infilled
8 with channel sands.

9 But those streams from what I've seen
10 in the Cardinale Report and from other reports
11 that address that, these streams are not
12 particularly large and so if you're, and so
13 it's sort of a shot in the dark whether a
14 particular sample was collected in an infilled
15 channel or in a, for that particular horizon,
16 a relatively undisturbed area. So that's just
17 not something I can fully address in a
18 meaningful way.

19 **DR. CLARK:** Robert, I think I'm going to
20 have to move on.

21 **MR. FAYE:** Okay, you're the boss.

22 **DR. CLARK:** I don't know about that. I
23 doubt that.

24 **MR. FAYE:** This, again, relates almost
25 exclusively to the IRP sites that we talked

1 about, and these are the sites that are
2 addressed in the Soil and Groundwork
3 Contamination Report that's in your three-ring
4 binder. Again, don't ask me what tab because
5 I don't know.

6 This shows basically the site names
7 and the area of exposure based on the monitor
8 well distributions at the particular sites.

9 And this is what I was talking about,
10 Lenny. If you wanted to actually look at data
11 density, this is what you ought to be looking
12 at in terms of the areas of interest.

13 And this is what we call the landfill
14 area, the northern part, Site 88, and the
15 Hadnot Point Industrial Area. Those are the
16 three major areas of groundwater contamination
17 or at least the contamination of interest to
18 us from the IRP sites.

19 This shows the density of the sampling
20 points where we have samples for, that were
21 analyzed for PCE, TCE and their degradation
22 products. And that's pretty much exclusive.
23 I mean, if they analyzed for PCE, they go
24 through the whole enchilada of degradation
25 products.

1 **DR. BAIR:** Excuse me, Bob. That map is
2 showing wells, not aquifers.

3 **MR. FAYE:** Exactly.

4 **DR. BAIR:** Okay.

5 **MR. FAYE:** We'll get to the aquifer part in
6 a minute. Bear with me.

7 **DR. HILL:** I'm sorry, also that's just PCE.

8 **MR. FAYE:** That's PCE.

9 **DR. HILL:** But there was, I thought at
10 Building 820 in the Hadnot Boulevard area,
11 just a little cluster on the bottom.

12 **MR. FAYE:** Right, it's right here.

13 **DR. HILL:** There was BTEX-free product
14 there.

15 **MR. FAYE:** Just give me a chance, Mary.
16 Give me a chance.

17 This is TCE, same idea. Those are the
18 wells where we sampled for TCE. Here you go,
19 Mary, that's where we show benzene. This is
20 the site that Mary was talking about, 820. Of
21 course, all of these concentrations I should
22 have pointed out use a concentration range
23 based on the size of the point that was used
24 on the map.

25 And if Mr. Clark will bear with me

1 here, I'll go back and point that out. I'll
2 point out Site 88 here, which is a site of
3 major PCE contamination and also PCE
4 contamination here and PCE/TCE contamination
5 here as well as a lot of TCE contamination in
6 the HPIA and major BTEX contamination within
7 the HPIA as well.

8 This might address what you're talking
9 about, Dr. Bair. This is our PCE
10 concentrations, our PCE sampling points at
11 depth along a section line -- this is very
12 gross -- that runs basically from the New
13 River over toward the landfill area, New River
14 Site 88, Industrial Area West, Industrial Area
15 East, and the landfill area. This gives you a
16 notion of the depths that were sampled. So
17 you're looking at, in terms of our identified
18 aquifers and confining units, you're looking
19 at that sampling that was actually all the way
20 down to the middle Castle Hayne aquifer here.

21 **DR. BAIR:** Yes, I had a couple questions
22 about that if you don't mind.

23 **MR. FAYE:** No, I don't mind at all.

24 **DR. BAIR:** Is the geology along A Prime
25 consistent enough to draw some of the

1 formation tops and bottoms and label that?

2 **MR. FAYE:** Oh, yeah, we actually have for
3 each one of the units that's listed in, what,
4 Table 14?

5 **DR. BAIR:** Yeah, that ^ [report -ed.] is
6 really hard for me to digest.

7 **MR. FAYE:** Yeah, the data report?

8 **DR. BAIR:** It really helped me because I'm
9 just getting used to this. If you would add
10 some of the geology on.

11 **MR. FAYE:** Well, I apologize. We actually
12 have contour maps of the top and the thickness
13 of every one of those units that ^ [are in -
14 ed.] the model.

15 **DR. BAIR:** And then the question I had is
16 probably going to come up on this one, and I'm
17 going to anticipate your next slide and your
18 next slide. That is you have a lot of hits of
19 PCE/TCE very deep.

20 **MR. FAYE:** Well, let's look at that for a
21 second.

22 **DR. BAIR:** And does that go back to --

23 **MR. FAYE:** Those are the samples where we
24 actually had a hit above detection limits.
25 That's TCE at the same sites that are here,

1 okay? And these are the places where we
2 actually had a hit above detection limits.
3 These are the samples.

4 See, you can see there's actually a
5 fairly decent reduction from the total number
6 of samples to the samples where we actually
7 have a defined concentration. But the
8 distribution with depth is pretty much the
9 same, but these are the hit sites.

10 **DR. BAIR:** Can you go back one? I'm even
11 more confused now. So the yellow-colored
12 pluses and dots within the circles, those are
13 --

14 **MR. FAYE:** The yellow crosses.

15 **DR. BAIR:** -- below your detection limit.

16 **MR. FAYE:** Those are below detection limits,
17 right.

18 **DR. HILL:** Could we draw a distinction
19 between reporting limit and detection limit?
20 Because you've got a measurement at those
21 pluses, it's just below, I mean, detection
22 limit sort of implies that you couldn't even
23 measure it. You have a value there.

24 **MR. FAYE:** No, that's not what it implies at
25 all. That's the way it's reported. If you

1 look on the tables again in -- god, I've got
2 to repeat this a lot -- if you look on the
3 tables again in the Soil and Contaminant
4 report that's in your three-ring binder that I
5 wrote, you will see that the analyses will say
6 something like, there'll be like less than 0.5
7 whatever it is. Well, that 0.5 indicates the
8 reported detection limit for that particular
9 sample, for that particular analysis, and it
10 means less than.

11 **DR. DOUGHERTY:** No, no, there's great
12 variety from laboratory to laboratory on
13 whether that means a method detection limit, a
14 sample quantitation limit, which is a sample-
15 adjusted method detection limit for media and
16 interferences, or whether it's a reporting
17 limit, which is a laboratory^ arrangement
18 between a client and laboratory, where do I
19 report. And the point is not to say that we
20 know which of those it is.

21 **MR. FAYE:** Well, I do know which of those it
22 is. I've looked at dozens of these reports,
23 and I'm telling you that that is defined as a
24 detection limit. Now, there is also a few
25 quantitation limits. Now if the person who

1 wrote the report didn't understand the
2 distinction that you just made, then I can't
3 address it. But those are reported as
4 detection limits.

5 **DR. DOUGHERTY:** Are these laboratory reports
6 or engineering reports?

7 **MR. FAYE:** They're what I would call site
8 assessment reports written by consultants and
9 they include the laboratory, they actually
10 include, most of the reports actually include
11 the raw data output from the laboratory. And
12 that has a whole bunch of abbreviations that
13 qualify the various concentrations and they
14 say detection limit, and that's what I say
15 here.

16 **DR. BAIR:** Bob, if you don't mind, I'd like
17 to pursue this a little bit. If you were to
18 add the geology on there, one of my questions
19 in getting to, say, some of the yellow pluses
20 and other things is, does that sample
21 represent a 50-foot screen, a 20-foot screen,
22 a ten-foot screen? Does the screen go across
23 multiple aquifers?

24 And, if so, this could be telling you
25 which are poor calibration targets for your

1 model and which are strong calibration targets
2 because you don't want the sample from a
3 commingled well. You want to limit it to the
4 shortest screens that correspond to your
5 layering in your model.

6 **MR. FAYE:** That's right.

7 **DR. BAIR:** And then that gets back to Dave's
8 question about the construction of the wells
9 and whether there was grout in there or
10 whether the ~~titees~~ [detects -ed.] or whatever
11 small notations are, deep, whether that's just
12 coming down the well bore. And I think that's
13 critical to your setting up calibration
14 targets.

15 **MR. FAYE:** Well, almost all of these wells
16 that you see here that are represented, are
17 monitor wells. I would say that the vast
18 majority of them have a screen interval of
19 between ten and 20 feet. That doesn't worry
20 me a whole lot in terms of identifying a
21 particular contributing unit except, it
22 doesn't worry me too much for PCE because of
23 the -- and the sampling procedures are
24 generally well described, particularly after
25 about 1990. So we know that they evacuated

1 five casing volumes et cetera, et cetera, et
2 cetera.

3 What it does bother me though is with
4 the BTEX analyses because these are monitoring
5 wells. The BTEX that's there is sitting in a,
6 probably in that most upper cylinder, actually
7 has ~~three-phase~~ [free phase -ed.] in a lot of
8 cases in that upper cylinder. So rather than
9 sampling a four- or five-foot interval,
10 they're sampling the whole ten-foot or 15-foot
11 interval. So, yeah, you have to qualify that
12 somehow. I'm not sure.

13 Later on about 1998, 2000, they
14 actually started to recognize that problem
15 with BTEX, and they shortened up their screen
16 intervals to about five feet. So those
17 analyses are a little more reliable in terms
18 of what was actually there.

19 **DR. DOUGHERTY:** Quick question on that. Do
20 you know if their protocol was if they found
21 ~~three-phase~~ [free phase -ed.] in the
22 monitoring well, they did not sample?

23 **MR. FAYE:** No, no, what they did if they
24 found ~~three-phase~~ [free phase -ed.], they
25 adjusted their water level measurement and --

1 you know, I don't know. I know there's a --

2 **DR. DOUGHERTY:** 'Cause it may be censoring
3 some of your data.

4 **MR. FAYE:** I think...

5 **DR. DOUGHERTY:** And at a number of sites
6 where if they find ~~three-phase~~ [free phase -
7 ed.], they're not going to sample part five.

8 **MR. FAYE:** You know, just looking at it,
9 they had a lot of sensitivity with respect to
10 the water level measurement, but I believe
11 you're right. I don't recall a lot of
12 analyses at the sites where they actually
13 found significant ~~three-phase~~ free phase -
14 ed.]. I think you're right. Yeah, that was
15 part of their protocol.

16 **MR. HARDING:** So high concentrations are
17 going to be underrepresented in some sense?

18 **MR. FAYE:** Yes, right. But the saving grace
19 at those sites is we do know the thickness of
20 the ~~three-phase~~ [free phase -ed.] so we're in
21 shape there.

22 **DR. BAIR:** Bob, before you move on, there's
23 a high correlation between where you looked
24 and where you found TCE, which isn't too
25 surprising, but if we look at those deep

1 occurrences there, and if you just go look at
2 the section, it does go fairly close to two of
3 the water supply wells there. There are ^ --

4 **MR. FAYE:** Oh, more than two.

5 **DR. BAIR:** Okay, and so the question is,
6 maybe you can answer this, but I've thought we
7 were talking about the monitoring wells. But
8 the question is does the proximity to one of
9 the supply wells lead to a --

10 **MR. FAYE:** Oh yeah. I think I addressed
11 that in the report as well. And in particular
12 with respect to the BTEX, which my
13 understanding of the situation is if the BTEX
14 is left to its own devices, it's just happy
15 just floating up on the water table.

16 And when you find it 150, 200 feet in
17 the subsurface near a relatively, in relative
18 close proximity to a pumping well, why, you've
19 got the vertical gradient -- now the vertical
20 gradient's caused by that pumping. You've got
21 advection, and that's what's forcing the BTEX
22 way down into the subsurface.

23 And I do -- of course, the PCE being a
24 D-NAPL [DNAPL -ed.], it wants to migrate
25 vertically downward. But when you look at

1 these depths, particularly in the landfill
2 area, I think you're looking at a lot of
3 influence from HP-651, which we talked about
4 earlier.

5 **DR. BAIR:** And I was actually, I probably
6 inferred it too much. If the supply wells are
7 as Dave indicated, that you can get water
8 moving along the outside of the annular space,
9 and this supply well is off and 651 over there
10 is on, you could be pulling contamination from
11 shallow to deep through the annular borehole
12 in one supply well going to another just
13 because it can communicate hydraulically
14 across that.

15 **MR. FAYE:** I think that happens and also as
16 well -- no pun intended -- you get like 651 is
17 right in here. I think, what is this, 653,
18 610. Six-ten is down here. You have these
19 wells. They may not be pumping in a, at the
20 same time, but they're moving that mass around
21 at depth between each other all the time every
22 time they're operating.

23 This goes back to, I think, what Peter
24 was talking about in terms of how these
25 operations affect the simulated concentrations

1 that we would actually find, the actual
2 operation 12, 16 hours a day versus some
3 stress for a whole month, that type of thing.
4 And we can test that.

5 **DR. DOUGHERTY:** Just a quick thing on this
6 section since I can't put together the nearby
7 supply wells with this cross-section.

8 **MR. FAYE:** Well, I can tell you there's a
9 lot of supply wells here that surround the
10 perimeter of the HPIA, and I'm saying at least
11 a half a dozen or more that were active over
12 time. And in the landfill area the most
13 direct influence would have been HB-651, but
14 there's probably three or four other wells in
15 that general area or even immediate area that
16 perhaps affected the vertical distribution.

17 **DR. DOUGHERTY:** Was this a cross-section
18 showing all of those projected?

19 **MR. FAYE:** All of those what?

20 **DR. DOUGHERTY:** So all of the landfill area
21 wells are projected onto this thing?

22 **MR. FAYE:** Yes, they are. You can see, you
23 know, it's a gross, it's an informational
24 slide.

25 **DR. DOUGHERTY:** That's fair once I

1 understand it. And again, just for
2 information, what is the screen of these water
3 supply wells?

4 **MR. FAYE:** HB-651 would have been and
5 screened in at least two intervals below land
6 surface.

7 **DR. BAIR:** I've got it right here.

8 **MR. FAYE:** Okay, there you go. I just hated
9 to say you could look on table so-and-so.

10 **DR. BAIR:** No, I've got it. It's minus 93
11 to minus 103; minus 108 to minus 155 and minus
12 157 to minus 19 --

13 **MR. FAYE:** And those are intervals from land
14 surface.

15 **DR. DOUGHERTY:** I have a different number
16 from Table C-3 for 651. It's 125, 135, 140,
17 155 ^[, 189, 194 -ed].

18 **MR. FAYE:** In the table it's depth below
19 land surface.

20 **DR. BAIR:** My only point was to demonstrate
21 for others who are not so ground-watery (sic),
22 roughly where the screens are in this cross-
23 section tend to be 150 feet down so they're
24 down below where we're seeing the hot spots,
25 yet those are providing high concentration

1 water to the treatment plants. So there's got
2 to be some way to get from those hot spots
3 down to there to the wellhead.

4 **MR. FAYE:** That's just the vertical
5 gradient's caused by -- in my opinion, that's
6 largely due to the vertical gradients caused
7 by pumping at the supply wells and within the
8 radius of influence of that pumping.

9 **DR. HILL:** You have five measurements at
10 depth and of those two are hits. And if you
11 think proportionately to what's above in terms
12 of the proportion of hits you have two non-
13 detects, it's actually pretty similar or
14 perhaps a greater proportional concentration
15 at depth. So the fact that you're not getting
16 that many hits might just be because you
17 didn't look. There's no indication in that
18 data that the water in general at that stratum
19 is any less polluted than what's above.

20 **MR. FAYE:** Well, that's exactly right.
21 There's a lot fewer sampling points down here
22 than there is up here, maybe by as much as a
23 ratio of five to ten to one.

24 **DR. HILL:** Right, the ratio of hits is
25 actually as high.

1 **MR. FAYE:** Well, yeah, okay, okay. And the
2 obvious reason is they were looking for
3 contamination at shallow depths, later on got
4 kind of surprised they found it at a deeper
5 depth, but they had a much greater density of
6 shallow monitoring wells versus their deep
7 monitoring wells.

8 **DR. HILL:** I just wanted to make the point
9 that there's no indication on this data that
10 it isn't as polluted at depth as it is --

11 **MR. FAYE:** That's exactly right. I would
12 totally agree with that.

13 **DR. ROSS:** Were there no deep hits below
14 the, what I call the DNAPL site, Site 88, or
15 is the key just covering up what might be
16 there?

17 **MR. FAYE:** I think, Dr. Ross, the key there
18 is that there just were no deeper wells.

19 **DR. CLARK:** Can we wrap it up?

20 **MR. FAYE:** A few more to go, and that's why
21 we're here, right? There's the PCE now.
22 Those are the hits. Now, as Dr. Bair alluded,
23 he anticipated what we were going to see here.
24 You have the PCE contamination. This is every
25 sample including the non-detects, and then

1 here's the detects, and it shows the maximum
2 and minimum concentrations that we found. And
3 all of these questions that related to the
4 previous two slides relate to this. Here's
5 benzene.

6 There's the whole enchilada, and
7 there's our hits again at depth. And here
8 you're seeing that the HPIA where there was a
9 massive benzene spill, a lot of surface
10 contamination. Actually, now from the LUST
11 reports we know that this contamination
12 actually goes a little deeper down, around 150
13 feet. So there you see that.

14 There's our major plume systems that
15 we've identified. Now this will change when
16 and if we get into the LUST reports there's
17 going to be a major plume of BTEX up here,
18 probably another one right in here, definitely
19 a big mess in here in the HPIA. So that will,
20 we'll accrue a few more plumes when we look at
21 the LUST data in detail.

22 Hopefully, this next slide says
23 questions.

24 **DR. CLARK:** Jason, are you ready to go?

25 (no audible response)

1 DR. CLARK: Okay, Jason's up next.

2 DATA ANALYSES -- GROUNDWATER

3 WELL CAPACITY AND USE HISTORY

4 MR. SAUTNER: I'm just going to give a brief
5 description of how we constructed the well
6 capacity histories and I want to thank Bob
7 ahead of time because I think a lot of the
8 questions the panel will have ^ asked them in
9 the ^. Louder? Okay.

10 Basically, just the well capacity
11 history is essentially a timeline without
12 lulls operated at the capacities from when
13 they were put in service to the time when they
14 were terminated or permanently taken out of
15 service. Information we have for well
16 capacity histories, we had over 100 supply
17 wells that we were dealing with at the Hadnot
18 Point-Holcomb Boulevard large distribution
19 system areas.

20 Basically, we obtained a well packet
21 of information for each supply well that
22 contained driller logs, well capacity tests,
23 well construction drawings, operation records,
24 various other miscellaneous sources of
25 information. We also had several other
documentation sources examined.

1 We had well data lists, raw water
2 supply lists, building dimension lists,
3 operational records, water level tables,
4 transmittal and correspondence letters,
5 numerous CLW documents and various published
6 reports. And on top of that we also obtained
7 the daily logs for well pumps, which
8 everyone's been discussing, as the 1998
9 through 2008 daily status of how wells were
10 operated on or off.

11 This is just a figure of where the
12 well locations are throughout both systems,
13 throughout both areas. Now, here's an example
14 of well capacity history. This is for HP-633.
15 This is constructed for each of 100 or more
16 than 100 wells basically just gives a date,
17 capacity and operational status and a data
18 source.

19 So for the date that we have, the date
20 when it was put in service. We have the
21 capacity at certain dates throughout when it
22 was in service; the operational status and
23 whether it was in service, out of service or
24 when service was terminated, and then the data
25 source of where that information came from.

1 And you can see where all these blanks
2 are in capacities; we just simply didn't have
3 a capacity given for that source of
4 information. So that would be carried down in
5 time, so that'll be carried down to the
6 following empty block. This one here will be
7 carried down to the bottom, too, and so forth.

8 The daily log for well pumps, simply
9 just a scanned sheet for each month, for each
10 well from 1998 through 2008. So it's a lot of
11 information. There's I believe over 10,000
12 sheets. And the main two columns we're
13 interested in are when the pump was on and
14 when the pump was off. And as you can see
15 for, this was just for January 1999 for HP-
16 633, it was only on for the first seven days,
17 and it was off the rest of the month.

18 And what we did was we used the ^
19 determine well capacity on monthly adjusted
20 capacities. So from using these where we
21 obtained the number of days it was operating
22 each month along with the well capacity at
23 certain times from the well capacity history,
24 we created these tables.

25 This is just for all of 1999 so let's

1 focus on the first column or first row here
2 first. This is January of '99. We know from
3 seven days right here, add up the total number
4 of days. We have a capacity of 205, which
5 came from down here, the well capacity
6 history.

7 From that we computed the gallons
8 pumped per month. We know the total number of
9 days in the month, from that we can get the
10 adjusted capacity. So assuming that this well
11 was pumped 31 days a month, instead of pumping
12 at 205 gallons per minute, it would be pumping
13 at 46.3 gallons per minute. And this could be
14 computed for each well from 1998 all the way
15 through 2008.

16 This is just an example of the number
17 of days it was operated. The reason the time
18 period is from '98 through 2000 is because the
19 well was taken out of service or service was
20 terminated in October of 2000. For several of
21 the other wells we will have a full ten years
22 of data on the number days that it was
23 operated.

24 One thing that we're considering
25 exploring doing is actually -- and this was

1 discussed during Bob's presentation -- is
2 actually taking our known number of days for a
3 certain period of time and trying to sort
4 historical trend back in time for a study
5 period from '68 through '85.

6 There's different ways we're going to
7 look into doing this, and we'll be using this
8 trend, also using, we know our total average,
9 our total annual rates from '68 through '78,
10 '68 through '85 as well. This is a slide that
11 Bob also showed showing you the available
12 pumpage data. So basically, by using this '98
13 through 2008 daily data, we're going to try to
14 back track and try and fill in the gaps
15 between all these type of data time frames,
16 taking '84 all the way back through '68.

17 And just to summarize it we had more
18 than 100 supply wells. There's a lot of
19 information to review in order to create a
20 well capacity history for each supply well.
21 And information for the past ten-to-15 years
22 is more detailed than information for 50-to-60
23 years ago, obviously. And again, we're going
24 to explore ways to find historical trends of
25 how that well was pumping on a monthly basis

1 using the detailed daily information as well
2 as the annual information that we have.

3 With that I will give up to questions.

4 **DR. GRAYMAN:** Can you go back to slide
5 number three? That variation in capacity, do
6 you think this represents some changes in the,
7 intrinsically in the wells or do you think
8 there's some of that significant uncertainty
9 between the tests?

10 **MR. SAUTNER:** I guess it would be really
11 depending on, well, most of this information
12 came from well capacity tests. They were
13 fairly consistent in the way they conducted
14 them. I'm not really sure as to what
15 variation, what would be the cause of the
16 variation.

17 **DR. GRAYMAN:** Without looking at the dates I
18 mean you see a change from 221 down to 159,
19 but that's an eight year period so that makes
20 some sense.

21 **MR. SAUTNER:** Nineteen sixty-nine to '77.

22 **DR. GRAYMAN:** Can you go to the next slide?
23 And there's a column over near the right where
24 it says time checked. Do you know anything
25 about the operation where they operated, they

1 tend to be operated on a daily basis or was
2 there a particular time when they checked it
3 to see whether it was on or off?

4 **MR. SAUTNER:** I believe they -- this slide
5 came from Camp Lejeune here -- I think they
6 had a certain time of the day where they would
7 send a [well -ed.]person out, and they would
8 check the wells and report back. I'm not --

9 **DR. GRAYMAN:** When you say check, would they
10 turn them on or off? I mean, did the wells
11 tend to stay on for 24 hours?

12 **MR. SAUTNER:** I don't believe -- oh, yeah,
13 that's, we did ask that question. If the pump
14 was on, it was on one day. And if it was on
15 the next day, it was on the complete time. So
16 for day one to day two it was on for that
17 whole 24 hours, yes.

18 **MR. HARDING:** I think this may, it raises
19 this point. I know I've flogged this horse a
20 lot, but there's a difference here between
21 what you're going to do for the groundwater
22 modeling and what you'll have to do for the
23 water distribution modeling. Because while
24 your stress period's a month in the
25 groundwater model, the way that contaminants

1 behave in the water distribution system during
2 these interconnection events is going to be
3 very dramatically affected by what pumps you
4 assume are operating and the hourly, you know,
5 flow rates.

6 In other words a pump can't run at an
7 average of whatever it was. I can't remember
8 the numbers but the average amount. It either
9 runs on or it runs off. And if the
10 contaminated well is on, it's on all the way,
11 and then the contaminants can move out into
12 the system during times of low demand or
13 perversely in this situation, when the high
14 demand comes on the golf course, that's when
15 that interconnection opens up and that tends
16 to have it move further in the system. So you
17 can't use the same approach, I just want to
18 caution, for both water distribution and
19 groundwater modeling.

20 **MR. SAUTNER:** Right, and just to clarify,
21 all of these supply wells pump directly to the
22 water treatment plant. So we are going to be
23 --

24 **DR. GRAYMAN:** They all pump directly to the
25 treatment plant.

1 **MR. SAUTNER:** They don't pump into the
2 system.

3 **DR. POMMERENK:** I think the wells that pump
4 into a manifold collection system, there's a
5 difference. They don't all pump against the
6 same head. So depending on what combination
7 of wells is on, the actual flow rate that is
8 delivered by the well pump may vary as well.
9 So it's just some added complication. I think
10 one of the earlier figures you clearly saw
11 that the wells had essentially streamed on a
12 large water collection main. And depending on
13 the size of the thing, I guess somebody would
14 do a hydraulic calculation to see how well
15 operation would affect the head ~~at each pump~~
16 ~~as it pumped~~ that each pump pumped -ed.]
17 against, so just as an additional caution.

18 **MR. HARDING:** So another clarification, is
19 there a booster pump, is there a storage tank
20 and then a booster pump at the water treatment
21 plant that then sets the grade line for the
22 water distribution system?

23 **MR. SAUTNER:** Yes.

24 **MR. HARDING:** So there, and there's an
25 unpressurized storage tank then at the water

1 treatment plant and -- okay.

2 DR. KONIKOW: So if you go back to the
3 previous slide, again, I agree. There are
4 many sources that there are uncertainty in
5 this, but what I want to look at here is
6 filling in the gaps. Between your data points
7 you had implicated that like from '69 we have
8 221 to 1977 we have 159. You would use a 221
9 the whole time.

10 MR. SAUTNER: Yeah, or one way to do it
11 would be maybe to do a trend and step it down.

12 DR. KONIKOW: Which did you do? What are
13 you doing or what should be done?

14 MR. SAUTNER: This is the information going
15 to the generator and it hasn't been used as
16 input.

17 DR. KONIKOW: So that's not in the
18 groundwater.

19 MR. SAUTNER: Correct.

20 DR. CLARK: We have a swift comment from the
21 audience.

22 MR. WILLIAMS: Yeah, I just wanted to
23 clarify that the 24-hour pumping, which would
24 only be indicative of the Hadnot Point wells,
25 not at Holcomb Boulevard.

1 DR. CLARK: We're going to have to move on
2 to the next presentation.

3 DR. GRAYMAN: Can he just clarify? Well,
4 the Holcomb wells, how were they operated?

5 MR. WILLIAMS: Something less than 24 hours.

6 MR. SAUTNER: I think they were automatic,
7 correct?

8 MR. HARDING: Did the Holcomb wells pump,
9 did they pressurize the system or was it a
10 similar situation where they pumped into an
11 unpressurized storage tank and then were
12 boosted into the --

13 MR. SAUTNER: It's the same situation.

DATA ANALYSES -- GROUNDWATER

14 MASS COMPUTATIONS

15 DR. CLARK: Okay, Mass Computation.

16 MS. ANDERSON: I'm going to talk at you
17 about the subsurface mass computation and make
18 it very brief hopefully. This is a quick
19 overview. I'm going to recap the site
20 locations. I'm going to highlight some
21 groundwater contaminant statistics and outline
22 the purpose, scope and proposed methods for a
23 mass computation and then finish with an
24 illustration of a mass computation for TCE.

25 So you've seen this map a couple of

1 times already. I just wanted to recap again
2 the IRP sites, the Installation Restoration
3 Program sites are outlined in the dark red.
4 The orange outline shows scenarios that we
5 talk about a lot, Site 88, the landfill area
6 and the Hadnot Point Industrial Area or the
7 HPIA. That's where we're finding a lot of
8 contamination, particularly the PCE and TCE
9 contamination.

10 So I wanted to emphasize some relevant
11 numbers for the groundwater contaminant
12 datasets. Our available contaminant data span
13 about 20 years from 1984 to 2004. We have
14 over 2,400 groundwater sample analyses for
15 PCE, TCE and their degradation products. We
16 have over 2,600 groundwater sample analyses
17 for benzene and related compounds.

18 And I've listed some maximum detected
19 concentrations in groundwater there in
20 micrograms per liter. Of course, the PCE
21 level at 170,000 micrograms per liter, that's
22 at or above the solubility limit depending on
23 what reference you use. That detection was at
24 Site 88 where we know there was some pre-phase
25 product in the past.

1 So our primary purpose for contaminant
2 mass computation is to provide really a
3 starting point and a lower limit for a mass
4 loading parameter when you do the fate
5 transport modeling. The mass estimates will
6 also be helpful in assessing plume stability
7 over time, and we can look at those numbers to
8 compare to other similar sites as well, but
9 our primary purpose is for the mass loading
10 parameter for the fate transport model.

11 For this work we're going to focus on
12 PCE, TCE and benzene for mass computations.
13 We're going to primarily compute the dissolved
14 phase contaminant mass. We do have some data
15 for some areas for the unsaturated zone and
16 free product areas that we may address with
17 some computation but primarily the dissolve
18 phase contaminants. And we will be looking at
19 multiple areas across the study site.

20 So this slide kind of outlines our
21 general methodology, proposed methodology
22 starting from the left there to select and
23 prepare the contaminant datasets from the
24 point data that we have. We're going to
25 develop two-dimensional horizontal

1 concentration grids that represent the
2 horizontal distribution of contaminants using
3 interpolation techniques to generate those.

4 And then we'll calculate the average
5 contaminant concentration across these
6 horizontal plumes. And finally, we'll
7 calculate contaminant mass by combining that
8 average contaminant concentration in a
9 horizontal distribution with information we
10 have about the aquifer porosity and the
11 vertical extent of the aquifer where these
12 contaminants occur. That's kind of a general
13 depiction of our methodology.

14 **DR. KONIKOW:** So is the goal to estimate the
15 mass in the system at one point in time or as
16 an initial condition? Because contaminants
17 are released over some long period of time.
18 And so I'm wondering how does this relate to
19 what you're going to put into the model?

20 **MS. ANDERSON:** Sure. I think that's part of
21 the data exploration that we have to do.
22 Obviously, there's a sort of a temporal
23 distribution to the data that we have to look
24 at and kind of slice it in different ways and
25 look at what makes sense, and then look at

1 those calculations and decide what makes sense
2 to put into the model. So it's kind of a
3 number of steps there that will be involved in
4 the whole mass computation and then entering
5 into the model. Maybe the next slide or two
6 will explain that better.

7 **DR. BAIR:** I have a question, too. You're
8 looking at aquifer thickness and the
9 concentration in each one of the aquifers and
10 then summing them for a grid block looking
11 down?

12 **MS. ANDERSON:** There may be some other
13 slides that explain that a little better, but
14 yes, this process, I mean, essentially when we
15 had the contaminant data -- and you saw in
16 some of Bob's slides the vertical distribution
17 -- obviously, when we derive horizontal
18 representation of the distribution, we've got
19 to look at a single aquifer and just only
20 collect the data points for that aquifer, do
21 an estimation, extend 3-D the calculation over
22 that aquifer, and that would be a mass for
23 that aquifer. Another aquifer would be a
24 whole 'nother of that process repeated and
25 then add --

1 **DR. BAIR:** Right, well, my question is that
2 are you doing this just for the aquifers?
3 Because the confining layers have mass in
4 them, too.

5 **MS. ANDERSON:** I think, yes, that's a valid
6 point, and we can look at --

7 **DR. BAIR:** And they are as thick as the
8 aquifers in some places, and their porosity
9 probably is not too different. So my question
10 actually gets at porosity. Are you using a
11 uniform porosity across everything?

12 **MS. ANDERSON:** Right now, the illustration I
13 have here, I'm just talking about the porosity
14 for one aquifer that we're looking at. But I
15 think we do need to refine that and kind of
16 look at different aquifers, different
17 porosities if we have the data. Clay units,
18 we have some data based on Site 88
19 investigations for porosity there.

20 So I think that's a valid question,
21 and that's something -- it's really going to
22 be data driven. Where we have the data and
23 then what can we extrapolate from there and
24 how can we extend that knowledge.

25 **DR. BAIR:** It also should be put into the

1 sensitivity analysis, and that's the
2 sensitivity of the source term and the release
3 of the source term, the concentration and
4 timing of the release of the source term.

5 **MS. ANDERSON:** Yeah, and I think as we
6 explore the data and kind of do some of those
7 vertical plots that Bob has shown in his
8 presentation, we can get a better sense of
9 where we have to go with the other steps, the
10 other sensitivity analysis.

11 **DR. BAIR:** But that's my point is the plots
12 that Bob showed are all biased towards the
13 permeable intervals where they've done
14 monitoring wells, and the contaminants exist
15 in between sampled intervals, otherwise they
16 wouldn't get down to the deeper parts.

17 **MS. ANDERSON:** Actually, I do have one slide
18 where we can maybe explore that a little bit
19 more and kind of talk about what you're
20 getting at I think, but we're welcoming the
21 input and how we should approach that.

22 **DR. HILL:** In step two considering the
23 thickness you're using as the whole aquifer
24 thickness that you're not making slices
25 through it, it seems odd to me in step two not

1 to do a 3-D interpolation of the data. I
2 mean, there'd be no reason not to at that
3 point, and then integrate, I mean.

4 **MS. ANDERSON:** Again, it's kind of data
5 driven. There's a slide --

6 **DR. DOUGHERTY:** It's Surfer driven.

7 **MS. ANDERSON:** Surfer driven? We actually
8 did look at some 3-D interpolation with GMS,
9 and I think -- I haven't explored it yet --
10 but ^ with Surfer does some 3-D interpolation.
11 And I think that it will be good to kind of
12 run this method and then do some other
13 comparisons with other tools to look at those
14 types of interpolations.

15 **DR. HILL:** So when you do step two,
16 obviously when we saw before, we had high
17 concentrations and then low concentrations.
18 What do you use as your point value in 2-D
19 space given that you've had all this variation
20 vertically?

21 **MS. ANDERSON:** Give me a slide or two.

22 **DR. HILL:** Sorry.

23 **MS. ANDERSON:** As Bob said, Mary, hang
24 with me for a second. We'll get there.

25 So I just wanted to present a few

1 details about the data preparation and
2 interpolation, which obviously we're talking
3 about. We need to select the datasets and
4 sort of group them based on some
5 considerations. The horizontal distribution,
6 and that's kind of picking areas across the
7 study site that will isolate and do
8 calculations.

9 The vertical distribution, which we
10 discuss a lot. The sample altitudes and what
11 we're going to consider as datasets for doing
12 those horizontal distributions. And then the
13 temporal distribution we need to isolate sort
14 of or aggregate some datasets based on the
15 temporal characteristics of the data.

16 When we do the interpolations, we'll
17 have to look at multiple detections at the
18 same location and kind of generate a single
19 value. I think it makes sense, typically
20 we'll be using the average value, but there
21 may be some occasions where maximum values are
22 appropriate for that.

23 The non-detects and the censored non-
24 detects for the calculations I'm showing you
25 here, I set those to zero. Now, we can

1 consider different schemes for that if
2 necessary, but by censored non-detects I mean
3 the data that are less than whatever stated
4 reported value, less than five, less than ten.

5 Non-detects, literally there are
6 reported values that are just ND, and we have
7 no reporting or quantitation limits to go off
8 of on that data. So that's what I'm talking
9 about, those non-detects and censored non-
10 detects.

11 **DR. DOUGHERTY:** Just for those if you have a
12 non-detect and a nearby close detect, do you
13 somehow take into account that the non-detect
14 may not be representative? I'm thinking about
15 from the regulator side, of course, and from
16 the other side you want to say well the other
17 one's an outlier and it's a laboratory
18 problem.

19 **MS. ANDERSON:** I think we're not to that
20 point yet, but that's certainly a refinement
21 that could be made. Initially, we're dealing
22 with a very large dataset even when we isolate
23 it to one location or area of the base. So
24 that's certainly something we can consider and
25 kind of refine that non-detects and censored

1 non-detects to assign some values or discard
2 data that we don't feel are appropriate.

3 **DR. POMMERENK:** Actually, with setting them
4 to zero you would, you know, whatever your
5 statistic is that you would use to represent
6 the total mass and then you would
7 underestimate the, that statistic was set down
8 to zero so you may want to consider using some
9 type of robust regression to -- you don't
10 actually assign values to the non-detects, but
11 you compute your statistic on distribution of
12 values based on that there are values. We
13 just don't know the numbers. And --

14 **MS. ANDERSON:** We have the ~~HASL~~* [Helsel -
15 ed.] text, and I think that that is something
16 --

17 **DR. POMMERENK:** Yes, the ~~HASL~~ [Helsel -ed.]
18 text will help you --

19 **MS. ANDERSON:** -- yeah, that we can consider
20 after we do some baseline using this
21 methodology. I think it would be good to sort
22 of try to incorporate the non-detects in non-
23 parametric methods and sort of try to do some
24 analyses that way.

25 For the interpolation schemes kind of

1 looking at, we've explored some different
2 options for that as well, but I think we'll
3 probably just use the ordinary pre-game using
4 standard default assumptions in Surfer
5 Software. We did explore a little bit the
6 autofit ^ [semivariogram -ed.] ~~gram~~, compared
7 that to standard default assumptions in
8 Surfer, and they seem to come out very similar
9 for the mass computations, but that's
10 something we can continue testing as we move
11 forward. For the calculations that I'm
12 showing here -- in our initial runs through
13 this we're using ten foot-by-ten foot grid
14 cell size.

15 So I kind of want to go through just a
16 quick illustration, and it is just a slice,
17 just a subset kind of illustrating the
18 approach of the mass computation method. This
19 is for TCE. This is the map that Bob showed
20 as well showing the distribution of TCE across
21 the study site. It's concentrated in a couple
22 of different areas there.

23 We're going to focus for this
24 illustration just on the landfill area. And
25 this is the temporal distribution of data that

1 we have for the landfill area. You can see in
2 the middle there, there's the extraction well
3 start up in October 1996. We have some data
4 before that, a good bit of data after that.

5 For this illustration again I'm going
6 to kind of look at this pre-extraction well
7 start up database 1984 to 1993 and do some
8 calculations with that. Certainly, we can run
9 calculations with the first few years after
10 extraction well set up or start up because
11 there's very low flow with those extraction
12 wells, and we may be able to use some of that
13 contaminant data in a more extensive
14 monitoring well network that was in place to
15 do some mass calculations there.

16 **DR. DOUGHERTY:** Just to clarify, this is a
17 remediation extraction well as opposed to a
18 water supply --

19 **MS. ANDERSON:** Correct.

20 **DR. DOUGHERTY:** -- extraction well.

21 **MS. ANDERSON:** Yes. That's one, the
22 remediation wells, the extraction wells were
23 put in place in October 1996, when they
24 started cleaning up the site.

25 So I'm going to focus on that earlier

1 data range there. And this is the vertical
2 distribution of TCE in the landfill area just
3 for that selected time frame that we're
4 looking at, 1984 to 1993, so it's a little
5 bit, it's like the slide Bob was showing, but
6 it's a little more refined just to include the
7 selected dataset.

8 I have included off to the left there
9 just some general kinds of boundaries for the
10 different aquifer systems: the Brewster
11 Boulevard, the Tarawa Terrace aquifer and
12 Castle Hayne aquifer system. And these are
13 very general. They're kind of averages of top
14 elevations and thicknesses across just the
15 landfill area. So I haven't extended it
16 across because there obviously are local
17 variations. We're still dealing with a pretty
18 large area so I just kind of added that
19 guideline on the left-hand side there.

20 So you can see with this vertical
21 distribution that we have data, contaminant
22 data, just for two different aquifer systems,
23 the Brewster Boulevard, the upper aquifer
24 system Brewster Boulevard and then the Castle
25 Hayne aquifer system.

1 There's really no data except for that
2 one non-detect off to the left there for the
3 Tarawa Terrace, intervening Tarawa Terrace
4 aquifer system. So it's a constraint of the
5 data for this time period. I think for later
6 time periods we do have some data for Tarawa
7 Terrace, that aquifer system.

8 But again, to illustrate mass
9 computation, I'm just going to pick this one
10 slice, this one horizontal slice of data in
11 the upper Castle Hayne aquifer, the River Bend
12 unit, and kind of run the calculation with
13 that because I think that's how we'll have to
14 proceed. Looking at grouping the data
15 vertically, doing separate calculations for
16 each and then kind of summing them, stacking
17 them up.

18 So this is again, as I outlined in the
19 general approach, we'll take that contaminant
20 dataset, the data points, and interpolate them
21 into a concentration grid, a two-dimensional
22 horizontal grid, and that's what is shown
23 there on the left, a traditional contour map,
24 planar view. On the right I'm showing a 3-D
25 wire mesh representation of the contaminant

1 concentrations with the Z axis being TCE
2 concentration in micrograms per liter.

3 So once we've established this
4 concentration grid, we can use Surfer's grid
5 volume utility to obtain both the planar area
6 of the plume and also the grid, quote, volume,
7 which I think this 3-D wire frame grid kind of
8 illustrates the volume that I'm talking about;
9 it's kind of these strange units of micrograms
10 per liter multiplied by base area of each
11 cell. It's essentially an area weighted
12 concentration for each cell grid summed up to
13 represent the volume of that concentration
14 grid.

15 **DR. HILL:** Can I just ask a question?

16 **MS. ANDERSON:** Sure.

17 **DR. HILL:** I don't know that you can do this
18 now, but it's really kind of critical where
19 the points are that you're contouring, and
20 they're not clear in that figure.

21 **MS. ANDERSON:** Yeah, the post points are not
22 big enough there, are they? But that's
23 something obviously we're, with our
24 interpolation techniques kind of running
25 interpolations and checking the post map to

1 try and make sure it's a good representation
2 of the data that we have.

3 DR. HILL: If those ^ aren't supported.
4 It's just ^.

5 DR. DOUGHERTY: Clearly, they're supported
6 by over-fitting, I suggest.

7 DR. CLARK: Scott, go ahead.

8 DR. BAIR: Barbara, my question would be if
9 you look at the fishnet plot on the lower
10 right, that would be one, two, three, four
11 units that you're representing there?

12 MS. ANDERSON: Aquifer units?

13 DR. BAIR: No, just four horizontal units.
14 There's a horizontal line going down from the
15 peak and then there's a shoulder off to the
16 left, and then there's another -- those are
17 concentrations?

18 MS. ANDERSON: Yeah, that corresponds to the
19 legend over there on the left --

20 DR. BAIR: Okay, so how many aquifer units
21 are within that then? One?

22 MS. ANDERSON: Yeah.

23 DR. BAIR: Got you.

24 MS. ANDERSON: We're just taking that one
25 slice of the upper Castle Hayne River Bend

1 unit and looking at that.

2 DR. CLARK: Rao was next.

3 DR. GOVINDARAJU: I think I want to follow
4 up on that next question. That is, this is
5 going from 1984 to 1993, so this one unit you
6 are computing is somehow over time, and time
7 does not seem to factor in.

8 MS. ANDERSON: Right. I don't have a, we
9 aggregated or I aggregated this data before
10 the extraction well started up in 1996 because
11 really if I plotted -- I have another plot and
12 I didn't overlay it on here, but these
13 numbers, the bar graph showed the total
14 analyses we have, but the detections for each
15 of these are the lower number, obviously. So
16 if we want to just aggregate just 1984 to 1987
17 as one unit. There really aren't sufficient
18 detections there to do an accurate
19 interpolation. It would make more sense I
20 think to use smaller time frames. But in this
21 case there just weren't enough detections to
22 really do a good interpolation so it's
23 aggregated across that whole time frame. Is
24 that --

25 DR. CLARK: In order to meet our streaming

1 video guidelines we're going to have to wrap
2 this up. So let's take just one more question
3 and then, Barbara, can you wrap it up?

4 **MS. ANDERSON:** Sure. But maybe not, it's
5 Lenny's question so I don't know.

6 **DR. KONIKOW:** So then the question is how do
7 you go, you'll calculate a mass, but then how
8 do you go back in time and use that to
9 estimate what the mass loading rate is over
10 the duration of the model? The Tarawa Terrace
11 situation you had essentially a point source
12 with a known location and a fairly constant
13 over time disposal rate. Here I'm not sure
14 how you're going to reconstruct the history of
15 mass loading.

16 **MS. ANDERSON:** Yeah, I think that's going to
17 be a challenge. I will say -- and Bob can
18 chime in where he sees fit, but I think that
19 for the landfill area I think Bob has, from
20 his expert analysis of all the data that he's
21 looked at, has determined that at Site 88
22 there was a dry cleaner, same as ABC Cleaners
23 there was a base dry cleaner. And this
24 landfill contamination is probably tied to
25 disposal of filters from the, spent filters

1 from the dry cleaning operation at Site 88,
2 and there may be other sources. There may be
3 buried drums, what have you, at the landfill
4 area, but --

5 **MR. FAYE:** The issue, Lenny is basically,
6 you know, you take what you get. We want to
7 have a computation of mass prior to the onset
8 of extraction. Yeah, and the data are over a
9 particular period of time so, yeah, you had
10 some concentration reductions because of
11 degradation over that period of time, et
12 cetera, et cetera, et cetera.

13 But I won't say the time is relatively
14 immaterial here, but if we have this mass at
15 this time, it basically gives us a minimum
16 mass that we can work from. And what it is, I
17 mean, it's basically, you know, you've got a
18 flawed starting point or you've got no
19 starting point. So, I mean, that's really
20 what it comes down to. Of course, it's better
21 to have a flawed starting point in my opinion.

22 **DR. KONIKOW:** You've had extraction wells
23 over the whole duration of the system, but
24 they were called water supply wells.

25 **MR. FAYE:** There again, sure there was mass

1 removed from the system, but still we don't
2 know what that mass was or we have a couple of
3 concentrations that we could maybe make some
4 estimates, but you'd have so much uncertainty
5 you wouldn't assign a lot of reliability to
6 that. But here again, I mean, it's not a
7 perfect system. It's not a perfect analysis.
8 But it gives us a starting point which is what
9 we're after.

10 **DR. CLARK:** Let's give Barbara a chance to
11 wrap up her presentation.

12 **MS. ANDERSON:** Sure, really after this I'm
13 just illustrating how we can use, there's a
14 Surfer utility to obtain both planar area and
15 this grid volume and we can use that to easily
16 obtain the average TCE concentration across
17 this horizontal plume that was generated.
18 There's a Journal article, Joseph Ricker*
19 published in 2008 in "Groundwater Monitoring
20 and Remediation" that kind of illustrates this
21 if you want more information. But that's kind
22 of what we were following with this approach.
23 And then I just was showing the general
24 equation there at the top and the parameters
25 and values that I used for this illustration.

1 The first couple of values, the planar area,
2 the average TCE concentration. Obviously, as
3 I said, obtained from Surfer utility. Aquifer
4 thickness. Here we're just using an average
5 estimated thickness for the particular aquifer
6 that we're looking at. And aquifer porosity
7 we can look at effective or total porosity.
8 We have some, I think, good values for that,
9 20 percent that was used in the Tarawa Terrace
10 work and discussed extensively in one of the
11 chapters in the Tarawa Terrace reports. The
12 40 percent total porosity just for this upper
13 Castle Hayne River Bend unit, again, is from
14 some site-specific data from Site 88
15 investigations. And we can refine this
16 hopefully for each aquifer and each area that
17 we're doing these calculations.

18 **DR. KONIKOW:** What did you use -- a couple
19 more -- why did you use 22 feet for this
20 system here when your earlier slide shows a
21 box around it that looked like it was at least
22 35 feet thick where you encapsulated the data?
23 And then the second question is why not
24 account for the spatial variations, the
25 elevations at the tops and bottoms? Why don't

1 you use Surfer to get, why don't you consider
2 multiplying all those concentrations? And why
3 an average thickness? Why don't you use a
4 thickness at each grid point?

5 **MS. ANDERSON:** I think we can do that as a
6 refinement. We can import the extrapolation
7 we've done with the model and GMS and kind of
8 get actual cell-based aquifer thickness. And
9 the other about the average that we've used
10 here, I think -- and I noticed this in your
11 comments you were referring to the Tarawa
12 Terrace report which I think are a bit north
13 of our location.

14 **DR. KONIKOW:** Just go back a few slides for
15 this location. There, that looks like a
16 vertical interval of 30 to 35 feet that you
17 encapsulated the data yet you're using 22
18 feet. That's a pretty big percent difference.

19 **MS. ANDERSON:** That's the contaminant data.
20 When you look at the actual extrapolation of
21 any boring location or boring data that we
22 have, and you look at the encapsulating
23 aquifer system, we actually have a more
24 refined sort of estimate of the thickness
25 based on other data.

1 **DR. KONIKOW:** Are you saying that the data
2 points here are --

3 **MS. ANDERSON:** Right, right. I think some
4 of these data's a question of local variation.

5 **DR. CLARK:** Let's draw this to a conclusion
6 so we can meet our deadline. So we'll pick it
7 up at 1:30 this afternoon.

8 (Whereupon, a lunch break was taken between
9 12:37 p.m. and 1:30 p.m.)

10 **DR. CLARK:** Okay, we're ready to start up
11 again. Video streaming is going to be online
12 in a few seconds. Morris has got a few things
13 he wants to do, wants to introduce Dr. Aral.

14 **MR. MASLIA:** Thank you for that morning
15 session. This is the type of feedback we're
16 looking for. We had some very interesting and
17 informative and probing questions so we're
18 going to continue this afternoon. Just a
19 couple of housekeeping things before I
20 introduce Dr. Aral.

21 If people would like to go out to
22 dinner other than the hotel, there's a couple
23 of restaurants in the area. One's a little
24 bit more expensive, a nice French restaurant.
25 I can see if they have room. We can talk at

1 the next break and just see. Or if everybody
2 just wants to do their own plans and maybe get
3 together that's fine with me. Y'all may not
4 want to eat with me, dinner. Actually, my
5 wife would like to see me at home one day
6 during the past two weeks for dinner. But at
7 the next break maybe we can sort of formulate
8 plans.

STRATEGIES FOR RECONSTRUCTING CONCENTRATIONS:

PRESENTATIONS AND PANEL DISCUSSION

9
10 With that said, as we saw from this
11 morning, a lot of data, a lot of information
12 and how exactly to analyze it, how to make
13 sense of what it is and how should we put it
14 together so we can, if we want to, try to do a
15 numerical model like we did with Tarawa
16 Terrace. Questions you asked, Lenny, and
17 pointed out, there is not a single source so
18 where do we begin in that temporal
19 distribution?

20 So after we had completed Tarawa
21 Terrace and just looking at the surface of
22 this, I asked our cooperator at Georgia Tech
23 perhaps there might be a method either
24 available or maybe we could look into
25 developing one where we might be able to use

1 some of the data that's captured, the
2 contaminant data that's captured in either our
3 supply wells or observation wells.

4 And would there be from a screening
5 level a way to avoid or minimize having to
6 transfer the data that we have in reports and
7 analyses to then trying to categorize it for a
8 numerical model. Just some of the issues on
9 assigning supply well pumpages from the
10 scheduling that we've got versus actually
11 putting it into the model.

12 And so Georgia Tech and Dr. Aral have
13 come up with a screening-level method. It was
14 described in the notes, but Dr. Aral's going
15 to describe it in more detail, and again, it
16 is meant as a screening level, but it may be
17 something very useful for us to either proceed
18 with that initially or provide more
19 information from that standpoint. So I'm
20 going to turn it over to Dr. Aral, and let him
21 proceed.

22 **SCREENING-LEVEL METHOD**

23 **DR. ARAL:** Thank you, Morris, and welcome
24 back. When I heard this task from Morris, I
25 said this is a difficult task. This is not

1 easy to do. But then I'm sitting there and
2 listening all of the critique that you guys
3 are giving to the other approach, and I said
4 my task is very simple because none of those
5 critiques apply to what I am doing.

6 Our task is if we know what we know
7 today, can we predict what has happened in the
8 past? And then we are thinking about this at
9 Georgia Tech where I work, and we thought,
10 well, we do the opposite all the time as
11 engineers. If we know what we know today, can
12 we predict what is going to happen tomorrow?
13 So let's look at that approach, and let's see
14 whether we can get some insight and make some
15 use of that analysis in predicting what has
16 happened in the past.

17 So predicting the future and using the
18 information from the future events is based on
19 some control theory analysis. And I'm going
20 to give you three simple examples where we use
21 this approach and then try to extract some
22 insight from this analysis to use to answer
23 the question that we are trying to answer in
24 this case.

25 For example, everybody has a car.

1 Everybody has a cruise control. You are
2 driving down the highway, and you don't want
3 to worry about the gas pedal. You just want
4 to enjoy the scenery. What you do is you set
5 your cruise control to a given speed, and you
6 would like to watch the scenery after that.
7 You assume that something in your car is going
8 to adjust everything such that the system
9 output is going to be that speed.

10 That's a custom control mechanism that
11 is installed in your car. What it does it
12 looks at the speed of the car, senses it, and
13 then based on a computer program or a chip
14 installed in your car, controls the system
15 which happens to be in your case in the car,
16 an engine, adjusts the carburetor, adjusts the
17 system input which is the gas, so it maintains
18 the speed. This is the simplest application
19 of a control based analysis in our daily life.

20 Other applications are a little bit
21 more complex. For example, we do, as
22 engineers, reservoir management. We try to
23 maintain a certain volume of water to supply
24 the demand at all times by controlling the
25 spillway gates. It is based on the same

1 principle. In that case, of course, we have
2 to predict the future.

3 We have to predict that there will be
4 some drought season in the future or rainy
5 season in the future, et cetera, such that
6 based on that prediction we adjust the
7 spillway gates. We release or retain water to
8 keep the supply meet the demand. That's
9 another application.

10 Another application is in power
11 systems. We cannot store energy so we have to
12 generate power at the time of use. We have to
13 predict how many million people is going to
14 turn off the switch in their homes and predict
15 how many million are going to turn on and then
16 estimate the demand at that time and then
17 produce the energy required at that time.

18 All of those analysis is a time
19 series-based analysis, and it's a control
20 theory-based analysis. We have different ways
21 of looking at this. We have intelligent
22 control systems, optimal control systems, et
23 cetera, et cetera, et cetera. This field is
24 well established in engineering analysis.

25 Now what are the characteristics of

1 this system? In the examples that I have
2 given the system information is known. We
3 know how engine works. We know how to
4 calculate the volume of a reservoir, et
5 cetera.

6 What we don't know is how to maintain
7 the system output. System input is fixed.
8 It's today's information or yesterday's
9 information. So what the controller does
10 given this information on the system it
11 adjusts the system behavior a little bit so
12 that the output becomes what we want. So
13 this is the basic idea of control theory based
14 analysis.

15 Now, what we have here is the same
16 system but in a reversed order in the sense
17 that we know the system output. As you have
18 seen this morning, there are numerous
19 monitoring wells which are located at
20 different locations in the site, which has
21 been monitoring the site for the past 15
22 years. So the system output is known.

23 We don't know the aquifer properties;
24 that's what we heard again this morning. We
25 are trying to characterize the aquifer system.

1 Now, the question here is this yellow is the
2 same yellow here, the system input. What
3 should be the system input such that as it
4 passes through the aquifer gives us what we
5 have observed for the past 15 years. So this
6 is a control theory-based analysis similarly,
7 but the question is we are not going to
8 predict the system output, we are going to
9 predict the system input. That's the whole
10 idea, and that's the only difference.

11 And there's one other difference and
12 that's the following. We don't know the
13 aquifer properties as well. We don't know how
14 the system behaves. So this is a basic
15 introduction to the idea, but I will go into
16 details of the algorithm in a little bit more
17 detail later on.

18 We are still in Camp Lejeune. We are
19 looking at contamination sites at Hadnot Point
20 or landfill area or other regions of the
21 Holcomb Boulevard. And what we have done in
22 the past is one of those sites, which happens
23 to be the Tarawa Terrace area. The model that
24 is used in this area is well calibrated,
25 tested, applied, et cetera, and we have some

1 existing models that we can implement in this
2 study.

3 Now let's understand how the
4 traditional way of looking at this problem
5 goes. It goes as follows, and you have heard
6 this all morning. Collect the data, develop
7 groundwater flow and contaminant fate and
8 transport modeling. That will hopefully give
9 you some concentration profiles in certain
10 water supply wells in the aquifer, create a
11 mixing model, put it into water distribution
12 system eventually giving you the exposure
13 pattern at the site. So this is the
14 traditional way of looking at this problem:
15 data, to model, to mixing model, to water
16 distribution system analysis.

17 Now, the purpose of the current study
18 is a little bit different. All these steps
19 that we have discussed this morning, and I
20 have summarized here, takes a lot of time, a
21 lot of energy. There's a lot of uncertainty
22 as you have heard.

23 And the question we were asked to
24 answer is if we know the field data, and this
25 happens to be the Tarawa Terrace Area PCE

1 Contamination Database, can we skip all that
2 intermediate steps or modeling of fate and
3 transport analysis and jump to the final step
4 of estimating the contaminant levels in the
5 wells without using models or the models that
6 we use traditionally? So that's the purpose
7 of this study.

8 First of all we have to immediately
9 identify what our limitations are. How we are
10 going to overcome those limitations. So let's
11 describe that. As Morris has said, this is
12 going to be a screening-level procedure. We
13 are not claiming that we will get exactly the
14 same accuracy level -- and some of you are
15 questioning that already -- exactly the same
16 accuracy level going through the process of
17 modeling. We accept that.

18 The other important difference is that
19 the proposed method is not going to be applied
20 to the whole area that you see here, which is
21 Holcomb Boulevard and the Hadnot Point, but it
22 is going to be applied locally in the
23 following sense. We have talked about data
24 clusters, density, data density this morning.
25 So we are going to make use of that density

1 and apply this method locally, to landfill
2 area maybe, just look at that region.

3 Or apply it at some other source
4 contamination where there's data, where
5 there's monitoring stations, where there's
6 monitoring data for 15 years, which we can
7 use. That's the idea. So we can pick this
8 method and apply it to different places. And
9 as I have demonstrated in my report, we have
10 also applied to Tarawa Terrace area creating a
11 synthetic data to see how it works, and I'm
12 going to discuss that today.

13 Other limitations, of course, quality
14 and quantity of the data is extremely
15 important. If we feel that at a certain site
16 we don't have enough data, we will not apply
17 this method. It's that simple. It doesn't
18 work. So we have to wait for the site data
19 analysis to be complete for us to implement
20 this method at Hadnot Point or Holcomb
21 Boulevard areas.

22 The other advantage of this is we can
23 use this method at any of these small regions
24 where we have some data to characterize
25 different chemicals whether it be PCE, whether

1 it be benzene or TCE, et cetera. If we have a
2 fingerprint, we can use the method. If we
3 don't have a fingerprint, we cannot use the
4 method. So this is the starting point in our
5 expectations in this method.

6 Let's also look at the technical
7 details a little bit. I have to go back to
8 the same procedures that we use in our
9 traditional approach. What do we do? Well,
10 we use groundwater flow modeling. This is the
11 basic governing differential equation for that
12 system. From this we get the \hat{v} [velocity -
13 ed.] ~~the~~ field in a multi-layer system.

14 We put that information into
15 contaminant fate and transport, and then
16 whichever method you use, finite difference,
17 finite elements, ~~meta~~ [method -ed.] of
18 characteristics, et cetera, this procedure
19 lends itself to a matrix system to solve for
20 the concentrations at the points of interest.

21 Time rate of concentration multiplied
22 by some matrix M usually called in finite
23 element terminology mass matrix, concentration
24 times another matrix S, usually called the
25 stiffness matrix, and then some loading

1 functions whatever they may be.

2 So I would like you to remember this
3 final outcome. If you go through this process
4 properly, calibrate the model, and this and
5 that, you end up at this stage which is not
6 going to change after that point. This is
7 your solution system.

8 This matrix equation represents the
9 system itself after the procedures are
10 properly implemented and the models are
11 properly calibrated. So I would like you to
12 remember this because I'm going to refer to
13 this later on.

14 Let's also remember or look at the
15 data that we may have at Hadnot Point. This
16 is the general trend in the databases that we
17 have seen so far in Hadnot Point area.
18 Contamination starts at a zero and between T-
19 zero and T-A, there is no monitoring of the
20 site. There is no monitoring data, but during
21 this period from T-zero to T-A, there is water
22 supply wells operating at the different
23 locations at different schedules at the site.

24 And then at time T-A the contamination
25 events are discovered, water supply wells are

1 shut down and the sites are being monitored.
2 So we enter a period of no pumping of water
3 supply wells and a period of observation.
4 This is traditionally about three or four
5 years from T-zero to T-A, and this is about 15
6 years from T-A to T-F, on that range.

7 And at certain sites we also have some
8 internal points which is going to be very
9 important for us in our analysis. Not at all
10 points these internal observation points are
11 available, but at certain sites there is some
12 internal data points during pumping period.
13 So keep that data structure in mind as well.

14 So what are we going to do? Well, as
15 I have proposed, we are just going to skip all
16 that modeling. We are going to look at the
17 aquifer system as a black-box model, and we
18 are looking at observation well concentrations
19 or monitoring well concentrations, which are
20 characterized in director X of T and X1, X2,
21 X3, et cetera, are different monitoring
22 stations which are recording concentrations
23 over time. So X of T at the forward time,
24 that is, after T-A is known at several
25 monitoring locations. And we are interested

1 in this time series change of this monitoring
2 database as it happens over time. We are
3 trying to understand that or trying to solve
4 that.

5 Now, what does our aquifer system
6 include, this black-box that I have drawn?
7 It's not black but golden box in this case.
8 Well, it includes everything. ^[Hydraulic -
9 ed.] conductivities, different aquifers,
10 advection, dispersion, diffusion, reaction,
11 contaminant sources.

12 We don't know where they are, but we
13 don't care because we are only looking at the
14 monitoring locations. We are trying to solve
15 everything at the monitoring locations. We
16 are not trying to bring the contaminant from
17 the source to the monitoring location.

18 What is an external forcing function
19 that characterizes the behavior of this
20 aquifer system that is the pumping rates at
21 water supply wells which occurred between T-
22 zero and T-A time period? And after T-A time
23 period UFT is equal to zero. So those
24 schedules we know, and actually so being
25 characterized as you have heard this morning.

1 So our control theory based system is
2 based on this black-box model, and we are
3 trying to predict the time series evaluation
4 of this XFT which is the concentration values
5 at different monitoring stations at the site
6 and not the whole Holcomb Boulevard, not the
7 whole Hadnot Point, just landfill area, just
8 another contamination site somewhere else in
9 the site.

10 Now, this is the same matrix that I
11 have shown you earlier. If you multiply the
12 earlier matrix by M inverse, you get a matrix
13 M instead of S and then as a load vector you
14 get a matrix Θ , which is in front of this
15 forcing function, UFT. So what is the size of
16 this matrix M ? It's an N -by- N matrix, N being
17 the number of observation points. If we have
18 five observation points, it's just five-by-
19 five matrix.

20 What is the size of this Θ matrix?
21 It's N -by- N . It's the number of observations
22 times the number of pumping wells that we have
23 at the site. UFT is the pumping schedules.
24 X -dot is the rate of change of the
25 concentrations at the observation points. X -

1 zero is the initial value of the concentration
2 at the observation point.

3 It's our assumption that if we look at
4 the start time of contamination, whatever the
5 contamination was, it's not going to be
6 immediately observed at the monitoring
7 station, so X-zero is always zero to start the
8 solution. It will take some time for the
9 contaminant to reach the monitoring well.
10 That's my assumption.

11 So if we solve this matrix equation
12 using our forward time integration -- and just
13 using some symbolism here which is standard --
14 we can write the resulting matrix in the
15 squared parentheses here as A and Θ times Θ
16 as B, and our step-by-step solution becomes
17 this. So starting from time zero at K is
18 equal to zero, we can incrementally go forward
19 in time to solve for the concentration
20 profiles in five, ten, 20, 50 monitoring
21 stations, however many we have if we know the
22 matrices A and B.

23 But we don't know that. And that is
24 the system matrices that we identify as A, and
25 this is the forcing function matrix that we

1 identify as B. So our task to solve this
2 problem is very simple now. Can we determine,
3 can we find a method to determine the matrix A
4 and the matrix B? Well, actually, I'm
5 introducing this as well, we can use a
6 backward time integration process as well and
7 look at the development of the matrices.

8 The outcome is basically the same. It
9 goes backward in time from K-plus-one to K,
10 but there are still two unknown matrices, A of
11 B and B of B to subscript indicates that it's
12 a backward system matrix. So backward,
13 forward, the procedure is not going to change,
14 and we can handle both of them.

15 Now, so our task now is to determine
16 the matrix A and B. But let's look at this
17 database. This period from T-A to T-F where
18 we have all kinds of monitoring data is a
19 period of no pumping. So if you look at our
20 forward time integration scheme, U of K in
21 that period is zero, no pumping. So our
22 matrix becomes much simpler for that period.

23 If we have a time series of X of K, we
24 should be able to determine the matrix A very
25 easily. It's a least squares application,

1 very straightforward. And this matrix A
2 characterizes the aquifer properties at the
3 monitoring location not in a region, at the
4 monitoring location neighborhood. That's all
5 we care. So we have determined the matrix A
6 using a least squares method.

7 Now the next task is a little bit more
8 difficult. We would like to determine the
9 matrix B. A is already there. It will be
10 always there because it's already solved. To
11 determine the matrix B we use an optimization
12 method in the following sense, that we
13 describe the objective function first.

14 This objective function says that the
15 difference between the simulated
16 concentrations at observation wells at time T-
17 A or the difference between the simulated
18 values and the observed values should be
19 minimized. This is our procedure, objective
20 function of our solution for matrix B.

21 If we're going to minimize this
22 difference in a least square sense again
23 subject to the conditions that this is the
24 time series solution of this monitoring well
25 behavior, and if we know A already, then the

1 only unknown is B. So this objective function
2 through a minimization process determines the
3 coefficients of B such that this task is
4 accomplished as best as it can be
5 accomplished.

6 So this is the optimization analysis
7 that we use to determine the matrix B.
8 Basically, we have used genetic algorithms to
9 solve this optimization problem which
10 incrementally adjusts the coefficients of the
11 matrix B such that when we start from T-zero
12 and start predicting the monitoring station
13 concentrations, we end up as close as possible
14 to the values of observation, observed values
15 of concentrations at the monitoring stations
16 at time T-A. That's the constraint here.

17 This method is that simple. We do
18 these types of analyses as engineers
19 routinely. This optimization method is not
20 any different than what I have used earlier in
21 other applications. Now, let's try to apply
22 this to our Tarawa Terrace site and see how
23 good we are.

24 So what we have done is we have used
25 the calibrated models that we have at the

1 site, Tarawa Terrace, input the same mass
2 loading at ABC Cleaners, selected a smaller
3 region -- as I said, this applies to a smaller
4 region -- and generated a plume based on
5 certain pumping schedules which we knew at the
6 Tarawa Terrace area.

7 We used the pumping schedules at TT-
8 26, TT-53 and TT-67. And this is the plume
9 that we have generated over about 40 years
10 starting from the contamination event that has
11 occurred at time T-zero at ABC Cleaners. Then
12 we have selected in our finite element match
13 or if it's a finite difference, it's a center
14 point as well, certain points where we have
15 recorded the data. This is going to be our
16 observation points.

17 So we know what this observation
18 point, this observation point, et cetera,
19 recorded. We have information on the pumping
20 schedules of these three pumps with one
21 difference. We have stopped the pumping
22 schedule of these three pumping wells. This
23 is the pumping schedule for the wells that we
24 have selected at stress period, that is month
25 408, and let the simulation continue after

1 that without any pumping at the site.

2 This is going to generate exactly what
3 we expect to have data at Hadnot Point, a
4 pumping period and no pumping period, and we
5 will see what has happened to our
6 concentrations. This is what has happened.

7 Contaminants start at time-zero and
8 increase at these five nodes that we have
9 selected as our observation period or as our
10 pumping period. And then when we stop pumping
11 at 408 stress period, some of the nodes are
12 showing as a decrease in concentration like
13 these, and the others are showing increase
14 because the plume is moving. The downstream
15 observation points are seeing more
16 concentration over time as the plume moves
17 downstream even if we have stopped pumping.

18 So this is our initial database. What
19 we are going to do is we are going to blank
20 that out. We don't know what has happened
21 there. We are going to predict that part. We
22 are going to predict that part using what,
23 only the data points on this side. And also,
24 we are going to predict that part using the
25 concentrations at time T-A. Those are the

1 values that we have used in our optimization
2 model. We try to reach to that point. And I
3 think I'm going to show you some of the
4 results that we have next.

5 After we determine the matrix A using
6 the data after the pumping has stopped, we
7 wanted to see whether our matrix A behaves
8 nicely. For these five locations, obviously,
9 the least squares method works. We expected
10 that anyway. So the simulated and the
11 reconstructed profiles after the stoppage of
12 the pumping works very well, and the matrix A
13 is well-defined for this region of five
14 observation points.

15 So that side is fine, but when we go
16 back now we have to predict 40 years of system
17 behavior when there is pumping. And initially
18 I am showing you here the zero internal points
19 case. That is, there is no internal points
20 that we have used in this application.
21 Obviously, this is not that good but the trend
22 is there.

23 If we add some internal points, and in
24 this case we are adding only eight internal
25 points out of 34 years of database, and not

1 eight data points on each line. It's just
2 eight data points randomly placed, and here
3 they are. As you can see, the objective
4 function performs well. It just matches the
5 internal data points between predicted and
6 observed values very nicely.

7 So as you can see the data gets
8 better, the predicted concentration profiles
9 gets better in the pumping period. If we add
10 just 15 points, this is what we have. So I'm
11 very happy with this in the sense that there
12 is such a method that we can utilize, and
13 obviously, the accuracy of the procedure is
14 improving as we include some internal points.

15 And I can do that over the weekend in
16 terms of time associated with the task, and
17 this is the 15 points that I have used in this
18 case. I can look at the backward process.
19 I'm just going to go through the slides very
20 quickly. This is the verification of the
21 matrix A sub B , and then, of course, this is
22 the zero internal point backward solution.

23 And backward solution by that we mean
24 we start from here and move backwards in
25 solution to time zero, and then eight internal

1 points and then 15 internal points. As you
2 have noticed now, we have two procedures,
3 going forward, going backward. These are
4 independent procedures.

5 Then we said can we link them.
6 Obviously, if we link them this method is
7 going to use some information from one
8 another, and it becomes an intuitive process.
9 And if the process converges, then we have a
10 very good method in our hands to apply at our
11 site.

12 The way we are going to use the
13 backward/forward solutions iteratively is as
14 follows: We know internal points improve the
15 solution, and we know from our experience so
16 far the forward method works better closer to
17 the time T-A. Backward method works better
18 towards times zero.

19 So what we are going to do is we are
20 going to assign some random solution points
21 obtained from the forward solution close to
22 the T-A time frame as data points in the
23 backward solution. And then use the backward
24 solution, get some random points from the
25 backward solution closer to time T-zero, use

1 it as internal data points in the forward
2 solution. And if this converges, then we have
3 a very good method in our hands.

4 So in summary, our next step is the
5 use of forward/backward procedures iteratively
6 to improve the solution, and we know also how
7 to add confidence bands to the solution. We
8 can give you plus or minus ten percent error,
9 and we can propagate the field measurement
10 error as well as computational error that we
11 may have in our analysis and provide a band of
12 accuracy interpretation over these databases.
13 And finally, if all goes well, we are going to
14 apply this to Hadnot Point area.

15 With that I will stop and answer any
16 questions if you have any.

17 **MR. HARDING:** Yeah, I have some questions.
18 This looks very interesting. It seems like
19 this method will lump a discontinuous,
20 inhomogeneous system into something more
21 homogeneous that can make, you know, can help
22 simplify, accelerate computational effort and
23 things like that.

24 Two questions: A, you still will need
25 pumping schedule if I understand this

1 correctly. Secondly, where do the internal
2 points come from? And this also seems to rely
3 heavily on the initial condition that you
4 applied here, that X at T-zero is zero. How
5 do we know what T-zero is?

6 **DR. HILL:** Can I add one condition onto that
7 so you can do it all at once? Also, your
8 calibration in the non-pumping period require
9 you to, you did it to simulated results from
10 the original model, and so also comment on
11 when you don't, obviously, you're trying to
12 replace the model, and you wouldn't have
13 simulated values. You would have the noisy
14 measured values at that point. And it seems
15 to me that's a problem, too.

16 **DR. ARAL:** The first question, this aquifer
17 here is extremely heterogeneous, non-
18 homogeneous and all that. But this aquifer
19 here, which is the landfill area, we can very
20 easily make the assumption that everything is
21 homogeneous there. So that's not a big deal.

22 We are not proposing to apply this
23 method to the whole region. We're applying it
24 to a smaller area where we have monitoring
25 data, and that is what we are trying to

1 characterize. And we are going to apply this
2 at different locations separately. So the
3 matrix A is going to change. Every time we
4 use this at a different site, based on the
5 fingerprint that we have, the matrix A will
6 change.

7 The matrix A will also change based on
8 the characteristics of the contaminant as
9 well. It's fate and transport. That's also
10 included in the system behavior. If we have a
11 PCE at this location, the matrix A is
12 different than if we have a TCE at this
13 location because degradation rates are
14 different. The behavior of the observation
15 points are different.

16 The other question was how do we
17 synthesize the data? We are going to exclude
18 obviously any data which we cannot predict a
19 trend. The data that we can use in this
20 analysis should give us a profile of some
21 concentration over time. If it is an
22 oscillating database, we will simply discard
23 that monitoring database. We will not use, we
24 will not model or we will not predict the
25 concentration at that location. We will use

1 another place where we have a better data. If
2 we have none, we will not use this method.

3 The other question was --

4 **MR. MASLIA:** The observation internal points
5 --

6 **DR. ARAL:** Okay, the internal points, we
7 discussed this with ATSDR or ATSDR group.
8 There are some sites at Hadnot Point and
9 Holcomb Boulevard where there is some internal
10 data which is available. And that doesn't
11 have to be a time series data like the one
12 that we discussed a minute ago, after the
13 stoppage of pumping has to be a time, a one-
14 time observation, which is fine. So we can
15 use that internal data if available as a
16 database to improve our solution as I have
17 demonstrated in the case of Tarawa Terrace
18 application.

19 **MR. SAUTNER:** Also T sub zero, Dr. Aral.

20 **DR. ARAL:** What did you say?

21 **DR. DOUGHERTY:** Also T sub zero.

22 **DR. ARAL:** Oh, T sub zero, okay. Remember,
23 we are looking at the monitoring locations.
24 The T sub zero is associated with the
25 beginning of time somewhere out there which

1 starts looking at the conditions of the
2 monitoring well data. What we are assuming at
3 that point is -- and that only appears in the
4 forward time solution -- we are going to start
5 this solution at a time where there was no
6 contamination at the monitoring well.

7 That is our initial assumption. We
8 are not saying year 1952 is the start of
9 contamination. All we are saying is at 1952
10 there was no contamination observed. Let's
11 start from there forward, move forward. Now,
12 having said that, I want to point out one of
13 my slides here, the backward solution.

14 Look what happens. We start from here
15 and move backwards, and we end up with a zero
16 concentration at this known point at a given
17 time. The backward solution also interprets
18 us the beginning of contamination, expected
19 beginning of contamination at this monitoring
20 location. That's an added information. I
21 haven't even discussed that.

22 So we are not saying that we are
23 starting at time zero as zero, but it's all
24 zero from zero to 80 stress periods according
25 to this analysis. So the use of backward

1 solution has that advantage as well.

2 Yes.

3 **DR. BAIR:** I may be missing the obvious,
4 which happens a lot, in the bigger picture
5 this is giving you concentrations at
6 monitoring wells. How does that help with the
7 water distribution model? Can you make that
8 link?

9 **DR. ARAL:** Of course. If we have
10 concentrations at the water supply wells
11 measured after time T-A, which we do have, we
12 can include those as our monitoring locations
13 in our database. So the matrix A is going to
14 characterize the water supply well locations
15 as well.

16 And then when we predict, one of these
17 lines that you see here is going to be
18 associated with the water supply well
19 position. So now we know the contaminant
20 profile at the water supply well, and then we
21 can take it to the water distribution system
22 after that. So the monitoring locations that
23 I'm referring to always doesn't have to be
24 monitoring locations, but it can be water
25 supply well locations where we have data on

1 concentrations between stress free period 408
2 all the way to, I don't know what, 600.

3 So that's a good question, but the
4 information is in there if we have -- in other
5 words, let me put it this way. We have to
6 have concentration profiles observed at the
7 water supply well locations to predict the
8 concentration profiles before T-A. There are
9 other ways to answer that question, but I
10 don't want to go into that.

11 **DR. BAIR:** Okay, let's do it.

12 **DR. GOVINDARAJU:** Just a couple of points.
13 In your last slide you said you were
14 introducing Kalman filtering?

15 **DR. ARAL:** Yes.

16 **DR. GOVINDARAJU:** And so that is to
17 basically take into account both error in
18 observations and perhaps model error also. Is
19 that correct?

20 **DR. ARAL:** No. We have a, it's again, when
21 I use control theory-based analysis, we
22 exactly didn't use the control based theory
23 analysis. We have adopted some computational
24 procedures to propagate random errors in data
25 collection and errors in computation into our

1 matrix analysis system to create bands of
2 confidence levels. It's not exactly like you
3 and I know in Kalman filtering analysis. Uses
4 the similar concept, and we are using the name
5 there, but we are not using the Kalman
6 filtering approach.

7 **DR. DOUGHERTY:** So you're propagating a
8 noise vector rather than using the system
9 matrices so you're estimating the effect?

10 **DR. ARAL:** We are propagating a noise vector
11 in the observation database into the system.

12 **DR. DOUGHERTY:** And then presumably for
13 dealing with the system noise, you're applying
14 the same sort of thing. You jiggle the
15 matrix. You get an estimate for how much it
16 impacts the vector and create a vector and
17 drive the original system back.

18 **DR. ARAL:** Exactly.

19 **DR. DOUGHERTY:** I have a couple, I have lots
20 of questions, but I'll try keep it focused.
21 One was in the presentation you talk about the
22 source strength as one of the input factors to
23 the gold-box system, yet the source strength
24 doesn't appear in the matrix equations, at
25 least explicitly. So the question was, are

1 there circumstances in which it needs to
2 appear explicitly?

3 **DR. ARAL:** No, because the source is not at
4 the monitoring locations. The source is
5 somewhere else.

6 **DR. DOUGHERTY:** I understand that.

7 **DR. ARAL:** Right, so it is turning into the
8 aquifer. It is moving down, and we are
9 looking at what is happening at the monitoring
10 locations. We don't know how much source
11 there was, what the total mass is.

12 **DR. DOUGHERTY:** I understand, but in the
13 same way you're using three pumping wells
14 which are not the monitoring wells, so those
15 things that are exogenous to monitoring are
16 important to the system. So the question is
17 still why does the source strength factor not
18 appear in some way?

19 U is located spatially. It's not co-
20 located with your monitoring wells, yet it's a
21 factor in a linear system. So in the same way
22 just because the source is some place else, it
23 could still appear in the system.

24 **DR. ARAL:** It is. It is characterized in
25 this matrix A. Wherever the source is,

1 however it was, how long it discharged is
2 being observed in the monitoring station, A or
3 B or C, which is characterized by this matrix
4 A. As I said from the beginning,
5 concentration sources, aquifer parameters,
6 diffusion, dispersion, reaction is a black-box
7 in here.

8 **DR. DOUGHERTY:** I understand it's a black
9 box. They don't appear in the stiffness
10 matrix. They appeared in forcing function,
11 which is what you reduced to be U. So I
12 didn't want to get into that level of detail
13 here. I don't think it's appropriate.

14 **DR. ARAL:** The only forcing function that we
15 think is going to influence the profile of
16 appearance of a contaminant at a monitoring
17 station is the pumping that was going on
18 nearby that -- we are not going --

19 Okay, let me back up a little bit.
20 Here, when we use this method in this landfill
21 area, we're only going to use the water supply
22 wells in this little box. We are not going to
23 use the --

24 **DR. DOUGHERTY:** I understand.

25 **DR. ARAL:** Right. So we are only going to

1 look at the water supply wells near the
2 monitoring stations, which influences the
3 velocity field of the aquifer, which I think
4 is important to characterize based on T-zero
5 to T-A time frame.

6 **DR. GOVINDARAJU:** I think two points perhaps
7 for clarification. What you are doing is you
8 are using present data to predict past
9 behavior. And let's say you focus on the
10 landfill, and you only look at data in the
11 landfill region. So there is an assumption
12 that whatever let's say was happening in
13 Hadnot Point before, the same pattern is
14 occurring now also.

15 **DR. ARAL:** Okay.

16 **DR. GOVINDARAJU:** Because otherwise right
17 now the analysis the way it's doing is not
18 being influenced by what is happening at
19 Hadnot Point. We're assuming that whatever
20 concentration behavior we are observing, that
21 is capturing everything. So that relationship
22 changed over time, then it's going --

23 **DR. ARAL:** The answer is in this matrix.
24 Once you calibrate the groundwater flow model
25 and calibrate your contaminant transport

1 model, you get your matrix system like this.
2 Do you change that?

3 DR. DOUGHERTY: Yes.

4 DR. ARAL: How?

5 DR. DOUGHERTY: Because S depends on Q which
6 depends on the pressure which is time-
7 dependent.

8 DR. ARAL: It depends on q.

9 DR. DOUGHERTY: Little q meaning specific
10 discharge. Sorry, I want to make sure I get
11 it right.

12 DR. ARAL: But that happens to be in our
13 system already in the matrix A, but the
14 overall system that you have here, are you
15 going to change aquifer parameters? Are you
16 going to change the foundation coefficients?
17 Are you going to -- you know, all of that is
18 in there.

19 DR. DOUGHERTY: So it's a big linearization
20 step to get from A to B.

21 DR. ARAL: My model is as linear as this
22 one.

23 DR. HILL: It's not only a linearization
24 step, it's a very strong lumping step. You're
25 putting a lot in there. What that produces is

1 a system that can't be cross-checked.

2 **DR. DOUGHERTY:** Well, there's nothing else
3 to cross-check because he's using all the
4 data.

5 **DR. HILL:** Yeah, you can't cross-check
6 anything. You can't cross-check whether the
7 hydraulic conductivities make sense. You
8 can't cross-check whether the source strength
9 makes sense. You can't cross-check anything.
10 And also, the data you put in there, all the
11 fits you showed, fit the data points
12 perfectly, which always makes me nervous. So
13 how do you deal with data noise as well?

14 **DR. ARAL:** First of all, cross-checking
15 hydraulic conductors, it doesn't interest me
16 in this case because I'm not using this
17 differential equation to generate matrix A.
18 I'm not using this differential equation to
19 generate the matrix M or S. That's
20 irrelevant. I really am looking at ten
21 observation points characteristics for their
22 behavior based on a database.

23 Now how am I going to propagate the
24 error that I have in those observation points?
25 The bands that I have described earlier is

1 going to give us information. If we have
2 field data error it will propagate in our
3 solution. We will have computational error.
4 It will propagate in our solution.

5 **DR. DOUGHERTY:** Even though your interests
6 may not lie in matching conductivity values,
7 the consistency between a data-driven system
8 and a physics-based system are going to
9 provide some measure of comfort to a lot of
10 people.

11 So one possibility that might be
12 considered is to take local scale flow and
13 transport models, and so your original
14 differential equation system, apply it to a
15 measurement matrix so you basically are
16 condensing the system down to the number of
17 monitoring locations. And then comparing the
18 condensed matrix coefficients to the
19 coefficients that are derived out of this
20 linear control system.

21 And I understand, I understand, but
22 because you've got, they aren't going to be
23 the same because to get to a linear control
24 system you have to do, you do have to do some
25 linearization. It's true, but it may help

1 with some comfort to look at those, to look at
2 a static condensation of the finite element
3 matrix, you want to think of it that way,
4 versus a control matrix.

5 DR. ARAL: The way you come up with the
6 matrix A in a finite difference or a finite
7 element method is completely different.

8 DR. DOUGHERTY: I understand.

9 DR. ARAL: But you should also ask the
10 question to the person who's doing or choosing
11 that path to give the comfort level of
12 predicting the assimilated or observed values,
13 right? And that's what you do. That's what
14 you do. And in this case that's what we have
15 done. We have totally used a different method
16 to generate the matrix A or B, and we have
17 confirmed the outcome that we have observed at
18 the site are a match.

19 DR. CLARK: Richard is the next one in line,
20 and [then -ed.] we're going to have to move on
21 again I think. This is something that we may
22 want to come back to if we have time this
23 afternoon.

24 But go ahead.

25 DR. CLAPP: Yeah, this actually might be a

1 question that jumps the gun. I'm actually
2 wondering about at the bottom of the, at the
3 end of this process how does this advance
4 identifying finished water at a location where
5 a child with a birth defect lived? What their
6 consequence was or at least what their
7 categorization was.

8 **DR. ARAL:** We have discussed that partially.
9 We can use this method to determine the
10 concentrations at water supply wells as a
11 profile as well if we have information on
12 concentrations. So once we have generated our
13 profiles as solution, for example, if this is
14 our water supply well data, if we are
15 predicting this, our predictions will be used
16 after this point the same way the other
17 procedures would have used it going through
18 groundwater flow, contaminant transport
19 modeling.

20 **DR. BAIR:** It's a follow up. So if you do
21 this at those three locations that are the
22 local locations you indicated on the one map
23 where the spots came out?

24 **DR. ARAL:** Any. Any location. Not three.

25 **DR. BAIR:** I thought you said you were using

1 at the three where you had the most data and
2 it couldn't be applied at areas --

3 **DR. ARAL:** We have not, we have not decided
4 where we will use this yet. We are going to
5 be totally data driven in that aspect. I am
6 just giving you here some characteristic small
7 locations that we may use.

8 **DR. BAIR:** Okay, so you could take that gold
9 spot and move it all the way out along the
10 line of wells that extends to the west where
11 there's not much data at all?

12 **DR. ARAL:** The answer to that question is
13 here. If there is no data, we will not use
14 this.

15 **DR. BAIR:** Okay, so there will be water
16 supply wells in the area we've talked about
17 today where you can't apply this method.

18 **DR. ARAL:** Right. If that is the case --

19 **DR. BAIR:** So then what is used for the
20 exposure assessment if this method doesn't
21 apply? You still need a deterministic flow
22 and transport model?

23 **DR. ARAL:** That's a good point. If we don't
24 have, if there are water supply wells around
25 here which we are using to contribute to the

1 whole system supply or add to the system
2 supply, then using water supply concentration
3 profiles here is not going to add as much
4 information for the whole picture.

5 DR. BAIR: So my question was how many water
6 supply wells will be left out?

7 DR. ARAL: I have not looked into that yet.
8 I don't know what the data structure is. We
9 are just working on the method.

10 DR. BAIR: So it does mean that there will
11 be two approaches to the same problem running
12 in parallel?

13 DR. ARAL: Uh-huh.

14 DR. BAIR: Is that right?

15 DR. ARAL: That's correct.

16 DR. CLARK: Why don't we move on.

17 Morris.

18 MR. MASLIA: I may not have shown it, but
19 somewhere in the notebook there was a
20 flowchart, and it gave a double path. One was
21 the traditional fate transport model, whether
22 we use deterministic, probabilistic or
23 grabber* estimation. The other approach was
24 using this screening level model, and that
25 would, depending on the data that you have

1 available, would determine the approach.

2 **STRATEGIES FOR RECONSTRUCTING CONCENTRATIONS:**
3 **PRESENTATIONS AND PANEL DISCUSSION NUMERICAL METHODS**

4 At this point I think we're going back
5 to the traditional method that we had a lot of
6 questions about this morning, but then the
7 purpose of this is to at least generate some
8 alternatives or get more input from you. So
9 Rene Suarez started halfway as we completed
10 the Tarawa Terrace modeling or as part of
11 that, and we'll move into Rene's presentation.

12 **MR. SUAREZ:** Good afternoon. My name is
13 Rene Suarez as Morris said. I am with ATSDR
14 on the Exposure Dose Reconstruction Team and
15 during the next few minutes I will be talking
16 about the proposed approach to numerical
17 groundwater flow and contaminant fate and
18 transport modeling for the Hadnot Point and
19 Holcomb Boulevard study.

20 The outline of this approach and kind
21 of this presentation is groundwater flow
22 modeling on the regional scale. Here we are
23 going to develop and ^ [calibrate ed.] a
24 steady-state model. We as well we [-ed.]are
 going to develop and calibrate a transient
 model for the groundwater flow. Then we will

1 have to develop and calibrate groundwater
2 flows for the local scale where we have the
3 contaminants ~~of~~ [in -ed.] the areas of
4 concern. And ^ [calibrate -ed.] contaminant
5 fate and transport models for those ~~local~~ ^
6 [locally refined -ed.] models.

7 First of all I'll describe a little
8 the Tarawa Terrace model. I know some of you
9 were involved in the expert panel on this.
10 The approach is very similar so I will just
11 briefly describe the approach that was used
12 for Tarawa Terrace.

13 In the yellow box we have Tarawa
14 Terrace and what was used there was, [-- -ed]
15 we developed and calibrated a groundwater flow
16 model in MODFLOW. It was a steady-state
17 model. Then a transient model was developed.
18 From that we developed and calibrated a
19 contaminant fate and transport model using
20 MT3DMS, which gave us the concentration over
21 time for the area of the model.

22 Then we used a simple mixing model to
23 estimate the exposure concentration using the
24 flow data of the supply wells and the
25 concentrations from the model. And finally,

1 we verified ~~those~~ [the -ed.] estimated
2 exposure concentrations in ~~that~~ [the -ed.]
3 water distribution model that was ~~building~~
4 [built in -ed.] EPANET.

5 In this slide I'm showing the proposed
6 Hadnot Point/Holcomb Boulevard model. And
7 first I would like to point out the difference
8 in areas of the Tarawa Terrace model that we
9 have here in the yellow box and Hadnot Point
10 and Holcomb Boulevard.

11 The area is five square miles for
12 Tarawa Terrace, and I think Morris in one of
13 the slides had 50, but the proposed [area is
14 84 square miles -ed.], I think that was like
15 [, ed.] this is a more updated area. It's
16 about 17 times larger for this model. The
17 size of the total domain is 51,000 feet in the
18 Y direction and 45,000 feet in the horizontal
19 direction.

20 Some of the features of this model we
21 have [are -ed.] a specified head in ~~data~~
22 [layer -ed.] number one of this model. That
23 is representing New River here in this dark
24 blue. On the right side, or the west side of
25 this model, we have a no-flow boundary that

1 mostly represents a topographic divide.

2 **MR. MASLIA:** Excuse me, Rene, can you speak
3 up a little?

4 **MR. SUAREZ:** Yeah, sure.

5 We have a no-flow boundary on the ~~west~~
6 [east -ed.] side [which -ed.] is represented
7 by a topographic divide. In some areas we
8 have some general head boundaries where we
9 have supply wells. We also have about eight
10 small creeks that are represented by drains
11 here in the model in green, and we have 100
12 supply wells in the area of Hadnot
13 Point/Holcomb Boulevard.

14 In terms of the grid design that we
15 are proposing, the model has been subdivided
16 into 343 rows, 303 columns. This gave us
17 square cells of about 150 feet per side. The
18 model had been subdivided vertically into ten
19 layers.

20 On the right side of this slide we
21 have a table where we have the geohydrologic
22 units on the left-hand side and the
23 corresponding model layers on the right side.
24 We have seven aquifers and seven confining
25 units. The confining units are underlined in

1 red. And please notice that the Brewster
2 Boulevard is lumped into one model layer.

3 Horizontal hydraulic conductivity for
4 the different aquifer was obtained from
5 aquifer test analysis [. -ed.] ~~for~~ [For -ed.]
6 the confining units. [-ed.] ~~It~~ [it -ed.] was
7 assigned a constant value of one ~~fit~~ [feet -
8 ed.] per day. Effective ^ [recharge or
9 infiltration -ed.] was obtained from
10 precipitation data, kind of the same approach
11 that Bob described earlier that was used in
12 Tarawa Terrace.

13 And elevation of the different layers,
14 elevation for the, for layer one, the top
15 layer, was obtained from ^ [digital -ed.]
16 elevation model [and -ed.] topographic
17 information and ~~for~~ [-ed.] the elevation for
18 the other layers was obtained from borehole
19 log data and geophysical data.

20 From here we proceeded to -- and
21 please understand. This is the proposed
22 approach, so it's not really like in the step
23 of being calibrated or being completely built.
24 So just keep that in mind while you're
25 thinking there.

1 So the model was calibrated using that
2 [kind of a -ed.] trial and error approach
3 first, ~~kind of a code approach~~ [-ed.]. And
4 then the PEST optimization is going to be or
5 was run under this model, this steady-state
6 model. Over here in the center we have
7 horizontal hydraulic conductivity.

8 The layers that are currently missing
9 are the confining units that were not included
10 in the PEST optimization at this step.

11 ~~Research [? -ed.], two ^ [parameters -ed.]~~
12 [Two recharge zones -ed.] were identified
13 during the calibration process, [. -ed.] and
14 [And -ed.] basically what we're doing is
15 trying to review this ~~subjective~~ [objective -
16 ed.] function in the PEST optimization. The
17 objective function is just the sum of squared
18 error. This is the observed heads, and this
19 is the simulated heads. This simulation, ~~[-~~
20 ed.]the PEST optimization, ~~[-~~ ed.]took 78
21 MODFLOW simulations, and it took about two
22 hours to perform that.

23 **MR. HARDING:** Can I ask you a question?

24 **MR. SUAREZ:** Sure, sure.

25 **MR. HARDING:** I guess I'm not a groundwater

1 modeler. Why are you calibrating the recharge
2 when you can make a reasonably good estimate
3 of it and it's a time series?

4 **MR. SUAREZ:** Well, we're going to use both
5 like we have in some starting points some
6 precipitation data, weather data, but we still
7 don't have, we only have like one weather
8 station for that whole area and recharge
9 definitely should vary in that area. So it's
10 still going to be a parameter that we want to
11 include in the calibration process.

12 **MR. HARDING:** You could get gridded precip.

13 **MR. SUAREZ:** You can get what, sir?

14 **MR. HARDING:** You can get gridded
15 temperature and precip from the PRISM database
16 on a four-kilometer grid, which is not super
17 fine, but it's better than your weather
18 station probably. Anyway, I disagree.

19 **DR. DOUGHERTY:** This is the net of what
20 actually gets in the ground.

21 **MR. HARDING:** Yeah, you'd have to make that
22 calculation, but you've got all the data to do
23 it.

24 **DR. HILL:** But you don't. It's not
25 something --

1 **MR. HARDING:** No, you don't.

2 **DR. DOUGHERTY:** Changes in soil moisture.

3 **DR. BAIR:** On a monthly basis, how much does
4 that -- is that a problem? It's a pretty well
5 drained area.

6 **MR. FAYE:** The only thing you've got are
7 regional estimates of Blaney-Criddle stuff.
8 You don't really have anything that you can
9 pinpoint down to an area like this.

10 **MR. HARDING:** It's a starting point. That's
11 where you start, but --

12 **DR. DOUGHERTY:** You've got the
13 precipitation. These are pretty good
14 estimates. They're interpolated from point
15 [data -ed.]^ . You've got temperature and dew
16 point, you can use that in a physical-based
17 equation to calculate ET. So then what am I
18 missing about the rest of it? If the rain
19 falls on the ground, where does it go?

20 **DR. BAIR:** Some's into ET, some's into
21 plants, some's into runoff and some continues
22 downward into groundwater.

23 **DR. DOUGHERTY:** And some stays in storage.

24 **DR. BAIR:** And some stays in storage until
25 something happens to it, maybe in your 18

1 model.

2 **MR. HARDING:** Stays in storage in the
3 surficial layers?

4 **MR. FAYE:** In the soil moistures.

5 **MR. HARDING:** Doesn't it make sense to use
6 this information to inform this somehow?
7 Because, I mean --

8 **DR. DOUGHERTY:** Usually something like that
9 would be a starting point. You get a rough
10 number and use a starting point.

11 **MR. HARDING:** Rather than just calibrating
12 it. It seems to me you know a lot about it
13 from the precipitation --

14 **DR. HILL:** So you'd expect it to be that
15 value maybe, plus or minus a factor of maybe
16 up to two, probably not more than two.

17 **MR. HARDING:** I'd be surprised if it was
18 anything close to there.

19 Okay, go on, I'm sorry.

20 **DR. BAIR:** Rene, I have a question. Can you
21 go back one slide?

22 **MR. SUAREZ:** Sure.

23 **DR. BAIR:** So if you look at iteration six,
24 those are your best fit, right, the row going
25 across from iteration six?

1 **MR. SUAREZ:** Yeah, well, I will call this it
2 was the best fit without considering any
3 specific information about the different
4 layers and that, but, yeah.

5 **DR. BAIR:** So then if you look at model
6 layer four, that's an aquifer.

7 **MR. SUAREZ:** Uh-huh.

8 **DR. BAIR:** And model layer three is a
9 confining layer and five is a confining layer?

10 **DR. DOUGHERTY:** No, no, he said he didn't
11 include any confining --

12 **DR. HILL:** He said estimated --

13 **DR. BAIR:** No, no, they're there. They're
14 there in the model. Right, so my question is
15 if model layer three has a hydraulic
16 conductivity of one, and model layer four has
17 a hydraulic conductivity of 1.2, and model
18 layer five has a hydraulic conductivity of
19 one, who's confining whom?

20 **MR. SUAREZ:** Well, these values were not
21 really bounded like very specifically during
22 the optimization process. That's why I'm
23 presenting the approach. If we go to the
24 green row, these values are more based on the
25 aquifer test data. So, yeah, I expect these

1 values to be higher during the optimization
2 process.

3 **DR. BAIR:** And I apologize. It's just hard
4 for me as a member of the panel to tell what's
5 final and what's preliminary, so if I ask too
6 many questions it's because my impression is
7 this is the final stuff that you're presenting
8 and not some preliminary work.

9 **MR. MASLIA:** Now, let me just again clarify.
10 I tried to find a nice fit between giving
11 enough information so we could provide the
12 methodology that we want to use and not
13 committing too many resources that we've gone
14 down the path of trying to calibrate a model
15 and then receiving feedback from the panel
16 that's not going to work or you need to make
17 some major changes because then in terms of
18 resources and efforts we need to back track.

19 I didn't want to not show or present
20 anything so again, especially on the numerical
21 modeling part more so than the data analysis
22 because it's really --

23 **DR. CLARK:** I think they're going to be
24 depending on you to recommend --

25 **MR. MASLIA:** -- just an approach.

1 **DR. CLARK:** -- forward.

2 **DR. HILL:** Can I make one comment on this?
3 Just that when, in regression when you have
4 parameters that go to unreasonable values,
5 generally that's indicating that there's some
6 conceptual problem with the model. So instead
7 of just putting limits on that to keep it
8 reasonable, I would suggest re-evaluating your
9 conceptual model.

10 **MR. SUAREZ:** Sure, sure.

11 **DR. KONIKOW:** Well, another related issue is
12 why not, if you want to assume all the
13 confining layers have the same hydraulic
14 conductivity, why not at least treat it as one
15 parameter? Then why not estimate that? Just
16 make it part of the whole system.

17 Well, on a conceptual basis maybe this
18 is a good time to discuss it, but maybe go
19 back to the previous slide. And one of my
20 major conceptual concerns is for the flow and
21 transport model lumping those four upper units
22 into one model layer. This seems like a major
23 conceptual flaw.

24 Somewhere in your report it said that
25 you had field evidence that that upper clay

1 unit was very substantial in retarding the
2 movement of the DNAPLs and had a significant
3 effect on the contaminant ~~transporting~~
4 [transport -ed.], yet here you're lumping two
5 aquifers and two confining units into one
6 model layer, which means you're going to
7 smooth out all the influence of the
8 heterogeneity, and a very significant
9 heterogeneity, in layering on contaminant
10 transport.

11 And this is the unit into which the
12 contaminants are introduced and you're losing
13 all the controls by this lumping. I just
14 don't see conceptually how this can be
15 justified.

16 **MR. SUAREZ:** Well, one of the plans is to
17 subdivide that when we go to the more
18 localized model because this is --

19 **DR. KONIKOW:** Well, you -- I don't think
20 when you go to the localized -- if you're
21 using MODFLOW, maybe Mary could say something
22 about this. I don't think in the localized
23 models you could change the vertical, the
24 model layering, can you?

25 **DR. HILL:** Yeah, you can.

1 Are you doing this to avoid dry cells?

2 **MR. SUAREZ:** Yes.

3 **DR. HILL:** Yeah, don't.

4 **MR. SUAREZ:** Well, it's one of the reasons -
5 - let me explain. We don't have to the extent
6 that we're proposing this model the, basically
7 the interpolation scheme that we're using to
8 interpolate those layers. Now you get a lot
9 of layers that kind of like kind of disappear,
10 appear and disappear, and it's kind of
11 difficult to at this moment I'm not presenting
12 at this moment just to have a structure that
13 makes sense.

14 **DR. HILL:** Use the Huff* [HUF (hydrologic
15 unit flow) -ed.] package and assigned, and use
16 defined thickness layers using your contoured
17 water table for those layers. And get in the
18 ballpark in terms of hydraulic conductivity.

19 **DR. CLARK:** Rao had a comment he would like
20 to make and then I think we need to let Rene
21 continue his presentation.

22 **DR. GOVINDARAJU:** This is Rao from Purdue.
23 I think along the same lines my feeling is
24 even if you get the conceptual model
25 correctly, and you just let the optimization

1 run its course, it may give disparate value
2 the confining layers which are less than the
3 aquifer conductivities.

4 I think once you think a conceptual
5 model is correct, you must do a constraint
6 optimization. If the assumption or the belief
7 is that the confining layers are about one-
8 tenth of the conductivity of the main layers,
9 then you should, I suppose, impart that
10 knowledge to the optimization routine.

11 **DR. KONIKOW:** But is that knowledge or is
12 that just an assumption?

13 **DR. GOVINDARAJU:** That's an assumption.

14 **DR. HILL:** Well, I would say it's knowledge.
15 It just depends on how you want to use that
16 knowledge. And one way to use it is to apply
17 it as constraints so that you constrain what
18 values your parameters can take. Another way
19 to use that knowledge is to say, okay, I'm not
20 going to apply this as a constraint. I'm
21 going to see what fits my data best and if
22 those values are unreasonable, I'm going to
23 sit back and say, okay, if I have enough
24 sensitivity, if I have enough, if my targets
25 or observations --

1 **DR. CLARK:** Let's let Rao go on and, I mean
2 [then -ed.], let's let Rene go on and present
3 his --

4 **DR. HILL:** I was almost done.

5 **DR. CLARK:** Okay.

6 **DR. HILL:** -- then go ahead and if my
7 observations provide enough information to
8 estimate those things, and they provide a lot
9 of information, if my estimated value is
10 wrong, it implies a problem with the
11 conceptual model. So it's just how you use
12 that information.

13 **DR. CLARK:** Let's let Rene go on and finish
14 his presentation.

15 **MR. SUAREZ:** I will point out something
16 maybe related to that. So just to show [how -
17 ed.] the calibration was from that preliminary
18 model as we mentioned we were using, we used
19 PEST. One of the things we also are
20 considering [is -ed.] UCODE. The root mean
21 square for this model was 5.46, and on the
22 right side we have a plot of the simulated
23 versus observed water level values. The
24 values in red are monitor well data, and the
25 values in blue are supply well data.

1 And please notice [in -ed.] this
2 slide, overestimation of the supply well data
3 because this was just to kind of like try the
4 method. Because this includes all the data,
5 one thing that when you go and check on case-
6 by-case of the observed data, some of the
7 observed data that I include I shouldn't have
8 included in because it was being subjected to
9 draw-down effect, and at this time we're not
10 concerned with pumping. So there's a lot of
11 refinement that I have to go and select what
12 data I will include into the optimization
13 process.

14 **DR. DOUGHERTY:** Quick question, and all
15 these are equal weights?

16 **MR. SUAREZ:** What?

17 **DR. DOUGHERTY:** You're using equal weights
18 on all of the data?

19 **MR. SUAREZ:** Yes, right now, yes.

20 **DR. DOUGHERTY:** So you're not using the
21 measurement error differences?

22 **MR. SUAREZ:** No, at this moment, no.

23 So this just showed the results from
24 that preliminary model, and we have a head
25 difference of about four feet from east to

1 west. This plot also showed the head
2 residuals. We have in blue less than minus
3 five feet, in green minus five feet to five
4 feet, and in red, larger than five feet. One
5 of the ~~common~~[^] [comments -ed.] about data
6 density that we're [we were ed.] talking
7 before, although this model is really large,
8 actually the area is very concentrated, and
9 it's hardly difficult to calibrate the models
10 in some areas that we don't have data, and at
11 this step we're just trying to build a
12 regional model and then we'll have to
13 calibrate that model. But then we'll have [,
14 ed.] I will say[, -ed.] plenty of data to
15 calibrate those local models.

16 Just comparing the Hadnot
17 Point/Holcomb Boulevard and the Tarawa Terrace
18 model side-by-side I just want to point out
19 what I would think is the two major difference
20 in terms of building these two models. We
21 have fairly [large -ed.] difference in [the -
22 ed.] size of the model. That will include
23 steps that were not contemplated, were not in
24 Tarawa Terrace. Like here we will have to
25 build a regional model and go to more refined

1 local models.

2 Also, we have a lot more data that is
3 good for calibration, but it will also make it
4 more complex. So we will need to ~~do~~ [-ed.]
5 use optimization process for this model. And
6 that will include a lot of effort in
7 calibrating the steady state transient models
8 for each one of the regional/local models and
9 the contaminant fate and transport.

10 **DR. HILL:** Excuse me. Those observed the
11 concentrations that you have listed there, do
12 they include the non-detects?

13 **MR. SUAREZ:** No, these are locations. If
14 you look at this I may not have made the
15 difference. Locations where we have data in
16 terms of contaminant --

17 **DR. HILL:** It is important to use the non-
18 detects as well, and UCODE provides a formal
19 mechanism for using non-detects.

20 **MR. SUAREZ:** Sure, sure. I saw that in your
21 notes. And definitely that's something that
22 we'll contemplate.

23 So we can proceed with the discussion.
24 What I want to do is summarize ~~like~~ [-ed.] the
25 approach, so you can see in perspective of the

1 amount of data that we have at this moment and
2 amount of data that we may need to check
3 within the documents that we still haven't
4 really realized that we have.

5 We are going to build our numerical
6 model, and we gave some information of a
7 preliminary numerical model that we have
8 built. We are going to run a steady state
9 model. We also gave some preliminary
10 information on that. We are going to run this
11 model using MODFLOW-2000 and PEST for
12 calibration. We're going to do that as well
13 with the transient model, same situation.
14 Then that's for the regional model.

15 From there we're going to go to a more
16 localized model where we're going to choose
17 some areas where we need refinement. And when
18 I said refinement or local areas, the bulk of
19 our contamination is located, for example, in
20 this picture, the landfill area and the HPIA
21 area, Site 88, we'll need to build local
22 models for them.

23 We will have to evaluate the effects
24 of pumping on those because we have a lot of
25 supply wells and not all of them are pumping

1 on the same times. So we'll have to evaluate
2 the effect of pumping on those boundaries.
3 And from there we'll have to run our transport
4 models in those local grid refined models ~~or~~ [^]
5 ~~models~~ [-ed.] using MT3DMS, the same approach
6 that was used in Tarawa Terrace and PEST or
7 UCODE for calibration.

8 From here we can start the discussion.

9 **DR. BAIR:** Rene, with respect to the
10 calibration, is there any time, money --
11 they're kind of both the same anymore -- to
12 get a velocity data that you could use to help
13 calibrate? You have a lot of head data, but
14 it would be nice to get, and I know it's not
15 easy here, stream flow gain or loss so you can
16 get some discharge data, a flux out of your
17 system. Or some tritium/helium age dates so
18 you can do some backward particle tracking to
19 check to see if the physics of your model
20 matches the chemistry of the tritium/helium to
21 give you confidence in some of the velocities.

22 **MR. SUAREZ:** I'm sorry, you're combining
23 something about money or I was just thinking -
24 -

25 **DR. BAIR:** No, the money was just a comment

1 for the people way up there. That's for the
2 people in the corner. You're on a time frame
3 and time costs money and this would be getting
4 more field data. So can you put in a couple
5 monitoring wells out in that area where you
6 don't have a lot of data?

7 **MR. MASLIA:** Let me address that
8 specifically because that's what I picked up
9 on the field data. Can we gather more field
10 information, which we could gather in a
11 shorter span of time compared to the effort of
12 doing a full-blown calibration here. And that
13 would really depend on discussions from our
14 agency management and the Navy or the funding
15 party. And could it either meet our existing
16 time schedule or extend it less longer in
17 time.

18 And that was one of -- I'm glad you
19 asked that question because it fits right
20 into, and maybe it was not clear why we went
21 to Dr. Aral and his group at Georgia Tech to
22 try to come up with an alternative method.
23 After we finished Tarawa Terrace we saw the
24 effort that went into it. And regardless of
25 if you think the confidence is not large

1 enough or narrow enough, you have a model that
2 produces reasonable results.

3 And we saw the effort that went into
4 it. Looking at what we had, just looking at
5 the data that we have, it became apparent
6 right away is what can we do to come up with
7 some initial answers, not throwing out the
8 baby with the baby carriage at the same time,
9 but either using it as a starting point to
10 help augment or help us jump start that or as
11 a check.

12 As somebody said if we're going to
13 spend another year or two years, you still
14 have the question of how confident are you in
15 those hydraulic conductivities or how
16 confident are you in a much, much larger
17 model. And so I made the decision to see if
18 we could come up at least with a screening-
19 level model, you know, something to put our
20 teeth in.

21 I think your suggestion we need to
22 talk about and think about could that Dr.
23 Aral's method then also be combined in
24 conjunction with maybe a small field effort to
25 give us a method and some information to more

1 rapidly get to the point of where we now want
2 to distribute the --

3 **DR. BAIR:** I mean, I guess what I was
4 getting at, Morris, is there a couple obvious
5 areas where you need data? In the north part
6 of your model area where you don't have many
7 water levels, there aren't many pumping wells
8 up there so a current water level would
9 actually give you some guidance for applying
10 backwards in time.

11 I also think you need to look at some
12 of the confining layers in more detail, not
13 only their lateral continuity but their
14 permeability because they're restricting the
15 contaminants flowing downward. And assuming
16 one foot when the aquifers are ten feet per
17 day, you know, a difference of a factor of ten
18 isn't much of a confining layer. It's just
19 the heterogeneity within most aquifers.

20 So I just thought it would be your
21 time, Rene -- and I didn't mean to scare you
22 with that and somebody else's money, but I
23 just thought if there's an opportunity to
24 discuss that, that there are some -- I don't
25 think it's expensive. It's time that I got

1 the impression that's pushing you.

2 And I personally would much rather you
3 see take the extra year to get the answer
4 right or closer. And it reminds me of that
5 Jack Nicholson film with Tom Cruise where they
6 were in the Marines and there was that -- what
7 was the name of the movie? A Few Good Men,
8 yeah.

9 And I show that, a clip in my class,
10 and Cruise is on the stand and Nicholson says,
11 "You can't handle the truth." Well, I turn
12 that around and say, "You can't afford the
13 truth." How much of the truth do you want to
14 pay? And in the bottom line when you're done
15 would have spending 25,000, 50,000, 100,000
16 more dollars to get more of the truth and lose
17 a year, is that going to be beneficial. And
18 that's not a decision for the panel. That's a
19 decision up there. So that's my two bits.

20 **MR. FAYE:** Dr. Bair, how much
21 differentiation in time can you get from the
22 age-dating analyses that you're talking about?
23 What was it, a helium/tritium type?

24 **DR. BAIR:** Well, I use this with one of my
25 Ph.D. Students up at Woburn, and we used the

1 tritium/helium dates to help calibrate our
2 flow model. So we, too, were forecasting
3 backwards in time, and what we were interested
4 in is if our steady-state model or our
5 transient model prior to turning on the wells,
6 wells G and H.

7 Now that the wells were off in 2002,
8 when we did the sampling, could we replicate
9 those velocities in our model that we measured
10 in terms of the groundwater ages in 2002. So
11 they're two different times, but neither of
12 them are transient at that moment because
13 neither of the wells were on. And that gave
14 us a comparison of physics-based travel times
15 and chemical-based travel times. And it
16 turned out to make us feel comfortable.

17 So I think what everybody's looking
18 for here is for your models to demonstrate a
19 level of professional comfort among all the
20 different professionals in the whole room.
21 And if tritium/helium helps you or some other
22 technique helps you --

23 **MR. FAYE:** But what is your tolerance on
24 those ages? I mean, is it like of you get an
25 age of 1950, does that mean it was somewhere

1 between 1940 and 1960 or, I mean, what's the
2 tolerance there on that?

3 **DR. BAIR:** I have my Woburn presentation in
4 here. Kip Solomon* did those for us at the
5 University of Utah, and he puts an error bar
6 on every one of those. So the error bars
7 there are less than a year, slightly more than
8 a year. And then we compared it to the error
9 bars on our reverse particle tracking, which
10 accumulates a conservative age.

11 And our error bars there were putting
12 particles all over the well screens and
13 tracking them backwards to the water tables.
14 So we were looking for our variation in
15 backwards travel times to be within Kip's plus
16 or minus. And we did it pretty well except
17 for the deepest wells that were closest to the
18 metamorphic bedrock where they get a helium
19 signature from the decay of some of the
20 minerals in the granite.

21 So that's esoteric, but I think you
22 need a little more field work.

23 **DR. CLAPP:** I was just going to ask Dr.
24 Bair, actually, my impression is that that
25 additional work in Woburn hasn't changed the

1 results of the case-control study. And in
2 terms of how it's implied or applied in
3 epidemiologic study it may be been --

4 **DR. BAIR:** It's done subsequent to the case-
5 control.

6 **DR. CLAPP:** Right, I understand, but would
7 it have mattered in terms of the case-control
8 study as an outcome?

9 **DR. BAIR:** I've shown our results to the
10 Massachusetts Department of Health people, and
11 they wished, they told me they wished they had
12 had this when they had done their work. What
13 my student was able to do is what you're
14 asking yourselves to do is to come up with a
15 month-by-month exposure concentration for each
16 one of the water districts in Woburn.

17 Woburn has a very mixed system so the
18 water distribution model was much different.
19 And we're able to come up with bands of what
20 the concentration would have been during
21 gestation, during the first year, seven years,
22 et cetera. And they didn't have that. I
23 don't think most epidemiologists are used to
24 getting that type of information. So it's
25 something groundwater people haven't been able

1 to provide with much confidence until the last
2 many years. But, no, it didn't change them.
3 They had already published it so Costace* and
4 Condon*...

5 **UNIDENTIFIED SPEAKER:** (Inaudible).

6 **DR. BAIR:** I don't know. They would have
7 had to have different approach because I, we
8 can give exposures. I don't know if in terms
9 of parts per million, micrograms per liter.

10 **DR. CLAPP:** They were looking at ranks and I
11 doubt that the ranks would have changed much
12 to be honest.

13 **DR. WARTENBERG:** Why didn't they re-do it if
14 your data were available?

15 **DR. BAIR:** What's that?

16 **DR. WARTENBERG:** Why didn't they re-do it,
17 their analysis?

18 **DR. BAIR:** I don't know, budgets.

19 **MR. BOVE:** I'll tell you one thing, if they
20 have all the data it can't cost that much.

21 **DR. BAIR:** One of the problems we had there
22 was statistics of really small populations so
23 there are 28 children who developed leukemia
24 in Woburn over that period of time, '68 to
25 '84. Seven of them were involved in a

1 lawsuit.

2 It's the lawsuit testimony that gave
3 us the birth dates and the gestation periods.
4 The other 21 sets of data are sealed by the
5 State of Massachusetts under a nondisclosure
6 agreement. So I have seven. I wish, you
7 know, I tried bribery. I tried lunches,
8 tickets to the Ohio State-Michigan game,
9 everything and couldn't get those released.

10 **MR. FAYE:** Dr. Bair, let me ask another
11 question. Most of the wells that were
12 contaminated are destroyed now. They're not
13 available for sampling, so what would an
14 alternative be if we're lucky enough to have
15 like a monitor well along the flow path or --

16 **DR. BAIR:** Yeah, you would want to use
17 monitor wells along a flow path, and that's
18 what we used more as a pre-pumping wells, G
19 and H, potentiometric surface and particle
20 tracking for was to determine a long flow path
21 and then sample wells at distance along that
22 flow path and then at depth.

23 **DR. CLARK:** Morris had a question.

24 **MR. MASLIA:** Yeah, a question. Combining
25 two thoughts here, wells G and H at Woburn,

1 I'm thinking they may, assuming you've got the
2 data, there may be an opportune moment here to
3 test out Dr. Aral's method on some real data.

4 **DR. KONIKOW:** I have a couple things, but
5 one, you know, I think there can be some value
6 to doing age dating, but I do think you have
7 to be careful. This system has been so
8 heavily pumped. Things have been mixed up so
9 much in this system.

10 You have boreholes that are open to
11 multi-aquifers. You have flow down the
12 annulus. Getting an undisturbed, natural, a
13 sample that reflects an actual travel time
14 through the system under natural conditions.
15 It may be difficult. It may be impossible. I
16 don't know. I'm not saying don't do it. I
17 think there is value of getting those age
18 dates. But the band of uncertainty about your
19 ages may be wider than the geochemists will
20 tell you on the basis of the lab analyses.

21 Another point if we jump to the
22 transport modeling -- well, let me go back one
23 step. Again, on the age, the point I was
24 trying to make there, whether or not you do
25 the age dating and get the samples, I want to

1 follow up on something that Scott suggested
2 and reinforce that the use of MODPATH to
3 simulate advective transport.

4 Even though it doesn't give you
5 concentrations, can give you for such a low
6 computational effort and low computational
7 cost a lot of insight into how fast things are
8 moving, where they're going, what the effects
9 of transient flow are. Extremely valuable to
10 improve your conceptual understanding at
11 almost no cost. I mean, this is really
12 relatively easy to do once you've developed a
13 reasonably good transient flow model. And
14 it's just a logical step to do before you go
15 to the, all the headaches of transport
16 modeling. And so I would really encourage you
17 to add a few days or a few weeks to the
18 timeline to get a lot of insight from the
19 MODPATH.

20 **MR. MASLIA:** That's what we added. People
21 would love it.

22 **DR. CLARK:** Mary and then Walter and then we
23 need to get back on our video streaming again.

24 **DR. HILL:** Two things. One is you also
25 mentioned stream flow data, and Cudgels'

1 [Codgels -ed.] Creek -- I don't know if I'm
2 pronouncing that correctly -- is entirely
3 within the model and there's, actually, you
4 have several streams that are entirely within
5 the model and many of them go under roads
6 which provides perhaps when the road was
7 constructed, they might have done some kind of
8 analysis about stream flow that you can use to
9 get a low flow measurement. You might have a
10 fairly large, a small weight, a large variance
11 on that. But it's extremely important to have
12 some kind of flow data to compare your model
13 against.

14 **MR. FAYE:** The USGS in North Carolina does
15 have their standard regression equations with
16 soils and drainage area and whatever for
17 estimating average flow conditions and things
18 like that. Probably in the upstream reaches
19 of these streams that would be a possibility.
20 The downstream reaches are all tidally
21 affected, and Wallace Creek is tidally
22 affected big time. So we could definitely
23 take some shots at estimating a long-term
24 average, low flow or average flow, whatever.

25 **DR. CLARK:** Walter, go ahead.

1 **DR. GRAYMAN:** Just briefly, just actually
2 going back to what Ben was saying. I wasn't
3 quite satisfied with the closure on the
4 recharge issue. Within PEST do you set bounds
5 on the, do you give it an initial recharge
6 value and then set bounds on it and allow it
7 to --

8 **MR. SUAREZ:** Yes, an initial value and you
9 can set your bounds --

10 **DR. GRAYMAN:** I think we may be getting a
11 little bit into an interface issue. And I'm
12 talking about here an interface issue in terms
13 of professions between surface water
14 hydrologists and groundwater hydrologists.
15 And then I think Ben is probably the only one
16 here who's probably kind of the official
17 surface water hydrologist.

18 **MR. HARDING:** ^.

19 **DR. GRAYMAN:** Well, but we're all
20 hydrologists. I'm not sure that we really
21 explored that as much as possible because I
22 tend to agree with Ben. At least surface
23 water hydrologists feel they can fairly well
24 accurately estimate what the amount of water,
25 at least entering the upper zones of the soil

1 than maybe what groundwater hydrologists feel
2 surface water hydrologists can do. I'll leave
3 it at that.

4 **DR. CLARK:** Let's wrap it up then. We have,
5 it's our break time, and we reconvene at 3:30
6 at which time we'll hear questions from the
7 public.

8 (Whereupon, a break was taken between 3:15
9 p.m. and 3:30 p.m.)

10 **MR. MASLIA:** Panel members here because
11 there's a decision or a thumbs up or thumbs
12 down approach for the panel to -- because it's
13 really your decision as panel members. So
14 I'll just wait 'til all our panel members are
15 here.

16 According to the schedule, we're
17 supposed to have another half hour of
18 discussion and then go into the public
19 presentation part. We have allotted two
20 hours. Right now there's a 30-minute
21 presentation by a member of the CAP, Jerry, as
22 well as a presentation-slash-statement by a
23 member of the Department of the Navy, Dr. Dan
24 Waddill.

25 What we're proposing was brought to my

1 attention by Scott Bair is he's got a prepared
2 presentation for other purposes about Woburn
3 that may have some important information for
4 us in terms of what we're doing here at Camp
5 Lejeune and I would be interested in it from a
6 professional standpoint if nothing else, and
7 it may, in fact, generate more questions.

8 So what I'm proposing is that we move
9 the public presentation to start now. Do the
10 public presentations and then we should have
11 sufficient time for Scott to make his
12 presentation and then we can follow that with
13 additional questions. Is there any issue?
14 Does anybody on the panel have an issue with
15 that adjustment to the schedule?

16 Walter?

17 **DR. GRAYMAN:** Can we move Scott's to right
18 at the end, the last thing?

19 **MR. MASLIA:** That's after the public
20 presentations.

21 **DR. GRAYMAN:** Okay so the stuff you were
22 talking about --

23 **MR. MASLIA:** Well, no, not his but it may
24 add more information that we want to take into
25 account to, and so we would basically end the

1 day with maybe a longer discussion period than
2 that. So is there any, is that okay with
3 everybody?

4 DR. CLARK: Is that a problem with the, Dr.
5 Waddill and Mr. Ensminger?

6 MR. ENSMINGER: No.

7 MR. MASLIA: So if that's the case we're
8 into public presentations.

PANEL CHAIR ACCEPTS STATEMENTS AND QUESTIONS
FROM PUBLIC
(REPEAT STATEMENT OF PURPOSE OF PANEL)

9 DR. CLARK: According to protocol I'm
10 supposed to read the charge again to the panel
11 so that everybody will know that this is a
12 public meeting and what it's supposed to
13 accomplish. So in order to follow protocol
14 I'm going to do that if you'll bear with me.

15 This is an expert panel assessing
16 ATSDR's methods and analysis for historical
17 reconstruction of groundwater resources and
18 distribution of drinking water at Hadnot
19 Point, Holcomb Boulevard and vicinity, U.S.
20 Marine Corps Base, Camp Lejeune, North
21 Carolina. The purpose and scope of this
22 expert panel is to assess ATSDR's efforts to
23 model groundwater and water distribution
24 systems at the U.S. Marine Corps Base, Camp

1 Lejeune, North Carolina.

2 This work includes data discovery,
3 collection and analysis as well as water
4 modeling activities. To assist the panel
5 members with their assessment, they have been
6 provided with the methods used and the results
7 obtained from ATSDR's previous modeling
8 efforts at Camp Lejeune which focus on the
9 area of Tarawa Terrace and vicinity. The
10 panel is specifically charged with considering
11 the appropriateness of ATSDR's approach,
12 methods and time requirements related to water
13 modeling activities.

14 It is important to understand that the
15 water modeling activities for Hadnot Point,
16 Holcomb Boulevard and vicinity are in the
17 early stages of analysis; hence, the data
18 interpretations and modeling methodology are
19 subject to modifications partly based on input
20 provided by members of this panel.

21 ATSDR expresses a commitment to weigh
22 questions from the public and to respond to
23 public comments and suggestions in a timely
24 fashion. However, in order for this panel to
25 complete its work, it must focus exclusively

1 on data discovery and analysis and water
2 modeling issues. Therefore, the panel will
3 only address questions or comments that
4 pertain to data discovery and analysis and
5 water modeling efforts.

6 For all non-modeling water questions
7 or statements, the public can contact the
8 ATSDR Camp Lejeune Information Hotline at
9 telephone ~~7-7-0-4-8-8-3-5-1-0~~ [770-488-3510 -
10 ed.] or e-mail atsdrcamplej@cdc.gov.

REPRESENTATIVE OF CAMP LEJEUNE COMMUNITY ASSISTANCE

11 **PANEL (CAP)**

12 And with that, why, we can begin the
13 public presentations and we're going to hear
14 from Jerome Ensminger first.

15 **MR. ENSMINGER:** Good afternoon. My name is
16 Jerry Ensminger. I am a member of the ATSDR's
17 Camp Lejeune Community Assistance Panel, and
18 I've been involved in this incident since
19 August of 1997. Over these past 12 years I
20 have viewed thousands of documents related to
21 this situation and what I have discovered is
22 both disheartening and disgusting.

23 Department of the Navy and United
24 States Marine Corps officials and
25 representatives have in the past and continue

1 right up to the present to misrepresent and
2 deny the facts. They have done this by making
3 false and misleading statements, providing
4 incomplete or false data and by withholding
5 key data that is crucial to the findings of
6 truth in this situation.

7 I don't expect any one of you to take
8 my word as proof of these serious allegations
9 I'm making against these supposed honorable
10 government entities. That's why I've provided
11 all of you with some of the actual historical
12 documents which came directly from their files
13 so you can witness the deception with your own
14 eyes.

15 Now, I want to take you through some
16 of these documents, and you have them in a
17 binder there in front of you, and I've picked
18 out some key documents. And these are only a
19 few examples of what went on here.

20 But the first document is a letter
21 dated 3 February from 1986 from the United
22 States Environmental Protection Agency Region
23 Four. And it states, "Dear Sir: On November
24 1st, 1985, Messrs. Mathis and Holdaway of this
25 Agency met with Facilities Engineering Staff

1 at Marine Corps Base Camp Le Jeune."

2 Okay, I want to skip down to the
3 second paragraph, what's highlighted on your
4 document. "Both Messrs. Holdaway and Mathis
5 became aware that there was evidence from
6 sampling as early as 1983 or 1984 of diffuse
7 contamination of the groundwater with
8 unspecified organic substances, and that as a
9 result of detection of unspecified volatile
10 organic compounds in raw potable water
11 samples, certain potable wells at Hadnot Point
12 were taken out of service. In consideration
13 of the fact that the major portion of the
14 resident population of Camp Le Jeune is
15 dependent on Hadnot Point well field as its
16 potable water supply, the parties in the
17 meeting agreed that any potential
18 contamination of this resource should be
19 investigated as expeditiously as practical.
20 It was also established that there was no
21 contamination detected in treated potable
22 water..."

23 Let me say that again. "It was also
24 established that there was no contamination
25 detected in treated potable water distributed

1 at Camp Le Jeune, however the extent and
2 sensitivity of analytical procedures for
3 specific organic substances was not fully
4 discussed."

5 This was 1986. They found
6 contamination in the potable water at the tap
7 in Camp Lejeune as early as 1980. Let's go
8 down to the second page of that letter.

9 It says, "This Agency is concerned
10 that a potential for human exposure to
11 hazardous substances and hazardous wastes via
12 the Camp Le Jeune water supply may exist due
13 to the presence of such materials in the
14 groundwater in the general vicinity of the
15 potable well field. The existence of such a
16 potential exposure would warrant consideration
17 of this area for inclusion on the National
18 Priority List, with an attendant increase in
19 the expediency of investigation and
20 remediation." Now, the EPA didn't believe
21 them and that's why they recommended this to
22 go on.

23 Now, this next document comes from a
24 technical working committee which was the
25 predecessor to the Restoration Advisory Boards

1 for the EPA. And they had members from the
2 EPA. They had members from the state
3 environmental regulatory agency there. They
4 had members from the local community there.
5 They had members from the ~~LANDIV~~* [LANTDIV -
6 ed.]. And this is a court-recorded document,
7 and the gentleman by the name of Bittner was
8 the City Manager for Jacksonville. And they
9 were discussing the contamination in the
10 Hadnot Point system at this point.

11 And Mr. Bittner asked the question,
12 “What kind of tests were you getting when you
13 were running those contaminated wells in terms
14 of water quality?” He says, “I imagine it
15 would be pretty much diluted but you were
16 still probably getting some readings if you
17 ever took a scan.”

18 Mr. Bob Alexander who was the
19 environmental engineer for Camp Lejeune
20 answered his question. He said, “We had very
21 little, if any data, before we realized our
22 ground water was contaminated.” I mean that
23 is an out-and-out lie.

24 So Mr. Bittner follows up. “So
25 there’s no record of it in terms of what you

1 were pumping." Alexander, "We had some tests-
2 -like at the Tarawa Terrace area--before we
3 realized that ABC Cleaners was polluting our
4 wells there. We had some tests and ended up
5 with some measurable concentrations. But they
6 were almost at the detectable level. When
7 you're taking out of the Hadnot Point area 35
8 wells that had been servicing that system,
9 probably a well would only run for about two
10 days. It would only be about five or six
11 wells running, so we had a rotating cycle of
12 operating on those wells. It would be
13 practically impossible to say what wells
14 contributed what compounds on any given day.
15 You'd have to backtrack from the residence
16 time in the reservoir and all that to see what
17 wells were going two days ago."

18 So Bittner says, "And, basically, Bob,
19 there's no record of that." And he says, "It
20 would be practically impossible to track that
21 down."

22 And then Ms. Cheryl Barnett, who was a
23 representative from ~~LANDIV~~ [LANTDIV -ed.] up
24 in Norfolk, Department of the Navy, who is by
25 the way now a high ranking official up there

1 with their environmental branch, Barnett pipes
2 in and says, "There were no requirements, you
3 know, the requirements to test your finished
4 water for VOCs; it's a new requirement. It's
5 a new EPA drinking water requirement, so there
6 was no prior testing program before. It is
7 just purely in the course of this
8 investigation that we discovered that problem
9 to begin with and since that time they've been
10 monitoring the finished water effluents, but
11 it was never a requirement."

12 Now, that statement, "it was just
13 purely in the course of this investigation
14 that we discovered that problem to begin
15 with..." This is a person that was trusted
16 with our environmental health. She is a high-
17 ranking official now in the Department of the
18 Navy's environmental program. I want you take
19 a look, and she was talking about the
20 confirmation study when they discovered this
21 contamination.

22 This letter was written on 10 August,
23 1982, by Grainger Analytical Laboratories out
24 of Raleigh, North Carolina. The chemist up
25 there and the part-owner of the laboratory saw

1 these samples, saw the interferences in the
2 TTHM testing that they were doing, and they
3 took it upon themselves to isolate the
4 interfering chemicals and quantify them. And
5 they wrote this letter to the Commanding
6 General of Camp Lejeune.

7 Previously all samples from site TT
8 and HP, which is Tarawa Terrace and Hadnot
9 Point, "presented difficulties in performing
10 the monthly Trihalomethane analyses. These
11 appeared to be at high levels and hence more
12 important from a health standpoint than the
13 total Trihalomethane content. For these
14 reasons we called the situation to the
15 attention of Camp Lejuene personnel. Results:
16 The identity of the contaminant in the well
17 field represented by samples 206 and 207 was
18 suspected to be Tetrachloroethylene.

19 And at Hadnot Point it was
20 Trichloroethylene. If you'll go to the second
21 page of that letter, there's where they broke
22 it down. Those were the results that they got
23 from those samples. Sample 120 was Hadnot
24 Point tap water, 1,400 parts per billion.

25 Whenever the fuel leak took place at

1 the Holcomb Boulevard water system in January
2 of 1985, they called the state in to do split
3 samples because they thought they had all
4 their contaminated wells offline already
5 anyhow. Guess what? They still had one, one
6 contaminated well online, Well 651 at Hadnot
7 Point. They had shut the Holcomb Boulevard
8 plant down and opened the valves up and put
9 them back on Hadnot Point water to flush the
10 system out, to flush the fuel that had leaked
11 out of a backup generator line into their
12 treated water storage tank.

13 These were the samples, these were the
14 results of the samples that the state took.
15 Now, this was dated, well, you can see the
16 date of the analysis, February of '85. Now
17 these people sat in these meetings subsequent
18 to these tests, these analytical results and
19 those initial letters that I read to you, and
20 lied. I mean, this was one contaminated well
21 that was creating these results in February of
22 '85, 1,148.4 parts per billion at the
23 elementary school in Berkeley Manor housing
24 area.

25 If you'll go down to your next

1 document which is a TTHM test. When the TTHM
2 regulation was coming into effect, the
3 Department of the Navy contracted with the
4 Department of the Army to have their
5 environmental hygiene team come to Camp
6 Lejeune and other Naval facilities and do,
7 start doing TTHM tests for their water
8 systems. You can see this one was dated 29
9 December, 1980. The first test that they did
10 was in October of '80. You can see what they
11 wrote down here at the bottom, heavy organic
12 interference. You need to analyze for
13 chlorinated organics by the GC/MS method.

14 Go to the next one, January of '81.
15 You need to analyze for chlorinated organics
16 by GC/MS. February of '81, water highly
17 contaminated with other chlorinated
18 hydrocarbons, in parentheses, solvents. Yet
19 these people sit in meetings and say they
20 didn't know?

21 ATSDR, you know, while they've had
22 their own faults throughout this process, has
23 had one devil of a time trying to get
24 information from these people. There has been
25 stonewalling, you name it. This is a letter

1 written on September 2nd, of 1994 from ATSDR to
2 what was known as the Navy Environmental
3 Health Center then, complaining about Camp
4 Lejeune, about the Marine Corps and Department
5 of the Navy, about getting documents and data.

6 ATSDR identifies and obtains documents
7 needed for evaluation to develop the public
8 health assessment by discussing the public
9 health issues with the installation and having
10 them send us documents where the information
11 can be found. As you are aware, we have had
12 much difficulty getting the needed documents
13 from Marine Corps Base Camp Lejeune. We have
14 sent Marine Corps Base Camp Lejeune several
15 requests for information and, in most cases,
16 the responses were inadequate and no
17 supporting documentation was forwarded. That
18 was September 2nd of 1994.

19 Go down to these e-mails. Ms. Kelly
20 Dreyer, who worked at Headquarters Marine
21 Corps, was put in charge of the Camp Lejeune
22 water contamination issue. ATSDR had been
23 provided incorrect water system data for not
24 only the public health assessment, but for a
25 study that was being done on small for

1 gestational age in adverse pregnancy outcomes.
2 They never told ATSDR that the Holcomb
3 Boulevard water system wasn't constructed
4 until 1972.

5 ATSDR went through this entire process
6 thinking that those, all those housing areas
7 on the other side of Wallace Creek on the main
8 part of the base, three major housing areas:
9 Midway Park, Berkeley Manor and Paradise Point
10 were always on that clean Holcomb Boulevard
11 system. Well, the study period for ATSDR was
12 1968 through 1985. Well, the Holcomb
13 Boulevard plant wasn't built 'til '72.

14 When I first saw that study, and it
15 came out -- well, it came out a long time ago,
16 but the first time I really looked at it in
17 depth, I said what the devil's going on here.
18 They only had 31 babies identified in that
19 study as being long-term exposed in utero to
20 trichloroethylene, TCE. I said that can't be
21 right.

22 I called Dr. Bove up -- I didn't call
23 him. I sent him an e-mail. And he sends me
24 an e-mail back and he goes what the hell are
25 you talking about. So I picked the phone up

1 and I called him, and I said you had I don't
2 know how many thousand housing units over
3 there, I said, that was, I said, the Hadnot
4 Point water system wasn't constructed 'til
5 '72. I said you only identified 31 babies in
6 this study as being exposed to
7 trichloroethylene, and I said, all those
8 housing areas were on Hadnot Point water all
9 those years. He goes oh my god.

10 Now when the Marine Corps was asked
11 why they didn't provide the correct data
12 whenever this e-mail was sent to them by Kelly
13 Dreyer, who was the project manager for this
14 thing, Tom Townsend, who is a retired major
15 and lives in a cave out in Idaho -- he doesn't
16 really live in a cave, but he likes to say
17 that. He's like a hermit.

18 But he wrote over a thousand FOIAs.
19 He lost a son and also his wife, and he was
20 very diligent in writing Freedom of
21 Information Act requests. And Tom Townsend
22 identified this. And Tom Townsend you've got
23 to understand, everything he writes, he does
24 it by hand on a yellow legal pad, and that's
25 his official correspondence. He don't type.

1 He doesn't use a computer, and that's how he
2 sends his stuff out.

3 The Marine Corps said they used, they
4 saw that he had copied ATSDR on his initial
5 letter pointing out this incorrect data. So
6 they surmised that ATSDR was going to use his
7 letter pointing out the wrong, the incorrect
8 water system data as their notification. They
9 said this in a press interview with Dan Rather
10 and an AP article.

11 Well, you saw what kind of trouble
12 ATSDR had on 2 September in 1994. Here's a
13 letter from December 9th of 2005. "ATSDR has
14 experienced delays in obtaining requested
15 information and data pertaining to historical
16 water-quality sampling data and site remedial
17 investigation reports." And they were told.

18 "ATSDR staff is attempting to meet the
19 project completion timelines discussed with
20 Marine Corps staff in August. To do so, we
21 must be provided all documents that relate to
22 base-wide water issues immediately. The
23 Marine Corps is responsible for the
24 identification and timely sharing of all
25 relevant documents relating to the base-wide

1 drinking water system. This includes
2 documents that ATSDR may not be aware of as
3 well as documents that are in possession of
4 DOD but may no longer be located at the Camp
5 Lejeune base. Discovery of this documentation
6 must not rely on specific requests from our
7 staff, but on our shared goal of ensuring
8 scientific accuracy of our study and DOD's
9 responsibility to provide the information.
10 ATSDR staff can coordinate with the United
11 States Marine Corps staff to determine the
12 appropriateness of any document as it relates
13 to our study. We request that your staff
14 verify and confirm the existence of the
15 documents listed in the attachment. We also
16 request that your staff identify for us any
17 other documents that may be useful to ATSDR
18 for its water modeling analyses," and it goes
19 on and on.

20 Yesterday we find out, we had our
21 Community Assistance Panel meeting, that
22 there's another whole file of documents
23 related to underground and aboveground storage
24 tanks, some electronic portal from a
25 contractor. I mean, this never ends.

1 These are a few examples of the
2 misinformation, disinformation, half-truths
3 and outright lies that have been told by
4 representatives of the Department of the Navy
5 and the United States Marine Corps. There are
6 many, many more. They have provided
7 inaccurate data to the ATSDR, they have
8 misrepresented the levels and the extent of
9 the contamination to the media and to the
10 public at large. They have, and they continue
11 to misrepresent their negligent behavior which
12 created the conditions that led to the
13 drinking water contamination aboard the base.

14 Their negligent behavior was they just
15 ignored it. They had warning after warning
16 after warning. They were told by I don't know
17 how many different analytical laboratories in
18 I don't know how many analytical samples and
19 results that they had a problem with these
20 contaminants, and they never tested their
21 wells. They never tested the individual
22 drinking water wells until they started in
23 July of 1984 knowing full-well they had a
24 problem.

25 The Marine Corps' representative, who

1 did the interview for Dan Rather's story last
2 October, was a Lieutenant Colonel Mike Tencate
3 from Headquarters Marine Corps. He's a
4 lawyer. He sat right there and told Mr.
5 Rather that whenever they discovered that they
6 had a problem with their wells, they took them
7 offline. Mr. Rather asked him, he said where
8 do you get your water? He said from wells.
9 But you never tested them? You knew you had
10 this stuff in your tap water, you never tested
11 them? He repeated his answer again. Whenever
12 we discovered that it was in the wells, we
13 took them offline.

14 They tried to make the excuse that
15 they thought they had AC-coated pipes that was
16 creating this stuff in the water. Trouble is
17 they never went back and even checked what the
18 construction materials of their own water
19 system was to verify or deny that claim.
20 Morris, in his water modeling, has shown that
21 there was only AC-coated pipes in one water
22 system, and that was Holcomb Boulevard. The
23 two highest contaminated systems had none in
24 it, Tarawa Terrace and Hadnot Point.

25 And in my statement here it says in a

1 recent interview with Dan -- I already went
2 over that. As soon as they discovered he said
3 they took the wells offline. Well, the sole
4 source for drinking water at Camp Lejeune are
5 deep ground water wells. Exactly where did
6 the authorities at Camp Lejeune think this
7 contamination was coming from or emitting
8 from. It wasn't coming from the supply wells.
9 Perhaps they had some rogue water treatment
10 plant operator at the treatment plant pumping
11 these chemicals into their treated water,
12 right?

13 The truth is that base officials knew
14 about it by August of 1982 that the well
15 fields for Tarawa Terrace and Hadnot Point
16 were the source of the contamination aboard
17 the base's water supply system. Instead of
18 decisive action, excuses were made, the base
19 supervisory chemist offered a suggestion that
20 some of the contamination could be coming from
21 asbestos coated pipes in the systems. Well,
22 the only instances where any contamination was
23 discovered in that system was when the base
24 operators were opening in the clean Holcomb
25 Boulevard system, was when the operators were

1 opening and closing the isolation valves which
2 interconnected the Holcomb and Hadnot Point
3 systems.

4 And, you know, there are some very
5 pertinent questions which need to be asked
6 here. Why didn't the Department of the Navy
7 and USMC officials research the construction
8 materials of the contaminated system back in
9 the early 1980s? The main question would be
10 why did it take more than four years to sample
11 the supply wells? In that, that question has
12 been asked multiple times and no one can get a
13 straight answer from the Department of the
14 Navy or the Marine Corps.

15 It was my understanding that this
16 expert panel was requested by the Department
17 of the Navy. It is my opinion that they are
18 hoping that this forum will kill the Hadnot
19 Point water system modeling. In fact, I
20 believe they would like nothing more. If
21 science is ever going to have a better
22 understanding of the effects of these
23 chemicals have on human beings, it is
24 imperative that this effort continue. If the
25 victims of this tragedy are ever going to

1 fully understand what they were exposed to or
2 what caused the death of their loved ones or
3 their illnesses, this water modeling effort
4 must be seen through to its completion.

5 And my involvement in this is my
6 daughter, Janie, was the only child of mine
7 that was conceived while her mother and I
8 lived at Camp Lejeune in one of the
9 contaminated housing areas. When Janie was
10 six years old, she was diagnosed with acute
11 lymphocytic leukemia. I watched Janie go
12 through hell for two and a half years before
13 her ultimate death.

14 And from the date of her diagnosis
15 until the date that I found out about the
16 contamination, I did what any normal parent
17 that had a child, who lost a child to a
18 catastrophic long-term illness would do. I
19 wondered why. And it was fourteen and a half
20 years until I was walking in the living room
21 with a plate of spaghetti to watch the evening
22 news and the Public Health Assessment had come
23 out. And one of the local TV stations picked
24 up on the story and did a blurb on the evening
25 news.

1 And I was -- I just walked into my
2 chair. I was standing there and the reporter
3 said the contaminants that have been found in
4 Camp Lejeune's drinking water from 19 -- they
5 erroneously said from 1968 through 1985 at
6 that point -- were linked to childhood cancer,
7 primarily leukemia. I dropped my plate of
8 spaghetti on the living room floor, and it was
9 like God had opened the sky up and said,
10 Jerry, that nagging question that has been
11 with you for fourteen and a half years, here
12 is a possible answer to it, not a confirmed
13 but a possible one.

14 And I started making phone calls and
15 started digging. Here I am. That was August
16 of 1997, and I've been asked when I'm going to
17 give this up. And I've made the statement to
18 the press and I made a statement indirectly to
19 the Commandant of the Marine Corps. I said
20 I'll give this up when you do what's right by
21 our people or when you pat me in the face with
22 a damn shovel and blow Taps over me, that's
23 when I'm going to quit. And I mean it. Thank
24 you.

25 **DR. CLARK:** Mr. Ensminger, we thank you for

1 your statement. Would you be willing to take
2 some questions?

3 **MR. ENSMINGER:** Certainly.

4 **DR. CLARK:** Does the panel or anyone in the
5 audience have any questions or comments?

6 **MR. HARDING:** Bob, I have some for Mr.
7 Ensminger. I suspect I know the answer to
8 this, but I'd like you to address it directly
9 because one of the charges that we have is to
10 ask if the timeline of this study is
11 sufficient. And you've heard, you've been
12 here the whole time. You've heard all of the
13 discussions about the technical difficulties
14 and the complexities of this and some
15 discussion about whether it can be done by,
16 what is it, December. And I wanted to know
17 what you and also your sense of the rest of
18 the stakeholders you're associated with think
19 of a longer time to get an answer if the
20 answer could be better.

21 **MR. ENSMINGER:** I, personally, and I know
22 some people that said, you know, that there's
23 been enough time spent. Those people aren't
24 really as deeply involved in this, but anyone
25 who is deeply involved -- and Mike Partain is

1 another victim back there.

2 He was born at Camp Lejeune. His
3 father and mother lived there, and he was
4 conceived there and born there. He ended up
5 with being diagnosed with male breast cancer
6 two years ago. We've also identified ten
7 other cases of people at Camp Lejeune, either
8 dependents or male Marines who had breast
9 cancer.

10 But to answer your question, I know
11 science takes time; good science does take
12 time. And I have no qualms at all with taking
13 more time to ensure a good product, and that's
14 my answer.

15 **DR. HILL:** Just a quick question, the
16 excerpt from CERCLA 47, do you have a year for
17 that?

18 **MR. ENSMINGER:** A year? Yeah, it was May --
19 no, I'm sorry, August of 1988.

20 **DR. HILL:** Nineteen eighty-eight. Thank
21 you.

22 **DR. CLARK:** Any more questions or comments
23 from panel or audience?

24 (no response)

25 **MR. ENSMINGER:** Now, to go back to that

1 other question about how much time it's going
2 to take. What I do take exception to is the
3 dragging this thing out by the trickle of
4 documents. And every time something new comes
5 out it kicks this thing to the can further
6 down the road, and that pisses me off. I
7 mean, I should say it frustrates me. Dr.
8 Sinks does not like some of my mannerisms.
9 I'm me. I'm a retired former Marine. I was a
10 drill instructor and I am what I am and you
11 get what you see.

12 **DR. CLARK:** Anyone else have comments or
13 thoughts, questions they'd like to raise for
14 Mr. Ensminger?

15 **MR. HARDING:** I just have a comment to the
16 panel. Just many of you may be aware of this,
17 but there was a, if you will, an epidemic of
18 TCE contamination events discovered in the
19 fall of 1980, and I guess Bob might know this.
20 I think it was a regulatory requirement at EPA
21 that this testing for THMs be done.

22 And I've seen other documents just
23 like this. And it, literally with the GC
24 trace on it with an arrow saying, you know,
25 possible TCE contamination. And this is how,

1 I know it was true in Phoenix. I think it was
2 true in Redlands, California. I can't
3 remember, a number of the cases that I've seen
4 where this October of 1980, there's a lot of
5 this that went on.

6 **DR. CLARK:** It turned out that when we were
7 working on the THM methods that they were very
8 good for capturing VOCs at the same time. And
9 it was kind of a confounding and puzzling
10 effect. But the point that Mr. Ensminger
11 makes is absolutely valid. And I do have a
12 question.

13 First, Mr. Ensminger, you identified
14 correctly, I think, the fact that the THM
15 samples had VOCs in them. Did you look at
16 anything other than just the three samples
17 that you --

18 **MR. ENSMINGER:** Oh, yeah, there's many more.
19 I mean, there's, we've got a whole file of the
20 TTHMs from the Army Environmental Hygiene team
21 and then the Grainger Laboratory that wrote
22 the letter. We understand that they were told
23 by the Department of Navy to quit quantifying
24 the amount of chemicals, the interfering
25 chemicals, they were finding.

1 So they put on there by it with an
2 asterisk that this chemical was still being
3 found in that water system and
4 tetrachloroethylene was still being found in
5 the Tarawa Terrace system. They quite
6 quantifying it, but the actual analytical
7 results, there's many of them, and they're in
8 the files.

9 **DR. CLARK:** Did you do any looking at
10 samples at a given location over time, for
11 example, after those wells had been taken
12 offline to see if there'd been changes in the
13 THM values?

14 **MR. ENSMINGER:** I really didn't see that
15 many TTHM samples after the fact. I don't
16 know. I haven't seen them. I'm sure they're
17 somewhere.

18 **DR. CLARK:** They would be required to submit
19 them to the state, but that's something --

20 **MR. ENSMINGER:** The State of North Carolina
21 is like, you know.

22 **MR. PARTAIN:** Jerry, that had that TTHM
23 problem, too, at the air station.

24 **MR. ENSMINGER:** Yeah, they had a problem
25 over at the air station with TTHMs. They

1 exceeded the MCLs at the air station. And
2 they had salt water intrusion over there.

3 **DR. CLARK:** Probably brominated compound.
4 It's probably getting brominated compound.

5 **MR. ENSMINGER:** Yeah, that's what it was.

6 **DR. ASCHENGRAU:** I just want to follow up
7 with you or the ATSDR folks about that file
8 that you said was, came to light yesterday.

9 **MR. ENSMINGER:** Yeah, Morris had that on one
10 of his slides this morning.

11 **DR. ASCHENGRAU:** So has it been given to
12 ATSDR for review to see if there's any useful
13 information in it?

14 **MR. FAYE:** That's your call, Morris.

15 **MR. MASLIA:** Bob's punting to me. Actually,
16 in a series of e-mail communications between
17 Bob, myself and the Marine Corps we became
18 aware of it the beginning week of March of
19 this year. And we did ask, it's, as Jerry
20 pointed out correctly, it's housed at a
21 website, web portal, by a consultant to
22 NAVFAC, Katlan Associates, Katlan Engineers.

23 We have been given a password and
24 access to that. Bob initially downloaded over
25 100 documents. We have -- not pages,

1 documents some of which are hundreds of pages
2 long -- and that's why I referred to it as
3 information because we've done an initial
4 catalogue of that. We've got that on an Excel
5 file.

6 And that's when I was discussing
7 earlier today that perhaps one way to use this
8 in the most efficient manner as the universe
9 of information is expanding and trying to
10 stick on some timeline, whatever that may be
11 or the panel recommends, would be to view this
12 as a second, quote, independent set of data
13 that we might cull from those documents.
14 Develop a model, calibrate to a set that's
15 already been described here that Rene and Bob
16 and Barbara have described, and then perhaps
17 be able to test or give ourselves more
18 confidence on running the model with this
19 second set.

20 That would do two things. One, it
21 would not completely ignore this other data.
22 It would keep us going down the path, but it
23 would also answer questions that we, as people
24 have pointed out that with Tarawa Terrace we
25 did not have the opportunity to because the

1 data just weren't there as a second set of
2 information. So that's thrown out.

3 Consider in your recommendations, if
4 you would, for the panel members. But that's
5 our thinking right now is that is a
6 possibility. Obviously, you have do nothing
7 with it, which I don't want to go down that
8 road, or incorporate it with our current data,
9 which we know how long we've been, what, since
10 June of 2007, Bob?

11 **MR. FAYE:** Probably a year and a half.

12 **MR. MASLIA:** A year and a half already on
13 data analysis and going through these
14 documents and stuff like that. So if the
15 panel would, I think we would appreciate some
16 feedback on that.

17 **DR. ASCHENGRAU:** And then there's really no
18 way of knowing right now if there are still
19 yet other undiscovered sources of information?

20 **MR. ENSMINGER:** Well, we know that there's
21 some key stuff that's missing from the files.
22 I don't know if -- one thing I forgot to
23 mention was that there's an Associated Press
24 article out today, ATSDR withdrew the entire
25 Camp Lejeune Public Health Assessment

1 yesterday.

2 **DR. HILL:** What does that mean?

3 **MR. ENSMINGER:** It's invalid. Benzene was
4 left off of it. And we found, Mike Partain,
5 who's my brain back there, he's been a godsend
6 to me. We've been going through all these
7 CERCLA documents and putting two-and-two
8 together, and we discovered that the
9 contractor that was doing the confirmation
10 study at Camp Lejeune in 1984, in their plan
11 of work and safety, work and safety plan for
12 their contract in early 1984, agreed to a
13 monthly progress report on their efforts to,
14 on the confirmation study on all the
15 contamination sites on the base to start in
16 1984.

17 We found the progress report for May,
18 June and July. And in July the first samples
19 were taken of monitoring wells and water
20 supply wells that were close to the
21 contamination sites. Oddly enough, we don't
22 have any more progress reports for that
23 confirmation study. They ended at July. So
24 when they would have got started getting the
25 results back, the August, September, October,

1 November reports, they're missing from the
2 files.

3 But we did find a report of the
4 analytical data. We can't even find the
5 confirmation study report. The Marine Corps
6 absolutely refused, they disagreed with the
7 conclusions. I've got this in writing. And
8 absolutely refused to release that report to
9 any outside agency, but they did agree to
10 release the analytical data.

11 We found the results from the July
12 sample from Well 602, which was right by the
13 Hadnot Point fuel farm, and it had high levels
14 of benzene in it in July. Do you know when
15 the well was taken offline? 30 November. You
16 can't tell me this company didn't alert them
17 that they had high levels of benzene in that
18 well when they found it in that analytical
19 result. That's why we can't find the progress
20 reports for August, September, October, and
21 November.

22 **DR. ASCHENGRAU:** So I do think it does fall
23 within our purview to make a recommendation
24 that all of the relevant information should be
25 given to the research group and that would

1 affect our other recommendations for the
2 modeling, et cetera.

3 **MR. ENSMINGER:** That would be appreciated.

4 **DR. CLARK:** Morris wants to say something.

5 **MR. MASLIA:** Yeah, I want to clarify for
6 those who are on the panel who are not really
7 familiar with the Health Assessment process.
8 What Jerry just mentioned that the Health
9 Assessment for Camp Lejeune, it's the 1997
10 Health Assessment, was pulled.

11 In a series of discussions, as Jerry
12 said, one of the factors were -- and this is
13 in one of the tables, I think Table 8 or C-8,
14 C-10 in Bob's report -- you'll see benzene
15 levels 720, 380 and so forth. That was
16 completely omitted from the Health Assessment.
17 That's point one. Yet, a year later, the 1998
18 Health Study coming out of Frank's division,
19 mentioned benzene contamination of 700. So
20 obviously, the data was not put into the
21 Health Assessment.

22 Other issues, as have been pointed out
23 previously, was the start-up date with the
24 Holcomb Boulevard plant was incorrect. There
25 have also been issues of, I guess when ATSDR

1 was moving offices, some of the original
2 references to support the Health Assessment
3 cannot be located.

4 **MR. ENSMINGER:** Not some, all. They can't
5 even provide the supporting documentation for
6 the thing that created the document. How in
7 the hell can you make a stand, stand on a
8 document and stand behind it when you don't
9 have the supporting documents that it was
10 created from? It's worthless.

11 **MR. MASLIA:** As a consequence, yesterday our
12 Division Director and Tom Sinks told the CAP
13 that the Health Assessment, the 1997 Health
14 Assessment, was being removed from the
15 website. It's still, as any document would
16 be, in hard copy if someone requests it. But
17 if they request it there'll be a caveat or
18 some letter with it explaining that.

19 And, of course, then they would wait
20 until we finish the current study
21 investigation for Tarawa Terrace and then also
22 the Hadnot, Holcomb Bridge area to do whatever
23 Agency management decides what approach they
24 want to take. So I just wanted to clarify
25 that for those who are not familiar or with

1 the Health Assessment itself.

2 DR. CLARK: Walter, you wanted to make a
3 comment?

4 DR. GRAYMAN: Yeah, this morning there was
5 at some point, there was a graph shown in
6 which it showed that there's a lot more data
7 available from 1998 to the present time. And
8 the explanation was that, and I can't remember
9 whether it was federal or state law
10 regulations that the utility hold onto the
11 records for ten years. Is there something
12 that can be done to ensure that that period is
13 extended so we don't start losing data that
14 becomes ten years old and then is lost?

15 DR. CLARK: I'm assuming that that's
16 probably a state agreement in conjunction with
17 EPA, but I don't know that.

18 MR. ENSMINGER: It's a CERCLA requirement.
19 And it's required to be maintained for 50
20 years on any site that's declared a ~~super-fund~~
21 [Superfund -ed.] site. And there's all kinds
22 of stuff from Camp Lejeune missing. Now they
23 keep saying they have this seven year, in-
24 house requirement to purge their files. I
25 hate to tell them, but they're in violation of

1 the CERCLA laws.

2 And, you know, Morris and Bob Faye had
3 an experience up at the State of North
4 Carolina's archives when they were trying to
5 find all the operating permits for the water
6 system at Camp Lejeune. And they went in
7 there, and they found everything from the
8 beginning of the base, to the opening up of
9 all the different water treatment plants, the
10 water distribution systems, and it went from
11 1941 to all the way up to, what, 1968, or no,
12 '68? And then from '68 all the way to 1990 or
13 '91, the file folder was there. Everything
14 was gone. And then from that point to present
15 everything was there. You tell me.

16 DR. CLARK: Any more questions of Mr.
17 Ensminger?

18 (no response)

19 DR. CLARK: Comments?

20 (no response)

21 DR. CLARK: Well, thank you very much for
22 your presentation. I think --

23 DR. CLAPP: I was just going to say the same
24 thing the Chair just said. I'd like to thank
25 Jerry for his service and his presentation.

1 **DR. CLARK:** Well, I think he reminds us that
2 there's a human dimension to this study that
3 we have to keep in mind. I think we, it's
4 very easy, as you can, if you remember from
5 the previous discussions today, to get lost in
6 the science and the wonders of that aspect of
7 what we're doing. And we'll have more of that
8 tomorrow, but there's a human, real tragedy in
9 some sense, involved in this situation.

10 **MR. ENSMINGER:** We have a website we created
11 for the victims of this thing, and it's
12 www.TFTPTF, that's the abbreviations for The
13 Few, The Proud, The Forgotten-dot-com. And
14 I'm going to tell you, people contact me all
15 the time. You would not believe the cases of
16 non-Hodgkins lymphoma, the cases of leukemia,
17 liver cancer, kidney cancer, bladder cancers
18 of former Marines and sailors and their family
19 members that are coming to our website.

20 It's horrible, and I'm fearful, when
21 we finally do find out the truth in this
22 thing, when we uncover it, we're going to be
23 uncovering one grave at a time. I hope not,
24 but I believe that's what's coming. And I
25 have one more thing to say. You saw the

1 examples of the lies. You've got them right
2 there in your hands. There's only one reason
3 to lie, and that's because you're guilty.

4 **MR. PARTAIN:** I'd also like to invite the
5 members of the panel, on the website there is
6 a historical timeline of events that's
7 referenced with actual documents. Most of
8 them are available on the website. We can
9 pull a document up and read that. It's under
10 the historical document section.

11 It's rather long boring reading, but
12 it at least gives you an idea of what
13 happened. And that goes from basically 1950
14 to 1989, and I'm currently working on the
15 second half of that project, 1990 to the
16 present day. And there's also on the
17 discussion board on the website there is a
18 discussion called Betrayal of Trust and Honor,
19 which is an historical discussion.

20 My degree's in history -- I'm a former
21 teacher -- you'll see I can read the stuff.
22 And it's all referenced to historical
23 documents, too, and that will give you an idea
24 of what was going on. Jerry mentioned in his
25 presentation about Cheryl Barnett saying that

1 we didn't know until this study. Well, the
2 study she's referring to is the confirmation
3 study of 1984.

4 **DR. CLARK:** Thank you very much.

5 **DR. GOVINDARAJU:** Actually, could you please
6 repeat that website again? I wrote it down.

7 **MR. PARTAIN:** It's The Few, The Proud, The
8 Forgotten. If you take the initials, Tango,
9 Frank, Tango, Peter, Tango, Frank-dot-com,
10 TFTPTF.com.

11 **DR. CLARK:** Mary.

12 **DR. HILL:** So there's been mention of health
13 effects that are further along in life than
14 some of the ones that are formally being
15 considered here. And I assume there was some
16 investigation into those and there wasn't
17 enough data to support that, but I just wanted
18 to -

19 **DR. BOVE:** No, no, no, no. That's our
20 future studies, which we can talk about at
21 some point if we -

22 **DR. CLARK:** I suspect we'll end up
23 discussing that further on as we get further
24 into the discussion. I have the same reaction
25 that you do.

1 Any more comments, questions on this
2 particular, on Mr. Ensminger's presentation?

3 (no response)

4 **DR. CLARK:** Okay, to continue on --

5 **MR. HARDING:** Bob, just a comment on what
6 Frank said and Mr. Ensminger, I wasn't
7 completely clear that there were going to be
8 follow-on studies, but it just raises the
9 point again that this, that the key to all of
10 that is going to be the exposure information.
11 And so it's important that that be done as
12 well as it can be. And I want to encourage,
13 and this will be something I advocate in the
14 panel, that ATSDR really focus its efforts on
15 the things and maybe we can help them do that,
16 that are most important to getting that
17 information.

18 **DR. CLARK:** Very good comment.

19 Anything else?

20 (no response)

21 **REPRESENTATIVE OF DEPARTMENT OF NAVY**

22 **DR. CLARK:** We'll let Mr. Dan Waddill from
23 the Department of the Navy ~~to~~ [-ed.]continue
24 and I guess conclude our public discussion.

25 **DR. WADDILL:** Well, my name is Dan Waddill

1 and I'd like to thank you all and ATSDR for
2 this opportunity to address this expert panel.
3 I work in the Navy's environmental clean up
4 program as the head of the Engineering Support
5 Section at NAVFAC Atlantic. My group provides
6 technical support for Navy and Marine Corps
7 sites across the continental United States and
8 Alaska.

9 My educational background is in
10 modeling of groundwater flow and contaminant
11 transport, and I've been involved in numerous
12 applications of these models at sites, Navy
13 and Marine Corps sites. Last year I
14 contributed to Navy comments on the ATSDR
15 water modeling report for Tarawa Terrace, and
16 I believe you have copies of those comments
17 and responses.

18 I would like to say that the Navy and
19 Marine Corps fully support the scientific
20 effort to determine exposure concentrations
21 and their effects at Camp Lejeune, and in
22 particular, we support the work of this expert
23 panel, and we do thank you for your efforts.
24 As you move forward with your discussions
25 today and tomorrow, I'd like to ask you to

1 consider three issues related to the
2 groundwater modeling efforts.

3 But before I do that I'd like to
4 explain how I'll use the words accuracy and
5 precision in my comments because I think that
6 will help clarify what I'm talking about. In
7 the way that I'll use it accuracy is the
8 extent of agreement between model output and
9 measured data, and accuracy would be estimated
10 by comparing the model to the real world.

11 For example, at Tarawa Terrace we
12 would compare model-simulated PCE
13 concentrations with measured PCE
14 concentrations and that would give us a sense
15 of model accuracy. Precision is the extent of
16 agreement among various model runs, so
17 precision would be estimated by comparing one
18 model run to another as we do, for example,
19 during Monte Carlo analysis.

20 So to get to the first issue in the
21 existing charge to the expert panel, Section
22 2B asks which modeling methods do panel
23 members recommend ATSDR use in providing
24 reliable monthly mean concentration results
25 for exposure calculations. And we certainly

1 think that is a good question for you to
2 consider.

3 In addition to that I'd like you to
4 consider a more preliminary question which is,
5 or issue, which is whether or not modeling at
6 Hadnot Point is capable of providing reliable
7 average concentrations on a month-by-month
8 basis. And in other words can we expect the
9 model to distinguish concentrations from one
10 month to the next with a degree of accuracy
11 that would be useful for the epidemiological
12 study or is monthly simply too fine a
13 resolution for the model to achieve.

14 And why do I ask you to consider this
15 issue? Well, we know that the modeling
16 efforts at Tarawa Terrace and Hadnot Point
17 both face a fundamental difficulty caused by
18 the limited availability of real-world
19 concentrations. The models are being asked to
20 reconstruct historical concentrations back to
21 the '40s or '50s, but prior to the 1980s there
22 are no measured concentrations of PCE, TCE and
23 the other contaminants.

24 For Tarawa Terrace ATSDR determined,
25 and the Navy concurs, that there is not enough

1 measured PCE data for a meaningful model
2 verification step. And since measured PCE
3 concentrations are available only in the
4 1980s, model output from the late '70s or
5 early '80s back to the 1950s cannot be
6 compared to actual PCE data.

7 And we know that we have to ask the
8 model to fill in data gaps. If we had enough
9 measured data, we wouldn't need to model at
10 all. We'd just use the measured data. But
11 the question is, is 30 years, is that too big
12 of a gap to be filled in by a model on a
13 month-by-month basis.

14 To evaluate model uncertainty
15 probabilistic analysis was used at Tarawa
16 Terrace, numerous model runs compared against
17 each other. So that gives an idea of model
18 precision and the uncertainty based on model
19 precision. And this is good information.
20 It's a standard modeling technique, standard
21 approach. And it gives us a sense of how
22 tightly clustered that model output is. But
23 it doesn't necessarily tell us if that cluster
24 of output is centered around the real result.
25 Is it hitting the real-world target?

1 For Hadnot Point the situation is
2 similar in that the model would need to
3 extrapolate concentrations back in time over
4 roughly 30-to-40 years. As we've discussed
5 already, the overall situation at Hadnot Point
6 is that it's significantly larger and more
7 complicated than Tarawa Terrace was.

8 So the second issue I'd like to look
9 more closely at model uncertainty, as I
10 mentioned before at Tarawa Terrace,
11 probabilistic analysis was used to examine
12 uncertainty with respect to model precision.
13 And this work occurs in the model world. I
14 would also like to examine how the model
15 compares to the real world and that would help
16 us better understand uncertainty with respect
17 to model accuracy.

18 And obviously there are long stretches
19 of time without real-world concentrations, you
20 know, they're just not available for
21 comparison. But we do have those in the
22 1980s, and those comparisons were made for the
23 Tarawa Terrace model during calibration. So
24 that degree of fit that was attained during
25 the model calibration gives us a sense of the

1 uncertainty that we might expect with respect
2 to accuracy of the model.

3 For the earlier decades when we can't
4 compare the model to real-world concentrations
5 that accuracy is somewhat unknown, and I guess
6 I would ask you to consider whether we would
7 think the model would be more accurate in
8 those earlier years than it was in the '80s or
9 might it be similar.

10 And so just to sum up, I think it's
11 important to consider the model precision,
12 model accuracy, and to consider how the
13 uncertainty in the accuracy can be assessed
14 and conveyed to the model users. That would
15 include the public as well as the
16 epidemiologists.

17 Just as an example, you know, this
18 morning when Dr. Bove showed the table of
19 monthly model-derived exposures, the panel,
20 you all asked, commented on the three
21 significant figures. And there's a comment
22 that it might be appropriate to show a range
23 of values instead of a single value. And I
24 certainly think that these are good
25 suggestions, and it would be helpful to know

1 what that range would be as we move forward.

2 And just as an illustration, and I'm
3 picking these numbers out of the air, if we
4 have a value of 90 micrograms per liter, does
5 that fall within a range of 60 to 150 or is
6 the range more like 30 to 300 or is it 10 to
7 1,000. It would just be useful to have this
8 kind of information passed along to the users
9 of the model.

10 And the third issue is related to the
11 second one. I'd like to look more closely at
12 model calibration. The existing charge to the
13 panel asks whether there are established
14 guidelines for applying calibration targets
15 and what the calibration targets ought to be,
16 and again, I think this is very useful and
17 appropriate.

18 Given that approach though I'd like to
19 ask the panel to consider also how the model
20 results ought to be interpreted when the
21 calibration targets aren't met. And maybe
22 that's not a good way of asking that question.

23 I thought perhaps a better way and a
24 more general and useful way to ask that
25 question would be simply how do we assess and

1 convey to model users the performance of the
2 model during the calibration process. And I
3 think this is important because it will shed
4 light on model accuracy and the uncertainty
5 associated with accuracy.

6 So just to sum up I'm asking the panel
7 to consider three issues. First, given the
8 limited availability of measured
9 concentrations and the site-related
10 difficulties and uncertainties that we've
11 talked about, would modeling at Hadnot Point
12 be capable of providing reliable average
13 concentrations on a month-by-month basis?

14 And second, in addition to considering
15 uncertainty with respect to model precision,
16 how should uncertainty with respect to model
17 accuracy be assessed and conveyed to the model
18 users?

19 And third, how do we assess and convey
20 the performance of the model during
21 calibration? And issues really two and three
22 could really be lumped together into one main
23 concern that would be that model users be
24 given a clear understanding of the model
25 uncertainty.

1 And, you know, I've been working with
2 Camp Lejeune for a year and a half or two
3 maybe, so I certainly don't understand all the
4 issues associated with it. But I can say that
5 the Navy goal for this expert panel is simply
6 to get your best recommendations for the best
7 science that could come out of this result.
8 And I know that you have a difficult job.
9 This is a difficult site, and we certainly
10 thank you for your efforts.

11 **DR. CLARK:** Dr. Waddill, would you be
12 willing to take a few questions?

13 **DR. WADDILL:** Yes.

14 **DR. CLARK:** Do we have questions from the
15 panel for Dr. Waddill?

16 **DR. GRAYMAN:** It's more a comment than a
17 question. One danger when you talk about
18 ranges for values is if the perception is that
19 that range, that every point within that range
20 is equally likely, and I would suggest maybe
21 rather than a range of values, a likely
22 distribution of what the values are going to
23 be so the points at the end are probably less
24 likely than the ones nearer the middle.

25 **DR. WADDILL:** I would agree with that and

1 really, I'm not asking you to, I'm just asking
2 you what sort of recommendations might you
3 have. I'm not trying to endorse a range.

4 **DR. CLARK:** Do we have any more? Mary.

5 **DR. HILL:** Just one thing. In talking about
6 model fit, it's not true that just a really,
7 if I was given, if I gave you a model that fit
8 the data exactly, I would expect you to be
9 suspicious.

10 **DR. WADDILL:** Right.

11 **DR. HILL:** So there's a balance there that's
12 not always easy to deal with ~~and certainly~~
13 [uncertainty -ed.] from your position.

14 **DR. WADDILL:** I agree. I agree with you
15 completely.

16 **DR. CLARK:** Do we have any more comments
17 from the panel or -

18 **MR. HARDING:** Yeah, sort of along those
19 lines it's common to view analytical results
20 as the truth, as the true value. But in fact,
21 they are only an estimate of the true value,
22 and what that value is depends on the question
23 that's asked. And the model's being asked a
24 slightly different question because we're
25 dealing with a month-long stress period.

1 Somebody walks out with a sample
2 bottle and takes a sample out of a well. And
3 as I think Mr. Faye, Dr. Faye talked about the
4 fact that things can change pretty fast under
5 pumping regimes. We've seen cases where
6 they'll change two orders of magnitude over a
7 period of a couple of weeks of pumping.

8 And so I think it's really important
9 as you think about that if you have a value
10 that doesn't agree, so it affects your
11 definition of accuracy, you really have to
12 look at that in a much more, in a much richer
13 way, a much deeper before you decide whether
14 that's really saying the model isn't
15 performing the way it should.

16 **DR. WADDILL:** Yeah, I agree, and I really
17 just, you know, there are all kinds of issues
18 associated with sampling and analysis, and
19 there are inaccuracies associated with that,
20 too. I just think that what I'm asking is
21 that you consider the comparisons to the real-
22 world samples that we have and to address
23 among yourselves what's the best way to assess
24 uncertainty. And I didn't mean to imply that
25 I have an answer for that. That's a tough

1 one, and I'm just asking you to consider it.

2 **DR. CLARK:** Do we have any more -

3 **DR. GRAYMAN:** Bob, just an add-on to what
4 Ben says is that when you start going into
5 distribution systems and look at water
6 quality, you can have changes literally within
7 minutes because of the dynamics. I could very
8 much see this being the case in Holcomb
9 Boulevard where you take the sample, and it
10 reads something. And ten minutes later you
11 took another sample, and it may be absolutely,
12 totally different. So you have to be very
13 careful in distribution systems.

14 **DR. CLARK:** Do we have any more? Richard.

15 **DR. CLAPP:** Just one more time. Dr. Bove
16 said this morning I think the National Academy
17 of Sciences Report, which has been delayed,
18 will say the same thing, which is that we're
19 not actually looking for numerical values for
20 each individual subject. We're looking for a
21 ranking of those, and just to make that point
22 again.

23 **DR. HILL:** I have a question. Oh, go ahead.

24 **DR. ROSS:** Along those lines and for
25 clarification of folks like me without much

1 epi background, there's a response to the
2 Don's comments that reads if I could just
3 humor me for a second. I'll bore you.

4 A successful epidemiological study
5 places little emphasis on the actual-
6 parentheses-absolute estimate of
7 concentration, and rather emphasizes the
8 relative level of exposure. Can you enlighten
9 me? And this speaks to the objectives of the
10 model. What the objectives are.

11 **DR. CLAPP:** Well, I don't know how to say it
12 more clearly than that actually. It is, for
13 each individual subject, and that's like I
14 said, for example, a child with a birth defect
15 or a control in that study or later on in a
16 person who died of kidney cancer versus a
17 person who was at the base but didn't die of
18 that.

19 We're looking to see whether in a
20 relative scale, the exposed people were more
21 likely to have gotten the disease, and so it
22 can be -- for example in Woburn, in my own
23 work on Woburn, we were looking at categories
24 highly exposed, moderately exposed and either
25 not exposed at all or unexposed. And we saw

1 it. We actually saw that result that the
2 highly exposed were much more likely, in my
3 first study ten times more likely, to have
4 been diagnosed with childhood leukemia than
5 the controls, so in that stratum of highly
6 exposed.

7 So it's really not about that you have
8 to have had a cumulative lifetime exposure of
9 500 parts per billion or 531 parts per billion
10 versus 497 parts per billion. It's are you in
11 the high exposed, the medium exposed or low
12 exposed. And that's how most of these studies
13 are done. And especially in a situation like
14 this where the data are either going to be
15 uncertain or sparse. That's the best we can
16 do.

17 **DR. WARTENBERG:** Just to follow up on that,
18 the methodology that's used for those, the
19 analysis Dick's talking about, look at if one
20 goes up is that associated with a greater
21 likelihood of disease. So it doesn't really
22 use the numbers. You can back out of some of
23 the numbers to try and have a handle to talk
24 about it. But, in fact, the analysis doesn't
25 care if the numbers are from one to ten or

1 from one to a thousand. It still looks for
2 that association. And that's why the comment
3 is don't worry about the numbers. That's not
4 the point of the analysis.

5 **DR. WADDILL:** I guess as long as the model
6 is accurate enough to get the trend right and
7 the ranking right, that would be my
8 understanding.

9 **DR. WARTENBERG:** Where it becomes trickier
10 is when you start grouping the data, I mean,
11 what Dick was saying about having different
12 categories, then that also becomes sort of
13 tricky in terms of either making clear what
14 the association is, but if it's done some
15 ways, it can also make it more obscure.

16 **DR. CLAPP:** And luckily we have an expert on
17 how to do those cut points sitting right here.

18 **DR. HILL:** So if I consider a first order
19 analysis to be take the existing data I have
20 at these different wells, and just assume,
21 from that get some average concentration for
22 those wells over time, and then apply the
23 pumping schedule, I would get exposure rates
24 for different communities, and they could be
25 fit into these different categories. That

1 would just be a first order.

2 Okay, so the question becomes in what
3 ways can we use a groundwater model to improve
4 on that first order estimate. Is that a
5 rational --

6 **DR. CLAPP:** That's what I think we're doing
7 here, yes.

8 **DR. HILL:** Has that first order analysis
9 ever been done?

10 **DR. CLAPP:** Not yet, but I mean for example
11 for Tarawa Terrace, that is now available to
12 do that. It needs to be --

13 **DR. HILL:** Right, for either the numerical
14 modeling or this first order analysis, you
15 have to figure out some pumping schedule, but
16 that's a step that's in common to both of
17 them.

18 **DR. CLAPP:** Yeah.

19 **DR. HILL:** So it's just, it seems to me like
20 that's the framework I'm thinking of in terms
21 of --

22 **DR. CLARK:** Frank, did you have a comment?

23 **DR. BOVE:** No.

24 **DR. CLARK:** Do we have any more comments or
25 thoughts for Dr. Waddill while we have him

1 here?

2 (no response)

3 **DR. CLARK:** Thank you very much. We
4 appreciate your coming in, sir, very relevant,
5 very important and good advice to the panel.
6 Thank you.

7 **MR. MASLIA:** We can hook Scott up. We'll
8 take a ten minute break?

9 **DR. BAIR:** I'm a lot more nervous about this
10 than I was an hour ago.

11 **MR. MASLIA:** Take a minute break while we
12 hook you up. So if we can start back at five
13 o'clock.

14 (Whereupon, a break was taken between
15 4:50 p.m. and 5:00 p.m.)

16 **DR. CLARK:** I guess they've been live video
17 streaming all through this break so time to
18 get back on board and get going. Scott's
19 going to talk about some of his studies at
20 Woburn, which I think would be very
21 informative and useful for our discussion.

22 (Whereupon, a presentation was made by Dr.
23 Scott Bair from 5:00 p.m. to 6:00 p.m. The
24 meeting concluded for the day at 6:00 p.m.)

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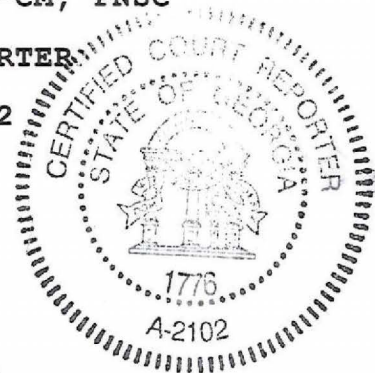
CERTIFICATE OF COURT REPORTER**STATE OF GEORGIA****COUNTY OF FULTON**

I, Steven Ray Green, Certified Merit Court Reporter, do hereby certify that I reported the above and foregoing on the day of April 29, 2009; and it is a true and accurate transcript of the testimony captioned herein.

I further certify that I am neither kin nor counsel to any of the parties herein, nor have any interest in the cause named herein.

WITNESS my hand and official seal this the 19th day of June, 2009.

Steven Ray Green, CCR
STEVEN RAY GREEN, CCR, CVR-CM, PNSC

CERTIFIED MERIT COURT REPORTER**CERTIFICATE NUMBER: A-2102**

2

EXHIBIT 10

THE U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

convenes the

EXPERT PANEL MEETING

Analysis and Historical Reconstruction of
Groundwater Resources and Distribution of
Drinking Water at Hadnot Point, Holcomb
Boulevard and Vicinity, U.S. Marine Corps
Base, Camp Lejeune, North Carolina

APRIL 30, 2009

The verbatim transcript of the Expert Panel Meeting
held at the ATSDR, Chamblee Building 106,
Conference Room A, Atlanta, Georgia, on Apr. 30,
2009.

ORIGINAL

STEVEN RAY GREEN AND ASSOCIATES
NATIONALLY CERTIFIED COURT REPORTING
404/733-6070

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April 30, 2009

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TRANSCRIPT LEGEND

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In the following transcript: a dash (--) indicates an unintentional or purposeful interruption of a sentence. An ellipsis (...) indicates halting speech or an unfinished sentence in dialogue or omission(s) of word(s) when reading written material.

-- (sic) denotes an incorrect usage or pronunciation of a word which is transcribed in its original form as reported.

-- (phonetically) indicates a phonetic spelling of the word if no confirmation of the correct spelling is available.

-- "uh-huh" represents an affirmative response, and "uh-uh" represents a negative response.

-- "*" denotes a spelling based on phonetics, without reference available.

-- "^" represents inaudible or unintelligible speech or speaker failure, usually failure to use a microphone or multiple speakers speaking simultaneously; also telephonic failure.

-- “[-ed.]” represents a correction made by the editor

EXPERT PANEL

Analysis and Historical Reconstruction of
Groundwater Resources and Distribution of Drinking Water
at Hadnot Point and Holcomb Boulevard and Vicinity, U.S.
Marine Corps Base, Camp Lejeune, North Carolina.

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 ATSDR/DHAC
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Glossary of Acronyms and Abbreviations

ASCE	American Society of Civil Engineers
AST	above ground storage tank
ATSDR	Agency for Toxic Substances and Disease Registry
AWWA	American Water Works Association
BTEX	benzene, toluene, ethylbenzene, and xylenes
CAP	community assistance panel
CD-ROM	compact disc, read-only-memory
CERCLA and Liability Act	Comprehensive Environmental Response, Compensation, and Liability Act
CI	cast iron
DCE	DCE: dichloroethylene
	1,1-
DCE:	1,1-dichloroethylene or 1,1-dichloroethene
	1,2-
DCE:	1,2-dichloroethylene or 1,2-dichloroethene
	1,2-
cDCE:	<i>cis</i> -1,2-dichloroethylene or <i>cis</i> -1,2-dichloroethene
	1,2-
tDCE:	<i>trans</i> -1,2-dichloroethylene or <i>trans</i> -1,2-dichloroethene
DHAC	Division of Health Assessment and Consultation, ATSDR
DOD	U.S. Department of Defense
DON	U.S. Department of Navy
EPANET or EPANET 2	a water-distribution system model developed by the EPA
ERG	Eastern Research Group, Inc.
gal	gallons
gpm	gallons per minute
HPIA	Hadnot Point Industrial Area
HUF	hydrologic unit flow
IRP	installation restoration program
LGR	local-grid refinement
MESL	Multimedia Environmental Simulations Laboratory, Georgia Institute of Technology
MGD	million gallons per day
µg/L	micrograms per liter
MODFLOW	a three-dimensional groundwater flow model developed by the U.S. Geological Survey
MODPATH	a particle-tracking model developed by the U.S. Geological Survey that computes three-dimensional pathlines and particle arrival times at pumping wells based on the advective flow output of MODFLOW
MT3DMS	a three-dimensional mass transport, multispecies model developed by C. Zheng and P. Wang on behalf of the

1		U.S. Army Engineer Research and Development Center,
2		Vicksburg, Mississippi
3	NAVFAC	Naval Facilities Engineering Command
4	NCEH	National Center for Environmental Health, U.S. Centers
5		for Disease Control and Prevention
6	NTD	neural tube defect
7	PCE	tetrachloroethylene, tetrachlorethene, PERC® or PERK®
8	PEST	a model-independent parameter estimation and
9		uncertainty analysis tool developed by Watermark
10		Numerical Computing
11	ppb	parts per billion
12	PVC	polyvinyl chloride
13	SGA	small for gestational age
14	Surfer®	a software program used for mapping contaminant
15	plumes in groundwater	
16	TCE	trichloroethylene, 1,1,2-trichloroethene, or 1,1,2-
17	trichloroethylene	
18	TechFlowMP	a three-dimensional multiphase multispecies contaminant
19		fate and transport analysis software for subsurface
20		systems developed at the Multimedia Environmental
21		Simulations Laboratory (MESL) Research Center at
22		Georgia Tech
23	TTHM	total trihalomethane
24	USEPA	U.S. Environmental Protection Agency
25	USMC	U.S. Marine Corps
26	USGS	U.S. Geological Survey
27	USPHS	U.S. Public Health Service
28	UST	underground storage tank
29	VC	vinyl chloride
30	VOC	volatile organic compound
31	WTP	water treatment plant
32		
33		

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P R O C E E D I N G S

(8:15 a.m.)

HOUSEKEEPING RULES

DR. CLARK: Morris has got a couple of things that he wanted to go over, sort of general issues. One thing that we had talked about is if ~~I don't know~~ [-ed.] whether Scott can finish his presentation perhaps during lunchtime if that would be possible.

How long would it take? About 15 minutes or so to --

DR. BAIR: Ten or 12.

DR. CLARK: Okay, we'll try to work that out because I think you were right at the point, sort of the punch line, and we sort of missed that, very interesting.

Morris, you have a couple things you want to say?

MR. MASLIA: First of all I wanted to thank Barbara for bringing in the biscuits and all that this morning. That was a welcome treat, and Rene, ~~and Rene,~~ [-ed.] and also our staff, Kathy Hemphill, Rachel Rogers and Liz for administrative help in getting things going.

1 Second of all, for those who are
2 turning in or traveling on ERG's money, you
3 can mail in your receipts to Liz when you get
4 back or e-mail them or however you want to do
5 that. Then thirdly, and perhaps this was a
6 misunderstanding but hopefully we can clear it
7 up to this morning. I wanted to make sure
8 everyone understood that the notebooks and the
9 materials that were sent to you were not
10 intended to imply they were anywhere near
11 completion.

12 I think that impression may have been
13 observed because we gave a time schedule and
14 it showed we were planning originally to be
15 finished by December of 2009. So that was not
16 the intent. I apologize if that message sort
17 of came about to appear and to sort of
18 demonstrate we talked a lot about Table C-7
19 through C-13 yesterday so I printed them out
20 for you.

21 And if you go to any one of the
22 tables, even the last table, you'll see that
23 it takes seven, eight, nine, ten, 12, a dozen,
24 couple dozen files just to compile the data
25 for one table. So the files are massive to go

1 through, and so this was sort of our
2 compilation of data that we had completed.

3 And it was not intended to imply that
4 we are ready to send this thing out for
5 clearance or peer review or anything like
6 that. It was really to get your feedback, and
7 in fact, feedback in terms of the timeline and
8 everything else. So hopefully, that clears
9 that up, and I think that is about all.

10 We really want to try to stick to the
11 schedule. We did pretty good yesterday.
12 Today, because I know some people have some
13 near five o'clock or six o'clock flights, so
14 we do want to do the final round of input from
15 the panel, which we're looking forward to the
16 recommendations to the Agency that, I believe
17 is scheduled to begin at 2:30.

18 So with that, that's all I have to
19 say, and Mr. Chair, I will -- oh, and they
20 have asked us, we are having audio problems if
21 you're watching it on streaming, and they've
22 asked that you clip the remote onto your belt
23 and the lapel up here, not hang this in a
24 shirt or in your pocket or anything like that.
25 So with that, we're up, is Jason ready?

1 **RE-INTRODUCTION OF PANEL AND SUMMARY OF DAY 1**

2 **ISSUES AND DISCUSSION**

3 **DR. CLARK:** One thing I want to do just for
4 the record is go around the room and have
5 everybody give their name so we know who's in
6 attendance officially. So I'll start with
7 Randall.

8 **DR. ROSS:** Randall Ross, U.S. EPA.

9 **DR. KONIKOW:** Lenny Konikow, U.S. Geological
10 Survey.

11 **DR. GOVINDARAJU:** Rao Govindaraju, Purdue
12 University.

13 **MR. HARDING:** Ben Harding, AMEC Earth and
14 Environmental.

15 **DR. CLAPP:** Dick Clapp, Boston University.

16 **DR. POMMERENK:** Peter Pommerenk.

17 **DR. WARTENBERG:** Dan Wartenberg, Robert Wood
18 Johnson Medical School.

19 **DR. BAIR:** Scott Bair, Ohio State
20 University.

21 **DR. ASCHENGRAU:** Ann Aschengrau, Boston
22 University.

23 **DR. DOUGHERTY:** Dave Dougherty, Subterranean
24 Research.

25 **DR. HILL:** Mary Hill, U.S. Geological

1 Survey.

2 DR. GRAYMAN: Walter Grayman, Consulting
3 Engineer, Cincinnati.

4 DR. CLARK: And I'm Bob Clark.

5 We're going to start off this morning
6 with a discussion of water distribution system
7 modeling. Heard a lot about groundwater
8 yesterday.

9 Jason, you're up.

10 **WATER-DISTRIBUTION SYSTEM MODELING**

11 MR. SAUTNER: Can everyone hear me? Is this
12 on? Is that better?

13 Today I'm going to talk about the
14 historical reconstruction of the water
15 distribution systems, and just as an overview
16 I'll go over some background. I think many of
17 you have a good idea about the background from
18 discussions yesterday, and then I'll go into
19 more of the water distribution system
20 modeling. It's going to be an all-pipes
21 calibration. I'll go into the
22 interconnection, which is going to be a big
23 topic, of transfer of water between systems.
24 And then I'll go into some historical
25 reconstruction and talk about some preliminary

1 scenario results.

2 Overall, the water treatment plant
3 service areas, we have Hadnot Point, which
4 everyone knows about. It's 74 miles of
5 pipelines. Approximately 71 percent of it is
6 PVC. There's four elevated tanks. The
7 controlling tank is SFC-314, which is right
8 down in here in this area. All of the
9 elevated tanks are 300,000 gallons. Delivered
10 water is approximately 2.3 million gallons per
11 day in 2004.

12 And then we have the Holcomb Boulevard
13 system up here. It's about 73 miles of
14 pipelines, approximately 67 percent cast iron.
15 There's three elevated tanks. The controlling
16 tank is right up here. It's Paradise Point
17 S2323. It's a 200,000 gallon tank. And the
18 delivered water in Holcomb Boulevard was
19 approximately one million gallons per day in
20 2004. And there's two interconnections which
21 we talked about. The Wallace Creek, which I
22 guess now we're going to call the Marston
23 Pavilion to avoid confusion. And that's the
24 bypass valve located right here. And then we
25 also have booster pump 742, which is a 700

1 gallon per minute booster pump.

2 Some significant events that occurred
3 between 1941 through 1987: In 1941, the
4 Hadnot Point water treatment plant comes
5 online, which is located right here. In 1952,
6 the Tarawa Terrace treatment plant came
7 online. I don't have the Tarawa Terrace water
8 distribution system model on here, but it's
9 located right up here. And in '72, the
10 Holcomb Boulevard water treatment plant,
11 located right here, came online in June of
12 '72.

13 From November of '84 through February
14 of '85 is when most of the several supply
15 wells were shut down due to VOC contamination.
16 And January 27th through February 4th of '85,
17 there was about a nine-day period where the
18 Marston Pavilion bypass valve was open
19 continuously. In 1987, the Holcomb Boulevard
20 water treatment plant was expanded to provide
21 water to the Tarawa Terrace and Camp Johnson
22 areas. And in 1987, the Tarawa Terrace water
23 treatment plant was taken out of service.

24 As for the Hadnot Point water
25 distribution model, it's an all-pipes model.

1 We used EPANET. I think many of you are aware
2 with EPANET and its capabilities. It
3 simulates spatially distributed contaminant
4 concentrations throughout the network, and it
5 can perform extended period simulations of
6 hydraulic and water quality behavior within
7 the network.

8 The Hadnot Point model consists of
9 about 3,900 junctions, about 4,000 pipes. And
10 what we did was we conducted a hydraulic and
11 water quality field test May 24th through 27th
12 of 2004. During this test we collected and
13 recorded hydraulic data, such as pressure and
14 flow. And we also injected a calcium chloride
15 and sodium fluoride at the water treatment
16 plant, which was our source location. And we
17 measured this continuously throughout
18 locations in the distribution system.

19 Here are some calibration results.
20 The Hadnot Point, the model was initially run
21 using a single demand pattern. And this was
22 obtained from a water balance on the
23 distribution system. Eventually what we did
24 was we used the PEST model to estimate eight
25 different well, we aggregated eight different

1 demand patterns throughout using the Water
2 Conservation Analysis Report from 1999 in
3 which they estimated water usage in different
4 zones, and we allocated eight different
5 groups. And by using PEST we estimated
6 different 24-hour demand patterns.

7 The blue dots on this graph show the
8 SCADA data, which is what we recorded in the
9 field. It's actual water level data at SFC-
10 314, which is the controlling tank at Hadnot
11 Point. The red line is simulated data from
12 the water balance, and the green line, which
13 is a little difficult to see here, is the PEST
14 water level simulation data. And you can see
15 that the fit got much better by using PEST.

16 Over here we have some concentration
17 graphs.

18 **DR. HILL:** With PEST what was it you were
19 estimating? What values were you changing to
20 create that fit?

21 **MR. SAUTNER:** The 24-hour demand patterns,
22 and it was actually a colleague of ours,
23 Claudia Valenzuela that did the PEST modeling.
24 So we have a full report on it and details of
25 how she conducted it.

1 Here is fluoride concentration just at
2 a random logger that I chose in the system.
3 You can see the blue line is what our
4 continuous monitor recorded, and the red line
5 is what we're simulating. And the same down
6 here with the chloride concentration. The
7 blue line still is field data from what we
8 recorded on the continuous monitor, and the
9 red line is the simulation.

10 **MR. HARDING:** Jason, can I ask you a
11 question?

12 **MR. SAUTNER:** Yes.

13 **MR. HARDING:** On that, was that a four- or
14 five-day period that you, yeah. Did you, if I
15 recall what you said, you said you had eight
16 different classifications for water demand --

17 **MR. SAUTNER:** Correct.

18 **MR. HARDING:** -- diurnal patterns, right?
19 Did you use the same pattern? Did you
20 calibrate one pattern that was used on the
21 24th, 25th, 26th or did you calibrate a five-day
22 pattern that -- you see what I'm saying?

23 **MR. SAUTNER:** Yeah, that's what Claudia did.
24 I'm not exactly sure of how she did the
25 calibrations for the PEST.

1 **MR. HARDING:** What I'm getting at is if you
2 calibrate an exact pattern for these five
3 days, that's the best fit for those five days,
4 you're not going to be able to extrapolate
5 that to other periods of time when you don't
6 have calibration data. You're going to have
7 to have a pattern that you can use going back
8 in time, and typically you have one 24-hour
9 pattern for each category of use.

10 **MR. SAUTNER:** Right, and I'll get into this
11 a little later. We assume that generally
12 throughout both the distribution systems that
13 the demand patterns didn't really change much.
14 There was, I mean, historically. While there
15 were significant changes that I showed you in
16 that list of significant changes throughout
17 the systems, overall demand in the systems
18 didn't change much.

19 **MR. HARDING:** Yeah, that's fine, but I guess
20 what I'm getting at is, is that if you are
21 going to take a single 24-hour pattern for
22 each of eight categories of use, then that's
23 the way the calibration results ought to be
24 shown. In other words the same pattern should
25 be used on the 24th, 25th, 26th, so on and so

1 forth.

2 **MR. SAUTNER:** Okay, you're saying a 24-hour
3 average of this.

4 **MR. HARDING:** Well, I don't know. You said
5 you didn't know how she did it. Because you
6 could fit it both ways. You could fit it to
7 look at the, what is it, the five days -- I
8 haven't done the math -- yeah, five days
9 altogether or you could fit it to a single 24-
10 hour period and then replicate that period.
11 And that's what you're going to have to do --

12 **MR. SAUTNER:** Right, for historical extended
13 simulations.

14 **MR. HARDING:** Right, so you just need to --
15 I don't know how you did it, and it sounds
16 like you don't know, but the way you should do
17 it is to do your calibration exactly the way
18 you're going to do your extrapolated
19 simulations.

20 **MR. MASLIA:** (off microphone) But the way
21 the PEST model was run, because we've got all
22 the files and stuff like that is we ran it for
23 the entire period of the test. We put in what
24 we thought were the initial ^ [diurnal
25 patterns -ed.], and we did that based on five

1 ^ [days -ed.]. Then we ran a test based on
2 continuous water levels throughout the entire
3 test period to go in and adjust ^ [the diurnal
4 -ed.] patterns and we got a five-day length of
5 time ^.

6 **MR. HARDING:** Yeah, and the problem with
7 this is it violates Mary's first law, which is
8 it looks scary. And it's too good a fit,
9 right? And the reason is, is that you've
10 fitted every hour of the water demand to the,
11 and so what you should do, because you're not
12 going to be able to do that in 1969 and '70.
13 So what you should do, at least this is my
14 recommendation -- Walter can weigh in -- but
15 you should fit a 24-hour pattern for each
16 category of use just like you started out
17 with. But you're going to get one that's
18 fitted, and then replicate that over the five
19 days and see how your calibration works.
20 That's what I suggest.

21 **MR. MASLIA:** But you have your data that
22 you're measuring will vary over, during the
23 test.

24 **MR. HARDING:** Right, it's going to vary. I
25 mean, people don't behave exactly the same way

1 each day, and when you look at, when you
2 compare your idealized pattern to the actual
3 pattern, it's not going to be the same in
4 life. But this five-day pattern isn't going
5 to be the same five-day pattern you see on May
6 24th of 1972, for example.

7 **DR. GRAYMAN:** Yeah, I agree with you, though
8 what I'd like to see is that graph and then do
9 the next step which take what would be the
10 best repeating 24-hour pattern and see how
11 that works. And I guess the other question on
12 it is what does, the resulting best-fit demand
13 patterns, do they look reasonable or are they,
14 in effect, just --

15 **MR. SAUTNER:** Do you mean the demand
16 patterns in terms of diurnal demand patterns?

17 **DR. GRAYMAN:** Yeah.

18 **MR. SAUTNER:** Yeah, they're all reasonable.

19 **DR. GRAYMAN:** But in the end you do want to
20 come up with a repeating 24-hour pattern,
21 which you can then use for future or past
22 modeling.

23 **DR. HILL:** So on these other years when you
24 don't have so much data, what data do you
25 have?

1 **MR. SAUTNER:** Well, I'll get into the
2 historical reconstruction later in the
3 discussion --

4 **DR. HILL:** Okay, as you go. And just one
5 thought about, you might do instead of a daily
6 pattern repeated, you might do a weekly
7 pattern.

8 **MR. SAUTNER:** That's one thing I also
9 thought of because for the Holcomb Boulevard,
10 which I'll show you next, we have a longer
11 period of time.

12 So the Holcomb Boulevard system has
13 about 4,800 junctions, 4,900 pipes, and we did
14 a field test in which we just shut off the
15 fluoride feed at the water treatment plant, at
16 the Holcomb Boulevard water treatment plant.
17 We shut it off and watched it drop down to
18 background levels to about 0.2 micrograms per
19 liter, and then we turned it back on and
20 watched it go back up.

21 This test was, we did about a 21-day
22 test with continuous monitors out there. You
23 can see the date here is about September 23rd,
24 2004 through -- oh, I only have four days
25 showing here, but the test did go from

1 September 23rd 'til October 11th or 12th. On
2 this graph I just represented four days of
3 data. And similarly, the blue dots are the
4 SCADA data, which is what the operation rooms
5 recorded. The red line was simulated from the
6 water balance, and the green line was
7 simulated from PEST.

8 **DR. HILL:** I'm sorry. I may have missed it.
9 But how do you get the water -- what --

10 **MR. SAUTNER:** Water balance?

11 **DR. HILL:** The water balance, where does
12 that come from?

13 **MR. SAUTNER:** That's just, it's taking
14 what's stored in the tanks, how much water's
15 delivered to the system, what the demand is on
16 the system and during, you know, adding,
17 subtracting and determining how much water was
18 used in the system basically.

19 Is that an easy way to describe it,
20 Walter?

21 **DR. GRAYMAN:** (off microphone) And then use
22 a single common pattern, ^ [diurnal -ed]
23 pattern for all ^[days -ed.].

24 **MR. HARDING:** Yeah, that's the difference,
25 Mary. They have one pattern, and then they're

1 going to break it down to different categories
2 of use.

3 **MR. SAUTNER:** Right.

4 **MR. MASLIA:** Jason, I think it's important
5 to point out, and Mary, initially, where the
6 patterns were derived from is each military
7 installation had a water use survey done.
8 They used a, a program was developed to really
9 see how they could conserve, it was a
10 conservation study. And the conservation
11 study basically provides a gross amount on the
12 average daily usage, what showers are being
13 used, what swimming pools are being used. And
14 so to start this effort off we derived initial
15 estimates from those values to get the model
16 going.

17 **MR. SAUTNER:** Thank you, Morris.

18 I know again it looks like this file
19 lacks Mary's first law; however, I guess I
20 should have chosen a different graph. This
21 one is located close to the source so you're
22 going to get better results right near the
23 source.

24 You can see the, so now we have the
25 date here from September 23rd through October

1 11th around. And you can see the fluoride
2 concentration's starting out around one
3 microgram per liter dropping down to about 0.2
4 and then going back up to one.

5 Here's some, I guess this is a little
6 misleading. It says PEST-derived demand
7 factors is actually the allocations, the
8 different categories that we used. The red is
9 bachelor housing. There's a gray, which is
10 the cooling system. The light blue is family
11 housing. There's a heating plant, vehicle
12 washing, office and work areas. And
13 unfortunately, I don't think this is in the
14 packet that you have of my slides. I added
15 this one.

16 Now I'll get into some
17 interconnections discussions.

18 **MR. HARDING:** Jason, so how did you then
19 allocate spatially to the nodes, the base
20 demand that you varied with your diurnal
21 pattern? How did you allocate across the
22 categories? Did you do a separate demand
23 pattern for each node?

24 **MR. SAUTNER:** No, no, no. There's eight
25 different patterns, so depending on what

1 location, you know, each node was identified
2 as, it would get a certain pattern.

3 **MR. HARDING:** Those were in actual use. I
4 see what you're saying.

5 **MR. SAUTNER:** So now interconnections, which
6 I guess is going to be a big discussion. As
7 you know there are two interconnections, the
8 Wallace Creek, which we're calling Marston
9 Pavilion now, and the booster pump 742.

10 It was originally thought that Marston
11 Pavilion bypass valve and the booster pump 742
12 were operated only on very rare occasions and
13 solely for emergency situations. However,
14 additional data discovery and discussions with
15 both former and current water utility staff
16 have led us to believe that historically water
17 was transferred from Hadnot Point to Holcomb
18 Boulevard more frequently than originally
19 thought.

20 As previously mentioned, the Marston
21 Pavilion bypass valve was not easily accessed
22 so it was not typically open long enough to be
23 considered a significant source of water
24 transfer. Basically, the historical scenarios
25 that I've constructed, I don't open the bypass

1 valve; however, through suggestions we can
2 open it and run different scenarios just to
3 see how the water reacts going through there.

4 As Ben pointed out, I think he alluded
5 to yesterday, if you were to turn on the 700
6 gallon booster pump, and you had that bypass
7 valve open, water is simply just going to go
8 right back down. And I saw that. I ran a
9 scenario. Exactly what you said happened.

10 However, there was that about a nine-
11 day period from January 27th through February
12 4th where that Marston Pavilion bypass valve
13 was open for about nine consecutive straight
14 days, and from the logbooks and discussions
15 with the water utility staff, we determined
16 that booster pump 742 was generally used
17 during late spring and early summer months to
18 account for irrigating the Scarlet Golf
19 Course.

20 There was actually two golf courses
21 loaded up, located in Holcomb Boulevard, and
22 that created such a demand on the Holcomb
23 Boulevard system that water needed to be sent
24 from Hadnot Point to Holcomb Boulevard.

25 **DR. GRAYMAN:** Jason, can I ask a question?

1 During that long period, what was it, nine
2 days?

3 **MR. SAUTNER:** Uh-huh.

4 **DR. GRAYMAN:** Was the booster pump running,
5 too?

6 **MR. SAUTNER:** That's another thing, I'm not
7 sure of. Logbooks, we were told that whenever
8 the bypass valve was open, the booster pump
9 was always running first. If the booster pump
10 couldn't supply enough water, they would open
11 the bypass valve. I don't understand, as what
12 I just discussed your scenario of if you have
13 the booster pump pumping and you open the
14 valve, water's simply going to go back down.

15 **MR. HARDING:** Well, nobody could see the way
16 the water's flowing. There's no
17 instrumentation or anything to reveal this, so
18 people misunderstood the value of opening the
19 valve, and it actually was a counterproductive
20 action. So it would cause the penetration of
21 the water from the booster pump to happen much
22 faster. Right, Walter?

23 **DR. GRAYMAN:** Well, I think we need to
24 establish, I assume there are pumps at each of
25 the treatment plants essentially that are

1 pumping the water from the treatment plant up
2 to the tanks, which is the gray line in those
3 two. And I'm guessing that the gray line is
4 probably fairly similar between the two or the
5 normal water levels in the tanks are they the
6 same in Hadnot Point as they are in Holcomb
7 Boulevard?

8 **MR. SAUTNER:** I believe they're fairly the
9 same.

10 **DR. GRAYMAN:** And so then they'll put the
11 booster pump on just essentially it's
12 dedicated to moving the water from the
13 treatment plant in Hadnot Point into the
14 Holcomb system. And so whether the direction
15 the water's going to be going if they open the
16 bypass is really going to depend on what the
17 water levels are in the two tanks and what the
18 demands are. So you may not necessarily get a
19 circulating system.

20 **MR. SAUTNER:** Right, if you had lower levels
21 in the Holcomb Boulevard, you would have
22 higher levels, and higher levels in the Hadnot
23 Point tanks, you would have water pressure --

24 **MR. HARDING:** For any sustained operation
25 eventually you'll get to the point where the

1 flow is coming back through the valve. I
2 can't imagine any other --

3 **DR. GRAYMAN:** Except when they turned off
4 the Holcomb Boulevard treatment plant which is
5 what they did right there in this case.

6 **MR. HARDING:** If there was an enormous
7 demand, that's right. But your model will
8 tell you this. The model will answer this
9 question pretty well.

10 **MR. SAUTNER:** And to answer your initial
11 question, logbooks indicate that the bypass
12 valve was open. They never mention anything
13 about the booster pump during this nine-day
14 period. Typically, logbooks were pretty
15 consistent and had good information on what
16 was open and what was closed. However, during
17 this nine-day period it does not indicate
18 whether the booster pump's on. I can run
19 different scenarios for both open, just the
20 bypass valve open, you know, see how it
21 reacts.

22 **MR. HARDING:** It should be fairly clear
23 because if your tanks are really, if your
24 heads are going down, if your grade's really
25 low, it would probably not be tolerated and so

1 they were probably running the booster pump,
2 and that seemed like that was their normal
3 mode of operation.

4 And where's the second, I found one of
5 the golf courses. Where are the two golf
6 courses? One was in Hospital Point --

7 **MR. ENSMINGER:** Both of them are there.

8 **MR. SAUTNER:** Both located in there.

9 **MR. HARDING:** Oh, okay.

10 **MR. ENSMINGER:** One's on one side of the
11 street, and the other one's on the other side.

12 **MR. HARDING:** Okay, I didn't count the
13 holes.

14 **MR. SAUTNER:** So as far as the
15 interconnections, from the Camp Lejeune
16 logbooks. We have information from 1978
17 through 1986. There are a few data gaps. You
18 can see here in '79 we have no information, in
19 '81, '82 we have no information.

20 The booster pump 742 operations, it's
21 a 700 gallon per minute rated capacity during
22 the study timeframe. That was later replaced
23 with a 300 gallon-per-minute pump, and it's
24 currently out of service. It was operated
25 mostly in late spring to early summer, April,

1 May, June, July, and it was operated more
2 frequently in the mid-'80s as you can see here
3 than it was in the early '70s.

4 I'm sorry, this is the number of days
5 that it was operated for each month. You can
6 see in the early '70s it was operated seven
7 days, one day, three days in 1980. And then
8 towards the middle '80s you can see it
9 operating a lot more.

10 **MR. ENSMINGER:** I have a question. What is
11 the, we understand that there was a valve
12 right there at Building 670, the Holcomb
13 Boulevard plant, that could be opened right
14 into the treated water in the water treatment
15 plant that was inter-tied to the Hadnot Point
16 system. And from the discussion I had with a
17 former water treatment plant operator, he said
18 they could transfer water from the Hadnot
19 Point system without running the booster pump
20 from the elevated tanks, just gravity flow.

21 **MR. SAUTNER:** I don't believe that there's a
22 --

23 Joe, you might be able to help me
24 answer this question.

25 -- I don't believe that there was an

1 interconnection directly to the Holcomb
2 Boulevard treated tank.

3 **MR. HARTSOE:** There's check valves in the ^
4 [Holcomb Boulevard -ed.] pump room that would
5 prevent it from going back to the treated
6 water reservoir. The only connection I know
7 that he's talking about would be the 12-inch
8 line coming from the booster pump. There was
9 a bypass --

10 **MR. SAUTNER:** But that doesn't run directly
11 to the treatment plant. It runs to the
12 intersection but not to the treatment plant.
13 It runs into the distribution system and not
14 directly to the treatment plant.

15 **MR. ENSMINGER:** Where was that valve that
16 opened and closed that 12-inch line?

17 **MR. HARTSOE:** Well, you had cut-off valves
18 between the booster pump and Holcomb
19 Boulevard, but if you have the valve shut off
20 in the booster pump itself, then the pump was
21 off. So there was no way to go back.
22 Somebody had to either go in there and open up
23 a valve inside the building itself and cut the
24 ^ [valve to -ed.] booster pump ^ [742 -ed.].

25 **MR. ENSMINGER:** Well, would it be possible

1 for somebody to take a short cut and leave
2 that valve open at the booster pump and just
3 shut the valve up at the plant off at the
4 intersection there?

5 **MR. HARTSOE:** We never messed with that
6 valve. I don't know of anybody messing with a
7 valve there. It would still have to go
8 through the pump, some way it would have to
9 gradually feed through the pump and --

10 **UNIDENTIFIED SPEAKER:** And the flow would be
11 so low that it probably wouldn't really make a
12 big difference ^, because that's the reason
13 why you have a booster pump that's to transfer
14 a large amount of water.

15 **MR. HARTSOE:** I don't know who would have
16 cut the valve, ^[on -ed.].

17 **MR. SAUTNER:** So the next graph is going to
18 be occurrences of the bypass valve openings,
19 the number of days. As far as the logbooks
20 are concerned, there's no openings all the way
21 until a first occurrence which was the nine-
22 day continuous opening on January of '85. And
23 then beyond that nine-day period it's opened
24 only a handful of times. One day here, four,
25 three and one day here.

1 This is kind of just an overall
2 summary graph of the hourly operation of
3 booster pump. It's a little difficult to see
4 on this scale since it goes from '78 all the
5 way through '87. It's zero hours to 24 hours,
6 and this is just simply when it was turned on
7 or when it was turned off. To zoom in and get
8 a little bit better of a picture this graph
9 right here to the right is May of '86, and you
10 can see this is the one that was used most
11 frequently. I think it was used about half
12 the amount of days of the month. And we
13 averaged, it was used from about nineteen
14 hundred hours to twenty-four hundred hours.

15 So we came up with some different
16 scenarios. As I said, it was operated most
17 frequently in May of '86. The hours of
18 operation according to the logbook are
19 nineteen hundred to 24 hours, and it operated
20 about half the days during the month, and that
21 was in May of '86. Then we also came up with
22 just a typical May of 1980 case. The average
23 hours that it was operated was seventeen
24 thirty through twenty-three forty-five, which
25 is about 5:30 p.m. to 11:45 p.m. And it

1 operated about three days during the month.
2 And we confirmed with Camp Lejeune former and
3 current water utility staff that they would
4 typically shut the valve off at twenty-four
5 hundred hours when the operator's shift was
6 over.

7 **MR. ENSMINGER:** You mean the pump.

8 **MR. SAUTNER:** What did I say?

9 **MR. ENSMINGER:** Valve.

10 **MR. SAUTNER:** Valve, yeah, sorry. Booster
11 pump 742. Sorry about that.

12 Just to refresh your memory on the
13 water distribution systems now. On the Hadnot
14 Point system, the treatment plant's right
15 here, the controlling tank down here. And
16 then we have the Holcomb Boulevard system with
17 the water treatment plant right here, the
18 controlling tank over here. Golf courses. We
19 have Berkeley Manor, which will become
20 important in terms of the historical
21 reconstruction simulations. Berkeley Manor is
22 right here with an elevated tank right here.

23 And another important thing is to know
24 that the golf courses during this timeframe
25 were irrigated with potable water which is

1 what created the big demand on the water
2 distribution system. And we also have our two
3 interconnections, which is the Marston
4 Pavilion bypass valve, and the booster pump
5 742. So again, remember these are all
6 preliminary results, nothing's finalized.

7 We have our first scenario which is no
8 interconnection. This was done as the May
9 2004 extended period simulation so there'll be
10 no water transfer between Hadnot Point and
11 Holcomb Boulevard. This is controlling tank
12 S-2323, which is the Holcomb Boulevard
13 controlling tank. And you can just see
14 extended period simulation simply fluctuates
15 all the way out 744 hours, which is 31 days.

16 Now, we did some interconnection
17 scenarios. This is May of '86 where it's open
18 every other day. The booster pump was pumping
19 every other day, nineteen hundred to twenty-
20 four hundred hours, and you can see it cycling
21 every other day. And we also have our third
22 scenario which is May of 1980 which is the
23 green line. And you can see fluctuation three
24 days in the middle of the month which is when
25 we planned it to operate.

1 So now our concentrations in the
2 controlling tank for Holcomb Boulevard, no
3 interconnection, there's obviously no transfer
4 of water from Hadnot Point to Holcomb
5 Boulevard. But it was open every other day in
6 May of 1986, there was still no transfer of
7 water to the controlling tank. And then
8 obviously if it was only three days, there was
9 no transfer of water. So no concentration was
10 making it to the controlling tank in Holcomb
11 Boulevard from the Hadnot Point water
12 distribution system.

13 Now however, if you look at Berkeley
14 Manor tank with no interconnections you can
15 see the water level fluctuating. With the
16 interconnection open every other day in May of
17 '86 you can see it fluctuate every other day.
18 And when it was open three days in the middle
19 of the month, similarly just three days of
20 fluctuation right here.

21 When we look at the concentrations,
22 and this is assuming just 100 micrograms per
23 liter or 100, I guess it would be considered
24 units, just to get a percentage-wise, to get a
25 feel for how much water from Hadnot Point went

1 into Holcomb Boulevard, with no
2 interconnection no water transfer, zero
3 concentration.

4 With the interconnection every other
5 day you can see concentrations build up in the
6 tank at Berkeley Manor. When it was open
7 three days in the middle of the month, the
8 green line, you can see the three steps in the
9 very middle of the month, and then there's no
10 more water transfer so the tank has
11 concentration in it and then you just see it
12 start to dilute out.

13 Interesting thing is, is that this is
14 for May of 1980. If you were to do, go ahead
15 and simulate June of 1980, you would have to
16 put this concentration in as a starting point.

17 Overall this is just a figure to look
18 at the distribution of the concentrations
19 throughout the systems. With no
20 interconnection all the water stays down in
21 Holcomb Boulevard -- I'm sorry, in Hadnot
22 Point. And there's zero water transferred
23 into the Holcomb Boulevard system. With the
24 interconnection -- again, these are all just
25 averaged out. So instead of running, well,

1 with running the extended period simulation,
2 instead of looking at over time, every value
3 was just averaged.

4 So with water connection in May of
5 1986 conditions, you can see no water in these
6 areas. Again, the yellow dots are zero-to-
7 five percent and the orange dots are five-to-
8 20 percent. So you can see on average in the
9 Berkeley Manor about, it actually comes to
10 about 22 percent water, well, 22 percent was
11 averaged in the tank. Overall the system it's
12 about 20 percent around these nodes.

13 And then with the three days in the
14 middle of the month when it was open in May of
15 1980, you see no water transferred in this
16 area. You see a few areas in here where
17 you're going to get between five and 20
18 percent of water from the Hadnot Point system.

19 So future considerations that we have
20 for this are to try and develop some
21 historical trends, explore using climatic data
22 which is directly related to when the golf
23 courses were irrigated along with the known
24 booster pump 742 operating conditions from
25 1978 to 1986 to try to estimate historical

1 booster pump operations from 1973 to 1977.
2 Remember, we don't need operations from '68 to
3 '72 because Holcomb Boulevard received all of
4 its water from Hadnot Point. So it was really
5 only a five-year period that we're missing
6 data right here on booster pump operations.

7 Some other considerations for
8 historical reconstructions, we have actual
9 data so instead of maybe doing an average
10 condition for May of '86 and saying that the
11 booster pump opened at nineteen hundred hours
12 and closed at twenty-four hundred hours, we
13 have the actual data on a daily basis and an
14 hourly basis of when the booster pump was open
15 and when it was closed. We could actually put
16 this into the model and still run it as an
17 extended period simulation.

18 We also want to run some scenarios
19 where I include Marston Pavilion bypass valve
20 opening into the historical reconstruction.
21 As I was discussing with Ben, I've run some
22 preliminary simulations. It appears that
23 there's little influence in the Holcomb
24 Boulevard area when the bypass valve is open.

25 And that's mainly because there's, I

1 guess it would be more influence in the Hadnot
2 Point area. Water kind of goes from Holcomb
3 Boulevard to Hadnot Point rather than going
4 from Hadnot Point to Holcomb Boulevard. This
5 can be changed also as we discussed with
6 varying tank levels to create different
7 pressure variants.

8 And also want to run the scenario
9 where the nine-day event from January 27th
10 through February 4th of 1985 with the bypass
11 valve open continuously. And with that I'll
12 leave it open to questions.

PANEL DISCUSSION: WATER-DISTRIBUTION SYSTEM

13 **MODELING**

14 **DR. DOUGHERTY:** Remind me about 1972 and why
15 there's no consideration in the second half of
16 1972.

17 **MR. SAUTNER:** In 1972 that is when --
18 correct me if I'm wrong -- isn't that when
19 Holcomb Boulevard, in June of '72, Morris?

20 **MR. MASLIA:** June of '72 is our best
21 estimate of when the Holcomb Boulevard water
22 treatment plant came online.

23 **DR. DOUGHERTY:** So the assumption is that --

24 **MR. SAUTNER:** Prior to '72 it was receiving
25 all of its water from Hadnot Point.

1 **DR. DOUGHERTY:** I understand, but there was
2 no interconnection you had to worry about
3 between the start up, which probably would be
4 ~~pre-transferred~~ [pre-transfer -ed.] to the
5 Department of Defense, and --

6 **MR. SAUTNER:** And so you're speaking the
7 actual June of 1972, July of '72. Yeah, I
8 suppose I could change that figure to be '72
9 through '77 and use, there would be no
10 transfer, well, it would be all Hadnot Point
11 water for April, May of '72. June/July we
12 might want to also find historical --

13 **DR. DOUGHERTY:** Right because it does
14 generate an additional exposure potential.

15 **MR. SAUTNER:** Correct.

16 **DR. POMMERENK:** Jason, for these very short-
17 term interconnections in your illustrations
18 here, you used 100 micrograms per liter as the
19 mass and as coming across the interconnection.
20 What are you planning on using for the
21 historical reconstruction? Are you going to
22 use the monthly mean that you get from your
23 groundwater model or, because, you know,
24 obviously these concentrations can change on a
25 daily basis in the system.

1 **MR. SAUTNER:** You're talking about
2 concentration input for the model?

3 **DR. POMMERENK:** Yes.

4 **MR. SAUTNER:** Well, we're not at that point
5 yet, but one way to do it is to whatever
6 number they get from the groundwater model,
7 whatever number they give me, I put it in as a
8 simple, we have a start, you know, they will
9 give me a date, a time when the concentration
10 was like that, and that will go into the model
11 as is.

12 **DR. POMMERENK:** Okay, but I want to caution
13 because we're going to have a monthly average
14 concentration. In reality, of course, the
15 concentrations can change on a daily basis.
16 And if you look at Table C-13, it nicely
17 illustrates how Building 20, which is the
18 Hadnot Point plant is 900 micrograms per liter
19 TCE, another day several days later 430 and
20 then another day later non-detect which means
21 within the distribution system there will be
22 also considerable fluctuation.

23 Now, I guess from an epi standpoint,
24 if you're using the mean that's fine for
25 Hadnot Point. But for the short-term

1 interconnection, you need to have some idea of
2 how much is going, how much mass is across
3 going across that interconnection during the
4 six hours or whatever that pump was on in
5 order to determine what the exposure will be
6 downstream. Because you cannot simply assume
7 it was mean concentration because it may have
8 been zero or may have been a thousand ^
9 [micrograms per liter during -ed.]
10 interconnection.

11 **MR. SAUTNER:** I don't think that there's any
12 way we can tell that though. I mean.

13 **DR. POMMERENK:** That's my point.

14 **MR. SAUTNER:** Well, it's going to end up
15 being an average. I understand that you're
16 talking about a short period interconnection.
17 We have what information we have. So I can
18 run different scenarios and --

19 **DR. POMMERENK:** Yeah, I mean, I think it's
20 going to be a stochastic problem though. Of
21 course, you don't know but that's my question.
22 How are you going to approach this in terms of
23 uncertainty which is again what, I guess, the
24 epi study's looking for since you don't know
25 but you need to provide some kind of measure

1 of how certain is your, of your exposure
2 modeling results. How are you going to
3 account for the fact that it could have been
4 during the six hours of interconnection that
5 the source could have had non-detect or 2,000,
6 that's what I'm --

7 **MR. SAUTNER:** Yeah, I guess we'll cross that
8 bridge when we get to it and discuss more
9 later. That's probably a discussion for the
10 panel to help determine. Maybe we could run
11 some Monte Carlo simulations or --

12 **DR. GRAYMAN:** You're right in terms of
13 there's both stochasticity due to the source
14 term at the treatment plant plus a great deal
15 in terms of when the booster pumps were on.
16 And I think you do have to consider both of
17 them. But it's, I mean, the amount of
18 information you have in terms of exactly what
19 the source concentrations are going to be at
20 any given time, how they're varying around the
21 mean and also when the actual booster pump was
22 turned on and off, especially in this three
23 year period where you have no information.
24 You're really going to have to do it in a
25 probabilistic manner.

1 **DR. CLARK:** We had a question from the
2 audience back here I think.

3 **MR. HARTSOE:** Let me clarify something. I
4 may have to get back with you on some of it.
5 I was thinking about what Jerry said about a
6 valve. I was thinking about what Jerry was
7 saying about a valve at 670 cut on. And
8 during that timeframe when the reservoir was
9 contaminated with the gas leak, 670 was shut
10 down, but water was still supplied through
11 that 12-inch line.

12 Jerry is talking about to 670. I
13 mean, it was being delivered water to 670, but
14 670 was not pushing any water out because the
15 reservoir was cut off. The water would not go
16 back to the reservoir because of the check
17 valves on the high-lift pumps, and I'm
18 wondering if what they were talking about when
19 they say a valve, during that time when we put
20 the, when we were putting the reservoir back
21 online and having to fill it up and took all
22 sorts of tests after that to make sure the
23 water was good enough to drink before we sent
24 it out.

25 We did have times when they probably

1 had to backwash a filter. And there is a
2 valve on the outside of the reservoir that you
3 had to, you could cut on, and that would be
4 coming from Building 20. So that may be what
5 valve -- I'm not sure and I'll have to get
6 back with you. I could see where they would
7 open that valve just to backwash the filters.

8 **UNIDENTIFIED:** And that's what I recall as
9 well.

10 **MR. HARTSOE:** I mean, I can get back with
11 you --

12 **MR. SAUTNER:** We'll get together in the
13 future and discuss the --

14 **MR. HARTSOE:** And, Jerry, that may be, I
15 don't know of any other valve they could cut
16 on but that one. So I'll be glad to get back
17 with Jason on that.

18 **MR. ENSMINGER:** And this other question
19 about the contaminant levels when the booster
20 pump was running and whether what the
21 contaminant, the idea that you didn't really
22 know what the levels were of the
23 contamination. Well, we only have one test
24 that shows what those levels were, and that
25 was the split samples taken by the state which

1 I gave all of you in your packet of documents
2 there. The analytical results showed the
3 levels in the Holcomb Boulevard system.

4 **DR. CLARK:** Dave, you had a comment.

5 **MR. ENSMINGER:** And that was one of them
6 that showed 1,148 parts per billion of TCE at
7 the Berkeley Manor housing area's elementary
8 school.

9 **DR. CLARK:** Dave, you had a comment?

10 **DR. DOUGHERTY:** It was just a question on,
11 and I'll reference Table C-13 kind of as an
12 example. Do we know the sampling protocol for
13 this 1985 data? These, just to get it right.

14 **MR. FAYE:** What was that question again?
15 I'm sorry.

16 **DR. DOUGHERTY:** Do we have a sample protocol
17 for the 1985 data from taps and those sorts of
18 things? In other words are these --

19 **MR. FAYE:** Protocol as to what?

20 **DR. DOUGHERTY:** The sampling protocols, how
21 the samples are actually taken.

22 **MR. FAYE:** No, but I suspect from earlier
23 information that in terms of the sampling,
24 which is not really that definitive, in late
25 1984 samples were collected in glass bottles,

1 iced and shipped to the laboratory.

2 **DR. DOUGHERTY:** How were they transmitted
3 into the bottle?

4 **MR. FAYE:** I think it was just you open up
5 the tap. You fill up the bottle.

6 **DR. CLARK:** You're thinking of the
7 volatilization issue I presume and the loss of
8 contaminant because of that sampling.

9 **MR. FAYE:** Oh, yeah.

10 **DR. DOUGHERTY:** I'm thinking of that and
11 then in terms of for using these as part of
12 the calibration targets that these may be
13 considered somewhat less than an actual --

14 **MR. FAYE:** Sure, and also I think the issue
15 that, the main issue is determining at the
16 beginning of this process, when Hadnot Point
17 was actually turned on to supply all of
18 Holcomb Boulevard, we don't really know what
19 the concentrations of the various, TCE for
20 example here, were at Hadnot Point at that
21 time.

22 But we know, number one -- well, first
23 of all, we know all the wells that were
24 pumping at this time. We know all but one of
25 the contaminated wells was turned off at this

1 time. And we do have concentrations in the
2 contaminated well at this time at the
3 beginning, which would be 651. So actually,
4 you could just do a simple mass balance. And
5 we know the pumping rates.

6 So we could just do a simple mass
7 balance and estimate what that source
8 concentration was at the beginning of this
9 intervention. So I don't really think that's
10 an insurmountable problem.

11 **DR. CLARK:** But I think you're correct. As
12 I recall at that time sampling was an issue
13 particularly for inexperienced utilities who
14 were just beginning to learn how to take
15 volatile samples of THMs and the VOCs as well.
16 It's a good point.

17 **MR. HARDING:** What's absolutely critical
18 about understanding the sample is the time of
19 day and the, really what's important, it's 100
20 feet from one of the tanks. I can't remember
21 the number, I think. Looking at it on Google
22 maps. Whether that tank's filling or emptying
23 has a profound impact on how you interpret the
24 sample.

25 If you remember Scott's little diagram

1 of how the plumes move, well, it happens the
2 same way in a water distribution system. I
3 mean, water flows downhill or down gradient,
4 however you want to think about it, but it
5 happens much faster. Your divide shifts can
6 happen in a matter of minutes, you know, the
7 switch from flow direction can change in a
8 matter of moments.

9 And so the exact moment you took this,
10 the snapshot of conditions at that moment
11 matters a lot. And we can't ever get that
12 exactly right, so you have to keep that in
13 mind when you're trying to calibrate a water -
14 - you have way more measurements out in the
15 system than I have ever had. I've got the
16 luxury of maybe two or three samples out in
17 the system most of the time. You've got this
18 wonderful fluoride calibration stuff.

19 I mean, you should be able to do a
20 pretty good job of getting a model that's
21 reasonable. You shouldn't try to fit it
22 perfectly because -- I'm going to talk about
23 this a little bit later -- you're over-fitting
24 your water demands right now, and we have to
25 back off from that.

1 But what I wanted to do was address
2 Peter's comments about the variability, and in
3 part it's this how incredibly dynamic a water
4 distribution system is, and how you could have
5 a sample at 8:00 a.m. and a sample at 2:00
6 p.m., and they could be completely different
7 depending on which source happened to be
8 supplying that node.

9 But just thinking out loud
10 conceptually what you need to do is you need
11 to have a, you're going to have a groundwater
12 model that gives you wellhead concentrations.
13 This is a term I use. This is that average,
14 vertically average, concentration on a monthly
15 basis. And then you have to have a model of
16 your well dispatch -- I've talked about this
17 several times -- that will bring the water
18 together into your unpressurized tank that
19 then is at the water treatment plant. And
20 this may or may not require a hydraulic model
21 because of the differences in head at the
22 different wells and the pump curves. You have
23 to decide that.

24 And then you're going to have the rest
25 of your water distribution model which you've

1 seen. And you're going to have to model this
2 concentration all the way through. You're
3 going to have one model that's integrated
4 together and it'll have to be stochastic
5 because you don't know how they operated the
6 wells absolutely, and you're going to have to
7 make a model.

8 But you can inform that model with
9 standard operating procedures or human
10 tendencies. And we've done the same sort of
11 thing before, you just have to do your best,
12 but you have to recognize the uncertainty and
13 quantify it. So I don't know, Walter may want
14 to add to that.

15 **MR. MASLIA:** Ben, can I just clarify
16 something because what you've said is
17 absolutely correct, but we're not going to be
18 getting that complex. From the start we made
19 a decision not to model the actual transfers
20 of water within the distribution system or
21 from the different wells in other words. If
22 the wells mixed in a single tank we would get
23 that single concentration. If not, we would
24 take the concentration on the finished water
25 side of the treatment plant. Now, in this

1 particular, a case like in Table C-13, and I
2 agree with you, I mean, throughout all the
3 data we have, except for the data that we
4 collected, we have no time data. This is, if
5 you put that together with the fluoride data
6 that we gathered, I think we've got a very
7 rich set to calibrate and test to. In other
8 words so you've only got one well pumping
9 during this period, and that's 651.

10 **UNIDENTIFIED:** Only one contaminated well.

11 **MR. MASLIA:** Only one contaminated well
12 pumping. To me it would seem to be, to use
13 this if you want to either verify the
14 calibration that we already have based on our
15 current field data and then try to model this
16 and see what it would take in terms of either
17 well combinations or opening-closing valves to
18 try to duplicate this.

19 **MR. HARDING:** Just as a general comment, you
20 guys focus too much on calibration and not
21 enough on the practical question of how you're
22 going to go back and extrapolate out the
23 periods when you don't have enough
24 information. It's wonderful to get your model
25 to fit and then you violate Mary's first law.

1 But you have to think about how you're going
2 to get a realistic model, a reliable model
3 that goes back in time to 1972 and 1976 when
4 you're not going to have any information.

5 And that's why I'm saying, and which
6 well is on. I mean, obviously -- I can't
7 remember all the numbers, but 651 was the real
8 bad boy here, right? If 651 isn't on, no
9 problem, right? Well, let me step back and
10 say something about that in a second. But if
11 it's on, then you've got big problems.

12 Now, one of the things that Jason
13 illustrated up here is the reason why you have
14 to do really long-term, extended-period
15 simulation because that trace went off the end
16 of the month. And typically what we would do
17 is we would run a year at a time, continuous
18 simulations, and then we would initialize the
19 next year with our tank concentrations and
20 even our pipe volume, the mass that was in the
21 pipes, because the pipes can store a
22 substantial amount of water and contaminant.

23 And so you'll have a memory in those
24 tanks. It is the memory of the system, and
25 you really have to respect that. If the tank

1 at the school there was discharging at the
2 time you took that measurement, that means
3 your tank had a milligram per liter in it. If
4 it was filling it, and it was getting
5 initialized with a milligram per liter. So I
6 just want to make that point.

7 But you really have to think about how
8 you're going to go back and not worry so much
9 about getting a trace that looks really,
10 really nice. But figuring out how you're
11 going to get a realistic and reliable model
12 and go back.

13 **DR. HILL:** In order to do that, and in order
14 to get an analysis of uncertainty it would be
15 really nice to use the dataset you do have and
16 do cross-validation where you'd leave off the,
17 use your different, but instead of leave one
18 out, leave a whole period out. And then go
19 ahead and calibrate however you want to to
20 your one set, and then look to see how well
21 you do when you come back to the set that's
22 not included in your calibration.

23 And you're going to want to use, for
24 those periods you don't have information,
25 you're going to want to use the method that

1 gives you the best power in that cross-
2 validation test. And that cross-validation
3 test will give you a measure of how well you
4 do when you don't have data.

5 And that's your uncertainty analysis
6 so you don't go back and do Monte Carlo, you
7 actually have an evaluation of how well you do
8 when you don't have data for the period of
9 interest. So it'll probably be faster than
10 what you're doing now in terms of an
11 uncertainty analysis, and it will have a
12 better statistical background.

13 **DR. GRAYMAN:** I just had a comment on what
14 Ben said. First of all, I'd turn it around a
15 little bit. What I'd say is you're probably
16 in a much more fortunate situation in terms of
17 having a better intrinsic model of the
18 distribution system than is normally the case
19 in any of these. So what it's done is it's
20 reduced the uncertainty in that part of the
21 model, so that's good.

22 But then carrying on that's a starting
23 point. We still have all of this
24 probabilistic analysis has to be done for the
25 source concentration for the operations. In

1 terms of what Mary said, I'm a little
2 concerned, and I guess I don't fully
3 understand what information you have, what
4 water quality information you have in the
5 distribution system. It just seems to be very
6 anecdotal still.

7 And so anything where you did an
8 analysis, where you tried to calibrate the
9 model and match this, and I'm not talking
10 about today's --

11 **DR. HILL:** I wasn't talking about the
12 concentration data. I was talking about the
13 pumping schedules. In terms of your
14 concentration data, I mean, what was done at
15 Tarawa Terrace is to just throw all this raw
16 data at the groundwater model and say fit it,
17 when, if you looked at the data, there was
18 absolutely no, you weren't providing a
19 function that was consistent with the data.

20 Now, what the inconsistency was there
21 I don't know, but you need to think about the
22 concentration data in the context of some of
23 the things people have brought up. Because
24 it's pretty clear, I mean, things change so
25 much day-to-day, there's something going on

1 with the collection activity or, and I don't
2 know those processes enough, but this data
3 needs to be evaluated with that in mind first
4 and altered.

5 So if these are all biased low because
6 of processes you know occurred, there has to
7 be some adjustment to those. If you throw
8 this into the regression, it just tries, I
9 mean, the models just try to match it, so you
10 have to, that was one aspect that was
11 presented by Professor Aral yesterday is that
12 you need to really look at your data and try
13 to develop, figure out what trends, your
14 underlying trends, are involved there, not
15 just throw the raw data at the model.

16 **MR. HARDING:** Let's be very clear --

17 **DR. GRAYMAN:** When you say this data, let's
18 be very clear which data we're talking about.

19 **DR. HILL:** That was the concentration data I
20 was talking about.

21 **DR. GRAYMAN:** The concentration data in the
22 distribution system or from the sources?

23 **DR. HILL:** Well, I mean, you can calibrate
24 the groundwater model on both of those. I
25 think individual well data has been dealt with

1 more frequently, and in either period -- I
2 can't remember -- are there periods of time
3 when we have distribution, we have finished
4 water concentrations, and we don't have
5 individual well concentrations?

6 **MR. FAYE:** I can answer that. The data to
7 the best of my knowledge that we collected at
8 several intervals, May of '84 was one where we
9 were all out there, these were when we were
10 injecting various --

11 Go ahead, Walter.

12 **DR. GRAYMAN:** Two thousand and four.

13 **MR. FAYE:** I'm sorry, 2004, yeah. We were
14 all injecting the fluoride and some other,
15 calcium chloride, into the distribution
16 system. That was strictly an effort to
17 calibrate the distribution system models. And
18 then similar things were done for Holcomb
19 Boulevard and Tarawa Terrace.

20 Now, there was no interest in
21 collecting any well data at that time. There
22 was, to the best of our knowledge, there were
23 no contaminated wells active at that time. So
24 this was strictly an effort to collect data to
25 calibrate the water distribution system

1 models, EPANET 2.

2 Now, to the only data that we have
3 where a contaminated well or wells were
4 operating and where contaminant concentration
5 data were actually collected within the
6 distribution system. Those data are all
7 presented with respect to the distribution
8 system on Table C-13, which you have in front
9 of you now. The --

10 Excuse me, Mary, go ahead.

11 **DR. HILL:** I think that the issue is that if
12 you have concentration -- I was going to say,
13 if you have concentration data into the
14 individual wells, I would think it would be
15 better to use that even if at the same time
16 you have finished water concentrations. But
17 then I was thinking, well, maybe that's not
18 the case because of the, there are so many
19 contentious problems with the samples. Maybe
20 it's not a bad thing to have duplication.

21 **MR. FAYE:** Let me just finish my thought,
22 and then we can address what you're trying to
23 say I think.

24 The only time that we actually have
25 data coincident in time where contaminant

1 concentration data were collected within the
2 distribution system and when we have knowledge
3 of the contaminated well or a well or wells
4 being pumped, was for this nine- or ten-day
5 period in late January and early February of
6 1985.

7 And those data in terms of the
8 distribution system are presented on Table C-
9 13. And the contaminant data at the
10 individual wells are also in tables, well,
11 it'd be Table C-7, basically, just Table C-7.
12 And in terms of the actual WTP, that would be
13 on Table -- help me here, folks, if you looked
14 at it. That would be on Table C-11.

15 And we also have daily records of
16 which wells were being pumped during this time
17 and which were not so we can actually, but
18 there was only one contaminated well at the
19 time and that was HP-651. So whatever was
20 going on, the other wells that were pumping
21 were actually diluting HP-651. I mean,
22 whichever ones they were, they were not
23 contaminated or were very minimally
24 contaminated, you know, as far as detection
25 limits were concerned.

1 So those are the only data that we
2 have where well data and distribution data
3 were collected relatively simultaneously.

4 **DR. HILL:** And you don't have the pumping
5 schedule. They destroyed those records,
6 right?

7 **MR. FAYE:** Well, we know which wells were
8 pumped on a daily basis, and because of the
9 extreme conditions that existed at that time,
10 it wouldn't be unreasonable to assume that
11 those wells were just pumping 24 hours a day.
12 They had to get the water into the system to
13 maintain, to supply demand. So if those
14 wells, you know, I think that would be a
15 reasonable assumption.

16 **DR. HILL:** If you really, I mean, given that
17 two-week period of time where you have this,
18 you have measured concentrations at the wells,
19 delivered concentrations, pretty good
20 knowledge of the flow system, so you could use
21 that as a test period, a really good test
22 period for your entire system of modeling.

23 **MR. FAYE:** Yeah, to demonstrate the validity
24 of the accuracy, precision, all the other
25 terms that were used, we could demonstrate it

1 as a test for that particular period of time.

2 **MR. SAUTNER:** And, Bob, also just to note.
3 We have pumping schedules not just for that
4 ten-day period. We have, I believe it's for
5 two months, right around there, isn't it?
6 December, January and February.

7 **MR. FAYE:** Right. So the whole process, I
8 want to make a point again, the whole process
9 is highly simplified because of the
10 extraordinary condition that existed, that the
11 wells were going full bore, full out to meet
12 demand. We know the pumping rates at the
13 wells, and there was only one contaminated
14 well at the time that was pumping.

15 And that turned out to be one that was
16 a real mess in terms of contamination. So it
17 is sort of a fortunate situation where all
18 this information happened to be -- and it was
19 totally accidental as far as I can tell -- but
20 it just turned out that that was the case.

21 **UNIDENTIFIED:** What were those days?

22 **MR. FAYE:** Basically from about January 27
23 or so of 1985 to February 11th, 12th, 13th,
24 1985. Something along those lines.

25 **DR. GRAYMAN:** I think it would be extremely

1 useful to take that period and it's almost --
2 I'll call it an exercise, but that's a little
3 bit pejorative -- but that you go through the
4 exercise of seeing that the model can
5 realistically match what happened during that
6 one-month period. But unfortunately, it's
7 such an unusual period that I'm not sure
8 you're going to be able to gain much in terms
9 of using that to simulate the other periods.

10 So it's almost going to be, it's going
11 to be necessary that you be able to reasonably
12 match it, but I'm not sure that that's going
13 to be that useful in extending it for the rest
14 of the 15-year period or 12-year period.

15 **DR. HILL:** You could use it as a test
16 period, as a check period. Don't use it as
17 calibration and do daily time steps.

18 **DR. CLARK:** We have a question back here in
19 the audience.

20 **MR. PARTAIN:** Just an observation, on the
21 May 1982 Grainger Lab report, actually, not
22 the report is going to have that, but there
23 was a sample taken from a point within the
24 Hadnot Point distribution system. I believe
25 it was Hospital Point and came with a reading

1 of 1,400 parts per billion within the system.
2 Can that not be a snapshot of what was going
3 on in that system so you can compare it to
4 what you got in 1985?

5 So you've got two different points
6 separated by three years. One with a 1,400
7 parts per billion reading at the hospital and
8 then later on the January '85 testing within
9 Holcomb Boulevard, and you've got the school
10 at 1,100 parts per -- 1,148?

11 **DR. HILL:** You can. The thing about this
12 other situation is you have a pretty good
13 handle on every piece. You have the pumping,
14 the -- and that's what makes it so unusual.
15 So the one you're talking about I'm not sure
16 that it's a similar set of circumstances or
17 not. I mean, maybe there is. I don't know.

18 **MR. PARTAIN:** That was a ^ [water-quality -
19 ed.] sample that they were doing and the lab
20 technician took it upon himself to actually
21 quantify the levels, and he came up with a
22 1,400 part per billion reading for ^[TCE -
23 ed.].

24 **MR. ENSMINGER:** Yeah, and three years later
25 you get 1,148 parts per billion of TCE in

1 another sample, and it's about 300 parts per
2 billion less than the '82 sample. Well, you
3 had some other contributing wells that had
4 been already taken offline, but you still had
5 that one hot one online, 651.

6 **MR. PARTAIN:** And that same technician also
7 noted that they had, they did that sample,
8 went looking again, and it dropped off, and
9 then several months later the technician has a
10 conversation with the base supervisor chemist
11 and says, hey, the peaks are back and they're
12 high again, but it doesn't quantify ^.

13 **DR. CLARK:** We'll let Morris get a point in
14 here.

15 **MR. MASLIA:** No, I've got a question
16 actually for both the epi people and the water
17 modelers.

18 Since the case or the set of data as
19 has been pointed out for the January '85 date
20 seems to be our most complete in terms of all
21 parts of the supply and delivery system or
22 distribution system that we've got information
23 on, and we know one contaminated well, 651,
24 was pumping being diluted by other wells,
25 which we know were pumping going in there,

1 could we not use that from the epi side, would
2 you not consider that potentially a worst case
3 scenario?

4 **MR. HARDING:** How could that be the worst?
5 Oh, for Holcomb Boulevard.

6 **MR. MASLIA:** Did they pump all the
7 contaminated wells at the same time?

8 **MR. HARDING:** I couldn't even --

9 **MR. FAYE:** No, you wouldn't consider that in
10 terms of the groundwater pumping. You
11 wouldn't even come close to considering that
12 as a worst case scenario. Because you could
13 have a situation easily where 651 prior to
14 1984, 651 -- or July '84, actually -- 651,
15 602, 608, 634 -- what others, could all be
16 pumping at the same time, and they'd be
17 dumping contaminants into the Hadnot Point WTP
18 like there's no tomorrow, so that would be
19 more of a worst case than just one
20 contaminated well pumping.

21 **DR. DOUGHERTY:** The entire 1968 through '72
22 period which --

23 **MR. FAYE:** Yeah, from 19, yeah, and prior
24 to, actually, 651 came online in I think 1970,
25 but prior to that you certainly had a good

1 number of contaminated wells that existed,
2 pumping into Hadnot Point WTP and being
3 distributed through the Holcomb Boulevard pipe
4 system. So, no, I wouldn't --

5 **MR. ENSMINGER:** If you use just the January
6 samples that would not be, another reason it
7 wouldn't be your worst case is because all
8 your benzene contaminated wells were offline
9 by that point.

10 **MR. FAYE:** Oh, yeah, I mean, considering
11 your individual constituents, yeah. You can
12 go right down the line and be indicative of
13 that. I'd say this 1982 sample that was
14 brought up that's on Table C-11 at the
15 hospital, 5/27/82, 1,400 micrograms per liter
16 TCE, that -- I'm just kind of blowing smoke
17 here -- but probably 651 was pumping then.

18 We don't really know, but that
19 concentration is comparable to some of the
20 January '85 concentrations. So there might
21 have been a similar situation going on. But,
22 yeah, in terms of worst case we really don't
23 know, but I wouldn't say January of '85 was
24 the worst case, just my thought.

25 **MR. HARDING:** You need to know to be able to

1 make a statement like that, you need to know a
2 lot, and you'd need to know where the water
3 was coming from that was at -- I can't think
4 of the name of the point, but the school.

5 **MR. FAYE:** Berkeley Manor.

6 **MR. HARDING:** You'd have to know, and it
7 could be coming out of the tank. It could be
8 a blend. And it's really hard to know. At
9 Hospital Point it's going to be a little more
10 stable I would think because it's sort of out
11 on the --

12 **MR. FAYE:** Out at the end of the
13 distribution system.

14 **MR. HARDING:** And I can't see well enough to
15 see if there's a tank between it and the water
16 treatment plant.

17 **MR. SAUTNER:** There is because here's
18 Berkeley tank right here.

19 **MR. HARDING:** I'm color blind too so I can't
20 see the pointer. So anyway, you can't make a
21 blanket statement like that. This is why you
22 build the model is to make this evaluation.
23 And you have to -- I want to make a little
24 editorial comment here -- you have to
25 comfortable going out on a limb and making

1 some subjective judgments about whether this
2 is a reasonable model or not. You're going to
3 have to do that because you just can't do
4 everything based on data analysis, as Mary
5 said. You're just going to have to test and
6 come out with, it's a great tool I think, but
7 you're just going to come out with something
8 that's over-fitted.

9 **DR. DOUGHERTY:** Just a quick question on
10 this early '85 data. So they have the
11 measurements at the treatment plant, and we
12 have measurements at wells, and we have
13 pumping rates.

14 **MR. FAYE:** Right.

15 **DR. DOUGHERTY:** Have you just done the
16 mixing calculation to see if the well
17 concentration and the treatment plant
18 concentration match?

19 **MR. FAYE:** No, as Morris hopefully clarified
20 earlier this morning, I mean, this work that
21 you all have in your notebooks here is very,
22 very preliminary work, very early in the
23 process of the project in terms of getting
24 some definitive results. So we just haven't
25 got to that point yet.

1 **DR. CLARK:** So there is a point, I think
2 Ben's got a good point. You could use the one
3 scenario to validate and calibrate the model
4 and then add in other wells as you think they
5 might have occurred during some of these
6 maximum contaminant mixing scenarios. You can
7 get a pretty good picture, I think, of what
8 might be going on within the system.

9 **MR. FAYE:** Absolutely. And whether we want
10 to use it as a sort of a test as Mary
11 suggested or as part of a full-blown
12 calibration, I mean, I think those points of
13 view just need to be worked out in a dialogue
14 amongst the staff and you folks and whatever.
15 But, yeah, it is the only time, it is the only
16 time where we actually can integrate the
17 complete system, pumping wells and their
18 respective models, the distribution system and
19 their respective models and then look at the
20 results.

21 **DR. DOUGHERTY:** I really encourage you to
22 take the ten minutes and do the calculation to
23 see if the mixing of the well data to the
24 treatment plant in that period of time is
25 self-consistent, and if not, it may give you

1 some sense of some response error and hence a
2 measurement error.

3 **MR. FAYE:** I agree, and it's neat because it
4 is a fairly simple thing to do.

5 **DR. CLARK:** But one thing I haven't heard
6 discussed is the potential for degradation.
7 Has any of that been factored into the
8 calculations at this point? We haven't really
9 done those simulations either, I know, but it
10 seems to me some of that could be important.

11 **MR. FAYE:** Absolutely. We know from Tarawa
12 Terrace as far as the groundwater's concerned
13 that probably degradation is a major issue.
14 Within the distribution system, that I don't
15 know.

16 **DR. CLARK:** Well, there's some pretty long
17 residence time in some of those tanks. I
18 haven't done the calculations, but if you're
19 given vinyl chloride as an endpoint then you
20 have a very serious issue.

21 **MR. FAYE:** Right, right.

22 **MR. HARDING:** I think the residence times
23 are ^[important -ed.].

24 **DR. CLARK:** It could be degradation also.
25 Well, like also, well, some of it may be

1 degradation within the system, but I don't
2 know. The times might be sufficient for
3 degradation.

4 **DR. KONIKOW:** Well worth looking at it, but
5 the residence time in the groundwater much,
6 much, much longer than the residence time in
7 the tank.

8 **MR. HARDING:** If this is a matter of triage
9 I wouldn't spend very much time on worrying
10 about degradation in the water treatment
11 system. You've got lots of other good stuff
12 you could spend time on here that's way more
13 important than that. Don't focus on the
14 details, focus on the big picture.

15 I want to ask some more questions
16 about water use, because water use, you have
17 continuity, and you have energy that balance
18 in these models, and some of us think in terms
19 of continuity, and some of us think in terms
20 of energy, and the systems are different,
21 sensitive in different ways. But in this
22 particular case where you've got this big old
23 golf course out there, and that's what's
24 driving some of these interconnections. You
25 know, understanding the pattern of water use

1 is going to be important.

2 And I'm concerned that I haven't heard
3 enough, I don't quite understand exactly what
4 you've done during your calibration period,
5 but more than that I don't understand your
6 plan for going back and modeling this during
7 the periods for which there are no data. And
8 the way I've approached it, and I think
9 Walter's done it the same way.

10 We first sort of load the nodes with a
11 kind of a fraction of the water use on a daily
12 basis. And then apply a unit-less pattern of
13 diurnal water use. I'm sort of getting the
14 sense that what you've done is you've fitted
15 both the total daily water demand and the
16 diurnal pattern, using PEST, and again, it
17 makes a beautiful chart, but it isn't going to
18 help you when you go back in time. I don't
19 know if you have daily records of water
20 production at the water treatment plant, do
21 you?

22 **MR. SAUTNER:** Daily? Daily records?

23 **MR. FAYE:** Yeah, we do have daily records I
24 think in terms of production. That was on one
25 of my slides the other day, yesterday.

1 What is it, Jason, 2004 to 2008 and
2 then there's '95 through --

3 **MR. HARDING:** No, I meant back in the time
4 that matters.

5 **MR. FAYE:** No.

6 **MR. HARDING:** So you're going to have to
7 come up with a pattern of use on a total
8 system use and then you're going to have to
9 disaggregate that to the nodes spatially. And
10 then you have to disaggregate it with your
11 diurnal pattern. And so those are some of the
12 conceptual steps. I mean, you can throw up
13 your hands and say we can't do it, but I've
14 done it. Walter's done it. You have to do
15 it.

16 **DR. GRAYMAN:** I'm not clear. I think you
17 weren't sure either in terms of when PEST was
18 done. Was it done just to give you these
19 representative eight diurnal, say, normalized
20 patterns? Or was it also to try to determine
21 the quantity of water that was used, say, over
22 that period?

23 **MR. SAUTNER:** No, I believe it was just done
24 for the diurnal.

25 **DR. GRAYMAN:** Yeah, that was my

1 understanding.

2 **MR. SAUTNER:** The quality, we used the water
3 conservation analysis study.

4 **MR. HARDING:** How does that get water to the
5 individual nodes? How do you know how much
6 water was used at or near the school in
7 Berkeley Manor, for example, just as an
8 example? How did you understand that from the
9 water balance?

10 **MR. SAUTNER:** Well, from the water
11 conservation study we had different categories
12 of demand, whether they were bachelor
13 housings, family housings, so we know Berkeley
14 Manor is a family housing area. Most of the
15 demand nodes in that area were assigned.

16 **DR. GRAYMAN:** Okay, so the equivalent of
17 having a meter, an annual meter.

18 **MR. HARDING:** That's good. That's good.

19 **DR. BAIR:** That's great, and I misunderstood
20 that because I thought you were fitting --

21 **MR. SAUTNER:** I'm sorry. I wasn't clear, I
22 guess.

23 **DR. BAIR:** No, that's the way, that's
24 conceptually the way it should be done. And
25 then but you're going to have to come up with

1 a set of patterns that are either constant or
2 respond to certain rules. For example, Mary
3 suggested doing it every day of the week.
4 It's probably not going to help you much, but
5 you definitely want to take into account
6 weekend days, for example.

7 On your golf course you know they're
8 not going to water the golf course at two
9 o'clock in the afternoon, right? You know
10 they're going to water it at night --

11 **MR. MASLIA:** Actually, that's not correct.
12 Ben, seriously, they water it when the general
13 calls up and says he wants to have a tee-time,
14 and then they turn it on.

15 **MR. SAUTNER:** We were told anywhere from
16 early morning to afternoon to late at night it
17 could have been watered.

18 **MR. ENSMINGER:** Having lived there I have
19 some resident knowledge of the water usage on
20 that base. Wallace Creek separates those two
21 areas right there. The Hadnot Point and
22 Holcomb Boulevard system -- that's Wallace
23 Creek. It separates, this is Hadnot Point.
24 This is the Holcomb Boulevard system. At
25 eighteen hundred every evening, the water

1 demand down in here where all the troops are
2 at would drop off dramatically.

3 **MR. PARTAIN:** The Officer's Club?

4 **MR. ENSMINGER:** No, no, the Officer's Club
5 was up here. It was up in here, right in
6 here. All these housing areas, Midway Park,
7 Berkeley Manor, Paradise Point, those demands
8 in the evenings would go up because the people
9 were coming home.

10 Now the troops, after we got off work
11 we had PT, and then we'd secure the troops.
12 They'd go back to the barracks and they'd
13 either, well, they'd get their showers, and
14 then they would put their civvies on and go to
15 chow hall or head out to town to the bars. So
16 the water demand over here would drop off.
17 Then in the morning about 0500, the water
18 demand here would start picking up again and
19 level out. You know you had morning PT,
20 showers, chow hall, formation, back to work,
21 and then you had that same cycle.

22 On the weekends, the weekends the
23 water demand here was low. On Hadnot Point
24 the water demand here would be high because
25 everybody would be home.

1 **DR. CLARK:** What about light industrial use
2 or lawn watering in residential areas?

3 **MR. ENSMINGER:** You didn't have many people
4 watering their lawns in base housing unless
5 you had a few people that were trying to get
6 yard of the month or something. I never did.
7 But industrial, most of your industrial, all
8 of your industrial use water would have been
9 at Hadnot Point.

10 **DR. GRAYMAN:** Right. I think one step you
11 want to take is take a look at those patterns
12 as you develop from a PEST modeling and really
13 to check them for being reasonable based on
14 what he was saying.

15 **MR. MASLIA:** We actually, if you go back
16 when we were, when we tested like the Hadnot
17 Point system and injected the calcium
18 chloride, you actually saw that exact diurnal
19 pattern. It jumped up at 5:00 or 6:00 a.m. in
20 the morning and then leveled off and then
21 Hadnot Point went down around four or six or
22 whatever. That we saw when we did the test.
23 And so I mean from that standpoint, the PEST
24 just confirmed that. It was just trying to
25 optimize the tank water level

1 **UNIDENTIFIED:** And the different patterns
2 for the different types of units.

3 **MR. MASLIA:** Yes, yes, that's correct.

4 **DR. HILL:** One thing on the, just thinking
5 about those patterns and looking at like one
6 of the figures -- it's Figure 8 in the text --
7 but this is, it's May 24th through May 28th.
8 That's a Monday through Friday. And if you
9 look at the different days, there's not,
10 Monday and Tuesday it looks like they're kind
11 of similar in pattern. But then the other
12 days look, Thursday and Friday look similar.
13 But to my mind there's not a lot of diurnal
14 similar patterns in this.

15 **MR. HARDING:** This is real life.

16 **DR. HILL:** Well, yeah, so I guess any
17 patterns we think about could be compared
18 against this data and that could be part of
19 what goes into the model testing.

20 **MR. HARDING:** Let me make a comment here
21 that you can't expect under normal sort of
22 modeling extrapolation conditions to be able
23 to predict what happened at 2:00 p.m. on
24 Tuesday, June 12th. You can't do that so you
25 have to average things after, you've got to

1 run these models on an hourly or shorter time
2 step because you don't get the dynamics of the
3 system. But then you've got to average things
4 up.

5 And your goal is to get good
6 statistics that support the epidemiology study
7 over these sort of windows of three months,
8 right? So you probably have a rolling average
9 of over three months because that's your
10 resolution need.

11 For these case studies where you've
12 got a critical case, like this case we're
13 talking about here at Berkeley Manor and maybe
14 the Hospital Point, yeah, that would be great
15 diagnostics to go down and just really detail
16 this down and lock everything down and see if
17 it's all consistent, but I wouldn't put too
18 much stock in it. You've got to set your
19 error bars. You've got to be comfortable with
20 the fact that you're going to have some error
21 bars in this.

22 **MR. SAUTNER:** I just want to add one thing
23 also for the calibration procedures. We had
24 other hydraulic information and we put some
25 water meters out to record flows. So we have

1 that as another calibration measure. We had -
2 - Walter was in with us when we conducted some
3 fire flow tests. So we do have shorter period
4 of times that we can go in and look at more
5 specifically for our calibration.

6 **MR. PARTAIN:** When we were talking about the
7 golf course, I did want to show you all this
8 memo here, and this is, if you look at the
9 date, July 1985. So this is post -- I'll put
10 quotes around it -- post discovery of the
11 contamination. And this is a memo from the
12 Base Maintenance Officer to the Assistant
13 Chief of Staff Facilities. If you look on
14 here, let's see, they currently have two 250
15 GPM booster pumps to provide pressure for the
16 pump and sprinklers on the north course. It's
17 one course.

18 **MR. ENSMINGER:** The whole course.

19 **MR. PARTAIN:** One course, which when
20 operating do draw a considerable amount of
21 water. We really need to pursue this. And
22 looking at the rounding slip, let's proceed
23 with vigor -- I can't read from here.

24 **MR. ENSMINGER:** Info from PWO.

25 **MR. PARTAIN:** Public Works Officer. Can you

1 read that for me, Jerry? I can't see that
2 from this side.

3 **MR. ENSMINGER:** When do you think we'll have
4 -- incorporated?

5 **MR. PARTAIN:** Information, and that's Mr.
6 Price, his comments.

7 **MR. ENSMINGER:** He was the head ^.

8 **MR. PARTAIN:** And then on the back, "Yeah,
9 thanks, Bill, this is good idea. We should
10 push hard." So the golf course is an issue
11 here. I mean, they're, yeah, this is
12 priority. They realize they've got to drain
13 the system. And keep in mind now we've got
14 wells offline. There's water problems.

15 We have documentation that there's
16 water issues at this point, and there's a
17 concern here. So the golf course evidently is
18 drawing a lot of water somewhere. And one
19 course, we've got two, basically, two 250
20 gallon pumps -- I'm sorry, two 250 gallon per
21 minute pumps pumping out and what kind of draw
22 is that going to put on the system.

23 **MR. ENSMINGER:** And this plan was actually
24 realized and initiated in 1987. They drilled
25 separate wells alongside of some of the water

1 hazards on the golf course. They were pulling
2 the water from the water hazard and
3 replenishing the water hazard with water from
4 the wells.

5 **DR. KONIKOW:** Would the recharge rate onto
6 the golf course be higher than everywhere
7 else? Was that in the groundwater flow model?

8 **MR. FAYE:** No, except for a couple of
9 isolated areas out there, Lenny, what we call
10 the Brewster Boulevard aquifer system is
11 essentially a sand pile with some disconnected
12 clays and lenzoidal clays in that system,
13 which we call the confining units, respective
14 confining units, but it's basically a sand
15 pile. So what you basically got is whatever
16 there's left over after ET goes, is
17 infiltrated probably. And the water table's
18 ten, 15-to-20 feet depending on the contours,
19 the land contours. So that's essentially
20 conceptually what I think is going on there.

21 **DR. BAIR:** Aren't you surcharging it with
22 the golf course irrigation water in addition
23 to the rainfall?

24 **MR. FAYE:** Yeah, that was the question that
25 he asked.

1 **DR. BAIR:** So is that area given more
2 recharge than other areas in the model?

3 **MR. FAYE:** Sure, well, like I said, there is
4 no model right now. The work that Jason
5 talked about yesterday is very preliminary,
6 and so that represents, what he was doing
7 represents a long-term, average condition.
8 For the transient model, yes, there would have
9 to be some higher rates of recharge for that
10 area.

11 **DR. DOUGHERTY:** (Off microphone;
12 indiscernible).

13 **MR. FAYE:** Yeah, yeah, and as somebody
14 mentioned yesterday, it actually might even be
15 what they call a SWAG, which is a Scientific
16 Wild Ass Guess.

17 **DR. BAIR:** I guess I have a bad idea that
18 I'd like to pass along. As we talk about golf
19 courses, I'm a golfer. I hate the trees, but
20 I think the trees might provide you with a
21 surrogate for some information you're looking
22 at on a longer average than what we've been
23 talking about on the water distribution
24 system.

25 But some types of trees take up TCE,

1 and if you were to core some of the trees on
2 the golf course in Berkeley Manor and other
3 places, I suspect you can find a laboratory
4 that could analyze the annual growth rings for
5 the amounts of TCE. Now, it won't tell you a
6 microgram per liter, but it will tell you a
7 high, low, none. And you could use that
8 timeframe as a surrogate for what's being
9 distributed across the base by looking at
10 different trees across the base. So that's my
11 bad idea.

12 **DR. GRAYMAN:** I was just going to comment
13 it's either brilliant or totally off the wall.

14 **DR. KONIKOW:** I'll go for off the wall.

15 **DR. GRAYMAN:** I think it's a good idea,
16 Scott. At least look at it.

17 **MR. ENSMINGER:** I saw that capability. I
18 saw exactly what he's talking about. They do
19 test and they can help.

20 **DR. GRAYMAN:** So what are the trees like on
21 the course.

22 **DR. BAIR:** Are there trees on the course?

23 **MR. ENSMINGER:** Oh, yeah.

24 **UNIDENTIFIED:** But they're not watering the
25 trees. They're watering the --

1 **MR. ENSMINGER:** Yeah, but those roots go way
2 down.

3 **DR. BAIR:** They're watering the fairways,
4 too, aren't they? They have to be.

5 **MR. FAYE:** Well, that's probably what we
6 need to do (off microphone).

7 **DR. BAIR:** Right, and then you could go to
8 the yard of the month and get tree rings from
9 that.

10 **MR. ENSMINGER:** Don't be cutting all the
11 trees down, Scott.

12 **DR. HILL:** You don't have to cut the tree
13 down. You just core it.

14 **DR. BOVE:** This is an interesting idea, but
15 aren't we talking about from '72 to '85, we're
16 talking about a few days a month during the
17 summer months. That's what we're talking
18 about. We're not talking -- and before '72,
19 yes, Hadnot Point is serving this area. But
20 after '72 we're talking about a few days in a
21 few months during the summer so I don't see
22 the point. Am I missing something?

23 **DR. HILL:** You're getting data for the
24 period you don't have any information on.

25 **MR. HARDING:** Yeah, I think the button is on

1 the golf course. I'm sorry, but I thought it
2 was a good idea for Hadnot Point in general,
3 and I forgot that the golf course was outside
4 of Hadnot Point probably because it was such a
5 small event it may not show up. But other,
6 it's an interesting idea for Hadnot Point.
7 The thing is is that sort of the anecdotal
8 evidence indicates there was a lot of TCE a
9 lot of times there probably in Hadnot Point
10 itself.

11 **DR. BAIR:** Anywhere there's an irrigation
12 system on the base. Are they keeping the
13 Headquarters' petunias nice?

14 **MR. PARTAIN:** There are sources of TCE
15 within Hadnot Point, too.

16 **MR. ENSMINGER:** I don't know that would find
17 anything that was a confounding factor.

18 **DR. BAIR:** It was just an idea. I mean, as
19 an academic it's my job to come up with
20 something that uses my time and other people
21 pay for it.

22 **MR. ENSMINGER:** But in the Hadnot Point
23 system I don't think you'd find anything that
24 had a constant irrigation in it.

25 **DR. GOVINDARAJU:** I just wanted to go back

1 to this question of calibration. So the test
2 that was conducted in 2004, was the purpose of
3 that test to back calculate the demand
4 pattern? Because that means there's an
5 expectation that that demand pattern is going
6 to be repetitive of what happened in '84.

7 **MR. SAUTNER:** I'm sorry. So this test right
8 here?

9 **DR. GOVINDARAJU:** Yes.

10 **MR. SAUTNER:** This was a test we did --
11 let's do this test here. We actually injected
12 fluoride and chloride into the systems. This
13 was to help us calibrate the model, and we
14 gathered different hydraulics on the system
15 and pressures and water levels, flows.

16 **DR. GOVINDARAJU:** True, but when you are
17 fitting, you are saying I will ~~assimilate~~
18 [simulate -ed.] by fitting let's say the
19 demand patterns or demand factors from test.
20 So it looks like the purpose of this test was
21 to basically get the demand patterns out. Was
22 that the goal of the test then?

23 **MR. SAUTNER:** Yeah, well, we did not have
24 demand patterns except for a water balance, so
25 we used the water conservation analysis to get

1 a general demand allocation.

2 **DR. DOUGHERTY:** So did you fit only the
3 water patterns or other parameters, too?

4 **MR. SAUTNER:** Well, we did other sensitivity
5 analysis. We tried to change pipe frictions
6 and stuff like that.

7 **DR. DOUGHERTY:** Tank mixing?

8 **MR. SAUTNER:** Tank mixing, yeah.

9 **DR. GOVINDARAJU:** So basically, my feeling
10 is that system parameters [^][including -ed.]
11 perhaps tank mixing and all, those have been
12 ~~formatted~~ [fitted -ed.] because with that you
13 can perhaps get an estimate of what the
14 friction factors were back in '84. The demand
15 pattern is going to be, even if you prepare it
16 very correctly with this, the chances of being
17 able to reproduce it for '84 are very
18 difficult. Already I think we have heard
19 about what you are going to get are monthly
20 averages which you have to somehow fractionate
21 or disaggregate into much smaller intervals.

22 **MR. MASLIA:** Can I make a couple of comments
23 to maybe hopefully clarify what we have and
24 what we did and why we did it? We came in
25 there in 2003 and there was, from a model

1 standpoint, a description of the distribution
2 system. There was no information available as
3 to daily demand patterns and things like that.

4 What we had, as I said previously, as
5 most military bases have done, they've got a
6 conservation study that was done. Not only
7 for Lejeune, the Air Force has done it. The
8 Army's done it at all their military bases.
9 The purpose of that really was to study on an
10 average basis the water use and see how they
11 might reduce or conserve water.

12 And so it identified different water
13 outlets, swimming pools, showers, latrines and
14 so on and so forth. That was really our --
15 and then we knew the volumes of the tanks
16 obviously. That was the only real, you know,
17 that type of information that we needed. And
18 when we summed up the water balance from the
19 conservation study, we were off -- I mean, I
20 say we, I mean taking the numbers from the
21 study, off by about 30 percent from if you
22 added up the storage in the tanks and the
23 stuff the wells were pumping and all that sort
24 of stuff. So there was a discrepancy in
25 information there.

1 So one of the purposes in conducting
2 the distribution system test was to see if, in
3 fact, we could account for this discrepancy
4 because we knew we would have to have a more
5 robust -- I won't use the word accurate --
6 description of the distribution system.

7 We also made the assumption, and I
8 believe it's still a correct assumption, is
9 that the distribution system, with the
10 exception of obviously separating off Holcomb
11 Boulevard from Hadnot Point, but the activity
12 patterns would have been the same whether the
13 troops were there when we were doing the test
14 or the troops were there in 1968 or whatever.
15 And as Jerry correctly pointed out and we did
16 in the test, they get up, run the shower at
17 6:00 a.m. or whatever and then it goes on in
18 the Hadnot Point area.

19 In doing the test or gathering the
20 data, we then were able to, as we had
21 suspected, were able to, through using PEST,
22 determine that the friction factors were
23 insensitive. The system, the changes to that
24 were basically insensitive. That left a
25 demand pattern and water levels that were

1 measured in the tanks through the SCADA
2 available. And so we adjusted the demand
3 patterns. In fact, we were able to match what
4 actually was flowing through the system based
5 on our measured data.

6 What was interesting also was at the
7 end of the test, and I believe, was that, that
8 may have been a Thursday or a Friday, as
9 troops left for the weekend or whatever,
10 because we got folks at the Hadnot Point to
11 flow the system, I think it was, what, 2,100
12 gallons per minute, something like that. They
13 came to us and asked if they'd cut that back
14 because they were spilling water out of the
15 controlling tank, French Creek tank was
16 spilling water because they were pumping it at
17 an average rate of what we had gone through
18 the data and figured that the average flow
19 was.

20 So he's correct. Over the weekend it
21 drops. But our entire concept was that from
22 average operational sense what we saw when we
23 were doing the field test, which is what our
24 goal was, that we could use that at any
25 typical period historically to provide input

1 to the epidemiological study. And hopefully,
2 that clears where we got initial information
3 from.

4 **DR. CLARK:** Was the pipe material ~~the same,~~
5 ~~had been~~ [-ed.] pretty much the same over the
6 years or was there a switch from, say, cast
7 iron to vinyl chloride at some point?

8 **MR. MASLIA:** Joe can probably give you a
9 better idea, but at least now when they
10 replace it they use PVC, don't you -- right,
11 when they replace it presently, they're
12 replacing it with PVC. But to give you an
13 example, Tarawa Terrace was basically the same
14 as it was, and it's got a mix of cast iron and
15 PVC currently.

16 And even though C factor was not very
17 sensitive, it was much more sensitive to PVC
18 than it was to cast iron. And I've got those
19 plots in Chapter I report under the water
20 distribution part or the sensitivity of the
21 water distribution system. It really was the
22 purpose of the test or our concept going in is
23 that there was, in terms of where the pipes
24 went and all that, it would be no significant
25 changes from the historical system.

1 And that's why we felt or why we
2 justified that we could go out and get some
3 field data. But it was basically what the
4 primary driving factor was this big
5 discrepancy of 30 percent between what the
6 water conservation study said summing it up
7 and what we knew presently was the volume that
8 they were, you know, having.

9 **MR. HARDING:** The water conservation claim
10 was summing it up from estimates of individual
11 either categories of use or -- I'm not alarmed
12 by a 30 percent difference then. Those are
13 the same number. You've got to think in
14 astronomical terms sometimes.

15 Yeah, I mean, if you had measurements
16 coming out of the water treatment plant, those
17 obviously would be your best piece of
18 information which you don't have.

19 **DR. KONIKOW:** You're talking about
20 historically, right?

21 **MR. HARDING:** Yeah, if you had the flow
22 meter and you had the daily records, those,
23 I've had cases like that, then that's great.
24 We've had situations where all we had were
25 monthly data. You don't even have that, but

1 you're going to make an assumption about your
2 stress periods, right?

3 And the assumptions you make should be
4 the best you can make. Then they should be
5 consistent with the water distribution model,
6 and then you're going to have to disaggregate
7 that down to a daily pattern. There's a
8 variety of ways to do that. You know, you
9 have to understand and be comfortable with
10 this, it's going to be wrong. But as Locke
11 said it will be useful. And that's the
12 comfort you have to have. You have to be
13 willing to be wrong but provide a useful piece
14 of information.

15 **MR. FAYE:** We do have monthly data back to,
16 into the 1950s and also into the '70s and '80s
17 and '90s. So we do have a lot of monthly data
18 to deal with.

19 **DR. GRAYMAN:** Can I broaden this a little
20 bit? We can bring it back, but looking at the
21 schedule where we're scheduled to talk about
22 distribution system really for the rest of the
23 morning, I think at some point the group
24 should be looking at a little more broadly and
25 that we really have by my count at least five

1 different areas we're trying to simulate what
2 we're going to be giving to the
3 epidemiologists.

4 We have to be looking at wellhead
5 concentrations, which we talked a lot about
6 yesterday in terms of the groundwater flow
7 models. We have to look at the well operation
8 scenarios. How were the various wells
9 combined at any given time. The
10 interconnection scenarios, how was the booster
11 pump operated and the Wallace Creek valve.
12 The water use demand scenarios, which we have
13 ideas from the present study, but these are
14 still a lot of unknown. And then there's a
15 system operation scenario and that's primarily
16 how did they operate the system not from the
17 wells but once from the treatment, when would
18 the treatment plant pumps come on, how were
19 the tanks operated.

20 And I think it would be useful as a
21 group to try to discuss how are we going to
22 bring all these together. I've heard the idea
23 of using Monte Carlo simulation or some kind
24 of partition hypercube, but we're talking
25 about a large number of scenarios in all these

1 different dimensions. And I hope we can at
2 least start addressing that at some point.

3 **DR. KONIKOW:** Well, I don't think the
4 epidemiologists want all of that information.
5 They want -- correct me if I'm wrong -- they
6 don't want to know the details of the
7 groundwater flow model or the details of the
8 groundwater transport model or even the
9 wellhead concentrations. They want to know
10 the outcome. What went through the
11 distribution system.

12 **DR. GRAYMAN:** No, exactly what gets
13 delivered to the customer.

14 **DR. KONIKOW:** Exactly.

15 **DR. GRAYMAN:** But all of those things bear
16 upon making that vital decision.

17 **DR. KONIKOW:** Exactly, yeah.

18 **DR. ASCHENGRAU:** Just to add to that, I
19 mean, to me there were lots of issues that
20 came up yesterday that are similar of this
21 sort, right, on the groundwater modeling. So
22 it has to go even further than that, and it's
23 just to me we would consider all those
24 sensitivity analyses. And so we would want to
25 know sort of the bounds of the estimates, the

1 monthly estimates, that we are trying to get.

2 **DR. KONIKOW:** Let me add that there were
3 quite a few, I think, important issues causing
4 uncertainty and error in what predictions
5 could be made that we didn't get to discuss
6 yesterday. I mean, it's really much more
7 complicated and uncertain than we even, we
8 just began to scratch the surface.

9 **DR. GRAYMAN:** Right, and what's complicated
10 here, when we were dealing with Tarawa
11 Terrace, we were at the point where we really
12 weren't that interested in the distribution
13 system because it wasn't one of the factors or
14 wasn't a primary factor or even a major factor
15 in contributing how much was delivered to the
16 customers. Here we're now having to,
17 everything that was said about Tarawa Terrace
18 and complicating it by the fact that Hadnot
19 Point and Holcomb Boulevard appear to be
20 significantly more complex situations. We
21 then have to overlay that with the water being
22 delivered to the customers primarily in this
23 interconnection phase.

24 **DR. HILL:** This is actually just going back
25 to something that Bob mentioned earlier, and

1 it's coming back to the groundwater model
2 study. I apologize for that. But the idea of
3 this is just a pile of sand, I would like to
4 back off from that a little bit.

5 From the Castle Hayne downward it's
6 been there for 20 million years, and it's a
7 deposit that has some structure to it and some
8 information that we can take advantage of.
9 And the idea of representing, thinking of it
10 as just a pile of sand, I'd kind of like to
11 back off, thanks.

12 **DR. KONIKOW:** Maybe it was mentioned, it
13 probably was and I just forgot, but what is
14 the present situation at Camp Lejeune? Where
15 is the present water supply coming from? And
16 on a related issue, were the wells that were
17 shut off and abandoned, how were those
18 plugged? How were those sealed? Did we, was
19 the annulus ~~crowded~~ [grouted -ed.]? So really
20 two separate questions: one, what's going on
21 there today for the water supply? And second,
22 what was done with the abandoned wells?

23 **MR. FAYE:** There are some slides showing the
24 well locations, the historical wells and the
25 modern wells. I'm not sure if Jason has any

1 handy there or we can flip something up. But
2 the well, the modern wells, the modern, active
3 wells, Lenny, have been distributed along
4 Brewster Boulevard and then through the, sort
5 of the eastern extension of Brewster Boulevard
6 and down North Carolina Highway 24. So
7 they're well north of -- we'll see here
8 hopefully in a minute. You can look on the
9 posters as well. Just a second. And down
10 Sneeds Ferry Road, and these are all well away
11 from points of known contamination and indeed
12 the sampling indicates that there's no
13 additional contamination happening. Here we
14 go.

15 **MR. ENSMINGER:** Unless it's munitions.

16 **MR. FAYE:** There you go. Lenny, these are
17 the modern wells right through here in this
18 area and then down here, down Sneeds Ferry
19 Road down in this area. These are the modern
20 wells.

21 **DR. KONIKOW:** Aren't those down gradient?
22 If you look at the head distribution, isn't
23 that down gradient from the contamination?

24 **MR. FAYE:** Sure, but you're looking at a
25 relatively small radius of influence here for

1 most of these modern wells out here. There's
2 not any influence in terms of contamination
3 unless there's an unknown source out there.

4 **DR. KONIKOW:** Well, what's the slope
5 direction?

6 **MR. FAYE:** Pardon me?

7 **MR. HARDING:** Yeah, I'd like to see a head
8 map, I guess for the side gradient.

9 **MR. ENSMINGER:** It flows toward the New
10 River.

11 **MR. FAYE:** What's your question in terms of
12 the regional flow patterns? They would be
13 toward the streams, Wallace Creek and then
14 toward the New River.

15 **DR. KONIKOW:** Well, it certainly isn't
16 shallow, but as you go deeper is there -- in
17 the upper Castle Hayne, is the flow direction
18 the same as in the shallow system?

19 **MR. FAYE:** Pretty much, yeah, left
20 undisturbed by pumping wells, yeah, it would
21 be very, very similar, very similar, just like
22 Tarawa Terrace actually. That goes back to my
23 comment that Mary objected to that it's kind
24 of a big sand pile out there. You see very
25 little head difference.

1 Actually, there's some -- and this is
2 discussed in one of the Tarawa, I think
3 Chapter C, Tarawa Terrace report. There's an
4 excellent set of observation wells out here
5 from the lower Castle Hayne aquifer all the
6 way up to the Brewster Boulevard aquifer.
7 This is observation well clusters by the North
8 Carolina folks, the State folks.

9 I think there's maybe like a three-
10 foot head difference between -- and this is
11 undisturbed -- three-foot head difference or
12 four-foot head difference between the lower
13 Castle Hayne aquifer and Tarawa Terrace
14 aquifer.

15 **DR. BAIR:** That's huge. That's enormous.

16 **DR. HILL:** That's up or down?

17 **MR. FAYE:** Well, of course, it's upward
18 because it's right next to Wallace Creek. You
19 have an upward flow pattern. So we have about
20 a four-foot head difference here.

21 **DR. BAIR:** Yeah, but that's an enormous head
22 difference. For a pile of sand you shouldn't
23 have any head difference.

24 **MR. FAYE:** I beg to differ. If you're by a
25 regional drain, I don't care whether you've

1 got a pile of sand or not. If you've got 300
2 feet of sediments or so, you're going to have
3 a vertical upward --

4 **DR. BAIR:** You won't have a vertical drain
5 without a head difference.

6 **MR. FAYE:** Pardon me?

7 **DR. BAIR:** It won't flow vertically unless
8 there is a head difference.

9 **MR. FAYE:** Well, if you have a highland area
10 here where you have recharge, and then you
11 have discharge down to your main drains, which
12 is the New River, Wallace Creek or whatever,
13 you're going to have a diffuse upward leakage
14 in the vicinity of the drains, and that's
15 going to be vertical.

16 **DR. DOUGHERTY:** It means that the best
17 technical data's a turning point.

18 **MR. FAYE:** Yeah, I mean, all you have to do
19 is look at what Hubbard [Hubbert -ed.] did
20 back in the middle '40s. You can look at what
21 Tete [Toth -ed.] said in '55. And you've got,
22 that's typical regional flow patterns.

23 **DR. HILL:** You've got three head maps in the
24 material that I have. One is in Report
25 Chapter B. It's on page B-30 and it's

1 estimated pre-development, and so this is
2 contour measured. But the points aren't on
3 here so I can't say what's controlling the
4 contours, but these are these contours.

5 Okay, then you have one in the
6 material we were sent in the notebooks. It's
7 Figure 1, page 8 under Tab 6 after the, in the
8 second section of that. And that's also
9 contoured measured. And then you also have
10 the contoured simulated values later in that
11 section if I can find it. And that's Figure
12 3.

13 In every one of these maps, the
14 contours next to the streams imply a
15 completely different hydraulic connection
16 between the groundwater system and the stream.
17 And that's true for the Northeast Creek and
18 the Wallace Creek. So I mean, you're talking
19 now about that the three-foot head difference
20 and what that means in terms of
21 interconnection with the stream.

22 And really, without the groundwater
23 flow model, I don't know. I don't know if
24 what you're saying is correct or not. But I
25 can say that your potentiometric surfaces in

1 these three figures imply, each of them
2 implies, I mean, there are some similarities,
3 but there's some drastic differences.

4 And I don't know if you have these in
5 front of you. We haven't seen them in any of
6 the slides, but the one from B-30, the Tarawa
7 Terrace report, but that figure goes down into
8 part of Holcomb Point.

9 **MR. FAYE:** If you look in Chapter C of the
10 Tarawa Terrace reports, there's a discussion
11 in there of the simulated potentiometric
12 surfaces, and you can't quite see the upland
13 areas of Tarawa Terrace here, but they would
14 be here. Where you have recharge in the
15 upland areas in layer one.

16 **DR. HILL:** I'm not talking about that.
17 These are really dramatic differences. I
18 mean, it didn't come up yesterday and I don't
19 have slides, but in Chapter B the Northeast
20 Creek shows that it's highly gaining like
21 this. The contours look like this indicating
22 water coming into the stream.

23 **MR. FAYE:** Right.

24 **DR. HILL:** But the contours on Figure 1 that
25 we were given show the contour is going

1 directly across the stream like this as if the
2 water was really just going --

3 **MR. FAYE:** No, that's a boundary for --
4 well, it may be true, but what I'm saying --

5 **DR. CLARK:** Is this something we might want
6 to take up after the break?

7 **DR. HILL:** Yeah, that's fine.

8 **MR. WILLIAMS:** The wells, there's a State
9 standard for ^ [abandoning -ed.] wells [; -ed]
10 fill them with generally with bentonite and so
11 that there won't be an interconnection between
12 the possible transportation of contaminants
13 between layers. So we did abandon those wells
14 according to the State standards.

15 **DR. DOUGHERTY:** That's really not very
16 definitive because it doesn't say that you,
17 because there are various stages of
18 abandonment. One of them is simply pulling
19 the pump and leaving it in reserve. Another
20 one is filling the existing casing with
21 bentonite cement, and another one is yanking
22 the casing and actually making sure you've
23 grouted the entire annulus because we had, I
24 think we have well water records that say that
25 the annulus is open. So if you just filled up

1 the casing, which I don't know North Carolina
2 State standards so please tell me. Did y'all
3 yank the casing or --

4 **MR. ASHTON:** No, we did not yank the casing.
5 And typically these are gravel-pack type
6 wells. And, no, we did not yank the casings.
7 Typically, how these wells are constructed is
8 about a 50-foot grout to prevent surface
9 influence. Then, of course, they go down
10 between 150 to, in some cases, we have some
11 wells that are 250, some that are even deeper
12 --

13 **DR. DOUGHERTY:** (Off microphone)

14 **MR. ASHTON:** Pardon me?

15 **DR. DOUGHERTY:** How were they installed
16 here?

17 **MR. WILLIAMS:** Oh, those were all rotary.

18 **MR. ASHTON:** Yes.

19 **DR. CLARK:** Why don't we take this up after
20 the break and give you a chance to get
21 together and talk about it?

22 **MR. WILLIAMS:** Yeah, and the other question
23 that was unanswered is what's the state of the
24 water system now. And we can take that up
25 whenever you want.

1 **DR. CLARK:** Why don't we address all this
2 after the break?

3 (Whereupon, a break was taken between 10:20
4 a.m. and 10:33 a.m.)

5 **DR. CLARK:** We're going to change the format
6 just a little bit and change the order a
7 little bit. I think that maybe we're not
8 giving ATSDR the kind of advice that they need
9 to continue on with their work.

10 So what I've asked Morris to do and
11 Frank to talk a little bit about what they
12 think they would do for the future and what
13 kind of advice and input they would like to
14 have from the panel. We've got you guys here,
15 an expert panel, tremendous input, tremendous
16 help, but I'm not sure they're getting the
17 kind of advice that ATSDR really needs to
18 continue on with their work.

19 So, Morris, why don't you go ahead?

20 **PANEL DISCUSSION: WATER-DISTRIBUTION SYSTEM**

21 **MODELING (RECOMMENDATIONS FROM THE PANEL)**

22 **MR. MASLIA:** What we would like to focus
23 really on is, and at the end of the day when
24 you make your recommendations, besides the
25 details is the big picture. Because what we
have to be able to do is go back, or if any of

1 our management is here, and also go back to
2 the Navy and say, yes, we're going to finish
3 in this timeframe or, no, here are the steps
4 we need to take to accomplish to provide the
5 epidemiologists with an estimate of exposure.

6 And to be able to do that I think we
7 need to step back or go back to the bigger
8 picture recognizing that the details are
9 important; however, what I've noticed is we
10 were, I thought, getting down to so much
11 detail that we lost sight of the big picture
12 in terms of the distribution of water
13 historically at Hadnot Point and Holcomb
14 Boulevard.

15 So I just put up, just real quickly
16 here, from 1941 when the system came online,
17 Hadnot Point supplied everything until Holcomb
18 Boulevard came online approximately in June of
19 '72. During that period you have one system,
20 and you have all the wells contaminated, non-
21 contaminated going into a water treatment
22 plant so we can go back to what we did at
23 Tarawa Terrace and use a simple mixing model.
24 So that takes the distribution system water
25 dynamics and water quality dynamics of a

1 distribution system out of the picture
2 completely, and we just have to concentrate
3 on, yes, important factors, but the well
4 cycling and from a groundwater standpoint.

5 From 6/72 when Holcomb Boulevard came
6 online to '87, from August through March
7 there's no indication that there are any
8 interconnection, the booster pump or the
9 Marston Pavilion valve was turned on. So
10 again, we still have simple mixing because the
11 wells are feeding into storage tanks,
12 combining into storage tanks. So again, that
13 takes the detailed water quality dynamics of a
14 distribution system out of the picture.

15 So that leaves us basically this time
16 period in here for April, May, June and July
17 with an interconnection issue a couple of days
18 during the month. So the question or the idea
19 would be can we use, can we come up with a
20 typical day, a typical day that we could say
21 during a typical day -- with bounds on it.

22 I mean, I'm not throwing out the
23 uncertainty, but with bounds on it that we
24 could then say during a typical day to the
25 epidemiologists, this is what the exposure

1 would be at different locations in the
2 distribution system given what data we have,
3 given that we have a two-week period where
4 we've got test data or sample data or whatever
5 when the line broke, given that we also have
6 field data that we collected in terms of
7 calibration or seeing that the system operated
8 realistically from a diurnal pattern. And
9 that's --

10 I guess, Frank, is that stating I
11 guess the big picture?

12 And that's what I'd like to throw out
13 to the panel here to see if we could focus the
14 discussion really on that so we can get,
15 hopefully, some direction as to how we should
16 proceed on that.

17 Frank.

18 **DR. BOVE:** The other big picture is can we
19 get monthly averages? Does that make sense
20 given the complexity of the situation? Can we
21 get quarterly, should we move to a quarterly
22 situation where we get just quarterly data
23 averages? So that's another question that the
24 epidemiologists, I would like to know.

25 **DR. KONIKOW:** Doesn't that hinge also on how

1 well we do in predicting what the wellhead
2 concentrations were?

3 **MR. MASLIA:** Yes, absolutely, absolutely.

4 **MR. HARDING:** You can't model at those
5 longer time steps in the water distribution
6 system. You have to do it on an hourly basis
7 or a sub-hourly basis. The model will choose
8 the time period that it needs. But what you
9 can do then -- I'm thinking out loud here, but
10 Walter and I had a discussion in the hall
11 here.

12 What we've done in the past, because
13 as the water distribution people are always
14 the tail of the dog, and the groundwater
15 people deliver their stuff to us at the last
16 second, and then we have to make our
17 calculations. And so we adopted as a matter
18 of convenience, but it happens to be good in
19 other ways though, using the method of super-
20 position to provide a fast way to make the
21 calculations of nodal concentrations to the
22 concentrations of the source in use.

23 And we have -- my brain isn't
24 completely functioning here, so correct me if
25 I'm wrong. But we have two sources of water

1 at Holcomb Boulevard during the
2 interconnections. We have the Holcomb
3 Boulevard water treatment plan, and we have
4 one, possibly two, interconnections. I think
5 the second one is when the booster pump is
6 running is going to prove to be a drain, but
7 you could do the modeling during those actual
8 interconnection periods.

9 The hydraulic modeling will calculate,
10 just like Jason did up there, and use a
11 hundred part per billion or use the source of
12 water function in EPANET and calculate the
13 percentage of water from each source and each
14 node, average that over a rolling three-month
15 period, which is your resolution that you
16 needed, and will help avoid overconfidence in
17 what you're predicting because you're going to
18 be wrong on any particular day. You know
19 that.

20 But over an average of a period of
21 three months, and that's usually what I felt I
22 had some confidence in, you should be getting
23 close. And then keep those coefficients
24 there, and then you can do whatever you want.
25 You can load them however you want with what

1 comes out of the Hadnot Point mixing model.

2 **MR. MASLIA:** I'm in absolute agreement with
3 you. In fact, we took a similar approach, not
4 contaminant-specific, but in Toms River. In
5 other words put a hundred units in and did it
6 that way as well. And that's I think what I
7 was trying to hopefully get to here is to try
8 to simplify that in that --

9 **MR. HARDING:** And in the Hadnot Point system
10 the memory in the tanks is going to be
11 important if the wells, if the contamination's
12 going on and off. If it's more smooth ^ but
13 if you've got contamination going on and off,
14 then the memory of the wells becomes
15 significant.

16 But you can use the same approach.
17 You can use the, what we call transfer
18 coefficient super-position approach to run it
19 once, and then use it to force it with a Monte
20 Carlo or whatever you come out of a resampling
21 from your groundwater results, just thinking
22 out loud. Walter had some thoughts as well.

23 **DR. GRAYMAN:** You were talking about
24 temporal averaging period. Spatially, under
25 most circumstances we'll be able to say, well,

1 we can treat Hadnot Point as a single unit
2 just as we did Tarawa Terrace. Holcomb
3 Boulevard, hopefully, we may be able to just
4 do it by ~~assume~~ [assuming -ed.] Berkeley Manor
5 is homogeneous. And that can be tested in the
6 water distribution system model to see if
7 that's the case.

8 **DR. WARTENBERG:** I have a question about
9 this temporal averaging. One of the things
10 that would be helpful for an epidemiologic
11 analysis is to know the variability of your
12 predictions. And I don't know where in the
13 process you're doing the averaging and whether
14 or not it's possible to give us more fine
15 scale data that epidemiologists would average
16 using rolling averages or some other approach
17 or finally give us some sense of that.

18 **DR. GRAYMAN:** Finer scale temporally or --

19 **DR. WARTENBERG:** Temporally.

20 **DR. GRAYMAN:** -- probabilistically?

21 **MR. HARDING:** You can do it, but you have to
22 then use it in a longer timeframe because
23 you're going to be wrong. You're not going to
24 have it exactly the right time. But if you
25 want to calculate frequency information, I

1 think you could do it.

2 **DR. WARTENBERG:** Well, all I'm saying is if
3 you asked me what's the right temporal
4 increment? Should it be one month, three
5 months? I don't know the answer. But if you
6 gave me the data, say, daily data, then I can
7 average it different ways and look at it.

8 **MR. HARDING:** It scares me if you're going
9 to use it and on a daily basis.

10 **DR. WARTENBERG:** No, I wouldn't use it on a
11 daily basis, but I could look at how it
12 changes and aggregate it weekly, monthly.
13 Otherwise I don't see that variability.
14 That's what I'm saying.

15 **DR. KONIKOW:** Look at the first page of
16 Table C-7 that they handed out this morning
17 and look at the wellhead concentration in the
18 first well, 602, over a two-week period. It
19 hit a high of 1,600. The next sample is 540
20 and the next was 300.

21 **DR. WARTENBERG:** Those are still going to be
22 the data, right? Those are the data, and
23 you're going to have to --

24 **DR. KONIKOW:** You want to know what the
25 variability is on a less than a mean monthly,

1 well, there's the information we have.
2 Whatever we reconstruct in the model to feed
3 into the water treatment plant isn't going to
4 be any better than this. And this is your
5 sample, and you know, you say, well, there's
6 three samples in two weeks. What's the odds
7 of actually hitting a peak? Well, pretty
8 small. Somewhere close to this time it was
9 probably much higher than 1,600. There you
10 have an example of the range in a contaminated
11 well, and if you go to the really bad well,
12 651, you see similar things over basically a
13 two and a half week period it went from 3,200
14 to 18,000. Well, there's your sample of a
15 local area --

16 **DR. HILL:** And I really agree with that, but
17 the model's going to give you a very smooth
18 representation of what that system was doing.
19 The actual variability is just what Lenny
20 said. You've got it there, and that's the
21 best information you're going to get.

22 **MR. HARDING:** It won't be smooth in the
23 water distribution model. It will be step
24 functions. It'll be on and off. It won't be
25 smooth. But when you average it, you -- but

1 it will be wrong on Tuesday, or Wednesday.

2 **DR. DOUGHERTY:** Right, but if we do a
3 multiplicity of scenarios and then provide
4 those averages across the scenarios on a sub-
5 daily basis, which way do you want to, it just
6 becomes risky.

7 **DR. KONIKOW:** Well, there's no way in terms
8 of the wellhead concentration according to the
9 plan modeling scenarios, there is no way that
10 you could possibly reproduce the observed
11 variance in what gets fed to the water
12 treatment plant.

13 **MR. HARDING:** I can't even speak to what
14 gets fed to the water treatment plant. That's
15 your business not mine, but I'm saying that
16 what happens in the water distribution systems
17 is going to be way more dynamic. That's the
18 point I'm making. And let me just ask this
19 question about objectives here.

20 All the work that I've done in the
21 past, we've been looking at chronic effects,
22 and we haven't been looking at acute impacts.
23 And so what we looked at was what we called
24 either whole body dose or intake of a
25 particular contaminant, typically TCE, vinyl

1 chloride or chloride sometimes. And so you
2 would be looking at the accumulation by on an
3 annual basis.

4 And the reason that you looked at it
5 on a shorter basis was because people moved in
6 and out and things like that. Now, in this
7 case we've got to look at it on a shorter
8 basis because somebody, because we're worried
9 about these trimesters. But is it really
10 necessary to know that, or even useful to
11 know, that that occurred in the first month or
12 the third month? See what I'm saying?

13 Because I'm very, I think you're going
14 too far if you break this down more than a
15 quarterly basis, but you could do a rolling
16 three month summarization. And I'll leave it
17 to the statisticians to figure out just how
18 much structure you could put into that
19 summarization. Typically, we've used the
20 mean.

21 **DR. GRAYMAN:** Let me ask you a couple [of -
22 ed.] questions and interpret how you'd use the
23 information. Would it be different if you
24 were to get the information, let's say, on a
25 monthly basis or on a three-month basis that

1 the average concentration in the water was 300
2 micrograms per liter. If you had that
3 information, but if we were to tell you that
4 during that same period, the concentration
5 varied between zero and 1,500, would you use
6 that information? But on average it was 300.
7 Would that impact your study?

8 **DR. WARTENBERG:** I guess I don't know enough
9 about what people think the mechanism might be
10 in terms of how the causation works, but
11 there's certainly been studies where people
12 looked at maximum exposure levels or percent
13 of time above some level. In other words how
14 many days were they exposed above, and I don't
15 think there's good theory behind it.

16 What I was trying to get a sense of if
17 you're telling me the data are, I don't care
18 if they're not reliable for that day, but are
19 they really representative of the variability,
20 then that's useful. If they're not, then
21 obviously it's not useful.

22 But for things which people can
23 actually measure over time, sometimes people
24 have taken these daily numbers and then looked
25 at different ways of summarizing the exposure

1 not assuming that the average is what makes
2 sense.

3 **MR. HARDING:** I think that's okay. There's
4 some technical or mechanical issues that have
5 to be resolved. I mean, this is not going to
6 fall right out of EPANET as it comes off the
7 shelf and you pull the shrink wrap off it. So
8 there's some mechanical difficulties, but
9 that's why we pay Morris the big bucks and
10 Jason the big bucks, right? I'd be happy to
11 describe the way we've modified it, but, yes,
12 you can do that.

13 And you can basically -- leave to the
14 statisticians to figure out just which of
15 these things would be valid. But I would
16 think that days above a threshold would be
17 valid and a mean. The problem is that if you
18 don't do this right, you're going to have to
19 go back and re-run the model to get it again
20 with a different threshold.

21 So I would suggest figuring out a way
22 that you can run it on these short timeframes
23 and store your transfer coefficients on a
24 short period and then be able to run it
25 through a subsequent processing step to --

1 these are technical details, but I think it
2 can be done.

3 **DR. WARTENBERG:** Yeah, but I don't know if
4 Frank's thought about this at all. Just
5 listening to you talk about the different
6 timeframes just occurred to me.

7 **DR. BOVE:** When it comes to, say, neural
8 tube defects, we're talking about a time
9 window here of vulnerability of a few days
10 during the fourth week of gestation. We
11 can't, of course, know when those four days
12 occurred based on what the birth date of the
13 child or even if we have LMP, last menstrual
14 period, where a clinician decides on
15 gestational age. I'm not sure we could
16 pinpoint those four days anyway, or five days.
17 But that's how tiny the window is for neural
18 tube defects.

19 For clefts we're talking more of a
20 week or two, a two-week period for each of the
21 clefts, cleft lip and cleft palate. So we're
22 talking small timeframes of window of
23 vulnerability, but there's also uncertainty as
24 to when those two weeks occurred given what we
25 know about the child's birth and the mother's

1 LMP. So those are issues.

2 MR. HARDING: Well, I think the best you can
3 hope for would be this percentage of time
4 above certain thresholds, and I think that
5 would be a valid statistic to calculate. I'm
6 looking for support here from somebody that
7 knows more about this, but I think you can get
8 that, and then from that you could probably
9 make some inferences about what the odds would
10 be that this particular causative factor was a
11 factor in that particular.

12 DR. BOVE: Where are these thresholds coming
13 from?

14 MR. HARDING: Well, let's say that you'd say
15 that during this particular three-month period
16 the concentration was above 300 parts per
17 billion for sixty percent of the time or
18 something like that. And if your threshold
19 for impacts a hundred, I mean, we could do a
20 hundred, too. Maybe it's 100 percent of the
21 time. And so you've got a clear answer there.
22 It's going to be diceyer [dicier -ed.] if your
23 threshold is, say, 200 and the percent of time
24 above 200 is 30 percent. I don't know.

25 I can't answer that question for you,

1 but I think you need to step back. I wanted
2 to go back to Walter's point here. You need
3 to just climb up to about 20,000 feet for a
4 minute and look at this, and you guys need to
5 look and ask for your endpoint what you need,
6 and then talk about how you're going to try to
7 get the best estimates of those things you can
8 from the models.

9 **DR. GOVINDARAJU:** I'm seeing two kinds of
10 variability right now. First is if you have a
11 model run which has all these behavior
12 fluctuations and ^ [temporal -ed.]
13 fluctuations, if you want to average them or
14 do the moving window of let's say one week or
15 ten days or three months, then you'll get
16 fluctuations within one single model run.

17 But if you want to incorporate the
18 variability you're getting from wellhead
19 concentrations and so on, then you're talking
20 about doing many of these model runs to try
21 and capture that variability as well. So
22 there is almost like an internal, intra-model
23 variability, and somehow we have to combine
24 all this information to answer questions like
25 what is the likelihood that you will exceed a

1 certain value over a continuous ten-day
2 period.

3 Or what would be -- and so some of
4 those we can, I think those could be done, and
5 we could perhaps attach some probability of
6 what is the likelihood, what is the
7 probability of this kind of event happening.

8 **MR. HARDING:** In fact, what you're dealing
9 with in the water distribution system is
10 variability. And what Rao's talking about is
11 uncertainty, I think. And I would suggest
12 bringing Owen Hoffman who's a guy we've worked
13 with before on the, to help frame this team.
14 He's a really excellent person on risk out in
15 Oak Ridge. But, yeah, that's the issue.

16 You've got variability in the water
17 distribution system, which is more profound
18 than in the groundwater system, but just
19 happens faster a little bit. There's still
20 variability in the water distribution system,
21 and then there's a profound imperfection in
22 our state of knowledge about this, which is
23 the uncertainty we face. And that's going to
24 be represented by different iterations of a
25 Monte Carlo, for example.

1 **DR. HILL:** So we have this range of things
2 that epidemiologists might want. We have just
3 give me bulk, high, low, medium exposure or
4 no, medium and high exposure. And then we're
5 getting into these ideas of, well, if I had
6 more detail, this is how I would use it so
7 that I could use it.

8 And we've talked about different
9 strategies for creating more accurate
10 concentrations at the wellheads and whether or
11 not those are worth it and maybe they're not
12 worth it if you're just trying to get
13 rankings. But maybe they're well worth it if
14 you're trying to dig any deeper.

15 So it seems to me like there's a goal
16 of this groundwater model that's a bit of a
17 moving target as of these last couple of days.
18 And I'd be interested in, and I don't know
19 what you think about this, but it seems to me
20 like the design and effort in the groundwater
21 model depends very much on these priorities.

22 **DR. GOVINDARAJU:** The answer is yes, but
23 just to bring the discussion back, I think
24 we're talking about just the water
25 distribution system right now. Is that

1 correct?

2 **MR. HARDING:** I don't want to limit it to
3 that.

4 **DR. HILL:** It seems like the, it may be that
5 the water distribution system impact
6 dominates. I don't know, but I wouldn't think
7 entirely.

8 **DR. GRAYMAN:** I think it's time to broaden
9 this discussion back.

10 **MR. HARDING:** But certainly it only
11 dominates for, it may not even dominate, but
12 it's ^ [important -ed.] in this relatively
13 small piece of a relatively small piece
14 probably of Holcomb Boulevard. Unless the
15 wells are going on and off and there's big
16 step functions in the forcings [? -ed.] from
17 the contaminants, which I think is probably
18 unlikely, then the tank memory in Hadnot Point
19 will become important. But if it's not, it's
20 not important.

21 **DR. CLAPP:** I'd like to just respond to
22 Mary's laying out of the range of opinion
23 that's been made by us epidemiologists. I
24 sort of staked out the three-category thing
25 yesterday. But it's definitely true that the

1 more, especially for Frank's birth outcome
2 studies, the more detail the better.

3 I guess what I'm worried about is that
4 we're getting to a point where we publish an
5 effect estimate that has so much uncertainty
6 bound or bundled up in it that the confidence
7 bounds go off the page, and you're left with
8 just a big fuzz ball. So if we can narrow the
9 bounds of uncertainty to the point where it's
10 useful on a monthly basis, fabulous, and not
11 just a guessing game.

12 **MR. HARDING:** Don't expect -- I keep saying
13 this. Think in log space. Think in terms of
14 astronomical framework. I mean, when I've
15 done this before, the medical causation people
16 think that way. I mean, if the exponent
17 doesn't change, we don't have a significant
18 difference. I mean, you've got to be to that
19 point. I mean, you're talking -- we never did
20 get to the calibration standards, but you're
21 talking about a half an order of magnitude
22 plus or minus, so you've got an order of
23 magnitude range just in your calibration
24 standards. So how can you expect to be
25 conceptually better than that in --

1 **DR. HILL:** And that was heads.

2 **MR. HARDING:** Yeah. But I just think if you
3 can't use it for an epi study in the log
4 space, maybe you can't answer the
5 epidemiological question. But there's a lot
6 of other questions certainly that can be
7 answered or be thought about.

8 **DR. WARTENBERG:** I don't know if the ^ will
9 fix that or not but I mean, some epidemiology
10 has really ^ [had -ed.] horrible exposure data
11 and worked. There are countless occupational
12 studies where if you worked in a given
13 profession versus not, there are really clear
14 associations with disease.

15 And then it goes off in the other
16 extreme where people have very fine-scale,
17 accurate estimates of exposures and can show
18 associations. So in something like this where
19 I think it's less, there's less data to say
20 what the association is, it's a little hard to
21 say what we really need to show an association
22 if one exists.

23 **MR. HARDING:** But if I've learned anything
24 here, the one thing you want to avoid is
25 misclassification, right? So if we can get

1 that right, then we've made a step forward.

2 **DR. WARTENBERG:** Right, misclassification
3 will just blur the whole thing.

4 **DR. HILL:** So let me go back to -- it seemed
5 to me yesterday there were three ways to deal
6 with the wellhead, developing wellhead
7 estimates of concentration. One was just to
8 take the measured concentrations that we
9 already have. Say, okay, I'm going to project
10 back in space or in time that this really
11 contaminated well had some kind of average
12 value back, almost a step function or
13 exponential or something.

14 And just say, okay, based on
15 measurements here, I'm just going to project
16 it back. No physics, no nothing, just a
17 direct, and then feed it through the mixing
18 system of the well distribution system and get
19 exposed node, high-level node, whatever in
20 three categories.

21 That would be like level one. Level
22 two or level three, whatever, the other two
23 options that were discussed were doing some
24 linearization of the system and doing what
25 Professor Aral said. And then the third one

1 is to go through the whole groundwater model.

2 And so if this is level one, it seems
3 to me that then you want to think really
4 closely about, okay, if I can start with this
5 level, what do I want to get out of those next
6 two levels, and very specifically. Because I
7 think if you have very specific objectives on
8 what you want to attain from those given the
9 data you have and given what you have a hope
10 to, then you can make some progress.

11 But I'm a little concerned that the
12 charge being given for the groundwater model
13 isn't focused and defined enough, and it's
14 just like, well, just represent the system
15 accurately. Well, given this data what does
16 that mean? So I'd be interested in a
17 discussion that kind of address those three
18 things and what to get out of it.

19 **DR. ASCHENGRAU:** So I think with going
20 further would be to get a more accurate
21 ranking of those study subjects, that that's
22 what all of that effort would do would be to
23 boost at that accuracy and get a more accurate
24 ranking that would be possible with the first
25 method. So and it just seems as though

1 there's a huge amount of effort that needs to
2 take place in order to do that.

3 **DR. BOVE:** I think Mustafa's approach does
4 not take a whole lot of effort and may still
5 give us some of what we got for Tarawa
6 Terrace, if I'm not mistaken. So I think
7 that's the approach we've been thinking about
8 all along. That that approach might give us a
9 good answer, a good answer for the epi study.

10 And then if we need to move beyond
11 that, we could use that part, step two, to
12 help us with step three if we wanted to go to
13 step three. But we could try step two to try
14 to get the monthly averages like Tarawa
15 Terrace. And then if that was sufficient, we
16 could stop. Does that make any sense?

17 **MR. HARDING:** How do you know it's
18 sufficient?

19 **DR. BOVE:** We make a judgment. I mean, --

20 **MR. HARDING:** That's fair, but the concern I
21 have -- and I'm not a groundwater --

22 **DR. BOVE:** Not by -- we make a judgment
23 without looking at the outcome, blinded by the
24 outcome, of course.

25 **MR. HARDING:** Coming out of the world of

1 litigation I know there's a huge weight put on
2 trying to acceptance and I think that it's a
3 novel idea, and it seems to conform to Clark's
4 law about a sufficiently developed technology.
5 It really is cool what it does though I have a
6 problem thinking that people are going to
7 accept this very much when they can't get in
8 and dig around and look at the physical
9 underpinnings and say that these make sense.

10 Do the constraining layers, you know,
11 we've gone into all these details, and that's
12 a real pain for the modelers. And some people
13 focus on little details that are their
14 specialty, but on the other hand that's the
15 way you're going to develop confidence with
16 this is that does it look reasonable. And
17 unfortunately, you can't do that with a matrix
18 that's got 16 elements in it or 25 elements.

19 **DR. GRAYMAN:** Yeah, building on that, again
20 from the legal standpoint or at least my
21 observation of it, is a lot of reliance is on
22 has this model been used before. So if you go
23 in and you say I've used MODFLOW. MODFLOW's
24 been used for 25 years all over the world. It
25 develops a certain confidence. If you use

1 something else that's new and innovative, then
2 you, the burden of proof is on you that that
3 is valid. It's a tough thing to prove.

4 **DR. KONIKOW:** Well, in this case if you get
5 to the point of trying to develop a history of
6 wellhead concentrations using this full-blown
7 modeling approach, deterministic approach,
8 it's really going to be difficult to defend it
9 in a litigation requirement. I mean, there
10 are just so many weaknesses in assumptions and
11 uncertainties in it that it really will be
12 very difficult. I mean, you get very open to
13 attack.

14 **MR. HARDING:** It is, but it's been done many
15 times.

16 **DR. GRAYMAN:** Is it more so than other
17 situations? Is it more --

18 **DR. KONIKOW:** In this case more so than
19 other situations.

20 **MR. HARDING:** I've seen some really messy
21 situations with not nearly as much data.

22 **DR. DOUGHERTY:** But is it more than the
23 linear control approach?

24 **DR. KONIKOW:** Well, no, I think they both
25 hinge on what do we know. And what we know is

1 very limited. And so whichever, it's a
2 question of how do you want to extrapolate
3 back. For the wellhead what we really need to
4 know are two things. One is the pumping
5 history of each well. That's important to
6 know if the modeling will not give us a clue
7 about that. We have to tell the model what
8 that is, not the other way around. So that's
9 one thing that's needed.

10 The other thing is the concentration
11 in the well or in the well discharge, the
12 history of that. Now that we could try to get
13 that starting from a very deterministic
14 approach. And I'm not saying it's not worth
15 doing, but I'm saying we better have something
16 to compare it against such as Mary's level one
17 and just see how they compare. I think we
18 could do a little bit better and still keep it
19 very conceptually simple but key into the
20 history that we have even though as limited as
21 it is, those are the knowns.

22 And then there were all kinds of
23 questions about what causes this variability.
24 Look at the contaminated wells. It shows a
25 peak. You know, you've got five data points,

1 it goes up and then down. Well, is that
2 variance, is that just representative of a
3 saw-tooth pattern or was this the real peak in
4 the whole full-blown history.

5 But what I would say, and you will
6 have to reconstruct something about the mass
7 loading history to do the transport model, so
8 you will have some estimate of that
9 information. Well, take that information, use
10 your flow model in MODPATH analyses from each
11 well to each source and reconstruct the
12 distribution of travel times.

13 Use that then to lock in the starting
14 points in growth history of a concentration
15 curve, and then just bring it, just use a
16 thick pencil and bring it up, if you want to
17 work on a log scale exponentially or on an
18 arithmetic scale, try them both, then just
19 bring it up, use your MODPATH to get you a
20 starting point, an initial curve, and then
21 bring it up to your known history. And then
22 feed that into your mixing. Do that for each
23 well.

24 You still need as good a groundwater
25 flow model as possible, but you use MODPATH

1 instead of -- but then you'll still have other
2 complications. Do you want to retard the
3 movement field or retardation factor to catch,
4 but at least you have a starting point, and
5 it'll be much simpler and more defensible and
6 easier to explain conceptually than the full-
7 blown transport model. Do the transport model
8 also, but I think have this simple, I'll call
9 it level 1.5, as a way to get at the numbers
10 you really need and --

11 **DR. CLARK:** What about linear control?

12 **DR. KONIKOW:** I don't understand that well
13 enough to know that it's any different from
14 the drawing with a thick pencil.

15 **DR. CLARK:** Dr. Aral.

16 **DR. ARAL:** I think Mary wanted to say
17 something before I --

18 **DR. HILL:** Oh, no, all I had just wanted our
19 discussion to progress further before Dr. Aral
20 talked, but if this is the appropriate time
21 for that, that's fine.

22 **DR. CLARK:** That's an issue, I gather, is
23 how appropriate the use of linear control
24 theory would be.

25 **DR. KONIKOW:** If the linear control theory

1 is as good as it looked, then fine. Do it for
2 the wells where there's enough data to do
3 that, then great, but I don't understand about
4 the ^.

5 **DR. BAIR:** To me the shortcoming of it is
6 not in where it can be applied, it's where it
7 can't be applied. And do you go forward with
8 something that is an incomplete picture of the
9 whole thing from 20,000 feet, which would be
10 the linear control model at three or four
11 places, where you have sufficient data to go
12 forward with it.

13 Can you ignore -- I don't know -- 70
14 percent of the area or 60 percent of the other
15 production wells? And how do you enter that
16 missing 60, 50, 40 percent into the water
17 distribution model? And if you're missing 40
18 percent, how do you analyze that in an
19 epidemiological way when you're missing 40
20 percent of the possible source terms because
21 you didn't address all the wells in the flow
22 system?

23 **DR. KONIKOW:** Yeah, one of the things that
24 the transport model could do for you that the
25 data don't is that at least within the

1 framework of the conceptual understanding of
2 things, it may show you some surprises. It
3 may show you a pulse of contamination going by
4 one water supply well where you have no
5 records of contamination because it came and
6 went before the period of observation. So
7 things like this could be gleaned from this.
8 You just don't know whether to believe it or
9 not. You don't know what to do except to say,
10 well, there's a possibility.

11 **MR. FAYE:** Let me just say that Lenny has
12 pretty well articulated what we have discussed
13 in our planning conversations amongst the
14 staff. And in terms of the deterministic
15 model about the approach, the methods and how
16 to do it. And somewhere I hope there's a
17 verbatim transcript of that because it lays
18 out very well, as I said, what we have looked
19 forward to doing.

20 The issues with the linear model, the
21 difficulty there is what Dr. Bair talked about
22 is that you need concentration data at the
23 supply wells, and there's very little
24 concentration data for all of the abandoned
25 supply wells through time, and there is none.

1 And unless you have something going on at that
2 well that represents in the linear model,
3 there's no way to construct anything from that
4 in terms of a monthly concentration, quarterly
5 concentration, whatever.

6 **DR. HILL:** Okay, now I'm confused. Because
7 it seems to me that you have been advocating
8 the use of that approach, and now it seemed to
9 me that that was a very clear explanation of
10 why it was really pretty limited and so now
11 I'm confused.

12 **MR. FAYE:** Why are you confused? Because it
13 was totally presented yesterday as a screening
14 tool. I mean, well, it was, as I heard --

15 **DR. BAIR:** Twenty minutes ago it wasn't.

16 **MR. FAYE:** -- as I heard it was to be used
17 as a screening tool, as an adjunct to
18 developing our deterministic model.

19 **DR. HILL:** I have definitely been getting
20 mixed signals about how it would be used
21 exactly.

22 So, and Frank, some of your comments,
23 particularly made me think you were thinking
24 of it in a more, in a broader perspective. So
25 maybe you can --

1 **MR. MASLIA:** Let me clarify because we've
2 got some objectives here that need to be
3 mutually compatible. And that is that we need
4 to give the epidemiologists results that they
5 have some confidence in. And at the same time
6 we do not have an infinite amount of time or
7 resources. So what we need to try to do --
8 and I'm not necessarily talking about the
9 December date that we had thrown out. I'm
10 just saying in realistic, you know, we can't
11 go on for another five years like that.

12 With that said we were looking to
13 develop a screening-level method that could
14 initially give us some rough cut or estimate
15 to give us some handle on what the
16 concentrations would be back in time, and at
17 the same time, as Lenny and Bob said, perhaps
18 help us avoid from going to the full,
19 dispersive fate and transport approach and
20 using a much smaller sized advective transport
21 model.

22 **DR. GOVINDARAJU:** Well, I think one of the
23 things that we could consider is from what
24 Professor Aral explained yesterday, his method
25 is allowing us at least to have an idea of

1 what happened in the past for the wells that
2 we have observation. For wells that we have
3 observations recently, it can also reconstruct
4 some of the stuff in the past.

5 So we could use that information and
6 then have that also constrain the full-blown
7 groundwater model. Because the groundwater
8 model as it is has too many unknowns, too many
9 things that we aren't able to pin. So having
10 some other guidance to perhaps pin it at these
11 locations and for wells which have no data,
12 you're right, we have no data, let the
13 groundwater model, full-blown model, do its
14 best.

15 It'll already have a lot to do just
16 trying to capture that. So if it is outcome
17 guided in some other way with some other
18 information, I think we should use it.

19 **DR. DOUGHERTY:** Okay, I'm an engineer so I'm
20 trained to be conservative and have big safety
21 factors on things. So with that as a preface,
22 I'd like to move on. I'm in agreement with
23 Lenny in many respects here. I like the idea,
24 the linear control, the black-box model,
25 whatever you want to call it, I think it's

1 intriguing, and I think it should be explored
2 in parallel.

3 I think hanging your hat on it is
4 inappropriate because you're going get too
5 many hits once the first document goes out the
6 door. I do think it's very intriguing, and I
7 think it should be explored in parallel in
8 those locations where they are appropriate.

9 But I think we need to move past it
10 and get on with the other significant things
11 to deal with, which are the sources of
12 uncertainty that drive it, pumping schedules,
13 source locations and release times and mass
14 loadings and all the other things that we've
15 talked about.

16 **DR. HILL:** One thing that I'd be interested
17 in talking about is what groundwater transport
18 model to use. Because there's -- and I
19 brought this up in my comments as well --
20 there are widely used transport models that I
21 believe simulate the processes that are being
22 simulated, that are of concern for this model
23 and instead of a relatively, new untested
24 model that's being used. In this highly
25 political situation, I really wonder about

1 that decision.

2 **MR. MASLIA:** We used MODFLOW and MT3DMS.

3 **DR. HILL:** Yes, but for the reactive
4 transport.

5 **MR. MASLIA:** For the degradation, one of the
6 reasons we went there is we thought we might
7 need to get into the unsaturated zone.

8 **DR. DOUGHERTY:** So the plan here moving
9 forward is to stick with MT3DMS --

10 **MR. MASLIA:** Or MODFLOW/MODPATH.

11 **DR. DOUGHERTY:** Or MODFLOW/MODPATH.

12 **MR. MASLIA:** Yes, that is correct.

13 **DR. DOUGHERTY:** So we don't foresee the
14 unsaturated issue showing up here? I mean,
15 this because I have a hard time --

16 **MR. FAYE:** Actually, it could because
17 there's issues with vapor from PCE, BTEX into
18 the buildings, particularly at the HPIA. We
19 didn't really even anticipate a problem of
20 that nature with Tarawa Terrace. It did show
21 up with respect to one of the schools there,
22 and we had, it was a good thing that we had
23 the unsaturated zone model. So all I can say
24 is we just don't know, but it would be handy
25 to have because there are issues out there

1 where it would be useful.

2 **DR. DOUGHERTY:** So do you see that in this
3 particular study or other studies that are in
4 planning --

5 **MR. FAYE:** Well, as it happened in Tarawa
6 Terrace, it turned out to be a secondary
7 thing, a post-modeling thing, but it did
8 happen, and we did have the model there to
9 attempt to deal with it. And so who knows?
10 If the very same, as Mary said, this could be
11 a highly litigious situation, and it could
12 come up just right out of the blue as it did
13 at Tarawa Terrace.

14 **DR. KONIKOW:** Well, in terms of informing
15 the calculated wellhead concentrations, I'm
16 not sure I see the connection.

17 **MR. FAYE:** No, there is none. It would just
18 be an ability to simulate the unsaturated
19 condition.

20 **DR. KONIKOW:** So in terms of the objective
21 maybe that's going a bit astray then.

22 **MR. FAYE:** In terms of the objective as it's
23 stated now, yeah. I would agree with that.
24 But like I said, at Tarawa Terrace it was the
25 same issue. I mean, it was a kind of a

1 research thing to do. It worked out nicely,
2 and we did the whole degradation scheme with
3 it.

4 It happened to have an unsaturated
5 zone component. And from the point of view
6 though of doing the degradation, the complete
7 degradation pathways, Lenny, that was a model
8 that we used. It just happened to have an
9 unsaturated zone component that came in handy
10 later on.

11 **DR. KONIKOW:** Yesterday when we were talking
12 about the models we, I mean, we're kind of at
13 a disadvantage here projecting where the
14 transient flow model and MODPATH and the
15 MT3DMS will get us, we really never talked
16 about them, but you were having some
17 experience with Tarawa Terrace. And looking
18 at some of the documents in the three-ring
19 binder, there are still many -- maybe we need
20 a day or two, you know, eight months from now
21 to talk about this.

22 But I'm really particularly concerned
23 about projections of degrading calculations
24 of degradation rates or decay rates in there.
25 Because I saw preliminary estimates using

1 observed concentrations assuming that there's
2 no advection, no dispersion, no nothing else
3 going on and ignoring the fact that there were
4 remediation efforts going on, just using the
5 best fit to get a decay rate. And then saying
6 --

7 **MR. FAYE:** It wasn't even a best fit. It
8 was just two points at a time.

9 **DR. KONIKOW:** And then saying that that's
10 the rate you should use in the transport
11 model, and this is circular reasoning that I
12 think will be difficult to defend. So I mean,
13 there are many issues on the transport
14 modeling, and that's just one example that
15 really will leave the whole thing open to
16 severe criticism. I don't see any easier way
17 around it.

18 **DR. DOUGHERTY:** Those particular pages I,
19 those should be red-lined right now. Throw
20 them out. I'll be direct. They're terrible.

21 **MR. FAYE:** Which ones are you talking about?

22 **DR. DOUGHERTY:** The biodegradation reaction
23 section in -- I forget which tab it was under
24 -- there are two pages ^, and they're not
25 biodegradation or reaction fittings.

1 **DR. ARAL:** Morris, they have to log on.

2 **MR. FAYE:** All I can say is with respect to
3 that, Lenny, you're right. There's all kinds
4 of limitations. We have on the one hand, we
5 have a lot more opportunity because of data to
6 compute degradation rates in this study from
7 field data. But they're still limited by the
8 same caveats that you describe regardless.

9 And then the other choice is
10 literature data. All I can say is you know
11 we'll do the computation so we'll take the
12 field data out. We'll take the literature
13 data and look at it and make our best judgment
14 and defend it as well as we can. We know
15 that. We're aware of the limitations of using
16 those field data, for sure.

17 **DR. HILL:** Just coming back to the transport
18 model, having the capability to deal with the
19 unsaturated zone is fine, but usually to deal
20 with the unsaturated zone you need a fairly
21 fine grid. So you might consider using a very
22 fine grid, a much finer grid usually than you
23 need for the saturated zone. So you might
24 consider using the more sort of tested and
25 accepted model for some of your simulations

1 and bring in the model with the unsaturated
2 zone for those simulations that have that
3 requirement.

4 **MR. FAYE:** Yeah, I think that the point's
5 well taken. The application of that model
6 would only be with respect to what Rene was
7 talking about yesterday was the child models,
8 you know, where the --

9 **DR. HILL:** Right, I understand.

10 **MR. FAYE:** And that would be a very high
11 grid resolution.

12 **DR. HILL:** Let me just finish. I just
13 wanted to mention that the name of that model
14 is RT3D, which you know I'm sure.

15 **DR. CLARK:** Right.

16 **DR. ARAL:** I'm not going to defend any model
17 or any procedure. I'm just going to summarize
18 probably what has been said in this group this
19 morning.

20 As a technician in this field in
21 developing models and as a technician in this
22 field in applying models, we all know that the
23 model sophistication can be put forward in
24 terms of its ability to model this and that
25 and other things in the field that we observe

1 in any which way we want.

2 In other words technically we are
3 capable of developing a mathematical
4 representation of a physical system and then
5 computationally discretizing it and solving
6 it. We are technically capable of doing that.
7 And I'm summarizing that in this slide here.
8 This is one sophistication level that we can
9 look at. We can go beyond this. We can go
10 backwards from this. So model sophistication
11 from a technical point of view can go forward
12 from that in any direction that we would like
13 to go.

14 However, in an application the model
15 to be used should be a function of
16 availability of data in the field. We cannot
17 go to a more sophisticated model than that if
18 we don't have available data for the
19 parameters that we introduce at that
20 sophistication level because as we go forward
21 in sophistication, we are adding additional
22 parameters. If we don't know the parameters
23 then the uncertainty that we introduce into
24 the outcome is going to be greater than the
25 capability of the model to represent the

1 physical system.

2 So this is what has been discussed in
3 this group all morning. I mean, basically, we
4 have limited data. We have to accept that.
5 Can we go to a daily pattern in a water
6 distribution system? Yes, I have worked in
7 that. Yeah, I can put a daily pattern in.
8 But do we have that data? No. So the
9 discussion has to concentrate and focus on
10 what we have and what the model can do in that
11 arena.

12 The other aspect of all this in my
13 opinion, what is the outcome that we are
14 after? Yes, the data is limitation. The
15 model can be of any sophistication level, but
16 what do we want as an outcome? That is the
17 other consideration which is also discussed in
18 this group that we need to address. The
19 outcome is what the epi people want. Do they
20 want monthly data output of concentrations?
21 Do they want daily output or quarterly output?
22 So that needs to be a driver. All of this I
23 think has been discussed, and all I'm saying
24 is let's summarize that, and let's look at it
25 from that perspective.

1 The other concept that has been
2 discussed here is in litigation we should use
3 established models. Well, if you put me to a
4 litigation desk, I can always criticize
5 MODFLOW. I can always criticize MT3D because
6 they are not sophisticated enough for certain
7 applications. And we have discussed why they
8 are not because vapor exposure. They don't
9 address that.

10 So if there's a model which does an
11 additional analysis over what other models can
12 do, if it is available, why not use it? If it
13 is available in terms of duplicating what
14 MODFLOW does, why not use it? Just because
15 MODFLOW has an earlier history doesn't make it
16 better.

17 So I just want to leave it at that. I
18 think the summary here is we have to look at
19 the data. We have to look at the output
20 required. The models are just tools. We can
21 choose A, B or C if it helps us getting from A
22 to Z, then that's okay. That's all I have to
23 say.

24 **DR. ASCHENGRAU:** Dr. Aral, have you
25 validated your methods against the other

1 methods or against data --

2 **DR. ARAL:** The new method that I have talked
3 to you today or yesterday? No, that's a
4 totally new method. The only validation that
5 you have seen is on the Tarawa Terrace
6 application. That's a totally new
7 application.

8 **DR. ASCHENGRAU:** But this third thing, the
9 matrix, it may be --

10 **DR. ARAL:** Oh, yes, this solution that we
11 have, I think it's the name was not mentioned
12 but ^[TechFlowMP -ed.] ~~FLOW-MP~~ is a new 3D
13 model -- not new, started in the '90s we are
14 working on it -- does solve these equations
15 similar to the way MODFLOW and MT3D solves.
16 On top of what they do in MT3D, it looks at
17 the unsaturated zone and the vapor transport.

18 **DR. DOUGHERTY:** I think there's some
19 confusion about which model's being discussed
20 in terms of questions and answers. So I think
21 Ann was asking about the linear control where
22 it has been validated against other methods in
23 any particular way. A majority of your
24 comments, I believe, are on the multi-phase,
25 multi-media.

1 **DR. ARAL:** My comments were referring to
2 groundwater flow, contaminant transport
3 analysis aspects. Those models can get to be
4 as complicated as we want. But in application
5 we are limited, as we are hearing all day
6 yesterday and today, we are limited by the
7 data. So the complicated nature of the model
8 doesn't make it better in terms of an outcome
9 if the data is not available to use that
10 complicated nature of the model. We have to
11 accept that.

12 **DR. ASCHENGRAU:** But it's just people who
13 have been expressing their discomfort with
14 some, with what I perceive as some new method
15 that other people haven't used yet. And so
16 I'm just trying to figure out is if we can be
17 more comfortable with it because that new
18 method has somehow been compared to the
19 existing methods. And so they shouldn't be as
20 comfortable about it. That's all I'm --

21 **DR. ARAL:** That's a very good point. We are
22 not proposing this black-box model to be used
23 which was developed three months ago. We
24 accept that. We developed this three months
25 ago. And we are not proposing to use this

1 without extensively validating it in other
2 areas, in other databases, so that it
3 establishes a footing in the field. We are
4 not proposing that. We have to test this
5 model over and over again to have confidence
6 on its outcome.

7 **DR. GRAYMAN:** Getting back to your comment
8 when you referred to when you were in court
9 testifying. I think we'd all agree as
10 scientists we want to use the best, most
11 appropriate method, and that sometimes is not
12 totally in line with what you see if you're in
13 a court case, and it just isn't. I mean,
14 court cases aren't necessarily about the best
15 science. They're about whatever they're
16 about.

17 But it would almost be like if you
18 were doing climate modeling and you'd
19 developed some new climate model that had some
20 additional processes. And you felt that this
21 was definitely much better than what the
22 established methods were that were tested by
23 the IPCC and had gotten the Nobel Prize for
24 it.

25 And you're in court and you're trying

1 to say, well, my model is better because --
2 and they ask you, well, has this been
3 validated. Has it been used other places.
4 And you say, no. You're going to be probably
5 a lot better off in convincing the court by
6 using one of the established models. And then
7 so we are in a situation of science versus a
8 legal situation, and I don't know where this
9 whole thing is going to go to.

10 **DR. ARAL:** Well, I fully appreciate that,
11 but --

12 **DR. BAIR:** There's a huge change in the law
13 for expert testimony in the mid-'90s between
14 the Frye Rule and then the Merrill-Dow
15 Pharmaceutical lawsuit where the judge now
16 sits as the gatekeeper of what is acceptable
17 science. And it is up to the scientist prior
18 to the trial and the expert witnesses or the
19 engineers to convince the judge, who's the
20 gatekeeper, that what they're doing is not
21 junk science that just appeared, but it has
22 foundations and validations in the steps that
23 people have been talking about.

24 So I just, I don't know where this is
25 headed one way or the other for lawsuits. It

1 seems like everybody's walking around the hat
2 without ever putting it on. But I think that
3 effort that you've talked about has to be way
4 up front before you put any of the effort into
5 looking at a Camp Lejeune.

6 **DR. ARAL:** Oh, I agree with that.

7 **DR. CLARK:** Morris, you wanted to make a
8 comment.

9 **MR. MASLIA:** Yeah, I wanted to make the
10 point again after we completed, essentially
11 completed the Tarawa Terrace -- and you need
12 to, I guess, put your administrative
13 organizational hat on --

14 **DR. CLARK:** Doesn't fit.

15 **MR. MASLIA:** -- I know, that's a problem for
16 us. We saw the effort that it took -- and
17 there's still a question about it, I mean,
18 looking at all sides and all questions, the
19 effort that it took to get the answers that we
20 got to give to the epidemiologists.

21 And we were looking for an approach to
22 speed us up to get some initial results. And
23 we wanted an alternative because you know the
24 amount of effort and multiply it by ten for
25 Hadnot Point. That's at least by ten if not

1 by a hundred. And if we do that, December
2 2009 is not even in the question. Probably
3 December 2012 is not in the question given the
4 discussion here.

5 So we have to, I think, look at some
6 alternative ways. One way, as they said,
7 let's cut out for the time being the
8 dispersive transport and all that and look at
9 a flow path approach to get some indication.
10 Another approach is where we have the
11 information and see if we can reconstruct the
12 concentrations from that. It does not in my
13 opinion invalidate the use of either one. It
14 actually may add some additional insight for
15 us to maybe enhance the more sophisticated
16 modeling.

17 And that's what I asked Georgia Tech
18 to do because I only had one tool in my
19 toolbox, and we knew it was too heavy at this
20 point to pick up and try to fix the second
21 part of the problem. So that's really our
22 objective is to see what results, does that
23 give us some additional insight while not
24 expending as much effort and resources.

25 **DR. CLARK:** To get back to Ann's point, are

1 you thinking in terms of using Tarawa Terrace
2 as a validation tool? Because you've done
3 traditional groundwater modeling in Tarawa
4 Terrace. Could you use that example as a
5 validation tool for the linear control theory
6 model?

7 **MR. MASLIA:** Well, Dr. Aral's used that
8 already. In other words he's tested the
9 method out on Tarawa Terrace, but again, that
10 is assuming that the simulation mean values or
11 whatever are, in fact, quote, surrogates for
12 real data. Now what needs to be done, and we
13 can go to other sites, do a literature search
14 or go to other sites, let's test it out on
15 some other site data, not necessarily Camp
16 Lejeune, and see if we get similar results or
17 results that build further confidence in it.
18 The fact is that this approach does not take a
19 lot of effort to run on subsequent datasets.

20 **DR. CLARK:** Do you have some datasets that
21 you can [use to -ed.] perform those validation
22 tests?

23 **MR. MASLIA:** I can't. I don't have them in
24 hand or know of them at this point.

25 **DR. ARAL:** Just a few comments on what I

1 have heard just now. Obviously, the judge is
2 the gatekeeper and established models have to
3 be used in court cases because they are
4 established. That's the only reason. But
5 that shouldn't hinder the science.

6 In other words science has to go
7 forward in bringing new ideas, new models, new
8 concepts into the field. And in the next 50,
9 60 years maybe they will be the accepted
10 models to be used in the court cases. Can you
11 imagine a world which is stuck to MODFLOW?
12 And a hundred years from now that will be
13 extremely limited because the science is
14 advancing. We have to bring that new science
15 into MODFLOW.

16 **DR. WARTENBERG:** But it seems to me that
17 they're two different issues here. There's no
18 question that science needs to go forward, but
19 that doesn't necessarily address why we're
20 here and what we're looking at. And it seems
21 that's that's --

22 **DR. ARAL:** I know. I'm looking from a, to
23 this problem from two perspectives. I will
24 continue with this method. I will publish
25 technical papers, and then it will be applied

1 or not at Hadnot Point is a different story.

2 DR. CLARK: I'm going to suggest that we go
3 ahead with our lunch break. I do have a
4 question.

5 Scott was in the process of giving a
6 presentation, and we cut him off due to
7 ~~technological~~ [technical -ed.] error problems.
8 Do you want to try to do it during the lunch
9 period, [or -ed.] at the end of the lunch
10 period?

11 DR. BAIR: I'd rather do it later than now.
12 I just think the demeanor in the room will
13 refresh itself over lunch.

14 MR. MASLIA: Bob, if he wants to, just
15 before the end of the lunch break, because I
16 am concerned --

17 DR. CLARK: Yeah, after you have the lunch
18 break.

19 MR. MASLIA: -- because we have to meet our
20 2:30 to start summarizing because some people
21 have planes.

22 DR. CLARK: Does 12:15 work?

23 MR. MASLIA: That's fine.

24 DR. BAIR: So I can be here at 12:15? Yeah,
25 and I think what you're going to see are some

1 of the comments that Ben made about what the
2 step functions are going to look like when you
3 get to the end of this.

4 (Whereupon, a lunch break was taken between
5 11:40 a.m. and 12:30 p.m.)

6 **DATA DISCOVERY - ADDITIONAL INFORMATION AND DATA**

7 **DR. CLARK:** We're reconvening. We're going
8 to modify the agenda again just a little bit.
9 From about 12:30 to 1:30 Morris and I guess
10 Frank are going to talk about data discovery
11 issues and new [, -ed.] additional
12 informational data.

13 **MR. MASLIA:** And I'm basically just opening
14 it up and let the panel also obviously join in
15 and all that. But as you see the data that we
16 have gone through, and there's a lot of it to
17 consider. And we mentioned yesterday this
18 data that are in the notebook represents the
19 IRP Program on the base. And there is about
20 another 100-plus documents that represent the
21 above and underground storage tank data.

22 And what our proposal is or our
23 approach to do with that is to actually
24 separate this report that you have or the
25 collection of, the draft report that you have,

1 and have two sets of reports, one strictly
2 with the IRP data, and then pull out any UST
3 data from that report. And then have a
4 separate report with the UST data. That's
5 the, I think, straightforward approach to
6 dealing with that.

7 As far as from a modeling or use of
8 data in whatever form of modeling we want,
9 whether it's calibration, verification or
10 whatever, our thoughts at this time are
11 probably to try to use that second set of data
12 as almost a verification stage. In other
13 words sort of treat it as if we don't know
14 about it right now. Use what we have.

15 And then if we get to the point of
16 where we have some confidence in model
17 simulation in terms of concentrations or
18 whatever, see how it compares to this other
19 set of data. I say that because to add, put
20 this into, quote, a calibration set or
21 whatever, still does not get us over this
22 hurdle of uncertainty, variability or anything
23 else.

24 So I think it's maybe limiting the use
25 of some data that could maybe even help

1 improve our confidence in the model. That's
2 just my thoughts right now. And I think that
3 also helps us in terms of resources expended,
4 people, time, money and stuff like that.

5 And it'll help us learn with the model
6 what the models may be doing or may not be
7 doing with an existing dataset that we've gone
8 through pretty thoroughly at this point. And
9 save that other dataset in terms of modeling
10 that may, as I said, help improve our
11 confidence which may be more of an advantage
12 for us and then lumping it all together.

13 And I'll just throw it out and see
14 what the panel thinks about that approach or
15 any other approach you may have. But that's
16 our thoughts right now as to how to handle
17 that.

18 So anything else, Frank?

19 **DR. POMMERENK:** Morris, let me get started
20 on a couple comments. And I also appeal to
21 those panel members who were here in 2005.
22 You know, there were several recommendations
23 made in 2005, and if I recall it correctly,
24 and I tried to focus the discussion back on
25 this, was the whole uncertainty analysis and

1 you addressed with Tarawa Terrace some of
2 those issues where you acknowledge the model
3 results and so on.

4 We saw this was at least piece-wise
5 brought up by panel members, you know, the
6 overly optimistic narrow band in the Tarawa
7 Terrace concentrations that we need to address
8 also uncertainty in other things which will be
9 for Hadnot Point no doubt be greater. We saw
10 it with the mass computations. So I just
11 would like to recall from the 2005 panel
12 meeting that one of those key recommendations
13 was, if I recall correctly, the focus should
14 not be on so much on the little details in the
15 groundwater model and hydraulic model versus
16 trying to quantify uncertainty because in all
17 the little errors that we may make in a non-
18 representative model or whatever, may be
19 swamped out by uncertainties upstream. For
20 example, in this case the mass was disposed in
21 the first place. So I think I should throw
22 out this just to refocus the discussion. I
23 hope that the other --

24 **MR. MASLIA:** I think that your point is very
25 well taken to incorporate what the previous

1 panel said. And that was I think impacted two
2 things. One, why a lot of effort and emphasis
3 both the Marine Corps and Navy in going out
4 and hiring a company to go through their
5 records. And we spent an additional amount of
6 time going through data and information. And
7 then the second thing is, and this brings us
8 back to this morning's discussion, is why --
9 I'll say I -- I asked Georgia Tech to try to
10 come up with a simpler method because that was
11 one of the recommendations out of the panel in
12 2005 is to look maybe at the bigger picture,
13 but a simpler representation because of all
14 these factors. So your point is very well
15 taken, very well taken.

16 **DR. POMMERENK:** Yeah, just as an aside on
17 that. You know that linear control theorem,
18 we may not care about what the individual
19 coefficients of that matrix or the matrices
20 represents because we may have sources of
21 uncertainty elsewhere that would ~~swap~~ [swamp -
22 ed.] out any little issues that we may have
23 with the groundwater flow model or the
24 hydraulic model or when interconnection was
25 there or not.

1 And that's why the panel and again in
2 my recollection, recommended the increased
3 efforts in data discovery where they have
4 actually hired a company to go through all the
5 records on base. That just is a reminder.
6 And I believe that is all documented
7 recommendations of the expert panel.

8 **MR. MASLIA:** Yes, it's in the yellow-color
9 folder report there that's available both --
10 yeah, that one. It's in Section 6 of the
11 report. That summarizes it, and then if you
12 want the detailed actual final recommendations
13 you can pull out the verbatim transcript
14 that's included on the CD there. But the
15 report just summarizes that in
16 generalizations. But that is correct.

17 And I know we focused, I mean, as an
18 Agency we did. We hired more people and
19 obviously tried to go through more, and I
20 think that's how some of this discussion on
21 the interconnection came about as well.
22 Because if you recall at that meeting or the
23 generalization was made that, well, if there's
24 no very limited interconnection, well, simple
25 mixing will do the trick. And that worked

1 correctly for Tarawa Terrace.

2 That was, we looked, and we could not
3 find any instances of, I used a rule of thumb
4 of a two-week period just at Tarawa Terrace,
5 and that was correct. But in looking further
6 and actually understanding what was written in
7 the logbooks, which takes some doing, you
8 know, how they make notations and what it
9 really means. And in discussing with the
10 present and former operators, we came across
11 the short intervals but pretty much
12 consistent, but that they would turn it on in
13 dry late spring or early summer months.

14 So again, I think what we do in your
15 recommendations here are adding to the
16 recommendations of the 2005 panel. But we do
17 have a much more complex issue, and that's
18 hopefully y'all can put some recommendations
19 down that we can take to both our management
20 and the Navy and tell them what our plan is
21 for concluding the study. I think that's
22 really what Frank's looking at is an exit
23 strategy that's satisfying.

24 **DR. BOVE:** Maybe not as quickly as some.

25 **MR. MASLIA:** Well, not as quickly as some.

1 I didn't mean to imply that we're walking out
2 the door today and that's our exit strategy.
3 But, no, and that's why I think it's
4 motivating me to say with the additional data
5 that we have, let's not be quick to just use
6 it or throw it in for model calibration right
7 away. Let's see what we can understand about
8 it first, and then maybe help us improve or
9 reduce maybe some of what we perceive to be as
10 uncertainty or build confidence in whatever
11 model or modeling approach we take for Hadnot
12 Point.

13 **DR. HILL:** And just one comment on that. In
14 terms of a simpler modeling approach, it can
15 be a simpler physical-based model. That's an
16 option instead of, so there's a lot of ways to
17 ^.

18 **DR. GOVINDARAJU:** I just wanted to, you know
19 before lunch we were talking about what if it
20 were to do a court case and so on. And when
21 you're given this charge and when I started
22 looking at the document, I was not preparing
23 myself by trying to advise people by what one
24 should do in case of litigation. And maybe if
25 that is the case our objective functions

1 should be somewhat different. I thought we
2 were going to be doing this to see how we can
3 reduce uncertainty and stuff like that. So I
4 just want us to be able to explain that if we
5 should be thinking in terms of what would fly
6 in a court of law or see what we can do --

7 **MR. MASLIA:** Well, the answer is anyone can
8 sue or sue anyone at any time of the day, but
9 for anything, so no, we're not gearing our
10 study for that. What we're gearing our study
11 for is for to be able to provide the
12 epidemiologists and the epidemiologists to be
13 able to assess epi results.

14 **DR. BOVE:** Maybe I should say this. There
15 is not much in the literature about the health
16 effects of these chemicals from drinking water
17 exposures. But there's even less about birth
18 outcomes in these. So the main reason we
19 embarked on these studies was to add to the
20 scientific literature. I mean, that was the
21 primary goal here. People want to know what
22 the effects are of these chemicals. Well, we
23 have occupational data, but we have very
24 little drinking water data. We have a birth
25 defects, one study in New Jersey looked at

1 birth defects that so far has been published.
2 We have a few studies looking at cancers and
3 these chemicals. And so that's what we have
4 that are published, a few studies out there,
5 and some of them may not even agree with each
6 other or they do to some extent with very
7 little good exposure information as well. So
8 that's what the literature is out there. We
9 want to add, make a major contribution if we
10 could to that literature. That's the primary
11 goal here. It's not litigation. It has
12 nothing to do with litigation.

13 **DR. CLARK:** Dick, you have a comment.

14 **DR. CLAPP:** I was just pointing at Dr.
15 Aschengrau, who's done some of the studies.

16 **DR. DOUGHERTY:** I have two things. One is I
17 took the litigation court of law as a metaphor
18 for other courts of opinion that bear on
19 reliability and judgments of reliability.

20 Second was a question. In the data
21 that we're talking about, do we know the
22 contents of these tanks?

23 **MR. MASLIA:** You mean the contents of the
24 database?

25 **DR. DOUGHERTY:** No, what materials were in

1 these, what chemicals are we talking about?

2 **DR. CLARK:** In the new information.

3 **MR. MASLIA:** Oh, in the new information.

4 **DR. DOUGHERTY:** Yes.

5 **MR. MASLIA:** Bob, I haven't looked at it. I
6 just catalogued the information, but Bob can
7 generally describe what's there.

8 **MR. FAYE:** Some of the tanks were just pure
9 gasoline, diesel fuel, heating fuel, waste
10 oils, that's pretty much the gamut of the
11 contents.

12 **DR. BAIR:** What else could you wish for?

13 **DR. WADDILL:** Would you like me to clarify
14 that?

15 **MR. MASLIA:** Yes, please.

16 **DR. WADDILL:** In regards to the new
17 documentation, this is all leaking underground
18 storage tank program studies, records of
19 decision. Clean up information related to the
20 leaking underground storage tank program per
21 NCD nuregs*. So it's all POL contamination.
22 Any solvent contamination falls under the IR
23 Program per ~~CIRCLA~~ [CERCLA -ed.].

24 **DR. DOUGHERTY:** What about the waste oil?

25 **DR. WADDILL:** Waste oil if it's solely

1 benzene or BTEX or POL falls under the [UST
2 program -ed.]. If it has solvent co-
3 contamination it usually goes into the IR
4 Program.

5 **DR. DOUGHERTY:** Thank you.

6 **DR. ROSS:** I have a comment that that
7 information may be useful because of all of
8 the compounds, the BTEX compounds are going to
9 serve as good fruit for the bugs for one thing
10 to break down the solvents over time.

11 **DR. POMMERENK:** Okay, since nobody else is
12 saying anything, I just want to make one
13 comment so it's in the record. Because we've
14 been talking all day today and yesterday about
15 the groundwater flow model and then the water
16 distribution system model, and the one thing
17 that I would like -- that's why I want it in
18 the record -- there's a big five entity [MGD -
19 ed.] treatment plant in between, between the
20 groundwater collection system and the
21 distribution system.

22 It consists -- and correct me if I'm
23 wrong -- of a ^ [ground storage -ed.] tank. I
24 don't remember what the size is, but it's
25 probably a million gallon or larger. The

1 Hadnot Point plant has a pump station that
2 pumps water from that water collection tank
3 into what are called catalytic softening units
4 or ~~spiracteristic (ph)~~ [spiractor -ed.] cones
5 to which ^ ~~lime~~ [lime -ed.] is injected to
6 facilitate softening and it overflows into a
7 central pipe.

8 It goes from there through a ~~currently~~
9 ~~still through~~ [-ed.] a rectangular basin that
10 used to be a re-carbonation base, and I'll get
11 back to that. And from there into gravity
12 filters and you know after chlorination and
13 fluorination into a finished water clear well.

14 Obviously, in this facility there's
15 several quiescent or not so quiescent surfaces
16 from which ^ [volatile -ed.] organic compounds
17 can escape. And that kind of depends on the
18 physical properties of these compounds, PCE
19 more so than TCE and so on. We made an
20 estimate a few years ago, a rough estimate,
21 that probably PCE and TCE, we didn't look at
22 BTEX, removal would be incidental, minor,
23 probably. The tanks are covered so there's no
24 way effluents could stir up things.

25 However, what was not looked at that

1 was, because of lack of information is the re-
2 carbonation basin. The re-carbonation basin
3 serves to, it's typically a small, flow-through
4 basin to which you inject carbon dioxide that
5 is generated from a propane generator or from
6 gas bottles. And carbon dioxide is an ~~asset~~
7 [acid -ed.] in water and ~~increases~~ [decreases
8 -ed.] the pH which has been pretty high prior
9 to, because of lime addition.

10 So that's how this whole softening
11 process works. You bring the pH up you're
12 still going to have calcium carbonate. Bring
13 the pH back down within the allowable limits.
14 So as far as I know, and as far as I can
15 recall, I've never seen this basin in
16 operation. It was just water flowing through.

17 However, it was put in for a purpose
18 originally some time in the '40s, and nobody
19 can tell me exactly if it ever has been
20 operated and how long it has been operated.
21 Because if it has been operated, it could have
22 ~~been~~ [caused -ed.] substantial removal of PCE
23 and TCE. It would have been in the 90 percent
24 removal.

25 And it kind of depends on the gas flow

1 rates. It kind of depends on the turbulence
2 that got generated. So there's a variety of
3 factors that would have presented. But it
4 could have affected removal of these compounds
5 in the plant. And again, we just looked at
6 PCE and TCE as from volatilization from the
7 basins that are there, not ~~re-carbonization~~
8 [re-carbonation -ed.] because we didn't have
9 any additional information.

10 But it might be worth looking into
11 BTEX volatilization from the basins, you know,
12 whether that as a source is uncertainty again.
13 And I'm not trying to get exact numbers or
14 anything, but it's another source of
15 uncertainty for the exposure calculations for
16 what could potentially be the removal of these
17 compounds from the plant, A. And B, finding
18 out whether this has ever been online, this
19 re-carbonization basin.

20 **MR. MASLIA:** Hopefully, we're sending five,
21 six people up to Lejeune this month, sometime
22 this month, because in the BAH when they
23 indexed the records that were there, we looked
24 at the Tarawa Terrace stuff knowing that we
25 would be back to look at Hadnot Point. And so

1 there may be some information on that in those
2 records. I don't know in other words. So we
3 have not gone through the ~~BAY~~ [BAH -ed.]
4 information index and then told, you know,
5 requested that those documents be pulled, if
6 in fact, there are documents in that index
7 that would be useful.

8 **DR. POMMERENK:** You may want to look first
9 in any purchasing records of propane or
10 whatever they used. You may want to start
11 talking to Bernash* [sic -ed.] when you get
12 down next time with him. I can't imagine it
13 has never been used because it's still
14 comparable, softening plants operated by the
15 Navy or Marine Corps. Kings Bay, Georgia,
16 they still use re-carbonation basin.
17 Guantanamo Bay has recarb basins, you know,
18 it's not uncommon. So if you look for these
19 kind of records. I always find these kind of
20 things.

21 **DR. DOUGHERTY:** So, Peter, when you were
22 there and there was not ^, were they not
23 dropping the ~~TH~~ [pH -ed.] or was there some
24 other procedure that they were doing?

25 **DR. POMMERENK:** As far as in dealing with

1 that plant, they've always softened just below
2 -- well, this is the secondary MCL anyway.
3 The ~~TH~~ [pH -ed.] leaving the plant should be
4 below nine, and they're always, eight-eight,
5 eight-nine, fluctuating. Of course, you know,
6 you have a certain ~~goal-treatment~~ [treatment
7 goal -ed.], the soft pH, its hardness, and if
8 they get within their 60-to-80 milligrams per
9 liter ^ carbonated range with that pH, that's
10 -- in fact, Holcomb Boulevard is operating in
11 the exact same manner and so is New River
12 across the river when it was still operational
13 as a lime softening plant. So it's not
14 uncommon with that type of water that you
15 would soften at a somewhat lower pH and not
16 adjust it finally. So that's not uncommon to
17 do that.

18 **DR. DOUGHERTY:** I just wanted to know if
19 there was a different process that they had
20 temporarily used or if it was just as he's
21 described, and they just bumped it up just
22 enough and left it there.

23 **MR. MASLIA:** The pH throughout the system
24 was fairly high. It was higher than I've seen
25 in other distribution systems. Because when

1 Jason and I were there, we were doing the
2 field test, we first thought the instruments
3 were out of calibration because it was always
4 well over eight, 8.5, 8.8, I mean.

5 And that's why we thought there was
6 something, you know, we had to go back and
7 recalibrate the instruments or whatever to
8 make sure. But then we checked with them
9 inside, so it's a pretty high pH.

10 **DR. POMMERENK:** With a gain in
11 precipitation.

12 **DR. ROSS:** Downstream?

13 **DR. POMMERENK:** I can't say. I mean, you
14 know they have had problems. I have pictures,
15 in fact, one of my memos that I sent to you a
16 while ago ~~it picks up~~ [depicts -ed.] the
17 ~~spiroactors*~~ [spiractors -ed.], so they get
18 pretty badly encrusted downstream. So all the
19 softening is not done in the ~~spiroactor~~
20 [spiractor -ed.]. Softening's going to go on
21 throughout. That's been one of the hassles
22 that they've always, ^ has been complaining
23 about. Now, I cannot say for sure what, how
24 much precipitation's going on in the
25 distribution system, but, yeah, it will

1 happen. And now to bring up a point here.
2 How does that affect POCs[VOCs -ed.]

3 **DR. CLARK:** Is it possible that they had
4 cast iron pipe in the system at one time?

5 **DR. POMMERENK:** Yeah, you should be able to
6 see. We inventoried that system.

7 **MR. MASLIA:** No, the system is cast iron,
8 and then when they would replace them, now
9 presently when they replace them, they
10 presently replace them with PVC. They've got
11 a few lines of ductile iron and very little AC
12 pipe at all. So it's mostly cast iron and PVC
13 now. And one would think it was historically
14 then cast iron.

15 **DR. POMMERENK:** Two years ago we had
16 excavated some pipe, four-inch pipe, in New
17 River which is across the river on the other
18 side where they also until 2007 operated a
19 lime softening plant in a similar manner. And
20 they got water from wells in what is called
21 the ^ [Verona Loop -ed.] area which is, you
22 know, you can see it west of New River, you
23 know the left, top corner. Left top, left,
24 left, left, left, left. All the way on the
25 left is --

1 DR. DOUGHERTY: The N[M -ed.]-C-A-S, Morris.

2 MR. MASLIA: Oh, here, okay.

3 DR. POMMERENK: Right down there, ^ wells
4 from a hardness standpoint a similar
5 composition as the wells at Hadnot Point. And
6 again coming back to those pipes that we
7 excavated, I don't know exactly where they
8 came from in the system, but they didn't show
9 any large amount of scale. There was
10 ~~tuberculation~~ [precipitation -ed.] and you
11 could clearly see on there ~~tuberculation~~
12 [precipitation -ed.], various layers of all
13 the different iron oxides and ^ mixtures of
14 that. But there was not a distinct calcium
15 carbonate layer.

16 DR. DOUGHERTY: Do we know the frequency of
17 well rehabilitation just as another indicator
18 of this?

19 MR. FAYE: We have some records of actually
20 a lot of records in the early '50s and perhaps
21 up to '65, '66, '67. Then there's a gap, and
22 then beginning in '78 up through '85, '86, '87
23 we have records of gross rehabilitation. On
24 the one hand the records may indicate things
25 like notes in the margins, well down May,

1 bearings replaced in pump. Or well down in
2 October, air line replaced. Things like that.
3 So you have to make a judgment. Was it down
4 for three days or three weeks? So that's kind
5 of the extent of that kind of information.

6 **DR. DOUGHERTY:** So there's no direct
7 information that the well was acidized or ^
8 [cleaned -ed.] up or something?

9 **MR. FAYE:** In some of the records that are
10 quite detailed, I've never seen those kinds of
11 activities take place or have no indication
12 that those activities took place.

13 **DR. KONIKOW:** I wonder if some of the local
14 well drillers would have that information more
15 readily available than the Marine Corps base,
16 maybe foot work there might.

17 **MR. FAYE:** Well, that's a good question,
18 Lenny, and it's a possibility based on my
19 experiences with drillers, some of them do
20 keep really good records. On the other hand a
21 lot of folks that work for government, and
22 particularly the military, I think they took
23 their training from squirrels. They take care
24 of everything. They hide everything, and so I
25 got a strong hunch if those records were

1 available, we'd know it.

2 **DR. CLARK:** Anybody else have any more
3 comments at this point?

4 (no response)

5 **DR. CLARK:** Well, one thing that occurred to
6 me, [and -ed.] I think Frank maybe alluded to
7 it at one point, is the possible extension of
8 the study to include something other than
9 birth issues. Some of the levels that were
10 being distributed in the finished water almost
11 ~~looks~~ [look -ed.] like occupational exposure
12 levels and could [have -ed.] inhalation and
13 dermal effects.

14 And I think you've mentioned that
15 you're giving some consideration to extending
16 the study to include that, but I didn't know
17 whether you wanted to talk about it now or
18 not.

19 **DR. BOVE:** Just briefly, we have two studies
20 that we're going to embark on this summer.
21 One is a mortality study of adults obviously
22 which will take into account hundreds of
23 thousands of Marines at the base plus a
24 comparison group at Camp Pendleton population.
25 And with that, monthly data, of course, isn't

1 as relevant in that kind of a study as it is
2 with a birth outcome study, the small for
3 gestational age study or the case-control
4 study we were talking about all day.

5 The other study is a health survey
6 which is going to ask people about their, any
7 cancers they may have had and other diseases
8 that we think are related to solvent exposure
9 that we see in the occupational literature as
10 well as any information from the drinking
11 water literature, which I already said was
12 very sparse. And then we'll confirm those
13 diseases as well as we'll confirm the deaths
14 and find out the cause of death.

15 So that's roughly, without going into
16 too much detail, what we plan to use this data
17 for as well as the current case-control study
18 and the re-analysis of the small for
19 gestational age study. So any questions about
20 those two studies I can answer them, but just
21 so you know that what we produce here in the
22 water modeling will be used for additional
23 studies.

24 **DR. CLAPP:** I don't think he's talking about
25 dermal or inhalation exposure as part of the

1 extension. He's talking about different study
2 types.

3 **DR. BOVE:** Right, what we assume -- well, in
4 the health survey as well as the case-control
5 study, we do ask about people's consumption
6 habits, how long they shower, for example. So
7 that we start getting at some of those routes
8 that way. But really, we assume that
9 everyone's pretty much getting the same kind
10 of exposure. They're showering roughly about
11 the same amount. They're getting the same
12 kind of dermal exposure, and they're ingesting
13 roughly about the same amount of water.

14 **MS. RUCKART:** Frank, we don't ask about that
15 on the health survey.

16 **DR. BOVE:** We don't ask about their
17 consumption at all?

18 **MS. RUCKART:** Just the case-control.

19 **DR. BOVE:** Okay, I'm getting confused
20 between studies. That's right. For the case-
21 control study we ask that question. Actually,
22 as I said yesterday, the usefulness of that
23 information is not that good.

24 There are also civilian employees who
25 were exposed and there we're going to take

1 into account their occupational exposures as
2 well as -- and also the military have
3 occupational exposures, too, and also where
4 they drank water at their occupational sites,
5 workplaces. So these are things that we're
6 going to take into account in the future
7 studies.

8 So does anyone have any questions
9 about that? I don't want to get into that
10 because we have so much to discuss about the
11 modeling and wanting to get advice. We had an
12 epi panel actually a year ago discuss these
13 two studies and the issues there.

14 **DR. CLARK:** Any reaction to ~~your~~ [the -ed.]
15 comments or thoughts on that?

16 (no response)

17 **DR. CLARK:** I know when we were ~~doing~~, [-
18 ed.] setting a radon standard ~~in~~ [for -ed.]
19 drinking water, we looked at some of those
20 kinds of issues. So there is some literature
21 in terms of --I think it's the University of
22 Pittsburgh that actually has a physical shower
23 where you can go and measure the transfer of
24 water of the radon from the water into the
25 air. And I would assume that [at -ed.] some

1 of those levels [, -ed.] that eventually the
2 household would be basically saturated with, [
3 -ed.] volatilized with solvents [BELJIN -ed.],
4 which would apply not only to the Marines, but
5 also their dependents and children.

6 DR. BOVE: Right, and then there's also some
7 concern, for example, cooks at the, in the
8 Hadnot Point area getting heavily exposed.

9 DR. CLARK: Yes.

10 DR. HILL: Laundry workers?

11 DR. BOVE: Laundry workers, yeah. So we'll
12 be looking at them in the future studies.

13 DR. CLARK: I gathered [gather -ed.] from
14 what Mr. Ensminger was saying, that he has had
15 contacts from people who'd been on the base
16 and adults who've had follow-up health issues
17 that kind of were linked to that sort of
18 exposure.

19 DR. BOVE: That's why we have to do these
20 studies.

21 DR. CLARK: This is the quietest I've ever
22 seen this particular group.

23 **PANEL DISCUSSION: INCORPORATING AND USING ADDITIONAL**
24 **INFORMATION AND DATA**

25 DR. HILL: I don't know if we want to get

1 into this now, but Lenny and I were talking at
2 lunch about looking at the model fit, and
3 methods to do that and some of the results.

4 Lenny, am I interpreting our
5 discussion correctly and did you want to start
6 with that? So it was model fit and the use of
7 the sort of preconceived criteria for
8 measuring whether or not the future model fit
9 was going to be good enough. And I'm not
10 quite sure, this is a discussion that's sort
11 of better done with a bunch of maps on a table
12 and pointing at this and this and saying why
13 is this ^.

14 So I'm not exactly sure how much of
15 this can be done in this kind of format, but a
16 couple of general things I'll start with was
17 there's -- and I'll start with the head data
18 just as a beginning -- and essentially what
19 head data gives you is sort of the pipes of
20 the groundwater system, kind of what are the
21 directions of flow. It's sort of similar to
22 topography on a land surface, but it's fully
23 3D, and you can't see it. And it's hard to
24 figure out.

25 And so the heads and the geology are

1 essentially what we have to constrain that and
2 also where concentrations go. And so in this
3 model there were two kinds of head data. The
4 data in pumping wells essentially taken with
5 air lines, which are known to be extremely
6 problematic.

7 And so one of my concerns was even
8 that they were put on the same graph with the
9 other kinds of head data. It seemed like it
10 should be analyzed separately. And one of the
11 things that allows you to do better, too, is
12 to look for patterns within the, so the
13 residuals are the observed minus simulated.
14 And ideally, they will be random spatially in
15 the system, and any distinct non-randomness
16 suggests bias in the model.

17 And when you had observations like
18 those air line observations that have so many
19 known problems, it's really unclear whether,
20 what they represent and how much you can
21 depend on them. And it could be that some of
22 them should not be considered at all and
23 others have good information.

24 But we have to look at where they are
25 in the system and what trends they might have.

1 Does it make sense? If the pumping from the
2 well is greater, do they actually -- you know,
3 do they make sense? And a thorough analysis
4 of that was perhaps outside the realm of some
5 of these reports, but really, without that
6 analysis, my feeling was there was just a lot
7 of data kind of thrown in, and it didn't fit
8 very well, and there were some patterns in
9 that set of data.

10 In particular, if I looked at the
11 graph, there's a band that goes through a
12 certain, I think it's observed versus
13 simulated, and I think the simulated range is
14 13 to 15 or something like that. So you have
15 a band that goes through. So there's issues
16 related to that. Maybe I'll stop there. You
17 were looking like you wanted to say something.

18 **MR. FAYE:** No, actually, I agreed with
19 almost everything you say. And also, I don't
20 take exception at all to your comment that we
21 threw everything in there but the kitchen
22 sink. You're exactly right. And it just came
23 down to a choice of on the one hand we felt
24 that we would be severely criticized if we
25 didn't try to deal with the data, and on the

1 other hand we felt we would be severely
2 criticized if we did deal with the data. So
3 we came down on the side of inclusiveness and
4 did our best. In fact, I appreciate your
5 comments very much about the air line
6 measurements because, frankly, there are some
7 people that just don't believe you and me that
8 those measurements are totally perfect, but be
9 that as it may.

10 **DR. BAIR:** Who are those people?

11 **MR. FAYE:** Well, I can mention a few that
12 I'd rather ~~new~~ [not -ed.] ~~of~~ [have -ed.] met,
13 but I won't. But anyway, your thoughts, I've
14 read your notes about the residuals and the
15 variability of the accuracy of the data. Very
16 well taken, and we definitely have already
17 decided to do some major analysis of the data
18 before we try to use it in this next model,
19 and so I accept that.

20 The only point I would take exception
21 to is the, I think it's your notions about the
22 graph and the boundary lines on there. I
23 thought I was doing a good thing when I copied
24 that directly out of the USGS report, but so
25 be that as it may, it is what it is and I

1 appreciate your comments very much.

2 **DR. HILL:** In other studies I've been
3 involved in if you don't have every data point
4 somewhere, someone will come and say did you
5 pay attention? Did you do this? Did you do
6 that? But my thought is that it could be,
7 that some of those points, I think this is
8 consistent with what you're saying. Some of
9 those points can appear in graphs that are
10 used to determine a trend, and then the trend
11 is used in the model calibration so it appears
12 in the report just not as a verbatim --

13 **MR. FAYE:** Yeah, in the report obviously we
14 tried to have our cake and eat it too. We did
15 not deliberately, explicitly attempt to weight
16 the data, weight the head data. The real
17 accurate data was fine, but what do you weight
18 the other data as? Is it a 1:2, 1:1, we just
19 didn't know.

20 So we didn't deliberately, explicitly
21 attempt to weight the data from a formal
22 analysis point of view. But then on the other
23 hand we did spend a lot of time explaining why
24 one set of data was better than the other. We
25 tried to have our cake and eat it too, and,

1 yeah, I'll take that. I'll take a hit for
2 that.

3 **DR. HILL:** That's all right. I don't mean
4 to hit.

5 Let's see. Another aspect of that is
6 the idea of sort of pre-processing the data,
7 thinking about it spatially and stuff and
8 getting trends. It could be that there are
9 situations where, for example, that vertical
10 thing we were talking about where there's a
11 three-foot decline at head. It might be
12 better to use that difference it had and have
13 some observations that are changes with depth,
14 changes at head with depth.

15 And specifically, and basically take
16 your data and -- on the one hand that's three
17 feet. On the other hand you are saying you
18 think your variability is plus or minus three
19 feet. Okay, so then that begs the question do
20 you have faith in that three-foot change.

21 Is the situation such that because of
22 where the well is or blah-blah-blah-blah-blah,
23 that you really think it is pretty close to a
24 three-foot decline which means when you take
25 that difference, you're getting a small,

1 you're getting rid of errors that might be
2 constant in some manner and actually the
3 difference, you have more faith in the
4 difference than the actual values.

5 **MR. FAYE:** No, actually, those are very
6 accurate measurements. So, yeah, I can answer
7 both because that's a bona fide well cluster
8 for the State of California. So it's good
9 data. I mean State of North Carolina. My
10 dreams have overtaken reality there for a
11 second. But we really didn't have data like
12 that to that detail, Mary, at Tarawa Terrace.

13 But we've got gobs of data in the
14 Hadnot Point-Holcomb Boulevard area where we
15 have well clusters, vertical gradients and
16 both at substantial depths even. So we can
17 really identify those issues in some pretty
18 good detail using actual field data. And it
19 would be typically like you would suspect.

20 In the Berkeley Manor area they're
21 sort of in the center of Holcomb Boulevard,
22 which is a highland area, your vertical
23 gradients are downward. You're close to the
24 Wallace Creek and other major drainages.
25 You've got your heads coming up. HPIA is a

1 similar area. It's in a highland area. You
2 know, your vertical gradients are downward, et
3 cetera, et cetera. So it all fits a pretty
4 good conceptual ~~Hubbard~~ [Hubbert- -ed.] type
5 model of the flow system, so it works pretty
6 well.

7 **DR. HILL:** Yeah, it's the graphs ^.

8 **DR. BAIR:** I was just going to say I think
9 that that's a really worthwhile calibration
10 target under a transient flow because you're
11 going to have certain pumping conditions that
12 either exacerbate or mitigate that vertical
13 gradient. And if you incorporate that as a
14 calibration target, that in turn, helps you
15 pin down the hydraulic conductivity to the
16 confining layers which so far one foot per day
17 because it's the confining nature that's going
18 to give you that large gradient, only a small
19 grade.

20 **MR. FAYE:** Absolutely, and also from a
21 limited number of aquifer tests, and again you
22 have the scale issues that you have to deal
23 with in terms of point data versus
24 extrapolating it out to a large model cell and
25 all that. But we do have some fairly decent

1 data, ~~Noyman~~[Neumann- -ed.] Witherspoon* and
2 where we've been able to apply some nice
3 aquifer test analyses and determine ~~leak-ins~~
4 [leakance -ed.] of confining unit. So for
5 whatever it's worth on a scale issue or a
6 scale-dependent value, we do have some of
7 those data.

8 **DR. KONIKOW:** Well, this also gets to, I
9 mean this first modeling phase, which
10 developed a steady state, full model
11 representative of pre-development conditions.
12 And that's part of our concern, I think, on
13 the data that you use in the calibrations is
14 that much of the data is so influenced by
15 transient conditions that it just probably
16 shouldn't have been in there.

17 **MR. FAYE:** That's really not true. And that
18 wasn't true at Tarawa Terrace either although
19 I think one of you gentlemen might have,
20 someone might --

21 **DR. KONIKOW:** I thought you were saying that
22 some of these, some of the data used from all
23 those measurements were influenced by --

24 **MR. FAYE:** They are. They are. But those
25 data were not used, to the best of my

1 knowledge, in determining the pre-development
2 surface. And also at Tarawa Terrace I think
3 there were like 50 or 60 measurements that I
4 listed in the report that I said, okay, these
5 were estimates of pre-development heads. And
6 someone did mention that they were possibly
7 influenced by pumping, and that is correct.
8 Six of those 60 were perhaps influenced by
9 pumping, but I --

10 **DR. KONIKOW:** I'm talking about the 5,000 or
11 so observations that were --

12 **MR. FAYE:** A number of those, Lenny, if
13 you've got ten years of data, and you can see
14 how it varies over time and the data are near
15 a pumping well, and you can see -- or a supply
16 well, and you can see some or infer that they
17 are being, that the heads are being influenced
18 even though the screens in the supply well are
19 rather deep, and you're looking at shallow, et
20 cetera, et cetera.

21 But you have ten years of data to look
22 at. So you can either select a data point
23 that seems to be the highest point or the one
24 that isn't influenced if you really, really,
25 really want to use that point as a control

1 point or you can disregard it.

2 But obviously 5,000 measurements,
3 hundreds of sites distributed throughout the
4 study area, you have an opportunity to filter
5 your data pretty readily. And at most of the
6 sites there was no, virtually no influence
7 except seasonal influences. And if you got
8 20, 30, 40 measurements over ten years, you
9 take an average, et cetera.

10 So that's pretty much the way those
11 control points were developed. There was a
12 pretty serious effort to filter out influences
13 from anything other than seasonal variations.

14 **DR. KONIKOW:** Okay, I didn't gather that
15 there was, but okay.

16 **DR. DOUGHERTY:** In the ~~permutation~~
17 [presentation -ed.] it said that there were
18 some obvious ones to pull.

19 **MR. FAYE:** Pardon me? Oh, Rene said
20 yesterday that he needed to look at some of
21 the data in addition. If he said it, I
22 believe it, but it wasn't a pervasive issue
23 with respect to the representation of the
24 potentiometric surface that he's showing. I'm
25 pretty sure of that, that he showed.

1 **DR. KONIKOW:** Now, when you go from the
2 steady state model ultimately you'll be going
3 to a transient model. I think you have to be
4 open to the idea that your boundaries and
5 boundary conditions and discretization,
6 particularly the vertical discretization, that
7 may be adequate for a steady state model,
8 might prove inadequate for a transient model.
9 And you may have to go back and revisit.

10 **MR. FAYE:** Absolutely. Those are, that's
11 good advice, and I believe that we've got our
12 arms around that issue pretty well.

13 **DR. KONIKOW:** On a more philosophical level
14 perhaps, I'm not sure I saw the value of
15 setting, you know, pre-determining calibration
16 targets in terms of accuracy and fitting. I'm
17 not sure I saw any outcome.

18 In other words it's just something to
19 measure against and one of the values of doing
20 that is you're assessing the accuracy of the
21 observations. But beyond that saying that
22 your goal is to come within plus or minus
23 three feet or 12 feet, I don't see the value
24 of that if you don't meet the target and then
25 don't do anything about it.

1 **MR. FAYE:** Well, that's not true because
2 it's a target that you meet as well as you
3 can. So what you see as far as Tarawa Terrace
4 is concerned is our best effort to meet the
5 target. So you don't know what the worst --

6 **DR. KONIKOW:** You're always making your best
7 effort to do the best that you could.

8 **MR. FAYE:** That's right. But before I get
9 to the issue though of calibration standards,
10 good or bad, though, you didn't see what our
11 worst effort was. So we progressively got
12 better and better and better. So you saw our
13 best effort in terms of the calibration
14 standard.

15 And, frankly, I agree with you a lot,
16 and I agree with what Mary's comments were and
17 her notes as well. From a practical point of
18 view I think having some explicit standards up
19 front at the initiation of calibration are
20 kind of a good idea. It gives you sort of a
21 target to shoot for based on your best
22 judgment about the quality of data, et cetera,
23 et cetera, et cetera, but at the end if you,
24 whether you really represent it as such or
25 don't, I don't really see it as a major issue.

1 **DR. KONIKOW:** Well, I mean, I'm just getting
2 at what does it mean.

3 **MR. FAYE:** It was more of a tactical tool to
4 provide some guidance perhaps I could say
5 during the calibration process rather than
6 something that we, and I think Mary made the
7 point that you might focus too much on
8 appeasing the standard rather than on the
9 conceptualizations and all the other things
10 that relate to a good calibration process.
11 But I don't think --

12 **DR. KONIKOW:** I mean, my concern is it's not
13 a standard. There's no standard approach for
14 doing that and picking a number ahead of time
15 really is rather on the arbitrary and
16 subjective side and doesn't lead to any action
17 afterwards when, I think, in the steady state
18 there were, if I recall, 55 percent of the
19 wells or the observations fell outside the
20 pre-determined calibration limits. And so
21 that's not a very good, you didn't meet the
22 target.

23 **MR. FAYE:** Well, I would also say that that
24 effort is, as Morris said this morning, that
25 that effort is somewhat to substantially

1 incomplete right now. I mean, it was just a
2 point in time that the staff said, okay, this
3 is as best as we're going to do up to this
4 time to get a notebook ready to send out to
5 the peer review panel.

6 Your point's well taken. I'm not
7 really arguing with you at all. I'm just
8 saying that in terms of what I did, what I
9 personally did and what I personally used it
10 for was, like I said, sort of a tactical tool
11 to make me feel warm and fuzzy if I got close
12 to it during calibration.

13 **DR. BAIR:** I guess what I'm hearing is the
14 panel people saying that philosophically that
15 they don't really care for that type of
16 criterion. And we would recommend that you
17 kind of drop it. I'd much rather not meet a
18 really stringent requirement than barely meet
19 a very loose one myself. And I think a more
20 accepted calibration target might be the mean
21 absolute error over the total relief in the
22 water table surface. So if you're at 100 feet
23 of relief and your mean absolute error is ten,
24 you've got about a ten foot error over that
25 distance. If you're in a mountainous terrain,

1 you have 1,000 feet of relief, a 100 foot
2 error is ten percent. You're in a very flat
3 terrain --

4 **MR. FAYE:** Well, we have -- if you look at
5 our good data, you know, the what we call the
6 monitor well data, I think our mean absolute
7 error for almost 300 of those data points was
8 less than two feet. And we have a total
9 topographic, i.e., water table drop of about
10 30 feet. On the other hand if you look at the
11 air line data --

12 **DR. BAIR:** Yeah, dump the air line data.
13 They're ruining you.

14 **MR. FAYE:** Your notion of being ruined might
15 be my notion of saving my ass, so that's kind
16 of a relative thing. But it is what it is,
17 and I accept the philosophical, it's really
18 not a philosophical difference of opinion. As
19 I said, I agree. And how we apply that, and
20 how we use it will hopefully be more pleasing
21 to y'all the next time around.

22 **DR. HILL:** I think, just one thing I want to
23 say is when you publish a standard, when you,
24 I don't mind you having that in the back of
25 your head and feeling warm and fuzzy when you

1 make it, but when you put it out front in the
2 beginning, you set an expectation up. And I
3 think it's that disappointment of expectation
4 that you're having trouble with.

5 **MR. FAYE:** I agree, no problem.

6 **DR. CLARK:** We have a comment. Randall has
7 a comment.

8 **DR. ROSS:** Just a question. Out of the
9 5,000 or so historical measurements you had,
10 it seems like you said a minute ago you took
11 the average, but I seem to recall you tried to
12 take the highest elevation. And in a
13 situation where you have precipitation ranging
14 from less than 40 inches to 80 inches between
15 years, would the high measurements kind of
16 bias?

17 **MR. FAYE:** Yeah, there's no question about
18 that. And if you're referring to the Tarawa
19 Terrace, we only had less than a hundred
20 compared to the 5,000 or so there. So we
21 really didn't have an opportunity to select
22 through a lot of data for Tarawa Terrace. I
23 can't even recall now. I think there was
24 something like 60 measurements that we
25 actually ended up using to estimate a pre-

1 development surface. Some of those were
2 earliest in time, and some of those where we
3 might have had two or three multiple
4 measurements at the most other than the air
5 line data. Again, let's not deal with that.

6 **DR. ROSS:** I'm with Scott. Bag the air line
7 data.

8 **MR. FAYE:** Yeah, bag the air line data. But
9 the good data, and those were all what I would
10 call high quality data that we used there for
11 that potentiometric surface. Where there were
12 two or three measurements that we actually did
13 have at the same point, I might have used
14 again the highest there, not necessarily the
15 earliest in time but the highest. It was a --

16 **DR. ROSS:** And something that we see at
17 sites all over the place is the lack of good
18 survey data for the wells. It's, for god's
19 sake given the cost of surveying the
20 monitoring points is nothing compared to the
21 other efforts that are going on at the site.

22 **MR. FAYE:** Again, most of those data that
23 are in that table for that use, those points
24 were surveyed in. And I don't know whether
25 it's actually explicitly noted in the report

1 or not, but it's true with all the tables in
2 Chapter C, if you happen to see head data
3 reported to the tenth of a foot, those were
4 all surveyed-in points. If you happen to see
5 data published to the nearest foot, those were
6 estimated from topographic maps or something
7 like that. I don't know that it's explicitly
8 said in that report, but that was the protocol
9 that was used.

10 **MR. HARDING:** Dr. Faye, let me ask a
11 question on that because I thought I saw in
12 there -- I'm poaching on the groundwater folks
13 -- a plus or minus two and a half foot
14 standard for those ground surfaces that were
15 taken from the topographic maps. Why can't
16 that be refined at low cost nowadays? I'm
17 just curious. Is that worth the effort to go
18 refine that since you've got this N-square
19 error of two feet? It seems like it's a
20 pretty big chunk of it.

21 **MR. FAYE:** I think it might be mixing some
22 apples and oranges there.

23 **MR. HARDING:** It could easily be.

24 **MR. FAYE:** To answer your first question,
25 no, I don't think it would be worth the cost

1 of refining those data at all. Second of all,
2 most of those 5,000 measurements that we
3 talked about for Holcomb Boulevard/Hadnot
4 Point, 5,000 plus measurements, I would say,
5 well, certainly the vast majority of those
6 relate to wells that are surveyed in.

7 And your two and a half foot issue
8 there is kind of a, I don't know whether it's
9 ever been formally recognized, but in 30 years
10 of work sort of a standard rule of thumb that
11 I've always used to estimate that altitude
12 using topo maps was plus or minus one-half the
13 contour interval. And the standard contour on
14 these maps that we were using was five feet,
15 i.e., the two and a half plus or minus rounded
16 off to make it simple to three feet. And
17 that's where the three-foot standard came
18 from.

19 **DR. DOUGHERTY:** Just to follow on, first,
20 I'm working on a project with some reasonable
21 data of questionable quality for reference
22 elevations, and we used a similar topographic
23 approach. So I'll just give you some
24 validation on that. But, and you can do it,
25 because it's not that expensive, but sometimes

1 it is. The thing I was going to talk about
2 was where these calibration curves, and again
3 this single plot that we're looking at, the Q-
4 Q plot or the one-on-one plot. If I didn't
5 have the units' ~~little blanks~~ [unit slope -
6 ed.] to guide my eye, I would not get a one-
7 on-one slope for this. I would say this is on
8 an inclined line that has a break point and
9 the slope of each leg, neither one has a slope
10 of one. So this is a fine type of plot, but
11 if you did the residuals versus the head, I
12 think you'd find that the errors are not
13 homoscedastic, and it would lead you to, the
14 residuals are not constant with the observed
15 heads.

16 **MR. FAYE:** I'm not sure there's a sexual
17 preference to the points but --

18 **DR. DOUGHERTY:** It's more political because
19 you've got red points and blue points. I did
20 notice that. Where are the purple points? If
21 you looked at these residuals as a function of
22 observed head, I think you'd find that there
23 is a structural issue that might inform you
24 how to go forward from here.

25 **MR. FAYE:** No argument. I think Mary

1 articulated those issues I think really,
2 really well in her notes and we acquiesced on
3 behalf of the project. I'll just say that we
4 acquiesced to those sentiments and heartily
5 agree, and we'll follow through on that. No
6 problem.

7 **DR. HILL:** So we have yet the concentration
8 data to discuss? And are we ready to go on?

9 **DR. CLARK:** I'm going to suggest we take a
10 break. A couple of housekeeping things. Who
11 has flights that are going to be tight?

12 (multiple responses)

13 **DR. CLARK:** Anybody else?

14 (no response)

15 **DR. CLARK:** Liz, can we make sure that they
16 get some better transportation?

17 (Whereupon, a break was taken between 1:40
18 p.m. and 1:55 p.m.)

19 **DR. CLARK:** First, Mary would like to start
20 a discussion on the concentration
21 calibrations. And then after that, we'll do
22 that for about ten minutes, and then we're
23 going to go around the panel, and I'm going to
24 ask for every panelist to give his opinion and
25 summarize for the record. And I think Walter

1 and Ben are tight on time. Who else, somebody
2 else was going to go with you in your cab.
3 Dan, okay, so three, so when we start out I'm
4 going to go with Walter, Dan and Ben.

5 **MR. HARDING:** I don't think we're that
6 tight.

7 **MR. FAYE:** That's really famous last words.

8 **DR. CLARK:** Well, let's start the discussion
9 that Mary wanted to have.

10 **MR. HARDING:** Then we have a three o'clock
11 cab.

12 **DR. HILL:** This will be real quick because
13 Lenny's laid all the foundation or the
14 foundation I was interested in. And that is
15 to take the concentration data and first
16 calibrate, use it to derive effective
17 transport paths and use those to calibrate
18 first to get yourself in the right direction
19 and then obviously, and then really manage
20 your water table non-linearity to your
21 advantage.

22 Don't let it, because that can add 50
23 percent to a project. It's amazing. And then
24 when you do bring the concentrations in you
25 can weight them so that you can consider your

1 heads at the same time and your stream flow,
2 we talked about the stream flow gains. I'll
3 open it up if anybody has questions or
4 comments about that.

5 **DR. KONIKOW:** You kind of mentioned earlier
6 that you have quite a lot of variability over
7 short periods of time in the observed
8 concentration. And that's really going to be
9 a big obstacle to calibrating the model.

10 **MR. FAYE:** It was and it is.

11 **DR. KONIKOW:** Look at Figure F-16 in your
12 Tarawa Terrace report. You have this
13 simulated curve that's coming up, a nice
14 smooth curve, and then there's one point in, I
15 guess, 1985, where you have five frequently,
16 samples collected over a short period of time
17 --

18 **MR. FAYE:** I know.

19 **DR. KONIKOW:** -- and they have a range much
20 greater than the long period of the --

21 **MR. FAYE:** I know. I know, Lenny. Let me
22 make a comment on that, and in part of my
23 comment I'll reference, for example, the Table
24 C-7, if you want to check that out.

25 **DR. KONIKOW:** Yeah, I've got it right here.

1 **MR. FAYE:** There's a lot of reasons for
2 variability of the concentration data. I'm
3 not going to go over all that again. We know
4 sampling, et cetera, et cetera. And the point
5 that I'm about to make I also make in Chapter
6 F, perhaps not well, but I attempt to make it
7 anyway.

8 My belief is that the major
9 variability that you're looking at in terms of
10 TT-26, I think in about a 28-day period,
11 there's a two and a half order of magnitude
12 difference in the water quality that was as a
13 result of sampling at this well. The highest
14 measurement and the earliest measurement, I
15 think which was about 1,580 micrograms per
16 liter, that's the greatest measurement, and
17 that's the earliest measurement.

18 That was sampled actually when that
19 well was probably still operating routinely
20 before they formally shut it down or was very,
21 very, very close to the time that they
22 actually shut it down. And the subsequent
23 samples there that were compressed within
24 about a three- or four-week period of time
25 were, my guess is -- this is my supposition --

1 were probably sampled with perhaps the well
2 turned on to evacuate maybe two or three
3 casing volumes or something like that.

4 And as a consequence, the result was
5 the fact that there was not a lot of
6 contaminants solute in the well at that time
7 at a concentration that would have been there
8 if the well had been operating for 12, 13, 16
9 hours, whatever, and more that mass of, from
10 the center of mass of a plume had been
11 attracted toward the well at the time.

12 And we see that. I give an example
13 with respect to TT-23 in Chapter E, I believe,
14 and Chapter F where indeed TT-23 was operated
15 for two hours and sampled and then operation
16 continued for another 22 hours so it was
17 operated for a total of 24, and the
18 contaminant concentrations doubled in that
19 period of time.

20 So my point is, after this long and
21 drawn out craziness, is that there's an issue
22 of how these supply wells were sampled in
23 terms of the length of time that they were run
24 prior to sampling. And I think that accounts
25 for a large amount of the variability that

1 we're seeing.

2 And you can look at 602 is another
3 example on page C-7 that the analysis there on
4 November 30th, 1984, that well was still
5 operating routinely at that time. And it was
6 very shortly after that shut down, and then
7 subsequently sampled quite frequently at week
8 intervals or several day intervals after that.
9 But it was not operating routinely at that
10 time.

11 Well, the latest data, water quality
12 data, that we have for the supply wells, I
13 think as far as data that I have, is for the
14 year 2000, and there was a massive undertaking
15 on the base as well as over at the air station
16 to sample supply wells at that time. And the
17 protocol observed for sampling at that time
18 was to let all of the supply wells run for 24
19 hours and then sample them. So I think
20 finally the issue, the sampling protocols,
21 were catching up to the real world finally by
22 the year 2000.

23 **DR. KONIKOW:** So this gets at really a basic
24 issue of when you get to the calibrating the
25 ~~solu~~ [solute -ed.] transport model, what are

1 you calibrating it against?

2 **MR. FAYE:** We made a point in Chapter F, I
3 believe, that we, again, perhaps we tried to
4 have our cake and eat it too, and maybe got a
5 ~~stomach-ache~~ [stomachache -ed.] over it, but
6 we made a point that we say that we believe
7 these data are more realistic in so many words
8 than other data. And again, it was this
9 earliest in time data.

10 **DR. KONIKOW:** Shouldn't you say that before
11 you calibrate the model though?

12 **MR. FAYE:** Pardon me?

13 **DR. KONIKOW:** Shouldn't that, I mean, in
14 keeping with your setting of pre-calibration
15 targets, shouldn't your decision about which
16 data are more reliable for a calibration
17 bracelet[bracket -ed.], that assessment should
18 be made before you decide to see which fit
19 match better.

20 **MR. FAYE:** We did. Those statements are
21 made in Chapter E which is a summary of all
22 the water quality data, and that was clearly
23 before we attempted to do any model
24 calibration or anything like that.

25 **DR. HILL:** But yes but, you didn't then use

1 that information and perspective to inform how
2 you actually conducted your calibration. And
3 let me just provide an example of that -- and
4 there's a bunch of things that come in here.

5 One is that you have this very long in
6 time kind of base model. And that's your goal
7 is to get this as accurate as possible. But
8 you end up having detailed concentration
9 information at different times along that
10 path. Now, you're using a methodology because
11 you have to sort of degrade your model and
12 because it's a long time period, you're using
13 a solution method for your transport that has
14 a lot of numerical dispersion, but it's fast.

15 Okay, so that's fine for your sort of
16 long-frame model, and when you get to that
17 point in time where you're trying to match
18 information at that well, it's probably a
19 higher concentration I would say that's going
20 to be consistent with that methodology. But
21 you could also take your model as calibrated
22 and for a fairly short simulation use a
23 methodology, a method that has very low
24 numerical dispersion.

25 You're going to have to figure out

1 your initial condition, your initial
2 concentration conditions. And then compare
3 that simulation, basically, what your short-
4 term, temporal data is telling you is that
5 once that well stops pumping, that it's the
6 pumping of the well that's making the plume
7 come over there. That if you stop pumping the
8 plume's going to recede. And you could test
9 to see if that occurs given the flow field you
10 have.

11 **DR. BAIR:** On a short-term basis.

12 **DR. HILL:** On a short-term basis. So there
13 might be some combination of kind of this
14 long-term calibration and then some short-term
15 simulations that test certain hypotheses.

16 **MR. FAYE:** Yeah, we did that at Lenny's
17 suggestion for another reason, basically, to
18 look, not to test the retreat of the mass,
19 contaminant mass in the plume, but we did that
20 to test the possibility of numerical
21 dispersion. We came right down to one-day
22 stress periods, so that's easy to do. And
23 that's a good idea. We can give that a try.

24 **DR. HILL:** And you can use one of the
25 solution methods then that's --

1 **MR. FAYE:** Oh, not only that. We can
2 actually use some of the field data that we
3 have to test that out.

4 **DR. CLARK:** As worthwhile as this discussion
5 is, I'm afraid we're going to have to cut it
6 here, but first off let me thank, in case I
7 don't get a chance to do this and they have to
8 leave in the middle of this discussion, I'd
9 certainly like to thank everybody for their
10 input, attention, perseverance and patience
11 for putting up with us. It's been very
12 interesting, and I hope it's been very useful
13 for ATSDR. I think it has.

CHAIR SOLICITS RESPONSE TO CHARGE FROM EACH

14 **PANEL MEMBER**

15 Why don't we just start with Walter.
16 We'll go around the table with Walter. I
17 guess Walter, Dan and Ben might have to leave
18 before we're finished. So, Walt, we'll start
19 with you.

20 **MR. MASLIA:** If you would, obviously all
21 comments are welcomed and desired, but if you
22 could try also to specifically address the
23 questions --

24 **DR. CLARK:** That were in the charge?

25 **MR. MASLIA:** -- that would help us out. And

1 anything else above that, that's also fine.
2 It would help us out if you focus.

3 **DR. GRAYMAN:** I'll start by seconding Bob
4 and just say it's been quite a privilege in
5 working with this distinguished group. And I
6 think this has been an excellent and hopefully
7 very useful to ATSDR. Thank you, Morris;
8 thank you, Liz, for organization, and the rest
9 of the group.

10 I'm going to concentrate on the area
11 of water distribution system analysis in my
12 comments. First of all, the previous work
13 that ATSDR has done in developing a detailed
14 water distribution system model has put them
15 in a good position to move forward in
16 analyzing the Hadnot Point and Holcomb
17 Boulevard during the interconnection periods.

18 Second, the water distribution system
19 analysis is going to be needed for analyzing
20 the impacts on Holcomb Boulevard, primarily
21 the Berkeley Manor area during the
22 interconnection periods with Hadnot Point.
23 For other times in the areas the mixing model
24 approach used in Tarawa Terrace should
25 suffice.

1 I think that the analysis of the
2 Holcomb Boulevard system during
3 interconnection can be separated into two
4 types of analysis, first of all the
5 groundwater wellhead, water treatment plant
6 type of analysis that was done in Tarawa
7 Terrace and second the distribution system
8 analysis, and I think it's important that they
9 can be separated. And it can take place by
10 using the distribution system model to
11 calculate the percentage of water from Hadnot
12 Point reaching points in Holcomb Boulevard.
13 In other words for each node in Holcomb
14 Boulevard you calculate the percentage of the
15 water reaching it at any time that comes from
16 Hadnot Point. Subsequently, the
17 concentrations reaching the customers can be
18 estimated by overlying that percentage of
19 water from Hadnot Point with the calculated
20 concentrations leaving the Hadnot Point water
21 treatment plant.

22 For assuming the concentrations
23 leaving the Hadnot water treatment plant can
24 be estimated probabilistically on a monthly
25 basis, then with a manageable amount of effort

1 in the distribution system area, I think that
2 a monthly probabilistic estimate of
3 concentrations reaching the Holcomb Boulevard,
4 Berkeley Manor customers can be made. And my
5 question for the epidemiologists is, is this
6 an acceptable form of results for them to
7 analyze.

8 And finally, the detailed data that
9 was available for that 1984-'85 period when
10 Holcomb Boulevard water treatment plant was
11 offline should be studied and used at least as
12 a partial validation exercise. However, it
13 really is not that useful as calibration
14 because of the operation during that period
15 was so different. That's all. Thank you.

16 **DR. CLARK:** Thank you.

17 Mary.

18 **DR. HILL:** Let's see. One thing I did want
19 to mention that I hadn't mentioned previously
20 was that, Morris, you had spoken about a
21 timeframe of 2012 for the modeling at one
22 point. And I think really that you can, I
23 actually do think the November deadline is
24 tight, but that something like next May is
25 plausible. So that's the kind of extension

1 that I might consider if recommending.

2 So that's one issue. The other issues
3 I've really, we've just been talking about
4 them, and I'm going to focus on the
5 groundwater model, but the issues of being
6 more strategic and more hypothesis testing
7 kind of focused in some of the testing that's
8 done with the model and that comes into
9 working with the observations in a more kind
10 of strategic way, having observations that
11 represent more solidly specific kinds of
12 dynamics in the system including vertical
13 flow, maybe even flows in different directions
14 you could have or have differences in
15 different parts of the model.

16 You might break it down
17 geographically. It'll depend on draw-downs
18 over time. That's another option. But having
19 graphs of residuals that make a little bit
20 more physical sense so it can be interpreted
21 better. Observations of any kind of stream
22 flow gain and loss that you can get your hands
23 on is just a really great cross-check.

24 In connection with that as well, you
25 might define, you might keep track of the

1 flows going in and out of the ~~conson~~-(ph)
2 [constant -ed.] head boundaries along the
3 rivers. Not that you have a very good handle
4 on what the values should be, but you might be
5 able to say that value's ridiculous.

6 And in terms of the concentrations, I
7 think we've spoken quite a bit about that.
8 Since we just did it I won't repeat. In terms
9 of the parameters for the model, obviously
10 we've talked a lot about over-fitting and
11 trying to avoid that because usually an over-
12 fitted model doesn't have great predictive
13 capability. And you can demonstrate that to
14 yourself with your model, using suppressed
15 validation exercises and stuff.

16 And being a geologist in my undergrad
17 and engineering in my grad, in grad work I
18 tend to really want to constrain models with
19 geology a lot, so I tend in that direction.
20 And I think this system has potential for
21 perhaps doing that more than has been done.
22 And that's all I have. Thanks.

23 **DR. CLARK:** Thank you.

24 Dave.

25 **DR. DOUGHERTY:** Here again, it's been a very

1 interesting couple of days, and I know I've
2 put a little bit of water from the fire hose
3 on the end. I suspect I'm not alone. I guess
4 my reactions are kind of mixed because in some
5 ways I feel we're coming in quite early in
6 this process, and in some ways we're coming in
7 a little bit late in the process. I'm not
8 sure exactly where the balance is.

9 But to try to answer the basic
10 questions, there seems to be a reasonable
11 possibility of delivering data useful to
12 epidemiologists with some periods of time
13 where that[data -ed.] may be less reliable
14 than others. And this interconnect time I
15 think is one that's going to be a little
16 testy.

17 We've talked about the data analysis
18 somewhat, some things to do with taking the
19 January '95 period data and doing a very
20 simple mixing model to make sure we have some
21 sense of measurement errors, either, not sure
22 of the treatment plant or to the production
23 well, but it will give us some sense of one
24 measure that we can use that constrains or
25 informs concentration measurement errors

1 because I don't feel we have a very good
2 handle on that.

3 In terms of calibration we talked
4 about looking at different ways of
5 representing the residuals so that we can
6 extract some information rather than just
7 saying we've made it, -- and I haven't seen
8 Mary's notes, so I don't know the details of
9 what she's given, but I'm sure she's given
10 them all, all the various plots.

11 On the concentration calibrations
12 looking forward, we didn't get into a
13 discussion of the treatment of non-detects in,
14 lower bounds of non-detects in the calibration
15 process. But they are, as I read it for
16 Tarawa Terrace, they're set at one microgram
17 per liter no matter what the detection and/or
18 reporting limit may be. That seems to me
19 inappropriate.

20 Think about it, another way to do it
21 if you're limited by taking logarithms, take
22 the log of one plus the concentration so that
23 your variable can be logged without blowing up
24 on you. Do something, use the data better
25 where it's limited.

1 ~~Simpler~~ by [Simplified -ed.]
2 physically-based models are the way to go. I
3 like the idea of pursuing a second path that's
4 totally data driven, but it can't be used in
5 preference to before the physically-based
6 modeling systems. I don't think it's
7 worthwhile spending a lot of time on fancy
8 transport systems. Try to keep them
9 relatively simple. The approach that Lenny
10 talked about earlier really simplifying,
11 grossly simplifying the transport processes
12 and getting some representation of early
13 arrival times makes a lot of sense to me.

14 With respect to arrival times, I would
15 note that in the documents at Tarawa Terrace
16 that both densities seemed out of line. There
17 may be a nomenclature issue. Both densities
18 were around 2.8 or 2.9 because I calculated
19 them. It seemed a little like one too high.
20 So it may be a nomenclature issue. It just
21 needs to be clarified and get it right so
22 we're not retarding excessively. Thank you.

23 **DR. CLARK:** Ann.

24 **DR. ASCHENGRAU:** Well, I just want to say
25 from an epidemiologist perspective, and it

1 might seem strange given the discussion of the
2 last two days, but that this is really state-
3 of-the-art, even beyond the state-of-the-art
4 epidemiologic study of drinking water
5 pollution. And what's been done here just
6 goes way beyond what's typically done in most
7 epidemiologic studies that have been able to
8 find effects and associations. So I have in
9 spite of all the problems we've heard about, I
10 have every confidence that the study has a
11 very good shot at finding an association if
12 it's there.

13 My problem comes more from the size of
14 the case control study, that that's a
15 limitation. But I'm heartened to hear also
16 that the great efforts that have been
17 undertaken will be used to reanalyze the prior
18 analysis of small for gestational age in the
19 two planned studies. So that's really
20 excellent.

21 That being said I also want to
22 reiterate the point that I made yesterday that
23 the Department of Navy should make every
24 effort to identify and give to ATSDR all of
25 the relevant data that they need to do the

1 best job possible and that they need to do
2 this immediately. I think it's a real shame
3 that they now have to go back and reanalyze
4 the study data from before because they didn't
5 have all of the necessary information.

6 I do think that the goal should be to
7 try to get monthly data for the current study,
8 so monthly exposure data that should be the
9 goal that people are aiming for. And that,
10 you know, if you don't reach it, that's okay.
11 Epidemiologists have never been stopped by
12 having imperfections in their data. It
13 doesn't stop us.

14 And the other impression I've had is
15 just that there are sort of lots of possible
16 sensitivity analyses that can be done with the
17 groundwater modeling, the distribution water
18 modeling. It just seems like a huge, huge
19 job, but that somehow some plan has to be made
20 for developing what needs to be done, and it
21 needs to be done strategically. And that the
22 goal should really be to keep the
23 epidemiologic study in mind and not spend a
24 lot of time on things that really won't make
25 such a difference in the exposure assessment

1 for the study.

2 In terms of just some particulars,
3 they're not so much to do with the exposure
4 modeling, but for the case control study of
5 cancer, I do think that the exposure
6 assessment should go beyond the first year of
7 life and that it should go up to the time of
8 the diagnosis of the cases and some comparable
9 date of the controls. That that may end up
10 being a large source of error if that's not
11 done. So you may have to go back and get
12 supplemental data from the study subjects or
13 somehow get that data from records.

14 And the other thing, well, is the
15 school. That really high value at the school
16 is problematic. And so I think that you
17 should monitor or assess the exposure, not
18 just at the residences but at the schools.
19 And so that would only be really relevant for
20 the cancer study I think at this point. And
21 that that source of exposure should be taken
22 into account.

23 And then my last point has to do with
24 the behavioral data so it's the water
25 consumption habits of the study participants.

1 Frank has said a couple of times he doesn't
2 think the data are very good. So I think that
3 the goal would be to try to pick up the
4 extremes so the people that take like long hot
5 showers basically, and drink a lot of tap
6 water and to try to distinguish them from the
7 other study subjects if that's possible.

8 **DR. CLARK:** Ann, thank you very much.

9 Scott.

10 **DR. BAIR:** Yes, I guess I'd like to also
11 thank people for inviting me. This has been a
12 very worthwhile and educational process for
13 me. I think the discussions over the last two
14 days have probably convinced those who already
15 recognize it at the table and elsewhere and
16 those of you in the audience that all models
17 are wrong. There are some models that are
18 useful.

19 So the goal here is to incorporate
20 enough uncertainty and analyze enough
21 sensitivity aspects that we come up with a
22 useful model that can be used by the
23 epidemiologists. So I don't want all the
24 discussion of the nitty gritty that went into
25 the making of the sausage to discourage people

1 that this can't be done. Because I, like Ann,
2 share a positive idea that this can be
3 accomplished. Having read the Tarawa Terrace
4 and the other reports that we were sent before
5 we got here, I was a little skeptical about
6 the amount of data that was available.

7 And through the discussions with Bob
8 and others there are a fair amount of data
9 that are present that can be used to help
10 constrain the models that I don't think have
11 been mined to their greatest extent yet. For
12 example, the grain size analyses, I think more
13 can be squeezed out of that just looking at
14 the percentage clay or looking at something as
15 simple as a uniformity coefficient or ratio
16 between D-60 and D-10.

17 I think being the geologist that Mary
18 mentioned, all three of my degrees, anything
19 that is deposited in water because of particle
20 size differences and settling through water,
21 is going to be anisotropic inherently. So I
22 think there's an anisotropy within each year
23 model layers that you may need to consider.
24 These are stacked channel deposits so they are
25 deposited in water. So I'd encourage you to

1 try to glean as much as you can.

2 The grain size data, there are
3 actually geophysical logs that we didn't get
4 to mention, SP logs and resistivity logs that
5 are giving you information that can be
6 interpreted to show that these are not
7 continuous layers, and they're in some of the
8 older wells, but I think that, too, needs to
9 be incorporated into the model either as an
10 uncertainty analysis, a what would happen if
11 this data point is correct and there's a hole
12 in the confining layer here or not. Getting
13 at the pumping test data, the slug test data
14 that Bob talked about and incorporating that
15 in the model I think is essential to get the
16 velocity fields pinned down a little bit.

17 Having said that, that y'all have a
18 lot of data to squeeze yet, I do think that
19 there are some simple pieces of data that you
20 can add within your timeframe to help you
21 lower the uncertainty in your model by adding
22 a couple monitoring wells and locations there
23 where water levels are sparse and then just
24 using that to help guide your model even
25 though you're going backwards in time, the

1 water level in the sparse areas probably has
2 not changed that much because it's not in the
3 middle of your well fields, and I'm thinking
4 specifically on the northeast border of the
5 model area.

6 Perhaps getting some tritium/helium
7 data would be useful to help get another full
8 velocity measurement like Mary talked about
9 getting stream discharge data to help
10 corroborate -- calibrate, corroborate --
11 what's going on. I think MODPATH is an
12 essential target of your future work, and it
13 wasn't in the Tarawa Terrace report, but I
14 think it should be an essential part.

15 And then the last thing I have, and we
16 really didn't get too great a discussion on
17 it, is the source term issues. For me one of
18 the biggest problematic areas you have is how
19 you're going to treat all these different
20 source terms. Are they going to be pulse
21 sources or are they going to be continuous
22 sources? If they're continuous sources, is
23 there known DNAPL at depth that can continue
24 to shed off dissolved phase TCE or PCE? What
25 are the initiation dates of those and how are

1 you going to bracket those in some sort of
2 uncertainty analysis?

3 That's about -- oh, yeah, one last
4 thing. Dump the air line measurements.

5 **DR. CLARK:** Scott, thank you.

6 Dan.

7 **DR. WARTENBERG:** I'm also going to thank
8 everyone. I found it fascinating to hear
9 about all the inter-season groundwater
10 modeling and the complexity and the difficulty
11 in obtaining accurate estimates. But as Ann
12 said, as epidemiologists we're used to
13 complicated problems and data that's not as
14 good as we want and are still able to move
15 forward.

16 But that having been said, I think
17 we've seen maybe the best data that can be
18 provided for this study because the better the
19 data, the more accurate would be the
20 epidemiological results, the more sensitive
21 the study will be. And also, fine scale data
22 are important in helping us resolve some of
23 the epidemiologic issues in terms of how the
24 exposed were related to outcomes.

25 I think that just speaks to the notion

1 of if it's at all possible to get the monthly
2 data to get an opportunity to try and see at
3 what stage in the pregnancy there is this
4 effect would be very important, although I
5 recognize that's going to be harder. And
6 there's always the opportunity to aggregate it
7 back up to whatever timeframes if needed to do
8 the analyses.

9 I think one of the other things that
10 would be useful to do which hasn't been talked
11 about as much is also to do some sensitivity
12 analysis from the epidemiologic studies in
13 terms of if they're different estimates based
14 on different assumptions. Those also can be
15 explored epidemiologically to see if there are
16 associations in different ways.

17 One of the challenges here is, I guess
18 there are a few challenges, there are a
19 moderate number of studies looking at TCE and
20 PERC and vinyl chloride in terms of cancer,
21 but there's much less in terms of reproductive
22 outcome. And being able to get a better
23 handle on that's pretty important. So I think
24 that trying to complete that picture, even the
25 cancer data right now is still very

1 controversial. But I think, again, it just
2 speaks to how important this study is in doing
3 as good a job as is possible.

4 I guess a couple other things to say
5 are that I support Ann's statement about
6 really asking the Navy to provide whatever
7 data are being requested and available to help
8 inform the study that that would be an
9 important component to try to understand
10 what's going on and trying to understand the
11 epidemiology of these compounds that we know
12 definitely affect people's health and to try
13 and better understand that.

14 I guess those are my main comments. I
15 just think again, just to reiterate, the
16 better data we can get the better the
17 epidemiologic data will be and the more
18 retrievable and reliable. I think that's an
19 important thing to try and strive for. Thank
20 you.

21 **DR. CLARK:** Thank you.

22 Peter.

23 **DR. POMMERENK:** Well, I'll say thank you
24 again for having me a second time on this
25 panel. I find a certain new perspective that

1 I hadn't heard about groundwater modeling
2 before, and I also heard some things that we
3 spoke about last time. And instead of
4 repeating again, I just want to keep it short
5 and want to reiterate that it appears critical
6 to this study that uncertainty is included
7 from the get-go.

8 From every aspect, starting upstream
9 from the mass that was deposited, when it was
10 deposited to have some measure of uncertainty
11 in all these estimates and how they propagate
12 through our model and whether it's the
13 simplified physical model or linear control
14 theory model or highly complex transport
15 model, the uncertainty that is upstream will
16 propagate ~~for~~ [through -ed.] the model and
17 will possibly skew it.

18 In the end we need to be, a logical
19 study needs to be able to distinguish certain
20 levels of exposure, whether it's not exposed
21 versus exposed or whether it's a little
22 exposed, medium exposure, high exposure and
23 just providing a number will not help that
24 cause. So it needs to be accompanied by some
25 level of certainty in those numbers.

1 So with that in mind from my
2 perspective certain things that will have to
3 be addressed in Hadnot Point is the pumping
4 schedules, having a well operate 24/7 over a
5 month at a reduced ~~apportion~~ [proportional -
6 ed.] flow rate may not be appropriate, and you
7 may want to look into at least a cursory
8 analysis of how using 12-hour stress periods
9 may affect the outcome.

10 For the Holcomb Boulevard wells you
11 may want to use 12-hour stress periods because
12 that's the typical amount of time they operate
13 versus Hadnot Point, those wells seem to
14 operate in ^ [continuously -ed.] for a week or
15 two or even a month. Anyway, it would be
16 worthwhile looking at how this type of model
17 or approach will affect the outcome and
18 uncertainty in the study.

19 And then secondly what I mentioned
20 earlier, we need to look at some of the issues
21 of volatilization up at the treatment plant.
22 You know, just a cursory analysis and say it's
23 significant or not. But it should be on
24 record somewhere because that question may
25 come up at one point.

1 And I think moving downstream from
2 there, again, it's a lot about uncertainty.
3 We need to wonder how much detailed modeling
4 we have to do in the distribution system.
5 Will that increase certainty in our, in the
6 end or is it not worthwhile by the time we get
7 to what [we want -ed.]^ . Anyway, that's all I
8 have.

9 **DR. CLARK:** Peter, thank you.

10 Dick.

11 **DR. CLAPP:** Thank you all for teaching us a
12 lot. I think some of you mentioned yesterday
13 there are boundary layers between the
14 engineers here. Well, there are tribal
15 differences I think between ^ [various -ed.]
16 epidemiology tribes. It's fascinating to
17 listen and learn from you all.

18 To me, I would like to reiterate the
19 points that Ann and Dan made from the point of
20 view of an epidemiologist. When you get the
21 final number that you'll use to assign a dose
22 or an exposure to a particular subject in a
23 study, that's the result of a lot of
24 phenomenal work, and it will have error bars
25 around it.

1 But there is still going to be a
2 central tendency for that number. I know it's
3 a sort of probability density function that
4 goes along with that number. Our goal is to
5 see that that's as peaked as possible, not as
6 flat and as compatible with anything as
7 sometimes happens. So that's the goal here,
8 and I think everyone has established that
9 that's what the modeling effort is going to
10 lead to. So anyway, I think that's in good
11 hands. As Ann said it's state-of-the-art
12 work, and I commend the ATSDR folks for doing
13 it.

14 I'd like to mention I think there is a
15 particular problem which is this Hadnot Point
16 to Holcomb Boulevard interconnects during four
17 months for a period of years from 1972 to 1987
18 where the problem is or a lot of the problem
19 is in the distribution system at least. And
20 so that seems to me to be a tractable problem,
21 that it's not as big as or hopeless as some of
22 our discussion today or yesterday might have
23 made it seem, especially today, I guess.

24 So I'm optimistic. I think this is
25 going to work. I think that the process that

1 we've engaged in is going to have a fruitful
2 outcome. I think it will be useful to
3 veterans, the people who lived and worked at
4 Camp Lejeune, and that we shouldn't lose sight
5 that that's what this is all about. And I
6 think some aspects of this we learned, for
7 example, there may be a simpler solution than
8 we realized, one of which can be done this
9 weekend. We may have data next Monday I think
10 from him, Dr. Aral. Without being too silly,
11 I'd like to say I think this is a useful
12 exercise that's going to lead to an important
13 finding and glad to be a part of it.

14 **DR. CLARK:** Thank you.

15 Ben.

16 **MR. HARDING:** Thanks, Bob. I want to thank
17 ATSDR for allowing me to have this
18 opportunity. I really learned a lot in the
19 first pass, and I've learned a lot from this
20 one. I thank all the panelists, too, for
21 allowing me to poach on your territory and
22 talk about things I don't really know that
23 much about.

24 And I want to say how remarkable
25 Morris is. I don't know what, does he drink

1 Tension Tamer Tea or something like that?
2 Your ability to stay calm in the face of all
3 this is really impressive.

4 **MR. MASLIA:** Thank you.

5 **MR. HARDING:** I'd like to know what it is.

6 Bob, I'm not going to say anything
7 about, or not much, about what happens below
8 the ground here. I do think it's feasible for
9 this work to contribute a lot of important
10 knowledge, at least at the exposure level.
11 And I'll leave it to the epidemiologists to
12 work from there. So I think there's a good
13 foundation, and it's feasible to complete this
14 successfully.

15 I would suggest, and I think you
16 probably already intend to do this, that you
17 step back and re-scope your remaining efforts
18 at this point. And from the program scenario
19 I think Walter laid out the components that
20 you need to think about quite well: wellhead
21 concentrations, the interconnection scenarios,
22 water use and then the system operation rules.

23 And with regard to the water
24 distribution, both the large view I agree with
25 Morris' breakdown and essentially the

1 difficult problem is the interconnections,
2 which others have mentioned here. In doing
3 that I suggest that you should use a detailed
4 hydraulic network model, an extended period
5 simulation of that.

6 There's no sort of technical or cost
7 problem with doing that. You already have it
8 essentially. That you will need to extend
9 your scenarios over potentially several months
10 depending on what you see in the tanks because
11 it can be a long time before the tanks clear
12 out.

13 In all of the phases of the work above
14 ground, we're going to need to have what you
15 call a simple mixing model, but it's actually
16 more complicated than that as Peter has
17 mentioned. So we need to have what I call a
18 well operation well supply model that will
19 take into account if there are hydraulic
20 effects on particular wells.

21 And I think you should develop an
22 informed model of well operations, as informed
23 as you can make it. It'll probably have to be
24 stochastic at some point, but you should
25 inform it as best you can with what you know

1 about the way they operated, the wells.

2 I think you should use the super-
3 position approach that Walter mentioned. It's
4 essentially similar to the Murphy method that
5 was portrayed. You know, he called it an
6 exposure index. We call it transfer
7 coefficients.

8 But that approach will allow a low
9 cost and rapid recalculation of the exposure
10 statistics which will happen because the
11 groundwater people will come up with new
12 numbers, and then the epidemiologists will ask
13 for new thresholds. I know. I've been to the
14 rodeo before so, and being able to recalculate
15 this in a short time is really important.

16 I think it's okay. I think it's
17 feasible and proper to be able to calculate
18 your exposure statistics over a one-month
19 period. That's been a real request from the
20 epidemiologists, but I wouldn't go any shorter
21 than that. I think you have to model a water
22 distribution system on an hour to even -- EPA
23 did a model of minutes if it has to get the
24 convergence.

25 But you have to model in a short

1 period to get the dynamics of the system. You
2 can roll it up to a month but no shorter, I
3 think. ^ a quarter but because you need the
4 resolution as long as you bear in mind there's
5 some additional uncertainty.

6 With regard to the control theory
7 approach, I thought it has a lot of use for
8 developing confidence in the physically-based
9 model, but that we should use a physically-
10 based model for the basic work. And I think
11 there's other reasons why the control theory
12 approach isn't appropriate because we can't
13 get a complete set of wellhead concentrations.
14 But it really was sort of nice to see how well
15 it agreed with the physically-based model.
16 That was interesting.

17 Echoing what Peter said, you should
18 focus on uncertainty at every step from start
19 to finish. I won't try to tell you how to do
20 that, but I think ultimately it has to be some
21 kind of Monte Carlo numerical approach. At
22 least make an analysis of sensitivities if
23 you're not, if you're going to treat things as
24 point values.

25 Overall, I want to say this. There's

1 hundred of thousands of people, and I guess
2 Frank said potentially up to a million people
3 that may have passed through this site during
4 this period that are interested in this event
5 and potentially exposed. And it's a bad thing
6 that's happened, but we should do our best to
7 learn from what happened and not repeat this
8 mistake. And whatever we can gain medically
9 and scientifically we should do that.

10 If this is done well, future people
11 will make medi-analyses of these results with
12 new information about the populations. So I
13 think it's really, really worth committing the
14 time and effort that are necessary to get this
15 done right, whatever right means, but to get a
16 good foundation in every spurt or step. I
17 mean, the flow model is going to be the
18 fundamental foundation that probably won't
19 change all that much. And as you build up
20 from it maybe some things will be refined, but
21 I really do think it's worth it.

22 You need to take the time and the
23 money to do that. With respect to time, I
24 think a year for the water distribution
25 modeling should be enough, and maybe you could

1 do it faster. I mean, we've done similar
2 things in a year. I think if you set your
3 mind to it, you could do it faster, but
4 there's a real value in rethinking things
5 every once in awhile.

6 But do focus on the essentials, just
7 what you essentially need to do to get the end
8 result. Try to avoid digression into details
9 where they aren't relevant. But I think
10 you've done a real good job, and I really do
11 appreciate the opportunity to be here with all
12 the panel members and your tolerance.

13 **DR. CLARK:** Thank you, Ben.

14 Rao.

15 **DR. GOVINDARAJU:** I, too, would like to
16 thank ATSDR and all of you for contributing to
17 my learning. I really enjoyed all this. I
18 have some recommendations, but they're not
19 necessarily out of the charge that was laid
20 down to us.

21 First, I would like to say that I
22 found out that more data has become available
23 very recently, 200 new ~~USG~~ [UST -ed.] reports
24 and many other data coming online. And this
25 data is not likely to be immediately ~~be~~ [-ed.]

1 used in a model. It's not in spreadsheet form
2 and all cleaned up. So by the time all that
3 data discovery from all this takes place, I
4 suspect it will take some time and I do not
5 know how large a team you have, how many
6 person hours you can throw at it. So I'm
7 going to suggest that December 2009 does not
8 look likely to me, at least one more year and
9 maybe more. But that's something I wouldn't
10 be able to tell. So that is in terms of the
11 timeline issue.

12 I'm also not comfortable, I would not
13 like to answer the question and say can we
14 promise a plus-minus half magnitude for
15 concentrations, which actually may not be
16 possible for such a complex system even with
17 the best methods available and even if we had
18 a lot of very good data. So I think what the
19 focus should be on is trying to reduce one
20 certainty to the extent possible using
21 whatever that can be done. Use the best
22 methods and so on. I think that would still
23 be useful even if it did not meet this plus-
24 minus half magnitude target.

25 I'd also like to say that I do not

1 think that all quantities that are produced,
2 all the things that are predicted or hind-
3 casted, let's say, they will be done equally
4 reliably. Some things will be done better,
5 and some things will not be done as well. So
6 renewed concentrations I'm not sure we'll ever
7 reproduce, but perhaps some we need to drop
8 the averages or different averages you could
9 do perhaps more reliably. So I feel that all
10 the information that we have should be used ^
11 uncertainty which has been pointed out as
12 being very crucial.

13 So right now we have uncertainty from
14 the groundwater models which is reflecting,
15 which is trying to predict concentrations in
16 these wellheads, and then this is going to be
17 translated or propagated into the distribution
18 network. But in between there's a step at the
19 treatment plant. I do not know how these
20 concentrations ^, and I do not see much -- and
21 we talked about it -- but I do not know what
22 work has be done about that, but that's
23 potentially useful.

24 Regarding the models I think the
25 models that you have selected, which is

1 MODFLOW, ~~MPT~~, [MT3DMS -ed.]. the ^ [Ga. Tech -
2 ed.] code for ~~selu~~ [solute -ed.] transport,
3 EPANET, ^ [and -ed.] what have you. I think
4 these are all fine models. I have no, I guess
5 I have no objection to these models. Any
6 simpler model you want to use that is fine,
7 too, if it does the job well.

8 Now for the EPANET water distribution
9 model, when you are trying to get
10 concentrations at the endpoints, I think one
11 of the greatest challenges is going to be to
12 try to reconstruct how to disaggregate this
13 one-month quantity that is being given to you
14 from the groundwater side to a daily or an
15 hourly time schedule like has been mentioned.
16 ^ calibration work and with the expectation
17 that patterns haven't changed, I feel it
18 should be possible to reproduce the
19 variability within the month.

20 I mean, you can consult that volume
21 within a month but you appropriate so that you
22 reproduce some of this variability. And then
23 looking at this variability over time and
24 perhaps over the front realizations which come
25 from different concentration values from the

1 groundwater, if you look at all of these, then
2 I think some meaningful decisions can be made
3 about what the exposure was, how likely the
4 concentrations to have been exceeded over
5 different time windows and so on. So a good
6 statistical analysis I think could be done and
7 could be quite revealing to the epi people.

8 Well, I think those are my oral
9 comments. I see there is a lot of hard work
10 that has been done by the ATSDR team, and I
11 have a feeling there's quite a bit more to
12 come also. Thank you.

13 **DR. CLARK:** Lenny.

14 **DR. KONIKOW:** Thank you. I'm going to keep
15 my comments from the ground level down and
16 focus basically on the one test. How do you
17 get or reconstruct the concentrations
18 unloading from the wellheads? And what I see
19 is the task at hand is enormously difficult,
20 and it's a challenging one, but it's very
21 important.

22 And it's very important that you
23 succeed, and I think you can succeed, but
24 there'll be some errors and uncertainty
25 associated with that. But if you recognize

1 that I think we can pass that information on
2 and let the next group above ground, they can
3 do something with that.

4 As you go forward and develop the
5 models and develop the insight, I think it's
6 very important that you clearly indicate all
7 the assumptions that underlie it and
8 conceptual models that we use to formulate
9 that. And I think that will help in your
10 defense of it in the future, and it would help
11 enable people to understand it.

12 Now, I've spent quite a bit of time in
13 Scott's proverbial modeling sausage factory so
14 I tend to see all these difficulties, and I
15 get very concerned about them because they do
16 affect the answers, and I have a few detailed
17 comments related to that.

18 But the other kind of big picture
19 thing I see here is that you've essentially
20 completed the work at Tarawa Terrace, and I
21 could nit pick a lot of little things in
22 there, but basically, I think that was a
23 successful effort. You did a good job there
24 within its own right was a very complicated
25 problem.

1 What concerns me here is that the
2 Hadnot Point-Holcomb Boulevard I see another
3 one or two orders of magnitude of complexity
4 here, and so I do get concerned. Is this
5 whole thing doable? And that's a reasonable
6 question to ask. I don't have the definitive
7 answer, but I do think you can do something.
8 I think what you do can be useful.

9 I think basically, I think you can
10 succeed within a certain framework, but maybe
11 keeping in mind what was done and what was
12 able to be done at Tarawa Terrace, what's able
13 to be done and our success in groundwater
14 science with groundwater flow modeling.
15 Transport modeling again just is another level
16 of complexity. So as I tell some people, the
17 secret to successful ~~solu~~ [solute -ed.]
18 transport modeling is to lower your
19 expectations.

20 And I think that's something we have
21 to do. We're just not, all the difficulty in
22 groundwater flow modeling will have that, but
23 we could do it. We're not going to be able to
24 do as well with transport. There's too many
25 other processes involved and there's too many

1 additional unknowns. So what this gets at
2 then, and I've worked in the sausage factory,
3 but I'm also a sausage salesman, so I don't
4 want to discourage you from this, and I'm
5 trying not to discourage you.

6 I think it is a valuable path to
7 follow, and you will learn a lot and on. But
8 be that as it may, with this complex approach,
9 as several of us have said earlier, it has to
10 be supplemented with simpler approaches both
11 to see if they could provide the necessary
12 information as well as to provide cross-checks
13 against the very concas (ph).

14 As we said again many times, no matter
15 what we do with the models, there's still a
16 very limited set of observations of
17 concentrations against which we could compare
18 the model results. So we have this enormous
19 field of a couple of decades of no data on
20 concentrations. So we've got to take a
21 couple, you should take a couple of different
22 paths.

23 The linear control theory I think is
24 certainly worth pursuing and get as much out
25 of that as you could. Other simple ways that

1 we've talked about which would encompass some
2 coupling of groundwater flow modeling with
3 MODPATH modeling and with very simple
4 interpolation extrapolation I think would be
5 very useful also, and I think you could do a
6 lot with that.

7 I think you could learn a lot from
8 using MODPATH more than was done in the Tarawa
9 Terrace approach. With this lack of data I
10 think you have to keep mining, searching,
11 doing what you can to get more data if it's
12 out there, and if it's available. Because one
13 extreme, and again, I don't want to sound like
14 an academic researcher who just always wants
15 more data, but one of the difficulties I've
16 had in doing this review in constructing my
17 comments was -- I think it was Dave mentioned
18 -- it's very early in your phase.

19 And my focus really has been on the
20 wellhead concentration, how we get there. And
21 yet we've had no document on the hydrogeologic
22 framework yet, no transient flow model yet, no
23 transport model yet. So it's hard to comment
24 on them because that's what's going to get us
25 to the wellhead concentrations.

1 So one recommendation that was
2 mentioned was that somewhere down the line
3 when you get further into that, but not too
4 far into it, get maybe a smaller group of
5 expert peer panel to look over your shoulder
6 and give you some advice and help maybe guide
7 you in a more efficient -- and by more
8 efficient I mean you're always going to have
9 some deadline facing you. So you want to get
10 this done as well as possible and in as short
11 a time as possible. And I think peer review
12 is a very useful way to help you do that.

13 On the data picture a lot of people
14 don't like to hear this, but consider getting
15 more data. I mean collecting more data so,
16 but before you do that you've had an enormous
17 amount of money spent on installation
18 restoration programs there. Have you mined
19 that for all the data that's available?

20 In the report I saw there was a 40-day
21 tracer test done at one of the sites, which I
22 can't remember. I mean, that should have
23 gotten you some effective porosity and
24 dispersivity data if they did it well. Is
25 that data available to you and have you looked

1 at it? They must have to do the kind of work
2 they do, and they must have taken some cores.
3 They must have looked at some of the clays and
4 the confining layers.

5 Did they measure any hydraulic
6 conductivities or porosities?

7 **MR. FAYE:** Was that rhetorical or do you
8 want an answer?

9 **DR. KONIKOW:** I don't want an answer right
10 now, but it wasn't rhetorical either. These
11 are things I want you to think about, and I'm
12 sure most of you've already thought about it,
13 but these are things that are just kind of
14 popping out of my mind now.

15 On the modeling and the work that's
16 done so far, again, I'm very concerned about
17 up to now -- I know it's preliminary still --
18 it's locking into one foot per day as a
19 hydraulic conductivity for the clays and for
20 all the clays.

21 I mean, that bothers me. One of the
22 things we talked about doing sensitivity
23 analysis. In your steady state, pre-
24 development flow model, those heads are not
25 going to be sensitive particularly to those

1 values, but your transient flow model it will
2 be, and in your transport model even more so,
3 that value is so few.

4 Rely on locking it into those values
5 based on the sensitivity test in your steady
6 state flow model, you may be making a big
7 mistake. And again, that's something I
8 mentioned before is when you go beyond the
9 steady state, you may have to re-examine
10 almost everything because what worked there
11 may not work for transport.

12 In a transport analyses again one of
13 the things that has certainly been highlighted
14 in the last 20 years or more is the control
15 and the importance of spatial heterogeneity in
16 the formations. And you're dealing with
17 models at the moment.

18 You're assuming each layer, each unit,
19 is homogeneous, and I'd like you to explore
20 the data to see if there are ways to not only
21 get at the spatial variability but other
22 aspects of heterogeneity including channeling
23 and connectivity of the sediments because
24 every study where there was detailed data
25 showed that this was the controlling factor on

1 ~~solu~~ [solute -ed.] transport. So if at all
2 possible, pay a little more attention to that.

3 Then there's all the uncertainty with
4 reaction, ~~absorption~~ [adsorption -ed.], fate,
5 you know, ~~absorption~~ [adsorption -ed.], decay
6 and all those other terms which we don't want
7 to get into right at the moment. But again,
8 like I think it was Scott mentioned his
9 concern about estimating the source terms.
10 Again, what's more critical for ~~solu~~ [solute -
11 ed.] transport model than how much gets in and
12 when and where.

13 And I didn't see all the answers yet
14 in the presentations here or how the approach
15 that was taken and described will actually get
16 to an estimate for the source term in the
17 model and how they'll be done. At Tarawa
18 Terrace you did a mass loading which I would
19 much rather see defining a source
20 concentration associated with the fluid that
21 goes in the model. Because otherwise you get
22 some conceptual inconsistencies that I think
23 need to be explained. So this gets into other
24 issues, but again be careful with that source
25 term because that's very critical and very

1 important.

2 So with that I guess I'll pass the
3 mike.

4 **DR. CLARK:** Lenny, let me thank you very
5 much.

6 Randall.

7 **DR. ROSS:** First, I'd like to thank ATSDR
8 and Morris for the opportunity to come and be
9 with such a talented group of individuals and
10 learn. And I had a professor that once said
11 water level maps are a figment of the artist's
12 imagination. And I'd say the same could
13 probably be said about groundwater modeling
14 results. But with that in mind it's also the
15 best that can be done. I don't want to say a
16 necessary evil, but it is. It's the best
17 answer that one can come up with with
18 confidence. And I think that's true.

19 One of the things about data gaps,
20 modeling, one of the benefits of modeling is
21 it forces you to look at your data, look at
22 what you have and identify your data gaps.
23 And I think Scott hit on this a little bit.
24 There may be some data gaps that come up in
25 the initial parts of the modeling exercise

1 that tell you where you need more information,
2 have better control on the situation.

3 With regards to the charge, with
4 respect to the question did the methods
5 provide an adequate level of accuracy and
6 precision, using Dr. Faye's definitions of
7 precision and accuracy, I'd say for precision
8 probably, for accuracy at Tarawa Terrace
9 probably, for Hadnot Point I'll refrain from a
10 final answer on that.

11 I'd say that the Tarawa Terrace
12 exercise represented one of the best case
13 scenarios that we've had an opportunity to see
14 with respect to coming up with concentrations
15 for exposure that will keep you folks happy.
16 And that's one thing I have written down here
17 is listen to the epi folks.

18 If you have another meeting like this
19 I'd say the first 15 minutes should be the epi
20 folks re-impressing upon all the people that
21 work below ground and above what they're
22 looking for. If it's enlightening to me to
23 hear that high, middle and low are acceptable.
24 And with that in mind I'd say whether or not
25 you could reach the accuracy, probably. And

1 that's a good thing.

2 Looking through the previous panel's
3 comments after we made our comments I noticed
4 there were a few things that we commented on
5 that in particular Dr. Konikow identified in
6 the last panel meeting that didn't seem to be
7 fully addressed. And that leads me to the
8 question of exactly what will become of the
9 comments that were submitted today and how
10 that will be addressed I guess.

11 Then I have a note here that says
12 listen to the geology. To go back to what Dr.
13 Hill said, basically. And this with respect
14 to including two marginal aquifers and a
15 confining unit in the same layer. I mean,
16 that's a no-no, and I think pretty much all
17 the modeling folks here, the hydrogeologists,
18 kind of cringed when they saw that. And there
19 was a reason for that because it flooded, the
20 nodes were flooded I understand. But as Dr.
21 Hill also said, don't do that. Fix it some
22 other way I guess.

23 I would say it's, I had a comment here
24 about the plus or minus three feet and the
25 plus or minus 12 feet, and I'd say that if

1 there are wells that haven't been surveyed, I
2 think it's well worth surveying them now.
3 These could provide valuable data in the
4 future.

5 And along those same lines one of the
6 recommendations that people get tired of
7 hearing me suggest is the implementation of or
8 deployment of pressure transducers. Yeah,
9 they produce a whole lot of data, but at the
10 same time they can provide a lot of insight
11 into how the system reacts to pumps shutting
12 on and off.

13 You can't do it in hindsight, but
14 hindsight being 20-20, we can look ahead and
15 say that might be a useful tool that could be
16 deployed. Pressure transducers in select
17 locations to give you a better understanding
18 of how the system reacts, hydrogeologic system
19 in general.

20 There were several comments I guess
21 that I included in our written comments, but
22 something then to consider with the, more of
23 the worst-case scenario I guess which would be
24 the whole Hadnot Point modeling exercise, not
25 worst-case scenario but certainly not as

1 friendly and nice. The looking at leakage
2 from your domestic production lines, the water
3 lines. Ten percent's not an uncommon number
4 that you hear batted around the modeling
5 community, but which could be a significant
6 number.

7 Likewise for sewer lines, they pump a
8 boatload of water out of the aquifer, well, if
9 you lose ten percent or 20 percent of that
10 usually the sanitary folks don't really care
11 if they don't see it and if nobody's
12 complaining that they're basements are
13 flooding. That could be a significant input
14 into the model as well and nobody measures it
15 or likes to.

16 Degradation rates, you've got to be
17 careful there. It's going to be completely
18 different I believe than the exercise at
19 Tarawa Terrace. There you really don't have
20 evidence that the bugs were really happy.
21 There's not a large quantity of -- at least I
22 haven't seen -- VC, DCE and compounds like
23 that, nor of the geochemical data that
24 indicate that the bugs were happy for reducing
25 conditions. I think there'll be a lot more of

1 that associated with the DNAPL sites as I'm
2 sure they are.

3 And that leads right into the source
4 term. You've got bugs that are munching away
5 at the dissolve[d -ed.] phase, but there's no
6 doubt in my mind just looking at the numbers
7 in a cursory manner that, I mean, you've got a
8 -- I've used the term boatload three times now
9 because I like it. There's an unknown, yet
10 probably very large quantity of dense ^
11 [nonaqueous phase -ed.] ~~disphase*~~ liquid TCE
12 and PCE in the subsurface especially below the
13 dry cleaner. How that will be handled as a
14 source, that'll be interesting, and I think
15 will have a significant impact maybe. Maybe.
16 It has an impact with respect to the longevity
17 of the source and remediation talk, but maybe
18 not necessarily on the high, middle and low
19 concentrations that you folks are really
20 looking for.

21 Echo what was said earlier about the
22 bulk density issue. It looks like there was
23 an error early on that was carried through.
24 It could be a nomenclature issue, but going
25 back to that original article and tracing it

1 through the documents, I think there's a, the
2 retardation factor in the model would be
3 modified by about 25 percent probably, just a
4 ballpark, back-of-the-envelope kind of
5 calculation.

6 Source issues we've talked about
7 transducers. Thank you for the opportunity to
8 participate in this.

9 **DR. HILL:** Can I say three words?

10 **DR. CLARK:** Sure.

11 **DR. HILL:** Two significant digits.

12 **DR. CLARK:** Words to live by.

13 I'd really like to thank all the panel
14 for your participation and your outstanding
15 insights. It's been a pleasure to work with
16 all of you. I'd certainly like to thank the
17 audience, too. We had some very good input
18 from a lot of the people who've been here and
19 observers, Dr. Aral. We certainly appreciate
20 the ATSDR staff and Liz, for all your help.
21 So it's made it possible to do this.

22 Morris, would you like to say a word
23 or two?

24 **MR. MASLIA:** Are you giving your
25 recommendations?

1 **DR. CLARK:** Well, I can. I didn't know if I
2 was allowed to do that as a panel member.

3 **MR. MASLIA:** Yes, definitely.

4 **DR. CLARK:** Very few. I thought everybody
5 did an outstanding job in recommendations, and
6 I support all that was said. The only things
7 that I thought were worth maybe re-emphasizing
8 for the fact that it seems to me that the
9 epidemiological study should probably go
10 beyond just child [and -ed.] in utero studies.
11 ~~That~~ [and -ed.] there's significant exposure
12 to adults and that's just almost totally
13 unknown.

14 And some of the levels that adults
15 have been exposed to are almost unbelievable.
16 I was looking at some of the vinyl chloride
17 levels that were pumped from one of the wells
18 in there, and when I was working on this sort
19 of thing with EPA, this would have been
20 frightening stuff. So I think that's
21 something that probably needs to be explored.

22 I still think that some of the
23 degradation byproducts issues have not been
24 explored thoroughly and should be. I think
25 ~~it's,~~ like the degradation rate [rates -ed.]

1 shown in the manual are a lot slower than
2 would be of concern in [-ed.] [- ed.] in a
3 distribution system, but it depends on where
4 you start from.

5 And I think it's something we were
6 always concerned with in our studies is just
7 how fast did some of these compounds degrade
8 the vinyl chloride in it. What would the
9 implications for that be? It wouldn't take,
10 ~~wouldn't be~~ [-ed.] very much vinyl chloride to
11 really have an impact on the outcomes in an
12 epidemiological study.

13 Another thing I wanted to mention was
14 the fact that I think you've missed an
15 opportunity to look at some direct exposure
16 data in terms of CHMs [THMs]. I know I gave
17 up on that earlier because I know Dave and ^
18 looked at it, and they didn't have the GC
19 traces so they sort of pushed it aside. But
20 looking at some of what I've seen, it seems to
21 me that's an opportunity to actually look at
22 direct exposure and transport in the
23 distribution system. I would encourage you to
24 go back and look at that very carefully and
25 see if there isn't some way to reconstruct

1 that. And I certainly would help you with
2 some of my contacts at EPA when you get into
3 some of the analytical chemistry issues. So
4 with that I'll conclude and thank everybody.

5 And Morris, you want to make a few
6 comments?

7 **MR. MASLIA:** I wanted to thank all the
8 people who participated in the panel. It's
9 obvious even the preliminary work is a large
10 volume of information for you to digest in the
11 short period that we gave you and then provide
12 us with feedback that we can implement and use
13 to carry the project forward to a successful
14 completion, so thank you very much for your
15 time and effort.

16 I also wanted to thank Bob Clark for
17 stepping in at the last minute and chairing
18 and guiding the panel, which he was not
19 expecting to do just a couple of days ago. So
20 that was a benefit to us. And I do agree. I
21 think was it Lenny that made the suggestion
22 and actually I was going to bring it up, but
23 since you said it, it's good is to reconvene
24 perhaps a smaller group as we get to different
25 aspects or phases, and sort of looking over

1 our shoulder and critiquing those aspects
2 rather than waiting a whole long time and
3 bringing a larger group together. And I think
4 that probably will provide us with much more
5 valuable input in a shorter time period. So I
6 thank you for bringing that up. It's a very
7 worthwhile suggestion.

8 And to answer Dr. Ross' question about
9 what happens is we will put a draft report
10 together similar to the one that we did. We
11 tried to, I think actually this panel was much
12 more succinct in their final recommendations
13 than the first panel, which is easier for us
14 to, and then we tried to implement it to the
15 best of our ability both in technically as
16 well as time and effort and money.

17 But again going back to Lenny's
18 suggestion I think if we do have smaller
19 groups of technical experts looking over every
20 so often that's easier to make sure we don't
21 miss anything or overlooking something that's
22 important. So thank you to everybody, and
23 thank you to all the administrative staff for
24 assisting us and thank you to our technical
25 staff who have spent at least the last months

1 just administratively putting the panel
2 together with all the material.

3 **DR. BOVE:** I want to thank all of you. I
4 think this has been very valuable to the
5 epidemiologists, both myself, Perri and I
6 think the epidemiologists on the panel learned
7 quite a bit today. So thank you very much. I
8 think your input was great and I think will
9 help the study immensely.

10 **DR. HILL:** Thank you.

11 **DR. CLARK:** With that the bus from the hotel
12 comes at 3:30, doesn't it?

13 (Whereupon, the meeting was adjourned at
14 3:12 p.m.)
15
16

1

CERTIFICATE OF COURT REPORTER**STATE OF GEORGIA****COUNTY OF FULTON**

I, Steven Ray Green, Certified Merit Court Reporter, do hereby certify that I reported the above and foregoing on the day of April 30, 2009; and it is a true and accurate transcript of the testimony captioned herein.

I further certify that I am neither kin nor counsel to any of the parties herein, nor have any interest in the cause named herein.

WITNESS my hand and official seal this the 19th day of July, 2009.

Steven Ray Green, CCR
STEVEN RAY GREEN, CCR, CVR-CM, PNSC

CERTIFIED MERIT COURT REPORTER**CERTIFICATE NUMBER: A-2102**

2

EXHIBIT 11

Expert Report

Prof. Mustafa M. Aral

Date: 10/23/2024

Prepared by,



Prof. Mustafa M. Aral, GA-PE 15254

Consultant, Environmental Modeling and Health Risk Analysis

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1. Background and Qualifications

I am a Professor Emeritus from the School of Civil and Environmental Engineering, Georgia Institute of Technology, Atlanta Georgia USA and an independent consultant residing in 270 17th St NW, Unit 809, Atlanta, Georgia USA. I hold a Ph.D. degree in Environmental Water Resources Management and Modeling (1971) and a master's degree in water resources engineering from the School of Civil and Environmental Engineering (1969), Georgia Institute of Technology. I have a bachelor's degree in civil engineering (1967) from the Middle East Technical University, Ankara, Turkey. I am a Professional Engineer registered in the State of Georgia (PE-15254).

I joined the Georgia Institute of Technology faculty in 1978 where I served until 2018 as Professor and the Director of Multimedia Environmental Simulations Laboratory (MESL), a research center established in 1993. In 2018 I was appointed as Professor Emeritus at Georgia Institute of Technology. During my career I have published over 100 technical publications in peer reviewed journals, five books, ten book chapters, and numerous conference papers and technical reports. I served as the Chair of several International Conferences. Among these the most noteworthy activities are the NATO Advanced Study Institute that I organized in Antalya, Türkiye in 1995; the Environmental Exposure and Health Conference held in Atlanta, GA, USA in 2005 which I co-organized; and I was the Technical Chair of the ASCE/EWRI IPWE 2013 International Conference held in Izmir, Türkiye in January 7-9, 2013. I am the Past-President of the American Institute of Hydrology (AIH), and a Fellow of the American Society of Civil Engineers (ASCE), a professional organization that represents over 190,000 civil and environmental engineers in the USA. During 2009 I established the International Journal on "Water Quality, Exposure and Health" published by Springer Publishers. I was the Editor-in-Chief of this journal from 2009 to 2014. I am also on the Editorial Board of several technical journals and serve as a consultant and reviewer on European Framework programs.

During my career I received twenty-eight honor citations from scientific organizations. Among these the most noteworthy national (USA) and international recognitions are American Society of Civil Engineers (ASCE), Cuming Medal (2000); two times the recipient of American Academy of Environmental Engineers Best Environmental Health Research Award (2003 and 2015); Centers for Disease Control and Prevention (CDC) Excellence in Applied Environmental Health Research (2006); and ASCE-Environmental Water Resources Institute (EWRI) James R. Croes Medal (2011). Among these, the Grand Prize Award received in Environmental Engineering in Research category given by the American Academy of Environmental Engineers (AAEE, 2015) is particularly important to this case since it is based on the quality and substance of the research work done in the Camp Lejeune water modeling historical reconstruction project.

My expertise includes the development and application of mathematical modeling techniques to environmental and engineered systems to evaluate the origins and fate and transport of contaminants in natural and engineered environments. I have more than 50 years of relevant professional experience evaluating the timing of chemical releases, developing enviro-geochemical models in multimedia environments and conducting environmental forensic analysis in the context of mathematical modeling techniques, regulations and guidance or directives established by the relevant agencies. My Curriculum Vitae and a list of my publications are provided in Exhibit A of this report. I have not testified by deposition or at trial in the last four years.

2. Assignment

In August 2022, I was retained by Bell Legal Group on behalf of the *Camp Lejeune Water Litigation* Plaintiffs as an environmental modeling expert to testify regarding the ATSDR Environmental Water Modeling Study conducted at U.S. Marine Corps Base Camp Lejeune, North Carolina and such other opinions as may become relevant. I am being compensated \$600 per hour for my work on this matter.

As an environmental modeling expert, I was tasked with the following:

- Provide a high-level explanation of the ATSDR's historical reconstruction process for both the Tarawa Terrace and Hadnot Point-Holcomb Boulevard study sites, including my involvement in it.
- Provide an explanation of the reported concentrations of contaminants in finished water at Camp Lejeune from 1953 to 1987.
- Provide an explanation of the calibration, sensitivity analysis, uncertainty analysis, and validation techniques used in the ATSDR study of the Camp Lejeune site.
- Summarize the conclusions and opinions included in the published ATSDR Reports.
- Provide additional opinions beyond those already included in the ATSDR published works.

Around the year 2000, the Multimedia Environmental Simulations Laboratory (MESL), a research center at the School of Civil and Environmental Engineering, Georgia Institute of Technology entered into a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR)/Centers for Disease Control and Prevention (CDC) to provide technical support to ATSDR in all aspects of the Camp Lejeune study for all three study areas on an as-needed basis. As the MESL research center director, I oversaw all aspects of this cooperative agreement at the Georgia Institute of Technology side. The cooperative agreement was extended to three five-year periods and ended in 2015. My involvement in the ATSDR Historical Reconstruction Project was supported by my graduate students at the MESL research center. There was no other faculty member involvement in the cooperative agreement from the Georgia Tech side. Over the 15-year period from 2000 to 2015, I and my team members worked with the other team members of the Exposure Dose Reconstruction Program (EDRP) at ATSDR to perform an analysis of the Tarawa Terrace, Holcomb Boulevard, and Hadnot Point study sites of the U.S. Marine Corps Base Camp Lejeune.

To conduct my evaluation and render my expert opinions, I relied on my education, research, professional experience, and the information base I accumulated over the years while working on the ATSDR Camp Lejeune study and other matters. The documents and information that I considered are of the type that can be reasonably relied upon to support my opinions and are regularly relied upon by practitioners in my field. The materials that I reviewed include, but are not limited to, published technical literature, reports, historic data sources, correspondence and meetings with state and regulatory agencies, participation in workshops and review of documents provided by independent experts at these gatherings. The list of documents I have considered and/or relied upon to render my opinions is provided in Section 8 of this Expert Report.

Opinions presented in this report were reached by applying accepted methods and information in the fields of hydrogeology, geochemistry, environmental sciences and mathematical and stochastic computational modeling. The opinions expressed in this report are my own and are based on my education, training, and experience, as well as the documents, public information, diagrams, data, and

facts that were available to me at the time of writing. I hold these opinions to a reasonable degree of scientific and engineering certainty. I reserve the right to supplement and/or amend my opinions on this matter as necessary as additional documents, depositions or information are made available to me.

3. Introduction

U.S. Marine Corps Base Camp Lejeune, North Carolina was established in 1942. Groundwater is the sole source of water supply for Camp Lejeune. In the 1980s, Navy water testing at Camp Lejeune detected Volatile Organic Compounds (VOCs) in some water-distribution systems at the base. In 1982 and 1983, continued testing identified two VOCs—trichloroethylene (TCE), a metal degreaser, and tetrachloroethylene (PCE), a dry-cleaning solvent—in two water-distribution systems that served base housing areas, Hadnot Point and Tarawa Terrace. In 1984 and 1985 a Navy environmental program identified VOCs, such as TCE and PCE, in some of the individual wells serving the Hadnot Point and Tarawa Terrace water-distribution systems. Ten wells were subsequently removed from service.

The extent of subsurface contamination, its impact on groundwater, and the associated potential health risks of water contamination prompted the U.S. Environmental Protection Agency (USEPA or EPA) to place Camp Lejeune on the EPA CERCLA (Superfund) National Priority List for cleanup (remediation) in 1989, leading to Remedial Investigations / Feasibility Studies and ultimately to Records of Decisions (RODs) for remedial action (EPA, 1993 for Tarawa Terrace / ABC One Hour Cleaners; EPA, 1993 for Hadnot Point Industrial Area; and EPA 1994 for Hadnot Point Landfill).

Hadnot Point was the original water-distribution system, serving the entire base with finished water beginning in the early 1940s. The Hadnot Point water treatment plant (WTP) was constructed and began operations in the 1941–1942 timeframe. The Tarawa Terrace WTP began delivering finished water during 1952, and the Holcomb Boulevard WTP began delivering finished water during June 1972, Figure 1. The Tarawa Terrace WTP was closed in March 1987 due to contamination, leaving Hadnot Point WTP to supply water to the Hadnot Point area, and the Holcomb Boulevard WTP to supply water to the Holcomb Boulevard and Tarawa Terrace base housing areas. The Holcomb Boulevard water-distribution system is connected to the Hadnot Point water-distribution system at the Marston Pavilion valve and at booster pump 742. While booster pump 742 was removed during 2007, the two systems can still be interconnected by opening a valve at the same location based on water supply demand. For operational reasons, the two water-distribution systems were occasionally connected—exceptions being some connections that occurred during late spring and summer months of 1972–1986 and a continuous 8-day period of 28 January to 4 February 1985 (ATSDR, 2007a). Tarawa Terrace, Hadnot Point, and Holcomb Boulevard water-distribution systems historically supplied finished water to most family housing units, enlisted personnel barracks, workplaces, and other facilities at the base (ATSDR, 2013a).

Department of Defense (DOD) and North Carolina officials concluded that on and off-base sources were likely to have caused contamination (GAO, 2007). With respect to Tarawa Terrace, PCE contamination of finished water occurred because PCE, a common dry-cleaning solvent, leaked into groundwater that supplied the Tarawa Terrace drinking water system from a dry-cleaner (One-Hour ABC Cleaners) located outside the Camp Lejeune base. In 1987, the military base shut down the Tarawa Terrace water treatment plant because of PCE contamination of the drinking water (ATSDR, 2007a, e). The Hadnot Point water system, which provided water to both the Hadnot Point and Holcomb Boulevard service areas, was contaminated with TCE, PCE and refined petroleum products because of waste disposed of at a landfill and activities within an industrial area, including vehicle service and maintenance, warehousing, auto body painting and maintenance, and heavy equipment maintenance. Active underground storage tanks (USTs) and solvent storage areas were in the Hadnot Point Industrial Area (HPIA), where substantial volumes of liquid hydrocarbon fuels were lost due to leakage to the subsurface.

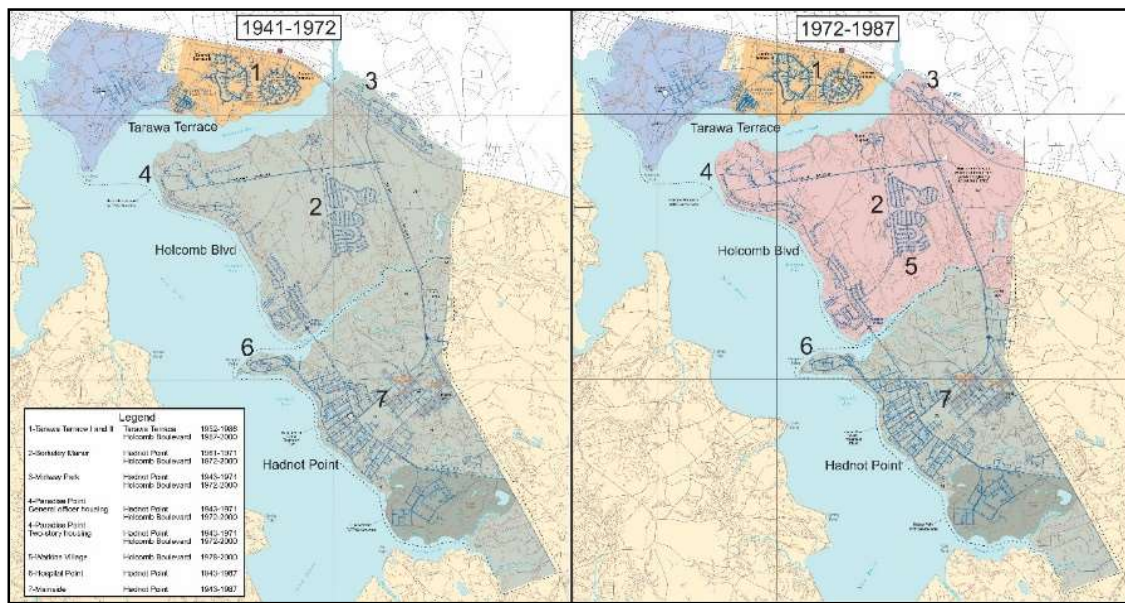


Figure 1: General map of U.S. Marine Corps Base Camp Lejeune in North Carolina (ATSDR, 2007a; ATSDR, 2013a)

The Agency for Toxic Substances and Disease Registry (ATSDR), an agency of the U.S. Department of Health and Human Services, conducted several studies to help Marines, civilians, health officials, and other interested parties understand more about the drinking water contamination at Camp Lejeune and whether it affected the health of persons living or working on the base during the period 1953-1987. The first was an epidemiological study to evaluate whether in-utero and infant exposures to volatile organic compounds in contaminated drinking water at Camp Lejeune were associated with specific birth defects and childhood cancers. The study included births occurring during the period 1968-1985 to women who were pregnant while residing in family housing at the base. Later, the epidemiologic studies were extended to cover other health effects as well. These epidemiologic studies and their findings are not within my expertise area.

Historical exposure data needed for the epidemiological case-control study were limited. To obtain estimates of historical exposure, ATSDR used water modeling techniques and the process of historical reconstruction to determine the extent of VOC-contamination at the site, to quantify historical concentrations of contaminants in the finished water, and to compute the level and duration of human exposure to the contaminated drinking water. The findings of the study were grouped in two series of reports: (a) Tarawa Terrace and Vicinity Study Reports (ATSDR-a/b/c/d/e/f/g/h/i, 2007); (b) Hadnot Point and Vicinity Study Reports (ATSDR-a/b/c/d/e/f/g/h/i/j/k/l, 2013), Figure 2. From this point forward these references will be quoted as (ATSDR, 2007) and (ATSDR, 2013) in bulk. From the context of the discussion, it will be clear which chapter is under consideration. In some references specific chapter references will also be given when necessary.

The ATSDR water modeling team was guided by an external ATSDR Expert Panel, whose members contributed significantly to the quality of the modeling effort. The members of the ATSDR Expert Panels are well-known and respected scientists in the field; their names are listed in the Expert Panel reports

(Maslia, 2005; Maslia, 2009). These are also available on the ATSDR website (<https://www.atsdr.cdc.gov/sites/lejeune/expert-panels.html>).

Water modeling enabled ATSDR to estimate monthly mean contaminant levels in drinking water within the Tarawa Terrace, Hadnot Point and Holcomb Boulevard water treatment plant service areas for the period 1942-2008. This work in turn helped ATSDR epidemiologists determine if populations were exposed to contaminants, at what levels and when they were exposed during the period 1953-1987 (ATSDR, 2007; ATSDR, 2013).

Table A2. Summary of ATSDR chapter reports on topical subjects of water-modeling analyses and the historical reconstruction process, **Tarawa Terrace and vicinity**, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[ATSDR, Agency for Toxic Substances and Disease Registry; VOC, volatile organic compound; PCE, tetrachloroethylene; WTP, water treatment plant]

Report chapter	Author(s)	Chapter title and reference citation	Topical summary
A	Maslia ML, Sautner JB, Faye RE, Suárez-Soto RJ, Aral MM, Grayman WM, Jang W, Wang J, Bove FJ, Ruckart PZ, Valenzuela C, Green JW Jr, and Krueger AL	Summary of Findings; Maslia et al. 2007 (this report)	Summary of detailed technical findings (found in Chapters B–K) focusing on the historical reconstruction analysis and present-day conditions of groundwater flow, contaminant fate and transport, and distribution of drinking water
B	Faye RE	Geohydrologic Framework of the Castle Hayne Aquifer System; Faye (In press 2007a)	Analyses of well and geohydrologic data used to develop the geohydrologic framework of the Castle Hayne aquifer system at Tarawa Terrace and vicinity
C	Faye RE, and Valenzuela C	Simulation of Groundwater Flow; Faye and Valenzuela (In press 2007)	Analyses of groundwater flow including developing a predevelopment (steady state) and transient groundwater-flow model
D	Lawrence SJ	Properties of Degradation Pathways of Common Organic Compounds in Groundwater; Lawrence (In press 2007)	Describes and summarizes the properties, degradation pathways, and degradation by-products of VOCs (non-trihalomethane) commonly detected in groundwater
E	Faye RE, and Green JW Jr	Occurrence of Contaminants in Groundwater; Faye and Green (In press 2007)	Describes the occurrence and distribution of PCE and related contaminants within the Tarawa Terrace aquifer and the Upper Castle Hayne aquifer system at and in the vicinity of the Tarawa Terrace housing area
F	Faye RE	Simulation of the Fate and Transport of Tetrachloroethylene (PCE); Faye (In press 2007b)	Historical reconstruction of the fate and transport of PCE in groundwater from the vicinity of ABC One-Hour Cleaners to individual water-supply wells and the Tarawa Terrace WTP
G	Jang W, and Aral MM	Simulation of Three-Dimensional Multi-species, Multiphase Mass Transport of Tetrachloroethylene (PCE) and Associated Degradation By-Products; Jang and Aral (In press 2007)	Descriptions about the development and application of a model capable of simulating three-dimensional, multispecies, and multiphase transport of PCE and associated degradation by-products
H	Wang J, and Aral MM	Effect of Groundwater Pumping Schedule Variation on Arrival of Tetrachloroethylene (PCE) at Water-Supply Wells and the Water Treatment Plant; Wang and Aral (In press 2007)	Analysis of the effect of groundwater pumping schedule variation on the arrival of PCE at water-supply wells and the Tarawa Terrace WTP
I	Maslia ML, Suárez-Soto RJ, Wang J, Aral MM, Sautner JB, and Valenzuela C	Parameter Sensitivity, Uncertainty, and Variability Associated with Model Simulations of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Drinking Water; Maslia et al. (In press 2007b)	Assessment of parameter sensitivity, uncertainty, and variability associated with model simulations of groundwater flow, contaminant fate and transport, and the distribution of drinking water
J	Sautner JB, Valenzuela C, Maslia ML, and Grayman WM	Field Tests, Data Analyses, and Simulation of the Distribution of Drinking Water; Sautner et al. (In press 2007)	Field tests, data analyses, and simulation of the distribution of drinking water at Tarawa Terrace and vicinity
K	Maslia ML, Sautner JB, Faye RE, Suárez-Soto RJ, Aral MM, Grayman WM, Jang W, Wang J, Bove FJ, Ruckart PZ, Valenzuela C, Green JW Jr, and Krueger AL	Supplemental Information; Maslia et al. (In press 2007a)	Additional information such as synoptic maps showing groundwater levels, directions of groundwater flow, and the distribution of PCE based on simulation; a complete list of references; and other ancillary information and data that were used as the basis of this study

Table A1. Summary of ATSDR chapter reports and supplemental information sections, **Hadnot Point–Holcomb Boulevard** study area, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[ATSDR, Agency for Toxic Substances and Disease Registry; PCE, tetrachloroethylene; TCE, trichloroethylene; LNAPL, light nonaqueous phase liquid; IRP, Installation Restoration Program; WTP, water treatment plant; RCRA, Resource Conservation and Recovery Act of 1976; BTEX, benzene, toluene, ethylbenzene, and xylenes]

¹ Report chapter	² Authors and reference	Chapter or supplemental information section title	Topical summary
A	Maslia ML, Suárez-Soto RJ, Sautner JB, Anderson BA, Jones LE, Faye RE, Aral MM, Guan J, Jang W, Telci IT, Grayman WM, Bove FJ, Ruckart PZ, and Moore SM (Maslia et al. 2013)	Summary and Findings	Summary of detailed technical findings (found in Supplements 1–8 and Chapters B–D) focusing on historical reconstruction analyses and present-day conditions of groundwater flow, contaminant fate and transport, and distribution of finished water
A–Supplement 1	Sautner JB, Anderson BA, Suárez-Soto RJ, and Maslia ML (Sautner et al. 2013a)	Descriptions and Characterizations of Data Pertinent to Water-Supply Well Capacities, Histories, and Operations	A comprehensive listing and analysis of historical through June 2008 water-supply wells, their capacities, operational histories, and supply of finished water
A–Supplement 2	Telci IT, Sautner JB, Suárez-Soto RJ, Anderson BA, Maslia ML, and Aral MM (Telci et al. 2013)	Development and Application of a Methodology to Characterize Present-Day and Historical Water-Supply Well Operations	Describes a method that uses recorded data, other ancillary information, and a training algorithm to synthesize monthly water-supply well operations, 1942–2008
A–Supplement 3	Faye RE, Jones LE, and Suárez-Soto, RJ (Faye et al. 2013)	Descriptions and Characterizations of Water-Level Data and Groundwater Flow for the Brewster Boulevard and Castle Hayne Aquifer Systems and the Tarawa Terrace Aquifer	Describes water-level data for the Brewster Boulevard and Castle Hayne aquifer systems and Tarawa Terrace aquifer, analyzes water-level trends, and presents a potentiometric surface map derived from the water-level data and resulting groundwater-flow directions
A–Supplement 4	Suárez-Soto RJ, Jones LE, and Maslia ML (Suárez-Soto et al. 2013)	Simulation of Three-Dimensional Groundwater Flow	Describes the application and calibration of a three-dimensional groundwater-flow model used to simulate steady-state (predevelopment) and transient groundwater flow for the period 1942–2008

Table A1. Summary of ATSDR chapter reports and supplemental information sections, **Hadnot Point–Holcomb Boulevard study area**, U.S. Marine Corps Base Camp Lejeune, North Carolina.—Continued

[ATSDR, Agency for Toxic Substances and Disease Registry; PCE, tetrachloroethylene; TCE, trichloroethylene; LNAPL, light nonaqueous phase liquid; IRP, Installation Restoration Program; WTP, water treatment plant; RCRA, Resource Conservation and Recovery Act of 1976; BTEX, benzene, toluene, ethylbenzene, and xylenes]

¹ Report chapter	² Authors and reference	Chapter or supplemental information section title	Topical summary
A–Supplement 5	Guan J, Anderson BA, Aral MM, and Maslia ML (Guan et al. 2013)	Theory, Development, and Application of Linear Control Model Methodology to Reconstruct Historical Contaminant Concentrations at Selected Water-Supply Wells	Describes the model developed using linear control theory that is capable of reconstructing historical contaminant concentrations using limited geohydrologic and aquifer information; model is applied to water-supply well HP-651 in the Hadnot Point landfill area
A–Supplement 6	Jones LE, Suárez-Soto RJ, Anderson BA, and Maslia ML (Jones et al. 2013)	Source Characterization and Simulation of Fate and Transport of Selected Volatile Organic Compounds in the Vicinities of the Hadnot Point Industrial Area and Landfill	Describes the application and calibration of three-dimensional models of contaminant fate and transport used to reconstruct historical groundwater concentrations of PCE, TCE, and benzene in the vicinity of the Hadnot Point Industrial Area and landfill area for the period 1942–2008
A–Supplement 7	Jang W, Anderson BA, Suárez-Soto RJ, Aral MM, and Maslia ML (Jang et al. 2013)	Source Characterization and Simulation of the Migration of Light Nonaqueous Phase Liquids (LNAPLs) in the Vicinity of the Hadnot Point Industrial Area	Describes the estimation of LNAPL volume in the subsurface and the development and application of a three-dimensional contaminant fate and transport model used to simulate LNAPL and dissolved-phase benzene in the vicinity of the Hadnot Point Industrial Area for the period 1942–2008
A–Supplement 8	Sautner JB, Grayman WM, Telci IT, Maslia ML, and Aral MM (Sautner et al. 2013b)	Field Tests, Data Analyses, and Simulation of the Distribution of Drinking Water with Emphasis on Intermittent Transfers of Drinking Water Between the Hadnot Point and Holcomb Boulevard Water-Distribution Systems	Describes field tests conducted and data gathered during 2004 for the Hadnot Point and Holcomb Boulevard water-distribution systems and simulations of the intermittent supply of Hadnot Point finished water to the Holcomb Boulevard water-distribution system during the period 1972–1985
B	Faye RE (Faye 2012)	Geohydrologic Framework of the Brewster Boulevard and Castle Hayne Aquifer Systems and the Tarawa Terrace Aquifer	Describes detailed analyses of well, borehole, and geophysical data used to develop the geohydrologic framework of the Brewster Boulevard and Castle Hayne aquifer systems and the Tarawa Terrace aquifer; hydraulic characteristics for several geohydrologic units are tabulated; hydraulic conductivity maps are included
C	Faye RE, Anderson BA, Suárez-Soto RJ, and Sautner JB (Faye et al. 2010)	Occurrence of Selected Contaminants in Groundwater at Installation Restoration Program Sites	Detailed accounting of the occurrences of contaminants of concern and their related degradation products in groundwater at IRP sites within the service areas of the Hadnot Point and Holcomb Boulevard WTPs
D	Faye RE, Suárez-Soto RJ, and Maslia ML (Faye et al. 2012)	Occurrence of Selected Contaminants in Groundwater at Above-Ground and Underground Storage Tank Sites	Summaries of RCRA investigations with detailed accounting of the occurrence and distribution of BTEX components, such as benzene, within the soil and groundwater at selected RCRA sites within the service areas of the Hadnot Point and Holcomb Boulevard WTPs

¹ Letter designation of chapters for series, “Analyses and Historical Reconstruction of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Drinking Water Within the Service Areas of the Hadnot Point and Holcomb Boulevard Water Treatment Plants and Vicinities, U.S. Marine Corps Base Camp Lejeune, North Carolina;” supplemental information sections are part of Chapter A, provided on CD–ROM

² See References section for complete reference citation

Figure 2. Summary of ATSDR reports on Camp Lejeune site (ATSDR, 2007; ATSDR, 2013)

Over the past years several agencies and organizations have reviewed ATSDR’s studies and the outcomes that were reported by ATSDR (ATSDR, 2007; ATSDR, 2013). One review was provided by the National Academy of Sciences - National Research Council (NRC, 2009a), which was sponsored by the U.S. Department of the Navy. My contemporaneous response to this review was submitted to ATSDR on June 27, 2009, which became an internal document for ATSDR. The contents of this document is set forth in Section 7 of this report.

The government accountability office also reviewed the ATSDR studies and the NRC review. In their conclusions the following point was referenced (GAO, 2007).

- Members of the expert panel that the National Academy of Sciences convened generally agreed that many parameters of ATSDR's current study are appropriate, including the study population, the exposure time frame, and the selected health effects (GAO, 2007).

At the time (GAO, 2007), ATSDR's epidemiology studies were ongoing. Since then, these studies have been concluded. The findings of these studies are given in ATSDR epidemiology reports which are beyond my expertise area.

ATSDR study of the Camp Lejeune site also went through the critical review of an Expert Panel organized by another branch of CDC outside the EDRP/ATSDR group working on the study. The Tarawa Terrace ATSDR study underwent extensive external peer review by an expert panel of leading scientists as documented in Maslia et al. 2009 (Appendix B, P. 46, (<https://www.atsdr.cdc.gov/sites/lejeune/expert-panels.html>)), as was the Hadnot Point and Holcomb Boulevard study (Maslia et al., 2009; Maslia et al., 2013, P. A98). The scientists on these panels have international reputations as leaders in this field. EDRP/ATSDR program took several steps to respond and adapt to the recommendations of the Expert Panel throughout the study.

The rigorous peer review done by the ATSDR expert panels was followed with another level of peer review in the published journal articles, and a major national award by American Academy of Environmental Engineers (AAEE, 2015) which recognized the quality of ATSDR work product completed at the Camp Lejeune site. This further substantiates the general acceptance of ATSDR's modeling and reconstruction methodology in the pertinent scientific community.

As stated above, an additional level of scrutiny of ATSDR's modeling work came from publication of the Tarawa Terrace and the Hadnot Point/Holcomb studies in two separate peer-reviewed articles published in high quality Q1 (top quartile) journals as given below:

- Maslia, M.L. et al. 2009(b). "Reconstructing Historical Exposures to Volatile Organic Compound-Contaminated Drinking Water at a U.S. Military Base." *Water Quality, Exposure, and Health*. 2009, 1, 49-68.
- Maslia, M.L. et al., 2016. "Reconstructing Historical VOC Concentrations in Drinking Water for Epidemiological Studies at a U.S. Military Base: Summary of Results." *Water*. 2016, 8, 449, 1-23.

This is the summary background of the water modeling studies that have been conducted at the Camp Lejeune site by ATSDR.

4. Principles of Water Modeling and Application at Camp Lejeune

4.1 Water Modeling

In the absence of historical and continuous water quality sampling data, environmental scientists commonly rely on modeling to both predict future contaminant levels and to reconstruct historical contamination at a site. The use of modeling for historical reconstruction is an accepted methodology to predict past exposure or contamination levels, as demonstrated both in the scientific literature (Reif et al. 2003; Maslia et al., 2005; Sahmel et al., 2010) and in site specific studies such as Jacksonville, FL Naval Air Station (USGS, 2003); Tucson International Airport / Hughes Aircraft Facility (EPA, 1988); Oak Ridge National Lab (ATSDR/ChemRisk, 2000); Hanford Site (PNL, 1991); and Toms River / Dover Township (ATSDR, 2000). In its study of the Camp Lejeune site, the ATSDR created four interlinked models using scientifically valid, state of the art modeling tools that are based on fundamental groundwater flow and contaminant migration principles that are widely accepted and routinely utilized in practice for predicting contaminant movement (e.g., during natural spread or enhanced cleanup scenarios) and/or for historical reconstruction efforts such as at Camp Lejeune and other sites (Sahmel et al., 2010; Anderson et al., 2015; Bedient et al., 1999).

My opinions, within a reasonable degree of scientific and engineering certainty, on modeling techniques, their principles, and their application to the Camp Lejeune site include the following:

- Water Modeling (environmental modeling) is a science-based approach to describe and develop domain-based knowledge on contaminant migration within and across domains to understand environmental responses to natural or human perturbations.
- A scientific model (in this case Water Modeling) can be defined as an abstraction of some real system - an abstraction that can be used for decision making and management purposes. Development of a scientific model may include physical, mathematical and statistical procedures. In ATSDR studies of the Camp Lejeune site both mathematical and statistical procedures were used.
- Since all models are an abstraction of the real system, they need to be presented and analyzed in a computational or physical environment which may include an analysis of calibration, validation (section 6.7), uncertainty and variability before they are used in simulation to predict future or past conditions at a site. In ATSDR studies of the Camp Lejeune site all aspects of these computational procedures were successfully employed using computational methods.
- As such, Water Modeling is a reliable and widely accepted method of reconstructing historical contamination in natural and engineered environmental systems. Natural environmental systems may include surface, subsurface and air media; and engineered systems may include water distribution systems, constructed water ways and harbors, etc.
- Under all circumstances, trying to fit a physical system to an available off-the-shelf model approach should be avoided in water modeling. In all cases the best models that describe the system adequately should be used or developed when necessary (USEPA 2009, p. 31).
- The models and techniques used by the ATSDR for historical reconstruction, including fundamental equations, input parameters, parameter estimates, calibration, uncertainty and sensitivity analyses, were and remain reliable, scientifically valid and state of the art procedures that are consistent with standard practices used and are generally accepted in this field.
- The model results show finished water at U.S. Marine Corps Base Camp Lejeune was contaminated with varying levels of TCE, PCE, 1,2-tDCE, benzene and vinyl chloride from 1953 to 1987.

- The simulated monthly mean concentrations of TCE, PCE, 1,2-tDCE, benzene and vinyl chloride at Tarawa Terrace, Hadnot Point and Holcomb Boulevard included (tabulated or in figures) in ATSDR reports are reliable and represent, within a reasonable degree of scientific and engineering certainty, the contaminant levels in finished water at Camp Lejeune from 1953 to 1987.
- The analyses published in all ATSDR chapter reports (ATSDR, 2007; ATSDR, 2013) and supplemental information regarding Camp Lejeune (see Figure 2), including the conclusions and monthly concentration data, were all done applying proper scientific and engineering methodologies and remain to this day to be mathematically reliable, statistically accurate and correct.

4.2 Basis of Opinions

The basis of my opinions outlined in this expert report is my 50 years of work in this field and my fifteen years of Camp Lejeune related work providing technical assistance to ATSDR under a cooperative agreement established between the Centers for Disease Control and Prevention (CDC) and Georgia Tech and my fifty years of expertise and knowledge in this area of research as an educator, researcher and engineer. I have reviewed and relied on published literature, reports, historic data sources, correspondence and participation in meetings with state and regulatory agencies, participation in workshops and the review of documents provided by independent experts at these gatherings, as documented in this report (Section 8).

My opinions are based on my understanding of sound science, engineering, mathematical and statistical formulations that follow the current technology, scientific and engineering methodology that is used in archival literature.

5. Models used in ATSDR Study at Camp Lejeune

The Agency for Toxic Substances and Disease Registry (ATSDR), an agency of the U.S. Department of Health and Human Services, was requested to conduct an epidemiological study to evaluate health issues at U.S. Marine Corps Base Camp Lejeune, North Carolina. The scientific protocol on these studies received approval from the Centers for Disease Control and Prevention Institutional Review Board and the U.S. Office of Management and Budget.

Historical water contamination data needed for the epidemiological study were limited. To obtain estimates of historical exposure, ATSDR used water modeling techniques and the process of historical reconstruction of contamination levels at the base. These methods are used to quantify concentrations of contaminants in finished water at the base and to compute the level and duration of human exposure to contaminated drinking water.

Owing to the complexity, uniqueness, and the number of topical subjects included in the historical reconstruction process of each study area, several reports were prepared that provide comprehensive descriptions of information, data, and methods used to conduct historical and present-day analyses at both Tarawa Terrace (TT) and Hadnot Point–Holcomb Boulevard (HP-HB), Figure 2.

These reports provide comprehensive descriptions of modeling results used to reconstruct historical contaminant concentration levels and timing of contaminant movement at Camp Lejeune. The study represents the efforts of about 20 experts whose combined expertise from a variety of scientific and engineering disciplines spans every relevant area and specialty involved in water modeling. This body of work forms the foundation for many of the opinions I have included in this report. In this report, I am also offering a more in-depth level of detail on some of those opinions when necessary. To allow the reader the easiest access to this extensive body of work as it relates to this expert report, some of the figures and tables were copied/reproduced from these reports and included here with proper references to the source of the information.

5.1 Modeling Tools

The methods and approaches used to complete the historical reconstruction process for the Tarawa Terrace, Hadnot Point and Holcomb Boulevard study areas, the ATSDR study included the following steps of analysis:

- i. Information discovery, field study, data mining and data analysis.
- ii. Three dimensional, steady-state (predevelopment) and transient groundwater-flow modeling application using **MODFLOW**-2005. This study included a trial-and-error calibration of the model which also included the use of objective parameter estimation technique using **PEST-12**.
- iii. Determining historical water-supply well scheduling and operations using **TechWellOp** and **PSOps**, a sub-model developed by MESL, Ga Tech.
- iv. Three-dimensional dissolved phase groundwater fate and transport modeling of VOCs using **MT3DMS**-5.3.
- v. Estimating the volume of light nonaqueous phase liquid (LNAPL) released to the subsurface at the Hadnot Point Industrial Area using **TechNAPLVol**, a sub-model developed by MESL, Ga Tech.
- vi. LNAPL and dissolved phase fate and transport analysis using **TechFlowMP**, a sub-model developed by MESL, Ga Tech.

- vii. Reconstruction of water-supply well concentrations at the Hadnot Point landfill area using the linear control theory model (LCM) **TechControl**, a sub-model developed by MESL, Ga Tech.
- viii. Computation and analysis of flow-weighted average concentrations of VOCs assigned to finished water delivered by the water treatment plants using a volumetric mass balance analysis (simple mixing).
- ix. Extended period simulation of hydraulics and water quality in the water-distribution system using **EPANET 2**.
- x. Probabilistic analysis of intermittent connections (1972–1985) of the Hadnot Point and Holcomb Boulevard water-distribution systems using the **TechMarkovChain**, a sub-model developed by MESL, Ga Tech.
- xi. Calibration and sensitivity analysis of hydraulic and fate and transport models, and numerical-model parameters.
- xii. Uncertainty analysis of model simulations.
- xiii. The result of the historical reconstruction process included the estimation of monthly mean concentrations of selected VOCs in finished water distributed to Tarawa Terrace housing areas and vicinity, and for the Hadnot Point and Holcomb Boulevard study areas of Camp Lejeune served by the TTWTP, HPWTP and HBWTP.

The models and techniques used by the ATSDR to complete the historical reconstruction process for the Tarawa Terrace, Hadnot Point, and Holcomb Boulevard study areas were and remain reliable, state of the art and consistent with standard engineering practices used in the field of water modeling. The governing mathematical and statistical methods and models used in these applications are standard techniques that are used in technical literature and are well established (Anderson et al., 2015; Aral, 2010; Bedient et al., 1999, Rao, 1996).

Modeling tools (software) used for multiphase flow and multi-species transport in the subsurface and engineered systems at the site include the following public-domain applications developed by the US government agencies:

- The **MODFLOW**-2005.5 application, a three-dimensional finite-difference groundwater-flow model developed by the U.S. Geological Survey (USGS) that is used in groundwater modeling, (<https://igwmc.princeton.edu/modflow/>).
- **MT3DMS**, a public domain application developed by USGS. **MT3DMS** is a three-dimensional multi-species solute transport model used for solving advection, dispersion, and chemical reactions of contaminants in saturated groundwater flow systems. **MT3DMS** interfaces directly with the U.S. Geological Survey finite-difference groundwater flow model **MODFLOW** for the groundwater flow solution and supports the hydrologic and discretization features of **MODFLOW**. **MT3DMS** contains multiple transport solution techniques in one code, which can often be important, including for model calibration. (<https://pubs.usgs.gov/publication/70189204>).
- The **HSSM.5** application, a one-dimensional semi-analytical model developed by the U.S. Environmental Protection Agency to estimate volume of spills at contaminated sites. (<https://www.epa.gov/water-research/hydrocarbon-spill-screening-model-hssm>).
- Developed by USEPA, **EPANET** application is a software application that is used throughout the world to model water distribution systems. It was developed as a tool for understanding

the movement and fate of drinking water constituents within water distribution systems and can be used for many different types of applications in water distribution systems analysis. It can also be used to model contamination threats and evaluate resilience to security threats or natural disasters relevant to water distribution systems. (<https://www.epa.gov/water-research/epanet>).

The applications listed above are all in the main core of tools used in the ATSDR studies of the Camp Lejeune site. They are all accepted methodologies and software that were used in similar studies at other sites by government agencies and consulting firms.

In addition to the above listed standard applications used in the water modeling field, ATSDR needed to investigate in more detail some of the questions that were raised by the expert panel convened by ATSDR/CDC. For that purpose, MESL research program capabilities were used to supplement the main core applications described above.

These supportive (sub-model) applications used in the ATSDR study of the Camp Lejeune site include:

- The **TechFlowMP** application is a multiphase flow and multispecies contaminant transport model developed in MESL studies (Jang, W. and Aral, MM, 2005; Jang, W. and Aral, MM, 2007; ATSDR 2007h; Jang, W. and Aral, MM, 2008: a, b; Jang, W. and Aral, MM, 2011). In **TechFlowMP** model the coupled equations for flow of water, gas, and NAPL phases and transport of multispecies contaminants in saturated and unsaturated subsurface systems and heat energy transport were formulated and analyzed. To solve those equations, a three-dimensional finite element numerical model (software) was developed. The origin of these studies at MESL research program dates to 1997. **TechFlowMP** model has been verified using analytical solutions and experimental data that are published and available in the literature. To investigate the fate and transport of VOCs in the subsurface, the model was used in conducting numerical analysis on the following other topics in other MESL studies: (i) multiphase flow and contaminant transport in subsurface environments; (ii) biological transformations of contaminants in multiphase environments; (iii) in-situ air sparging analysis (IAS); and, (iv) thermally enhanced venting (TEV) that is used in contaminated groundwater treatment processes. In these numerical studies, the **TechFlowMP** model successfully simulated the migration of contaminants between phases and between the unsaturated/saturated zones of a subsurface system, the dynamic movements of gas phases in the unsaturated zone, and remedial processes under in-situ air sparging (IAS) and thermally induced remediation (TEV) studies of the MESL program.

This application was used to explore saturated and unsaturated zones and vapor phase contaminant distributions at the Camp Lejeune site. It also served the purpose of independent reconfirmation of the predictions of the calibrated multiphase subsurface models used by ATSDR at the Camp Lejeune site as described above (Figure 11). The ATSDR water modeling team first utilized the **MODFLOW** and **MT3DMS** codes in its groundwater simulations and analysis at the Camp Lejeune site. These two models are widely accepted public domain codes that have been tested and verified in other studies and are universally used in the modeling field for the analysis of groundwater flow and fate and transport of contaminants in subsurface systems (see above cited web sites). In addition to these studies, to enhance the understanding of conditions at the site, ATSDR extended its analysis. The ATSDR water modeling team applied the **TechFlowMP** software to understand and evaluate the unsaturated zone injection and migration conditions at

the site. **TechFlowMP** is a public domain code that can be accessed from the Georgia Tech website for individual use (<http://mesl.ce.gatech.edu/>, MESL 2017).

The **TechFlowMP** code has been tested and verified against other applications in the literature. The details of verification analysis developed for **TechFlowMP** model can be found in the following references (Jang, W. and Aral, MM, 2005; Jang, W. and Aral, MM, 2007; ATSDR 2007h; Jang, W. and Aral, MM, 2008: a, b; Jang, W. and Aral, MM, 2011). This list of peer reviewed publications provides detailed information on the verification of this model in subsurface application. The application of the **TechFlowMP** model to Camp Lejeune site and calibration, sensitivity and reliability analysis can be found in the references (ATSDR, 2007g; ATSDR, 2013a) and in, <http://mesl.ce.gatech.edu/PUBLICATIONS/Publications.html>).

- The **TechNAPLVol** sub-model: This is a spilled LNAPL volume estimation model which is based on the USEPA **HSSM.5** analysis mentioned above. In this case the USEPA **HSSM.5** procedures are extended to three-dimensional analysis and used to estimate the volume of spilled BTEX compounds at the Camp Lejeune site.

For the overall project, the area of interest was the entire Hadnot Point–Holcomb Boulevard (HPHB) study area (Figures A1 and A12 in ATSDR, 2013a, Figure 1). The focus for the modeling and analyses of LNAPL volume estimates is in an area of the Base designated as the Hadnot Point Industrial Area (HPIA). Various fuels, solvents, and other chemicals were stored, used, and inadvertently released to the environment during routine operations at the HPIA. Of particular interest in this study was the historical presence and subsequent fate and transport of subsurface light nonaqueous phase liquid (LNAPL) associated with fuel storage system releases at the HPIA. Results from the analyses are integrated with the results from other models and approaches as a part of the overall project objective to produce estimates and uncertainty bounds for the concentration of contaminants over time in selected water-supply wells and water-distribution systems.

The objectives of the LNAPL volume estimate analysis were to:

- i. Investigate the migration and distribution of fuel-related LNAPL released into the unsaturated zone above a shallow aquifer for a hypothetical scenario.
- ii. Estimate the volume and distribution of LNAPL in the subsurface at the HPIA using historical field data for LNAPL (free product) thicknesses measured over time in site monitoring wells; and,
- iii. Analyze the dissolution of benzene and total xylenes from the LNAPL source areas and the subsequent dissolved phase fate and transport of these contaminants under unsteady hydrologic and variable water supply well pumping conditions in the underlying groundwater system at the HPIA.

The purpose of the hypothetical scenario used is to illustrate and explore the behavior of LNAPL in a multiphase environment and provide insight about the potential variability of results involving LNAPL movement. LNAPL movement is just one component of the overall fate and transport process for the applied analysis at the HPIA. For the HPIA analysis, LNAPL movement and estimates of LNAPL distribution in soil were also integrated with the **TechFlowMP** model including the LNAPL dissolution process and subsequent transport of

the dissolved phase contaminants in the groundwater. The goal of the integrated analysis is to evaluate contaminant arrival over time at water-supply wells in the area.

The **HSSM** and **TechFlowMP** models were used in parallel to investigate the migration of LNAPL in the unsaturated zone and at the water table and to explore the distribution of LNAPL saturation in soil over time. Using LNAPL thickness data measured in monitoring wells, the **TechNAPLVol** model code was used to estimate the spatial distribution of LNAPL saturation and the volume of LNAPL in a three-dimensional subsurface domain within the HPIA. The **TechFlowMP** model used saturation profiles from the LNAPL analysis as a starting point for modeling the dissolution of benzene and total xylenes from free-phase LNAPL and the subsequent fate and transport of dissolved phase benzene and total xylenes in the underlying groundwater system.

Technical details of this analysis which follows the USEPA methods of analysis (Farr et al, 1990; USEPA, 1986) are given in (ATSDR, 2013, Chapter A–Supplement 7), Figure 3. This approach is used in ATSDR study to estimate volume of spilled contaminants at the Camp Lejeune site. As indicated in the ATSDR study reports the results confirm the observed data at the site (ATSDR, 2013a, Tables A15, A16). These comparisons are given in Figure 3.

Table A15. Estimates of fuel loss, free product in the subsurface, and fuel recovery at the Hadnot Point Industrial Area fuel farm, Hadnot Point–Holcomb Boulevard study area, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[USMCB, U.S. Marine Corps Base; HPFF, Hadnot Point fuel farm; ATSDR, Agency for Toxic Substances and Disease Registry]

Type of estimate	Volume, in gallons	Reference
Fuel-loss estimates		
USMC documentation of known release from underground fuel line in 1979	20,000–50,000	Water and Air Research, Inc. (1983)
USMC documentation of known fuel releases and inventory losses during 1979–1987	23,150–33,150	O'Brien and Gere Engineers, Inc. (1988, 1990), CH2M HILL (2001)
Model-derived estimates		
¹ SpillCAD™ model estimate of free product (LNAPL) in the subsurface using free product measurements collected during 1988–1995	830,324–1,061,901	UST Management Web Portal Files (2010–2012) ²
Order-of-magnitude estimate of total fuel in the subsurface based on available documentation as of 2001 (specific methodology not described)	400,000–1,100,000	CH2M HILL (2001)
Fuel recovery estimate		
Reported total fuel recovery from HPFF/Building 1115 area remediation systems as of July 2010	414,118	³ USMCB Camp Lejeune (July 2010)

¹SpillCAD™ was developed by Environmental Systems & Technologies (1993)

²Draft report by Baker Environmental, Inc., contained in UST Management Web Portal File #01185, p. 526–562

³From information presented at the ATSDR–DON Data Mining & Discovery Technical Work Group Meeting, USMCB Camp Lejeune, July 21–22, 2010

Table A16. Estimated volumes of light nonaqueous phase liquid in the subsurface, using semi-analytical solutions and numerical integration, Hadnot Point Industrial Area fuel farm, Hadnot Point–Holcomb Boulevard study area, U.S. Marine Corps Base Camp Lejeune, North Carolina.¹

¹ Method and model (scheme number)	² Light nonaqueous phase liquid (LNAPL) volume, in gallons		
	Minimum	Maximum	Mean
³ Analytical solution using depth of LNAPL in wells; TechNAPLVol model; (Scheme 1)	939,000	1,408,000	1,174,000
Numerical integration of three-dimensional domain using LNAPL depth in wells (apparent thickness); TechNAPLVol model; (Scheme 2)	939,000	1,409,000	1,174,000
Numerical integration of three-dimensional domain using LNAPL depth in soil (actual thickness); TechNAPLVol model; (Scheme 3)	1,079,000	1,618,000	1,348,000

¹Results listed are a summary of multiple simulation scenarios. Refer to Jang et al. (2013) for details and descriptions of each scheme; see Jang et al. (2013, Tables S7.6 and S7.7) for full range of results and seven different simulation scenarios; also see Jang et al. (2013, Figure S7.12)

²Volumes reported are for fresh gasoline; for aged gasoline, minimum volumes increase about 20 percent

³Analytical solution derived by Farr et al. (1990)

Figure 3. Spill volumes reported by other agencies (Table A15, pp. A49, ATSDR, 2013a) and Spill volumes estimated by **TechNAPLVol** application (Table A16, pp. A50, ATSDR, 2013a)

- The **Pumping Schedule Optimization System, PSOpS** sub-model: To complement ATSDR's historical contamination reconstruction studies, the pumping schedule variation analysis was conducted to describe the effect of groundwater pumping schedule variations on the arrival times of Tetrachloroethylene (PCE) and other by-products at water-supply wells and the water treatment plant (WTP).

During the historical reconstruction study, the groundwater flow and fate-and-transport of contaminants in the Tarawa Terrace area of the Camp Lejeune base and its vicinity have been simulated to evaluate the contaminant concentration in the WTP. Due to the uncertainty residing in the reconstructed input data used in these simulations, uncertainty may be present in the simulated contaminant concentrations in the water-supply wells and the WTP, and hence in the times for contaminant concentrations to reach the maximum contaminant level (MCL) at these locations. A contributor to this uncertainty is the uncertainty in pumping schedules used in the ATSDR model, therefore, in this study the focus was on the uncertainty associated with the pumping schedules. The study included the development of a simulation and optimization (S/O) procedure identified as **PSOpS (Pumping Schedule Optimization System)**, which combines field data, simulation models and optimization techniques to optimize the pumping schedules to identify maximum or minimum contaminant concentrations in the WTP consistent with the reported pumping schedules. Based on the optimized pumping schedules, variations of PCE concentration and the maximum contaminant level (MCL, PCE) arrival time at water-supply wells and the WTP were evaluated (Wang and Aral, 2008).

The MESL-Georgia Tech research group developed **PSOpS** sub-model, an optimization application to yield answers to specialized uncertainty-related question raised by the ATSDR Expert Panel (March 2005) (<https://www.atsdr.cdc.gov/sites/lejeune/expert-panels.html>). The analysis is based on the **MODFLOW** family of codes in the generation of the database used to solve an optimization problem. The question ATSDR Expert Panel members raised in this case was related to the uncertainty of a pumping-schedule operation that may be implemented at the site and the characterization of its effects on the study outcome. The **PSOpS** model that was developed for the purposes of this analysis and used in the ATSDR water modeling study to address this question became part of the peer reviewed PhD thesis of a graduate student at Georgia Tech. The detailed documentation of this model, which uses the principles of optimization (Rao, 1996) can be found in the PhD thesis of Dr. J. Wang, which is public domain information (Wang, 2008). The overall methodology that used these applications are set forth in detail in the series of reports published by ATSDR, (ATSDR, 2007a, h; ATSDR, 2013a and S2).

- The **TechMarkovChain** sub-model: As described earlier (see Section 3), the Tarawa Terrace WTP was closed in March 1987 due to contamination. During this period, Hadnot Point WTP supplied water to the Hadnot Point area, and Holcomb Boulevard WTP supplied water to the Holcomb Boulevard and Tarawa Terrace base housing areas. The Holcomb Boulevard water-distribution system is connected to the Hadnot Point water-distribution system at the Marston Pavilion valve and at booster pump 742. While booster pump 742 was removed during 2007, the two systems can still be interconnected by opening a valve that exists at the same location based on water demand conditions. For operational reasons, the two water-distribution systems were occasionally connected (depending on water demand)—exceptions being connections that

occurred during late spring and summer months of 1972–1986 and a continuous 8-day period of 28 January to 4 February 1985 (ATSDR, 2007a, ATSDR, 2013 S8). Because the information pertaining to times when interconnection events occurred is limited and for some years unknown (e.g., 1972–1977, Figure S8.37; ATSDR, 2013), a Markov process (Ross, 1997) was applied by using available field data and information to estimate the probability and number of monthly interconnection events that occurred during the months of April–August for 1972–1985.

A Markov process (a stochastic process) analyzes the tendency of one event to be followed by another event based on the data available on a sequence of events during a calibration period. By using this analysis, one can generate a new sequence of random but related events, which will be statistically correlated to the original calibration data. The stream of events generated is called a Markov Chain.

In this study, a probabilistic approach based on Markov Chain simulations was used to estimate the yearly numbers of booster pump/valve openings. For the calculation of transition probabilities of this Markov Chain model, the conditional probabilities of transfer events given the temperature, precipitation, or delivered finished-water volume value in a day were calculated using Kernel density estimator and Bayes' theorem. Also, the probabilities of transfer were conditioned on the values of pairs of parameters by using the Copula concept. The Markov analysis first estimates the number of historical booster pump opening events on a yearly basis. Next, the numbers of events are distributed among the dry months (April–August) during each year. Graphical techniques and data analyses (of daily recordings of temperature, precipitation, and raw-water volume in the HBWTP) were then used to estimate the occurrence of daily finished-water transfers during individual months. Table S8.20 (ATSDR, 2013, S8) lists the number of recorded interconnection events, and the number of monthly events predicted by using a Markov Chain analysis for the period 1972–1985.

This methodology is an efficient and effective way of utilizing the available data to predict the number of booster pump/valve openings monthly (Ross, 1997; Rao, 1996). The results show that predictions made using the Markov methodology analysis are statistically correlated and mimic the historical operations within a statistical confidence interval (Table S8.20, ATSDR, 2013, S8). These outcomes are used in contaminant fate and transport simulations for the Holcomb Boulevard and Hadnot Point water-distribution systems in ATSDR study. The details of the Markov analysis methodology are given in Appendix S8.4 (ATSDR, 2013a, S8).

- **TechControl** sub-model: A linear control theory model and software developed by MESL, Ga Tech. It is used to address the question of the application of simpler models to predict contaminant concentrations at certain locations of the Camp Lejeune site (HPLF) (ATSDR, 2013, S5). The development of the software was based on a request that was initiated by the ATSDR Expert Panel of scientists (Expert Panel 2005) (<https://www.atsdr.cdc.gov/sites/lejeune/expert-panels.html>).

- The **Linear Control Theory, LCT** analysis: Linear Control Theory is a scientific methodology of the field of control engineering and applied mathematics. The methodology deals with the control of dynamical systems in engineered processes. In the case of ATSDR study of the Camp Lejeune site, the methodology was applied to groundwater contaminant transport analysis as a simple application to predict concentration values at a specific point in space and time based on limited data available at the site (ATSDR, 2013, S5). This study was requested by the expert panel (Expert Panel 2005) which reviewed the ATSDR Camp Lejeune site study and provided scientific advice.
- The **TechWellOp** sub-model: A subsurface pumping well estimation model and software developed by MESL, Ga. Tech. The methodology uses the daily data in the Training Period to determine the monthly operational behavior of the water supply wells at the Camp Lejeune site that would satisfy the total water volume delivered to the water treatment plants. Once the average monthly working days in the Training Period are estimated for each calendar month, they are utilized in the prediction stage which is based on the same principle of satisfying the total monthly flow delivered to the treatment plant at those periods. This methodology is an efficient and effective way of integrating the available data in recent years to the prediction process for the past years. The development of the software was based on a discussion that was initiated by the ATSDR Expert Panel of scientists (Maslia, et al., Expert Panel 2005, ATSDR, 2007a; ATSDR, 2013, S2).

The use and application of specialized codes to address specific problems that standard codes such as **MODFLOW** and **MT3DMS** cannot address is an accepted methodology. As stated in the U.S. Environmental Protection Agency report, "Guidance on the Development, Evaluation, and Application of Environmental Models" (USEPA 2009, p. 31): "However, the Agency acknowledges there will be times when the use of proprietary models provides the most reliable and best-accepted characterization of a system." The point being made in this statement is that the most appropriate model should be applied to characterize a system, not necessarily, the most popular or often-used off-the-shelf models. This is the modeling philosophy and approach that ATSDR took when applying the **TechFlowMP**, **TechNAPLVol**, **TechWellOp**, **TechControl**, **TechMarkovChain** and **PSOpS** models that were used at the Camp Lejeune site.

5.2 Multimedia Environmental Simulation Laboratory (MESL) involvement in the ATSDR study

In Figure A2, the first in Figure 4 below (ATSDR, 2007; ATSDR, 2013), the components of the Tarawa Terrace modeling study are shown. The red arrows on this figure indicate the areas where the MESL team was involved, and the yellow arrows indicate where the MESL team provided an oversight of the study components. In Figure A2, the second in Figure 4 below (ATSDR, 2007; ATSDR, 2013), the components of the Hadnot Point – Holcomb Boulevard modeling study are shown. The red arrows on this figure indicate the areas where the MESL team was involved, and the yellow arrows indicate where the MESL team provided an oversight of the study components.

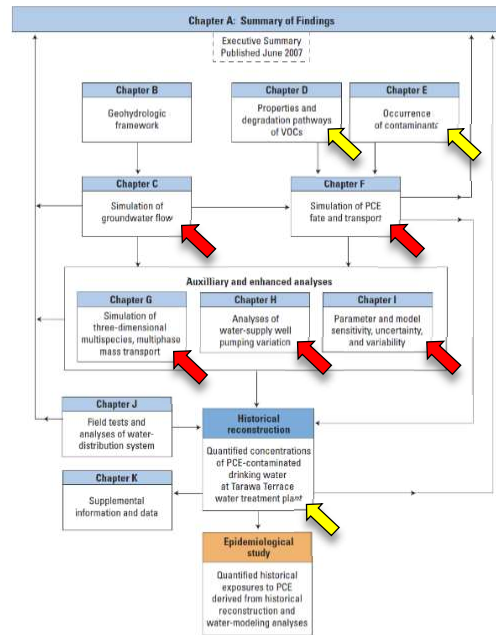


Figure A2. Relation among Chapter A report (Summary of Findings), Chapters B-K reports, historical reconstruction process, and the ATSDR epidemiological case-control study, Tarawa Terrace and vicinity, U.S. Marine Corps Base Camp Lejeune, North Carolina. [VOCs, volatile organic compounds; PCE, tetrachloroethylene]

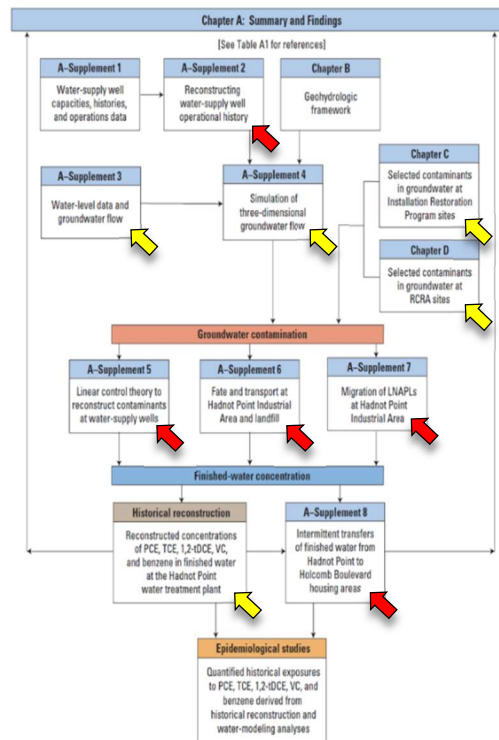


Figure A2. Relation among Chapter A report (Summary and Findings), Chapter A supplements (1-8), Chapters B-D reports, historical reconstruction process, and the ATSDR epidemiological studies, Hadnot Point-Holcomb Boulevard study area, U.S. Marine Corps Base Camp Lejeune, North Carolina. [RCRA, Resource Conservation and Recovery Act of 1976; LNAPL, light nonaqueous phase liquid; PCE, tetrachloroethylene; TCE, trichloroethylene; 1,2-dCE, trans-1,2-dichloroethylene; VC, vinyl chloride]

Figure 4. MESL involvement in ATSDR modeling tasks at TT and HP/HB Camp Lejeune site (ATSDR, 2007; ATSDR, 2013)

6. Evaluation of ATSDR Camp Lejeune Study Results

6.1 Environmental Modeling Processes used in ATSDR Study

A scientific model can be defined as being an abstraction of some real system - an abstraction that can be used for prediction and management purposes. Thus, the purpose of a scientific model is to make some predictions on the modeled system. While making these predictions, a scientific model also enables the analyst to determine how one or more changes in various aspects of the modeled system may affect the other aspects of the system, the system itself, and the results predicted, in a cost-effective manner. Because models are an abstraction of the real system and cannot be a complete depiction of the real system, they need to be presented and analyzed in a computational environment which includes an analysis of uncertainty, variability, calibration and validation.

Uncertainty analysis may take the form of sensitivity analysis, or for more complicated applications, statistical uncertainty analysis may be utilized. It is important to distinguish the difference between the terms “uncertainty” and “variability.” As expected, they refer to two different and distinct concepts (Aral, 2010).

Uncertainty is a measure of knowledge of the magnitude of a parameter. Thus, uncertainty can be reduced by further research, i.e. the parameter value can be refined through further experimentation or further data collection. Variability on the other hand is a measure of the heterogeneity of a parameter, event or the inherent variability in a chemical property at a site. Variance cannot be reduced by further research, but a model can be developed such that it would mimic the variability of the parameter or event used in the model. Statistical variability analysis is a common approach used in modeling studies to envelope these variations at a site and understand its effects on the outcome. This analysis provides some degree of confidence in model output.

Models include parameters that need to be associated with values. These parameter values are used as input to mathematical models to produce numerical output. Ideally, these parameters should have a good definition and a physical basis for the environmental system under study. Usually, these parameters either are calculated using the mathematical representation of their physical basis, or they are measured in field or laboratory studies. Often, however, the values of these parameters are unknown or only known approximately. Thus, a range of these parameters can be input into a model to yield the best outcome when compared to an observation made in a field or laboratory study. Appropriate values of the parameters are needed in the model to achieve the appropriate output that is observed at a site. Thus, calibration of models is necessary. Calibration of a model can then be defined as the stage where we adjust the parameters of the mathematical model such that the model agreement is maximized with respect to the observation data we have on the modeled system output. In this sense, model calibration is fine tuning the model to a set of parameter data on the modeled system. Calibration procedures used in the ATSDR study for all models considered adhere to the standards used in the technical literature (Bedient, 2003; Anderson, 2015, Mei 2023).

The calibration process followed by validation of complex systems is another important aspect of model development and use as it is implemented in ATSDR studies. The seemingly complex definitions of these two terms may get further complicated when several models are used in environmental applications where overlapping models are necessary to describe the behavior of the complex system. In complex system analysis several interlinked modeling phases are used to describe the behavior of the system

modeled. Thus, as a typical example, the calibration and validation procedures used in a simple steady state groundwater modeling application will be different than an interlinked study of a complex system. A complex system may include a steady/unsteady groundwater flow model that is linked to a transient contaminant transport model which is further linked to a water treatment plant condition that is linked to a water distribution system analysis. Since these phases are not independent and occur within the same envirosphere and time frame of analysis, one should not ignore the integrated calibration and validation processes involved in these applications. In complex systems the interlinked behavior of the models used is the key response that is in question which is sometimes ignored, overlooked or not properly understood. The ATSDR study of the Camp Lejeune site represents such a complex system where steady groundwater flow, unsteady groundwater flow, unsteady multispecies multiphase contaminant transport and the engineered water treatment and water distribution system applications are all components of the same envirosphere and operate within the same time frame. As such, calibration and validation processes should be considered as interlinked processes.

Having described the definition of the calibration process above, validation is another contended modeling concept that was and still is debated in scientific literature. For example, in Konikow and Bredehoeft (1992) it is stated that: "Ground-water models are embodiments of scientific hypotheses. As such, the models cannot be proven or validated, but only tested and invalidated," or "...The absolute validity of a model can never be determined" (NRC, 1990). This is partly a semantic issue and partly a philosophical one. In the main text of this report, I will not go into the details of the philosophical discussions on this subject although I believe they have merit within the context the authors describe the process in their scientific discussions. However, I will evaluate this process within the context of complex systems analysis in Section 6.7 of this expert report to bring clarity to the definition of this process as it is used in the Camp Lejeune study. In this expert report I will adopt the standard (traditional) definition of validation of a model. In traditional definition, validation is understood as a process that results in an explicit statement about the behavior of a model in an application. That is, the common definition of validation is the demonstration that a model, within its domain of applicability, possesses satisfactory accuracy consistent with the intended application of the model (Sargent, 1984; Curry et al., 1989; Konikow and Bredehoeft, 1992). This demonstration builds confidence in the model and indicates that the model is acceptable for use. As such, validation procedures used in the ATSDR study for all models considered adhere to the standards used in technical literature (Aral, 2010; Bedient, 2003; Anderson, 2015, Sargent, 1984; Curry et al., 1989; Konikow and Bredehoeft, 1992; Mei, 2003).

The calibration, validation, uncertainty and sensitivity analysis concepts used in the ATSDR study are clearly described on page 23 of Chapter A report (ATSDR, 2007a; Fig. A9) Figure 5. In these definitions, the hierarchical approach to calibration and validation is conceptually described in terms of the Venn or set diagrams (Borowski and Borwein 1991), Figure 5. Such diagrams are useful for showing logical relations between sets or groups of like items and are shown in Figure A9 for each hierarchical calibration level. What is meant by this description is that at level 1 (Figure A9a, Figure 5), there may be many combinations of parameters that yield solutions to the predevelopment groundwater-flow calibration conditions. However, only a smaller set of these feasible solutions, the subset of solutions indicated by circle "A" in Figure A9a yields an acceptable combination of parameters for a calibrated transient groundwater flow condition. Viable solutions are indicated by circle "B" (Figure A9b, ATSDR, 2007a), Figure 5. Only those solutions that successfully simulate both predevelopment and transient groundwater flow conditions can be accepted and classified as resulting in calibrated transient and predevelopment groundwater flow models. As such, the next level modeling used not only serves as the independent validation of the previous level application, but it is also used in the iterative recalibration process of the previous system if validation process does not yield satisfactory outcome. Similarly, the

next level of modeling phase, which is the transient contaminant transport analysis serves as the next independent validation of groundwater flow models, but it is also used in the recalibration of the complete system up to that stage. Thus, in all levels, the last level serves as an independent validation of the previous level and sometimes necessitates the recalibration of all the previous system levels. This is an important distinction which needs to be considered in complex system analysis and modeling as opposed to simple modeling applications.

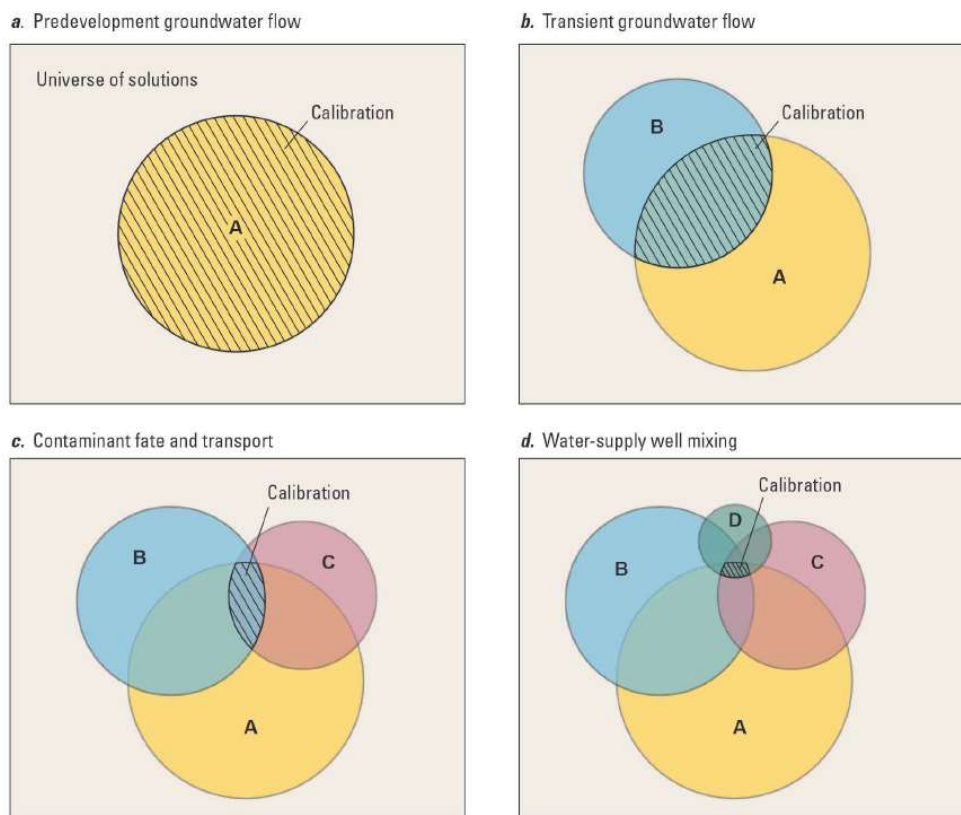


Figure A9. Venn diagrams showing hierarchical approach of model calibration used to estimate concentration of finished water: (a) predevelopment groundwater flow, (b) transient groundwater flow, (c) contaminant fate and transport, and (d) water-supply well mixing, Tarawa Terrace and vicinity, U.S. Marine Corps Base Camp Lejeune, North Carolina.

Figure 5. Venn diagram representations (Figure A9, page A23, ATSDR, 2007a)

The ATSDR study of the Camp Lejeune site falls into the category of a “Complex System” as defined above. Thus, iterative calibration and validation of all models used in the ATSDR study adhere to the standards used in the technical literature within the concept of complex system analysis (Aral, 2010).

It is my opinion that these concepts are properly and successfully developed and employed in the models that are used in ATSDR studies for the Camp Lejeune site (ATSDR, 2007a; ATSDR, 2013a).

6.2 Contaminants Studied at the Camp Lejeune Site

The specific VOCs that ATSDR studied at the Camp Lejeune site (TT, HP-HB sites), include:

- trichloroethylene (TCE),
- tetrachloroethylene (PCE),

- *trans* 1,2-dichloroethylene, (1,2-tDCE),
- vinyl chloride (VC), and
- benzene or BTEX compounds.

Trichloroethylene: Trichloroethylene (TCE) is a volatile, colorless liquid organic chemical. TCE does not occur naturally in the environment and is created by chemical synthesis. It is used primarily to make refrigerants and other hydrofluorocarbons and as a degreasing solvent for metal equipment. TCE is also used in some household products, such as cleaning wipes, aerosol cleaning products, tool cleaners, paint removers, spray adhesives, carpet cleaners and spot removers. Commercial dry cleaners also use trichloroethylene as a spot remover. (extracted from: <https://www.cancer.gov/about-cancer/causes-prevention/risk/substances/trichloroethylene>).

Tetrachloroethylene: Tetrachloroethylene is a nonflammable colorless liquid. It is widely used for dry cleaning of fabrics; hence it is sometimes called "dry-cleaning fluid". It also has its uses as an effective automotive brake cleaner. Other names for tetrachloroethylene include perchloroethylene, PCE, PERC, tetrachloroethene, and perchlor. (extracted from: <https://en.wikipedia.org/wiki/Tetrachloroethylene>).

Trans-1,2-dichloroethylene: Trans-1,2-dichloroethylene is a colorless liquid, with a sharp, harsh odor, and is highly flammable. The primary uses for trans-1,2-dichloroethylene are as a solvent in processing and in formulations for cleaning and degreasing.

Vinyl chloride: Vinyl chloride is a colorless gas that burns easily. It does not occur naturally and must be produced industrially for its commercial uses. Vinyl chloride is used primarily to make polyvinyl chloride (PVC), a hard plastic resin used to make a variety of plastic products, including pipes, wire and cable coatings, and packaging materials (extracted from: <https://www.cancer.gov/about-cancer/causes-prevention/risk/substances/vinyl-chloride>).

BTEX: A group of VOCs, collectively known as BTEX, comprising benzene (B), toluene (T), ethylbenzene (E) and xylene (X) (often expressed as total xylenes) are important industrial solvents and frequently encountered in petroleum products.

Benzene: Benzene is a colorless or light-yellow liquid chemical at room temperature. It is used primarily as a solvent in the chemical and pharmaceutical industries, as a starting material and an intermediate in the synthesis of numerous chemicals, and in gasoline. Benzene is produced by both natural and man-made processes (extracted from: <https://www.cancer.gov/about-cancer/causes-prevention/risk/substances/benzene>).

The contamination conditions based on these chemicals at the Tarawa Terrace, Hadnot Point and Holcomb Boulevard areas will be examined in more detail in the following sections of this expert report.

6.3 Contaminants Observed at the Camp Lejeune Site

Contamination vs Pollution are two synonymous terms that are commonly used in technical literature and in the common language that is associated with environmental studies and health risk analysis. Contamination that is present in the environment at low concentrations and thus does not cause adverse environmental or health effects should not be confused with pollution. It is when these contaminant levels exceed a certain threshold and cause health effects is of concern in health studies. When that happens, contaminants at a site are classified as environmental pollution (Meharg, 2005; Aral, 2010).

In this context it is important to reference the reported (observed) PCE concentrations in water supply wells in Tarawa Terrace study area reports. In Table A9, page A27, we see the elevated PCE concentrations in water supply wells (ATSDR, 2007a), Figure 6. In this table, the numbers in the fourth column are all observed PCE levels in water supply wells; the MCL level for PCE is 5 µg/L.

Table A9. Summary of model-derived values and observed data of tetrachloroethylene at water-supply wells, Tarawa Terrace, U.S. Marine Corps Base Camp Lejeune, North Carolina.¹

[PCE, tetrachloroethylene; µg/L, microgram per liter; J, estimated; ND, nondetect]

Model-derived value		Observed data				
Month and year	PCE concentration, in µg/L	Sample date	PCE concentration, in µg/L	Detection limit, in µg/L	Calibration targets ² , in µg/L	Sample number ³
Supply well TT-23						
January 1985	254	1/16/1985	132	10	41.7–417	1
February 1985	253	2/12/1985	37	10	11.7–117	2
February 1985	253	2/19/1985	26.2	2	8.3–82.9	3
February 1985	253	2/19/1985	ND	10	1–10	4
March 1985	265	3/11/1985	14.9	10	4.7–47.1	5
March 1985	265	3/11/1985	16.6	2	5.2–52.5	6
March 1985	265	3/12/1985	40.6	10	12.8–128	7
March 1985	265	3/12/1985	48.8	10	15.4–154	8
April 1985	274	4/9/1985	ND	10	1–10	9
September 1985	279	9/25/1985	4J	2	1.3–12.6	10
July 1991	191	7/11/1991	ND	10	1–10	11
Supply well TT-25						
February 1985	7.3	2/5/1985	ND	10	1–10	12
April 1985	9.6	4/9/1985	ND	10	1–10	13
September 1985	18.1	9/25/1985	0.43J	10	0.14–1.4	14
October 1985	20.4	10/29/1985	ND	10	1–10	15
November 1985	22.8	11/4/1985	ND	10	1–10	16
November 1985	22.8	11/12/1985	ND	10	1–10	17
December 1985	25.5	12/3/1985	ND	10	1–10	18
July 1991	72.7	7/11/1991	23	10	7.3–72.7	19
Supply well TT-26						
January 1985	804	1/16/1985	1,580.0	10	500–4,996	20
January 1985	804	2/12/1985	3.8	10	1.2–12	21
February 1985	798	2/19/1985	64.0	10	20.2–202	22
February 1985	798	2/19/1985	55.2	10	17.5–175	23
April 1985	801	4/9/1985	630.0	10	199–1,992	24
June 1985	799	6/24/1985	1,160.0	10	367–3,668	25
September 1985	788	9/25/1985	1,100.0	10	348–3,478	26
July 1991	670	7/11/1991	350.0	10	111–1,107	27
Supply well TT-30						
February 1985	0.0	2/6/1985	ND	10	1–10	28
Supply well TT-31						
February 1985	0.17	2/6/1985	ND	10	1–10	29
Supply well TT-52						
February 1985	0.0	2/6/1985	ND	10	1–10	30
Supply well TT-54						
February 1985	6.0	2/6/1985	ND	10	1–10	31
July 1991	30.4	7/11/1991	ND	5	1–5	32
Supply well TT-67						
February 1985	4.1	2/6/1985	ND	10	1–10	33
Supply well RW1						
July 1991	0.0	7/12/1991	ND	2	1–2	34
Supply well RW2						
July 1991	879	7/12/1991	760	2	240–2,403	35
Supply well RW3						
July 1991	0.0	7/12/1991	ND	2	1–2	36

¹Model-derived values for water-supply wells based on simulation results obtained from the fate and transport model MT3DMS (Zheng and Wang 1999); see the Chapter F report (Faye In press 2007b) for details

²Calibration targets are ±½-order of magnitude for observed data; when observed data are indicated as ND, upper calibration target is detection limit and lower calibration target is 1 µg/L

³See Figure A.11

Figure 6. The reported (observed) PCE concentrations at the Tarawa Terrace study area water supply wells (column four Table A9, page A27, Tarawa Terrace site, ATSDR, 2007a.)

Similarly, the reported (observed) TCE, PCE, 1,1-DCE, 1,2-tDCE, 1,2-cDCE, Total 1,2-DCE, and VC concentrations at Hadnot Point – Holcomb Boulevard study area are given in Figure 7. In this table, the numbers highlighted in red are all observed levels that are above the detection limits for the compound identified in the header of the table; the MCL level for TCE and PCE is 5 µg/L.

Table A4. Water-supply wells with reported detections of tetrachloroethylene (PCE), trichloroethylene (TCE), 1,1-dichloroethylene (1,1-DCE), *trans*-1,2-dichloroethylene (1,2-tDCE), *cis*-1,2-dichloroethylene (1,2-cDCE), total 1,2-dichloroethylene (total 1,2-DCE), or vinyl chloride (VC), Hadnot Point–Holcomb Boulevard study area, U.S. Marine Corps Base Camp Lejeune, North Carolina.¹

[<, constituent is less than the detection limit. Number following the "<" is the detection limit; —, constituent concentration not determined in laboratory analysis; ND, constituent not detected; J, estimated concentration; D, sample diluted for analysis]

Well name	Sample date	Concentration, in micrograms per liter					
		PCE	TCE	1,1-DCE	1,2-tDCE	1,2-cDCE	Total 1,2-DCE
HP-602	7/6/1984	<1.9	<1.4	<1.3	7.8	—	<0.9
	11/30/1984	34	1,600	2.4J	630	—	18
	12/10/1984	<500	540	<500	380	—	<500
	12/13/1984	3.2	300	—	110	—	—
	12/14/1984	<50	340	<50	230	—	<50
	2/4/1985	1.5J	38	<10	74	—	<10
	11/12/1986	<4.1	2.2	<2.8	14	—	<4.9
	1/22/1991	<5.0	0.7J	<5.0	—	—	12
	12/4/1984	<10	4.6J	<10	<10	—	<10
	12/12/1984	<10	<10	<10	<10	—	<10
HP-603	1/16/1985	<10	<10	<10	<10	—	<10
	8/11/1988	<10	<10	<10	<10	—	<10
	6/26/1990	<5.0	<5.0	<5.0	—	—	<10
	1/22/1991	<5.0	1.0J	<5.0	—	—	<10
	9/20/1995	<0.50	3.0	<0.50	<0.50	2.4	<0.50
	12/4/1984	<10	110	<10	5.4J	—	<10
	12/10/1984	<10	13	<10	2.4J	—	<10
HP-608	2/4/1985	<10	9.0	<10	<10	—	<10
	11/12/1986	<4.1	66	<2.8	8.5	—	<4.9
	2/4/1985	<10	<10	<10	<10	—	<10
	10/1/1992	<1.0	37	—	—	—	<2.0
HP-634	12/4/1984	<10	<10	<10	<10	—	<10
	12/10/1984	<10	<10	<10	2.3J	—	<10
	1/16/1985	10	1,300	<10	700	—	6.8
	11/12/1986	<4.1	<1.9	<2.8	2.9	—	<4.9
	1/22/1991	<5.0	<5.0	<5.0	—	—	1.0J
HP-637	12/4/1984	<10	<10	<10	<10	—	<10
	12/10/1984	<10	<10	<10	<10	—	<10
	1/16/1985	<10	<10	<10	<10	—	<10
	1/22/1991	<5.0	0.90J	<5.0	—	—	<10
	8/26/1992	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
HP-651	1/16/1985	386	3,200	187	3,400	—	655
	2/4/1985	307	17,600	<200	8,070	—	179
	2/4/1985	400	18,900	<200	7,580	—	168
	11/12/1986	45	32	7.0	140	—	140
	1/22/1991	53	13	2.0J	—	—	75
HP-652	1/16/1985	<10	9.0	<10	<10	—	<10
	11/12/1986	<3.0	<3.0	<2.8	<1.6	—	<1.0
	1/22/1991	<5.0	<5.0	<5.0	—	—	<10
	9/20/1995	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
	12/11/2001	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
HP-653	1/16/1985	<10	5.5	<10	<10	—	<10
	11/12/1986	<4.1	2.6	<2.8	<1.6	—	<4.9
	1/22/1991	<5.0	<5.0	<5.0	—	—	<10
HP-660	12/4/1984	5.0J	210	<10	88	—	<10
	12/10/1984	4.4J	230	<10	99	—	<10
	1/16/1985	<10	26	<10	88	—	<10
	11/12/1986	<4.1	<1.9	<2.8	<1.6	—	<4.9
	1/22/1991	<5.0	1.0J	<5.0	—	—	2.0J

¹ See Faye et al. (2010) for a complete tabulation of contaminants in water samples collected at water-supply wells in the Hadnot Point–Holcomb Boulevard study area

² Concentrations above the detection limit are highlighted in red

Figure 7. The reported (observed) TCE, PCE, 1,1-DCE, 1,2-tDCE, 1,2-cDCE, Total 1,2-DCE, VC concentrations at Hadnot Point – Holcomb Boulevard study area (Table A4, pp. A21, HP/HB Camp Lejeune site, ATSDR, 2013a)

Similarly, the reported (observed) BTEX concentrations at Hadnot Point – Holcomb Boulevard study area are given in Figure 8. The numbers highlighted in red are all concentrations above detection levels for the compound identified in the header of the table; the MCL level for Benzene is 5 µg/L.

Table A5. Water-supply wells with reported detections of benzene, toluene, ethylbenzene, or total xylenes, Hadnot Point–Holcomb Boulevard study area, U.S. Marine Corps Base Camp Lejeune, North Carolina.¹

[<, constituent is less than the detection limit. Number following the "<" is the detection limit; —, constituent concentration not determined in laboratory analysis; ND, constituent not detected; J, estimated concentration]

Well name	Sample date	² Concentration, in micrograms per liter			
		Benzene	Toluene	Ethylbenzene	Total xylenes
Hadnot Point Water Treatment Plant Service Area					
HP-602	7/6/1984	380	10	8.0	—
	11/30/1984	120	5.4J	<10	—
	12/10/1984	720	<500	<500	—
	12/13/1984	<1.0	<1.0	<2.0	—
	12/14/1984	230	12J	<50	—
	2/4/1985	<10	<10	<10	—
	11/12/1986	50	<6.0	<7.2	<12
	1/22/1991	17	<5.0	<5.0	<5.0
HP-603	12/4/1984	<10	<10	<10	—
	12/10/1984	<10	<10	<10	—
	1/16/1985	<10	<10	<10	—
	8/11/1988	<10	<10	<10	<10
	6/26/1990	<5.0	<5.0	<5.0	<5.0
	1/22/1991	<5.0	<5.0	<5.0	<5.0
	9/20/1995	<0.50	<0.50	<0.50	<0.50
	HP-608	12/4/1984	3.7J	<10	<10
12/10/1984		4.0J	<10	<10	—
2/4/1985		1.6	<10	<10	—
11/12/1986		<4.4	<6.0	<7.2	<12
HP-651	1/16/1985	<10	<10	<10	—
	2/7/1985	<10	<10	<10	—
	11/12/1986	<4.4	<6.0	<7.2	<12
	1/22/1991	<5.0	0.9J	<0.5	<0.5
Holcomb Boulevard Water Treatment Plant Service Area					
HP-645	2/4/1985	<10	<10	<10	—
	11/6/1986	20	7.5	ND	ND
	2/17/1987	290	15	38	36
HP-706	9/19/1995	0.60	<0.50	<0.50	<0.50
	1/13/1998	6.1	—	—	—

¹ See Faye et al. (2010) for a complete tabulation of contaminants in water samples collected at water-supply wells in the Hadnot Point–Holcomb Boulevard study area

² Concentrations above the detection limit are highlighted in red

Figure 8. The reported (observed) BTEX concentrations at Hadnot Point – Holcomb Boulevard study area (Table A5, pp. A22, HP/HB Camp Lejeune site, ATSDR, 2013a).

As seen in the tables above, the observed and modeled contaminant levels of TCE, PCE, their by-products and BTEX compounds at the Camp Lejeune site are all at elevated levels (ATSDR, 2007; ATSDR, 2013).

6.4 Dissolved phase pollution vs NAPL, LNAPL and DNAPL pollution.

Nonaqueous phase liquids (NAPLs) are hydrocarbons that exist in a subsurface environment as a separate, immiscible (nonmixing) phase when in contact with water and/or air. Differences in the physical and chemical properties of water and NAPL result in the formation of a physical interface between the liquids which prevents the two fluids from mixing. Nonaqueous phase liquids are typically classified as either light nonaqueous phase liquids (LNAPLs) which have densities less than that of water,

or dense nonaqueous phase liquids (DNAPLs) which have densities greater than that of water (Newell et al., 1995).

Upon release to the environment, NAPL (i.e., LNAPL or DNAPL) will migrate downward under the force of gravity. If a small volume of NAPL is released to the subsurface, it will move through the unsaturated zone where a fraction of the hydrocarbon will be retained by capillary forces as residual globules in the soil pores, thereby depleting the contiguous NAPL mass until movement ceases. If sufficient LNAPL is released, it will migrate until it encounters a physical barrier (e.g., low permeability strata) or is affected by buoyancy forces near the water table. Once the capillary fringe is reached, the LNAPL may move laterally as a continuous, free-phase layer along the upper boundary of the water-saturated zone due to gravity and capillary forces (Newell et al., 1995). DNAPL pollution on the other hand, because its density is higher than that of water, will continue its downward motion under the force of gravity in a water saturated subsurface system.

Modeling techniques used for each of these contamination types and dissolved phase modeling techniques are distinctly different from one another. The governing equations, mathematical definitions of migration and diffusion-dispersion processes differ from one another and a model developed for one case cannot represent the contaminant fate and transport in the other case.

A NAPL phase which is in physical contact with ground water will dissolve (solubilize, partition) into the aqueous phase. The solubility of an organic compound is the equilibrium concentration of the compound in water at a specified temperature and pressure. For all practical purposes, solubility represents the maximum concentration of that compound in water at a given temperature. At the maximum concentration, the solution is said to be saturated and thus the NAPL phase exists. Thus, to distinguish NAPL pollution from dissolved phase pollution at a site, the relative magnitude of solubility of the alien substance and the concentrations observed at a site can be used. If the concentrations of the alien substance observed at a site is less than ~10% of the solubility range of the alien substance, then the alien substance plume can be identified as a dissolved phase plume rather than an NAPL plume (Hulling and Weaver, 1991).

Characterization of tetrachloroethylene (PCE) contamination in groundwater at the ABC One-Hour Cleaners site and at Tarawa Terrace base housing as a “free-phase” or “pure-phase” DNAPL plume (NRC 2009, p. 38) contradicts and misrepresents the concentration data presented in ATSDR and in other reports and documents in the water phase. Those reports and documents describe the PCE in groundwater in the vicinity of ABC One-Hour Cleaners as “dissolved-phase” PCE (Shiver 1985, Roy F. Weston, Inc. 1992, 1994, Faye and Green 2007). The solubility limit of PCE in water occurs at a concentration of at least 210,000 µg/L (Pankow and Cherry, 1996, Lawrence 2007). PCE solubility is given in the range 150,000 µg/L – 1,503,000 µg/L at 25 °C in (Fetter, 1998: page 163). PCE in groundwater that occurs at concentrations much less than the solubility limit is, by the definition given above, a dissolved-phase PCE plume. The ATSDR conceptualization of groundwater flow and of dissolved-phase PCE conditions at ABC One-Hour Cleaners and the Tarawa Terrace base housing area is shown below in Figure 9. PCE-concentration data presented in ATSDR reports (Faye and Green 2007, Tables E5 and E7) indicate that concentrations of PCE in groundwater at Tarawa Terrace and vicinity occur at much less than 10% of the solubility limit. Thus, the characterization of the PCE plume in the vicinity of ABC One-Hour Cleaners as a dissolved phase plume is the most appropriate characterization of conditions at the site.

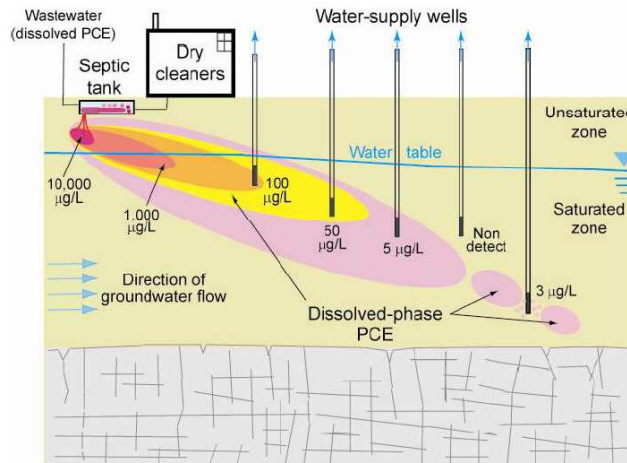


Figure 9. Conceptual model of groundwater flow and dissolved-phase PCE transport at, and in the vicinity of, ABC One-Hour Cleaners (solubility of PCE is at least 210,000 µg/L, Pankow and Cherry 1996, Lawrence 2007)

Further, the processes selected to remediate free-phase DNAPL PCE plume in groundwater are totally different from processes used to remediate dissolved-phase PCE plume in groundwater. The remediation process at the ABC One-Hour Cleaners and at Tarawa Terrace was coordinated under the auspices (directives) of the U.S. Environmental Protection Agency (USEPA). The remediation process selected was approved by the North Carolina Department of Environment and Natural Resources (NCDENR) and is correctly described as “groundwater extraction by wells and treatment by air stripping (i.e., pump-and-treat process).” This remediation process is appropriate only for dissolved phase PCE contamination and not for DNAPL phase PCE plume (NCDENR 2003, Weston Solutions Inc. 2005, 2007).

Given the definitions and data presented above, it is my opinion that the dissolved phase plume characterization used in the ATSDR study of the Tarawa Terrace area is appropriate and consistent with the definitions given above.

6.5 Tarawa Terrace Study

The construction of the Tarawa Terrace housing area dates to 1951. The area was subdivided into housing areas I and II which contained a total of 1,846 housing units and accommodated a resident population of about 6,000 people (fluctuating), Figure 10.

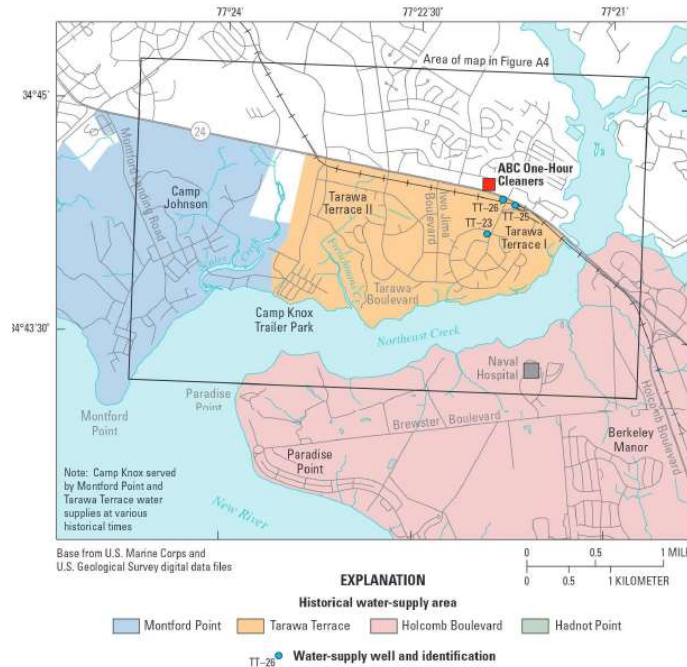


Figure A1. Selected base housing and historical water-supply areas, Tarawa Terrace and vicinity, U.S. Marine Corps Base Camp Lejeune, North Carolina.

Figure 10. Tarawa Terrace study area, location of ABC One Hour Cleaners and geographic boundaries of the site. (Figure A1, page A3, ATSDR, 2007a)

Groundwater is the sole source of water supply at the Tarawa Terrace site. To analyze and reconstruct contaminant concentrations and the timeline of contaminant movement at the site, a series of modeling techniques were used by the EDRP/ATSDR modeling group. These are:

- The analysis of predevelopment (steady state) groundwater flow conditions at the site (**MODFLOW**);
- The analysis of transient (pumping) groundwater flow conditions at the site (**MODFLOW**);
- The analysis of fate and transport of PCE and its by-products from its source at ABC One-Hour Cleaners to water-supply wells (**MT3DMS and TechFlowMP**);
- The analysis of concentration of PCE and its by-products in finished water at the Tarawa Terrace WTP were determined by using a material mass balance model (**Mass Balance, simple mixing**), where the flow-weighted average concentration of the aforementioned contaminants was calculated. The water from the Tarawa Terrace WTP was delivered to residents living in family housing; and,
- Assessment of parameter sensitivity, variability, and uncertainty associated with model simulations of groundwater flow, contaminant fate and transport, and water-distribution system analyses were also conducted (ATSDR, 2007).

For the implementation of these stages proper sub-models developed by MESL were also used as appropriate. The details of these sub-models were described earlier in this report (see Section 5). The calibration and validation analyses were successfully completed for all the modeling stages given the

complex system analysis techniques described earlier in this expert report (see Section 6.1). The details of this analysis can be found in (ATSDR, 2007) which will not be repeated here.

After calibration and validation analyses were successfully completed the simulation results of PCE and its by-products at the WTP were generated. These results are summarized in Figure 11.

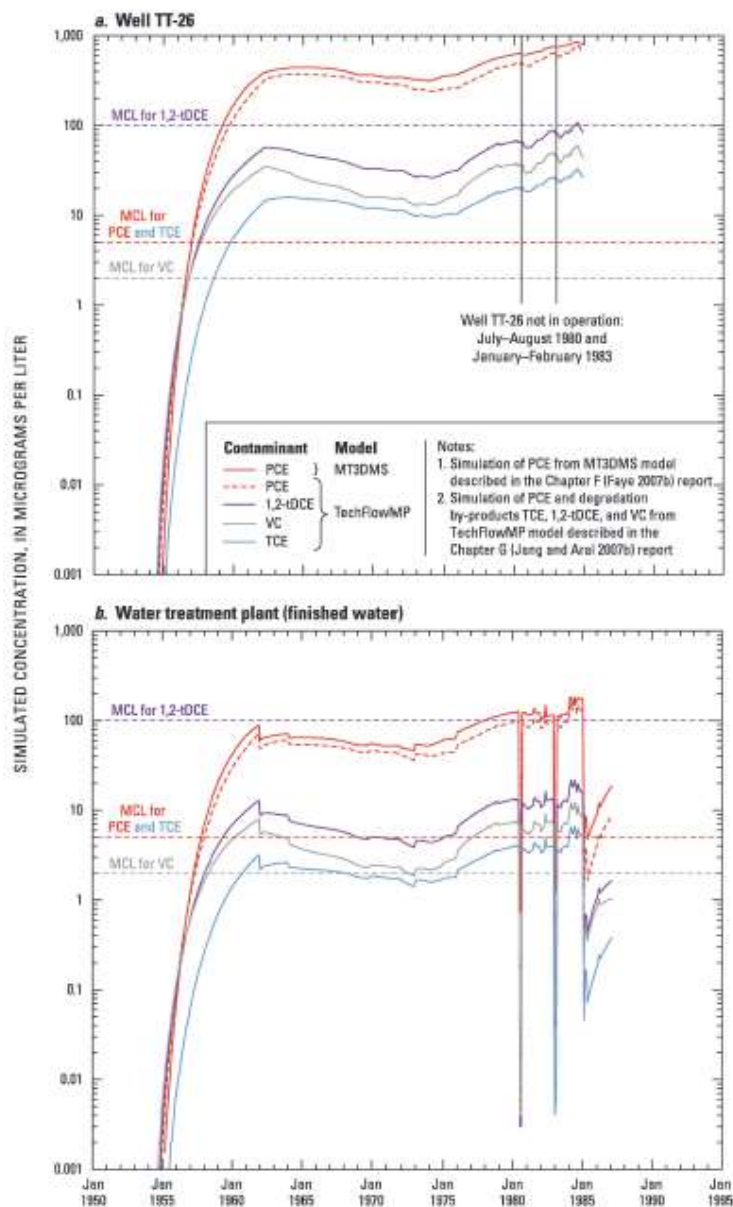


Figure A19. Simulated concentration of tetrachloroethylene (PCE) and degradation by-products trichloroethylene (TCE), *trans*-1,2-dichloroethylene (1,2-tDCE), and vinyl chloride (VC) (a) at water-supply well TT-26 and (b) in finished water from water treatment plant, Tarawa Terrace, U.S. Marine Corps Base Camp Lejeune, North Carolina. [MCL, maximum contaminant level]

Figure 11. Simulated PCE concentrations and its by-products at water supply well TT-26 and the WTP of Tarawa Terrace site (Figure A19, page A43, ATSDR, 2007a)

Uncertainty and sensitivity analyses were also successfully completed for the Tarawa Terrace study. The uncertainty analysis included the porous media parameter uncertainty, contaminant property uncertainty, model setup uncertainty and environmental factor uncertainty as described in Figure 12a. The parameter uncertainties were introduced using two stage Monte Carlo simulations (MCS). Pumping schedule uncertainties were introduced using sub-models developed by MESL program (see section 5.1). The results of this analysis yielded the outcome given in Figure 12b for PCE. In this figure the range of PCE concentrations derived from the probabilistic analysis using MCS is shown as a band of solutions and represents 95% of all possible results. The current MCL for PCE (5 µg/L) was first exceeded in finished water during October 1957-August 1958; these solutions include November 1957, the date determined using the calibrated fate and transport model (ATSDR, 2007b)-a deterministic modeling analysis approach. The PCE concentration in Tarawa Terrace WTP finished water during January 1985, simulated using the probabilistic analysis, ranges from 110-251 µg/L (95 percent of Monte Carlo simulations). This range includes the maximum calibrated value of 183 µg/L (derived without considering uncertainty and variability using MT3DMS (ATSDR, 2007b) and the maximum measured value of 215 µg/L. The red line trend includes the variability observed when pumping schedule uncertainty is included in the analysis. Therefore, the probabilistic analysis results-obtained by using two stage Monte Carlo simulation-provide a sense of confidence in the historically reconstructed deterministic PCE concentrations that were delivered to residents of Tarawa Terrace in finished water from the WTP.

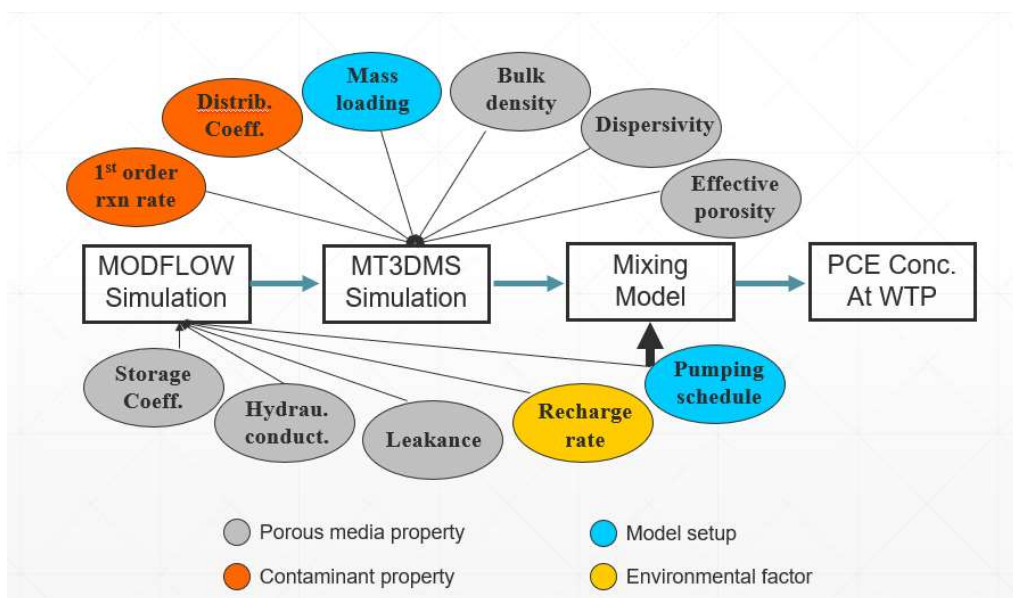


Figure 12a. The parameter uncertainty, model setup uncertainty and environmental factor uncertainty analysis structure used in ATSDR study of the Camp Lejeune site.

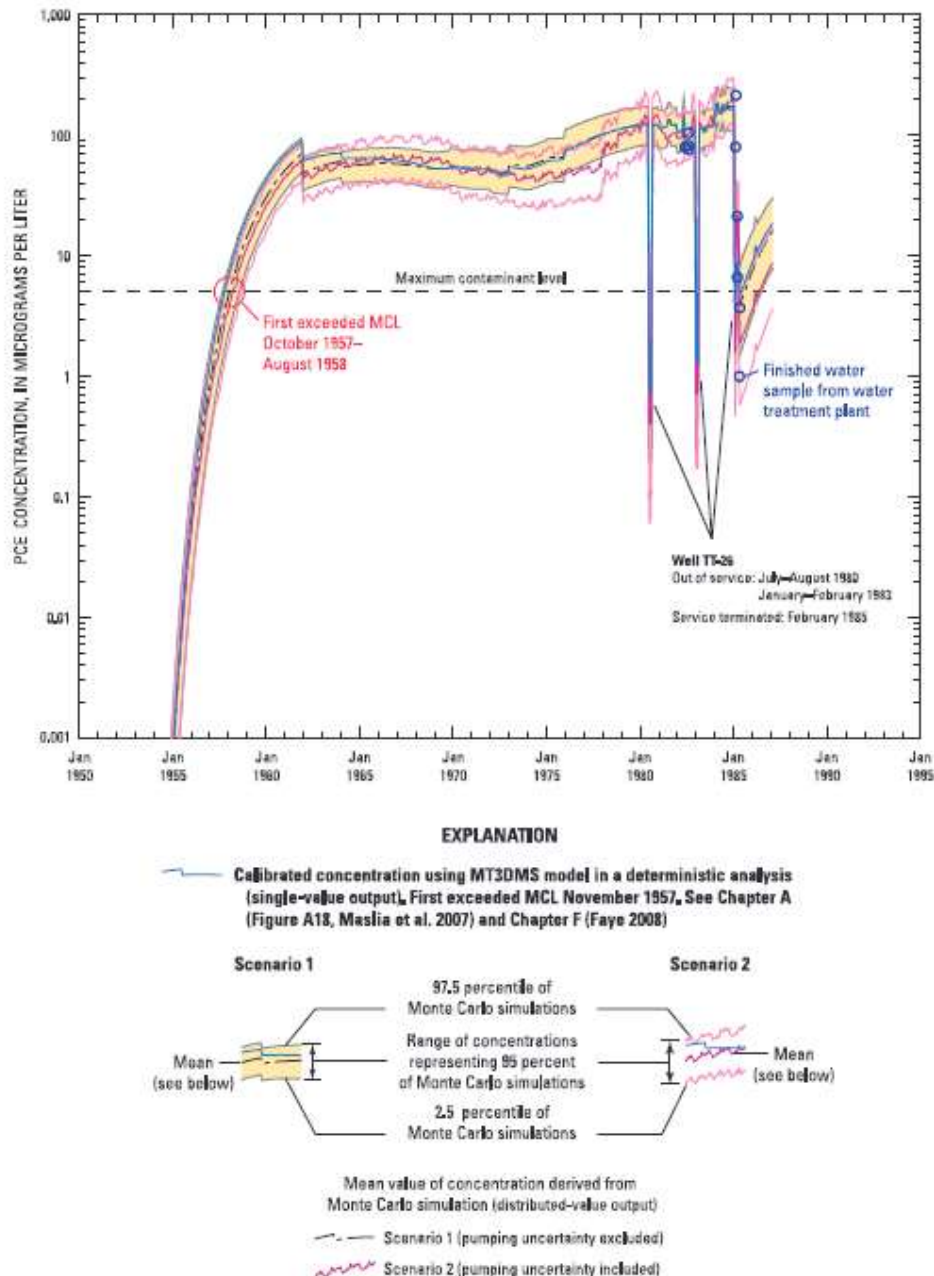


Figure 129. Concentrations of tetrachloroethylene in finished water at the water treatment plant derived from scenario 1 (pumping uncertainty excluded) and scenario 2 (pumping uncertainty included) probabilistic analyses using Monte Carlo simulation, Tarawa Terrace, U.S. Marine Corps Base Camp Lejeune, North Carolina. [See Appendix 15 for tabular listing; PCE, tetrachloroethylene; MCL, maximum contaminant level]

Figure 12b. Reconstructed drinking water concentrations at the Tarawa Terrace Water Treatment Plant including parameter uncertainty and pumping uncertainty, (Figure I29, page I55, ATSDR, 2007i)

Tabulated results of computed versus observed PCE concentrations at WTP were also given in Chapter F report, Figure 13. Third column in Table F14 indicates that the predicted values were all in calibration range except for four predicted values which indicates good capture of the observed values at the WTP. Detailed analysis of sensitivity analysis is also included in (ATSDR, 2007i) which will not be repeated here.

Table F14. Computed and observed tetrachloroethylene (PCE) concentrations in water samples collected at the Tarawa Terrace water treatment plant and calibration target range, U.S. Marine Corps Base Camp Lejeune, North Carolina.

[µg/L, microgram per liter; TTWTP, Tarawa Terrace water treatment plant; ND, not detected]

Date	PCE concentration, in µg/L		Calibration target range, in µg/L
	Computed ¹	Observed	
² TTWTP Building TT-38			
5/27/1982	148	180	25–253
7/28/1982	112	³ 104	33–329
7/28/1982	112	³ 76	24–240
7/28/1982	112	³ 82	26–259
2/5/1985	176	³ 80	25–253
2/13/1985	3.6	⁵ ND	0–10
2/19/1985	3.6	⁴ ND	0–2
2/22/1985	3.6	⁵ ND	0–10
3/11/1985	8.7	⁴ ND	0–2
3/12/1985	8.7	⁴ 6.6	2.1–21
3/12/1985	8.7	⁴ 21.3	6.7–67
4/22/1985	8.1	⁵ 1	0.3–3.2
4/23/1985	8.1	⁵ ND	0–10
4/29/1985	8.1	³ 3.7	1.2–11.7
5/15/1985	4.8	⁵ ND	0–10
7/1/1985	5.5	⁵ ND	0–10
7/8/1985	5.5	⁵ ND	0–10
7/23/1985	5.5	⁵ ND	0–10
7/31/1985	5.5	⁵ ND	0–10
8/19/1985	6.0	⁵ ND	0–10
9/11/1985	6.0	⁵ ND	0–10
9/17/1985	6.0	⁵ ND	0–10
9/24/1985	6.0	⁵ ND	0–10
10/29/1985	6.0	⁵ ND	0–10
² TTWTP Tank STT-39			
2/11/1985	176	⁵ 215	0–10

¹Weighted-average computation

²See Plate 1, Chapter A report, for location (Maslin et al. 2007)

³Detection limit is unknown

Figure 13. Reconstructed drinking water concentrations at the Tarawa Terrace Water Treatment Plant and a comparison with the observed concentrations at the WTP during the period (1982 – 1985), (Table F14, page F42, ATSDR, 2007f)

Modeling results for Tarawa Terrace show that former Marines and their families who lived in Tarawa Terrace family housing units from November 1957 through February 1987 received finished water primarily contaminated with Tetrachloroethylene (PCE), a dry-cleaning solvent. Levels of PCE in finished water during this period exceeded the amount currently allowed by the Environmental Protection Agency (USEPA) under the Safe Drinking Water Act, known as the Maximum Contaminant Level (MCL), which was set at 5 µg/L in 1992 (ATSDR, 2007a). PCE concentrations first exceeded the MCL in

November 1957 and routinely exceeded it, except for two “two-month” periods when Well TT-26 was not in operation, until February 1987, when the water treatment plant was finally decommissioned.

In summary, based on field data, modeling results, and the historical reconstruction process, the following observations can be made with respect to water contamination at Tarawa Terrace (ATSDR, 2007):

- Simulated PCE concentrations exceeded the current MCL of 5 µg/L at water-supply well TT-26 for 332 months—January 1957–January 1985; the maximum simulated PCE concentration was 775 µg/L; the maximum measured PCE concentration was 1,580 µg/L during January 1985.
- Simulated PCE concentrations exceeded the current MCL of 5 µg/L in finished water at the Tarawa Terrace WTP for 346 months—November 1957–February 1987; the maximum simulated PCE concentration in finished water was 176 µg/L; the maximum measured PCE concentration in finished water was 215 µg/L during February 1985 (Figure 13).
- Simulation of PCE degradation by-products—TCE, *trans*-1,2-dichloroethylene (1,2-tDCE), and vinyl chloride—indicated that maximum concentrations of the degradation by-products generally were in the range of 10–100 µg/L at water-supply well TT-26; measured concentrations of TCE and 1,2-tDCE on January 16, 1985, were 57 and 92 µg/L, respectively (Figure A19, 2007a).
- Maximum concentrations of the degradation by-products in finished water at the Tarawa Terrace WTP generally were in the range of 2–15 µg/L; measured concentrations of TCE and 1,2-tDCE on February 11, 1985, were 8 and 12 µg/L respectively. Max TCE 7 µg/L and max 1,2 tDCE 22 µg/L levels were simulated as given in Table A13, page A44 (ATSDR, 2007a).
- PCE concentrations in finished water at the Tarawa Terrace WTP exceeding the current MCL of 5 µg/L could have been delivered as early as December 1956 and no later than December 1960. Based on probabilistic analyses, the most likely dates that finished water first exceeded the current MCL ranged from October 1957 to August 1958 (95 percent probability), with an average first exceedance date of November 1957.
- PCE and PCE degradation by-products contamination in finished water ceased after February 1987; the Tarawa Terrace WTP was closed March 1987.

Based on the Tarawa Terrace study results (ATSDR, 2007) the following conclusions can be drawn for the PCE contamination of finished water at Tarawa Terrace:

- PCE concentrations in the finished water at Tarawa Terrace first exceeded MCL level of 5 µg/L during the period 1957-1958.
- During the period 1957 – 1962, the PCE concentrations in the finished water at Tarawa Terrace continued to increase sharply from 5 µg/L to a range of 42 µg/L – 92 µg/L, Figures 11 and 12b.
- During the period 1962 – 1987, the PCE concentrations in the finished water at Tarawa Terrace continued to gradually increase from 42 µg/L – 92 µg/L range to a range of 110 µg/L – 250 µg/L, Figures 11 and 12b, except for two “two-month” periods when Well TT-26 was not in operation.
- Similar observations can be made for the degradation by-products of PCE from Figure 11.
- The simulated monthly mean concentrations and confidence boundaries given in ATSDR reports and the conclusions reported above are reliable and represent, within reasonable scientific and engineering certainty, the contaminant levels in finished water at Camp Lejeune from 1953 to 1987.

I confirm that the conclusions I summarized above and others that exist in ATSDR reports were reached by applying generally accepted methods in the fields of hydrogeology, geochemistry, environmental sciences, engineering and mathematical and stochastic computational modeling. These conclusions are my own and are based on my education, training, and experience, as well as the documents, public information, diagrams, data, and facts that were available to me at the time of writing. I hold these conclusions to a reasonable degree of scientific and engineering certainty. I reserve the right to supplement and/or amend my conclusions on this matter as necessary as additional documents or information are made available to me.

6.6 Hadnot Point – Holcomb Boulevard Study

The Hadnot Point Water Treatment Plant (HPWTP) (building 20) was likely constructed during 1941 and 1942, along with much of the original infrastructure of the Base, Figure 14.

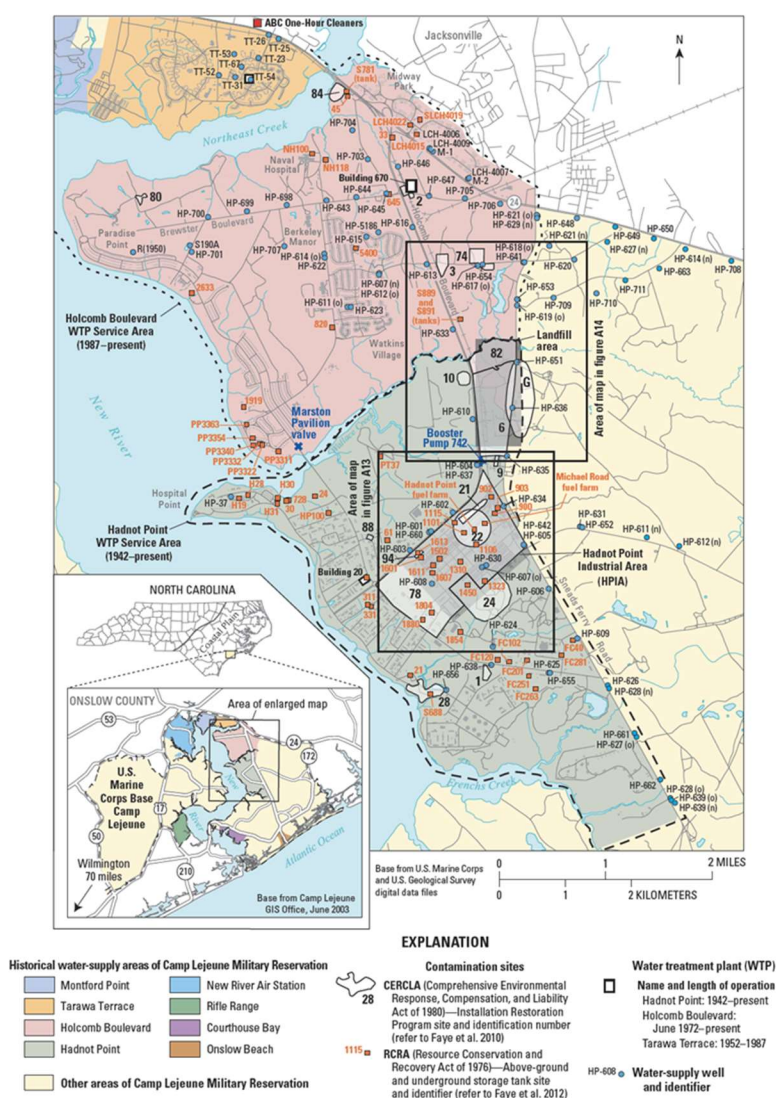


Figure A1. The Hadnot Point-Holcomb Boulevard study area, U.S. Marine Corps Base Camp Lejeune, North Carolina.

Figure 14. Hadnot Point Holcomb Boulevard study area and geographic boundaries. (Figure A1, ATSDR, 2013a)

The original capacity of HPWTP is unknown. However, July 21, 1954, USMCB Camp Lejeune property record card indicates a capacity of 5 million gallons per day (MGD) (Scott R. Williams, USMCB Camp Lejeune, written ATSDR communication, February 22, 2012).

During 1942, the 21 original water-supply wells at Camp Lejeune (HP-601 to HP-621) were placed into operation and provided a total combined capacity of 7.3 MGD (CLHDW CDR File #2292, p. 1). Throughout the years, additional water-supply wells were brought online to increase system capacity or to replace abandoned wells. Some of the water-supply wells were removed from service and eventually were abandoned because of contaminants found in groundwater at nearby disposal sites and in the supply wells themselves (ATSDR, 2013a). As of June 2008, 27 wells were supplying groundwater to HPWTP with a total combined capacity of about 5.9 MGD and a delivered groundwater (raw water) flow rate of 2.2 MGD (ATSDR, 2013a).

Until the summer of 1972, all finished water distributed to bachelor and family housing units and all other facilities within the Hadnot Point-Holcomb Boulevard study area were supplied by the HPWTP (Building 20). After June 1972, finished water distributed to Berkeley Manor, Midway Park, Paradise Point, and Watkins Village family housing areas was supplied by the HBWTP. Also included in the HBWTP service area are the current U.S. Naval Hospital (from 1983), the USMCB Camp Lejeune high school, and the Brewster Boulevard junior high school. The Holcomb Boulevard water-distribution system is linked to the Hadnot Point water-distribution system near McHugh Boulevard and Wallace Creek (Marston Pavilion valve) and near Holcomb Boulevard and Wallace Creek at booster pump 742. For operational reasons, the two water-distribution systems were occasionally connected—exceptions being some documented connections that occurred during the late spring and early summer months of 1972–1986 (ATSDR, 2013a).

The historical reconstruction analysis of the Hadnot Point and Holcomb Boulevard area is more complex than the Tarawa Terrace study area described above. This is because there are multiple contamination sources and multiple contaminants at the site. The study also includes a water distribution system analysis, and the study area is much larger than the Tarawa Terrace study area. Accordingly, the historical reconstruction analyses discussed herein will focus on two general areas (within the Hadnot Point-Holcomb Boulevard study area) that contributed most substantially to water-supply well contamination. These are the Hadnot Point Industrial Area (HPIA) and the Hadnot Point landfill (HPLF) area.

The Hadnot Point-Holcomb Boulevard historical reconstruction covers the period 1942–2008. The first year, 1942, was chosen because operations at USMCB Camp Lejeune began in late 1941. The last year, 2008, was chosen to take advantage of more recent water-supply well operational data and contaminant concentration data to assist with model calibration.

As is the case with the Tarawa Terrace site, groundwater is the sole source of water at this site. Of critical need, in terms of historical reconstruction, was information and data on the monthly raw water production of supply wells (to enable computation of flow-weighted finished-water concentrations) and the distribution of finished water to family housing areas. The supply of finished water for the Hadnot Point-Holcomb Boulevard study area was composed of the following: (1) supply of water from groundwater wells to the HPWTP (1942–present) and the HBWTP (1972–present), (2) delivery of finished water from the WTPs through a network of pipelines and storage tanks to housing areas and other facilities, and (3) intermittent transfers of Hadnot Point finished (contaminated) water through connecting pipelines to the Holcomb Boulevard water-distribution system during late spring and early summer months for years 1972–1985.

Groundwater is the sole source of water supply at the site. To reconstruct contaminant concentrations and the timeline of contaminant movement at the site a series of modeling techniques were implemented. These are:

- To simulate predevelopment groundwater-flow conditions, the **MODFLOW** code was used. In addition to the trial-and-error calibration procedures, the estimates of model parameter values were supplemented using the objective parameter estimation code **PEST-12** (Doherty 2003, 2010).
- To simulate the transient (unsteady) effects caused primarily by the onset and continued operation of water-supply wells in the study area, historical water-supply well operating schedules were developed and again the **MODFLOW** code was used. The operating schedules of water supply wells was accomplished for the period 1942–2008 using **TechWellOp** and **PSOpS** sub-models described earlier (Section 5.1).
- Groundwater contaminant fate and transport analysis of TCE and benzene were simulated using **MT3DMS** and **TECHFLOWMP**. In addition, the fate and transport of PCE and TCE from source areas in the HPLF area to water-supply well HP-651 was simulated using the **MT3DMS**, **TechFlowMP**, and **LCM-TechCONTROL** code (Section 5.1).
- The occurrence of benzene as an LNAPL in the subsurface in the vicinity of the Hadnot Point Fuel Farm (HPFF) and HPIA is described in (ATSDR, 2013) and in Section 6.4. Estimates of subsurface LNAPL volume were developed using historical measurements of LNAPL thickness over time—monitor well data—in the HPIA combined with the **TechNAPLVol** code that uses semi-analytical and numerical methods in a three-dimensional domain (ATSDR, 2013). The resulting saturation profile from the LNAPL volume analysis was used within the **TechFlowMP** model code to simulate the dissolution of LNAPL constituents and the fate and transport of dissolved phase benzene (Section 5.1).
- An alternative method, a linear state-space representation of a contaminated aquifer system designated as the linear control model (**LCM**) methodology, was developed to reconstruct contaminant concentrations in water-supply wells (ATSDR, 2013). Using the model code **TechControl**, this simplified approach was used to reconstruct historical contaminant concentrations, including PCE, TCE, 1,2-tDCE, and VC, in water-supply well HP-651 in the HPLF area. A description of this code is given in Section 5.1 of this report. A more detailed description of the methodology can be found in (ATSDR, 2013; Guan, 2009). Results from the LCM application at water-supply well HP-651 were compared to simulated PCE and TCE concentrations obtained using the **MT3DMS** numerical fate and transport code later when the **MT3DMS** study was completed. The comparisons of these solutions and the analytical analysis of these comparisons are discussed extensively in (ATSDR, 2013, Chapter A supplement 5) for the results of the **TechControl** application at the HP-HB site which will not be repeated here.
- Reconstructed (simulated) monthly mean concentrations of PCE, TCE, 1,2-tDCE, VC, and benzene for finished water at the HPWTP were determined by using a materials mass balance model (**Mass Balance, simple mixing**) to compute the flow-weighted average concentration of the aforementioned contaminants. The use of the material mass-balance method is justified because all raw water from water-supply wells within the HPWTP service area was mixed at the HPWTP prior to treatment and distribution.
- Intermittent operations of booster pump 742 and the opening of the Marston Pavilion valve transferred contaminated Hadnot Point finished water to Holcomb Boulevard family housing areas and other facilities. Owing to missing data related to pump and valve operations, probabilistic analyses of the intermittent water transfers during the period 1972–1985 were conducted

using a Markov analysis (Ross 1977) and the code **TechMarkovChain** (Section 5.1). Results provided probabilistic estimates of the intermittent transfer of contaminated Hadnot Point finished water to the Holcomb Boulevard family housing areas.

- Using the reconstructed monthly mean concentrations of PCE, TCE, 1,2-tDCE, VC, and benzene in finished water from the HPWTP and the Markov analysis to estimate the occurrence of intermittent water transfers, extended period simulations of hydraulics and water quality for the water-distribution system serving the Holcomb Boulevard housing areas and other facilities were conducted. **EPANET 2** (Rossman 2000) was used for the water distribution system analysis.
- Assessment of parameter sensitivity, variability, and uncertainty associated with model simulations of groundwater flow, contaminant fate and transport, and water-distribution system analyses were also conducted (ATSDR, 2013).

The calibration and validation analyses were successfully completed for all these modeling stages following the complex system analysis techniques described earlier in this expert report (see Section 6). The details of this analysis can be found in (ATSDR, 2013) which will not be repeated here. After successful completion of calibration and validation analyses the simulation results of contaminants at WTP were generated. These results are summarized in Figure 15, 16 and 17 as Tables and Figures.

Table A18. Selected measured and reconstructed (simulated) concentrations of tetrachloroethylene (PCE), trichloroethylene (TCE), *trans*-1,2-dichloroethylene (1,2-tDCE), vinyl chloride (VC), and benzene at the **Hadnot Point water treatment plant, Hadnot Point-Holcomb Boulevard study area**, U.S. Marine Corps Base Camp Lejeune, North Carolina.
[µg/L, microgram per liter; J, estimated]

Contaminant	¹ Measured data		² Reconstructed (simulated)		² Reconstructed (maximum value)	
	Sample date	Concentration, in µg/L	Simulation date	Concentration, in µg/L	Simulation date	Concentration, in µg/L
PCE	5/27/1982 ¹	15	May 1982	21	Nov. 1983	39
	7/27/1982 ⁴	100	July 1982	27		
	12/4/1984 ⁶	3.9J	Nov. 1984	31		
	2/5/1985 ⁷	7.5J	Jan. 1985	16		
TCE	5/27/1982 ¹	1,400	May 1982	438	Nov. 1983	783
	7/27/1982 ³	19	Aug. 1982	670		
	7/27/1982 ⁶	21	Aug. 1982	670		
	12/4/1984 ⁵	46	Nov. 1984	639		
	12/4/1984 ⁶	200	Nov. 1984	639		
	12/12/1984 ⁶	2.3J	Dec. 1984	43		
	12/19/1984	1.2	Dec. 1984	43		
	2/5/1985 ⁷	429	Jan. 1985	324		
1,2-tDCE	12/4/1984 ⁶	83	Nov. 1984	358	Nov. 1983	435
	12/4/1984 ⁵	15	Dec. 1984	26		
	12/12/1984 ⁶	2.3J	Dec. 1984	26		
	2/5/1985 ⁷	150	Jan. 1985	163		
VC	2/5/1985 ⁷	2.9J	Jan. 1985	31	Nov. 1983	67
Benzene	11/19/1985 ^{7,8,9}	2,500	Nov. 1985	3	Apr. 1984	12
	12/10/1985 ⁷	38	Dec. 1985	3		
	12/18/1985 ⁷	1.0	Dec. 1985	3		

¹ Data from Faye et al. (2010, Tables C11 and C12)

² Simulation results represent the last day of each month (e.g., May 31); results reported for simulation month nearest the sample date; refer to Appendix A7 for complete listing of reconstructed finished-water concentrations

³ Water sample collected at Building NH-1; data reported as unreliable

⁴ Water sample collected at Building FC-530

⁵ Untreated water

⁶ Treated water

⁷ Treatment status unknown

⁸ Laboratory analysis noted with: "Sample appears to have been contaminated with benzene, toluene, and methyl chloride" (JTC Environmental Consultants 1985)

⁹ Data noted with: "Not Representative" (U.S. Marine Corp Base Camp Lejeune Water Document CLW #1356)

Figure 15. Selected simulation results for TCE, PCE and other by-products at HPWTP. More detailed results and their analysis can be found in (ATSDR, 2013a).

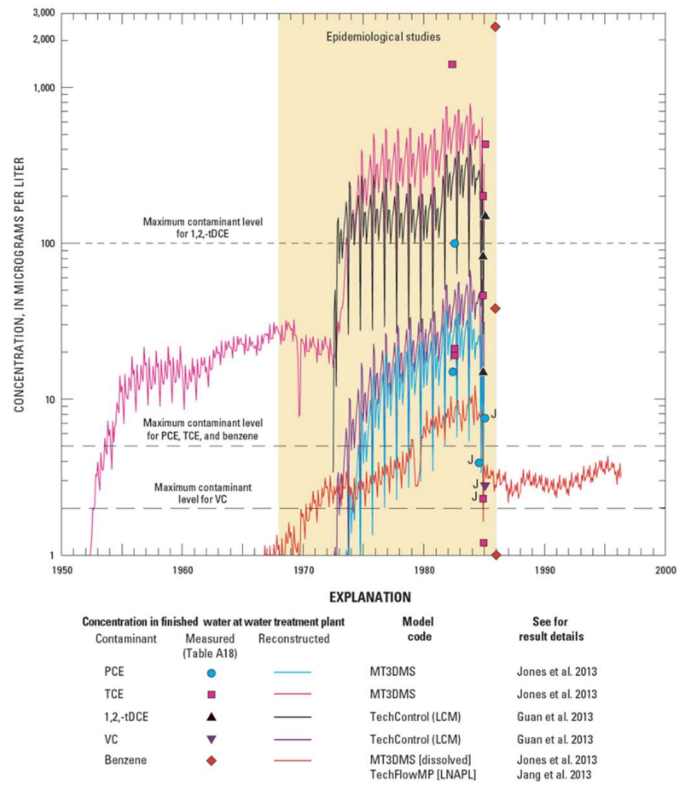


Figure A27. Reconstructed (simulated) finished-water concentrations of tetrachloroethylene (PCE), trichloroethylene (TCE), *trans*-1,2-dichloroethylene (1,2-tDCE), vinyl chloride (VC), and benzene, and measured concentrations, Hadnot Point water treatment plant, Hadnot Point–Holcomb Boulevard study area, U.S. Marine Corps Base Camp Lejeune, North Carolina. (Note: See Appendix A7 for monthly mean finished-water concentration and Table A3 for detailed list of current maximum contaminant levels.) [J, estimated; LCM, linear control model; LNAPL, light nonaqueous phase liquid]

Figure 16. Selected simulation results for the HP and HB areas. More detailed results and their analysis can be found in (ATSDR, 2013a).

Results provided in Figure 16 and summary statistics provided in Figure 15 indicate a reasonable capture of the concentrations at the WTP.

Table A14. Summary statistics for reconstructed contaminant concentrations at selected water-supply wells and the Hadnot Point water treatment plant, Hadnot Point–Holcomb Boulevard study area, U.S. Marine Corps Base Camp Lejeune, North Carolina.^{1,2}

[MCL, maximum contaminant level; TCE, trichloroethylene; PCE, tetrachloroethylene; VC, vinyl chloride; 1,2-*t*DCE, *trans*-1,2-dichloroethylene; N/A, not applicable; µg/L, microgram per liter]

Water-supply identification (contaminant)	Reconstructed (simulated) concentration, in micrograms per liter				³ Duration in months exceeding MCL (month and year first exceeding MCL)	Date well stopped pumping in model
	¹ July 1942–June 1996			Range during health study period of interest (January 1968– February 1985)		
	Maximum (date of maximum)	Mean	Standard deviation			
⁴ Hadnot Point Industrial Area (HPIA)						
HP-602 (TCE)	658 (Jan. 1959)	359	222	357–499	390 (Oct. 1951)	Dec. 1984
HP-608 (TCE)	50 (Sept. 1972)	25	20	28–50	307 (Aug. 1957)	Dec. 1984
HP-634 (TCE)	659 (Oct. 1968)	391	170	212–659	283 (Aug. 1960)	Dec. 1984
HP-602 (benzene)	236 (Nov. 1984)	53	65	48–236	309 (July 1958)	Dec. 1984
HP-603 (benzene)	179 (May 1996)	29	43	6–129	345 (Aug. 1967)	June 1996
HP-608 (benzene)	11 (Sept. 1979)	4	4	6–11	201 (June 1966)	Dec. 1984
⁴ Hadnot Point landfill (HPLF)						
HP-651 (PCE)	353 (Dec. 1982)	249	122	⁵ 0–353	142 (Apr. 1973)	Feb. 1985
HP-651 (TCE)	7,135 (Dec. 1978)	5,831	2,071	⁵ 1–7,135	150 (Aug. 1972)	Feb. 1985
HP-651 (1,2- <i>t</i> DCE)	4,037 (Dec. 1984)	3,284	572	⁵ 69–4,037	150 (Aug. 1972)	Feb. 1985
HP-651 (VC)	660 (Nov. 1984)	391	173	⁵ 8–660	151 (July 1972)	Feb. 1985
⁴ Hadnot Point water treatment plant (HPWTP)						
HPWTP (PCE)	39 (Nov. 1983)	4	8	0–39	114 (Aug. 1974)	N/A
HPWTP (TCE)	783 (Nov. 1983)	107	180	0–783	374 (Aug. 1953)	N/A
HPWTP (1,2- <i>t</i> DCE)	435 (Nov. 1983)	53	95	0–435	128 (Nov. 1972)	N/A
HPWTP (VC)	67 (Nov. 1983)	6	13	0–67	144 (Nov. 1972)	N/A
HPWTP (benzene)	12 (Apr. 1984)	2	3	0–12	63 (Jan. 1979)	N/A

¹For periods of time when concentrations are equal to or exceed the current MCLs for TCE, PCE, and benzene; non-rounded concentration values used to calculate statistics

²Current MCLs are as follows: vinyl chloride, 2 µg/L; PCE, TCE, and benzene, 5 µg/L; 1,2-*t*DCE, 100 µg/L (see Table A3)

³Statistics are computed solely for periods of operation

⁴See Appendix A3 for complete listing

⁵Water-supply well HP-651 did not start pumping until July 1972; values shown represent dates of July 1972–February 1985

⁶Finished-water concentrations; see Appendix A7 for complete listing

Figure 17. Summary statistics for reconstructed contaminant concentrations at selected water-supply wells and the Hadnot Point water treatment plant, Hadnot Point–Holcomb Boulevard study area, U.S. Marine Corps Base Camp Lejeune, North Carolina

Based on field data, uncertainty and sensitivity analyses, and the historical reconstruction process, the following conclusions are made with respect to groundwater and finished-water contamination of the Hadnot Point–Holcomb Boulevard (HPHB) study area.

For the Hadnot Point water treatment plant (HPWTP):

- Within the HPWTP, TCE routinely exceeded its current MCL during the period (1955–1985). TCE concentrations in finished water at the HPWTP ranged from about 10 to 30 µg/L for the period 1955–1972, prior to the onset of pumping from water-supply well HP-651 (Figure A27, ATSDR, 2013). After the onset of pumping of water-supply well HP-651 during July 1972, finished-water concentrations increased to a maximum computed value of 670 µg/L during August 1982 (Table A18, ATSDR 2013). Measured concentrations of PCE, TCE, 1,2-tDCE, VC, and benzene and historical reconstruction (simulated) results for the HPWTP are listed in Table A18 (ATSDR, 2013a).
- The reconstructed contamination of finished water exceeding the current maximum contaminant level (MCL) for TCE was 374 months (August 1953–January 1985) (Table A14, ATSDR, 2013a) Figure 17. With the onset of pumping at well HP-651 during July 1972, the concentration of TCE in well HP-651 affected the resulting finished-water concentrations of TCE at the HPWTP, which exceeded 750 µg/L during November 1983 (Table A14, ATSDR, 2013). Measured TCE concentrations in finished water at the HPWTP during the period May 1982 through February 1985 ranged from 1.2 µg/L to 1,400 µg/L (Faye et al. 2010, Table C11, ATSDR, 2013).
- The reconstructed contamination of finished water exceeding the current MCL for PCE was 114 months (August 1974–January 1985) (Table A14), Figure 17, also a consequence of the onset of pumping of well HP-651. The maximum reconstructed finished-water concentration of PCE was about 39 µg/L during November 1983 (Table A14, ATSDR, 2013a). Measured PCE concentrations at the HPWTP ranged from below detection limits (1–10 µg/L) to 100 µg/L during the period May 1982–February 1985 (Faye et al. 2010, Table C11, ATSDR, 2013).
- The reconstructed duration of contamination of finished water exceeding the current MCL for benzene was 63 months (January 1979–November 1984) (Table A14, ATSDR, 2013a), Figure 17.
- The maximum reconstructed finished water concentration of benzene was about 12 µg/L during April 1984 (Table A14, ATSDR, 2013). Measured benzene concentrations at the HPWTP ranged from below detection limits (10 µg/L) to 38 µg/L during the period December 1984–December 1985. An unexplained value of 2,500 µg/L of benzene was measured on November 11, 1985 (Faye et al. 2010, Table C12, ATSDR, 2013).

For the Holcomb Boulevard housing area:

- When this housing area was serviced by the HPWTP (prior to June 1972), the maximum reconstructed (simulated) monthly mean TCE concentration in finished water (January 1968–December 1985) was 32 µg/L during August 1968 and August 1969 (Appendix A7, ATSDR, 2013a). The minimum reconstructed (simulated) monthly mean TCE concentration in finished water (January 1968–December 1985) was 8 µg/L (September and October 1969). TCE concentrations in finished water first exceeded the MCL during August 1953 (Appendix A7, ATSDR, 2013).
- After June 1972 when the Holcomb Boulevard water treatment plant (HBWTP) came online to service this housing area, an interconnection analysis indicates that the maximum reconstructed

(simulated) TCE concentration in finished water was 66 µg/L during February 1985 for the Paradise Point area (Figure A29(H), ATSDR, 2013a).

- After June 1972 when the HBWTP came online to service this housing area, the maximum reconstructed (simulated) monthly concentrations for PCE, 1,2-tDCE, and VC in finished water for the Holcomb Boulevard housing area occurred during February 1985 and were 3 µg/L, 33 µg/L, and 6 µg/L, respectively (Table A21(H), ATSDR, 2013a). The maximum reconstructed (simulated) monthly concentration for benzene was 3 µg/L, occurring during January, February, April, May, and June 1972 (Table A21(H), ATSDR, 2013a).

For the Hadnot Point Industrial Area (HPIA):

- The maximum reconstructed (simulated) monthly mean TCE concentrations at water-supply wells HP-602, HP-608, and HP-634 were 658 µg/L during January 1959, 50 µg/L during September 1972, and 659 µg/L during October 1968, respectively (Table A14, ATSDR, 2013a). Measured TCE concentrations at well HP-602 ranged from an estimated 0.7 µg/L to 1,600 µg/L during the period of record, July 1984 to January 1991 (Table A4(H), ATSDR, 2013a). Corresponding concentrations at well HP-608 ranged from 9 µg/L to 110 µg/L during the period of record, December 1984 to November 1986. In well HP-634 between December 1984 and January 1991, TCE concentrations ranged from less than detection limits to 1,300 µg/L.
- Substantial volumes of liquid hydrocarbon fuels were lost due to leakage to the subsurface within the Hadnot Point Industrial Area (HPIA). This area contained as many as 10 active water-supply wells. Despite the large volumes lost, finished-water concentrations of benzene only exceeded the current MCL of 5 µg/L in some of the wells during the period 1980–1985.
- At water-supply wells with measured benzene concentrations exceeding detection limits (HP-602 and HP-608), the maximum reconstructed (simulated) monthly benzene concentration was 236 µg/L at well HP-602 during November 1984 and 11 µg/L at well HP-608 during September 1979 (Table A14, Appendix A3, ATSDR, 2013). Measured benzene concentrations at well HP-602 during the period of record, July 1984 to January 1991, ranged from less than 1.0 µg/L to 720 µg/L. Measured benzene concentrations at well HP-608 during the period of record, December 1984 to November 1986, ranged from 1.6 µg/L to an estimated 4.0 µg/L. All measured benzene concentrations in well HP-603 were below detection limits (Table A5(H), ATSDR, 2013a).

For the Hadnot Point landfill (HPLF) area:

- The maximum reconstructed (simulated) monthly mean TCE concentration at water-supply well HP-651 was 7,135 µg/L during December 1978 (Table A14, ATSDR, 2013a), Figure 17. Measured TCE concentrations during the period of record, January 1985 to January 1991, ranged from 13 µg/L to 18,900 µg/L (Table A4(H), ATSDR, 2013a).
- The maximum reconstructed (simulated) monthly PCE concentration at water-supply well HP-651 was 353 µg/L during December 1982 (Table A14, ATSDR, 2013), Figure 17. Measured PCE concentrations during the period of record, January 1985 through January 1991, ranged from 45 µg/L to 400 µg/L (Table A4(H), ATSDR, 2013a).
- The maximum reconstructed (simulated) monthly mean 1,2-tDCE concentration at water-supply well HP-651 was about 4,037 µg/L during December 1984 (Table A14), Figure 17. Measured 1,2-tDCE concentrations during the period of record, January 1985 to November 1986, ranged from 140 µg/L to 8,070 µg/L (Table A4(H), ATSDR, 2013a).

- The maximum reconstructed (simulated) monthly mean VC concentration at water-supply well HP-651 was 660 µg/L during November 1984 (Table A14, ATSDR, 2013), Figure 17. Measured VC concentrations during the period of record, January 1985 to January 1991, ranged from 70 µg/L to 655 µg/L (Table A4(H), ATSDR, 2013a).

In summary:

- The historical reconstruction process results show that finished water at U.S. Marine Corps Base Camp Lejeune was contaminated with varying levels of TCE, PCE, 1,2-tDCE, vinyl chloride and benzene from 1953 to 1987, (ATSDR, 2013).
- TCE contamination at the HP-HB finished water first exceeded MCL level of 5 µg/L during the period 1954 – 1955, Figure 16.
- During the period 1954 – 1973, the TCE contamination at the HP-HB finished water gradually increased from 5 µg/L to a range of 19 µg/L – 26 µg/L, Figure 16.
- During the period 1973 – 1985 there is a sharp increase in the TCE contamination at the HP-HB finished water from a range of 19 µg/L – 26 µg/L to a range of 380 µg/L – 620 µg/L, Figure 16.
- PCE contamination at the HP-HB finished water first exceeded MCL level of 5 µg/L during the period 1974 – 1975, Figure 16.
- During the period 1974 – 1985 there is a sharp increase in PCE contamination at the HP-HB finished water from 5 µg/L to a range of 20 µg/L – 30 µg/L, Figure 16.
- 1,2-tDCE contamination at the HP-HB finished water first exceeded MCL level of 100 µg/L during the period 1973 – 1974, Figure 16.
- During the period 1973 – 1985 there is a sharp increase in 1,2-tDCE contamination at the HP-HB finished water from 100 µg/L to a range of 220 µg/L – 390 µg/L, Figure 16.
- VC contamination at the HP-HB finished water first exceeded MCL level of 2 µg/L during the period 1972 – 1973, Figure 16.
- During the period 1972 – 1985 there is a sharp increase in VC contamination at the HP-HB finished water from 2 µg/L to a range of 34 µg/L – 52 µg/L, Figure 16.
- Benzene contamination at the HP-HB finished water first exceeded MCL level of 5 µg/L during 1980, Figure 16.
- During the period 1980 – 1985 there is a sharp increase in Benzene contamination at the HP-HB finished water from 5 µg/L to a range of 7 µg/L – 12 µg/L, Figure 16.
- The simulated monthly mean concentrations and confidence boundaries given in ATSDR reports and the conclusions reported above are reliable and represent, within reasonable scientific and engineering certainty, the contaminant levels in finished water at Camp Lejeune from 1953 to 1987.

I confirm that the conclusions I summarized above and others that exist in ATSDR reports were reached by applying generally accepted methods in the fields of hydrogeology, geochemistry, environmental sciences and engineering and mathematical and stochastic computational modeling. These conclusions are my own and are based on my education, training, and experience, as well as the documents, public information, diagrams, data, and facts that were available to me at the time of writing. I hold these conclusions to a reasonable degree of scientific and engineering certainty. I reserve the right to supplement and/or amend my conclusions on this matter as necessary as additional documents or information are made available to me.

6.7 Confidence in Validity of Historical Reconstruction Results

It is generally accepted that properly selected models that have been calibrated to site-specific conditions are appropriate for environmental management and decision-making – frequently there is no other form of guidance. While proper model calibration, sensitivity and uncertainty analyses improve confidence in model predictions, additional validation steps can increase confidence in simulation results. (Anderson et al., 1992; Bredehoeft and Konikow, 1993; Oreskes et al., 1994; Aral, 2010; Sahmel et al., 2010, Mei, 2003).

In an ideal world, the modeler would have an abundance of data. In that scenario, a portion of the data can be used to calibrate the model. The calibrated model can then be used to simulate values for comparison with the remaining independent data. This is the classical definition of model validation. In literature there are other definitions of validation as well. For example, IAEA (1982) defines validation as "A conceptual model and the computer code derived from it are validated when it is confirmed that the conceptual model and the computer code provide a good representation of the actual processes occurring in the real system." Or Schlesinger et al. (1979) defines validation as "substantiation that a computerized model within its domain of applicability possesses a satisfactory range of accuracy consistent with the intended application of the model." Or in Konikow and Bredehoeft (1992) it is stated that: "Ground-water models are embodiments of scientific hypotheses. As such, the models cannot be proven or validated, but only tested and invalidated." Or "...The absolute validity of a model can never be determined" (NRC, 1990).

Frequently, an abundance of data is unavailable (Maslia and Aral, 2004), and alternate validation means must be considered. In such situations, Sahmel et al. (2010) recommend alternative means to increase confidence (help validate) simulated exposure levels, including assessing:

i. Were the data used to formulate and calibrate the model taken from dependable and appropriate sources?

In my opinion, the ATSDR Camp Lejeune studies went to extraordinary measures to identify and collect all the dependable and appropriate sources of data for model calibration from Camp Lejeune archives.

ii. Has variability in the outcomes been considered?

There is abundant evidence in the ATSDR study that extensive analysis of stochastic uncertainty and sensitivity analysis was performed in the ATSDR study.

iii. Where possible, have multiple simulation approaches been utilized and generated similar results?

There were two additional modeling efforts employed in the ATSDR study which provided the reconfirmation of the results obtained from the standard applications that exist in public domain. These are the **TechControl** application that uses Linear control model and **TechFlowMP** application that is used to investigate the fate and transport processes at the Camp Lejeune site. These are two independent codes used in the analysis that satisfies the above criteria. One should also recognize the fact that two independent study groups implemented these parallel simulation approaches which yielded similar results. The comparisons of these solutions and the analytical analysis of these comparisons are discussed extensively in (ATSDR, 2013, Chapter A supplement 5) for the results of the **TechControl** application at the HP-HB site and in (ATSDR, 2007g) for the results of the **TechFlowMP** application (Figure 11) at the Tarawa Terrace site which will not be repeated here.

As philosophical discussion on validation concepts and definitions continues, as engineers working on the Camp Lejeune study, we believe being as close as possible to an observed system's behavior in modeling yields satisfactory answers to most practical problems that await immediate solutions. Having introduced some of the secondary philosophical discussions on validation concepts above, one must also recognize the following traditional validation step employed in ATSDR study as well. This step, described below, was completed for the models used in the ATSDR study of the Camp Lejeune site. I also notice that the completion of this step as an extra effort was not recognized or understood by some of the experts of the government in this case (see Dr. Dan Waddill's deposition, Tuesday, August 6, 2024).

As discussed in Sections 5 and 6 of this report, the ATSDR reconstruction model is a complex system and consists of five stages: i. pre-development (pre-pumping); ii. transient (pumping); iii. contaminant migration; and iv. production well mixing at the treatment plant; and v. the water distribution system analysis. The reconstructed sequence of model's ability to fit the independent data available for finished water (supplied to the consumer) at WTP (see Figures 12, 13 and 15) provides internal model validation that all four levels are accurately capturing the system behavior. For example, only those solutions that successfully simulate predevelopment (pre-pumping) and transient groundwater flow conditions can successfully capture the contaminant migration processes that would yield the independent data values we have at the WTP. Thus, in the final stage when WTP data is captured accurately, it requires that all three previous stages have been accurately incorporated into the model and validated appropriately. Thus, successful capture of the independent measured data at the WTP, as occurred here for Tarawa Terrace and Hadnot Point/Holcomb Boulevard, provides an internal validation of the **MT3DMS** model and the coupled complex modeling ensemble.

In summary, as stated by Dr. Robert Clark, Chair of the Expert Review Panel for the ATSDR Camp Lejeune studies, the ATSDR appropriately used the data sets that were available to it, and validated its model using the best approach under the circumstances:

"From a scientific viewpoint it would be ideal to have independent data sets. One set could be used to calibrate the models, and the second data set used for validation. If one is developing a model based on experimental data this approach can be built into the combined experimental and modeling effort. However, it has been my experience that such an ideal situation rarely exists in "real world" situations. Therefore, in my opinion, the best approach is to use available datasets in conjunction with sound engineering principles and the investigator's best judgment to establish the validity of the exposure models." Dr. Robert M. Clark, Chair Expert Review Panel, Maslia (Editor), 2009a, p. 76.

I concur with Dr. Clark's assessment given above. It is my opinion that ATSDR used the best available datasets, sound science and engineering principles, and professional judgment to establish the best possible reconstructed values of historical contaminant concentrations, and that, within a reasonable degree of scientific and engineering certainty, these were the contaminant levels delivered to Tarawa Terrace, Hadnot Point, and Holcomb Boulevard.

This assessment is reinforced by the successful peer review of ATSDR results in two top-tier journals (Maslia et al., 2009(b) for Tarawa Terrace and Maslia et al., 2016 for Hadnot Point-Holcomb Boulevard) along with the Grand Prize for Excellence in Environmental Engineering and Science Research (2015) from the prestigious American Academy of Environmental Engineering and Science for ATSDR's exemplary work at Camp Lejeune.

7. The NRC report

On June 27, 2009, I submitted a memorandum to EDRP/ATSDR which included my response to the NRC review comments on the Camp Lejeune study. The memorandum became an internal document for the Camp Lejeune study at ATSDR/CDC and was not released to the public. This section of my expert report includes both the contents of this memorandum and additional observations.

7.1 Comments on the NRC Report

The National Research Council (NRC) was requested to conduct a review by the Department of Navy (DON), under a mandate by the U.S. Congress (Public Law 109-364, Section 318). The U.S. Navy requested the NRC review to address whether adverse health outcomes are associated with past drinking-water contamination at U.S. Marine Corps (USMC) Base Camp Lejeune, North Carolina. The NRC review included an assessment of the Agency for Toxic Substances and Disease Registry's (ATSDR) overall study and in particular, the water modeling analyses and findings at Tarawa Terrace and vicinity. The NRC report released on July 13, 2009 (NRC 2009) covers a wide range of topics that include: (i) conceptual topics of exposure analysis and source characterization that are based on expert opinions of NRC committee members; (ii) water modeling based on observations of NRC committee and a critique of the science-based tools and analyses that are described in ATSDR technical reports on Tarawa Terrace and vicinity (Maslia et al., 2007; ATSDR, 2007); and, (iii) a critique of findings and interpretation of water-modeling study results that were completed by ATSDR at Tarawa Terrace and vicinity at Camp Lejeune.

On June 27, 2009, my responses to the NRC review were respectfully submitted to ATSDR to document my scientific evaluation of the findings of the NRC report. **Exhibit B** is the header of my original response to the NRC report.

To accurately respond to the comments made under each category I have identified above, the review comments I am providing below are grouped under two specific headings. This is in an effort so as not to confuse the reader and mix-and-match the review comments reported by the NRC committee which range from "conceptual topics" to the "comments on actual data reported" in the ATSDR water modeling study. I am confident that this approach will provide the reader with a clear picture of a range of topics critiqued in the NRC report. Accordingly, the discussion included in my review comments below will cover the range from "conceptual" perspectives on exposure analysis to "water modeling analysis" and "application specific" topics that are addressed in the NRC report.

It is important to note that the review comments I am providing below are only associated with the water modeling aspects of the ATSDR health study and the NRC report, and do not cover any epidemiologic study aspects since those topics are outside my expertise areas. All references to the "NRC report" refer to the NRC report titled, "Contaminated Water Supplies at Camp Lejeune: Assessing Potential Health Effects" and cited as NRC (2009) in the Reference section of this expert report. Furthermore, the reader should recognize that sentences in "italic font" under the heading "**Comment on...**" are extracted verbatim from the NRC report and statements in "regular font" under the heading "**Response**" are my responses to the specific NRC report statements.

7.2 Comments on the NRC report associated with conceptual topics of exposure analysis and site characterization.

Comment on p. 29: *Exposure assessment for epidemiologic studies of the effects of water-supply contamination includes two components. The first is estimation of the magnitude, duration, and variability of contaminant concentrations in water supplied to consumers. An important consideration is hydrogeologic plausibility: an association between a contaminant source and exposure of an individual or population cannot exist unless there is a plausible hydrogeologic route of transport for the contaminant between the source and the receptor (Nuckols et al., 2004). The second component is information on individual water use patterns and other water-related behaviors that affect the degree to which exposures occur, including drinking-water consumption (ingestion) and dermal contact and inhalation related to the duration and frequency of showering, bathing, and other water-use activities. Water use is an important determinant of variability of exposure to water-supply contaminants, particularly if it varies widely in the study population. Ideally, exposure-assessment strategies include both components, but in practice it may be difficult to obtain either adequately.*

Response: In this comment, which also includes a reference to the work of one of the committee members (Nuckols et al. 2004), the NRC committee is providing the reader with their understanding of the components of an exposure study that is associated with pollutants that may exist in an aquatic pathway at a contaminated site. The aquatic exposure analysis framework described in this statement is a conceptual statement and represents a very restrictive view of the exposure pathway analysis that needs to be considered at contaminated sites given the current understanding of the interaction between environmental pathways and the behavior of chemicals along those pathways. Current knowledge in this scientific field recognizes that in an aquatic exposure study the environment must be considered as a whole, and scientific and regulatory approaches alike must consider complex interactions between multimedia and intermedia interactions that exist in a multitude of potential environmental pathways at a site. In my opinion one should not emphasize only the concept of a “hydrogeologic connection” between the contaminant source and the exposure point as put forth by the NRC committee. This conceptual suggestion made by the NRC committee would be a very elementary and restrictive exposure analysis framework.

As specialists in this field, we know pollutants released to an aquatic environment are distributed among environmental media such as air, water, soil, vegetation etc., because of complex physical, chemical and biological processes. Thus, environmental pollution is a multi-pathway problem and environmental exposure assessment methods require that we carefully consider the transport, fate and accumulation of pollutants in the environment as a whole, (Cohen 1986; Aral, 2010). Methods that are proposed to evaluate environmental migration or exposure characterization in this envirosphere must consider all potential pathways and the interactions between these pathways. In scientific literature, the multi-pathway approach to environmental exposure analysis is identified as Total Exposure Characterization (TEC).

Elements of this multi-pathway analysis for an aquatic contamination source are imbedded in the ATSDR water modeling studies that were conducted for the Tarawa Terrace area of the Camp Lejeune site as much as possible. The specific pathways and processes considered in the ATSDR water modeling study are: (i) saturated groundwater; (ii) unsaturated groundwater; (iii) vapor emissions; (iv) multispecies analysis of contaminants in these three pathways; (v) mixing in the water treatment system; and (vi) estimates of contaminants in the water-distribution system. This was followed by proper epidemiologic studies that are not considered in this expert report.

In this analysis framework it is also important to recognize that one should not try to fit a physical problem to a model that may be readily available for use. Instead, appropriate models should be selected or developed that would fit the characterization of the physical problem at hand. Thus, selection of appropriate modeling tools to complete such an analysis is very important and is considered in sufficient detail in the ATSDR study. This is a very important point, which was either completely ignored in the NRC report or, steps taken by the ATSDR water modeling team to address these issues in a sound scientific and engineering manner were criticized by the NRC committee without providing any supporting evidence that is traceable to technical literature. I will revisit this issue in more detail in my comments below while providing case-specific public domain data and public domain information.

Comment on p. 33: *At a typical waste site, spent VOCs are present in the unsaturated zone (a partially saturated soil layer above the water table) in the form of dense nonaqueous-phase liquids (DNAPLs).....* (... after a lengthy discussion of what DNAPL is and how DNAPL-based contaminants behave in the subsurface and what the consequences of such a source are, the NRC report continues in this section with the following remarks linking DNAPL presence to the aquifers at Camp Lejeune.) *The presence of low-permeability units (such as the Castle Hayne confining unit or any clay units) would limit vertical migration of both DNAPL and dissolved contaminants.....*

Response: The NRC report does not provide any information for the justification of this conceptualization of the contamination source at the ABC One-Hour Cleaners site and Tarawa Terrace and vicinity other than providing a reference to a source concentration of 12,000 µg/L, reported in Chapter E of the ATSDR Tarawa Terrace report series (Faye and Green 2007, p. 38). This is followed by a reference to a number “110,000 µg/L” (p. 38 of the NRC report, second paragraph from bottom of page). As indicated in the NRC report, this is the highest possible concentration of tetrachloroethylene (PCE) in water. Because this reference value is given in the NRC report without a reference citation, I question the credibility of this reference value. The NRC report also does not discuss the importance of this number in their conceptualization of the contaminant source as a DNAPL. Furthermore, the NRC report does not refer to a data source on the solubility levels of PCE in water like those data sources reported in Chapter D of the ATSDR Tarawa Terrace report series (Lawrence, 2007). The NRC report does not refer to or cite a database that may exist in USMC files at Camp Lejeune, unknown to the ATSDR water modeling team, that NRC committee members may have had access to, that would indicate the presence of DNAPL-phase PCE at the site. The NRC report also does not refer to a systematic dry-cleaner disposal procedure that is reported in the documents they have reviewed for handling the disposal of the chemical PCE as a pure phase PCE at the ABC One-Hour Cleaners site.

In the NRC report, the highest concentration of dissolved PCE, 110,000 µg/L, must imply the NRC committee’s understanding of the solubility level of PCE in water. Because a reference is not provided, I could not confirm this number. However, our references indicate that the solubility of PCE in water is around 200,000 µg/L (= 200 mg/L) at 15°C or higher. In Chapter D of the ATSDR Tarawa Terrace report series (Lawrence 2007, p. D12, Table D9), solubility of PCE is reported to be 210, 000 µg/L (=210 mg/L) at 25°C, which is the solubility number I would like to work with for my analysis below. There are other references in the literature that report the solubility of PCE at much higher concentrations as well, which are not referenced here. This is because I would like to focus on what is reported in the ATSDR Tarawa Terrace series of reports (ATSDR, 2007a).

The 12,000 µg/L concentration reported in NRC report (and in Chapter E of the ATSDR Tarawa Terrace report series [Faye and Green 2007]) as a justification for the presence of a DNAPL phase is about 5.7%

to 6% of the solubility level of PCE ($12,000/200,000 = 6\%$ or $12,000/210,000 = 5.7\%$). The 12,000 µg/L concentration is the dissolved-phase PCE concentration in the groundwater at ABC One-Hour Cleaners as reported by ATSDR (Faye and Green 2007). Although this is a high concentration, this value is much less than PCE's solubility limit in water (200,000 µg/L at 15°C or 210,000 µg/L at 25°C). Even at the lowest solubility value reported by USEPA 150,000 µg/L this concentration level is at 8% of the solubility level (USEPA, 2024). The location of the highest concentration sample within Tarawa Terrace and vicinity can be used to identify the source location at the site. High concentrations at a site may suggest the possibility of non-aqueous phase (NAPL) PCE (PCE in form of NAPL) presence but this does not guarantee a NAPL presence at the site, because in this case, 12,000 µg/L is 6% or less of the solubility limit of PCE (see Section 6.4 of this expert report).

Thus, the conceptual DNAPL contaminant source characterization that is provided in the NRC report without any justification and without any field data support is bothersome. This reference to the presence of a DNAPL-phase contaminant source at the site not only appears in this comment on NRC report page 33, but it is repeatedly referred to in other pages of the NRC report which is not clear and correct understanding of the source conceptualization (see discussion of "Dissolved phase pollution vs NAPL, LNAPL and DNAPL pollution" in Section 6.4). In my opinion the NRC committee needs to provide further technical and field data evidence in support of their DNAPL conceptualization. Also reporting the solubility of PCE in water at about half the value of the data reported in the ATSDR Chapter D report (Lawrence 2007) without providing a reference (page 38 of the NRC report) is not scientifically acceptable. Short of citing field data evidence and an appropriate reference for the solubility level of PCE as reported in the NRC report, I would question the scientific basis of this conceptualization. Further, without field data evidence, the NRC review is based on hypothetical conditions and assumptions that are extracted from the scientific work of others (Figure 2-3 of the NRC report) which is based on studies that are conducted at other sites. It is my opinion that these sites have no relevance to the ABC One-Hour Cleaners site or Tarawa Terrace and vicinity. The purpose of this assertion (PCE as DNAPL source conceptualization) and misrepresentation of the site data by the NRC committee is not clear to me.

During the NRC committee review process, the question of the characterization of the source was brought to the attention of ATSDR water modeling team members in a request for information by an NRC committee member (Email communication from P. Clement to M.L. Maslia, ATSDR, May 5-11, 2008). At that time, ATSDR water modeling team members provided the NRC with data ATSDR had on the subject matter clearly showing why the modeling team elected to simulate the PCE source as a dissolved-phase source.

Furthermore, the modeling team clearly identified why the dissolved-phase injection procedure applied in the models used for the ATSDR water modeling analyses. The information that was provided to the NRC was based on data from several remedial investigation reports, site reports, and other DON and USMC files (Shiver 1985, Roy F. Weston 1992, 1994). In these field study reports, there is no recorded data reported by DON and USMC consultants that would provide evidence of, or substantiate the existence of, the presence of a DNAPL source at ABC One-Hour Cleaners or Tarawa Terrace. If the DNAPL source conceptualization that appears in the NRC report is based solely on the data source and information we provided to the NRC committee, then I do not agree with the NRC's source characterization. I, therefore, consider this to be a misinterpretation of the conditions at the site. If this conceptualization is based on any other information or data that I was not aware of, and if this information was provided to NRC by DON, the USMC, or their consultants, the modeling team should have been provided with that information and data. Because the reference to a DNAPL-phase in the

aquifers underlying ABC One-Hour Cleaners and Tarawa Terrace and vicinity appears in several places within the NRC report, I will revisit this topic again in my discussions below.

In the statement on page 33 of the NRC report, I also noticed that the NRC committee acknowledged that the PCE source was discharged to the unsaturated zone of the aquifer underlying ABC One-Hour Cleaners and Tarawa Terrace and vicinity. However, given that observation, the NRC committee fails to provide a justifiable critique of the use of the **MODFLOW** family of codes that only considers a saturated groundwater zone to analyze the physical problem at the site. On the contrary, the NRC committee considers the **MODFLOW** family of codes to be an acceptable modeling choice throughout the NRC report. This is probably because the NRC committee considers the **MODFLOW** codes as accepted state-of-the-art tools for typical groundwater pathway modeling. This is an example of a typical case of fitting a physical problem to a code “concept” I referenced in my response statement “7.2” above, which the ATSDR water modeling team tried to avoid as much as possible (see the discussion in section 6.1 and **TechFlowMP** application in section 5.1).

In recognition of this problem and in recognition of the general perception that prevails in the scientific community that the **MODFLOW** family of codes is an accepted procedure, the ATSDR water modeling team first utilized the **MODFLOW** and **MT3DMS** codes in their simulations. In addition, to enhance our understanding of conditions at the site, ATSDR extended its analyses. The ATSDR water modeling team applied the **TechFlowMP** software to understand and evaluate the unsaturated zone injection conditions that are implemented at the site. **TechFlowMP** is a public domain code that can be accessed from the Georgia Tech website for individual use without a fee (<http://mesl.ce.gatech.edu/>). The NRC report attempts to discredit this extra effort and the steps taken by the ATSDR water modeling team to simulate the proper source disposal conditions at the ABC One-Hour Cleaners site by classifying: (i) **TechFlowMP** code as a research tool; and (ii) as a proprietary code that is not verified. Again, this is very puzzling and a misrepresentation of the scientific and public domain facts of this case by the NRC committee. These NRC statements that appear in several places in the NRC report ignore a scientifically sound attempt by the ATSDR water modeling team to properly evaluate a physical problem, above and beyond a traditional **MODFLOW** and **MT3DMS** application which the NRC review committee accepts (NRC 2009, p. 43). Further, the NRC committee failed to check current technical literature and scientific publications containing substantial evidence of publications involving the **TechFlowMP**. The evidence that the **TechFlowMP** code has been tested and verified against other applications (see section 5.1) exists in this technical literature. (web site: <http://mesl.ce.gatech.edu/PUBLICATIONS/Publications.html>). This lack of due diligence by the NRC committee is puzzling.

It is equally important to note that the use and application of specialized codes to address specific problems that codes, such as **MODFLOW** and **MT3DMS**, cannot address, is not shunned by government-based scientific organizations, but rather, it is recognized and encouraged. As stated in the U.S. Environmental Protection Agency report, “Guidance on the Development, Evaluation, and Application of Environmental Models” (USEPA 2009, p. 31): “**However, the Agency acknowledges there will be times when the use of proprietary models provides the most reliable and best-accepted characterization of a system.**” The point being made in this statement is that the most appropriate model should be applied to characterize a system, not necessarily, the most popular or most often-used model; and this is the exact modeling philosophy and approach that ATSDR took when applying the **TechFlowMP** and **PSOps** and other sub-models at ABC One-Hour Cleaners and Tarawa Terrace and vicinity (see discussion of this topic in section 5.1).

7.3 Comments on the NRC report associated with science-based tools, analysis and interpretation of study results.

Comment on p. 43: *For example, **MT3DMS** can predict the transport only of dissolved contaminants, so a key approximation was made to represent the mass dissolved from the DNAPL source. To apply **MT3DMS**, ATSDR replaced the highly complex DNAPL contaminated source zone with a hypothetical model node where PCE was injected directly into the saturated aquifer formation at a constant rate (1.2 kg/day).*

Response: This NRC report statement relies on their unsubstantiated and undocumented source characterization concept (see my review comment above and in section 6.4). Using this conceptualization as an undisputable fact, the NRC committee then attempts to discredit the groundwater-modeling study conducted by ATSDR at the ABC One-Hour Dry Cleansers site and Tarawa Terrace and vicinity. This statement is a hyperbole, wherein first an “assumption” is made which is wrong and then that “assumption” is considered to be a “fact” to critique the findings of a study. This approach in a scientific critique is puzzling.

Comment on p. 43: *Unlike the MODFLOW and MT3DMS codes, the PSOpS and TechFlowMP codes lack validation by a broad spectrum of practicing geoscientists in an open-source environment.*

Response: I have addressed the point the NRC committee chose in reference to the misrepresentation of **TechFlowMP** as an unverified code in my response above. I will not repeat that here. In reference to the **PSOpS** and other sub-model developed by the Georgia Tech research group (see section 5.1), the following needs a clear answer: Can a reference to a public domain code be provided by the NRC committee members that is available through the published literature that provides the analysis performed by **PSOpS** and other sub-models? Has such a public domain code been developed for, and applied to, any study that they are aware of to manage pumping-schedule operations in an optimal manner for a complex system such as the one at Tarawa Terrace? The answer to these questions is obvious and the answer is: “This type of public domain model does not exist in the literature and needed to be developed to complete the study in appropriate scientific confidence bounds.”

PSOpS is an optimization application that was developed by the MESL-Georgia Tech research group participating in the ATSDR water modeling analysis to yield answers to specialized uncertainty-related questions pertinent to the current health study conducted at Camp Lejeune site. The analysis is based on the **MODFLOW** family of codes in the generation of the database used to solve an optimization problem. The development of this optimization model was necessary to respond to scientific questions raised by the ATSDR Expert Panel (March 2005) whose members guided our study and contributed significantly to its quality. The members of this ATSDR Expert Panel are well known and respected scientists in the field and their names are listed in the Expert Panel report (Maslia 2005) that is also available on the ATSDR website. The question ATSDR Expert Panel members raised in this case was related to the uncertainty of a pumping-schedule operation that may be implemented at the site and the characterization of its effects on the study outcome. The **PSOpS** model that was developed for the purposes of this analysis and used in the ATSDR water modeling analyses to address this question became part of the peer reviewed PhD thesis of a graduate student at Georgia Tech. In that sense, the theoretical background of the model is reviewed and accepted by independent PhD thesis committee members at Georgia Tech and the detailed documentation of this model can be found in the PhD thesis of Dr. J. Wang, which is public domain information (Wang, 2008).

In conclusion, the NRC committee is most likely aware of the following: (1) specialized models such as **PSOpS** are not available in the technical public-domain literature; and (2) codes such as **PSOpS** only are developed for the specialized purposes of the current study to find answers to specialized questions that are raised by the current water modeling analysis. The concept of using an optimization algorithm that is fed by a database through the **MODFLOW** family of models, which is a common and routine procedure, is both scientifically sound and scientifically necessary in a study such as the one ATSDR conducted at Camp Lejeune site. If a public domain model existed that can be used for this study, that would serve the same purpose, instead of the **PSOpS** model, we would have used that model instead of the **PSOpS** model. To my knowledge, such a model is not available. In my opinion, the NRC committee also should recognize that the ATSDR water modeling effort is not a run-of-the-mill work-product and the problem at hand is not a routine problem that can be or should be analyzed using routine models. In such cases it is expected that specialized methods can be developed and implemented; this should not be shunned by the NRC, but instead, it should be encouraged (see USEPA comment and reference above) (USEPA 2009, p. 31).

Comment on p. 44: *The DNAPL source zone was represented by using a model node where PCE was injected continuously into the unconfined model layer-1 of the saturated zone at a constant rate of 1.2 kg/day (Faye 2008).*

Response: Again, in this statement, the NRC committee is asserting that the DNAPL source zone was misrepresented in the current study. I refer to the reader to my previous comments in my response to the DNAPL source mischaracterization by the NRC committee also see section 6.4 of this expert report.

To reiterate, we have not represented a DNAPL source zone as an injection point in our models because there is no DNAPL source zone in the aquifer underlying the ABC One Hour Dry Cleaners site at Tarawa Terrace and vicinity. If the claim of the NRC committee can be substantiated by any field data, I stand corrected. Not only I would stand corrected, but also, I would strongly recommend that the U.S. Environmental Protection Agency (USEPA), their consultants, and the North Carolina Department of Environment and Natural Resources (NCDENR) should immediately abandon their remediation efforts at the ABC One-Hour Dry Cleaners site at Tarawa Terrace and vicinity and adopt remediation strategies that would yield more effective results for a DNAPL source contaminant. The U.S. Environmental Protection Agency (USEPA), their consultants, and the North Carolina Department of Environment and Natural Resources (NCDENR) conducted remediation efforts at the ABC One-Hour Dry Cleaners site at Tarawa Terrace and vicinity using remediation strategies directed toward a dissolved phase contaminant. The fact that USEPA and NCDENR field consultants did not implement DNAPL remediation technologies at the site is additional evidence that these agencies and their consultants also do not agree with the NRC committee as to the characterization of the contamination source as DNAPL phase PCE.

Comment on p. 48: *Because insufficient historical pumping data were available to constrain the model predictions from 1953 to 1980, the ability of the advanced optimization models to estimate the dates accurately is questionable.*

Response: There are obvious uncertainties in the physical problem being studied at ABC One-Hour Dry Cleaners and Tarawa Terrace and vicinity. The NRC committee would most likely agree with this statement. If we accept this statement, then the question becomes, should one completely ignore uncertainty in the analysis or should one try to develop techniques that would provide an estimate of the effects of uncertainty on the solution in a systematic way? In this study we have chosen the second route, which is the sound science alternative which documents the inherent level of uncertainty.

The NRC committee should accept the fact that answers to uncertainty questions cannot be answered “**accurately**” as the NRC report states in the above statement. Expecting that from an uncertainty analysis outcome would be scientifically irresponsible. Our uncertainty analyses are not provided to give “accurate” answers to the problem studied. Instead, our uncertainty analyses are used as estimates that would indicate the variability range of deterministic results provided earlier. The domain of uncertainty analysis is a scientific field which is not in the realm of the traditional groundwater fate and transport analysis expertise and should be viewed using a different microscope and expertise. ATSDR’s uncertainty analysis is a reliable and accepted methodology in the field of environmental modeling.

Comment on p. 48: *(5) there is no spatial variation in the microbiologic or geochemical characteristics.*

Response: The NRC committee correctly identified that in the application of the TECHFLOWMP model to the aquifers underlying the ABC One-Hour Dry Cleaners site and Tarawa Terrace and vicinity, we assumed no spatial variation of microbiologic characteristics. If the NRC committee is familiar with the finite element procedures used in the **TechFlowMP** model, they would acknowledge that this is not a restriction of the model but a restriction on the available field data for the site. If the microbial distribution in an aquifer can be accurately characterized, which we doubt can be accomplished in this case or in any case, we can certainly include that heterogeneity in our modeling effort.

Having pointed out this fact, I would also like to question issues pertaining to levels of acceptable homogeneity considered in our modeling effort and compare it with levels of unacceptable homogeneity that are shunned in our modeling analysis based on the critique presented in the NRC report. For example, the assumption of uniform infiltration across the model domain when the MODFLOW family of model codes is utilized was not critiqued in the NRC report, but the assumption of uniform microbial distribution in the multilayer aquifer domain is critiqued. Between these two processes, which would be the easier process to characterize and implement? I think the answer to this question is obvious, the infiltration process would be easier. Thus, although both processes are characterized by heterogeneity in the aquifer, accepting the homogeneity assumption for the infiltration case but not accepting homogeneity assumption for the microbial distribution case would be setting the bar too high and would be scientifically irresponsible considering the levels of data that may be available to characterize either process. A scientific review committee should be able to make these distinctions easily and come up with appropriate conclusions in their review comments.

Comment on p. 49: *However, there are some important limitations in ATSDR’s modeling efforts because of the sparse set of water quality measurements, the need to make unverifiable assumptions, and the complex nature of the PCE source contamination.*

Response: There are limitations of the modeling analyses conducted by ATSDR water modeling team. We would be the first to acknowledge these limitations. This is evident by the level of detail of the uncertainty analysis conducted as part of the water modeling analysis to envelope the effect of those uncertainties on the outcome presented. However, in my opinion, characterizing the uncertainty analysis outcome as not “**accurate**” as previously stated (see response above) or, that uncertainty analysis should only be conducted in “**verifiable**” cases as stated above is not a scientifically sound assessment or procedure. As we all agree, **an uncertainty that can be verified would be no longer uncertain.**

Regarding the lack of historically measured values of contamination, it was not required to measure these contaminants in the timeframe of interest, according to regulatory agencies. It was when

trihalomethane (THM) measurements were first required, those analytical techniques were utilized that could detect the presence of other halogenated (e.g., chlorinated) compounds like PCE and TCE. The lack of such measured values points to the need for historical reconstruction efforts – the NRC report offers no better alternative.

I fully agree with the NRC observation that “ATSDR applied best practices and cutting-edge modeling approaches to predict the complex groundwater-contamination scenario” (NRC, 2009; p 65) necessary for establishing reconstructed exposure levels. ATSDR conducted sensitivity analyses in both the 2009 Tarawa Terrace study (ATSDR, 2009) and the later 2013 Hadnot Point / Holcomb Boulevard study (ATSDR, 2013) that generated a range of possible exposure levels at a given point in time. Thus, in my opinion ATSDR not only satisfied but also built upon input from the NRC report to produce the best-possible engineering and scientifically valid information for assessing historical exposure levels at Camp Lejeune.

Comment on p. 49 first bullet: *The effects of the DNAPL in both unsaturated and saturated zones have not been included in the studies.*

Response: The NRC report brings back the DNAPL issue here again. Please see my response in the comments above.

Comment on p. 49 second bullet: *Constant values of dispersivity (longitudinal dispersivity of 25 ft and transverse 2.5 ft) were used in the transport model.*

Response: Although dispersivity is constant, based on the definition of the hydrodynamic diffusion coefficient, the hydrodynamic diffusion coefficients are variable because they depend on the velocity field at the site. This is a common assumption in most studies where field data are not available to support spatially variable dispersion/diffusion coefficients. This comment again is related to my discussion of acceptable homogeneity and unacceptable homogeneity conditions at a site study above.

Comment on p. 49 bullet four: *The numerical codes **TechFlowMP** and **PSOpS** used in the modeling are research tools and are not widely accepted public-domain codes, such as **MODFLOW** and **MT3DMS**, so their validation is important.*

Response: This characterization is a misrepresentation of the models, as clearly identified in my response above. The availability of codes with the capabilities of these models is very limited. In my opinion the use of these models in complex analysis should not be shunned by NRC, but instead, it should be encouraged since these models provide supplemental information beyond **MODFLOW** family of code applications (USEPA 2009, p. 31).

Comment on p. 49 bullet five: *The **PSOpS** modeling study is based on the premise that an optimization model can be used to evaluate pumping stresses. Without site-specific pumping and water-quality data, the results will be nonunique and uncertain.*

Response: **PSOpS** modeling concept is based on the effort of estimating the effects of uncertainty on the modeling outcome. This analysis is approached in a systematic manner following accepted processes such as an optimization analysis based on some constraints to satisfy the demands. The **PSOpS** model uses the **MODFLOW** family of codes as its database engine. We are not claiming that the outcome provides the exact conditions representing the problem at the site. But the outcome of the analysis provides us with an envelope which bounds our deterministic analysis. This is a standard uncertainty

analysis procedure like, for example, Monte Carlo analysis that is routinely used in uncertainty analysis. Monte Carlo analysis, according to a well-established procedure, systematically evaluates the effects of uncertainty on the problem solution based on random synthetic data generation. In such an application, it is not certain that the random numbers generated would exactly represent the actual conditions for the problem at the site. However, the bounding limits of the analysis are the goal of the analysis. The application of **PSOpS**, in essence, is very similar to that analogy.

As I have stated earlier, this goes back to the NRC report statement about the “**accuracy**” of the uncertainty analysis results that cannot be justified scientifically. Also, I must emphasize again what I stated earlier: The domain of uncertainty analysis is a scientific field which is not in the realm of the traditional groundwater fate and transport analysis expertise and should be viewed using a different microscope and expertise.

Comment on p. 49 bullet seven: *The **TechFlowMP** model predicted very high vapor concentrations. For example, **TechFlowMP** predicted that the PCE vapor concentration in the top 10 ft of soil beneath the Tarawa Terrace elementary school should be 1,418 µg/L. Studies of PCE vapor concentrations in buildings that house or are near a drycleaning facility have reported measured concentrations around 55 µg/L.*

Response: This reference to a vapor concentration at 1,418 µg/L is another example of misrepresentation of the results of the modeling analyses conducted by the ATSDR water modeling team. This aforementioned information was taken from Chapter A of the ATSDR Tarawa Terrace report series (Maslia et al. 2007, p. A44). The statement provided in the ATSDR report reads as follows: “**b. the maximum simulated PCE concentration in groundwater (model layer 1) at the Tarawa Terrace elementary school was 1,418 µg/L (Figure A15b), whereas the maximum simulated vapor-phase PCE (in the top 10 ft of soil) was 137 µg/L (Figure A20a)**”

The above sentence, taken directly from the ATSDR report submitted to NRC, clearly states that the groundwater (not vapor) concentration of PCE in layer “1” is at 1,418 µg/L concentration. Vapor concentration is given separately in the paragraph towards the end of that sentence. For the NRC report to represent this number (1,418 µg/L) as the vapor concentration that is simulated at the site to discredit a study is not appropriate for a scientific review. I will provide a more detailed analysis of this case using simulation results to bring clarity to the concern raised in the NRC report.

In this case, the work product referred to are the **TechFlowMP** modeling results and the analysis mentioned was conducted by the MESL - Georgia Tech research group participating in the ATSDR water modeling analysis of the ABC One-Hour Cleaners site and Tarawa Terrace and vicinity (Jang and Aral 2007). To provide the reader with clear evidence of scientific misrepresentation of the facts, the actual data reported in our report is presented below in sufficient detail, unlike the other responses I have provided to other comments in this document. In the numerical study of the multispecies, multiphase groundwater contamination at ABC One-Hour Dry Cleaners and Tarawa Terrace and vicinity, **TechFlowMP** simulations used two boundary-conditions to characterize the ground surface under the original pumping schedule: (1) GSBC = 0.01 and (2) GSBC = 1.0 (Jang and Aral 2007, p. G15). Here the acronym “GSBC” stands for the Ground Surface Boundary Condition. For the in-/out-flux of gas between the atmosphere and the unsaturated zone, if the ground surface does not have low-permeable zones or hindrances due to pavement, lakes, or buildings, the GSBC value is set to be 1.0. This implies that soil gas can be freely released into the atmosphere from the unsaturated zone. However, when some objects, including roads, buildings, ponds, or highly water-saturated areas, are present at the ground surface, the

soil gas cannot be released into the atmosphere freely. Under such a condition, GSBC is set to be 0.01 in the current study. In a typical application, any number between these two extremes can be considered in the analysis. However, just to show the bounds of the results, the discussion here will be confined to these two extreme cases.

To analyze the concentration distribution around the school area as it is referred to in the NRC report comment, the location of the school at Tarawa Terrace must be identified and is shown in Figure 1 (ATSDR, 2007; ATSDR 2013).

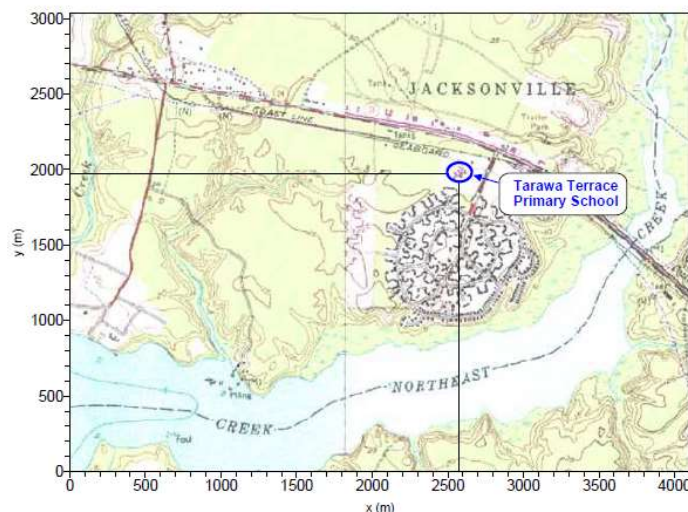


Figure 1. Location of the Tarawa Terrace Elementary School

In the school area, the groundwater table is near the ground surface (CH2MHILL 2007). In this study, the ground surface is at $z = 7.6$ meters (m, $z = 25$ ft), and the groundwater table is around $z = 2.4 - 4$ m ($z = 8 - 13$ ft) (Jang and Aral 2007, Figure G3, p. G10). Thus, the concentration distributions of the vaporized PCE at $z = 6$ m are presented below, where the unsaturated zone is at this location.

As shown in Figure 2 (ATSDR, 2007a), under $GSBC = 0.01$, which is more representative of an area where there are buildings and pavements, the predicted vaporized PCE concentrations in the pore space of the soil at the center of the school area ($x = 2,580$ m, $y = 1,975$ m) are about $15.5 \mu\text{g/L}$ during December 1984 (Figure 2a) and $3.7 \mu\text{g/L}$ during December 1994 (Figure 2b). Within the school area (marked with the circle in this figure), the PCE concentration ranges $0.1-100 \mu\text{g/L}$ during December 1984 (Figure 2a) and $0.1-50 \mu\text{g/L}$ during December 1994 (Figure 2b) (ATSDR, 2007a).

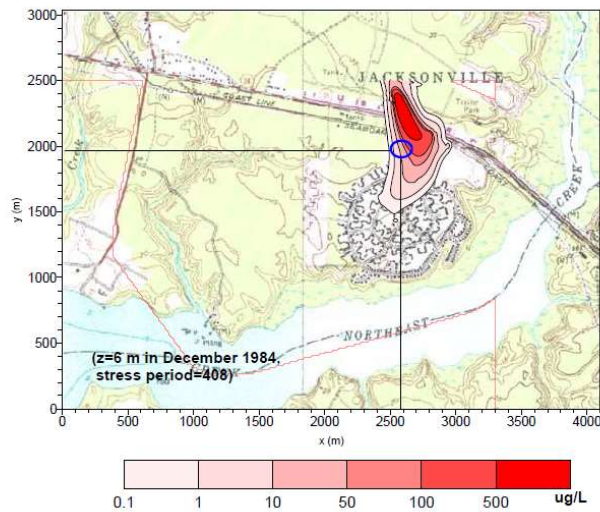


Figure 2a. Vaporized PCE concentrations in the gas phase under the original pumping schedule (PS-O) with GSBC=0.01, at z=6, December 1984.

In Figure 2, the vaporized PCE concentrations near the ABC One-Hour Cleaners site are very high where the contamination source is located. This is expected, but the vapor concentrations decrease sharply with the distance away from the ABC One-Hours Cleaners site. Furthermore, the simulated concentration of PCE in the gas phase, ranging from 0.1 to 100 $\mu\text{g/L}$, is not significantly different from the value of 55 $\mu\text{g/L}$, given in the NRC report.

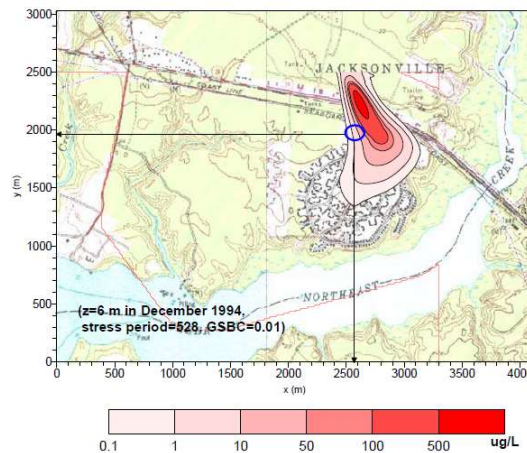


Figure 2b. Vaporized PCE concentrations in the gas phase under the original pumping schedule (PS-O) with GSBC=0.01, at z=6, December 1994.

Having provided this comparison, I also question the source of the reference number, 55 $\mu\text{g/L}$, that is used in the NRC report. The NRC report provides a reference for this case and this reference is McDermott et al. (2005). I was curious about this reference; therefore, I located and obtained a copy of the referenced paper. In the McDermott et al. (2005) study, the authors are analyzing and reporting data on the PCE vapor concentrations in a building where dry-cleaner operations are housed in New York City.

Does the NRC committee expect us to accept the concept that what is observed (measured) as vapor concentration in a building that houses a dry-cleaner facility in New York City should also apply to the subsurface pore space of the soil at the site of an elementary school area in Camp Lejeune, North Carolina? Or do they expect that what we have simulated in the pore space of the soils at a site in North Carolina should also confirm the observations made in New York City, 17-20 years beyond our final simulation date (2001-2003), in some dry-cleaner facility building? In my opinion, these types of comparisons, expectations, and assertions are scientifically not acceptable or credible.

In the groundwater contamination study that utilized TECHFLOWMP (Jang and Aral 2007), the local equilibrium of contaminant partitioning between the water and gas phases is implemented while calculating the contaminant distribution between the two phases (gas and liquid). Thus, we can use the Henry coefficient, H , in estimating PCE concentration in the gas phase from the concentration in the groundwater phase as follows:

$$C_{Vapor,PCE} = H C_{GroundWater,PCE}$$

For PCE, H is 0.35 (Jang and Aral 2007, Table G2). Using the dissolved PCE concentration in the groundwater shown in Figure G5 of Jang and Aral (2007) (in the unsaturated and saturated zones), the overall concentration distribution of the vaporized PCE within the gas phase in the unsaturated zone can also be estimated. This simple calculation could have been made by the NRC committee to confirm the vapor concentration numbers they are reporting in their statement. In Figure G5 of Jang and Aral (2007), the dissolved PCE concentration in the groundwater is 100-500 $\mu\text{g/L}$ near the ground surface at the location of the elementary school ($x = 2,580 \text{ m}$, $y = 1,975 \text{ m}$). Therefore, the vaporized PCE concentration will be approximately 35-175 $\mu\text{g/L}$ in the unsaturated zone near the school area. The cross-section line A-A, in Figure G5 is located at $x = 2,606 \text{ m}$.

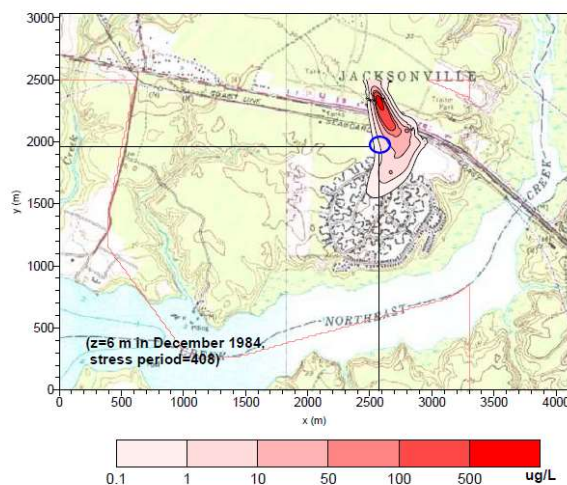


Figure 3a. Vaporized PCE concentrations in the gas phase under the original pumping schedule (PS-O) with GSBC=0.01, $z=6$, December 1984.

Let us also analyze the results of the other boundary condition that is used in the **TechFlowMP** model out of curiosity and see if the vapor concentration value of 1,418 $\mu\text{g/L}$ reported in the NRC report was

referring to that case. The results reported in (Jang and Aral 2007) under the condition GSBC = 1 are shown in Figure 3 (ATSDR, 2007; ATSDR 2013). The predicted vaporized PCE concentrations at the center of the school area ($x = 2580$ m, $y = 1975$ m) are about 0.99 during December 1984 (Figure 3a) and 0.1 $\mu\text{g/L}$ during December 1994 (Figure 3b) (ATSDR, 2007; ATSDR 2013) (i.e. more PCE vapor is released to the atmosphere and less is remaining in the pore space when compared to the previous results). Within the school area (marked with the circle in the figure), the concentration ranges 0.1-10 $\mu\text{g/L}$ in December 1984 (Figure 3a) and less than 5 $\mu\text{g/L}$ in December 1994 (Figure 3b) (ATSDR, 2007).

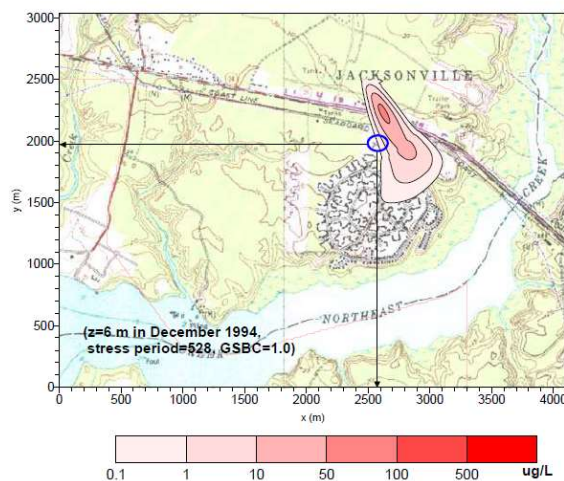


Figure 3b. Vaporized PCE concentrations in the gas phase under the original pumping schedule (PS-O) with GSBC=0.01, $z=6$, December 1994.

As can be seen from these results the number reported in the NRC report does not exist in the ATSDR water-modeling analysis as vapor concentration. This is a clear misrepresentation of the ATSDR water modeling results.

The field investigation during 2007 (CH2MHILL 2007) it was reported that the vaporized concentrations of PCE near the ground surface were below detection limits or very low, 3.9 ppbv (parts per billion volume), which is equivalent to 0.028 $\mu\text{g/L}$. Considering the time gap between the end of the historical simulation time (December 1994) and the field investigation time (July 2007), the simulation results that are provided in the Chapter G report of the ATSDR Tarawa Terrace report series (Jang and Aral 2007) provide reasonable modeling results and represent acceptable levels of expected vapor concentration near the Tarawa Terrace elementary school. Are we asserting that this is absolutely the case? The answer to that question is absolutely "No." This outcome is only an estimate based on the assumptions and limitations of the models considered and the boundary conditions used in the ATSDR water modeling analyses and the assumptions and limitations are based on our best judgment of the conditions that may exist at the ABC One-Hour Dry Cleaners site and Tarawa Terrace and vicinity.

The ATSDR water modeling reports do not report such high concentration of vaporized PCE concentration in the gas phase. The vaporized PCE concentration of 1,418 $\mu\text{g/L}$ is equivalent to a dissolved PCE concentration of 4,051 $\mu\text{g/L}$, in the groundwater which does not exist in our results:

$$C_{\text{Vapor,PCE}} = HC_{\text{GroundWater,PCE}}$$

$$C_{\text{GroundWater,PCE}} = 1418 / 0.35 = 4051.4$$

I also note that the unsaturated zone is located at a very thin layer near the ground surface ($z = 7.6$ m (25 ft)) in Jang and Aral (2007, Figure G5) which is characterized in terms of several layers in water-modeling analysis. The maximum thickness of the unsaturated zone is about 7.6 m.

In conclusion the data, the associated discussion of the vapor levels near the Tarawa Terrace elementary school area, and the reference provided in the NRC report (McDermott et al. 2005) are far from the facts of the case and the results that are presented by the ATSDR water modeling team.

Comment on p. 49 bullet eight: *The biodegradation model used within the **TechFlowMP** code is based on an untested preliminary research model.*

and also,

Comment on p. 50: *The **TechFlowMP** simulations assumed that the biodegradation byproduct of TCE is trans-1,2-DCE. However, the scientific literature indicates that cis-1,2-DCE is the predominant product of TCE reduction under in situ groundwater conditions.*

Response: The detailed description of why trans-1,2-dichloroethylene is chosen as the representative byproduct of TCE bioreaction at the Tarawa Terrace area instead of cis-1,2-DCE is given in page G4 of the report, Chapter G (Jang and Aral, 2007). An additional explanation regarding this issue is given below.

As shown in Figure G2 of the report (Jang and Aral, 2007), the anaerobic biological degradation of trichloroethylene (TCE) generates three isomers, cis-1,2-dichloroethylene (cis-1,2-DCE), trans-1,2-dichloroethylene (trans-1,2-DCE), and 1,1-dichloroethylene (1,1-DCE). As discussed in the report (Jang and Aral 2007), cis-1,2-DCE (1,2-cDCE) is the most common byproduct among the three DCE isomers produced theoretically (Wiedemeier 1998). Even though cis-1,2-DCE has been often used as a primary byproduct of TCE-biodegradation under the anaerobic conditions in contaminant transport modeling of chlorinated ethenes (Clement et al., 2000; Jang and Aral, 2008), but the primary byproduct of the TCE bioreaction highly depends on the chemical-biological conditions (especially, microorganisms and nutrients) at the contaminated sites (Bradley, 2003), implying that the biological reaction of TCE is highly site-specific. For example, Christiansen et al. (1997) and Miller et al. (2005) reported the anaerobic biological degradation of TCE produced more trans-1,2-DCE than cis-1,2-DCE. At the TCE contaminated site in Key West, Florida, the ratio of trans-1,2-DCE to cis-1,2-DCE was greater than 2 (SWMU9, 2002). Griffin (2004) reported that the ratio could reach up to 3.5, based on field data for several sites, including Tahquamenon River, MI; Red Cedar River, MI; Pine River, MI; and Perfume River, Vietnam.

In the modeling of contaminant transport at a contaminated site, the field measurement data at the site are very important in validating the numerical models and in obtaining more accurate simulation results. For the numerical study at the Tarawa Terrace area, we had limited field data regarding the concentrations of PCE, TCE, and trans-1,2-DCE. This is indicated in the following statement of the ATSDR report: Review of degradation byproduct data analyses, provided to ATSDR by the Department of the Navy, U.S. Marine Corps, the North Carolina Department of Environment and Natural Resources, and others indicated that the predominant degradation byproduct of TCE at Tarawa Terrace and vicinity was trans-1,2-DCE (Faye and Green 2007, Tables E2 and E7).

As mentioned above, since the primary byproduct of the biological degradation of TCE depends on site-specific conditions, it is more reasonable to select trans-1,2-DCE instead of cis-1,2-DCE as a primary TCE-bioreaction-byproduct in the study on the groundwater contamination at the Tarawa Terrace area.

The NRC critique, therefore, ignores site-specific TCE degradation by-product data pertinent to Tarawa Terrace and vicinity, listed in Chapter E of the Tarawa Terrace report series. This statement again clearly demonstrates the lack of due diligence by the NRC review committee in their review of the data that exists at the Tarawa Terrace, Camp Lejeune site and their lack of understanding of the facts of the site-specific case based on this data.

Comment on p. 50 next to last bullet: *In the absence of data, historical reconstruction efforts that use groundwater models can only provide a general conceptual framework for what happened at the site and why.*

Response: Historical reconstruction is a procedure that is accepted in literature. It uses models to predict the past in a conceptually similar manner to the models that are routinely used to predict the future in other engineering studies. The ATSDR response document provides references to such historical reconstruction applications.

Comment on p. 65: *Therefore, the committee recommends the use of simpler approaches (such as analytic models, average estimates based on monitoring data, mass-balance calculations, and conceptually simpler **MODFLOW/MT3DMS** models) that use available data to rapidly reconstruct and characterize the historical contamination of the Hadnot Point water-supply system. Simpler approaches may yield the same kind of uncertain results as complex models but are a better alternative because they can be performed more quickly and with relatively less resources, which would help to speed-up the decision-making process.*

Response: Use of simpler models may be easier to implement. We have also proceeded in that direction as well for the Hadnot point study. However, how the detailed questions that are raised in the NRC report could be answered using simpler models is not clear to me. Further, simpler models will not necessarily reduce the level of uncertainty. Instead, they may introduce conceptual misrepresentation of the physical system modeled. The ATSDR's approach, which in my opinion is the correct approach, is to use the most appropriate model that can provide the needed information, rather than the simplest or an off the shelf model.

CONCLUSIONS:

The scientific and engineering evidence presented in this response statement (submitted to EDRP/ATSDR as a memorandum in 2009) and the discussion of this evidence herein clearly indicate that the data and the analysis presented in the NRC report (NRC, 2009) are misrepresentations and mischaracterizations of the findings of the ATSDR water modeling analyses conducted at the ABC One-Hour Cleaners site, Tarawa Terrace area and vicinity. The conceptual characterization of the contaminant source made by the NRC committee also does not fit available field data or reported field conditions by the USEPA, their consultants, or the NCDENR which guided remediation efforts at ABC One-Hour Cleaners and Tarawa Terrace and vicinity.

Thus, I believe, due to the presence of numerous errors, misrepresentations and mischaracterization of the scientific facts of the ATSDR water modeling analyses, the NRC report cannot be used as a reliable

rebuttal to ATSDR conclusions on water modeling or a guidance document in its entirety. I reserve the right to update this report should any additional evidence or deposition testimony be provided to me that calls into question the conclusions of the NRC report or that concerns any other topic in my report.

8. References and Reliance Materials

8.1 References

Anderson, MP, Woessner, WW, Hunt, RJ, 2015. Applied Groundwater Modelling, Academic Press, Elsevier.

Aral, MM (ed), 1996. Recent advances in ground-water pollution control and remediation, NATO advanced study institute. Kluwer Academic, Dordrecht.

Aral, MM, 2005. Perspectives on environmental health management paradigms. In: Aral, Brebbia, Maslia, Sinks (eds) Proceedings of the 1st international conference on environmental exposure and health, Atlanta, GA, USA, pp 449–457.

Aral, MM, 2009. “Water Quality, Exposure and Health: Purpose and Goals,” Journal of Water Quality, Exposure and Health, Vol. 1, No. 1, pp. 1-4.

Aral, MM, 2010. Environmental Modeling and Health Risk Analysis, ISBN 978-90-481-8607-5, 470p.

ATSDR, 2007a. Analyses of Groundwater Flow, Contaminant Fate and Transport and Distribution of Drinking Water at Tarawa Terrace and Vicinity, U.S. Marine Corps Base Camp Lejeune, North Carolina: Historical Reconstruction and Present Days Conditions—Chapter A: Summary and Findings. Atlanta, GA: Agency for Toxic Substances and Disease Registry.

ATSDR, 2007b. Analyses of Groundwater Flow, Contaminant Fate and Transport and Distribution of Drinking Water at Tarawa Terrace and Vicinity, U.S. Marine Corps Base Camp Lejeune, North Carolina: Historical Reconstruction and Present Days Conditions—Executive Summary. Atlanta, GA: Agency for Toxic Substances and Disease Registry.

ATSDR, 2007c. Analyses of Groundwater Flow, Contaminant Fate and Transport and Distribution of Drinking Water at Tarawa Terrace and Vicinity, U.S. Marine Corps Base Camp Lejeune, North Carolina: Historical Reconstruction and Present Days Conditions—Chapter B, Geohydrologic Framework of the Castle Hayne Aquifer System, Atlanta, GA: Agency for Toxic Substances and Disease Registry.

ATSDR, 2007d. Analyses of Groundwater Flow, Contaminant Fate and Transport and Distribution of Drinking Water at Tarawa Terrace and Vicinity, U.S. Marine Corps Base Camp Lejeune, North Carolina: Historical Reconstruction and Present Days Conditions—Chapter C, Simulation of Groundwater Flow, Atlanta, GA: Agency for Toxic Substances and Disease Registry.

ATSDR, 2007e. Analyses of Groundwater Flow, Contaminant Fate and Transport and Distribution of Drinking Water at Tarawa Terrace and Vicinity, U.S. Marine Corps Base Camp Lejeune, North Carolina: Historical Reconstruction and Present Days Conditions—Chapter D, Properties and Degradation Pathways of Common Organic Compounds in Groundwater, Atlanta, GA: Agency for Toxic Substances and Disease Registry.

ATSDR, 2007f. Analyses of Groundwater Flow, Contaminant Fate and Transport and Distribution of Drinking Water at Tarawa Terrace and Vicinity, U.S. Marine Corps Base Camp Lejeune, North Carolina:

Historical Reconstruction and Present Days Conditions—Chapter E, Occurrence of Contaminants in Groundwater, Atlanta, GA: Agency for Toxic Substances and Disease Registry.

ATSDR, 2007g. Analyses of Groundwater Flow, Contaminant Fate and Transport and Distribution of Drinking Water at Tarawa Terrace and Vicinity, U.S. Marine Corps Base Camp Lejeune, North Carolina: Historical Reconstruction and Present Days Conditions—Chapter F, Simulation of the Fate and Transport of Tetrachloroethylene (PCE), Atlanta, GA: Agency for Toxic Substances and Disease Registry.

ATSDR, 2007h. Analyses of Groundwater Flow, Contaminant Fate and Transport and Distribution of Drinking Water at Tarawa Terrace and Vicinity, U.S. Marine Corps Base Camp Lejeune, North Carolina: Historical Reconstruction and Present Days Conditions—Chapter G, Simulation of Three-Dimensional Multispecies, Multiphase Mass Transport of Tetrachloroethylene (PCE) and Associated Degradation By-Products, Atlanta, GA: Agency for Toxic Substances and Disease Registry.

ATSDR, 2007i. Analyses of Groundwater Flow, Contaminant Fate and Transport and Distribution of Drinking Water at Tarawa Terrace and Vicinity, U.S. Marine Corps Base Camp Lejeune, North Carolina: Historical Reconstruction and Present Days Conditions—Chapter H, Effect of Groundwater Pumping Schedule Variation on Arrival of Tetrachloroethylene (PCE) at Water Supply Wells and Water Treatment Plant, Atlanta, GA: Agency for Toxic Substances and Disease Registry.

ATSDR, 2007j. Analyses of Groundwater Flow, Contaminant Fate and Transport and Distribution of Drinking Water at Tarawa Terrace and Vicinity, U.S. Marine Corps Base Camp Lejeune, North Carolina: Historical Reconstruction and Present Days Conditions—Chapter I, Parameter Sensitivity, Uncertainty, and Variability Associated with Model Simulations of Groundwater Flow, Contaminant Fate and Transport and Distribution of Drinking Water, Atlanta, GA: Agency for Toxic Substances and Disease Registry.

ATSDR, 2013a. Analyses and Historical Reconstruction of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Drinking Water Within the Service Areas of the Hadnot Point and Holcomb Boulevard Water Treatment Plants and Vicinities, U.S. Marine Corps Base Camp Lejeune, North Carolina—Chapter A: Summary and Findings. Atlanta, GA: Agency for Toxic Substances and Disease Registry.

ATSDR, 2013b. Analyses and Historical Reconstruction of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Drinking Water Within the Service Areas of the Hadnot Point and Holcomb Boulevard Water Treatment Plants and Vicinities, U.S. Marine Corps Base Camp Lejeune, North Carolina—Chapter A: Supplement 1, Descriptions and Characterizations of Data Pertinent to Water-Supply Well Capacities, Histories, and Operations, Agency for Toxic Substances and Disease Registry.

ATSDR, 2013c. Analyses and Historical Reconstruction of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Drinking Water Within the Service Areas of the Hadnot Point and Holcomb Boulevard Water Treatment Plants and Vicinities, U.S. Marine Corps Base Camp Lejeune, North Carolina—Chapter A: Supplement 2, Development and Application of a Methodology to Characterize Present-Day and Historical Water-Supply Well Operations, Agency for Toxic Substances and Disease Registry.

ATSDR, 2013d. Analyses and Historical Reconstruction of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Drinking Water Within the Service Areas of the Hadnot Point and Holcomb Boulevard Water Treatment Plants and Vicinities, U.S. Marine Corps Base Camp Lejeune, North

Carolina—Chapter A: Supplement 3, Descriptions and Characterizations of Water-Level Data and Groundwater Flow for the Brewster Boulevard and Castle Hayne Aquifer Systems and the Tarawa Terrace Aquifer, Agency for Toxic Substances and Disease Registry.

ATSDR, 2013e. Analyses and Historical Reconstruction of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Drinking Water Within the Service Areas of the Hadnot Point and Holcomb Boulevard Water Treatment Plants and Vicinities, U.S. Marine Corps Base Camp Lejeune, North Carolina—Chapter A: Supplement 4, Simulation of Three-Dimensional Groundwater Flow, Agency for Toxic Substances and Disease Registry.

ATSDR, 2013f. Analyses and Historical Reconstruction of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Drinking Water Within the Service Areas of the Hadnot Point and Holcomb Boulevard Water Treatment Plants and Vicinities, U.S. Marine Corps Base Camp Lejeune, North Carolina—Chapter A: Supplement 5 Theory, Development, and Application of Linear Control Model Methodology to Reconstruct Historical Contaminant Concentrations at Selected Water-Supply Wells, Agency for Toxic Substances and Disease Registry.

ATSDR, 2013g. Analyses and Historical Reconstruction of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Drinking Water Within the Service Areas of the Hadnot Point and Holcomb Boulevard Water Treatment Plants and Vicinities, U.S. Marine Corps Base Camp Lejeune, North Carolina—Chapter A: Supplement 6, Characterization and Simulation of Fate and Transport of Selected Volatile Organic Compounds in the Vicinities of the Hadnot Point Industrial Area and Landfill, Agency for Toxic Substances and Disease Registry.

ATSDR, 2013h. Analyses and Historical Reconstruction of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Drinking Water Within the Service Areas of the Hadnot Point and Holcomb Boulevard Water Treatment Plants and Vicinities, U.S. Marine Corps Base Camp Lejeune, North Carolina—Chapter A: Supplement 7, Source Characterization and Simulation of the Migration of Light Nonaqueous Phase Liquids (LNAPLs) in the Vicinity of the Hadnot Point Industrial Area, Agency for Toxic Substances and Disease Registry.

ATSDR, 2013i. Analyses and Historical Reconstruction of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Drinking Water Within the Service Areas of the Hadnot Point and Holcomb Boulevard Water Treatment Plants and Vicinities, U.S. Marine Corps Base Camp Lejeune, North Carolina—Chapter A: Supplement 8, Field Tests, Data Analyses, and Simulation of the Distribution of Drinking Water with Emphasis on Intermittent Transfers of Drinking Water Between the Hadnot Point and Holcomb Boulevard Water-Distribution Systems, Agency for Toxic Substances and Disease Registry.

ATSDR, 2013j. Analyses and Historical Reconstruction of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Drinking Water Within the Service Areas of the Hadnot Point and Holcomb Boulevard Water Treatment Plants and Vicinities, U.S. Marine Corps Base Camp Lejeune, North Carolina—Chapter B: Geohydrologic Framework of the Brewster Boulevard and Castle Hayne Aquifer Systems and the Tarawa Terrace Aquifer, Agency for Toxic Substances and Disease Registry.

ATSDR, 2013k. Analyses and Historical Reconstruction of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Drinking Water Within the Service Areas of the Hadnot Point and Holcomb Boulevard Water Treatment Plants and Vicinities, U.S. Marine Corps Base Camp Lejeune, North

Carolina—Chapter C: Occurrence of Selected Contaminants in Groundwater at Installation Restoration Program Sites, Agency for Toxic Substances and Disease Registry.

ATSDR, 2013I. Analyses and Historical Reconstruction of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Drinking Water Within the Service Areas of the Hadnot Point and Holcomb Boulevard Water Treatment Plants and Vicinities, U.S. Marine Corps Base Camp Lejeune, North Carolina—Chapter D: Occurrence of Selected Contaminants in Groundwater at Above-Ground and Underground Storage Tank Sites, Agency for Toxic Substances and Disease Registry.

ATSDR/ChemRISK, 2000. Oak Ridge Reservation Public Health Assessment, https://www.atsdr.cdc.gov/hac/pha/oakridgey12/oak_p7.html

ATSDR, 2000. Toms River Study, https://www.atsdr.cdc.gov/edrp/pdfs/tomsriver/dvrtwn_summary_30sep2001.pdf

Ayvaz, T., Karahan, H. and Aral, M.M., 2007. “Aquifer Parameter and Zone Structure Estimation Using Kernel-Based Fuzzy C-Means Clustering and Genetic Algorithm,” *Journal of Hydrology*, 343 (3-4): pp. 240-253.

Bedient, PB, Rifai, HS, Newell, CJ, 1999. Ground Water Contamination Transport and Remediation, Prentice Hall.

Bradley, PM., 2003. History and Ecology of Chloroethene Biodegradation: A Review. *Bioremediation Journal*. 7(2): 81-109.

Borowski EJ, and Borwein JM, 1991. The HarperCollins Dictionary of Mathematics. New York: HarperCollins Publishers.

CH2MHILL., 2007. Field Sampling Plan, Tarawa Terrace Elementary School, Marine Corps Base Camp Lejeune, North Carolina. Raleigh, NC: CH2MHILL.

Christiansen N, Christensen SR, Arvin E, and Ahring BK., 1997. Transformation of Tetrachloroethene in an Upflow Anaerobic Sludgeblanket Reactor. 47(1):91-94.

Clement, TP, Johnson, CD, Sun, YW, Klecka, GM, and Bartlett, C., 2000. Natural Attenuation of Chlorinated Ethene Compounds: Model Development and Field-Scale Application at the Dover Site. *Journal of Contaminant Hydrology*. 42(2-4):113-140.

Cohen, Y., 1986. Pollutants in a Multimedia Environment. New York: Plenum Publication Corp.

Colby, ME, 1990. Environmental management in development: the evolution of paradigms. World bank discussion papers, No 80. Washington, DC.

Curry, GL, et al. 1989. Discrete Simulation, Holden-Day, Oakland, CA.

Daugherty, JE, (2010, accessed 2024). PEST: Model-Independent Parameter Estimation and Uncertainty Analysis, <https://pesthomepage.org/>.

EPA, 1993. Record of Decision, ABC One Hour Cleaners, NC., EPA-ROD-R04-93-128.

EPA, 1994. Record of Decision, Marine Corps Base, Operable Unit 1, NC., EPA-ROD-R04-94-195.

EPA, 1988. Record of Decision, Tucson International Airport Area, AZ, EPA-ROD-R04-88-021.

Faye RE, and Green JW Jr., 2007. Analyses of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Drinking Water at Tarawa Terrace and Vicinity, U.S. Marine corps Base Camp Lejeune, North Carolina: Historical Reconstruction and Present-Day Conditions; Chapter E: Occurrence of Contaminants in Groundwater. Atlanta, GA: Agency for Toxic Substances and Disease Registry.

Farr AM, Houghtalen RJ, and McWhorter DB., 1990. Volume Estimation of Light Nonaqueous Phase Liquids in Porous Media. Ground Water, 28(1):48–56.

Fetter, CW. 1998. Contaminant Hydrogeology, Prentice Hall International NJ, USA, ISBN 0-13-751215-5.

GAO, 2007. Activities Related to Past Drinking Water Contamination at Marine Corps Base Camp Lejeune, U.S. Government Accountability Office, www.gao.gov/cgi-bin/getrpt?GAO-07-276.

Griffin BM, Tiedje JM, and Löffler FE., 2004. Anaerobic Microbial Reductive Dechlorination of Tetrachloroethene to Predominately trans-1,2-Dichloroethene. Environmental Science and Technology. 38(16): 4300-4303.

Holling, CS, 1978. Adaptive environmental assessment and management. Wiley, New York.

Hoffman, FO and Hammonds, JS, 1994. Propagation of uncertainty in risk assessment: the need to distinguish between uncertainty due to lack of knowledge and uncertainty due to variability, Risk Anal., 14(5):707-712.

Hoover, SV., Perry, RF. 1989. Simulation, Addison-Wesley, Reading, MA.

Hulling and Weaver, 1991. "Dense Nonaqueous Phase Liquids," Ground Water Issue, USEPA Office of Research and Development, EPA/540/4-91-002.

IAEA. 1982. Radioactive waste management glossary. Report IAEA-TECDOC-264, International Atomic Energy Agency, Vienna, Austria (Second Edition was published as IAEA-TECDOC-447, 1988).

Jang, W. and Aral, MM, 2005. Three-dimensional Multiphase Flow and Multispecies Transport Model, TechFlowMP, Multimedia Environmental Simulation Laboratory, School of Civil and Environmental Engineering, Georgia Institute of Technology, Atlanta, Georgia USA, MESL-02-05.

Jang W, and Aral MM. 2007. Analyses of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Drinking Water at Tarawa Terrace and Vicinity, U.S. Marine corps Base camp Lejeune, North Carolina: Historical Reconstruction and Present-Day Conditions Chapter G: Simulation of Three-Dimensional Multispecies, Multiphase Mass Transport of Tetrachloroethylene (PCE) and Associated Degradation By-Products. Atlanta, GA: Agency for Toxic Substances and Disease Registry.

Jang, W and Aral, MM, 2007. "Density Driven Transport of Volatile Organic Compounds and Its impact on Contaminated Groundwater Plume Evolution," Journal of Transport in Porous Media, 67(3): pp. 353-374.

Jang, W. and Aral, MM, 2008a. "Effect of Biotransformation on Multi-species Plume Evolution and Natural Attenuation" International Journal on Transport in Porous Media, 72(2): pp. 207-226.

Jang, W. and Aral, MM, 2008b. "Multiphase Flow Fields in In-Situ Air Sparging and It's Effect on Remediation" International Journal on Transport in Porous Media, 76, pp. 99-119.

Jang, W. and Aral, MM, 2011. "In-Situ Air Sparging and Thermal Venting in Ground Water Remediation," Chapter 11 in Groundwater Quality and Quantity Management, Editors Aral, M. M. and Taylor, S., ASCE, pp. 530-575, ISBN-978-0-7844-1176-6.

Konikow, LF and Bredehoeft, JD, 1992. Groundwater Models Cannot be Validated, Advances in Water Resources, 15, pp.75-83.

Lawrence SJ., 2007. Analyses of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Drinking Water at Tarawa Terrace and Vicinity, U.S. Marine corps Base camp Lejeune, North Carolina: Historical Reconstruction and Present-Day Conditions-Chapter D: Properties and Degradation Pathways of Common Organic Compounds in Groundwater. Atlanta, GA: Agency for Toxic Substances and Disease Registry.

Maslia, ML and Aral, MM. 2004. "ACTS - A Multimedia Environmental Fate and Transport Analysis System." ASCE Practice Periodical of Hazardous, Toxic, and Radioactive waste Management-ASCE 8(3): 181-198.

Maslia ML., 2005. Expert Peer Review Panel Evaluating ATSDR's Water-Modeling Activities in Support of the Current Study of Childhood Birth Defects and Cancer at U.S. Marine Corps Base Camp Lejeune, North Carolina: Atlanta, GA: Agency for Toxic Substances and Disease Registry.

Maslia, ML, Reyes, JJ, Gillig, RE, Sautner, JB, Fagliano, JA, Aral, MM, 2005. Public health partnerships addressing childhood cancer investigations: case study of Toms River, Dover Township, New Jersey, USA, International Journal of Hygiene and Environmental Health, Volume 208, Issues 1–2, Pages 45-54.

Maslia ML, Sautner JB, Faye RE, Suárez-Soto RJ, Aral MM, Grayman WM, Jang W, Wang J, Bove FJ, Ruckart PZ, Valenzuela C, Green JW Jr., and Krieger AL., 2007. Analyses of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Drinking Water at Tarawa Terrace and Vicinity, U.S. Marine Corps Base Camp Lejeune, North Carolina: Historical Reconstruction and Present-Day Conditions Chapter A: Summary of Findings. Atlanta, GA: Agency for Toxic Substances and Disease Registry.

Maslia, M.L. et al. 2009(a) Expert Peer Review Panel Evaluating ATSDR's Water-Modeling Activities in Support of the Current Study of Childhood Birth Defects and Cancer at U.S. Marine Corps Base Camp Lejeune, North Carolina: Atlanta, GA: Agency for Toxic Substances and Disease Registry. (<https://www.atsdr.cdc.gov/sites/lejeune/expert-panels.html>).

Maslia, M.L. et al. 2009(b). "Reconstructing Historical Exposures to Volatile Organic Compound-Contaminated Drinking Water at a U.S. Military Base." *Water Quality, Exposure, and Health*. 2009, 1, 49-68.

Maslia, M.L. et al., 2016. "Reconstructing Historical VOC Concentrations in Drinking Water for Epidemiological Studies at a U.S. Military Base: Summary of Results." *Water*. 2016, 8, 449, 1-23.

McDermott MJ, Mazor KA, Shost SJ, Narang RS, Aldous KM, and Storm JE., 2005. Tetrachloroethylene (PCE, Perc) Levels in Residential Dry Cleaner Buildings in Diverse Communities in New York City. *Environmental Health Perspectives.*, 113(1):1336 1343.

Mei J, 2023. "Ten strategies towards successful calibration of environmental models." *Journal of Hydrology*, 620, 129414.

Miller GS, Milliken CE, Sowers KR, and May HD., 2005. Reductive Dechlorination of Tetrachloroethene to trans-Dichloroethene and cis-Dichloroethene by PCB-Dechlorinating Bacterium DF-1; *Environmental Science and Technology*, 2631-2635.

McLaren/Hart-ChemRisk. 2000. Oak Ridge Dose Reconstruction Project Summary Report. Alameda, CA: McLaren/Hart-ChemRisk.

Meharg, AA, 2005. *Venomous Earth: How arsenic caused the worlds worst mass poisoning*, Macmillan, London.

McCarl, BA, 1984. An overview; with some emphasis on risk models. *Rev. Market Agric. Econ.* 52: 153-173.

Newell, CJ, Acree, SD, Ross, RR, 1995. *Ground Water Issue: Light Nonaqueous Phase Liquids*, USEPA, Office of Research and Development, 28p.

North Carolina Department of Environment and Natural Resources (NCDENR), 2003. Superfund Five-Year Review Report, ABC One Hour Cleaners, Jacksonville, Onslow County, North Carolina, EPA ID: NCD 024644494. Raleigh, NC; North Carolina Department of Environment and Natural Resources; 2003 August.

NRC, 1990. *Groundwater Models: Scientific and Regulatory Applications*, NRC, Washington DC, 303p.

NRC, 2009a. *Contaminated Water Supplies at Camp Lejeune: Assessing Potential Health Effects*, Committee on Contaminated Drinking Water at Camp Lejeune; National Research Council, ISBN: 0-309-13700-4, 340 pages.

NRC, 2009b. Scientific evidence of health problems from past contamination of drinking water at Camp Lejeune is limited and unlikely to be resolved with further study, NRC Press Release. Date: June 13, 2009, Office of News and Public Information.

Nuckols, JR., Wared MH, and Jarup L., 2004. Using Geographic Information Systems for Exposure Assessment in Environmental Epidemiology Studies. *Environmental Health Perspectives.* 112(9):1007-1015.

Oreskes, N. et al., 1994. Verification, Validation, and Confirmation of Numerical Models in the Earth Sciences, *Science*, 263(5147):641-646.

Pankow JF, and Cherry JA., 1996. *Dense Chlorinated Solvents and Other DNAPLs in Groundwater: History, Behavior, and Remediation*: Waterloo Press.

PNL, 1991, Hanford Environmental Report, <https://hmis.hanford.gov/files.cfm/1991PNL-8148UC-602.pdf>

Power, M, 1993. The predictive validation of ecological and environmental models. *Ecol. Model*, 68(1-2): 33-50.

Rao, SS, 1996, *Engineering Optimization, Theory and Practice*, John Wiley and Sons.

Reif JS, Burch JB, Nuckols JR, Metzger L, Ellington D, Anger WK. Neurobehavioral effects of exposure to trichloroethylene through a municipal water supply. *Environ Res*. 2003 Nov;93(3):248-58. doi: 10.1016/s0013-9351(03)00131-2. PMID: 14615234.

Rodenbeck, 2023. George AFB's Flawed Public Health Assessment (PHA), <https://www.georgeafb.info/george-afb-public-health-assessment/>

Ross SM, 1997. *Introduction to Probability Models*. London, UK: Academic Press.

Roy F. Weston, Inc. 1994. Remedial Investigation Report, ABC One-Hour Cleaners, Operable Unit 2, Jacksonville, North Carolina: Roy F. Weston, Inc.

Roy F. Weston, Inc. 1992. Remedial Investigation Report, ABC One-Hour Cleaners, Jacksonville, North Carolina: Roy F. Weston, Inc.

Sahmel, J., Devlin, K., Paustenbach, D., Hollins, D., & Gaffney, S. 2010. The role of exposure reconstruction in occupational human health risk assessment: Current methods and a recommended framework. *Critical Reviews in Toxicology*, 40(9), 799–843. <https://doi.org/10.3109/10408444.2010.501052>

Schlesinger, S. 1979. Terminology for model credibility. *Simulation*. v. 32, no. 3, pp. 103-104.

Seargent, RG, 1984. A tutorial on verification and validation of simulation models. In: *Proceedings of the 1984 Water Simulation Conference IEEE 84CH2098-2*, Dallas TX.

Shiver R., 1985. Groundwater Investigation to Define the Source(s) of Tetrachloroethylene that Have Contaminated Three Community Water Supply Wells at Tarawa Terrace I, Camp Lejeune Marine Corps Base, Onslow County: North Carolina Department of Natural Resources and Community Development.

SWMU 9., 2002. Treatability Study Annual Monitoring Report, Naval Air Facility, Key West, Florida. Norfolk, VA: Southern Division Naval Facilities Engineering Command, Tetra Tech. NUS, Inc.

Starfield, AM and Bleloch, AI, 1986. *Building models for conservation and wildlife management*. Macmillan, New York.

Telci, IT, Sautner, J, Suarez-Soto, R, Anderson, BA, Maslia, ML and Aral, MM, 2011. Historical Well Scheduling for Holcomb Boulevard and Hadnot Point Water Treatment Plants of Camp Lejeune, North Carolina, Multimedia Environmental Simulation Laboratory, School of Civil and Environmental Engineering, Georgia Institute of Technology, Atlanta, Georgia USA, MESL-01-11.

USEPA. Accessed 2024. Technical Factsheet on: TETRACHLOROETHYLENE, <https://archive.epa.gov/water/archive/web/pdf/archived-technical-fact-sheet-on-tetrachloroethylene.pdf>

U.S. Environmental Protection Agency. Underground Motor Fuel Storage Tanks: A National Survey. Washington, DC: U.S. Environmental Protection Agency, EPA-560/5-86-013; 1986.

USEPA., 2009. Guidance on the Development, Evaluation, and Application of Environmental Models. Washington, DC: U.S. Environmental Protection Agency, Office of the Science Advisor, Council for Regulatory Environmental Modeling; 2009 March. Report No.: EPA/100/K-09/003. [cited 2009 July 1]; Available from <http://www.epa.gov/crem/cremlib.html>

USGS, 2003. Fate and Transport Modeling of Selected Chlorinated Organic Compounds at Operable Unit 1, U.S. Naval Air Station, Jacksonville, Florida, Prepared in cooperation with the U.S. Navy, Naval Facilities Engineering Command, Scientific Investigations Report 2007-5043.

Wang J, and Aral MM. 2008. Analyses of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Drinking Water at Tarawa Terrace and Vicinity, U.S. Marine Corps Base Camp Lejeune, North Carolina: Historical Reconstruction and Present-Day Conditions, Chapter H: Effect of Groundwater Pumping Schedule Variation on Arrival of Tetrachloroethylene (PCE) at Water-Supply Wells and the Water Treatment Plant. Atlanta, GA: Agency for Toxic Substances and Disease Registry.

Wang J., 2008. Sensitivity and Uncertainty Analyses of Contaminant Fate and Transport in a Field-Scale Subsurface System. Ph.D. Dissertation. Atlanta, GA: Georgia Institute of Technology, School of Civil and Environmental Engineering.

Wiedemeier TH., 1998. Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water. Cincinnati, OH: National Risk Management Research Laboratory Office of Research and Development.

8.2 Reliance Materials

1. Maslia, M.L. et al. 2007. "Analyses of Groundwater Flow, Contaminant Fate, and Transport, and Distribution of Drinking Water at Tarawa Terrace and Vicinity, U.S. Marine Corps Base Camp Lejeune, North Carolina: Historical Reconstruction and Present-Day Conditions - Chapter A: Summary of Findings." ATSDR, July 2007.
2. Faye, R.E. et al. 2007. "Analyses of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Drinking Water at Tarawa Terrace and Vicinity, U.S. Marine Corps Base Camp Lejeune, North Carolina: Historical Reconstruction and Present Day Conditions - Chapter B: Geohydrologic Framework of the Castle Hayne Aquifer System." ATSDR, September 2007.
3. Faye, R.E. et al. 2007. "Analyses of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Drinking Water at Tarawa Terrace and Vicinity, U.S. Marine Corps Base Camp Lejeune, North Carolina: Historical Reconstruction and Present Day Conditions - Chapter C: Simulation of Groundwater Flow." ATSDR, November 2007.
4. Lawrence, S.J. et al. 2007. "Analyses of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Drinking Water at Tarawa Terrace and Vicinity, U.S. Marine Corps Base Camp Lejeune, North Carolina: Historical Reconstruction and Present Day Conditions -

Chapter D: Properties and Degredation Pathways of Common Organic Compounds in Groundwater.” ATSDR, September 2007.

5. Faye, R.E. and Green, J.W. 2007. “Analyses of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Drinking Water at Tarawa Terrace and Vicinity, U.S. Marine Corps Base Camp Lejeune, North Carolina: Historical Reconstruction and Present Day Conditions - Chapter E: Occurrence of Contaminants in Groundwater.” ATSDR, December 2007.
6. Faye, R.E. et al. 2008. “Analyses of Groundwater Flow, Contaminant Fate, and Transport, and Distribution of Drinking Water at Tarawa Terrace and Vicinity, U.S. Marine Corps Base Camp Lejeune, North Carolina: Historical Reconstruction and Present-Day Conditions - Chapter F: Simulation of the Fate and Transport of Tetrachloroethylene (PCE).” ATSDR, February 2008.
7. Jang, W. et al. 2008. “Analyses of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Drinking Water at Tarawa Terrace and Vicinity, U.S. Marine Corps Base Camp Lejeune, North Carolina: Historical Reconstruction and Present Day Conditions - Chapter G: Simulation of Three-Dimensional Multispecies, Multiphase Mass Transport of Tetrachloroethylene (PCE) and Associated Degradation By-Products.” ATSDR, April 2008.
8. Jang, W. and Aral, M.M. 2008. “Analyses of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Drinking Water at Tarawa Terrace and Vicinity, U.S. Marine Corps Base Camp Lejeune, North Carolina: Historical Reconstruction and Present Day Conditions - Chapter H: Effect of Groundwater Pumping Schedule Variation on Arrival of Tetrachloroethylene (PCE) at Water-Supply Wells and the Water Treatment Plant.” ATSDR, February 2008.
9. Maslia, M.L. et al. 2009(a). “Analyses of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Drinking Water at Tarawa Terrace and Vicinity, U.S. Marine Corps Base Camp Lejeune, North Carolina: Historical Reconstruction and Present-Day Conditions - Chapter I: Parameter Sensitivity, Uncertainty, and Variability Associated with Model Simulations of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Drinking Water.” ATSDR, February 2009.
10. Maslia, M.L. et al. 2013. “Analyses and Historical Reconstruction of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Drinking Water Within the Service Areas of the Hadnot Point and Holcomb Boulevard Water Treatment Plants and Vicinities, U.S. Marine Corps Base Camp Lejeune, North Carolina - Chapter A: Summary and Findings.” ATSDR, March 2013.
11. Sautner, J.B. et al. 2013. “Analyses and Historical Reconstruction of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Drinking Water Within the Service Areas of the Hadnot Point and Holcomb Boulevard Water Treatment Plants and Vicinities, U.S. Marine Corps Base Camp Lejeune, North Carolina - Chapter A–Supplement 1 - Descriptions and Characterizations of Data Pertinent to Water-Supply Well Capacities, Histories, and Operations.” ATSDR, March 2013.
12. Telci, I.T. et al. 2013. “Analyses and Historical Reconstruction of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Drinking Water Within the Service Areas of the Hadnot Point and Holcomb Boulevard Water Treatment Plants and Vicinities, U.S. Marine Corps Base Camp Lejeune, North Carolina - Chapter A–Supplement 2 - Development and Application of a Methodology to Characterize Present-Day and Historical Water-Supply Well Operations.” ATSDR, March 2013.
13. Faye, R.E. et al. 2013. “Analyses and Historical Reconstruction of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Drinking Water Within the Service Areas of the Hadnot Point and Holcomb Boulevard Water Treatment Plants and Vicinities, U.S. Marine Corps Base Camp Lejeune, North Carolina - Chapter A–Supplement 3 - Descriptions

and Characterizations of Data Pertinent to Water-Level Data and Groundwater Flow for the Brewster Boulevard and Castle Hayne Aquifer Systems and the Tarawa Terrace Aquifer." ATSDR, March 2013.

14. Suarez-Soto, et al. 2013. "Analyses and Historical Reconstruction of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Drinking Water Within the Service Areas of the Hadnot Point and Holcomb Boulevard Water Treatment Plants and Vicinities, U.S. Marine Corps Base Camp Lejeune, North Carolina - Chapter A–Supplement 4 - Simulation of Three-Dimensional Groundwater Flow." ATSDR, March 2013.
15. Guan, J. et al. 2013. "Analyses and Historical Reconstruction of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Drinking Water Within the Service Areas of the Hadnot Point and Holcomb Boulevard Water Treatment Plants and Vicinities, U.S. Marine Corps Base Camp Lejeune, North Carolina - Chapter A–Supplement 5 - Theory, Development, and Application of Linear Control Model Methodology to Reconstruct Historical Contaminant Concentrations at Selected Water-Supply Wells." ATSDR, March 2013.
16. Jones, L.E. et al. 2013. "Analyses and Historical Reconstruction of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Drinking Water Within the Service Areas of the Hadnot Point and Holcomb Boulevard Water Treatment Plants and Vicinities, U.S. Marine Corps Base Camp Lejeune, North Carolina - Chapter A–Supplement 6 Characterization and Simulation of Fate and Transport of Selected Volatile Organic Compounds in the Vicinities of the Hadnot Point Industrial Area and Landfill." ATSDR, March 2013.
17. Jang, W. et al. 2013. "Analyses and Historical Reconstruction of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Drinking Water Within the Service Areas of the Hadnot Point and Holcomb Boulevard Water Treatment Plants and Vicinities, U.S. Marine Corps Base Camp Lejeune, North Carolina - Chapter A–Supplement 7 - Source Characterization and Simulation of the Migration of Light Nonaqueous Phase Liquids (LNAPLs) in the Vicinity of the Hadnot Point Industrial Area." ATSDR, March 2013.
18. Sautner, J.B. et al. 2013. "Analyses and Historical Reconstruction of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Drinking Water Within the Service Areas of the Hadnot Point and Holcomb Boulevard Water Treatment Plants and Vicinities, U.S. Marine Corps Base Camp Lejeune, North Carolina - Chapter A–Supplement 8 - Field Tests, Data Analyses, and Simulation of the Distribution of Drinking Water with Emphasis on Intermittent Transfers of Drinking Water Between the Hadnot Point and Holcomb Boulevard Water-Distribution Systems." ATSDR, March 2013.
19. Faye, R.E. et al. 2012. "Analyses and Historical Reconstruction of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Drinking Water Within the Service Areas of the Hadnot Point and Holcomb Boulevard Water Treatment Plants and Vicinities, U.S. Marine Corps Base Camp Lejeune, North Carolina - Chapter B: Geohydrologic Framework of the Brewster Boulevard and Castle Hayne Aquifer Systems and the Tarawa Terrace Aquifer." ATSDR, January 2012.
20. Faye, R.E. et al. 2010. "Analyses and Historical Reconstruction of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Drinking Water Within the Service Areas of the Hadnot Point and Holcomb Boulevard Water Treatment Plants and Vicinities, U.S. Marine Corps Base Camp Lejeune, North Carolina - Chapter C: Occurrence of Selected Contaminants in Groundwater at Installation Restoration Program Sites." ATSDR, October 2010.
21. Faye, R.E. et al. 2012. "Analyses and Historical Reconstruction of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Drinking Water Within the Service Areas

of the Hadnot Point and Holcomb Boulevard Water Treatment Plants and Vicinities, U.S. Marine Corps Base Camp Lejeune, North Carolina - Chapter D: Occurrence of Selected Contaminants in Groundwater at Above-Ground and Underground Storage Tank Sites.” ATSDR, December 2012.

22. The documents, information and data identified in Appendix A2 (“Information sources used to extract model-specific data for historical reconstruction analyses, U.S. Marine Corps Base Camp Lejeune, North Carolina”) to Maslia et al., Analyses and Historical Reconstruction of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Drinking Water Within the Service Areas of the Hadnot Point and Holcomb Boulevard Water Treatment Plants and Vicinities, U.S. Marine Corps Base Camp Lejeune, North Carolina—Chapter A: Summary and Findings, ATSDR 2013.
23. Maslia, M.L. (Editor). 2005. “Expert Peer Review Panel Evaluating ATSDR’s Water-Modeling Activities in Support of the Current Study of Childhood Birth Defects and Cancer at U.S Marine Corps Base Camp Lejeune, North Carolina.” ATSDR, Meeting March 28-29, 2005, published October 2005.
24. Maslia, M.L. (Editor). 2009. “Expert Panel Assessing ATSDR’s Methods and Analyses for Historical Reconstruction of Groundwater Resources and Distribution of Drinking Water at Hadnot Point, Holcomb Boulevard, and Vicinity, U.S. Marine Corps Base Camp Lejeune, North Carolina.” ATSDR, April 29-30, 2009, published December 2009.
25. March 28, 2005 Expert Peer Review Panel Meeting Transcript, available at https://www.atsdr.cdc.gov/sites/lejeune/panel_report_groundwater.html
26. March 29, 2005 Expert Peer Review Panel Meeting Transcript, available at https://www.atsdr.cdc.gov/sites/lejeune/panel_report_groundwater.html
27. April 29, 2009 Expert Peer Review Panel Meeting Transcript, available at <https://www.atsdr.cdc.gov/sites/lejeune/expertpanels.html>
28. April 30, 2009 Expert Peer Review Panel Meeting Transcript, available at <https://www.atsdr.cdc.gov/sites/lejeune/expertpanels.html>
29. February 8, 2012 Deposition of Elizabeth Ann Betz and any exhibits referenced therein
30. June 30, 2010 Deposition of Morris Maslia and exhibits referenced therein
31. May 28, 2024 Deposition of General Anthony Zinni; Zinni Deposition Exhibits 1-8
32. August 5, 2024 Deposition of Kim Henderson; Henderson Deposition Exhibits 1-18
33. August 6, 2024 Deposition of Dan Waddill; Waddill Deposition Exhibits 1-20
34. August 14, 2024 Deposition of Jason Barry Sautner; Sautner Deposition Exhibits 1-10
35. August 15, 2024 Deposition of Rene Suarez-Soto; Suarez-Soto Deposition Exhibits 1-5
36. August 22, 2024 Deposition of Dr. Chris Rennix; Rennix Deposition Exhibits 1-6
37. September 26, 2024 Deposition of Morris Maslia; Maslia Deposition Exhibits 1-22
38. ATSDR Camp Lejeune Project File: CLJA_ATSDRWM01-0000000001-CLJA_ATSDRWM01-0000189563; CLJA_WATERMODELING-0000000001-CLJA_WATERMODELING-0000209307; CLJA_WATERMODELING_01-0000000001-CLJA_WATERMODELING_01-0000854197; ATSDR_WATERMODELING_01-0000854198-ATSDR_WATERMODELING_01-0000936235; CLJA_WATERMODELING_01-0000936236-CLJA_WATERMODELING_01-0001118025; CLJA_WATERMODELING_04-0000000001-CLJA_WATERMODELING_04-0000117996; CLJA_WATERMODELING_05-0000000001-CLJA_WATERMODELING_05-0001394405; ATSDR_WATERMODELING_05-0001394406-ATSDR_WATERMODELING_05-0001394413; CLJA_WATERMODELING_07-0000000001-CLJA_WATERMODELING_07-0002316354; CLJA_WATERMODELING_08-0000000001-CLJA_WATERMODELING_08-0000193508; CLJA_WATERMODELING_09-0000000001-CLJA_WATERMODELING_09-0000547124; ATSDR_WATERMODELING_09-0000547125-ATSDR_WATERMODELING_09-0000568329;

CLJA_WATERMODELIING_09-0000568330-CLJA_WATERMODELIING_09-0000615612;
CLJA_WATERMODELING_09-0000615613-CLJA_WATERMODELING_09-0000745917

39. Georgia Tech Camp LeJeune Water Modeling Working Files
40. 00897_PLG_0000067113-00897_PLG_0000067132
41. 00897_PLG_0000339484-00897_PLG_0000339588
42. 00897_PLG_0000063393-00897_PLG_0000063594
43. 00897_PLG_0000065633-00897_PLG_0000065659
44. CLJA_ATSDR_BOVE-0000006959-CLJA_ATSDR_BOVE-0000006960

The forthcoming depositions of Frank Bove, Susan Martel, and Scott Williams, including any accompanying deposition exhibits and any other materials later produced in this litigation for which I reserve the right to read, review and rely upon.

9. Glossary of Abbreviations, and Definitions

Definitions of terms and abbreviations used throughout this report are listed below in alphabetical order.

ATSDR: Agency for Toxic Substances and Disease Registry.

BTEX: Benzene, toluene, ethyl benzene, and xylenes. These compounds are some of the VOCs found in petroleum derivatives such as gasoline. BTEX compounds typically occur near petroleum and natural gas production sites, gasoline stations, and other areas with underground storage tanks (USTs) or above-ground storage tanks (ASTs) containing gasoline or other petroleum-related products

CDC: Centers for Disease Control and Prevention.

DCE Dichloroethylene; an industrial chemical that is not found naturally in the environment. The USEPA has determined that 1,1-dichloroethylene is a possible human carcinogen

1,1-DCE 1,1-dichloroethylene or 1,1-dichloroethene

1,2-DCE 1,2-dichloroethylene or 1,2-dichloroethene

1,2-cDCE *cis*-1,2-dichloroethylene or *cis*-1,2-dichloroethene

1,2-tDCE *trans*-1,2-dichloroethylene or *trans*-1,2-dichloroethene

total 1,2-DCE total 1,2-dichloroethylene or total 1,2-dichloroethene

DNAPL: Nonaqueous Phase Liquids that are denser than water.

DOD: Department of Defense.

DON: Department of the Navy.

DPL: Liquids that mix with water, as opposed to nonmixing phase liquids NAPL.

EPANET 2: A water-distribution system (or network) model developed by the USEPA (Rossman 2000)

GAO: Government Accountability Office.

GSBC: Ground Surface Boundary Condition.

HBWTP: Holcomb Boulevard Water Treatment Plant.

HPWTP: Hadnot Point Water Treatment Plant.

HSMM: A one-dimensional NAPL volume estimator model and software developed by USEPA (Weaver et al. 1996).

LCT: Linear Control Theory. A scientific methodology of the scientific field of control engineering and applied mathematics. The methodology deals with the control of dynamical systems in engineered processes. In the case of ATSDR study of the Camp Lejeune site, the methodology was applied to groundwater contaminant transport analysis as a simple application to predict concentration values at a specific point in space and time based on limited data available at the site. This study was requested by the expert panel which reviewed the ATSDR Camp Lejeune site study and provided scientific advice.

LNAPL: Nonaqueous Phase Liquids that are lighter than water.

Markov process: A process that analyzes the tendency of one event to be followed by another event based on the sequence of events. Using this analysis, one can generate a new sequence of random but related events, which will look similar to the original; a stream of events is called a Markov Chain.

MCL: Maximum contaminant level; a legal threshold limit set by the USEPA on the amount of a hazardous substance that is allowed in drinking water under the Safe Drinking Water Act; usually expressed as a concentration in milligrams or micrograms per liter (USEPA 2003, 2009).

MESL: Multimedia Environmental Simulations Laboratory, a research center at Georgia Institute of Technology.

MODFLOW: A U.S. Geological Survey modular finite-difference flow model, which is a computer code that solves the groundwater flow equations. Used worldwide in groundwater flow simulations in subsurface systems.

Monte Carlo analysis: Also referred to as Monte Carlo simulation; a computer-based method of analysis that uses statistical sampling techniques to obtain a probabilistic approximation to the solution of a mathematical equation or model (USEPA 1997).

MT3DMS: Three-dimensional mass transport, multispecies model developed on behalf of the U.S. Army Engineer Research and Development Center. MT3DMS-5.3 (Zheng and Wang 1999) is the specific version of MT3DMS code used for the Hadnot Point–Holcomb Boulevard study area analyses; references to MT3DMS in text, figures, tables, appendixes, and supplemental information refer to MT3DMS-5.3. It can be used linked to a **MODFLOW** model. Used worldwide in contaminant transport simulations in subsurface systems.

NAC: National Academy of Sciences.

NAPL: Nonaqueous phase liquids; hazardous organic liquids such as dry-cleaning fluids, fuel oil, and gasoline that do not readily dissolve in water. Dense NAPLs (DNAPLs), such as the chlorinated hydrocarbons (e.g., PCE, TCE) used in dry cleaning and industrial degreasing, are heavier than water and sink through the water column. Hydrocarbon fuels and aromatic solvents are described as light NAPLs (LNAPLs), which are less dense than water and float. These include lubricants and gasoline, pollutants often associated with leaking gasoline or oil storage tanks (e.g., benzene).

NRC: National Research Council.

PCE: Tetrachloroethylene, 1,1,2,2-tetrachloroethylene, or perchloroethylene; also known as PERC® or PERK®. PCE is a manufactured chemical used for dry cleaning and metal degreasing. In 2012, following its Guidelines for Carcinogen Risk Assessment (USEPA 2005), the USEPA characterized PCE as likely to be carcinogenic in humans by all routes of exposure (USEPA 2012).

PEST: Model independent, objective parameter estimation and uncertainty analysis code originally developed by Watermark Numerical Computing (Doherty 2003, 2010); the current version is PEST-12, available at <http://www.pesthomepage.org/Downloads.php>.

PSOps: Pumping Schedule Optimization System application developed by MESL, Ga. Tech. The study included the development of a simulation and optimization procedure identified as PSOps, which combines simulation models (MODFLOW, MT3DMS, TECHFLOWMP) and optimization techniques to optimize the pumping schedules to identify maximum or minimum contaminant concentrations in the WTP consistent with the reported pumping schedules and demands on finished water supply at Camp Lejeune site. Based on the optimized pumping schedules, variations of PCE concentration and the maximum contaminant level (MCL, PCE, TCE etc.) arrival times at water-supply wells and the WTP are evaluated (Wang and Aral, 2008, ATSDR, 2007; ATSDR, 2013).

Sensitivity Analysis: A method used to ascertain how a given model output (e.g., concentration) depends upon the input parameters (e.g., time-step size, pumping rate). Sensitivity analysis is an important method for assessing the quality of a given model and a powerful tool for analyzing the robustness and reliability model analyses.

TCE: 1,1,2-Trichloroethene; commonly referred to as 1,1,2-trichloroethylene or trichloroethylene. TCE is a colorless liquid which is used as a solvent for cleaning metal parts. In 2011, following its Guidelines for Carcinogen Risk Assessment (USEPA 2005), the USEPA characterized TCE as carcinogenic in humans by all routes of exposure (USEPA 2011).

TechControl: A linear control theory model and software developed by MESL, Ga Tech. It is used to address the question of application of simpler models to predicting contaminant concentrations

at certain locations of Camp Lejeune site. The development of the software was based on a request that was initiated by the ATSDR Expert Panel of scientists.

TechFlowMP: Three-dimensional multispecies, multiphase mass transport model developed by the Multimedia Environmental Simulations Laboratory at the Georgia Institute of Technology, Atlanta, Georgia.

TechMarkovChain: A model and software developed by MESL, Ga. Tech. It is based on a scientific mathematical methodology called Markov stochastic sequential processes (Ross, 1997). It is used to estimate intermittent connections (1972–1985) of the Hadnot Point and Holcomb Boulevard water-distribution systems based on the analysis of available field data collected at the Camp Lejeune site. The development of the software was based on a discussion that was initiated by the ATSDR Expert Panel of scientists (see section 5.9 for more details).

TechNAPLVol: A subsurface NAPL volume estimation model developed by MESL, Ga. Tech. It is a NAPL volume estimation model based on USEPA HSM analysis described above. In this case the USEPA HSM procedures are extended to three-dimensional analysis and used to estimate the volume of spilled BTEX compounds at the Camp Lejeune site. This software is an integral part of TECHFLOWMP (see section 5.10 for more details).

TechWellOp: A subsurface pumping well estimation model and software developed by MESL, Ga. Tech. The methodology uses the daily data in the Training Period to determine the monthly operational behavior of the water supply wells at the Camp Lejeune site that would satisfy the total water volume delivered to the water treatment plants. Once the average monthly working days in the Training Period are estimated for each calendar month, they are utilized in the prediction stage which is based on the same principle of satisfying the total monthly flow delivered to the treatment plant. This methodology is an efficient and effective way of integrating the available data in recent years to the prediction process for the past years. The development of the software was based on a discussion that was initiated by the ATSDR Expert Panel of scientists (see section 5.8 for more details and ATSDR, 2007).

Uncertainty: Lack of knowledge about specific factors, parameters, or models (for example, one is uncertain about the mean value of the concentration of PCE at the source).

Uncertainty analysis: Determination of the uncertainty (e.g., standard deviation) of the output variables' expected value (e.g., mean) due to uncertainty in model parameters, inputs, or initial state by stochastic modeling techniques (Schnoor 1996).

Unsaturated zone: Zone or area below ground in which the interconnected openings within the geologic medium contain a mixture of water under pressure less than atmospheric and air under atmospheric pressure; sometimes referred to as the vadose zone or the zone above the water table. The capillary fringe is part of the unsaturated zone and sometimes occurs as completely saturated.

USEPA: United States Environmental Protection Agency.

USMC: United States Marine Corps.

VC: Vinyl chloride or chloroethene; a colorless gas that burns easily, is not stable at high temperatures, and has a mild, sweet odor. It is a manufactured substance that does not occur naturally. It can be formed when other substances such as TCA, TCE, or PCE undergo biochemical degradation. The USEPA has characterized VC as a known human carcinogen (USEPA 2000). The NTP Report on Carcinogens (NTP 2011) has recognized vinyl chloride as a known human carcinogen based on sufficient evidence of carcinogenicity in humans.

VOC: Volatile organic compound; one of a group of carbon-containing compounds that evaporate readily at room temperature and can readily be inhaled. Examples of VOCs include tetrachloroethylene (PCE), trichloroethylene (TCE), vinyl chloride (VC), and benzene. These contaminants typically are generated from metal degreasing, printed circuit board cleaning, dry cleaning, gasoline, and

wood preserving processes. VOCs are environmental contaminants, and some are classified as known human carcinogens (e.g., TCE, VC, and benzene).

WTP: Water treatment plant.

Exhibit A

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EDUCATION:

Ph.D. in Environmental Fluid Mechanics with minor in Numerical Analysis and Applied Mathematics, Sept. 1971, School of Civil Eng., Georgia Institute of Technology, USA.

M.S. in Civil Engineering with major in Environmental and Water Resources Engineering, June 1969, School of Civil Eng., Georgia Institute of Technology, USA.

B.S. in Civil Engineering, June 1967, Department of Civil Engineering, Middle East Technical University, Turkey.

EMPLOYMENT:

2018-present	Emeritus Prof.	School of Civil and Environmental Engineering, Ga. Tech., USA.
2018-2020	Dean	College of Engineering, Architecture and Design, Bartın Univ., Turkey.
2018-2020	Vice President	International Programs and Research, Bartın University, Turkey.
2018-2020	Professor	Department of Civil Engineering, Bartın University, Turkey.
1993-2018	Prof. Director	Multimedia Environmental Simulations Laboratory, Ga. Tech. USA
1983-1993	Assoc. Prof.	School of Civil and Environmental Engineering, Ga. Tech., USA
1979-1983	Visiting Prof.	School of Civil and Env. Engineering Ga. Tech. (On sabbatical), USA
1974-1982	Adjunct Prof.	Marine Sciences Dept., Civil Eng. Dept., Eng. Science Dept., Middle East Tech. Univ., Turkey.
1977-1982	Assoc. Prof.	Mathematics Dept., Middle East Tech. Univ., Turkey.
1974-1979	Asist Chairman	Mathematics Dept., Middle East Tech. Univ., Turkey.
1971-1977	Assistant Prof.	Mathematics Dept., Middle East Tech. Univ., Turkey.

PROFESSIONAL REGISTRATION:

Professional Engineer (PE): GA.USA. 15254

HONORS:

1973, **NATO, Science Fellowship**, September 1973.

1976, **Best Teacher Award**, Middle East Technical Univ., Mathematics Department, May 1976.

1976, **NATO, Science Fellowship**, September 1976.

1980, **Who is Who in Science, Engineering and Education** series since 1980.

- 1984, **Award of Appreciation**, in acknowledgment of contributions to the organization of the ASCE International Conference held in Atlanta, American Society of Civil Engineers, June 1984.
- 1986, **Outstanding Faculty Member**, Georgia Institute of Technology, May 1986.
- 1986, **Sigma Xi Research Society**.
- 1986, **Best Teacher Award**, Georgia Institute of Technology, June 1986.
- 1995, **Award of Recognition**, for the Organization of the East-West Advanced Study Institute on Environmental Issues, NATO, Scientific and Environmental Affairs Division, August 1995.
- 1996, **Engineering Technical Excellence Award**, Public Health Serv., USDHHS 1996 for the technical paper: "Estimating Exposure to VOCs from Municipal Water System Pipelines: Use and Application of a Computational Model, *Archives of Environmental Health*, May 1996 (with co-authors).
- 1997, **Research Program Development Award**, in Recognition for Developing a Consistent and Comprehensive Research Program in Environmental Health, School of Civil and Environmental Engineering, Georgia Institute of Technology, May 1997.
- 1997, **Science Publication Award**, ATSDR, US DHHS, for the technical paper: "Use of Computational models to Reconstruct and Predict Trichloroethylene Exposure," in *Toxicology and Industrial Health*, April 1997 (with co-authors).
- 1997, **Award of Appreciation and Recognition**, in acknowledgment of contributions to the organization of the International Conference on Geology and Environment (GeoEnv'97), September 1997.
- 1998, **Engineering Literary Excellence Award**, Public Health Serv., USDHHS for the technical paper: "Exposure Assessment Using Analytical and Numerical Models: A Case Study," in *ASCE Practice Periodical of Hazardous, Toxic, and Radioactive waste Management*, April 1998 (with co-authors).
- 1998, **Honorary Professor of Environmental Sciences**, Huazong University of Science and Technology, Wuhan, Peoples Republic of China.
- 2000, **Cuming Medal Award 2000**, The Society of American Military Engineers award to Dover Township Water Distribution System Modeling Research Team.
- 2000, **Best Practice Oriented Paper Award**, ASCE Environmental & Water Resources Institute Planning and Management Council, for the technical paper "Using Water-Distribution System Modeling to Assist Epidemiologic Investigations," *ASCE Journal of Water Res. Plan. and Man.*, Vol. 126, No. 4, 2000.
- 2003, **Excellence in Environmental Engineering Award in Research Category**, American Academy of Environmental Engineers (AAEE). *Research Topic: "Enhancing Environmental Engineering Science to Benefit Public Health: Integrating Hydraulic Network Modeling, Spatial Analysis, and Genetic Algorithms with Epidemiologic Studies,"* Awarded to **M. M. Aral** for the Leadership of the ATSDR – MESL/GT Research Group.
- 2005, **Engineering Technical Excellence Award**, Public Health Service, USDHHS for the technical paper: "ACTS - A Multimedia Environmental Fate and Transport Analysis System." in *ASCE Practice Periodical of Hazardous, Toxic, and Radioactive Waste Management*, published in 2004 (with co-authors).
- 2006, **Excellence in Applied Environmental Health Research**, National Center for Environmental Health (NCEH), Centers for Disease Control and Prevention (CDC), for our work in assisting NCEH/CDC in an epidemiological study of childhood leukemia and central nervous system cancers that occurred in the period 1979 through 1996 in Dover Township, New Jersey and Camp Lejeune (Air Force Army Base) at North Carolina.

- 2010, **Best Research Paper Award**, ASCE Water Resources Management Council, for the technical paper "Saltwater Intrusion Hydrodynamics in a Tidal Beach," *ASCE Journal of Hydrologic Engineering*, Vol. 13, No. 9: pp. 863-872 (with co-authors).
- 2010, **US Public Health Service Engineering Best Research Paper Award**, CDC, DHHS. "Reconstructing Historical Exposures to Volatile Organic Compound-Contaminated Drinking Water at a U.S. Military Ba
- 2010, **ASCE Outstanding Service Award**, ASCE EWRI, for Groundwater Hydrology Committee Chair activities under EWRI Groundwater Council.
- 2010, **Life Member**, ASCE EWRI.
- 2010, **Fellow ASCE**, ASCE, EWRI.
- 2011, **James R. Croes Medal**, ASCE EWRI, for the paper: "Optimal Design of Sensor Placement in Water Distribution Systems," *ASCE Journal of Water Resources Planning and Management*, Vol. 136, No. 1, pp.5-18, 2010.
- 2011, **Founders Award**, American Institute of Hydrology for dedicated contribution to the profession.
- 2011, **USPHS Engineering Literary Award**, for an outstanding Engineering Management Paper entitled "Stochastic Analysis of Pesticide Transport in the Shallow Groundwater of Oatland Island, Georgia." Published in the International Journal on Water Quality, Exp. and Health, Vol. 2, No. 1, pp. 47-64.
- 2013, **Sustained Interdisciplinary Research Award**, in Recognition for Developing a Consistent, Comprehensive and Integrated Research Program within CEE, Georgia Institute of Technology.
- 2015, **Panel Leadership and Organization Recognition, 68. Turkish Geology Conference.** "Groundwater Supplies and Drought" Panel, 68. Turkish Geology Conference, Organized by Turkish Maden Tetkik Arama Kurumu and Turkish Geology Engineers, 6 April 2015, Ankara, Turkey.
- 2015, **Invited Speaker in the opening session of the 68. Turkish Geology Conference.** "Evolution of Environmental and Geological Engineering Systems Analysis in Modern Day," 68. Turkish Geology Conference, Organized by Turkish Maden Tetkik Arama Kurumu and Turkish Geology Engineers, 6 April 2015, Ankara, Turkey.
- 2015, **Grand Prize in Environmental Engineering Award in Research Category by Am. Acad. of Env. Engineers (AAEE).** Research Topic: "Using Environmental Engineering Tools, Scientific Analyses, and Epidemiological Studies to Quantify Human Exposure to Contaminated Drinking Water and to Benefit Public Health," Awarded to **M. M. Aral** for the Leadership of the ATSDR – MESL/GT Research Group.
- 2018, **Best Teacher Award**, Center for Teaching and Learning, Ga. Institute of Tech., January 09, 2018.
- 2018, **Invited Speaker, HIDRODER.** "Climate Change and its Effects on Water Quality and Quantity" Organized by HIDRODER-2018 National Hydrology and Water Resources Symposium, 27-29 September 2018, Ankara, Turkey.
- 2022, **Invited Speaker, IWA DIPCON, Istanbul, Turkey.** "The Institute of Environmental Sciences co-organized the International Water Association (IWA) 4th Regional Diffusion Pollution and Eutrophication conference held in Istanbul 24-28 October, 2022" Istanbul, Turkey.

BOOKS:

- Aral, M. M.**, Ground Water Modeling in Multilayer Aquifers - Steady Flow, *Lewis Publ. Inc.*, 1990.
- Aral, M. M.**, Ground Water Modeling in Multilayer Aquifers - Unsteady Flow, *Lewis Publ. Inc.*, 1990.
- Aral, M. M.** (2011) "Environmental Modeling and Health Risk Analysis," Springer Publishers, Berlin, 487p., ISBN 978-90-481-8607-5.

EDITED BOOKS:

- Aral, M. M.** (Editor), Recent Advances in Ground-Water Pollution Control and Remediation, NATO Adv. Study Inst., *Kluwer Acad. Publ.*, 609p, January 1996.
- Aral, M. M.**, Brebbia, C, Maslia M and Sinks, T. (Editors) (2005) "Environmental Exposure and Health," Proceedings of the 1st International Conference on Environmental Exposure and Health, Atlanta Ga. USA, WIT Press, 502p.
- Aral, M. M.** and Taylor S. (Editors) (2011) "Groundwater Quality and Quantity Management," ASCE, 573p., ISBN-978-0-7844-1176-6.

CHAPTERS IN BOOKS:

- Aral, M. M.**, C. Shea and F. Al-Khayyal, "Optimization Methods in Ground Water Management," Review Paper in Volume 8, "Applications of Management Science: Network Optimization Applications," JAI Press Inc., pp. 213-246, 1995.
- Aral, M. M.** C. Shea and F. Al-Khayyal, "Optimal Design of Pump-and Treat Well Networks," NATO Adv. Study Inst. on Ground Water Pollution Control and Remediation, *Kluwer Acad. Publ.*, pp. 307-333, January 1996.
- Aral, M. M.**, and Guan, J, "Genetic Algorithms in Search of Groundwater Pollution Sources," NATO Adv. Study Inst. on Ground Water Pollution Control and Remediation, *Kluwer Acad. Publ.*, pp. 347-369, January 1996.
- Aral, M. M.** and Maslia, M. L., Application of Monte Carlo Simulations in Analytical Contaminant Transport Modeling, Chapter 13, pp. 305-315, in ASCE book on "Groundwater Quality Modeling and Management Under Uncertainty," Ed. by Srikan Tamishra, 2003.
- Aral, M. M.**, and Gunduz, O., Scale Effects in Large Scale Watershed Modeling. Chapter 11 in "ADVANCES IN HYDROLOGY" Ed. by V. Singh and R. N. Yadava, 2003.
- Aral, M. M.** and Gunduz, O. Large-Scale Hybrid Watershed Modeling, Section 2 in "WATERSHED MODELS," CRC Press, 2005, Ed. Dr. Vijay Singh, 75-95pp.
- Aral, M. M.** (2010) "Saltwater Intrusion Management in Urban Area Aquifers - A Case Study for Savannah, Georgia," The Effects of Urbanization on Groundwater: An Engineering Case-based Approach for Sustainable Development, Editor, Ni-Bin Chang, ASCE/EWRI publication, pp. 51-89.
- Jang, W. and **Aral, M. M.** (2011) "In-Situ Air Sparging and Thermal Venting in Ground Water Remediation," Chapter 11 in Groundwater Quality and Quantity Management, Editors Aral, M. M. and Taylor, S., ASCE, pp. 530-575, ISBN-978-0-7844-1176-6.
- Aral, M. M.** (2011) "Groundwater Management," Chapter 14 in Groundwater Quality and Quantity Management, Editors Aral, M. M. and Taylor, S., ASCE, pp. 560-568, ISBN-978-0-7844-1176-6.
- Gunduz, O. and **Aral, M. M.** (2015) "Integrated Watershed Modeling," Handbook of Applied Hydrology, Edited by Vijay Singh. Chapter 56.

PATENTS:

Aral, M. M. Atlanta, USA and Demirel. E. Eskisehir, Turkey.

TITLE: "Baffle Design to Improve Mixing and Reduce the Flow Through Energy Requirements in Chlorine and Ozone Contact Tanks," USA Patent and Trademark Office, USA Patent # 62/498,260, USA and EUROPEAN Union and Turkey.

JOURNAL ARTICLES (Google Scholar h-index 33):

1. Martin, C.S. and Aral, M.M. (1971). "Seepage Force on Interfacial Bed Particles." Journal of the Hydraulics Division-ASCE 97(HY7): 1081-1101.
2. Aral, M.M. and Isilgan, N. (1973). "Seepage Through Earth Dams: A Finite Element Solution." Journal of Pure and Applied Sciences 6(2): 185-194.
3. Aral, M.M. and Gulcat, U. (1977). "Finite-Element Laplace Transform Solution Technique for Wave-Equation." International Journal for Numerical Methods in Engineering 11(11): 1719-1732.
4. Aral, M.M. (1980). "Steady Jet Impingement on Straight and Curved Surfaces." Journal of Pure and Applied Sciences 13(3): 349-368.
5. Aral, M.M. (1981). "A One-Dimensional Mass-Transport Model for Natural Rivers." Journal of Environmental Systems 11(2): 139-154.
6. Aral, M.M. and Sturm, T.W. (1982). "Groundwater Pumping from Shallow Axisymmetric Ponds." Journal of the Hydraulics Division-ASCE 108(12): 1469-1485.
7. Maslia, M.L. and Aral, M.M. (1982). "Evaluation of a Chimney Drain Design in an Earth-fill Dam." Ground Water 20(1): 22-31.
8. Ozsoy, E., Aral M.M., et al. (1982). "Coastal Amplification of Tsunami Waves in the Eastern Mediterranean." Journal of Physical Oceanography 12: 117-126.
9. Aral, M. M. and Maslia, M.L. (1983). "Unsteady Seepage Analysis of Wallace Dam." Journal of Hydraulic Engineering-ASCE 109(6): 809-826.
10. Aral, M.M. and Maslia, M.L. (1984). "Unsteady Seepage Analysis of Wallace Dam - Closure." Journal of Hydraulic Engineering-ASCE 110(5): 671-673.
11. Aral, M.M. (1985). "Aquifer Parameter Prediction in Leaky Aquifers." Journal of Hydrology 80(1-2): 19-44.
12. Aral, M.M. (1986). "A Regional Multilayered Aquifer Model for Microcomputers." International Journal for Microcomputers in Civil Engineering 1(1): 69-78.
13. Aral, M.M. (1987). "An Unsteady Regional Multilayered Aquifer Model for Microcomputers." International Journal for Microcomputers in Civil Engineering 2(3): 197-206.
14. Aral, M.M. and Tang, Y. (1988). "A Boundary Only Procedure for Time-Dependent Diffusion-Equations." Applied Mathematical Modeling 12(6): 610-618.
15. Aral, M.M. and Tang, Y. (1988). "A New Boundary Element Formulation for Time-Dependent Confined and Unconfined Aquifer Problems." Water Resources Research 24(6): 831-842.
16. Aral, M.M. (1989). "Semi analytic Boundary Element Solution of Groundwater Seepage Problems." Water Resources Research 25(7): 1495-1503.
17. Aral, M.M. (1989). "Waste Stabilization in Multilayer Aquifers by Optimal Hydraulic Control." Ground Water 27(4): 517-523.
18. Aral, M.M. and Tang, Y. (1989). "A Boundary-Only Procedure for Transient Transport Problems with or without 1st-Order Chemical-Reaction." Applied Mathematical Modeling 13(3): 130-137.
19. Zakikhani, M. and Aral, M.M. (1989). "Direct and Boundary-Only Solutions of Multilayer Aquifer Systems. A. Steady-State Solution." Journal of Hydrology 111(1-4): 49-67.
20. Zakikhani, M. and Aral, M.M. (1989). "Direct and Boundary-Only Solutions of Multilayer Aquifer Systems .B. Unsteady-State Solution." Journal of Hydrology 111(1-4): 69-87.
21. Aral, M.M. and Tang, Y. (1992). "Flow against Dispersion in 2-Dimensional Regions." Journal of Hydrology 140(1-4): 261-277.
22. Maslia, M.L., Aral, M.M., et al. (1992). "Evaluation of Groundwater-Flow Regime at a Landfill with Liner System." Journal of Environmental Science and Health Part a-Environmental Science and Engineering & Toxic and Hazardous Substance Control A27(7): 1793-1816.

23. Ratzlaff, S.A. and Aral, M.M. (1992). "Optimal-Design of Groundwater Capture Systems Using Segmental Velocity-Direction Constraints." Ground Water 30(4): 607-612.
24. Tang, Y. and Aral, M.M., (1992). "Contaminant Transport in Layered Porous-Media .1. General-Solution." Water Resources Research 28(5): 1389-1397.
25. Tang, Y. and Aral, M.M. (1992). "Contaminant Transport in Layered Porous-Media .2. Applications." Water Resources Research 28(5): 1399-1406.
26. Aral, M. M., Maslia, M.L. et al. (1993). "Groundwater Remediation Using Smart Pump and Treat - Discussion." Ground Water 31(4): 680-681.
27. Maslia, M.L., Aral, M.M., et al. (1994). "Exposure Assessment of Populations Using Environmental Modeling, Demographic-Analysis, and GIS." Water Resources Bulletin 30(6): 1025-1041.
28. Aral, M.M., Maslia, M.L. et al. (1996). "Estimating exposure to volatile organic compounds from municipal water-supply systems: Use of a better computational model." Archives of Environmental Health 51(4): 300-309.
29. Aral, M.M. and Liao, B. (1996). "Analytical Solutions for Two-Dimensional Transport Equation with Time Dependent Dispersion Coefficients." Journal of Hydrologic Engineering 1(1): 20-32.
30. Maslia, M.L., Aral, M.M., et al. (1996). "Use of computational models to reconstruct and predict trichloroethylene exposure." Toxicology and Industrial Health 12(2):139-152.
31. Maslia, M.L., Aral, M.M., et al. (1997). "Exposure assessment Using Analytical and Numerical Models: A Case Study." Practice Periodical of Hazardous, Toxic, and Radioactive Waste Management-ASCE 1(2): 50-60.
32. Aral, M.M., Zhang, Y. et al. (1998). "Application of relaxation scheme to wave-propagation simulation in open-channel networks." Journal of Hydraulic Engineering-ASCE 124(11): 1125-1133.
33. Guan, J. and Aral, M.M. (1999). "Optimal remediation with well locations and pumping rates selected as continuous decision variables." Journal of Hydrology 221(1-2): 20-42.
34. Guan, J. and Aral, M.M. (1999). "Progressive genetic algorithm for solution of optimization problems with nonlinear equality and inequality constraints." Applied Mathematical Modeling 23(4): 329-343.
35. Liao, B. and Aral, M.M. (1999). "Interpretation of LNAPL Thickness Measurements under Fluctuating Groundwater Table Conditions." Journal of Hydrologic Engineering 4(2): 125-134.
36. Aral, M.M. and Liao, B.S. (2000). "LNAPL thickness interpretation based on bail-down tests." Ground Water 38(5): 696-701.
37. Aral, M.M., Zhang, Y. et al. (2000). "Application of relaxation scheme to wave-propagation simulation in open-channel network - Closure." Journal of Hydraulic Engineering-ASCE 126(1): 91-91.
38. Liao, B.S. and Aral, M.M. (2000). "Semi-analytical solution of two-dimensional sharp interface LNAPL transport models." Journal of Contaminant Hydrology 44(3-4): 203-221.
39. Maslia, M.L., Sautner, J.B., Aral, M.M., et al. (2000). "Using water-distribution system modeling to assist epidemiologic investigations." Journal of Water Resources Planning and Management-ASCE 126(4): 180-198.
40. Aral, M.M., Guan, J. et al. (2001). "Identification of contaminant source location and release history in aquifers." Journal of Hydrologic Engineering 6(3): 225-234.
41. Aral, M.M., Guan, J. et al. (2002). "Closure to "Identification of contaminant source location and release history in aquifers" by Mustafa M. Aral, Jiabao Guan, and Morris L. Maslia." Journal of Hydrologic Engineering 7(5): 400-401.
42. Aral, M.M., Guan, J. et al. (2002). "Optimal reconstruction of hydraulic management of a water distribution system." Epidemiology 13(4): S86-S86.

43. Aral, M.M. and Liao, B. (2002). "Effect of groundwater table fluctuations on LNAPL thickness in monitoring wells." Environmental Geology 42(2-3): 151-161.
44. Maslia, M.L., Sautner, J.B. and Aral, M.M. (2002). "Using water-distribution system modeling to assist epidemiologic investigations." Epidemiology 13(4): S86-S86.
45. Jang, W. and Aral, M.M. (2003). "Concentration evolution of gas species within a collapsing bubble in a liquid medium." Env. Fluid Mechanics 3(3): 173-193.
46. Guan, J. and Aral, M.M. (2004). "Optimal design of groundwater remediation systems using fuzzy set theory." Water Resources Research 40(1): 1-20.
47. Maslia, M.L. and Aral, M.M. (2004). "ACTS - A Multimedia Environmental Fate and Transport Analysis System." ASCE Practice Periodical of Hazardous, Toxic, and Radioactive waste Management-ASCE 8(3): 181-198.
48. Park, C.H. and Aral, M.M. (2004). "Multi-objective optimization of pumping rates and well placement in coastal aquifers." Journal of Hydrology 290(1-2): 80-99.
49. Zhang, Y. and Aral, M.M. (2004). "Solute Transport in Open-Channel Networks in Unsteady Flow Regime." Environmental Fluid Mechanics 4(3): 225-247.
50. Kentel, E. and Aral, M.M. (2004). "Probabilistic-Fuzzy Health Risk Modeling," International Journal for Stochastic Environmental Research & Risk Assessment (SERRA), 18: 324-338.
51. Aral, M.M., Guan, J., Liao, B., Maslia, M.L., Sautner, J., Williams, R. and Reyes, J.J. 2004. "Optimal Reconstruction of Historical Water Supply to a Water-Distribution System: A. Methodology", Journal of Water and Health, 2:123-136.
52. Aral, M.M., Guan, J., Liao, B., Maslia, M.L., Sautner, J., Williams, R. and Reyes, J.J. 2004. "Optimal Reconstruction of Historical Water Supply to a Water-Distribution System: B Applications", Journal of Water and Health, 2:137-156.
53. Gunduz, O. and Aral, M.M. (2005). "River Networks and Groundwater Flow: Simultaneous Solution of a Coupled System," J. of Hydrology 301(1-4): 216-234.
54. Kentel, E. and Aral, M.M. (2005). "2D Monte Carlo versus 2D Fuzzy Monte Carlo Health Risk Assessment," Int. Journal for Stochastic Environmental Research & Risk Assessment (SERRA), 19: 86-96.
55. Maslia, M.L., Reyes, JJ, Gillig, RE, Sautner, JB, Fagliano, JA and Aral, M.M. (2005) "Public Health Partnerships Addressing Childhood Cancer Investigations: Case Study of Toms River, Dover Township, New Jersey, USA," Int. Journal of Hygiene and Env. Health, 208: pp. 45-54.
56. Guan, J. and Aral, M.M. (2005) "Remediation System Design with Multiple Uncertain Parameters using Fuzzy Sets and Genetic Algorithm," ASCE Journal of Hydrologic Engineering, 10(5): pp. 386-394.
57. Gunduz, O. and Aral, M.M. (2005) "A Dirac-Delta Function Notation for Source/Sink Terms in Groundwater Flow," ASCE Journal of Hydrologic Engineering, 10(5): pp. 420-427.
58. Guan, J., Aral, M.M., Maslia, M. L. and Grayman, W. M. (2006) "Identification of Contaminant Sources in Water-Distribution Systems Using Simulation-Optimization Method: A Case Study," ASCE, Journal of Water Resources Planning and Management, July 132(4): pp. 252-262.
59. Kentel, E. and Aral, M.M. (2007) "Fuzzy Multi-Objective Decision Making Approach to Evaluate Pumping Demands in Coastal Aquifers: A Case Study for Savannah Georgia", ASCE Journal of Hydrologic Engineering, March 12(2): pp. 206-217.
60. Kentel, E. and Aral, M.M. (2007) "Risk Tolerance Measure for Fuzzy Health Risk Assessment," Int. Journal for Stochastic Env. Research & Risk Assessment (SERRA), 21: pp. 405-417.
61. Park, C-H and Aral, M.M. (2007) "Sensitivity of the Solution of Elders Problem to Density, Velocity and other Numerical Perturbations," Journal of Contaminant Hyd., 92: pp.33-49.

62. Jang, W and Aral, M.M. (2007) "Density Driven Transport of Volatile Organic Compounds and Its impact on Contaminated Groundwater Plume Evolution," Journal of Transport in Porous Media, 67(3): pp. 353-374.
63. Ayvaz, T., Karahan, H. and Aral, M.M. (2007). "Aquifer Parameter and Zone Structure Estimation Using Kernel-Based Fuzzy C-Means Clustering and Genetic Algorithm," Journal of Hydrology, 343 (3-4): pp. 240-253.
64. Guan, J., Kentel, E. and Aral, M.M. (2008) "Genetic Algorithm for Constrained Optimization Models and Its Application," ASCE Journal of Water Resources Planning and Management, 134(1): pp. 64-72.
65. Jang, W. and Aral, M.M. (2008) "Effect of Biotransformation on Multi-species Plume Evolution and Natural Attenuation" International Journal on Transport in Porous Media, 72(2): pp. 207-226.
66. Kilic, G.S. and Aral, M.M. (2008) "Probabilistic Fugacity Analysis of Lake Pontchartrain Pollution after Hurricane Katrina", Journal of Env. Management, 88(3): pp. 448-457.
67. Park, C-H and Aral, M. M. (2008) "Saltwater Intrusion Hydrodynamics in a Tidal Beach," ASCE Journal of Hydrologic Engineering, 13(9): pp. 863-872.
68. Jang, W. and Aral, M.M. (2008) "Multiphase Flow Fields in In-Situ Air Sparging and It's Effect on Remediation" International Journal on Transport in Porous Media, 76, pp. 99-119.
69. Kilic, G.S. and Aral, M.M. (2009) "A Fugacity Based Continuous and Dynamic Fate and Transport Model for River Networks and Its Application to Altamaha River," Journal of Science of the Total Environment, Vol. 407, No.12, pp. 3855-3866.
70. Aral, M.M. (2009) "Water Quality, Exposure and Health: Purpose and Goals," Journal of Water Quality, Exposure and Health, Vol. 1, No. 1, pp. 1-4.
71. Maslia, M.L., Aral, M.M., Faye, R.E., Suárez-Soto, R. J., Sautner, J.B., Wang, J., Jang, W., Bove, F. J., and Ruckart, P.Z.. (2009) "Reconstructing Historical Exposures to Volatile Organic Compound-Contaminated Drinking Water at a U.S. Military Base," Journal of Water Quality, Exposure and Health, Vol. 1, No. 1, pp. 49-68.
72. Ilker, T.T., Nam, K., Guan, J. and Aral, M.M. (2009) "Optimal Water Quality Monitoring Network Design for River Systems," Journal of Env. Management, Vol. 90, pp. 2987-2998.
73. Anderson, B.A., Maslia, M.L., Caparoso, J.L., Ausdemore, D. and Aral, M.M. (2010) "Stochastic Analysis of Pesticide Transport in the Shallow Groundwater of Oatland Island, USA," Journal of Water Quality, Exposure and Health, Vol. 2, No. 1, pp. 47-64.
74. Aral, M.M., Guan, J., Maslia, M.L. (2010) "Optimal Design of Sensor Placement in Water Distribution Systems," ASCE Journal of Water Resources Planning and Management, Vol. 136, NO.1, pp.5-18.
75. Aral, M.M. (2011) "Editorial: Surgery was Successful but the Patient Died," ASCE Journal of Hydrologic Engineering, Vol. 16, No. 2, pp. 91-92.
76. Telci, T. and Aral, M.M. (2011) "Contaminant Source Location Identification in River Networks Using Water Quality Monitoring Systems for Exposure Analysis," Journal of Water Quality, Exposure and Health, Vol. 2, No. 4, pp. 205-218.
77. Goktas, R.K. and Aral, M.M. (2011) "Integrated Dynamic Modeling of Contaminant Fate and Transport within a Soil-Plant System," Vadose Zone Journal, Vol. 10, 1130-1150.
78. Maslia, M.L., Aral, M.M. et al.(2011) *Discussion on: "Complexities in Hindcasting Models—When Should We Say Enough Is Enough,"* by T. Prabhakar Clement, Groundwater, v. 49, no. 5: 620–629.
79. Aral, M.M., Guan, J. and Chang, B. (2012) "A Dynamic System Model to Predict Global Sea-Level Rise and Temperature Change," ASCE Journal of Hydrologic Engineering, Vol. 17, No. 2, pp237-242, doi:10.1061/(ASCE)HE.1943-5584.0000447.

80. Aral, M.M., Guan, J. and Chang, B. (2013) "A Dynamic System Model to Predict Global Sea-Level Rise and Temperature Change," ASCE Journal of Hydrologic Engineering, Closure, Vol. 18, No. 3, pp372-375.
81. Chuljin, P., Telci, I. Kim, S-H and Aral, M.M. (2013) "Designing Optimal Water Quality Monitoring Network for River Systems Using Constrained Discrete Optimization via Simulation," Engineering Optimization, DOI:10.1080/0305215X.2012.748049.
82. Dede, O. T., Telci, I. and Aral, M.M. (2013) "The Use of Water Quality Index Models for the Evaluation of Surface Water Quality: A case study for Kirmir Basin, Ankara, Turkey," Journal of Water Quality, Exposure and Health, Vol. 5, No. 1, pp. 41-56.
83. Aral, M.M. (2013) "Climate Change and Human Population Dynamics," Journal of Water Quality, Exposure and Health: Special Issue on Climate Change, Vol. 5, No. 4, pp. DOI: 10.1007/s12403-013-0091-5.
84. Guan, J., Chang, B. and Aral, M.M. (2013). "A Dynamic Control System Model for Global Temperature Change and Sea Level Rise in Response to CO₂ Emissions," Climate Research, Vol. 58: 55–66, DOI: 10.3354/cr01189.
85. Guan, J., Zhang, A. and Aral, M.M. (2013). "An Optimization Approach for Sustainable Development Planning of Savanna Systems," Journal of Arid Environments, Vol. 98, pp. 60-69: DOI:10.1016/j.jaridenv.2013.07.013.
86. Chang, B., Guan, J. and Aral, M.M. (2013). "Modeling Spatial Variations of Sea Level Rise and Corresponding Inundation Impacts: A Case Study for Florida, U.S.A.," J. of Water Quality Exposure and Health (Climate Change Special Issue), DOI 10.1007/s12403-013-0099-x.
87. Aral, M.M. (2014). Perspectives and Challenges on Climate Change and Its Effects on Water Quality and Health, Water Q. Exp. and Health, Vol. 6, pp1, DOI 10.1007/s12403-014-0125-7.
88. Zhang, A. and Aral, M.M. (2015). Characterization of CO₂ Injection into Deep Saline Aquifers Using Two-phase Darcy-Forchheimer Flow, ASCE Journal of Hydrologic Engineering. DOI: 10.1061/(ASCE)HE.1943-5584.0001097.
89. Morgan, W. and Aral, M.M. (2015). An implicitly coupled hydro-geomechanical model for hydraulic fracture simulation with the discontinuous deformation analysis, International Journal of Rock Mechanics and Mining Sciences. DOI 10.1016/j.ijrmms.2014.09.021.
90. Aral, M.M. (2015). Climate Change and Persistent High Temperatures: Does it Matter? Frontiers in Environmental Science, Section on Interdisciplinary Climate Studies. DOI: 10.3389/fenvs.2014.00045.
91. Chang, B., Guan, J. and Aral, M.M. (2015). "A Scientific Discourse: Climate Change and Sea-Level Rise," ASCE Journal of Hydrologic Engineering (Invited Special Issue paper), Vol. 20, No. 1, pp. A4014003-1–14. DOI: 10.1061/ (ASCE) HE. 1943-5584.0000860.
92. Aral, M.M. and Nam, K. (2015). "Optimal Monitoring Network Design for Wind Driven and Tidal Estuaries," ASCE Journal of Environmental Engineering (Invited Special Issue paper – DOI: 10.1061/(ASCE)EE.1943-7870.0001051).
93. Kim, S-H, Aral, M.M., Eun, Y, Park, JJ, Park, C. (2016) "Impact of Sensor Measurement Error on Sensor Positioning in Water Quality Monitoring Stations," Stochastic Environmental Research and Risk Assessment (SERRA), DOI 10.1007/s00477-016-1210-1.
94. Demirel, E. and Aral, M.M. (2016) "Unified Analysis of Multi-Chamber Contact Tanks and Mixing Efficiency Based on Vorticity Field. Part I: Hydrodynamic Analysis," Water, 8(11), 495; doi:10.3390/w8110495.
95. Demirel, E. and Aral, M.M. (2016) "Unified Analysis of Multi-Chamber Contact Tanks and Mixing Efficiency Based on Vorticity Field. Part II: Transport Analysis," Water, 8(11), 537; doi:10.3390/w8110537.

96. Aral, M.M. and Guan, J. (2016) "Global Sea Surface Temperature and Sea Level Rise Estimation with Optimal Historical Time Lag Data" Water, 8, 519; doi:10.3390/w8110519.
97. Maslia, M.L., Aral, M.M., Ruckard, P. Z., Bove, F. (2016) "Reconstructing Historical VOC Concentrations in Drinking Water for Epidemiological Studies at a U.S. Military Base: Summary of Results" Water, 8, 449; doi:10.3390/w8100449.
98. Aral, M.M. and Demirel, E. (2017) "Novel slot-baffle design to improve mixing efficiency and reduce cost of disinfection in drinking water treatment" ASCE Journal of Environmental Engineering DOI: 10.1061/(ASCE)EE.1943-7870.0001266.
99. Aral, M.M. and Chang, B. (2017) "Spatial Variation of Sea Level Rise at Atlantic and Mediterranean Coastline of Europe" Special Issue Invited Paper, Water, 9, 522; doi:10.3460/w8110444.
100. Okuducu, M.B. and Aral, M.M. (2017) "Knowledge Based Dynamic Human Population Models" Technological Forecasting & Social Change Journal, 122C pp. 215 - 243, 2017, DOI 10.1016/j.techfore.2017.05.008.
101. Demirel, E. and Aral, M.M. (2018) "An Efficient Contact Tank Design for Potable Water Treatment" Technical Journal, Turkey, pp. 8279-8294, Paper 499, DOI: 10.18400/tekderg.322491.
102. Demirel, E. and Aral, M.M. (2018) "Performance Assessment of Efficiency Indexes for Contact Tanks," ASCE Journal of Environmental Engineering DOI: 10.1061/(ASCE)EE.1943-7870.0001266.
103. Okuducu, M.B. and Aral, M.M. (2018) "Performance Analysis and Numerical Evaluation of Mixing in 3-D T-Shape Passive Micromixers," Micromachines Journal, Special Issue on Passive Micromixers, 9, 210; doi:10.3390/mi9050210
104. Kizilaslan, A. M., Demirel, E. and Aral, M.M. (2018) "Effect of Porous Baffles on the Energy Performance of Contact Tanks in Water Treatment," Water, 10, 1084; doi:10.3390/w10081084.
105. Telci, T.I. and Aral, M.M. (2018) "Optimal Energy Recovery from Water Distribution Systems Using Smart Operation Scheduling and Turbine Placement," Water, 10, 1464; doi:10.3390/w10101464
106. Demirel, E. and Aral, M.M. (2018) "Liquid Sloshing Damping in an Accelerated Tank using a Novel Slot-Baffle Design," Water, 10, 1565; doi:10.3390/w10111565
107. Okuducu, M.B. and Aral, M.M. (2019) "Computational Evaluation of Mixing Performance in 3-D Swirl-Generating Passive Micromixers," Processes, Special Issue on Water Quality Management, 7, 121; doi:10.3390/pr7030121
108. Kizilaslan, M. A, Demirel, E and Aral, M.M. (2019) "Efficiency Enhancement of Chlorine Contact Tanks in Water Treatment Plants: A Full-Scale Application," Processes 7, 551; doi:10.3390/pr7090551.
109. Okuducu, M.B. and Aral, M.M. (2019) "Novel 3-D T-Shaped Passive Micromixer Design with Helicoidal Flows," Processes, 7, 637, doi:10.3390/pr7090637.
110. Bayar, M. and Aral, M.M. (2019) "An Analysis of Large-Scale Forced Migration in Africa," Int. J. Environ. Res. Public Health, 16, 4210; doi:10.3390/ijerph1621.
111. Aral, M.M. (2020) "Knowledge Based Analysis of Continental Population and Migration Dynamics," Technological Forecasting and Social Change, 151(119848); doi.org/10.1016/j.techfore.2019.119848
112. Demirel, E. and Aral M.M. (2020) "A Design for Vortex Suppression Downstream of a Submerged Gate," Water, 12, 750; <https://doi.org/10.3390/w12030750>.
113. Nasyrlyayev, N., Kizilaslan, M. A., Kurumus, A. T., Demirel, E. and Aral, M.M. (2020) "A Perforated Baffle Design to Improve Mixing in Contact Tanks," Water, 12(1022), doi:10.3390/w12041022.
114. Yavuz, C., Kentel, E. and Aral, M.M. (2020) "Tsunami Risk Assessment: Economic, Environmental and Social Dimensions," Natural Hazards Journal, Springer Publishers, doi:10.1007/s11069-020-04226-y.

115. Yavuz, C., Kentel, E. and Aral, M.M. (2020) "Climate Change Risk Evaluation of Tsunami Hazards in the Eastern Mediterranean Sea," *Water*, Special Issue in Computational Methods in Water Resources, MDPI Publishers, 12(2881), doi:10.3390/w12102881.
116. Okuducu, M.B.; Aral, M.M. (2021) "Toward the Next Generation of Passive Micromixers: A Novel 3-D Design Approach." *Micromachines* **2021**, 12, 372. <https://doi.org/10.3390/mi12040372>
117. Aral, M.M. (2022) "Optimal Design of Water Treatment Contact Tanks," *Water*, Special Issue in Artificial Intelligence and Machine Learning Applications in Water Resources Management, MDPI Publishers, 14 (973), <https://doi.org/10.3390/w14060973> .
118. Chen, J., Aral, M.M., Kim, S-H., Park, C., Xie, Y. (2022) "Constrained Bayesian optimization and spatio-temporal surveillance for sensor network design in the presence of measurement errors," *Engineering Optimization*, 6, <https://doi.org/10.1080/0305215X.2021.2014475> .

PUBLICATIONS IN CONFERENCE PROCEEDINGS:

1. Aral, MM, Mayer, PG and Smith, CV, Finite Element Galerkin Method Solutions to Selected Elliptic and Parabolic Differential Equations, *Proceedings of the Air Force Third Conference on Matrix Methods in Structural Mechanics*, Wright-Patterson Air Force Base, Ohio, pp. 215-243, October 1971.
2. Aral, MM, Finite Element Galerkin Formulation of Heat Transfer Problems, *Proc. of the Conf. on Numerical and Functional Analysis*, Istanbul Technical University, Publ. No. 982, pp. 16-28, 1973.
3. Aral, MM and Yazici, A, Finite Element Solution of Problems with Unknown and Moving Boundaries, *Proceedings of the International Conference on Finite Element Methods in Engineering*, University of New South Wales, pp. 719-727, August 1974.
4. Aral, MM and Sezgin, M, A Comparison of Iterative Solutions of Navier Stokes Equations, *Proceedings of the International Conference on Finite Element Methods in Engineering*, University of New South Wales, pp. 555-567, July 1979.
5. Kunianski, E. and Aral, MM, Application of Digital Optimization for Parameter Estimation of Clayton Aquifer near Albany, Georgia, *Proceedings of the Conference, Water Resources of Georgia and Surrounding States*, Georgia Geologic Survey Bulletin 99, pp. 67-78, October 1983.
6. Aral, MM, and Zakikhani, M., Multi-aquifer Parameter Estimation of the Clayton-Clairborne Aquifer Near Albany, Georgia, *Proceedings NWWA East West Conference on Ground Water Management*, Orlando, Florida, pp. 272-298, 1984.
7. Aral, MM, Optimization Approach to the Identification of Aquifer Parameters in Multilayer Systems, *Proceedings VI Int. Conf. on Finite Elements in Water Resources*, Portugal, pp.359-369, 1986.
8. Haddad, EH and Aral, MM, Ground Water Flow Models and Applications for Microcomputers, *Proceedings 5th National Conf. on Microcomputers in Civil Eng.*, pp. 290-294, Orlando, Florida, 1987.
9. Aral, MM and Tang, Y., A Comparison of DR-BEM and SR-BEM Solutions for Parabolic Problems, *Proceedings of the Int. Conf. on Computational Eng. Science*, pp. 58iii1-58iii4, Atlanta, Georgia, 1988.
10. Aral, MM and Tang, Y., Semianalytic Boundary Element Solution of Time Dependent Partial Differential Equations, *Proceedings of the 11th Int. Conf. on Boundary Element Methods*, pp. 42-52, 1989.
11. Maslia, M., Aral, MM, and Gill, HE, "The Importance of Hydrogeologic Controls on Remedial Action Alternatives," *Geophysical Society of America*, Southeastern Section Meeting, Contaminant Hydrogeology Session, Vol. 24, No. 2, pp. 53, 1992 (invited).
12. Maslia, M., Aral, MM, Williams, R., Williams, S., Hayes, L. and Wilder, L., "Use of Computational Models to Determine Human Exposure Resulting from Remediation Activities at Hazardous Waste Sites," *Proceedings of the Water Environment Federation Specialty Conference How Clean is Clean*, 85p, January 10-13, 1993 (invited).

13. Maslia, M., Aral, MM, Williams, R., Williams, S., Hayes, L. and Wilder, L., "Use of Computational Models to Reconstruct and Predict Trichloroethylene Exposure," *Proceedings of the International Congress on the Health Effects of Hazardous Waste*, p 271-283, May 3-6, 1993 (invited).
14. Maslia, ML and Aral, MM, "Health Implications Associated with Hazardous Waste Site Clean-Up Goals: A Case Study of Trichloroethylene (TCE) Contamination", *Proceedings of the Annual Meeting of the Geological Society of America*, Boston, 1993 (invited).
15. Aral, MM and Maslia, ML, Radtke, TM, "Conducting Exposure Assessment of Populations by Integrating Environmental Transport Models, Demographic Analysis, and Geographic Information Systems," *Proc. of the Int. Symposium on Assessing and Managing Health Risks from Drinking Water Contamination: Approaches and Applications*, Rome, Italy, pp. 221-233, September 1994 (invited).
16. Lyverse, MA, Aral, MM and Tang, Y., "Liquid Hydrocarbon Recovery and Groundwater Protection at a Closed Refinery over a Sand and Gravel Aquifer", *Proceedings of the Conference on Petroleum Hydrocarbons and Organic Chemicals in Ground-Water: Prevention, Detection, and Remediation*, Houston, Texas, November 2-4, 1994.
17. Maslia, ML and Aral, MM, "Application of Geographic Information Systems and Numerical Models to Exposure Assessment", *Sixth Joint Conference of the International Society for Environmental Epidemiology and International Society for Exposure Analysis*, The University of North Carolina at Chapel Hill, September 18-21, 1994 (invited).
18. Aral, MM, ML. Maslia, "Evaluation of Human Exposure to Contaminated Water Supplies Using GIS and Modeling," *Proc. of the Int. Conference HydroGIS'96*, pp. 243-252, Vienna, Austria, 1996.
19. Aral, MM, ML. Maslia, RC. Williams, JE. Abraham, "ATSDR's Exposure-Dose Reconstruction Program: Case Studies in Public Health Analysis of Exposure to Environmental Contamination," *Proceedings of the 1995 Pacific Rim Conference on Occupational and Environmental Health*, (in publication), Sydney Australia, October 1995 (invited speaker).
20. Holm, DM, Maslia, ML, Reyes, JJ, Williams, RC, and Aral, MM, 195, *Geographic Information Systems: A Critical Resource in Exposure Assessment*, Superfund XVI Conference and Exhibition Proceedings, Vol. 2, pp. 860-866, Washington, DC, Nov. 6-8, 1995.
21. Aral, MM, Guan, J., "Optimal Groundwater Remediation Design Using Differential Genetic Algorithm," *International Conference on Comp. Methods in Water Res.*, Cancun Mexico, pp. 349-357, July, 1996.
22. Tang, Y., Aral, MM and Lyverse, M, "GIS Analysis of Subsurface LNAPL Volume Estimation," *Proceedings of the Eleventh Outdoor Action Conference on Groundwater Remediation, Characterization and Management*, pp. 156-178, Las Vegas, Nevada, April 1-3, 1997.
23. Aral, MM, M. L. Maslia, *Exposure Assessment Using Simulation and GIS*, *Proceedings CSCE/ACSE Environmental Engineering Conference*, Edmonton, Alberta, Canada, pp. 885-892, July 22-26, 1997.
24. Aral, MM and Guan, J., "Contaminant Source Identification Problem and its Importance in Health Sciences," *International Conference on Integrating Engineering and Health Sciences*, Mexico, October 1998 (invited key note speaker).
25. Zhang, Y and Aral, MM, "Modeling Transport and Fate of Contaminants with Sediment Interaction and Transient Storage in Streams," *Proceedings of the Second International Symposium on Environmental Hydraulics*, Hong Kong, China, pp. 733-738, 16-18 December, 1998.
26. Sautner, JB Maslia, ML and Aral, MM, "Water-Distribution System Modeling as a Tool to Enhance Epidemiologic Case-Control Investigations: A Case Study, The Dover Township (Toms River) Childhood Cancer Investigations," *26th Annual Water Resources Planning and Management Conference WRPMD '99*, ASCE, Tempe, Arizona, June 6-9, 1999.
27. Aral, MM, Liao, B., Guan, J., Maslia, ML, Sautner, J., Williams, R. and Reyes, JJ, "Reconstruction of Hydraulic Management of a Water-Distribution System Using Genetic Algorithms," *World Water & Environmental Resources Congress*, ASCE, Orlando, Florida, May 20-24, 2001.

28. Aral, MM, Maslia, ML, and Guan, J., "ACTS, A Multi-Media Contaminant Transport Modeling Platform," Proceedings of Envirosoft 2002, an International Conference on the Modeling, Monitoring and Management of Environmental Problems, pp. 403-412, Bergen, Norway, 6-8 May 2002.
29. Aral, MM, Guan, J., Maslia, ML, "Modeling techniques to aid exposure analysis through Water Distribution Systems," at An International ISEA/ISEE Symposium, August 11-15, 2002, Vancouver, BC, Canada. (invited)
30. Maslia, ML., Sautner, JB, Aral, MM., Gillig, RE, Reyes, JJ and Williams J. "Using Water Distribution System Modeling to Assist Epidemiologic Investigations," at International ISEA/ISEE Symposium, August 11-15, 2002, Vancouver, BC, Canada.
31. Gunduz, O. and Aral, MM. "Hydrologic Modeling of the Lower Altamaha River Basin," 2003 Georgia Water Resources Conference, Athens, Georgia, March 2003.
32. Park, C-H. and Aral, MM. "Saltwater Intrusion Control on Coastal Aquifers," 2003 Georgia Water Resources Conference, Athens, Georgia, March 2003.
33. Gunduz, O. and Aral, MM. "Simultaneous Solution of Coupled Surface Water / Groundwater Flow Systems," International Conference on River Basin Management, Edited by C.A. Brebbia, pp. 25-34, Gran Canaria Islands, April 28, 2003.
34. Gunduz, O. and Aral, MM. "Satellite Imagery Based Watershed Management Modeling," at International Conference on Water Res. Man. II, pp. 367-376, Gran Canaria Islands, April 23, 2003.
35. Maslia, ML, Aral, MM, and Sautner, J., Reconstructing Historical Operations of Water Distribution Systems. In: Bizier, P., and DeBarry, P., Eds. Proceedings of the American Society of Civil Engineers, World Water & Env. Res. Congress 2003 [CD ROM document]. Philadelphia, PA: June 23-26, 2003.
36. Aral, MM, and Maslia, ML. Application of Monte Carlo Simulation to Analytical Contaminant Transport Modeling: In: S. Mishra, editor. Proceedings of the Symposium, Groundwater Quality Modeling and Management Under Uncertainty, Environmental and Water Resources Institute of the American Society of Civil Engineers, Philadelphia, PA, Am. Soc. of Civil Engineers, pp. 305-312, June 23-25, 2003.
37. Aral, MM, and Gunduz, O., Scale Effects in Large Scale Watershed Modeling. In V. Singh and R. N. Yadava editors, Advances in Hydrology. Proceedings of the International Conference on Water and Environment (WE-2003), Bhopal India, pp. 37-51, December 15-18, 2003. (invited paper).
38. Kentel, E. and Aral, MM, "Optimization of Removal Rates of Target Contaminants from Water Supply Wells," at 6th International Congress on Adv. in Civil Eng., ASCE, Istanbul Turkey 6-8 October, 2004
39. Gokgoz, S. and Aral, MM, "Fugacity Analysis of Sediment, Biota and Aquatic pathway Environments and its Potential use in Exposure Studies," at 6th International Congress on Advances in Civil Engineering, ASCE, Istanbul Turkey 6-8 Oct., 2004.
40. Gunduz, O. and Aral, MM, "Dynamically Coupled Contaminant Transport Model for a River Aquifer System," at 6th International Congress on Adv. in Civil Eng., ASCE, Istanbul Turkey 6-8 October, 2004.
41. Jang, W and Aral, MM, Density-Dependent Transport And Sequential Biotransformation Of Trichloroethylene In The Variably Saturated Zone, The International Conference on Environmental Science and Technology, IC EST 2005, Am. Academy of Sciences, New Orleans, January 23-26, 2005.
42. Maslia, ML, Sautner, JB, Valenzuela, C, Grayman, WM, and Aral, MM, "Use of Continuous Recording Monitoring Equipment for Conducting Water Distribution System Tracer Tests: The Good, the Bad and the Ugly," Proceedings ASCE, EWRI World Water and Environmental Resources Congress: Impacts of Global Climate Change, Anchorage, Alaska, May, 15-19, 2005.
43. Aral, MM and J. Guan, "Computational Platforms for Environmental Modeling," Proceedings ASCE, EWRI World Water and Environmental Resources Congress: Impacts of Global Climate Change, Anchorage, Alaska, May, 15-19, 2005.
44. Sautner, JB, Maslia, ML, Valenzuela, C, Grayman, WM, Aral, M.M. and Green, JW, "Field Testing of Water-Distribution Systems at Marine Corps Base, Camp Lejeune, NC, in Support of an Epidemiologic

- Study," *Proceedings ASCE, EWRI World Water and Environmental Resources Congress: Impacts of Global Climate Change*, Anchorage, Alaska, May, 15-19, 2005.
45. Guan, J., Aral, MM and Maslia ML, "Identification of contaminant sources in water distribution system using optimization simulation method," *Proceedings of the 1st International Conference on Environmental Exposure and Health*, Atlanta, Ga, USA, October 2005.
 46. Park, S-K, Piyachaturawat P, Aral, MM and Huang, C-H, "Potential Enhanced *N*-Nitrosodimethylamine (NDMA) Formation under Water Treatment Conditions," *Proceedings of the 1st International Conference on Environmental Exposure and Health*, Atlanta, Ga., USA, October 2005
 47. Maslia, M. and Aral, MM, "Reconstruction of historical contaminant events: Use of computational tools to assist environmental engineers," *Proceedings of the 1st International Conference on Environmental Exposure and Health*, Atlanta, Ga., USA, pp. 175-187, October 2005
 48. Aral, MM. "Perspectives on environmental health management paradigms," *Proceedings of the 1st International Conference on Env. Exposure and Health*, Atlanta, Ga., pp. 449-457, USA, October 2005
 49. Kentel, E. and Aral, MM. (2005) "Effect of Fuzzy Aggregation Operators in Selecting Best Groundwater Management Strategies" *EWRA 2005, 6th Int. Conference*, Menton, France. September 7-10, 2005.
 50. Kentel, E. and Aral, MM. "Spatial Distribution of Groundwater Availability for Various Pumping Scenarios in Savannah Region," *ASCE World Environment and Water Resources Conference (EWRI)*, Nebraska, Omaha, 2006.
 51. Kilic, SG and Aral, MM. "Preliminary Analysis of Lake Pontchartrain Pollution after Hurricane Katrina," *ASCE World Environment and Water Resources Conference (EWRI)*, Nebraska, Omaha, 2006.
 52. Kijin, N. and Aral, MM. "Modeling Hydrodynamics and Storm Effects in the Altamaha River Sound," *ASCE World Environment and Water Resources Conference (EWRI)*, Nebraska, Omaha, 2006.
 53. Wonyong, J. and Aral, MM. "Modeling of Multiphase Flow and Contaminant Removal under In-situ Air Sparging," *Air and Waste Management Association Annual Conference (AWMA)*, 2006.
 54. Nam K. and Aral MM. Modeling Hydrodynamics and Storm Effect in the Altamaha River Sound. In: Graham R, Editor. *Examining the Confluence of Environmental and Water Concerns: Proceedings of the 2006 World Environmental and Water Resources Congress*; 2006 May 21-25; Omaha, US [CD-ROM]. Reston: ASCE; 2006
 55. Jang, W. and Aral MM, "Modeling of Multiphase Flow and Contaminant Removal under In-situ Air Sparging," *Air & Waste Management Association's 99th Annual Conference & Exhibition*, New Orleans, LA, June 20-23, 2006.
 56. Guan, J., Aral, MM, Maslia, ML. and Grayman, W. (2006) "Optimization Model and Algorithms for Design of Water Sensor Placement in Water Distribution Systems" *ASCE Water Distribution System Analysis Symposium (Battle of the Water Sensor Networks)*, Cincinnati, OH, August 27-30, [CD-ROM].
 57. Suarez-Soto, R., Maslia, M., Wang, J., Aral, MM. and Faye, R. (2007) "Uncertainty Analysis for Reconstructing Historical Tetrachloroethylene (PCE) Exposure in an Epidemiologic Study," *ASCE, World Environmental and Water Resources Congress*, Tampa, Florida, [CD-ROM].
 58. Nam, K and Aral MM. (2007). "Optimal Placement of Monitoring Sensors in Lakes," *University of Georgia Water Resources Conference*, Athens, Georgia, [CD-ROM].
 59. Rogers, SW, Guan, J., Maslia, ML and Aral, MM, "Nodal Importance Concept for Computational Efficiency in Optimal Sensor Placement in Water Distribution Systems," *Proceedings of the World Water and Environmental Resources Congress*, ASCE, Tampa, FL, May 15-19, 2007.
 60. Nam, K. and Aral, MM, "Optimal Sensor Placement for Wind-Driven Circulation Environment in a Lake," *Proceedings of the World Water and Env. Res. Cong.*, ASCE, Tampa, FL, May 15-19, 2007.
 61. Wang, J and Aral, MM, "The Effect of Historical Supply Well Schedule Variation on PCE Arrival Time," *Proceedings of the World Water and Environmental Res. Cong.*, ASCE, Tampa, FL, May 15-19, 2007.

62. Park, S-H., Wei S., Mizaikoff, B., Taylor, AE, Aral, MM and Huang C-H., "Mechanistic Insight for the N-nitrosodimethylamine (NDMA) Formation Potential of Amine-Based Water Treatment Polymers," *Proceedings of the 233rd American Chemical Soc. National Meeting*, Chicago, IL, March 25-29, 2007.
63. Kentel, E. and Aral, MM. (2007). "Groundwater Flow Simulation with Imprecise Parameters" *National Hydrology Congress*, Middle East Technical University, September 5-7, [CD-ROM].
64. Ayvaz, T., Karahan, H. and Aral, MM. (2007). "Determination of Aquifer Parameters and Parameter Structures with Genetic Algorithm," *National Hydrology Congress*, Middle East Technical University, September 5-7, [CD-ROM].
65. Suarez-Soto, R., Wang, J., Faye, RE, Maslia, LM, Aral, MM and Bove, F. J., "Historical Reconstruction of PCE-Contaminated Drinking Water Using Probabilistic Analysis at U.S. Marine Corps Base Camp Lejeune, North Carolina," *Proceedings of the World Water and Environmental Resources Congress, ASCE/EWRI*, Honolulu, Hawaii, May 12-16, 2008.
66. Telci, IT, Nam, K., Guan, J. and Aral, MM, "Real Time Optimal Monitoring Network Design in River Networks," *Proceedings of the World Water and Environmental Resources Congress, ASCE/EWRI*, Honolulu, Hawaii, May 12-16, 2008.
67. Guan, J. and Aral, MM, "Identification of Contaminant Sources in Aquifers under Uncertainty," *Proceedings of the World Water and Environmental Resources Congress, ASCE/EWRI*, Honolulu, Hawaii, May 12-16, 2008.
68. Aral, MM, Guan, J. and Maslia, ML, "A Multi-objective Optimization Algorithm for the Solution of Water Sensor Placement Problem in Water Distribution Systems," *Proceedings of the World Water and Environmental Resources Congress, ASCE/EWRI*, Honolulu, Hawaii, May 12-16, 2008.
69. Jang, W. and Aral, MM, "The Effect of Oxygen Transport on Biotransformation of Trichloroethylene in the Subsurface," *Proceedings of the World Water and Environmental Resources Congress, ASCE/EWRI*, Honolulu, Hawaii, May 12-16, 2008.
70. Maslia, ML, RE Faye, MM Aral, FJ Bove, and W. Jang. (2008) "Historical reconstruction of single-specie and multispecies PCE-contaminated drinking water, U.S. Marine Corps Base Camp Lejeune, North Carolina," *World Environmental & Water Resources Congress 2008*, American Society of Civil Engineers, Honolulu, HI, May 13-16.
71. Suarez-Soto, RJ, Anderson, BA, Maslia, ML. and Aral, MM, "A Comparison Between Biochlor and the Analytical Contaminant Transport System (ACTS) for a Case Study in Coastal Georgia," *Proceedings of the World Water and Environmental Res. Cong., ASCE/EWRI*, Honolulu, Hawaii, May 12-16, 2008.
72. Jang, W. and MM. Aral. (2009) "Modeling of chlorinated VOCs transport under dual bioreactions," *World Environmental & Water Resources Congress 2009*, American Society of Civil Engineers, Kansas City, Missouri, May 17-21.
73. Guan, J., Maslia, ML and MM. Aral. (2009) "A Novel Methodology to Reconstruct Groundwater Contamination History with Limited Field Data," *World Environmental & Water Resources Congress 2009*, American Society of Civil Engineers, Kansas City, Missouri, May 17-21.
74. Aral, MM, Guan, J., and Maslia, ML. (2009). "Reconstructing Groundwater Contamination History: A Control Theory Based Approach," *Water and Public health, American Public Health Association Conference*, Philadelphia, PA, November 7-11.
75. Jang, W. Maslia, ML and Aral, MM. (2010). "The Effect of Atmos. Chemical Release on the Reduction in Groundwater Pollution by CVOs," *ASCE, EWRI Water Res. Cong.*, Rhode Island. May 25-30.
76. Guan, J. Jang, W., Maslia, ML and Aral, MM. (2010). "Historical Reconstruction of Groundwater Contamination at Contaminated Sites and Uncertainty Analysis," *ASCE, EWRI Water Resources Congress*, Rhode Island. May 25-30.
77. Aral, MM. (2010) "Resilience Analysis of Climate Change Effects on Water Quality," *NATO Advanced Research Workshop on Climate Change and Health*, Izmir, Turkey.

78. Park, C., S.-H. Kim, I. Telci and MM. Aral. (2010). "Designing Optimal Water Quality Monitoring Networks for River Systems and Application to a Hypothetical case, Proceedings of the 2010 Winter Simulation Conference, Austin, TX. (Invited).
79. Guan, J., Maslia, ML and Aral, MM. (2011). "Reconstruction of Groundwater Contamination History in Hadnot Point Area of Camp Lejeune, North Carolina Using Linear Stochastic Model," ASCE, EWRI Water Resources Congress, Palm Springs California, May 25-30.
80. Maslia, ML, Aral, MM. and Faye R. (2011). "Impact of Historical Contaminant Source Uncertainty Analysis and Variability on Human Health Risk," ASCE, EWRI Water Resources Congress, Palm Springs California, May 25-30.
81. Aral, MM, Guan, J. and Chang, B. (2011). "Climate Change and Sea Level Rise," ASCE, EWRI Water Resources Congress, Palm Springs California, May 55-68.
82. Biao, C, Guan, J. and Aral, MM, (2012). "Semi-Empirical Modeling of Spatial Variations in Sea Level Rise," ASCE, EWRI Water Resources Congress, Albuquerque, NM, May.
83. Guan, J., Biao, C. and Aral, MM, (2012). "Exploration for Impact of Radiative Forcing on Global Warming and Sea-Level Rise," ASCE, EWRI Water Resources Congress, Albuquerque, NM.
84. Telci, IT and Aral MM (2012). "Renewable Energy Production from Water Distribution Systems." Hydro Research Foundation Conference.
85. Dede, OT, Telci, IT and Aral MM (2013). "Water Quality Index Assessment of Surface Waters near Ankara, Turkey," ASCE, EWRI, IPWE 2013 Congress, Izmir, Turkey, January 2013.
86. Chang, B, Guan, J and Aral MM (2013). "Spatial Analysis of Climate Change and Sea Level Rise," ASCE, EWRI, IPWE 2013 Congress, Izmir, Turkey, January 2013.
87. Aral, MM. (2014). Application of Water-Modeling Tools to Reconstruct Historical Drinking Water Concentrations in Epidemiological Studies, Exposure Science Integration to Protect Ecological Systems, Human Well-Being, and Occupational Health 24th Annual Conference of The International Society of Exposure Science, Cincinnati, Ohio.
88. Morgan, W. and Aral, MM. (2015). "Modeling Hydraulic Fracturing in Pre-Fractured Rock Using the Discontinuous Deformation Analysis." 49th U.S. Rock Mechanics/Geomechanics Symposium, June 28 – July 1, 2015, San Francisco, USA.
89. Aral, M. M. (2015) "Concepts and development of modeling principles in environmental analysis," 68th National Geological Eng. Conf., 6 – 10 April 2015, MTA Kultur Sitesi, Ankara, Turkey (Keynote speech.)
90. Aral, M. M. (2015) "Integrated modeling of coupled watershed processes," 68th National Geological Engineers Conference, 6 – 10 April 2015, MTA Kultur Sitesi, Ankara, Turkey (invited).
91. Kentel, E., Gunduz, O. and Aral, M. M. (2015). "Critical Infrastructure Management: Risk, Resilience, Extent Concepts," The International Emergency Management Society 2015 Annual Conference, 30th September - 2nd October 2015, Rome, Italy.
92. Aral, M. M. (2016) "Transition from simple, complicated to complex systems," YTSAM, Yeni Türkiye Bilim ve Araştırma Merkezi International Conference, Ankara, Turkey, September 14, 2016.
93. Kentel, E., Gunduz, O., Bayar, M. and Aral, M. M. (2017). "Critical Infrastructure Management: Risk, Resilience, Extent Concepts," 12th Conference on Sustainable Development of Energy, Water and Environment Systems. Dubrovnic, Croatia.
94. Kizilaslan, M. A., Demirel, E., Aral, M. M. (2020). "Pathogen Inactivation and By-Product Formation in a Full-Scale Contact Tank," 2020 11th international Conference on Environmental Science and Development (ICESD 2020), Barcelona, Spain, February 10-12, 2020.
95. Aral, M.M. and Demirel, E. (2020). "İçme Sularının Arıtılmasında Kullanılan Temas Tanklarının Verimlerinin Arttırılması için Tasarım Önerileri ve Elde Edilen Verimler," HİDRO 2020: Hidrojeoloji and Water Resources Sempozyum, June 18-20, Bartın, Turkey.

96. Demirel, E. and Aral, M.M. (2020). "Batmış Kapağın Mansabındaki Vortekslerin İncelenmesi ve Sönümlenmesi," HİDRO 2020: Hidrojeoloji and Water Resources Sempozyum, June 18-20, Bartın, Turkey.
97. Kizilaslan, M.A., Demirel, E., Aral, M.M., (2020). "Pathogen inactivation and by-product formation in a full-scale contact tank," 11th International Conference on Environmental Science and Development (ICESD 2020), E3S Conf., 167 (2020) 01011, <https://doi.org/10.1051/e3sconf/202016701011>.
98. Aral M. M., (2022). "Optimal Water Treatment Tank Design and Analysis" IWA DIPCON, Istanbul, Turkey. The International Water Association (IWA) 4th Regional Diffusion Pollution and Eutrophication conference held in Istanbul 24-28 October, 2022" Istanbul, Turkey.

RESEARCH PROJECTS:

1. Principal investigator of the project titled, *Finite Element Analysis in Continuum Mechanics: FEMAC Computer Program*, (Funded by Middle East Technical Univ. Research funds - \$18,000), 1972-73.
2. Principal investigator of the project titled, *An Analysis of Convective Diffusion Equation and Its Finite Element Solution*, (Funded by Turkish Sci. and Tech. Research Inst.- \$ 12,000), 1976-77.
3. Principal investigator of the project titled, *Analytical and Numerical Study of Jet Deflection from Curved Boundaries*, (Funded by Middle East Technical Univ. Research funds - \$ 19,000), 1976-77.
4. Principal investigator of the project titled, *Tsunami Study: Akkuyu Nuclear Power Plant*, (Funded by Turkish Electric Authority, Nuclear Energy Division - \$ 75,000), 1977-79.
5. Principal investigator of the project titled, *Analysis of the Development of Shallow Ground Water Supplies by Pumping from Ponds*, (Funded by the Department of the Interior, Office of Water Resources Research and Technology - \$ 48,000), 1979-80.
6. Principal investigator of the project titled, *Mathematical Modeling of Aquatic Dispersion of Effluents in Natural Rivers*, (Funded by the Health and Safety Division of the Oak Ridge National Laboratories, Oak Ridge Tennessee - \$ 52,000), 1979-80.
7. Principal investigator of the project titled, *Aquifer Parameter Prediction by Numerical Modeling*, (Funded by the Department of the Interior, Office of Water Research and Tech. - \$ 56,000), 1981-82.
8. Principal investigator of the proposal titled, *An Analysis of Rimming Condensate Flow*, (Funded by Beloit corporation, Beloit, Wisconsin - \$ 68,000), 1981-83.
9. Principal investigator of the project titled, *Parameter Identification in Layered Aquifer Systems*, (Funded by the Department of the Interior, Office of Water Policy - \$ 44,000), 1983-84.
10. Principal investigator of the project titled, *A Simplified Approach to Regional Multilayered Aquifer Analysis*, (Funded by the Department of the Interior, U.S. Geological Survey - \$25,000), 1986-88.
11. Principal investigator of the project titled, *Modeling Transient Ground Water Flow in Multilayered Aquifer Systems*, (Funded by the Department of the Interior, USGS - \$ 29,000), 1988-89.
12. Principal investigator of the project titled, *Multilayered Aquifer Modeling in a Landfill Site*, (Funded by the Waste Management, Inc., Geosyntec, Inc. - \$ 42,000), 1990-91.
13. Principal investigator of the Research Program titled, *Exposure-Dose Reconstruction at Graton Massachusetts*, (Funded by: U.S. DHHS - \$ 44,000), 1992.
14. Director, NATO Advanced Study Institute, *Recent Advances in Groundwater Pollution Control and Remediation*, (NATO - Directorate of Environmental Programs \$ 111,000), 1994.
15. National Science Foundation, *Water, Sustaining A Critical Resource*, Joint Proposal with Dr. A. Zoporozec, University of Wisconsin, \$ 30,000 1995.
16. Principal investigator of the Research Program titled, *Research Program on Exposure-Dose Reconstruction*, (Funded by: ATSDR/CDC- \$ 2,500,000), 2000-2005.

17. Principal investigator of the Research Program titled, *Analysis of Coastal Georgia Ecosystem Stressors Using GIS Integrated Remotely Sensed Imagery and Modeling: A Pilot Study for the Lower Altamaha River Basin*, (Funded by: Sea Grant Program - \$ 288,000), 2000-2003.
18. Principal investigator of the Research Program titled, *GIS Integrated Environmental Systems Modeling*, (Funded by: CDC - GT Bioengineering Center \$ 30,000), 2000-2001.
19. Principal investigator of the Research Program titled, *Research Program on Exposure-Dose Reconstruction*, (Funded by: ATSDR/CDC- \$ 2,500,000), 2005-2010.
20. Principal investigator of the research Program titled "*Potential n-Nitrosodimethylamine (NDMA) Formation at Water and Wastewater Treatment Plants and Exposure Pathway Analysis*," (Funded by: SNF FLOERGER, France, program period: 2004-2006. \$ 550,432).
21. Principal investigator (co-investigator Prof. Ching-Hua Huang) of the research Program titled "*Potential n-Nitrosodimethylamine (NDMA) Formation at Water and Waste water Treatment Plants and Exposure Pathway Analysis*," (Funded by: SNF FLOERGER, France, program period: 2007-2009. \$ 308, 821).
22. Principal investigator of the Research Program titled, *Research Program on Exposure-Dose Reconstruction*, (Funded by: ATSDR/CDC- \$ 2,500,000), 2010-2015.
23. Principal investigator of the Research Program titled, *Chinese Drywall Emission and Exposure through Inhalation*, (Funded by: ATSDR/CDC- \$ 500,000), 2012-2014.
24. Co-Principal investigator of the research program, "Combining Statistical Process Control and Optimization via Simulation for Robust Sensor Network Design in the Presence of Sensor Measurement Error," Funded by National Science Foundation, \$ 350,000), 2016 – 2018.
25. Co-Principal investigator of the research program, "EU-Horizon 2020 Energy Efficiency Program-Eco-QUBE," Funded by EU Horizon 2020 program, €4.5 million, 2020-2023.

PROFFESIONAL ACTIVITIES:

National (USA):

1. **Member**, American Society of Civil Engineers, (ASCE). (1969 – present)
2. **Member**, Sigma Xi Research Society, (U.S.A.). (1971- present)
3. **Member**, American Geophysical Union, (U.S.A.) (1978-2010).
4. **Member**, National Water Well Association, (U.S.A.) (1978 – 2010).
5. **Member**, American Water Resources Association, (U.S.A.) (1978 – 1989).
6. **Member, Task Committee on Ground Water Strategy**, ASCE Hydraulics Division, 1983-85.
7. Listed in the directory of experts in Ground Water and Ground Water Contamination, Prepared by Edison Electric Institute and by Dames & Moore Consultants, Co.,1984
8. Listed in the directory in Who is Who in Science and Engineering.
9. **Member** of the organizing committee of the conference, *The Water Resources of Georgia and Adjacent Areas*, Sponsored by Ga. TECH and Georgia Geologic Survey, October 1983.
10. **Session Chairman**, ASCE. Spring Convention, Atlanta, 1984.
11. **Session Co-Chairman**, Engineering Mechanics Society, Blacksburg, 1984.
12. **Member**, American Water Resources Association, Publications Committee and Conference Organization Committee, 1987 – 1989.
13. **Member** of the Organizing Committee of the conference and Session Chairman, *Key Problems in Hydrology, Hazardous Waste*, Sponsored by American Institute of Hydrology, 1987.
14. **Member**, American Institute of Hydrology (1978-present).
15. **Session Chairman**, Int. Conference on Computational Eng. Sci., Atlanta, April 10-14, 1988.

16. **Chairman, Multidisciplinary Geohydrology Program**, Georgia Institute of Technology, College of Engineering, 1988-present (founding member).
17. **Invited Speaker - Board of Scientific Counselors**, Agency for Toxic Substances and Disease Registry (ATSDR), U.S. Department of Health and Human Services, 1990 - 1992.
18. **Member, Sci. Review Board**, Waste Policy Institute, U.S. Department of Energy, 1991 – present
19. **Director, Multimedia Environmental Simulations Lab.**, CEE, Ga. Tech., 1994-present.
20. **Member, Scientific Review Panel on program Analytical and Monitoring Methods in Subsurface Remediation**, USEPA, 1995 – 2001.
21. **Member, Scientific Review Panel on program STAR Program**, USEPA, 1995-present.
22. **Member, Scientific Review Panel on Eastern Research Group**, 1997-present.
23. **Member, International Society of Exposure Analysis**, 2002 – present.
24. **Member, International Association of Hydrogeology**, 2002 – present.
25. **Organizing Committee Member**, Achieving Sustainable Water Resources in Areas Experiencing Rapid Population Growth, 2003 AIH International Conf., Atlanta, GA.
26. **Vice President for International Affairs, American Institute of Hydrology**, 2004 – 2006.
27. **Elected to the Board of Dir. of the Buried Asset Man. Inst.– International**, (2004 – 2007).
28. **Chair of the ASCE Groundwater Hydrology Technical Committee** (2007 – 2009).
29. **Member of the ASCE Groundwater Hydrology Technical Committee** (2007 – present).
30. **Vice-Chair of the ASCE, GWH Tech. Report Com. on Exp.-Dose Reconstruction** (2007 – 2009).
31. **Member of the ASCE, EWRI Ground Water Council** (2007 – 2009).
32. **Vice President for Int. Affairs, American Institute of Hydrology**, (2009 – 2011).
33. **Member of the ASCE, EWRI World Water Council**, (2010 – present).
34. **Member of the ASCE EWRI International Council (2010 – Present)**.
35. **Control Group Member, ASCE EWRI World Water Council (2012 – Present)**.
36. **Member of the ASCE, EWRI Env. Health and Water Quality Committee**, (2008–present).
37. **FELLOW ASCE/EWRI**, elected by the ASCE Board of Directors to the rank of ASCE Fellow, 2010.
38. **Co-Chair of the organizing committee**, ASCE EWRI IPWE 2013 Conference Izmir, Turkey.
39. Short Course on **“Environmental Modeling and Health Risk Analysis,”** ATSDR/CDC Atlanta, GA (2010, 2011, 2012) and Izmir, Turkey (2012).
40. Invited Speaker ORLOB INTERNATIONAL SYMPOSIUM ON THEORETICAL HYDROLOGY. Presentation Title: “Climate Change and Spatial Variability of Sea Level Rise,” University of California (Davis), August 4, 2013.
41. **PRESIDENT ELECT, 2013-2015 and PRESIDENT 2015 - 2017. American Institute of Hydrology (AIH)**. Elected by the AIH membership.

International:

1. **Member**, Association for the Advancement of Mathematical Sciences. (1971 – 1978)
2. **Member**, Marine Sciences Research Institute, (Turkey, founding member). (1971 – 1978)
3. **Member**, Computer Sciences Research Institute, (Turkey, founding member). (1971 – 1978)
4. **Member**, International Engineering Analysts, Southampton, England.
5. **Member**, International Association for Computational Mechanics (1987 – 1990).
6. **Director, NATO Advanced Study Institute**, “Recent Advances in Ground Water Pollution Control and Remediation.” June 1995.
7. **Session Chairman and Member** of the Organizing Committee of the conference, *International Conference on Geology and Environment*, Sponsored by Academy of Sciences of Turkey and other International Organizations, 1997.
8. **European Community FP6 – FP7 – FP8 proposal review panel member**. (2005 – present)

9. **Fulbright Senior Scientist.** (2005 – 2011).
10. **Short Course on ACTS/RISK** (Dec., 2011) Dokuz Eylul University, Izmir Turkey.
11. **Organization Committee Member,** ASCE/EWRI IPWE International Conference on Perspectives on Water Resources and Environment, Izmir, Turkey, 2013.
12. **Organizing Committee member, HydroEnv. Ist-2017.** International Association for Hydro-Environment Engineering and Research (IAHR).
13. **European Community Horizon 2020 panel member.** (2013 – Present).
14. **Austrian Science Fund review committee member.** (2015 – Present).

EDITORIAL AND REVIEWER WORK

Reviewer:

Journal of Pure and Applied Sciences, 1976 – 1985.
Environmental Protection Agency (review of proposals), 1980 – present.
U.S. Dept. of Int., Geological Survey (review of reports and proposals), 1980 – present.
TUBITAK Research Council, Turkey (review of reports and proposals), 1980 – present.
ASCE Committee on Computational Hydraulics, 1981 – 1995.
ASCE Journal of Engineering Mechanics Division, 1982 – 1995.
Journal of American Water Works Association, 1985 – 1995.
Water Resources Bulletin, American Water Resources Association, 1985 – 1995.
Journal of Hydrology, 1986 – present.
Journal of Computational Mechanics, 1986 – 1995.
Water Resources Research, 1985 – present.
ASCE, Water Resources Planning and Management Journal, 1998 – present.
Saudi Geologic Survey for Scientific Research, 2000 – present.
Turkish Scientific Research Council, 2000 – present.
Netherlands Organization for Scientific Research, 1999 – present.
Danish Organization for Scientific Research, 2000 – present.
NSF/NIH, Engineering Centers of Excellence review committee member. 2003 – 2004.
Advances in Water Resources, 2005 – present.
Water Resources Research, 1990 – present.
Journal of Contaminant Hydrology, 2004 – present.
European Community, F6, F7, F8, Horizon 2020 committee member. 2005 – present.
Journal of Transport in Porous Media, 2005 – present.
NSF, SBIR review committee member. 2005 – present.
USEPA, SBIR review committee member. 2005 – present.
Journal of Environmental Management, 2007 – present.
Journal of Water Quality, Exposure and Health, 2009 – 2016.
Journal of Environmental Monitoring and Assessment, 2007 – present.
Journal of Water Resources Management, 2007 – present.
Journal of Neural Networks, 2007 – present.
Environmental Science and Technology, 2008 – present.
Journal of Risk Assessment, 2008 – present.
Journal on Neural Networks, 2008 – present.
Journal on Water, Air and Soil Pollution, 2009 – present.
Journal of Environmental Modeling and Software, 2009 – present.
Journal of Environmental Engineering, 2010 – present.

USEPA, STAR Fellowship review committee member. 2013 – 2014.

Water Journal, 2015 – present.

Processes Journal, 2015 – present.

Associate Editor:

Journal of Environmental Science and Health, Am. Chem. Society, 1989 – 99.

ASCE, Journal of Hydrologic Engineering, Associate Editor, 1985 – 1995.

ASCE, Journal of Hydrologic Engineering, International Associate Editor, 1995 – present.

International Journal of Hydroelectric Energy, International Editor, 1998 – present.

ISI Journal of Hydraulic Engineering, Taylor & Francis, 2011 – present.

Journal of Engineering Sciences, (Turkey), 2011 – present.

Journal of Engineering and Environmental Sciences, (Turkey), 2013 – present.

Special Issue Editor:

Population Dynamics, Climate Change and Technology Nexus on Human Health (2019)

International Journal of Environmental Research and Public Health (Impact Factor: 2.47)

https://www.mdpi.com/journal/ijerph/special_issues/pdcctnhh

Water Quality Modeling (2019)

PROCESSES Journal (Impact Factor: 1.97)

https://www.mdpi.com/journal/processes/special_issues/Water_Model

Computational Methods in Water Resources (2020)

WATER Journal (Impact Factor: 2.53)

https://www.mdpi.com/journal/water/special_issues/computainal_methods

Chemical and Non-Chemical Water Treatment (2020)

WATER Journal. (Impact Factor: 2.53)

https://www.mdpi.com/journal/water/special_issues/ozone_treatment

Editor-in-Chief:

International Journal on Water Quality, Exposure and Health, Springer Publishers. 2008 – 2014.

ENGINEERING CONSULTING:

1. Allied Gulf Nuclear Services, (1978-80).
2. NATO, United Nations Development Program, (1979-present).
3. The Coca Cola Company, Corporate Engineering Department, (1983).
4. Georgia Geologic Survey, Department of Natural Resources, State of Georgia, (1983-85).
5. Dames and Moore (1987), Numerical study of flow through earth embankments, Sarasota reservoir.
6. Atlantic Richfield Co. (ARCO) (1990-92), Performance analysis of a cleanup operation in a vadose zone, numerical modeling of saturated-unsaturated flow pump-and-treat operation, Opa Locka, Florida and Numerical modeling of ground water flow and contaminant transport control in a multilayer aquifer with a slurry wall design at a Super Fund Site.
7. CHEVRON Products Co. USA (1992-2002), Numerical modeling of transport of NAPL

- contamination, Cleves, Ohio and CHEVRON Chemical Products Co., USA (1996-1997), Investigation of Agricultural Pesticides pollution, Ortho-CHEM plant, Missouri.
8. Expert Testimony: Atlanta Gas Light -vs.- various Environmental Insurance Underwriters (1993), Numerical modeling of transport of petroleum products in aquifers, Georgia.
 9. L&L Landfill Co. (1994), Transport of leachate through L&L landfill, Chicago, Illinois.
 10. DOD, Mass. Military Reservation, EDB plume modeling and exp. risk analysis, (1997-1998).
 11. GeoSyntec Consultants, Consultant (1994 - 2001) (subsurface resources and contaminant transport modeling support and expert testimony).
 12. Globex Engineering & Development, Consultant (1998 - 1999) (subsurface resources and contaminant transport modeling support, risk analysis and expert testimony).
 13. DOE, Waste Isolation Pilot Plant Project (WIPP), New Mexico (1998 - 1999) (Technical support for expert testimony).
 14. Texas Education Board, State Proposal Reviews, (1999-2000).
 15. Eastern Research Group, Subsurface Resources and Environmental Health related analysis and exposure assessment, (1998-2013).
 16. Hydraulic Fracturing and shale gas extraction, Washington Law Group, (2010 – 2017).
 17. Camp Lejeune Exposure Litigation, Bell Law Group, Atlanta, GA, USA. (2022 – Present).

SPECIALIZATION AREAS:

Research, teaching and engineering experience in the following specific areas:

- Groundwater flow and contaminant transport modeling in aquifers, aquifer remediation.
- Groundwater resources evaluation and management.
- Aerodynamic Analysis.
- Multimedia (air-surface water- groundwater) environmental simulations, risk based env. modeling.
- Exposure analysis, exposure-dose reconstruction.
- Environmental health.
- Renewable Energy.
- Climate Change, Water Resources and Environmental Health.
- Analytical and numerical analysis in aerodynamics, surface water, groundwater and air pollution.
- Evaluation of groundwater and surface water monitoring data, site assessment.
- Site characterization and surface water groundwater interaction.
- Saturated and unsaturated groundwater flow analysis.
- Miscible and immiscible groundwater flow analysis.
- Computational methods in environmental fluid mechanics.
- GIS applications in environmental systems.
- Optimization methods in environmental systems.
- Hydraulics and water resources engineering.
- Hydraulic Fracturing and shale gas extraction.
- Population Dynamics and Climate Effects.

PhD/MS Students:

Graduated 25 PhD students at Georgia Institute of Technology.

Graduated 68 M.S. students at Georgia Institute of Technology.

Exhibit B

MEMORANDUM

To: Morris Maslia, PE
Project Manager
Exposure-Dose Reconstruction Program
ATSDR, CDC

From: Prof. Mustafa M. Aral
Director, Multimedia Environmental Simulations Laboratory
School of Civil and Environmental Engineering
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E-mail: maral@ce.gatech.edu
WWW: <http://mesl.ce.gatech.edu/>

Date: June 27, 2009

Subject: Response to Comments of the NRC Report on ATSDR Water Modeling Study.

This memorandum was submitted to EDRP/ATSDR on June 27, 2009, and became an internal document for the Camp Lejeune study at ATSDR/CDC. Contents of this memorandum are now included in Section 7 of this expert report.

EXHIBIT 12

IN THE UNITED STATES DISTRICT COURT
FOR THE EASTERN DISTRICT OF NORTH CAROLINA
SOUTHERN DIVISION
No. 7:23-CV-00897

IN RE:

CAMP LEJEUNE WATER LITIGATION

This Document Relates to:

ALL CASES

EXPERT VIDEO-RECORDED DEPOSITION OF
LEONARD KONIKOW, PHD

Tuesday, February 25, 2025

9:38 AM EST

Reported by: Denise Dobner Vickery, CRR, RMR
Job No. MDLG7172979

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Tuesday, February 25, 2025
9:38 AM EST

Video-Recorded Expert Deposition of
LEONARD KONIKOW, PHD, held in the conference room
of:

WASHINGTON DULLES MARRIOTT SUITES
13101 Worldgate Drive
Herndon, VA 20170

Pursuant to notice, before Denise
Dobner Vickery, Certified Realtime Reporter,
Registered Merit Reporter, and Notary Public in
and for the Commonwealth of Virginia.

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11 202.616.4473

12 haroon.anwar@usdoj.gov

13 kailey.silverstein@usdoj.gov

14 giovanni.antonucci@usdoj.gov

15
16 ALSO PRESENT:

17 Gene Aronov, Videographer

18 PRESENT BY ZOOM:

19 Deanna Havai

Dennis Reich

20 Tim Thompson

Jeffrey Davis

21 Morris Maslia

Devin Botlon

22 Bill Williams

Alex Spiliotopoulos

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KONIKOW DEPOSITION EXHIBITS

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P R O C E E D I N G S

- - -

THE VIDEOGRAPHER: Good morning. We are now on the record.

My name is Gene Aronov. I'm videographer for Golkow Veritext division. Today's date is February 25th and the time is 9:38 AM.

This video deposition is being held at the Washington Dulles Marriott Suites, 13101 Worldgate Drive, Herndon, Virginia in the matter of Camp Lejeune Water Litigation versus United States of America for the Eastern District of North Carolina. The deponent is Leonard Konikow.

Would counsel please introduce themselves for the record.

MR. DEAN: Good morning. Kevin Dean on behalf of the Plaintiffs Leadership Group and the witness.

MS. BAUGHMAN: Laura Baughman on behalf of Plaintiffs Leadership Group and the witness.

1 MR. ANWAR: Haroon Anwar
2 Department of Justice for the United
3 States.

4 MR. ANTONUCCI: Giovanni
5 Antonucci for the United States.

6 MS. SILVERSTEIN: Kailey
7 Silverstein for the United States.

8 THE VIDEOGRAPHER: The remote
9 participants will be noted on the
10 stenographic record.

11 The court reporter is Denise
12 Vickery will now swear in the witness.

13 - - -

14 LEONARD KONIKOW, PHD
15 called for examination, and, after having been
16 duly sworn, was examined and testified as
17 follows:

18 - - -

19 EXAMINATION

20 - - -

21 BY MR. ANWAR:

22 Q. Good morning, Dr. Konikow.

23 A. Good morning.

24 Q. My name is Haroon Anwar. I am a

1 lawyer for the Department of Justice here to take
2 your deposition today in the Camp Lejeune Justice
3 Act Litigation.

4 A. Okay.

5 Q. Do you understand that?

6 A. Yes.

7 Q. Okay. Have you ever sat for a
8 deposition before?

9 A. One time.

10 Q. Okay. Well, you may recall that
11 experience, but I just wanted to go over some
12 ground rules to help the deposition today go as
13 smoothly as possible.

14 A. Good.

15 Q. First, you're -- you're under the
16 oath to tell the truth as if you were in an actual
17 court of law.

18 A. Okay.

19 Q. Do you understand that?

20 A. Yes, I do.

21 Q. And is there any reason, sitting
22 here today, that you would be unable to testify
23 truthfully?

24 A. No.

1 Q. Okay. We have a court reporter
2 sitting right next to you taking down everything,
3 typing down everything for the record.

4 A. (Nods head).

5 Q. To make life easier for her, if we
6 could avoid speaking over each other --

7 A. Okay.

8 Q. -- it will -- it will make for a
9 cleaner record and a happier court reporter. She
10 can't get everything down when we're speaking over
11 each other.

12 A. (Nods head).

13 Q. Fair enough?

14 A. Fair enough.

15 Q. Okay. And sort of corollary to that
16 is, to help with that, if you could pause or after
17 I ask my question, maybe pause for a second and
18 then respond.

19 Fair enough?

20 A. Okay.

21 Q. Okay. If I ask a bad question or a
22 question that you need clarification on -- and
23 it's very possible I would do that today -- could
24 you let me know, please?

1 A. I will.

2 Q. Okay. If you don't let me know, I
3 will assume that you understood the question.
4 Fair?

5 A. Yes.

6 Q. Okay. Now, we'll be going for a few
7 hours today. If at any point you need a break,
8 just let me know. This isn't intended to be
9 punishment. The only -- the only stipulation I
10 would put on that is if there's a pending
11 question, I'd ask that you answer that question,
12 and then we can take a break.

13 Fair enough?

14 A. Yes.

15 Q. Okay. And I'll try to take a break
16 every hour or so anyway.

17 A. Good. Okay.

18 Q. Now, I want to start by asking you
19 what you did to prepare for today's deposition.

20 A. Well, a number of things. Over the
21 past several weeks, I reviewed all of the reports
22 from ATSDR for the Tarawa Terrace model and Hadnot
23 Point/Holcomb Boulevard.

24 Last week I flew down to South

1 Carolina to meet with these lawyers, a few other
2 lawyers, and Morris Maslia were there for
3 basically two days of meetings. And then
4 yesterday I met with Kevin and Laura just to
5 discuss general questions, such as the things you
6 just pointed out to me and had to respond.

7 Q. Sure.

8 A. Yeah.

9 Q. For the meeting last week, the
10 two-day meeting in South Carolina with the lawyers
11 and Mr. Maslia, was there anyone else present
12 besides lawyers and Mr. Maslia?

13 A. Besides the lawyer -- there were
14 several lawyers and myself and that's -- that's
15 all I recall being there.

16 Q. Okay. No -- no non-lawyers other
17 than Mr. Maslia?

18 A. No what?

19 Q. No non-lawyers other than
20 Mr. Maslia?

21 A. I don't believe so.

22 Q. Did you review any documents during
23 that meeting?

24 A. What do you mean by "reveal"?

1 Q. Did you review documents?

2 A. Oh, review?

3 Q. Correct.

4 A. During the meeting?

5 Q. During the meeting last -- last
6 week, the two-day meeting with the lawyers and
7 Mr. Maslia.

8 A. We may have looked things up for to
9 check some facts, but I don't think there was
10 anything that was a review of a document
11 necessarily. I mean, we looked at some documents
12 to answer some questions, but, you know, in terms
13 of reviewing, if you mean like a technical review,
14 that was not done.

15 Q. Okay.

16 A. But for specific points, there may
17 have been discussions.

18 Q. Understood.

19 Did you -- I guess understanding I'm
20 not asking about technical review sort of from a
21 scientific perspective. Understanding that you
22 are a scientist.

23 Did the documents that you reviewed
24 with the lawyers and Mr. Maslia, did they help

1 refresh kind of your recollection about points
2 that you were discussing?

3 A. It did. Occasionally, you know,
4 something would come up, and we would look at one
5 of the reports that ASDR -- ATSDR published.

6 Q. Okay. Do you recall what documents
7 you reviewed during the two-day meeting last week?

8 A. I believe we looked at the chapter
9 of the Tarawa Terrace that described the summary
10 and findings and probably the groundwater flow
11 model and maybe even the transport model.

12 Q. That was for Tarawa Terrace?

13 A. Tarawa Terrace and similar, you
14 know, I don't remember exactly which ones we
15 looked at, but I suspect we did the same types of
16 documents for Hadnot Point when we talked about
17 that.

18 Q. Understood.

19 Do you recall during last week's
20 two-day meeting reviewing any other documents?

21 A. I do not.

22 Q. How about during yesterday's
23 meeting? Was that -- did that meeting take place
24 with Kevin and Laura?

1 A. It was in this room yesterday.

2 Q. Okay. And with the attorneys --
3 with your attorneys here present today; correct?

4 A. The two attorneys that are here
5 today, yes.

6 Q. Understood.

7 Did you review any documents during
8 yesterday's meeting?

9 A. I don't -- I don't recall that we
10 did. I mean, maybe I don't remember, but I don't
11 remember us reviewing any documents yesterday.

12 Q. Understood.

13 About how long -- how long did the
14 meeting yesterday last?

15 A. It was probably about six hours, not
16 counting lunchtime.

17 Q. All right. Did you do anything else
18 besides the two separate meetings that we've
19 discussed to prepare for your deposition today?

20 A. To prepare for the deposition? No,
21 not that I can think of.

22 Q. Okay. But -- and I should say,
23 besides the two meetings last week and this week
24 with your -- the lawyers and Mr. Maslia and then

1 you had testified, I believe, that you had went
2 through and reviewed the ATSDR modeling reports;
3 correct?

4 A. Yes.

5 Q. Okay. Besides that, did you do
6 anything else to prepare for your deposition
7 today?

8 A. No.

9 Q. Okay.

10 (Document marked for
11 identification as Konikow Exhibit 1.)

12 BY MR. ANWAR:

13 Q. I am handing you what is being
14 marked as Konikow Exhibit 1.

15 Have you seen this document before?

16 A. (Reviews document.)

17 Yes, this looks familiar.

18 Q. Okay. I'll represent to you it's
19 the notice for deposition and the subpoena
20 scheduling your deposition --

21 A. Yeah.

22 Q. -- today.

23 A. Okay.

24 Q. I wanted to direct your attention to

1 Attachment A. There are three document requests
2 there.

3 The first one is for e-mails,
4 letters, correspondence, text messages,
5 conversations, chats, voicemails, and
6 communications pertaining to Camp Lejeune prior to
7 your retention as an expert in this litigation.

8 Do you see that there?

9 A. Yes.

10 Q. And we received a document
11 production from your counsel last night.

12 A. Yeah.

13 Q. Did that document production contain
14 all of the responsive documents or communications
15 you have in response to request number 1?

16 A. Well --

17 MR. DEAN: Object to form,
18 except, you know, we've served an
19 objection.

20 MR. ANWAR: Understood.

21 MR. DEAN: So subject to that.

22 THE WITNESS: I had responded
23 I believe, several weeks ago with e-mails
24 and then yesterday with other documents

1 that I realized were covered up. But I
2 wasn't intentionally not, you know, I
3 wasn't intentionally not sending those
4 forward.

5 I just -- I was focused on the
6 e-mails, letters, correspondence part of
7 this, and I had some files from my
8 service on the expert panels in 2005 and
9 2009. And until Sunday, this past
10 Sunday, it just didn't pop into my head
11 that those were covered by this. It was
12 just an oversight on my part.

13 BY MR. ANWAR:

14 Q. Understandable and, you know, I'm
15 not suggesting you did anything --

16 A. Yeah.

17 Q. -- anything wrong.

18 I'm just trying to confirm --

19 A. Yeah.

20 Q. -- whether -- what was produced in
21 response to this subpoena.

22 And so request number 2 is
23 essentially the same thing. E-mails, letters,
24 correspondence, communications with any of --

1 anyone that has filed a claim in this litigation.

2 And then request number 3 asks for
3 bills, invoices, and other documents reflecting
4 compensation paid.

5 In response to these three requests,
6 did you give your lawyers everything that you
7 have?

8 A. At this time, I would say I gave
9 everything that I have, yes.

10 Q. Okay. Is there anything that you
11 can think of related to Camp Lejeune prior to your
12 retention as an expert in -- in this current
13 litigation, communications, documents that you
14 have in your possession currently?

15 A. That I have not turned over?

16 Q. Correct.

17 A. No. As far as I know, I've turned
18 over everything.

19 MR. ANWAR: Okay. Thank you.

20 You can set that aside.

21 (Document marked for
22 identification as Konikow Exhibit 2.)

23 BY MR. ANWAR:

24 Q. I'm going to hand you now what is

1 being marked as Exhibit 2. There you go.

2 Dr. Konikow, is this a true and
3 correct copy of the rebuttal report -- expert
4 report that you submitted in this case?

5 A. It appears to be.

6 Q. Okay. Is there anything in your
7 rebuttal report -- well, let me back up for a
8 second.

9 This rebuttal report on page 33 is
10 dated January 13; correct?

11 A. Yes.

12 Q. That's when you signed the report;
13 correct?

14 A. And sent it probably to Kevin, yes.

15 Q. Sure.

16 And is that your electronic
17 signature there on page 33?

18 A. It is.

19 Q. Okay. Since submitting the report
20 and giving it to the lawyers on January 13, 2025,
21 is there anything in your rebuttal report that you
22 now believe is incorrect?

23 A. Yes.

24 Q. What -- what is that?

1 A. On page 10 -- let me look at my
2 copy. Page 11 line 10 it says "equivalent to a
3 fraction or 0.001," the word or should be "of"
4 o-f. So just a typographical error.

5 Q. Understood.

6 And this is the sentence starting
7 with "OCC is equivalent to TOC?

8 A. Yes.

9 Q. "And 0.1% is equivalent to a
10 fraction of .001"?

11 A. Yes.

12 Q. Is there anything else, as you sit
13 here today, that you believe is incorrect in your
14 report?

15 A. No.

16 Q. Is there anything in your rebuttal
17 report that needs to be updated, as you sit here
18 today?

19 A. Not that I'm aware of, no.

20 Q. Is there any portion of your
21 rebuttal report that you believe is incomplete?

22 A. Not -- no, not that I can think of.

23 Q. And does your rebuttal report
24 contain all of the opinions that you intend to

1 offer in this case?

2 MR. DEAN: Object to the form.
3 Subject to anything that you might ask
4 him in the deposition not covered by the
5 notice -- I mean, the report.

6 THE WITNESS: I may have
7 other opinions. I'm not, you know, I
8 mean, from my review of those two expert
9 reports, these are the comments that I
10 felt were significant criticisms that I
11 thought were worth making.

12 If something else comes up, I
13 probably have another opinion. So I
14 don't think I could say that these are
15 the only opinions I would give. You ask
16 me a question, I'll give you my opinion.

17 BY MR. ANWAR:

18 Q. Sure.

19 So aside for any conversation we
20 have in the deposition today, does this report
21 contain all of the opinions that you intend to
22 offer in the litigation?

23 A. Well, you, again, if I, you know, if
24 I'm asked questions about something other than

1 this, I would offer an opinion on it.

2 So I'm really not sure about the
3 question what -- what it is encompassing but...

4 Q. Sure. I understand that.

5 I guess with the caveat that we may
6 discuss things both contained in your report and
7 not directly referenced in your report in today's
8 deposition.

9 Putting that aside, is there
10 anything -- are there any other opinions that
11 you're currently aware of that you intend to offer
12 in this case that aren't reflected in your report?

13 A. Not that I can think of.

14 Q. Okay.

15 (Document marked for
16 identification as Konikow Exhibit 3.)

17 BY MR. ANWAR:

18 Q. I'm going to hand you what I'm
19 marking as Konikow Exhibit 3.

20 A. (Reviews document.)

21 Q. Dr. Konikow, is this a complete list
22 of the materials you considered in forming the
23 opinions in your rebuttal report?

24 A. I believe so.

1 Q. Okay.

2 A. I'll look. There's a number of
3 documents listed at the end, and I'm not sure
4 exactly what those refer to.

5 Q. Okay. This document, Exhibit 3,
6 that I handed you, it's titled "January 2025
7 Rebuttal Expert Report of Leonard Konikow, PhD,
8 National Academy of Engineering" and then
9 underneath it says "Materials Considered List" and
10 it's dated January 21, 2025; is that right?

11 A. Yes.

12 Q. Okay. And as you sit here
13 currently, you're not aware of anything else that
14 should have been included on this Materials
15 Considered List that's not included?

16 A. Not that I'm aware of.

17 Q. Okay. Did you review the rebuttal
18 reports of or the rebuttal report of Morris
19 Maslia?

20 A. I believe I did.

21 Q. Okay.

22 A. I don't recall it specifically,
23 though.

24 Q. But you may have?

1 A. Yes.

2 Q. Did you review a rebuttal report
3 from David Sabatini?

4 A. I believe I saw it. I saw something
5 from Sabatini.

6 Q. Okay. Did you review the rebuttal
7 report from Norman Jones and Jeffrey Davis?

8 A. Yes.

9 Q. And did you review the rebuttal
10 report from Kyle Longley?

11 A. I -- I don't -- I -- yeah, I'm not
12 sure which report that was. Is that the one
13 related to the history or something?

14 Q. Yeah. Correct.

15 A. I think it was sent to me and I just
16 glanced at the first page or so, and I did not
17 review that whole report.

18 Q. Understood.

19 Do you have any opinions about
20 the -- any of those rebuttal reports that aren't
21 reflected in your -- in your own report?

22 A. Well, my report really focused on
23 Alex and Remy's report, and I don't think there's
24 any comments in here on the other rebuttal

1 reports.

2 Q. Okay. And as you sit here today,
3 you don't intend to offer comments on the other
4 rebuttal reports outside of any discussion we may
5 have today in the deposition?

6 A. Correct.

7 Q. Okay. Did you listen to or review
8 the transcripts for the deposition of Mustafa
9 Aral?

10 A. I did. Yes, I looked at it. I read
11 it.

12 Q. Okay. Did you either listen to or
13 review the transcripts for the depositions of
14 Norman Jones and Jeffrey Davis?

15 A. I believe I did.

16 Q. Do you have any opinions about
17 anything that was said in those depositions that
18 aren't reflected in your -- your own expert
19 report, your rebuttal report?

20 MR. DEAN: Object to the form.

21 Subject to whatever you may ask in this
22 deposition or I do as a follow-up.

23 BY MR. ANWAR:

24 Q. You can answer.

1 A. Well, there's nothing in my expert
2 report about the testimony or deposition of Jones
3 and Davis. I read it. I may have some opinions
4 on it, but it was nothing that belonged in my
5 rebuttal report.

6 Q. Okay. Outside of any discussion we
7 have today in the deposition, do you intend to
8 offer any opinions related to anything that was
9 said in -- well, strike that.

10 Outside of any discussion we have
11 today during our -- the deposition, as you sit
12 here, do you intend to offer any opinions based on
13 the depositions of Mustafa Aral, Norman Jones, and
14 Jeffrey Davis?

15 A. That's not my intent, but if I'm
16 asked, I would try to answer the question to the
17 best of my ability.

18 Q. Understood. Thank you.
19 Do you know Norman Jones?

20 A. I've met him once or twice. I do
21 not know him personally very well, just, you know,
22 other than an introduction at a professional
23 meeting or something like that.

24 Q. Where did you meet him?

1 A. I've attended so many professional
2 meetings in the last 40 years, I really -- I don't
3 remember. It may have been a National Ground
4 Water Association meeting. It may have been a
5 Geological Society of America meeting. I go to,
6 you know, many of these and occasionally our paths
7 him across. It was probably one or two sessions
8 where we were both speakers in a symposium, and
9 I'm sure I shook hands with him, said hello, but
10 nothing more than that.

11 Q. Understood.
12 Aside from crossing paths in
13 professional settings once or twice, it sounds
14 like you haven't -- you don't know Norman Jones
15 otherwise; correct?

16 A. When I was -- well, basically the
17 answer is no, I don't know him, but I believe I
18 had another interaction with him in the last five
19 years related to a man- -- I was editor-in-chief
20 of Groundwater Journal for four years. And during
21 that time, I believe he had submitted one
22 manuscript not related to Camp Lejeune, and so we
23 had some correspondence related to that, but had
24 nothing to do with Camp Lejeune.

1 Q. Do you have any recollection what
2 that manuscript was about?

3 A. I believe it was about an area
4 called Spring Valley in Nevada or an adjacent area
5 in Utah. I know it focused on the City of Las
6 Vegas, trying to develop well fields in an area
7 maybe a couple hundred miles north of Las Vegas,
8 but in a valley in Nevada that extended into Utah.
9 And they wanted to develop water supplies on the
10 Nevada side, pump a lot of wells, and it would
11 have had impacts on the Utah side. So he was --
12 the manuscript focused on that situation.

13 Q. Well, did that manuscript involve
14 groundwater or transport modeling? Do you recall?

15 A. My recollection it probably, but I
16 can't -- I don't have total recollection. It
17 probably involved groundwater flow modeling.

18 Q. Okay.

19 A. Probably did not involve transport
20 modeling.

21 Q. Understood.

22 In that instance, it sounds like it
23 may have involved groundwater modeling for the
24 purposes of developing supply wells outside of Las

1 Vegas; is that right?

2 A. It was related to that, but I think
3 his focus was on assessing the impacts of that
4 pumpage on water supplies on the aquifers in Utah.

5 Q. Okay. Aside from that manuscript,
6 have you worked with Norman Jones on any other
7 projects?

8 A. No.

9 Q. Do you know Mustafa Aral?

10 A. I've met him.

11 Q. Okay. In what context have you met
12 Dr. Aral?

13 A. Serving on expert peer review panels
14 for ATSDR in 2005 and 2009. I believe he was at
15 both of those meetings, to the best of my
16 recollection, and I met him there and we may have
17 talked. You know, I don't remember. I believe he
18 gave some presentations to the expert panel
19 committees, but I don't remember the details.

20 I don't recall ever meeting him
21 outside of those two meetings.

22 Q. Have you ever worked with Dr. Aral
23 before outside of those two meetings, the ATSDR
24 meetings?

1 A. No, not to recollection.

2 Q. Do you know Jeffrey Davis?

3 A. I believe I met him somewhere along
4 the line, but I can't recall the occasion. I saw
5 he said he was involved with the board of
6 directors of National Ground Water Association,
7 and while I was an editor for their journal, we
8 probably attended meetings together at their
9 annual meetings. And we probably talked there,
10 but I have no direct recollection of that.

11 Q. Okay. So outside of those
12 professional meetings, you don't know Jeffrey
13 Davis; is that right?

14 A. That's correct.

15 Q. Have you ever -- and you haven't
16 worked with Mr. Davis before?

17 A. Not that I could recall.

18 Q. Do you -- do you know David
19 Sabatini?

20 A. No.

21 Q. Never met?

22 A. Well, again, I may have met. If he
23 was at the 2005 or 2009 meetings, I probably met
24 him, but I do not recall meeting him.

1 Q. Understood.

2 Earlier you mentioned reviewing all
3 of the ATSDR reports.

4 It sounds like the modeling reports
5 for Tarawa Terrace as well as the model --
6 modeling reports related to Hadnot Point and
7 Holcomb Boulevard; is that right?

8 A. That's correct.

9 Q. Did you do anything further than
10 review the reports?

11 A. I'm not sure what that would --
12 could include, but no, I mean, I read the reports.
13 I didn't do anything else with them.

14 Q. Did you attempt to reconstruct
15 ATSDR's models for Tarawa Terrace or Hadnot Point
16 and Holcomb Boulevard?

17 A. I did not.

18 Q. Did you attempt to reevaluate the
19 input parameters or assumptions upon which the
20 Tarawa Terrace model or the Hadnot Point/Holcomb
21 Boulevard model were based?

22 A. Well, I mean, part of my review was
23 looking at their discussions of the parameter
24 values, and I certainly, you know, considered them

1 and looked at, you know, what, you know, that they
2 looked reasonable, you know.

3 Q. Outside of what's contained in your
4 report and what we -- we discuss today, do you
5 have any -- any opinions about ATSDR's parameter
6 of values or input values?

7 A. Can you repeat that, please?

8 Q. I guess -- well, let's -- we'll come
9 back to that. Let's that was maybe a bad
10 question.

11 I'm going to hand the court reporter
12 to hand you what is being marked as Konikow
13 Exhibit 4.

14 (Document marked for
15 identification as Konikow Exhibit 4.)

16 THE WITNESS: (Reviews
17 document.)

18 BY MR. ANWAR:

19 Q. The first page of Exhibit 4 states
20 "Attachment A" which was attached to your expert
21 report, and Attachment A is a copy of your
22 curriculum vitae; correct?

23 A. Yes.

24 Q. Okay. Is this a true and accurate

1 copy of your curriculum vitae?

2 A. Yes.

3 Q. Is it current?

4 A. Pretty current. I think I updated
5 it a couple months ago.

6 Q. To the best of your knowledge, as
7 you sit here today, is there anything that you
8 need to update on this curriculum vitae?

9 A. No. Again, this -- this
10 includes -- it's not a complete detailed list of
11 everything I've ever done professionally --

12 Q. Okay.

13 A. -- but it's, you know, what I could
14 get in two pages.

15 Q. Okay. How did you decide what to
16 include on your curriculum vitae versus what not
17 to include in terms of, you know, everything that
18 you've done professionally?

19 A. Well, I included the points that I
20 think people would expect to see in a curriculum
21 vitae, my education, so on, and highlights of
22 publications and professional side activities. A
23 few awards that I received that I thought were of
24 particularly high recognition, but I did not

1 include every award I've ever received or every
2 publication I've ever had published.

3 Q. Understood.

4 As part of Exhibit 4, there's also
5 an Attachment B, which is Attachment B to your --
6 your rebuttal report, and it's titled
7 "Publications During Past 10 Years."

8 Is that right?

9 A. Yes.

10 Q. Is this a complete list of your
11 publications during the past 10 years?

12 A. To the best of my knowledge, it is.

13 Q. I wanted to ask you a few questions
14 about items on your CV.

15 I wanted to start by asking you
16 whether you would describe yourself as a
17 hydrogeologist; is that right?

18 A. That's how I usually describe
19 myself, yeah.

20 Q. Is there any other title that you
21 describe yourself with?

22 A. Occasionally, you know, my official
23 job position with -- during my career with the
24 U.S. Geological Survey, most of the time I was

1 called, in fact probably all the time, I was
2 called a research hydrologist.

3 Q. Okay. Do you consider yourself an
4 expert in groundwater transport and water
5 distribution modeling?

6 A. I am not an expert in water
7 distribution modeling, but I do consider myself an
8 expert in groundwater flow and transport processes
9 in modeling.

10 Q. Is there any other subject area that
11 you consider yourself an expert in?

12 A. I think hydrogeology, groundwater
13 flow, and transport processes probably encompasses
14 all of it.

15 Q. Okay. Now, you spent the bulk of
16 your career at the U.S. Geological Survey; right?

17 A. Yes, sir.

18 Q. And then it looks like from your CV
19 your most recent role was editor-in-chief of
20 Groundwater Journal from 2020 to 2023; is that
21 right?

22 A. Yeah, four years.

23 Q. Four years from 2020 to 2023?

24 A. Yeah, inclusive. All those years,

1 you know, from January 1st of 2020 to December
2 31st of 2023.

3 Q. Understood.

4 Are you currently retired?

5 A. Yes. Well, except for this.

6 (Laugh).

7 Q. Except for the serving as a Camp
8 Lejeune expert; correct?

9 A. Yes.

10 Q. Okay. Under -- I wanted to talk to
11 you a little bit about some of your selected
12 professional activity on your CV.

13 It looks like that throughout your
14 career you've served on committees or panels for
15 the National Research Council; is that right?

16 A. That's correct.

17 Q. Okay. From -- and I'm looking at
18 your CV.

19 From 1981 to 1982, you served on an
20 NRC panel on groundwater contamination; is that
21 right?

22 A. That is correct.

23 Q. What did you do in this role?

24 A. Well, to the best of my

1 recollection, again, that one is, you know, more
2 than 40 years ago, but as a panel member, we
3 discussed the -- the problem of groundwater
4 contamination, which was just in the late '70s
5 becoming much more widely recognized as an
6 important problem.

7 And the National Research Council
8 had asked me to serve on this panel, and I thought
9 it was a worthwhile activity. We would typically
10 have discussions among the whole committee, as
11 well as listen to presentations from experts that
12 they brought in. I had no role in selecting who
13 they brought in but, you know, and then we would
14 have discussions.

15 And then somewhere after, you know,
16 the first or second meeting, we started working on
17 writing a report and, to the best of my
18 recollection, a book came out from that activity.

19 Q. What book came out of that activity?

20 A. I believe it was just a National
21 Research Council report published by National
22 Academy Press. Something in the title about
23 groundwater contamination. There may have been
24 some other words there, but I don't recall. I

1 haven't looked at that report in a while.

2 Q. Okay. Did you take part in writing
3 any part -- any portion of that book?

4 A. Most likely, yeah.

5 Q. So either on the book itself or in
6 the chapters, you likely would be listed as an
7 author?

8 A. I don't know that they listed
9 authors. I think they listed it in terms of who
10 was members of the committee that wrote the
11 report.

12 Q. Understood.

13 Do you know how you were selected to
14 serve on that NRC committee on groundwater
15 contamination?

16 A. No, I do not.

17 Q. You mentioned, I guess, other
18 experts served on that committee; correct?

19 A. Yeah. Yes.

20 Q. Would it be fair to say you were
21 selected to serve on that committee because of
22 your expertise as a hydrogeologist?

23 A. I presume so.

24 Q. Do you know how other experts were

1 selected to serve on that committee?

2 A. I do not.

3 Q. Do you remember any of the experts
4 that you -- you served on that committee with?

5 A. On that committee, I do not
6 remember. I did not look at that report probably
7 in the last year or two years or five years. I
8 just -- I don't remember who else was on that
9 committee. If I looked at the report, it would
10 refresh my memory.

11 Q. Understood.

12 Now, looking further on your CV, it
13 looks like from 1987 to 1989 you served on an NRC
14 Committee on Ground-Water Modeling Assessment; is
15 that right?

16 A. From '87 to '89, yeah. Committee on
17 Ground-Water Modeling Assessment, yes.

18 Q. What was the committee or what is
19 the Committee on Ground-Water Modeling Assessment?

20 A. Again, this is done at a time when
21 groundwater modeling was becoming much more
22 widespread and -- and, you know, particularly in
23 the public there wasn't a widespread appreciation
24 among the public or probably politicians and

1 others, senior level government officials, about
2 what groundwater models could do, how reliable
3 they were and so on. And so this -- this
4 committee was, I believe, was charged to review
5 the state of the art of groundwater modeling.

6 It's not shown here, but like a
7 subtitle of this committee, or at least of the
8 book that was produced, was something to the
9 effect of groundwater models in a regulatory and
10 environmental framework or assessment, something
11 like that. There was, you know, some additional
12 subtitle that is not listed here. I was trying to
13 keep everything on one line here.

14 Q. Understood.

15 What do you -- what did you do in
16 this role on the -- the NRC Panel on Ground-Water
17 Modeling Assessment?

18 A. We discussed the philosophy of
19 modeling. We discussed the mathematical basis
20 underlying the model. We discussed parameter
21 estimation for the models, how reliable the
22 results are, you know, things on that order, yeah.

23 Q. Do you know how it came to be that
24 you were selected to be on that committee?

1 A. No, I do not.

2 Q. Did you apply to be on that
3 committee?

4 A. No. I usually don't volunteer for
5 things. (Laugh).

6 Q. Understood.

7 It sounds like you were selected to
8 serve on that committee then?

9 A. Somebody asked me, I don't remember
10 who, and I thought it was a worthwhile activity at
11 the time and so I said sure.

12 Q. Okay. Do you recall any of the
13 members of -- the other members that served on the
14 Groundwater Modeling Assessment Committee?

15 A. I do.

16 Q. Who? Who were they?

17 A. Frank Schwartz was the chairman of
18 the committee. He is a professor at Ohio State
19 University. You know, I've known him off and on
20 for many years. Jim Mercer was on that committee.
21 Jim was one of the founders of a company called
22 GeoTrans. I was more or less personal friends
23 with Jim Mercer. He -- his company -- he used to
24 work for the USGS. Formed his own company around

1 1980. That company was later bought by Tetra
2 Tech, a larger consulting company.

3 I believe Charlie Andrews from
4 Papadopoulos & Associates was on this committee.
5 I've known Charlie off and on, you know, over the
6 years, at least since this time.

7 Just off the top of my head I can't
8 think. I know there were other people on the
9 committee, but I can't recall who.

10 Q. Sure.

11 Now, you mentioned some of the work
12 you did on that Committee about Ground-Water
13 Modeling Assessment.

14 Do you recall sort of more
15 specifically the nature of that work? Were you --
16 were you evaluating sites? Were you -- or were
17 you discussing sort of modeling as a -- as a
18 science of itself?

19 A. I would say both. I think the
20 report focused mostly on the state of the art of
21 modeling. I do recall there were two or three
22 case histories, site-specific studies that were
23 included in the book of examples to illustrate
24 examples of the application of models to real

1 world complex problems.

2 Q. Do you recall what any of those
3 sites -- three sites were?

4 A. I think one of them was a
5 contaminated site in Ohio. Maybe Dyncam, D-y-n.
6 I'm not positive, but that just sort of just
7 popped in my mind.

8 The other one or two examples I
9 just -- I can't recall at the moment but, you
10 know, if I looked at the book, I would see it but,
11 you know.

12 Q. Do you recall how groundwater
13 modeling was involved for that site in Ohio?

14 A. Since it was a contamination
15 problem, I assume there was a groundwater flow
16 model and a related groundwater transport model, a
17 solute transport model.

18 Q. Do you recall whether you were --
19 what the purpose of the model was for that Ohio
20 site?

21 A. I do not.

22 Q. Do you recall whether it was sort of
23 forward-looking or forecasting or whether it was
24 backwards looking and hindcasting?

1 A. I don't recall.

2 Q. Okay. Do you recall what the models
3 for the other two sites were used for?

4 A. I do not recall.

5 Q. Okay. Fair enough.

6 And then on your CV, from 1989 to
7 1997, it looks like you served on an NRC Committee
8 on Waste Isolation Pilot Plant?

9 A. Yes.

10 Q. Could you tell me about that?

11 A. Sure. The Department of Energy had
12 proposed a site near Carlsbad, New Mexico in thick
13 bedded salt deposits for the disposal of
14 radioactive waste, particularly plutonium waste
15 related to weapons production and, you know,
16 typically these were not high-level wastes in the
17 sense of fuel rods from power plants, which would
18 generate a lot of heat, even in a waste form.

19 These wastes although in a sense
20 were high level -- they were very toxic -- they
21 were not generating heat. It was basically
22 plutonium garbage waste products.

23 Q. Understood.

24 A. Yeah.

1 Q. And was there a component on that
2 committee -- committee that involved groundwater
3 flow or transport modeling?

4 A. Yes, that was one of the big
5 concerns, you know, in assessing the safety of the
6 site, the big concern, could anything escape from
7 the site and what's the likely pathway. And it
8 was deemed that, you know, one of the likely
9 pathways, particularly if the site operated to
10 completion in the future and was sealed and
11 closed, the most likely risk would come from water
12 breaching the repository area and then leaking
13 upwards into an overlying permeable aquifer.

14 And then what would happen to that
15 liquid waste in that aquifer. How fast would it
16 move through the aquifer? How would it spread?
17 What kind of risk did it pose to future humans
18 living downgradient of that?

19 So, you know, one of the focus of
20 the committee was to assess the Department of
21 Energy's safety assessment and so we were, you
22 know, we looked very critically at everything they
23 did in terms of trying to demonstrate safety.

24 This was -- and, again, the Waste

1 Isolation Pilot Plant, to my recollection, it was
2 originally proposed as a pilot plant, which
3 implies that this would be somewhat experimental
4 and, you know, not quite a full operational.

5 But at some point they changed the
6 name to the WIPP site, just the initials, and it
7 was pretty clear this was going to be an
8 operation. It wasn't an experiment. It was -- it
9 was planned to be an operational waste --
10 radioactive waste disposal site for what they call
11 transuranic wastes.

12 Q. Understood.

13 And it sounds like you were using
14 groundwater modeling, and you may have mentioned
15 transport modeling, but in this context, you were
16 using it for sort of management or planning
17 purposes, for purposes of?

18 A. Safety I'd say the overriding
19 purpose. There was groundwater flow modeling
20 involved. There was solute transport modeling
21 involved and the overall framework for that and,
22 again, this was just one aspect of many for this
23 committee.

24 Q. Sure.

1 A. The groundwater was just one aspect.
2 There were many things and many other experts
3 involved from other disciplines, but the
4 groundwater flow and transport was really based on
5 a safety assessment. And they were expected to
6 demonstrate safety of the site for 10,000 years
7 into the future.

8 Q. Understood.

9 On this Waste Isolation Pilot Plant
10 Committee, was there -- did you do any modeling
11 work that you would describe as hindcasting or
12 historical reconstruction?

13 A. No.

14 Q. On any of the three NRC committees
15 or panels that you served on, the ones that we've
16 just discussed, have you -- did you do any work
17 model -- modeling work attempting to estimate
18 exposure concentrations for purposes of -- excuse
19 me -- let me -- strike that. Let me -- let me ask
20 that again.

21 On any of these three NRC committees
22 that we've just discussed, did you do any modeling
23 work that was aimed at aiming -- aimed at
24 estimating contaminant concentrations to be used

1 for making exposure determinations on individuals?

2 A. Yes.

3 Q. Which one?

4 A. The WIPP site. The WIPP committee.
5 I didn't personally do those, but one of the
6 things that was done by DOE and evaluated by our
7 committee was potential doses to future humans,
8 farmers, living somewhere downgradient from the
9 site that might be exposed. You know, they might
10 have a well, and what if they or their cows drank
11 water from an aquifer after contaminants passed
12 by.

13 So -- so the answer is yes, that
14 kind of, the dose and the exposure and the
15 consequences had been considered and assessed, but
16 I was not personally involved in any of those
17 calculations, estimations, or assessments.

18 Q. Okay. And that was looking into the
19 future; correct?

20 A. It was looking into, I guess we
21 could say, a hypothetical future.

22 Q. Got you.

23 And I apologize if I asked you this.

24 What was your role specifically on

1 that committee, the WIPP committee?

2 A. Well, I mean, everyone on the
3 committee had, in a sense, an equal role to
4 contribute towards the goals of the committee and
5 assess presentations made to the committee by DOE
6 and their contractors related to the site. So we
7 were, you know, free and open to question anything
8 on any topic if we had questions about it.

9 But, you know, I focused on
10 groundwater flow and transport modeling, but I
11 also looked at their human intrusion scenarios and
12 the risk assessments that they made and, you know,
13 basically anything related to the WIPP site,
14 particularly anything that would have a geological
15 or hydrological connection was a primary interest,
16 but I looked at other things also.

17 Q. Sure.

18 Were you selected to serve on the
19 WIPP committee -- the WIPP site committee?

20 A. I must have been.

21 Q. Okay. In other words, did you
22 volunteer to join that committee, or did someone
23 ask you to join that committee?

24 A. Someone asked.

1 Q. Okay.

2 A. Yeah.

3 Q. Do you recall any of the other
4 members of that committee, the Waste Isolation
5 Pilot Plant, which we've been referring to as
6 WIPP?

7 A. Yeah. When I started on it, there
8 was a professor from Stanford named Konrad
9 Krauskopf, I think it is, who is a geochemist. He
10 was the chairman of the committee when I first
11 came on.

12 John Bredehoeft, a hydrogeologist
13 also worked with the USGS, at least I think at the
14 early part of that time. He retired somewhere
15 around 1990 or so from the Survey. He was on the
16 committee when I first entered, but he had stepped
17 off by the time, you know, before I ended my
18 participation.

19 A geochemist geologist named Rod
20 Ewing was on the committee. An engineer named
21 Chris Whipple was on the committee. You know, I'd
22 have to take another look.

23 Oh, John Garrick, who was an expert
24 in risk assessment was on the committee. There

1 were, you know, five or six other people on the
2 committee that I can't recall their names at the
3 moment.

4 Q. Fair enough.

5 You mentioned undertaking a review
6 of DOE's waste disposal plan on that committee;
7 right?

8 A. Of the Waste Isolation Pilot Plant,
9 yes.

10 Q. Oh, I'm sorry. Of the Waste
11 Isolation Pilot Plant?

12 A. Yes, that was the focus of the
13 committee.

14 Q. How thorough was that review?

15 MR. DEAN: Object to the form.

16 THE WITNESS: Well, you know,
17 I think it was a pretty detailed,
18 in-depth review. You know, I would say
19 always questioning what was presented to
20 the committee, looking to delve a little
21 deeper but, you know, the committee did
22 not, you know, reproduce or test or look
23 at every detail of what was presented to
24 us.

1 It just didn't have the time
2 to do that, but we had, you know, 10 to
3 12 experts in topics ranging from nuclear
4 physics to materials science, risk
5 assessment, probabilistic analyses,
6 hydrogeology, and so on, and so each
7 person tended to ask some pretty
8 thoughtful questions about areas within
9 their expertise.

10 I think there was one
11 expert -- I can't remember his name -- on
12 trains, railroads because it had been
13 proposed that the radioactive waste would
14 be transported by rail to the site.

15 So they got a committee member
16 who was an expert on safety of railroad
17 transportation, and so after a short
18 while they decided they were not going to
19 transport it by rail. So, you know, that
20 was -- but that's an example of the type
21 of expertise that was on the committee.

22 BY MR. ANWAR:

23 Q. Understood. Thank you.

24 Now, these were all NRC committees;

1 correct?

2 A. That was the National Research
3 Council. Sometimes NRC is confused with the
4 Nuclear Regulatory Commission --

5 Q. Okay.

6 A. -- which is also called the NRC.

7 Q. (Laugh).

8 A. But no, this was all National
9 Research Council, which, as best as I understand
10 it, is an arm of the National Academy of Sciences.

11 Q. Okay. And you anticipated my
12 question.

13 I was going to ask you: What is the
14 National Research Council?

15 A. Okay. I'm not sure exactly, but my
16 impression is it is somehow under the realm of the
17 National Academy of Sciences.

18 Q. Do you have any understanding about
19 the national research's -- National Research
20 Council's reputation?

21 A. Well, you know, I think their
22 reports are generally well-respected. It probably
23 varies from report to report, and that probably
24 varies from who the particular experts are on the

1 particular committee were. But if -- if, you
2 know, you want a general report, I think the
3 reports are considered -- for what they do,
4 they're considered to be, you know, reasonable,
5 reliable and, you know, frequently cited.

6 Q. Generally speaking, would you agree
7 that the NRC is considered a reputable and a
8 prestigious organization?

9 MR. DEAN: Object to the form
10 of the question.

11 THE WITNESS: I, you know, I
12 would say it depends on the particular
13 committee but, you know, in general, I
14 think their -- their reports or the books
15 they produce are, you know, considered to
16 be well thought out and reproduced, you
17 know.

18 You know, there's always
19 particular issues that many people might
20 disagree with but, you know, a broad
21 perspective, yes, they are respected.

22 BY MR. ANWAR:

23 Q. Okay. And you mentioned that the
24 National Research Council is part of the

1 national -- or an arm of the National Academy of
2 Sciences; correct?

3 A. Yes. I don't understand perfectly
4 what the relation is, but all I know is they
5 somehow fall under the National Academy of
6 Sciences.

7 Q. What is the National Academy of
8 Science?

9 A. Basically, there are three
10 organizations under that umbrella. One is the
11 National Academy of Sciences, one is the National
12 Academy of Engineering, and one is the National
13 Academy of Medicine and some other word, which I
14 can't remember.

15 So there's like three subspecialty
16 areas and three actually they're considered
17 separate institutes or academies that fall under
18 the national -- it's called the National Academies
19 of Science, Engineering, and Medicine Sciences,
20 something like that.

21 So it, you know, encompasses those
22 three areas and it's a -- my understanding is a
23 nongovernmental organization. Although a lot of
24 their funding comes from government agencies, but

1 I think -- and I may not have this completely
2 accurate, but my impression is they're
3 independent, standalone. They don't fall under
4 any federal agency.

5 Q. The National Academy of Science,
6 isn't it made up of scholars elected by their
7 peers?

8 MR. DEAN: Object to the form
9 of the question.

10 BY MR. ANWAR:

11 Q. You can answer.

12 A. In terms of members, they are
13 elected by existing members is my understanding.

14 Q. Is being elected as a member to the
15 National Academy of Science generally considered
16 to be an honor?

17 MR. DEAN: Object to the form
18 of the question.

19 THE WITNESS: I think so,
20 yes.

21 BY MR. ANWAR:

22 Q. And what is your understanding of
23 the National Academy of Science's reputation?

24 A. My impression is that it has a good

1 reputation. You know, I personally am -- I was
2 elected to membership in the National Academy of
3 Engineering in 2015, and I considered that a high
4 honor.

5 Q. I was going to ask. I was going
6 to -- you've been anticipating my question.

7 A. Sorry.

8 Q. I've heard membership in the
9 National Academy of Science to be considered one
10 of the highest honors a scientist can receive a
11 U.S. scientist.

12 It sounds like you agree with that?

13 A. Basically, yeah. Yes. Yeah.

14 Q. Now, on page 1 of your CV, under
15 Honors and Awards, you have there in bullet
16 points -- in bullet point sort of the last item
17 bolded among all of the items, "Elected to
18 National Academy of Engineering (2015)" --

19 A. Yes.

20 Q. -- correct?

21 A. Correct.

22 Q. Okay. What -- what is the National
23 Academy of Engineering?

24 A. It's one of the three divisions of

1 the National Academy. It's really the National
2 Academies.

3 Q. And why did you list it in bold
4 under a section of your CV entitled "Honors and
5 Awards"?

6 A. I wanted to make sure that it was
7 noticed. (Laugh).

8 Q. Sure.

9 A. I consider it an honor. All the
10 other things listed are honors, but I felt that
11 this was probably, among all of those, the highest
12 honor that I had.

13 Q. Okay. And you list NAE next to the
14 PhD in your name; correct?

15 A. Yeah. Yes. That indicates I'm a
16 member of the National Academy of Engineering.

17 Q. And reflecting the fact that you
18 consider it to be one of the highest honors that
19 you've received; correct?

20 A. Correct.

21 Q. Okay. Now, I wanted to talk to you
22 a little bit more about sort of the scope of your
23 expertise.

24 Earlier we discussed that you would

1 consider yourself a hydrogeologist with expertise
2 in groundwater flow modeling and solute, I think,
3 transport modeling; correct?

4 A. Yes.

5 Q. Okay. And if I understood you
6 correctly, there were -- there were no other areas
7 that you consider yourself an expert in; correct?

8 A. Yeah, I mean, I have some skills in
9 other areas and certainly understandings, but that
10 what you just said is, you know, where I consider
11 my main skills and interests.

12 Q. Okay. And so this is perhaps a bit
13 obvious, so forgive me, but you're not an
14 epidemiologist; correct?

15 A. Correct.

16 Q. You're not a toxicologist?

17 A. Correct.

18 Q. The findings of epidemiology, those
19 aren't within your area of expertise; correct?

20 A. Correct.

21 Q. And that includes the epidemiologic
22 studies or epidemiological studies performed
23 related to Camp Lejeune; correct?

24 A. Correct.

1 Q. You're not an expert on whether a
2 contaminant can cause a disease; correct?

3 A. I'm not an expert on that, no.

4 Q. And you're not an expert on the
5 amount of exposure to a contaminant that can cause
6 a disease; correct?

7 A. That's correct.

8 Q. Okay. Your report sort of in
9 passing or it references MC -- MCL in a few
10 places.

11 What is your understanding of an
12 MCL?

13 A. My understanding is that it stands
14 for maximum contaminant level, and I believe it's
15 a level set by the U.S. Environmental Protection
16 Agency, and it reflects their consideration that
17 any level higher than the MCL creates an undue
18 risk to anyone drinking water with concentrations
19 exceeding that. So it's a level that should not
20 be exceeded in any public water supply.

21 Q. Understood.

22 Have you ever been involved in
23 setting an MCL?

24 A. No.

1 Q. Okay. You're not aware of the
2 methodology that the EPA uses to establish an MCL,
3 are you?

4 A. No.

5 Q. Okay. And you're not aware of how
6 MCLs are set related to health risks; correct?

7 A. No, I'm not.

8 Q. You're not aware; correct?

9 A. Correct, not aware.

10 Q. Okay. Are you aware of whether an
11 exposure above an MCL presents a health risk?

12 A. My general impression is that
13 it's -- the MCL is set to distinguish between what
14 is reasonably safe and what poses a health risk.
15 So anything above it, I would assume, reflects
16 some undue risk.

17 Q. What is that based on? I guess what
18 is your -- that assumption based on?

19 A. It's based on my understanding of
20 why an MCL would be set for particular chemicals
21 by the EPA.

22 Q. Okay. But you haven't ever been
23 involved in setting an MCL yourself and you're not
24 aware of the methodology they use; correct?

1 A. Correct.

2 Q. Okay. Are you aware that for
3 certain chemicals MCLs are set as close to zero as
4 technically feasible?

5 A. No, I'm not aware.

6 Q. Okay. Now, your -- your rebuttal
7 report indicates that you're being paid \$400 an
8 hour for your opinion for your work in this case;
9 correct?

10 A. That's as of January 1st. In 2024 I
11 was charging a lower rate.

12 Q. Okay. What were you charging in
13 2024?

14 A. \$275 an hour.

15 MR. ANWAR: Okay. I'm going
16 to hand you two documents. I'm going to
17 hand to the court reporter to hand you.

18 (Document marked for
19 identification as Konikow Exhibit 5.)

20 (Document marked for
21 identification as Konikow Exhibit 6.)

22 BY MR. ANWAR:

23 Q. I will represent to you that --
24 well, so I've handed you documents that I've

1 marked as Exhibits 5 and 6. These are copies of
2 bills that -- billing records that were produced
3 to us by your counsel last night.

4 Are these true and accurate copies
5 of invoices that you've submitted to the lawyers
6 for time that you've worked on this case?

7 A. Yes.

8 Q. Okay. And so on Exhibit 5, it says
9 on the first page dates of service October 9, 2024
10 to October 21, 2024, that your hourly rate was
11 275, that you worked 19.75 hours, and that the
12 total amount that you charged was \$5,431.25;
13 correct?

14 A. Yes.

15 Q. Okay. And then the next invoice is
16 dated -- Exhibit 6 is dated, dates of service
17 December 12, 2020 -- excuse me -- December 11,
18 2024 to December 31, 2024 with an hour -- hourly
19 rate of 275 per hour, total hours 63.58 for a
20 total amount due of \$17,484.50; correct?

21 A. Correct.

22 Q. Okay. Have you issued any bills for
23 work performed in January yet?

24 A. Not yet. I hope to get to that

1 soon.

2 Q. Okay. Do you have any idea of the
3 total number of hours or the amount of the invoice
4 that you intend to submit for January?

5 A. Let's see. I would guess it's on
6 the order of 100 hours. I have a record of it at
7 home, but I -- I never added it up because I
8 haven't produced the, you know, I haven't gotten a
9 chance to prepare an invoice for January yet. I
10 hope to do that later this week.

11 Q. Okay. When you complete that
12 invoice and issue it to your lawyers, we would
13 request that a copy of that invoice be produced.

14 Is that okay with you?

15 MR. DEAN: No objection.

16 BY MR. ANWAR:

17 Q. And then you mentioned in 2025 your
18 hourly rate has increased to \$400 an hour --

19 A. Yes.

20 Q. -- correct?

21 A. Correct.

22 Q. Have you received any compensation
23 related to Camp Lejeune outside of your paid work
24 as -- currently as a -- as an expert in this

1 litigation?

2 A. No.

3 Q. And I understand that you served on
4 the two ATSDR expert panels on the water modeling;
5 correct?

6 A. Correct.

7 Q. And based on the documents that were
8 produced last night, at that time it looks like
9 you were -- you were with the U.S. Geological
10 Service; correct?

11 A. Survey. Yes.

12 Q. Survey. Excuse me.

13 A. Yeah.

14 Q. And based on the documents that were
15 produced to us last night, it looks like for your
16 participation on the ATSDR expert panels, the U.S.
17 Geological Survey entered into a contract with
18 ATSDR; is that right?

19 A. Yes.

20 Q. Okay. Did you receive any
21 compensation individually for your participation
22 in the expert panels?

23 A. No.

24 Q. Just your salary as a government

1 employee?

2 A. Just I -- yeah, my only compensation
3 was as an employee of the U.S. Geological Survey
4 and, you know, that -- that was it. The contract
5 was between the USGS and ATSDR and I presume to
6 compensate the Survey for my time.

7 Q. Okay. And based on the information
8 we received or the documents that were produced
9 last night, it looks like you were retained as an
10 expert witness in -- for this litigation in
11 October of 2024; is that right?

12 A. That's correct.

13 Q. Okay. And same, based -- based on
14 the e-mails that were produced to us last night,
15 it looks like it was Morris Maslia that put you in
16 touch with Mr. Dean; is that right?

17 A. That is right.

18 Q. Okay. How did you come to the
19 decision to serve as an expert witness for the
20 plaintiffs in this litigation?

21 A. Well, Mr. Dean had contacted me,
22 explained the -- what he was seeking, that he
23 wanted me to serve, you know, to review some
24 documents. I was hesitant because I'm retired,

1 but he explained the problem, and I had certainly
2 some familiarity with Camp Lejeune and the problem
3 because of my service on those two expert panels.

4 So I maintained an interest in it.
5 I thought it was an important issue, an
6 interesting problem from many perspectives, but it
7 was, you know, an interesting use of groundwater
8 modeling and transport modeling. And in spite of
9 being retired, I decided, okay, since this would
10 not be a full-time activity for me, I could take
11 this on.

12 Q. Understood.

13 A. You know, plus I would be
14 compensated at a, you know, what I thought was a
15 reasonable rate.

16 Q. Understood.

17 Now, it was Morris Maslia that
18 introduced you to Mr. Dean; correct?

19 A. He had contacted me and asked if it
20 was okay for him to give my contact information to
21 a lawyer.

22 Q. Okay.

23 A. I don't recall that he mentioned
24 Mr. Dean's name at the time, but he may have. I

1 don't know.

2 Q. Okay. How do you know Morris
3 Maslia?

4 A. I've known him for many years. He
5 used to work for the U.S. Geological Survey. I
6 believe he was an attendee at a training class for
7 which I was an instructor.

8 The USGS had a fairly extensive
9 training program. We have a National Training
10 Center in Lakewood, Colorado just outside Denver,
11 and I used to be involved as one of the
12 instructors and for a couple of years as the
13 coordinator for a class on solute transport
14 modeling. And I believe Morris sometime way back
15 was a student in that class, and that's probably
16 the first time I met him.

17 Q. Okay. Around what time frame would
18 that have been when you first met him?

19 A. It -- it was either the late '70s or
20 early '80s is what I gather or what I would guess
21 or estimate, but I don't recall specifically. I
22 would have to look up attendee lists and things
23 like that, which I may or may not even have.
24 But -- so it was probably in the late '70s to

1 early '80s, and then I knew at some point he
2 resigned from the Survey and went to work with
3 ATSDR.

4 Q. Okay. Have you worked with
5 Mr. Maslia on any projects other than the ones at
6 ATSDR related to Camp Lejeune?

7 A. Not that I could recall.

8 Q. Do you think of Mr. Maslia as a
9 professional colleague?

10 A. Yes.

11 Q. Do you consider him a friend?

12 A. In a general sort of way, yes. I
13 mean, we -- we've never socialized, but yeah, I
14 consider him a professional friend.

15 Q. And earlier we discussed the meeting
16 held last week in South Carolina, the two-day
17 meeting, and Mr. Maslia was in attendance;
18 correct?

19 A. Correct.

20 Q. Prior to your involvement in this
21 litigation, prior to your retention in October of
22 2024, when was the last time you had spoken with
23 Mr. Maslia?

24 A. It was several years before that. I

1 can't remember exactly when. We had some e-mail
2 communications. Actually speaking with him, I
3 don't recall the last time we actually spoke in a
4 phone call or anything like that. That's probably
5 quite a while, but we did occasionally have e-mail
6 communications.

7 Q. Understood.

8 Have you ever served as an expert
9 witness in any other litigation?

10 A. No.

11 Q. You mentioned at the beginning of
12 your deposition that you've -- you've been deposed
13 one other time.

14 A. Yeah.

15 Q. Can you describe for me the
16 circumstance of, how did that deposition come
17 about?

18 A. I had done early in my career a lot
19 of work on the Rocky Mountain Arsenal in Colorado
20 where there was pervasive groundwater
21 contamination. Some of the contaminants had
22 migrated beyond the boundaries and affected
23 agricultural lands and farmers north of the
24 arsenal.

1 I had worked on a project to develop
2 a groundwater flow and solute transport model of
3 that area of the whole problem. I probably worked
4 at least two years full time on that project.

5 Can you remind me what the question
6 was again?

7 Q. Sure.

8 A. (Laugh). I strayed off.

9 Q. Why were you deposed in the context
10 of that work?

11 A. Right. So several years after I had
12 completed my work on the Rocky Mountain -- excuse
13 me.

14 Several years later there, the
15 Superfund law was passed and -- and, you know,
16 things happened. During the time that I was
17 working on the, Shell Chemical Company had been
18 a -- had leased facilities on the Rocky Mountain
19 Arsenal and operated those facilities. I believe
20 their primary activity was manufacturing
21 pesticides and herbicides, as I recall.

22 Somewhere years, you know, after I
23 had finished my work, EPA or the government was, I
24 believe, suing Shell Chemical for having generated

1 the waste.

2 The Department of Justice and some
3 lawyers, I mean, they knew I had done work there.
4 So the DOJ sent people to my office to review
5 everything that I had, I mean, everything in my
6 files, related to the Rocky Mountain Arsenal. And
7 sometime after that, they asked me -- well, either
8 asked or told me -- that they wanted to depose me
9 to give a deposition.

10 Q. So you were deposed in that instance
11 as what we -- I guess the lawyers would describe
12 as a fact witness; right? You weren't -- you
13 weren't hired as an expert in?

14 A. I was not hired in any way and to
15 the best of my -- I don't remember the term a
16 "fact witness," but that seems to be a good
17 description of what I was.

18 Q. You were deposed about your
19 knowledge of the events that had taken place;
20 correct?

21 A. Correct.

22 Q. Okay. Now, you submitted your --
23 your expert rebuttal report in this case in
24 response to the reports of DOJ's -- Department of

1 Justice's experts; correct?

2 A. Two experts, correct.

3 Q. And one of those experts is Dr. Alex
4 Spiliotopoulos; correct?

5 A. Yes.

6 Q. And the other expert is Dr. Remy
7 Hennet; correct?

8 A. Correct.

9 Q. Okay. Do you know Dr. Alex
10 Spiliotopoulos?

11 A. Casually. Yes, I do.

12 Q. How do you know him?

13 A. Well, he works for Papadopoulos &
14 Associates. I believe he attended some of the
15 meetings for the expert peer review panels for
16 ATSDR. I've probably seen him occasionally when
17 I've interacted with Papadopoulos & Associates.

18 Q. Sure.

19 Do you know Remy Hennet?

20 A. Yes.

21 Q. How do you know Remy?

22 A. I've met him at a -- probably at
23 least twice at social events, dinner parties that
24 we were both invited to.

1 Q. Okay. Have you ever worked with
2 either Dr. Hennet or Dr. Spiliotopoulos?

3 A. No.

4 Q. Do you know a Gordon Bennett?

5 A. Yes.

6 Q. Okay. And Gordon Bennett, my
7 understanding is he worked at USGS for many years,
8 and is that right?

9 A. Yes.

10 Q. Okay. And then my understanding is
11 then he went on to become a principal at
12 Papadopoulos.

13 Is that consistent with your
14 understanding?

15 A. After he retired from the USGS, he
16 went to work for one consulting company, I believe
17 in Alexandria, but was not there very long, maybe
18 a year or less than a year. And then after that,
19 my understanding is he went to work for
20 Papadopoulos & Associates and worked for them at
21 least 10 years before fully retiring. I don't
22 know if he was a principal or what, but he was an
23 employee certainly.

24 Q. Sure. Okay.

1 And is it right, my understanding is
2 Gordon Bennett is considered the father of
3 MODFLOW?

4 A. Ooh. He played an administrative
5 role in getting it going. I would not have called
6 him the father of MODFLOW.

7 Q. Okay.

8 A. He played a role in getting that
9 done in terms of -- I believe he had a big role in
10 hiring the two people or designating the two
11 people, Harbaugh and McDonald, to work on this,
12 and I think administratively he pushed for this to
13 be a project to get this done. So.

14 Q. So he --

15 A. But I don't believe he actually
16 worked on the development of the code.

17 Q. Understood.

18 Are you generally familiar with SS
19 Papadopoulos & Associates?

20 A. In general, yeah.

21 Q. Okay. Do you have any opinion about
22 S.S. -- S.S. Papadopoulos & Associates?

23 MR. DEAN: Object to the form.

24 THE WITNESS: Well, I know

1 several individuals there, including
2 Stavros Papadopoulos. Most of the people
3 working there I do not know. I don't.
4 So I can't have any opinion about them or
5 their work.

6 Stavros used to work for the
7 Survey -- USGS for quite a while. He
8 left, I believe, in '79 or '80 to form
9 his own company as a consultant.

10 BY MR. ANWAR:

11 Q. Within the environmental, you know,
12 based on your experience, within the environmental
13 sort of consulting and, I guess, modeling
14 consulting community, is S.S. Papadopoulos from
15 your understanding generally considered a good
16 firm?

17 MR. DEAN: Object to the form
18 of the question. Asked and answered.

19 THE WITNESS: Well, again, I
20 think, you know, some of the people there
21 have good reputations and some of the
22 people there I don't know their
23 reputation. Most of the people there I
24 don't know anything about them.

1 BY MR. ANWAR:

2 Q. Okay.

3 A. So it's difficult to -- to say.

4 Q. Are you familiar with John Doherty?

5 A. Oh, John Doherty from Australia?

6 Q. Correct.

7 A. Yeah, I know the name. I've met him
8 certainly at professional meetings. I remember at
9 least one case at a National Ground Water
10 Association meeting where he was a guest speaker.
11 So, you know, said hello, interacted socially. I
12 know who he is, and I know, you know, kind of what
13 he's done in terms of developing the parameter
14 estimation code called PEST.

15 Q. Can you talk a little bit about
16 that, what he's done in terms of developing PEST?

17 MR. DEAN: Object to the form
18 of the question.

19 THE WITNESS: Well, I know
20 he's the principal author of the software
21 and a book that describes it. How he did
22 it I have no idea or, you know, what he
23 did specifically I have no understanding.
24 I don't know.

1 The PEST code, I know what it
2 does and I know it's -- it's generally
3 considered a state of the art software
4 tool --

5 BY MR. ANWAR:

6 Q. Understood.

7 A. -- that could be applied for ground
8 -- excuse me -- could be applied to groundwater
9 modeling problems. It's a general code that can
10 probably be applied to any modeling problem, not
11 just groundwater.

12 Q. Were you aware that John Doherty
13 also now works with S.S. Papadopoulos?

14 A. That he what?

15 Q. That he's also at S.S. Papadopoulos?

16 A. I'm not sure what you -- could you
17 repeat the question? That he was at?

18 Q. That John Doherty is now at S.S.
19 Papadopoulos?

20 A. I did not know that.

21 Q. Okay.

22 A. That he was. I knew there was some
23 linkage there and I know he had been at their
24 offices, but being -- I had no idea he worked for

1 the firm as an employee.

2 Q. Okay. And I think I might have
3 misspoke. I think you're perhaps right.

4 He used to be at S.S. Papadopoulos;
5 correct?

6 A. I don't know that.

7 MR. DEAN: Object to the form.

8 BY MR. ANWAR:

9 Q. You don't know.
10 You said --

11 A. I know he was at the -- in their
12 office.

13 Q. Okay.

14 A. I don't know what you mean by "at"
15 Papadopoulos & Associates.

16 Q. Okay. You said he used to be linked
17 to it.

18 What do you --

19 A. I know he visited there and, you
20 know, I know he -- it's my understanding or
21 recollection that he taught a short course for
22 them on the use of that, and I think he
23 collaborates or has collaborated with Matt Tonkin,
24 who is an employee of Papadopoulos & Associates,

1 but I have no direct knowledge of what they did or
2 how they did it.

3 Q. Okay. Aside from responding to
4 their opinions in this case, do you have any
5 opinion about Dr. Spiliotopoulos or Dr. Hennet?

6 A. No.

7 Q. Why don't we take a break. I think
8 this is a good place --

9 A. Good idea.

10 Q. -- to take a break. We've been
11 going over an hour.

12 THE VIDEOGRAPHER: We're going
13 off the record. The time is 11:06 AM.

14 (A recess was taken.)

15 THE VIDEOGRAPHER: Back on the
16 record the time is 11:15 AM.

17 BY MR. ANWAR:

18 Q. We are back on the record from a
19 short break.

20 Dr. Konikow, are you okay to
21 continue?

22 A. Yes.

23 Q. Okay. During the break, did you
24 speak with your -- your lawyers about the

1 substance of your testimony at all?

2 A. No.

3 Q. Okay. Before the break, we had just
4 wrapped up a conversation about John Doherty.

5 Do you recall that?

6 A. Yes.

7 Q. One other question occurred to me
8 that I wanted to ask.

9 I noticed in the documents that were
10 produced last night in response to the subpoena,
11 there was a document where you passed along
12 Doherty's -- John Doherty's contact information to
13 Mr. Dean.

14 Do you recall that?

15 A. Yes.

16 Q. Do you know, what is your
17 understanding about why you passed that contact
18 information along?

19 A. Well, I believe he asked me if I had
20 contact information --

21 Q. Okay.

22 A. -- for John Doherty, and I had some
23 information and so, you know, I sent it to him.

24 Q. Okay. Do you know what came of

1 that?

2 A. No.

3 Q. Okay. Have you -- when is the last
4 time you've spoken with Mr. Doherty?

5 A. Several years ago. Probably four or
6 five years ago.

7 Q. Okay. Understood.

8 A. Yeah.

9 Q. Now, we discussed earlier you served
10 on ATSDR's expert panel on the Camp Lejeune water
11 modeling; correct?

12 A. Correct.

13 Q. Okay. And there was an expert panel
14 in 2005; correct?

15 A. Correct.

16 Q. How did you come to serve on the
17 2005 expert panel?

18 A. Somebody asked me, and I would -- I
19 would guess that it was probably Morris asked if
20 I'd be interested in doing that. I don't recall
21 exactly who or when I was asked or how I was
22 asked, but I would guess it was probably Morris.

23 THE VIDEOGRAPHER: Counsel,
24 could you please put on your mic?

1 BY MR. ANWAR:

2 Q. What do you remember about the 2005
3 expert panel?

4 A. I remember they -- I think they had
5 asked us some questions in advance before meeting,
6 maybe four to six questions to get our preliminary
7 opinions. I think they had sent us some documents
8 or draft reports to review to prepare for it.

9 I remember, you know, going to
10 Atlanta. There were two days of meetings. There
11 were, you know, a fair number of people in the
12 audience, maybe -- I don't know -- 10 to 20 at
13 different times, maybe a few more.

14 I think there were probably
15 something on the order of 10 people on the expert
16 panel. May have been 12. I don't recall exactly.
17 We had meetings. We had presentations made to us
18 about what was expected of the committee.

19 And then we had technical
20 presentations from people such as Morris, Bob Faye
21 and others about the background of the situation,
22 the hydrogeologic framework, the groundwater flow
23 systems, the contaminant sources, and basically
24 everything related to that.

1 So there were technical
2 presentations. The committee members asked
3 questions. I think towards the end we met in a
4 closed session, and I believe we came to a
5 consensus of our assessments.

6 I can't recall specifically what
7 follow-up, if any, was done after the second day
8 of the meeting.

9 Q. Thank you. That's helpful.

10 Do you recall what draft documents
11 you were provided to review in advance?

12 A. I do not recall which ones, but
13 I -- I'm -- I would guess it was preliminary
14 versions of some of the reports that were
15 eventually published, but I don't recall.

16 Q. What did you understand about the
17 purpose of the ATSDR water modeling for Camp
18 Lejeune heading into the 2005 expert panel?

19 A. Well, my understanding I believe
20 then was similar to my understanding now that the
21 purpose of the modeling was to estimate what the
22 concentrations were coming out of the Water
23 Treatment Plant and going into the distribution
24 system.

1 Q. And that was in support of a
2 population level epidemiology study; right?

3 A. I knew there were epidemiological
4 studies that would be done and that, I presume,
5 would use the information from the -- from the
6 models. I have no knowledge of any of the
7 epidemiological studies, how they were done or
8 what the results were. I don't have that
9 information.

10 Q. Sure.

11 And that 2005 expert panel, that
12 took place over two days in March 2005; right?

13 A. I presume so. That sounds about
14 right.

15 And, again, the other thing I
16 believe is that it focused on the Tarawa Terrace
17 situation.

18 Q. Okay. And you said it took place in
19 Atlanta.

20 Did it take place at ATSDR's
21 facilities?

22 A. That's my recollection. That we
23 went into a CDC campus, and they brought us over
24 to an ATSDR facility, I think, but I don't recall.

1 I remember there was a gate, and we had to go in
2 and get, you know, approved to go into the
3 facility and then were directed somewhere, but I
4 don't remember those, any more details than that.

5 Q. Sure.

6 You mentioned Morris Maslia and then
7 Robert Faye, or Bob Faye.

8 Who is Bob Faye?

9 A. Bob Faye? He's a person who, when I
10 first met him, he worked for the U.S. Geological
11 Survey. I believe his position was as a regional
12 groundwater specialist, and at the time the Water
13 Resources Division of the U.S. Geological Survey
14 was divided into four regional offices.

15 The Southeast Region was
16 headquartered in Atlanta, and my recollection is
17 that for that regional office, Bob Faye was
18 considered the -- or had the position of being the
19 regional groundwater specialist.

20 So reports or any other issues
21 dealing with groundwater that came up in any of
22 the district offices in the Southeast Region, if
23 there was some issues, Bob Faye would be the
24 regional groundwater specialist is the one who

1 would assess, comment on, evaluate any problems or
2 issues.

3 Q. Understood.

4 Do you remember who any of the other
5 members of the expert panel were? The 2005.

6 A. The 2005 panel.

7 I, you know, I looked at the list of
8 members probably a week or two ago, but I
9 just -- I can't remember who was on the 2005
10 panel.

11 Q. That's okay. Fair enough. Thank
12 you.

13 You were an expert on the 2005
14 expert panel; correct?

15 A. Correct.

16 Q. Now, you mentioned it was focused on
17 ATSDR's water modeling efforts -- the 2005 panel
18 was focused on ATSDR's water modeling efforts
19 related to Tarawa Terrace; correct?

20 A. That's my understanding, yes.

21 Q. Do you recall whether there was any
22 discussion about the Hadnot Point/Holcomb
23 Boulevard modeling at that time?

24 A. Of the modeling? I doubt it, but of

1 the existence of Hadnot Point/Holcomb Boulevard,
2 I'm sure that was mentioned.

3 Q. Did you provide feedback or input
4 about the -- about ATSDR's water modeling efforts
5 related to Tarawa Terrace in 2005?

6 A. I'm sure I did.

7 Q. Do you recall what that feedback or
8 input was?

9 A. Well, specific explicit comments I
10 can't recall. I recall, you know, the -- you
11 know, I'm sure I had questions about parameter
12 values and how they did this or why they did it
13 this way. I'm sure there was a lot of questions,
14 comments and, you know, issues.

15 I know the bottom line at the end,
16 the expert peer review panel felt very positive
17 about what they were doing in the sense that I
18 think the consensus of the expert peer review
19 panel was that the work being done by ATSDR for
20 groundwater modeling flow and transport was state
21 of the art and excellent work, reliable work.

22 Q. Okay. Were there any concerns
23 expressed at the 2005 expert panel?

24 A. I'm sure there were.

1 Q. Why do you say you're sure there
2 were?

3 A. Well, our job was to critique and
4 review everything they done -- did and we would,
5 you know, question, why did you do this? Or where
6 did you get that value from? Or what's the basis
7 of this? Again, I can't recall specific
8 questions. If I thought about it, maybe I could.

9 But I know I had some concerns about
10 numerical dispersion in the transport model, about
11 the representation of model layer 1. You know, I
12 remember these were some of the specific issues
13 that concerned me before I could get any response
14 back from them, but I felt overall that they
15 addressed all of the concerns that I had.

16 Q. Do you recall if any of the other
17 members of the expert panel expressed concerns or
18 critiques about the Tarawa Terrace efforts?

19 A. I can't recall.

20 Q. Okay. Now, you also served on the
21 expert panel held by ATSDR on Camp Lejeune water
22 modeling in 2009; right?

23 A. Correct.

24 Q. Okay. And how did you come to serve

1 on the 2009 expert panel?

2 A. I assume someone asked me to serve
3 on it. I, you know, again, I -- I assume Morris
4 had some role in inviting me, but I don't know
5 that. You know, I just don't recall.

6 Q. Okay. What do you remember about
7 the 2009 expert panel?

8 A. It focused on the Hadnot
9 Point/Holcomb Boulevard areas and the models
10 developed for that area. There probably was some
11 discussion of Tarawa Terrace, but the main focus
12 was on Hadnot Point/Holcomb Boulevard.

13 I remember Mary Hill was on that
14 panel. Dave Dougherty was on that panel. But,
15 again, I looked at the names the other day and I
16 just can't remember right now who else was on it,
17 but, you know, again there were probably 10 to 12
18 experts on the panel.

19 Q. Sure.

20 And that panel took place over two
21 days in 2009?

22 A. Exactly, yes. Correct.

23 Q. Was there a Mr. Jerry Ensminger
24 on -- that participated in that expert panel?

1 A. My recollection that's the name of a
2 Marine who was -- I remember there was one Marine
3 in the audience, and he was given a chance to
4 speak. I believe that's the name that you gave,
5 but I can't -- I'm not absolutely certain.

6 Q. You said he was in the audience and
7 he was given an opportunity to speak?

8 A. That's my recollection.

9 Q. Okay. Mr. Ensminger is not a
10 modeling expert or an epidemiologist, to the best
11 of your knowledge?

12 A. Correct.

13 Q. Was there a Mr. Mike Partain that
14 attended the expert panel as well?

15 A. I don't recall that name.

16 Q. Okay. Did you provide feedback
17 about the Hadnot Point/Holcomb Boulevard modeling
18 efforts at the 2009 expert panel?

19 A. I'm sure I did. That's why I was
20 there.

21 Q. Do you recall the feedback that you
22 provided?

23 A. I know initially I came in with some
24 skepticism, which is, you know, normal in any

1 technical review, and I had some concerns about
2 how well they could define the source terms and
3 the timing. Specific comments I don't recall.

4 Q. Do you recall any comments from
5 other members on the expert panel?

6 A. Not that I -- I do not recall
7 specific comments.

8 THE VIDEOGRAPHER: Counsel, do
9 you need help with your mic?

10 MR. ANWAR: Excuse me?

11 THE VIDEOGRAPHER: Do you need
12 help with your mic?

13 MR. ANWAR: Yeah, I'm fixing
14 it.

15 THE WITNESS: I don't recall
16 specific comments of the other
17 participants off the top of my head.

18 BY MR. ANWAR:

19 Q. Okay. Were there -- do you recall
20 any critiques or concerns about performing the
21 Hadnot Point/Holcomb Boulevard water modeling?

22 A. Well, yeah. I mean, I know I had
23 some concerns but, you know, again I think they
24 addressed my concerns.

1 Q. What were your concerns?

2 A. Well, one of the concerns was
3 compared to Tarawa Terrace where there was
4 believed to be one single source of contamination
5 and its location was pretty well known and the
6 contaminant was pretty well known and the timing
7 of it was pretty well known, looking at the Hadnot
8 Point/Holcomb Boulevard, there seemed to be
9 multiple sources just spread out over the
10 industrial areas and the landfill areas and that
11 they could not be defined with the same precision
12 that the source term on the Tarawa Terrace area
13 could be defined. So this was a concern.

14 Q. Okay. Did you --

15 A. For --

16 Q. Go ahead.

17 A. I was going to add that, you know,
18 for both of them, there was, you know, no
19 observations of concentration for a period of
20 years before the problem became recognized, you
21 know, that's an issue that has to be addressed.

22 Q. Sure.

23 There -- there were observed
24 contamination levels or samples taken in 1982 and

1 1985 at Camp Lejeune; right?

2 A. I believe so, and maybe, you know,
3 in between. There may have been some '83, '84 I
4 believe, but I don't recall the exact dates. But
5 that sounds about right.

6 Q. Okay. And the ATSDR modeling
7 efforts related to Tarawa Terrace and Hadnot Point
8 and Holcomb Boulevard, they were attempting to
9 reconstruct historical contamination levels,
10 monthly contamination levels dating back to 1953;
11 correct?

12 MR. DEAN: Object to the form.

13 THE WITNESS: 1953 for Tarawa
14 Terrace, but I believe earlier for Hadnot
15 Point and Holcomb Boulevard.

16 BY MR. ANWAR:

17 Q. And the earliest available data
18 during that period was 19 -- and when I say
19 "available data" what I'm specifically referring
20 to is observed contaminant concentration levels of
21 sampling data.

22 The earliest data available during
23 that time was 1982; correct?

24 A. Yes, that's the observed, but I also

1 view the assumption at the start of the simulation
2 before there was any as equivalent to an observed
3 level of no contaminant in the aquifer as a known
4 condition. Even though there were no samples that
5 showed it was zero before 1953, that seemed like a
6 pretty reliable and accurate assumption.

7 Q. What is the assumption that you're
8 referring to?

9 A. That you have to -- in developing
10 the model -- and they started with Tarawa Terrace
11 in 1953. To solve any governing partial
12 differential equation, which is what the numerical
13 models do, you have to define boundary conditions
14 and initial conditions.

15 Definition of the initial conditions
16 for the solute transport model are the
17 concentration distribution of the solute of
18 concern at times zero, which would be 1953.

19 And inherently there's an assumption
20 that it was zero before any contaminant was
21 introduced, and that is a very reasonable, logical
22 assessment of the initial condition in terms of
23 what the concentration distribution was at that
24 time, which is zero.

1 Q. Understood.

2 But for the period prior to 1982,
3 there were no historical observed concentration
4 level data; correct?

5 MR. DEAN: Object to the form.

6 THE WITNESS: Not that I'm
7 aware of.

8 BY MR. ANWAR:

9 Q. Besides serving on these two expert
10 panels, the one in 2005 focused on Tarawa Terrace
11 and the one in 2009 more focused on Hadnot
12 Point/Holcomb Boulevard, did you contribute or do
13 any work related to ATSDR's water modeling efforts
14 for Camp Lejeune?

15 A. No.

16 Q. I saw that you're not listed as an
17 author on any of the reports; right?

18 A. Correct.

19 Q. You weren't involved in writing the
20 reports?

21 A. Not at all.

22 Q. And you didn't perform any of the
23 data collection or the field testing; right?

24 A. No, I did not.

1 Q. Okay. Have you ever visited Camp
2 Lejeune?

3 A. No, I have not.

4 Q. And earlier in your deposition I
5 think we discussed that at that time you were --
6 that you served on the -- the two expert panels,
7 you were employed by the U.S. Geological Survey;
8 correct?

9 A. Yes.

10 Q. And so other than your salary as an
11 employee of the U.S. Geological Survey, you were
12 not compensated at all to participate in the --
13 the 2005 or 2009 panels; correct?

14 A. That's correct.

15 MR. ANWAR: Okay. I'm going
16 to mark an exhibit. I'm handing to the
17 court reporter what is being marked as
18 Exhibit 7.

19 (Document marked for
20 identification as Konikow Exhibit 7.)

21 MR. DEAN: Can we agree that
22 this is not the entire book? Just select
23 to.

24 MR. ANWAR: We can agree this

1 is not the entire book.

2 BY MR. ANWAR:

3 Q. I've handed you an exhibit that I've
4 marked as Exhibit 7. This is -- this is an
5 excerpt from a book entitled "The Handbook of
6 Groundwater Engineering"; correct?

7 A. Yes.

8 Q. And you're familiar with this book;
9 right?

10 A. I haven't looked at it in years, but
11 I was a coauthor of that chapter. So yes.

12 Q. Okay. The book itself was published
13 in 1999; right?

14 A. (Reviews document.)

15 It says 19 -- yeah, it says
16 copyright 1999.

17 Q. Okay. And you just mentioned you
18 coauthored that chapter.

19 You coauthored Chapter 20 on
20 "Groundwater Modeling"; right?

21 A. Yes.

22 Q. Okay. And you coauthored it with a
23 gentleman named Thomas E. Reilly?

24 A. Correct.

1 Q. Who is Thomas E. Reilly?

2 A. Tom was a groundwater scientist or
3 engineer that worked with the U.S. Geological
4 Survey. I knew him as a colleague from the USGS.
5 We were in the -- we overlapped in the same office
6 for a while in the -- I think it's called the
7 Office of Groundwater, which was kind of a
8 headquarters quality assurance type of group.

9 Tom moved -- he had worked on Long
10 Island, New York in the Long Island office for
11 many years. Then he moved to Reston to join us
12 headquarters group. Then I left that to join the
13 research program, and several years later Tom did
14 the same thing and was in the research program.
15 We were colleagues there. Then he moved back into
16 the Office of Groundwater after a year or two in
17 the research program.

18 So, you know, we were colleagues,
19 you know, knew each other, and I had invited him
20 to help me prepare this chapter on "Groundwater
21 Modeling." He had more expertise on finite
22 element methods than I did and I thought he was,
23 you know, well-known and well-rounded in
24 groundwater modeling technique. I thought it

1 would be very beneficial to have him as a
2 coauthor.

3 Q. Understood.

4 And the words in this chapter in
5 Chapter 20 are yours and his; right?

6 A. Yes.

7 Q. Okay. I wanted to ask you a few
8 questions about Section 20.1 in Chapter 20, which
9 is the Introduction.

10 The opening line in the chapter
11 reads:

12 "Effective management of groundwater
13 requires the ability to predict subsurface flow
14 and transport of solutes, and the response of
15 fluid and solute flux to changes in natural or
16 human-induced stresses."

17 Did I -- did I read that correctly?

18 A. Yeah. Yeah.

19 Q. What do you mean by "effective
20 management of groundwater"?

21 A. Well, I mean, groundwater is a
22 resource. It's, you know, used to the benefit of
23 society, also to the benefit of individuals and
24 benefit of cities, benefit of factories, benefit

1 of agricultural. You know, there's just multiple
2 uses.

3 It's a resource that should be
4 managed and it's a resource that in many cases
5 throughout the U.S. and the rest of the world is
6 not managed at all. Because people -- a landowner
7 could drill a well and pump out as much water as
8 they want, in some cases without anyone overseeing
9 their use of the resource.

10 In the U.S. that varies greatly by
11 state to state. In some areas, particularly if
12 there have been some problems or limitations on
13 the use, it's been overdeveloped, then they form
14 management districts or laws are implemented in a
15 state or in a county to try to, well, in effect,
16 manage the resource and try to assure that it
17 lasts longer as a resource, as a usable resource
18 than it would if there was no limitations on
19 development.

20 So by "effective management," we're
21 really implying that there is some management
22 structure governing the use of groundwater that's
23 there for basically the benefit of society and the
24 common good. And, you know, I guess in our

1 opinion, the effective management, management that
2 is efficient and effective in trying to assure the
3 sustainability of a groundwater resource in an
4 area is just a necessary and valuable imposition
5 of some controls on the use of the resource, but
6 it's not done everywhere.

7 Q. Understood.

8 Does management entail planning?

9 A. Management should involve planning,
10 thinking ahead, yeah. If they're not thinking
11 ahead, then they're not doing a good job managing
12 it.

13 Q. And that I think you mentioned -- I
14 can't recall if it was scarcity or conservation of
15 water.

16 Is it management of?

17 A. Well, I think I put it in the terms
18 of sustainability.

19 Q. Sustainability, correct.

20 A. And, you know, that's easier to do
21 in some areas than in others.

22 Q. Sure.

23 If you turn the page to Chapter 20.2
24 on page 20-2, it's a subsection entitled "Models";

1 right?

2 A. Okay.

3 Q. And the first couple sentences
4 there:

5 "The word 'model' has so many
6 definitions and so overused that it's sometimes
7 difficult to discern its meaning."

8 And then there's a citation to you
9 and I think Fred Bredehoeft?

10 A. Bredehoeft. Bredehoeft.

11 Q. Bredehoeft.

12 And then the next line:

13 "A model is perhaps most simply
14 defined as a representation of a real system or
15 process. A conceptual model is a hypothesis for
16 how a system or process operates."

17 Did I read that correctly?

18 A. Yes.

19 Q. Okay. And so a model is a
20 simplified representation of a real world system
21 or process; that's what you're saying there?

22 A. That's what we said.

23 Q. Okay. And a conceptual model is a
24 hypothesis for how a system or process operates;

1 right?

2 A. In effect. It's a -- it's a verbal
3 description of your understanding.

4 Q. And the --

5 MS. BAUGHMAN: Were you
6 finished, Dr. Konikow?

7 THE WITNESS: Well, I was just
8 going to add: As a verbal description,
9 it could be either qualitative or
10 quantitative.

11 BY MR. ANWAR:

12 Q. Okay. And the start of the next
13 paragraph there it says:

14 "Most groundwater models in use
15 today are deterministic mathematical models."

16 Right?

17 A. That's what it says, yes.

18 Q. Okay. What -- what is a
19 deterministic model?

20 A. A deterministic model is one in
21 which the solution, the result is, in effect,
22 predetermined by the solution to a governing
23 equation. You have a mathematical equation that
24 describes quantitatively your understanding of the

1 processes that govern, let's say, groundwater
2 flow, and to solve the differential equation, you
3 need to define boundary conditions and initial
4 conditions and the solution to that, the results.

5 It's not random. It's predetermined
6 by the parameters you put in and the nature of the
7 equation and your definition of initial and
8 boundary conditions and, you know, if one person
9 does it here and another person does it there, if
10 they have all the same parameters and the same
11 equation, they should get the same results.

12 Q. Got it.

13 The next line in that second
14 paragraph says:

15 "Deterministic models are based on
16 conservation of mass, momentum, and energy and
17 describe cause and effect relationships."

18 Right?

19 A. Yes.

20 Q. Okay. And what does "conservation
21 of mass, momentum, and energy" mean?

22 A. Okay. These are basic thermodynamic
23 principles that, you know, if you have a certain
24 volume of water coming into a box, or an aquifer

1 or some kind of element, masses can serve that's
2 neither created nor disturbed, destroyed, except
3 for radioactive constituents and, you know, what
4 goes in has to be balanced by what comes out or
5 what the mass and storage in that unit changes.

6 Q. Does that mean that in a
7 deterministic model, the mass, momentum, and
8 energy remain constant throughout time?

9 A. No.

10 Q. Okay.

11 A. It just means that, you know, if you
12 add mass to the system at some later time, then it
13 all has to be balanced.

14 Q. I got you.

15 A. Yeah.

16 Q. So if we turn to -- well, it's on
17 the same printed page, but the next page of the
18 book is subsection 20.3 Flow and Transport
19 Processes.

20 A. Yes.

21 Q. I wanted to ask you about the --
22 that first line says or the first line of the
23 second paragraph -- paragraph:

24 "The purpose of a model that

1 simulates solute transport in groundwater is to
2 compute the concentration of a dissolved chemical
3 species in an aquifer at any specified time and
4 place."

5 Is that right?

6 A. I believe so.

7 Q. Okay. And then if we jump ahead a
8 little bit to the paragraph at the end of that
9 section starting with "The subsurface," it says:

10 "The subsurface environment
11 constitutes a complex, three-dimensional
12 herogeneous hydrogeologic setting. This
13 variability strongly influences groundwater flow
14 and transport, and such a reality can be described
15 accurately only through careful hydrogeologic
16 practice in the field."

17 Did I read that correctly?

18 A. Yeah. The word "heterogenous" was
19 on the first line.

20 Q. Oh, hetero. Yeah, heterogenous.

21 A. Yes, you read it correctly.

22 Q. Okay. These are your words, so
23 you'll agree with that; right?

24 A. Yes.

1 Q. Okay. And then "However" the next
2 sentence in that same paragraph.

3 "However, regardless of how much
4 data are collected, uncertainty always remains
5 about the properties and boundaries of the
6 groundwater system of interest."

7 Why -- why does uncertainty always
8 remain?

9 A. Well, the subsurface environment,
10 basically the geologic framework of an aquifer due
11 to geologic processes, its properties and
12 characteristics of permeability, porosity and so
13 on just vary in space because of the geologic
14 processes that led to the deposition of material
15 and its geologic modification subsequent to its
16 deposition, its burial by under sediments and so
17 on.

18 And these are complex patterns and
19 they're underground. You can't look at them
20 directly. So there you could use geophysical
21 methods to try to find out different
22 characteristics, change in space, but there's
23 limitations to how accurate that is.

24 You use wells to observe at a point,

1 but whatever you define at that point, the
2 properties could be a little different 10 feet
3 away or maybe even more than a little different.

4 In other words, it's out of sight
5 out of the ability of us to see underground to
6 completely characterize all the properties of the
7 system. It's, you know, it just can't be done
8 with present -- certainly not with present
9 technology.

10 Q. Understood.

11 A. And so we do the best we could,
12 interpolate between points where we have more
13 data, and then build that into a model.

14 Q. And there's no way to create a model
15 that perfectly recreates reality; right?

16 A. That's my belief.

17 Q. Okay. And you just explained it,
18 but a large part of that is because there are
19 aspects of the subsurface that we don't know
20 about; correct?

21 MR. DEAN: Object to form.

22 THE WITNESS: We --

23 MR. DEAN: You can continue.

24 THE WITNESS: Yeah.

1 That we can't observe directly
2 within any kind of feasible economic
3 framework. I mean, if you drill more and
4 more wells to observe more and more
5 spaces, pretty soon the wells themselves
6 are increasing the porosity of the
7 aquifer.

8 So there's a limit to how much
9 we could do, and certainly it's expensive
10 to drill one well. So you never have a
11 budget to drill an infinite number of
12 observation wells.

13 BY MR. ANWAR:

14 Q. And are subsurface conditions -- I
15 guess for lack of a better way of saying this, are
16 subsurface conditions changing based on sort of
17 the environmental conditions surrounding them?

18 A. The hydraulic properties very rarely
19 would change in time on a human time frame. That
20 just doesn't happen. The hydraulic conditions in
21 terms of pressure distributions and water levels,
22 those certainly can change quickly.

23 Q. Okay. How groundwater modeling and
24 transport is typically used for planning and

1 management purposes; right?

2 MR. DEAN: Object to form.

3 THE WITNESS: Can you repeat
4 that?

5 BY MR. ANWAR:

6 Q. Groundwater -- groundwater modeling
7 is typically used for planning and management
8 purposes; right?

9 MR. DEAN: Same objection.

10 THE WITNESS: Well, typical
11 uses of groundwater models? I wouldn't
12 say it's typical for that. Models are
13 used for management purposes, but they're
14 used for many other purposes, and I don't
15 know which purpose is more typical.

16 BY MR. ANWAR:

17 Q. What are some of the management
18 purposes that models are used for?

19 A. I think the first highest level use
20 is to understand the system to help. Good
21 management of the system requires that you
22 understand the system and understand which way
23 groundwater is flowing, what the head distribution
24 is, and how the whole system operates. How to

1 predict the effects of drilling a new well and
2 pumping it at a specified rate might impact other
3 users. It might impact the water table and the
4 sustainability of the resource. The model allows
5 you to do that in a quantitative way.

6 Q. And to understand the system, that
7 could be one of the purposes of sort of a model or
8 uses of a model would be to project water needs in
9 the future for -- for agriculture; right?

10 A. Well, not to project water needs,
11 but to project the impacts of water use. You
12 wouldn't use the model -- a groundwater model to
13 predict water use. You would use it -- you would
14 predict water use some other way based on
15 economic, climate, whatever.

16 There you would estimate water use,
17 and then you could say, what would happen to the
18 system if this water use is implemented in the
19 future? And the model could then help you assess
20 what the impacts of a proposed water use would be.

21 Q. Okay. That's really helpful.

22 And then a model can also be used to
23 estimate the movement of contaminants for
24 remediation efforts; right?

1 A. Certainly.

2 Q. Now, I'd like you to take a look at
3 your rebuttal report. It's Exhibit 2.

4 Okay. So looking at the first
5 paragraph under Introduction on page 1, it says
6 there that:

7 "ATSDR prepared reports describing
8 models developed to stimulate groundwater flow and
9 contaminant transport at two areas of Camp
10 Lejeune, North Carolina: Tarawa Terrace and then
11 Hadnot Point/Holcomb Boulevard area."

12 Correct?

13 A. Yes.

14 Q. And when we're talking about ATSDR's
15 Camp Lejeune water modeling efforts -- I think
16 this has been clear already, but I just want to
17 confirm.

18 When we're talking about ATSDR's
19 Camp Lejeune water modeling efforts, we're really
20 talking about two separate water models; correct?

21 A. Correct.

22 Q. ATSDR completed a water model
23 related to Tarawa Terrace; right?

24 A. Yes.

1 Q. And my understanding, at least of
2 the last report, it was completed around 2009.

3 Is that consistent with your
4 understanding?

5 A. I believe so. I don't remember the
6 dates on the reports, but that sounds about right.

7 Q. Okay. And for Tarawa Terrace, ATSDR
8 performed a groundwater model using MODFLOW;
9 right?

10 A. Correct.

11 Q. And then they performed a fate and
12 transport model using MT3DMS; right?

13 A. Yes.

14 Q. Is there -- the general uncertainty
15 that we just discussed in terms of flow and
16 transport processes, does that exist for
17 groundwater models as well?

18 MR. DEAN: Objection.

19 BY MR. ANWAR:

20 Q. For -- for flow models?

21 MR. DEAN: Object to the form.

22 THE WITNESS: Well,
23 groundwater flow models such as
24 MODFLOW --

1 BY MR. ANWAR:

2 Q. Yeah.

3 A. -- assume that the changes can be
4 described by a governing equation that is fairly
5 standard, well accepted by scientists and
6 engineers. You know, it's pretty common.

7 Parameters values, in other words,
8 the equation has coefficients in it, and those
9 coefficients need to be described in order to
10 solve the equation. Those coefficients include
11 hydraulic properties such as hydraulic
12 conductivity, the saturated thickness, how you
13 discretize the system, storage coefficients or
14 specific yields. If it's a transient flow
15 problem.

16 But, you know, one of the primary is
17 hydraulic conductivity, but you could also
18 sometimes refer to as transmissivity if you
19 account for the saturated thickness of the layer.

20 So you need to describe these and,
21 again, as with any other geologically based
22 parameter or property, yes, there is uncertainty.

23 Q. And I guess I was wondering.

24 When you -- so for the Tarawa

1 Terrace model, MODFLOW was used for the
2 groundwater flow model and MT3DMS were used -- was
3 used for the fate and transport model and then
4 they were linked together; correct?

5 A. Well, yeah, there's a linkage
6 between the two, but it's not necessarily, you
7 know, one integrated model.

8 Generally what is done, at least for
9 those codes, for MT3D, is you run the flow model
10 first and you generate a very large file that has
11 all the heads and specific discharges, all the
12 fluxes, and then you run -- afterwards you run
13 MT3D and the MT3D reads the file. There's some
14 linkage file that connects MT3D with the data that
15 was produced by the flow model.

16 Q. I guess my -- my question is that if
17 you use MODFLOW, a MODFLOW-based flow model and
18 with an MT3D-based flow and transport model, with
19 both models having some level of uncertainty, when
20 you use them -- when you use them together, does
21 that uncertainty sort of -- does it become
22 cumulative?

23 A. No, I wouldn't say that, but I would
24 correct you. MT3D is not a flow model.

1 Q. Oh, I'm sorry.

2 A. So it's just a solute transport
3 model. It uses the flows or fluxes that are
4 output or calculated by MODFLOW.

5 Q. Okay. I think that's what I meant
6 was it's a transport model; correct?

7 A. It's a transport model, and I would
8 not say that the, you know, uncertainty is
9 cumulative in any way.

10 Q. Okay. And for the Hadnot
11 Point/Holcomb Boulevard water modeling effort,
12 that was separate from Tarawa Terrace; right?

13 A. That's my understanding.

14 Q. Okay. And that was completed around
15 2013; right?

16 A. That's my understanding.

17 Q. And for that -- for Hadnot
18 Point/Holcomb Boulevard, ATSDR again used MODFLOW
19 for the groundwater flow model; correct?

20 A. I believe they used a newer version
21 of MODFLOW than was used in the Tarawa Tara
22 list -- Terra -- Tarawa Terrace model.

23 Q. Okay. And for the transport model,
24 they used MT3DMS --

1 A. Yes.

2 Q. -- again; right?

3 A. Yes.

4 Q. And then this time they also used a
5 water distribution model EPANET to simulate
6 intermittent connections between Hadnot Point and
7 Holcomb Boulevard; right?

8 A. Yes.

9 Q. Okay. To the best of your
10 knowledge, did ATSDR perform water models for any
11 other water distribution systems at Camp Lejeune?

12 A. At Camp Lejeune? Not that I'm aware
13 of.

14 Q. Okay. Now, looking at your report,
15 going back to your report, the next line after
16 that first sentence we -- we just discussed is:

17 "Their use of the models was
18 innovative in the sense that instead of a typical
19 use of a groundwater model to predict future
20 behavior, they used the model to 'predict' how the
21 system evolved in the past (before concentration
22 observations were made) from a known state (an
23 initial condition), in which no contaminants were
24 present, to a contaminated aquifer with a mapped

1 distribution in the early to mid-1980s when
2 contamination was observed at a number of
3 locations (wells, soils samples, and water
4 treatment plants)."

5 Did I read that correctly?

6 A. Yes.

7 Q. My question was about -- I guess my
8 question was a moment ago I asked you whether
9 models are typically used -- I guess groundwater
10 flow and transport models are typically used for
11 planning or groundwater -- groundwater management
12 purposes, and I think you said you weren't sure
13 whether they were used typically or not typically
14 for that purpose.

15 Is that a fair assessment?

16 A. Yeah, it's --

17 MR. DEAN: Hold on.

18 Object to form of the
19 question. Misstates his prior testimony.

20 BY MR. ANWAR:

21 Q. Was that a fair characteristic
22 -- characterization of your testimony?

23 A. Yes.

24 Q. Okay. And so here you say that the

1 ATSDR models were "innovative in the sense that
2 instead of a typical use of a groundwater model to
3 predict future behavior."

4 Groundwater and transport models are
5 typically used to predict future behavior; right?

6 A. Very often or to help understand
7 present behavior.

8 Q. And the ATSDR model, you know, here
9 in your report is innovative in the sense that it
10 was being used to predict past concentration
11 levels for which real world observed concentration
12 level data wasn't available; correct?

13 MR. DEAN: Object to the form.

14 THE WITNESS: Well, the
15 objective -- primary objective seemed to
16 be that historical reconstruction.
17 That's, I'd say, typically not the main
18 objective, but I didn't mean to imply
19 that -- that what you call historical is
20 never done. It's actually commonly done,
21 but not as the main purpose of the model.

22 BY MR. ANWAR:

23 Q. Can you elaborate on that a little
24 bit? When you say you didn't mean to imply that

1 it's not commonly done but not the main purpose of
2 the model, what do you mean by that?

3 A. What I mean is, for the Tarawa
4 Terrace, it seemed like a main objective in terms
5 of computing the concentrations over time. A main
6 focus was on reconstructing that concentration
7 distribution in that period in which there were no
8 data prior to 1982.

9 That the solution of the governing
10 equation for a period in which there's no
11 observation is actually very common in transport
12 models -- in contaminant transport models because
13 it's very common that there's a period of record
14 in which there is no observations.

15 For groundwater contamination
16 problems, people generally are not aware it's a
17 problem until it shows up someplace where it
18 doesn't belong.

19 A well is contaminated. Someone is,
20 you know, drinking. Then all of a sudden people
21 recognize a problem. Then they start making
22 measurements and observations, but groundwater
23 moves slowly. So that could be 10, 20, or 30
24 years before the problem is recognized and

1 observations are made.

2 If you're going to model that
3 system, you have to start back at time zero before
4 any contaminants are introduced, and so it's very
5 common that, you know, you would be doing
6 essentially the same thing, but it's very often
7 not called historical reconstruction.

8 Q. Understood.

9 The -- I think earlier in your
10 deposition we discussed that the ATSDR models were
11 attempting to reconstruct population level monthly
12 contaminant concentrations for use in an EPI
13 study; right?

14 MR. DEAN: Object to the form
15 of the question.

16 THE WITNESS: Well, I mean, I
17 don't know about population level
18 studies. I'm not even sure what that
19 means.

20 But we were aware that the
21 groundwater modeling would be used for
22 epidemiological studies.

23 BY MR. ANWAR:

24 Q. Okay. And I think I misspoke.

1 What I meant to say was the ATSDR
2 models were used to reconstruct or estimate past
3 monthly concentration levels to support a
4 population level epidemiological study; right?

5 MR. DEAN: Object to the form
6 of the question.

7 THE WITNESS: Yeah. Well,
8 everything you said after "support" I'm
9 not sure about, but yes, the models were
10 used to reconstruct the concentrations
11 distributions throughout the aquifer
12 prior to 1982.

13 BY MR. ANWAR:

14 Q. Okay. Are you aware of any other
15 models besides AT -- or strike that.

16 Are you aware of any models
17 attempting to reconstruct historical contaminant
18 concentration levels for the purpose of
19 determining exposure in individuals?

20 MR. DEAN: Object to the form.
21 Are you talking about Camp
22 Lejeune or just in general?

23 MR. ANWAR: I asked about any
24 models.

1 MR. DEAN: Okay.

2 BY MR. ANWAR:

3 Q. Are you aware of any modeling
4 attempting to reconstruct historical contaminant
5 concentration levels for the purpose of
6 determining exposure in human individuals in real
7 life?

8 A. For that purpose in real life? No.
9 I mean, I would say modeling at the WIPP site was
10 used to predict future exposure, and then they
11 were health studies or assessments made on that,
12 but that was all hypothetical a thousand years in
13 the future. But that's what the modeling was
14 done. It was related to exposure of a future
15 farmer living downstream. So yes, that was done
16 there.

17 I'm aware of many studies where that
18 historical reconstruction was done but not for the
19 purpose of exposure.

20 Q. Okay. And during that WIPP study,
21 did that model into the future actually simulate
22 estimated concentration levels?

23 A. Yes.

24 Q. It did?

1 A. Yes, but not -- the model itself did
2 not get into the health and exposure issue. It
3 just computed the concentrations how they would
4 spread under a hypothetical breach of the
5 repository.

6 Q. And then what was that information
7 used for?

8 A. As part of a safety assessment for
9 the proposed radioactive repository, and all of
10 those analyses were included in the safety
11 assessment that was submitted to EPA to get an
12 operational license for the site, and that
13 approval was granted somewhere in the mid-1990s or
14 late 1990s.

15 Q. Okay. Now, jumping back to
16 Exhibit 7, which is Chapter 20 of your book.
17 Yeah, Chapter 20. Your Chapter 20 of the book
18 that we looked at.

19 I'd like to ask you a few questions
20 about section 20.6.

21 A. Okay.

22 Q. That subsection is titled "Model
23 Design, Development, and Application"; right?

24 A. Yes.

1 Q. And the first sentence there in your
2 book -- excuse me -- in your chapter that you
3 coauthored states:

4 "The first step in model design and
5 application is to define the nature of the problem
6 and the purpose of the model."

7 Right?

8 A. Yes.

9 Q. Okay. And those are your words;
10 right?

11 A. Well, mine and Tom Reilly's.

12 Q. Okay. But you don't disagree with
13 those words; right?

14 A. Nope.

15 Q. Okay. Why is defining the nature of
16 the problem and the purpose of the model the first
17 step?

18 A. Well, you have to know the nature of
19 problems to know before you decide what the best
20 form of a model is to simulate it. Knowing the
21 purpose of the model, what it would be used for,
22 helps you assess what factors should be included
23 and what could be safely ignored.

24 Q. Understood.

1 And so if we go on, it says:

2 "Although this may seem obvious, it
3 is important -- it is an important first step that
4 is sometimes overlooked in a hasty effort to take
5 action. This step is closely linked with the
6 formulation of a conceptual model, which again is
7 required prior to development of a mathematical
8 model."

9 Did I read that correctly?

10 A. Yes.

11 Q. Okay. And those are words that you
12 coauthored; right?

13 A. Excuse me?

14 Q. Those are words that you coauthored;
15 right? Those are your words; right?

16 A. Yes.

17 Q. Okay. And you still agree with
18 what's said there; correct?

19 A. I believe so. Yes.

20 Q. And then if we jump to the end there
21 or if we go a little further down in the
22 paragraph, starting with the sentence that says
23 "Good judgment."

24 "Good" -- do you see where I'm at?

1 A. Yeah, I could see it.

2 Q. Okay.

3 "Good judgment is required to
4 evaluate and balance the trade-offs between
5 accuracy and cost, with respect to model
6 development, model use, and data requirements.
7 The key to efficiency and accuracy in modeling a
8 system probably is more affected by the
9 formulation of a proper and appropriate conceptual
10 model than by the choice of a particular numerical
11 method or code."

12 Did I read that correctly?

13 A. You did.

14 Q. Okay. And do you agree with that
15 statement?

16 A. Yes.

17 Q. Okay. And in particular, the
18 key -- what it says there is that the key to
19 efficiency and accuracy in a modeling system is
20 more affected by the formulation of a proper and
21 appropriate conceptual model; right?

22 A. Yes.

23 MR. ANWAR: Okay. I'm going
24 to hand -- I'm going to hand you what I

1 am marking as Exhibit 8.

2 (Document marked for
3 identification as Konikow Exhibit 8.)

4 BY MR. ANWAR:

5 Q. Exhibit 8 is the "Chapter A: Summary
6 of Findings" for ATSDR's Tarawa Terrace water
7 model; correct?

8 A. Yes.

9 Q. Okay. If you turn to -- it's page
10 Roman numeral III. Just a couple pages in. Under
11 the Foreword.

12 A. Yes.

13 Q. You see that?

14 A. Yes.

15 Q. It says:

16 "ATSDR, an agency of HHS, is
17 conducting an epidemiological study to evaluate
18 whether in utero and infant (up to 1 year of age)
19 exposures to volatile organic compounds in
20 contaminated drinking water at U.S. Marine Corps
21 Base Camp Lejeune, North Carolina, were associated
22 with specific birth defects and childhood cancers.
23 The study includes births occurring during the
24 19 -- during the period 1968 to 1985 to women who

1 were pregnant while they resided in family housing
2 at the base."

3 Did I read that correctly?

4 A. Yes.

5 Q. And as we discussed before, the
6 ATSDR's water model for Tarawa Terrace was
7 developed to obtain estimates of historical
8 exposure for the EPI study that they were
9 performing --

10 MR. DEAN: Object.

11 BY MR. ANWAR:

12 Q. -- correct?

13 MR. DEAN: Object to the form
14 of the question.

15 THE WITNESS: Well, I don't
16 know that it was developed that the
17 models would calculate exposures. The
18 models would calculate the concentration
19 distribution in time and space.

20 BY MR. ANWAR:

21 Q. The -- if we go to the next
22 paragraph just underneath, it says:

23 "Historical exposure data needed for
24 the epidemiological case-control study are

1 limited. To obtain estimates of historical
2 exposure, ATSDR is using water-modeling techniques
3 and the process of historical reconstruction."

4 Did I read that correctly?

5 A. You did.

6 Q. And that was the purpose of ATSDR's
7 model for Tarawa Terrace; correct?

8 A. Well, yeah. I think the next
9 sentence that you didn't read is critical also.

10 These -- these methods, the water
11 modeling techniques, "are used to quantify
12 concentrations of particular contaminants in
13 finished water and to compute the level and
14 duration of human exposure to contaminated
15 drinking water."

16 So I think that's a key part of it.

17 Q. Sure.

18 But that -- that was the purpose?

19 A. Yeah.

20 Q. What we both read; correct?

21 A. Yes. Yes.

22 Q. Okay. Now, if you turn to
23 page -- well, let me -- let me -- one question
24 before we turn the page.

1 Per the first paragraph, the EPI
2 study that was being performed was for the period
3 between 1968 and 1985; correct?

4 A. Apparently, yes.

5 Q. Okay. And if we turn the page to
6 A98.

7 A. To which page?

8 Q. A98.

9 A. A98.

10 Q. This is a -- this is part of a Q&A
11 about the Tarawa Terrace model and there's a
12 question there. The last question on A98 says:

13 "ATSDR's historical reconstruction
14 analysis documents that Tarawa Terrace drinking
15 water was contaminated with PCE that exceeded the
16 current maximum contaminant level (MCL) of 5
17 milligrams per liter during 1957 and reached a
18 maximum value of 183 micrograms per liter. What
19 does this mean in terms of my family's health?

20 Did I read that correctly?

21 A. Yes.

22 Q. Okay. And the answer is:

23 "ATSDR's exposure assessment cannot
24 be used to determine whether you, or your family,

1 suffered any health effects as a result of past
2 exposure to PCE-contaminated drinking water at
3 Camp Lejeune."

4 Did I read that correctly?

5 A. Yes.

6 Q. And it goes on to say:

7 "The study will help determine if
8 there is an association between certain birth
9 defects and childhood cancers among children whose
10 mothers used this water during pregnancy.
11 Epidemiological studies such as this help improve
12 scientific knowledge of the health effects of
13 these chemicals."

14 Did I read that correctly?

15 A. Yes.

16 Q. And, again, per this information
17 here, the model -- the -- the estimated monthly
18 concentration -- contaminant concentration levels
19 were for the purpose of epidemiological studies;
20 correct?

21 MR. DEAN: Object to the form
22 of the question.

23 And also note you didn't read
24 the entire answer to the question into

1 the record. You only chose a few select
2 sentences.

3 MR. ANWAR: You can the --
4 correct.

5 THE WITNESS: Could you
6 repeat the question?

7 BY MR. ANWAR:

8 Q. Sure.

9 The -- it's what we -- what we've
10 been talking about, that the purpose of the
11 simulated monthly estimated contaminant
12 concentrations produced by the Tarawa Terrace
13 model, those were intended to be used for an EPI
14 study, right, that ATSDR was performing?

15 MR. DEAN: Object to the form
16 of the question.

17 You've asked this same
18 question 50,000 times already. I'm not
19 going to instruct the witness not to
20 answer it but --

21 MR. ANWAR: Kevin, I'm going
22 to ask you to limit.

23 MS. HURT: -- you keep asking
24 the same question 40 different times, and

1 you're looking for a specific response
2 you're not getting. So I would --

3 BY MR. ANWAR:

4 Q. The answer is correct. It was used
5 for an EPI study; right?

6 MR. DEAN: Object to the form
7 of the question.

8 BY MR. ANWAR:

9 Q. It was intended for use for an EPI
10 study; right?

11 MR. DEAN: Object to the form
12 of the question.

13 THE WITNESS: I believe so.

14 BY MR. ANWAR:

15 Q. Okay. As you sit here today, as
16 someone that has reviewed all of the reports for
17 Tarawa Terrace, the Tarawa Terrace model, can you
18 point me to anywhere in the ATSDR report stating
19 that the TT model, the Tarawa Terrace model was
20 intended to be used for exposure -- exposure
21 determinations in individuals in the real world?

22 MR. DEAN: Object to the form
23 of the question.

24 This witness is not qualified,

1 and he's told you that, as an
2 epidemiologist.

3 THE WITNESS: The answer
4 would be no.

5 BY MR. ANWAR:

6 Q. Okay. And can you point me to
7 anywhere in the ATSDR reports stating that the
8 Tarawa Terrace model was intended to be used in
9 litigation as part of a causation analysis for
10 individual plaintiffs?

11 MR. DEAN: Object to the form
12 of the question.

13 THE WITNESS: I do not recall
14 seeing any mention of litigation in
15 there.

16 BY MR. ANWAR:

17 Q. Okay.

18 MR. DEAN: It was an
19 independent study performed by the United
20 States government.

21 MR. ANWAR: I am going to hand
22 you what I'm marking as Exhibit 9.

23 (Document marked for
24 identification as Konikow Exhibit 9.)

1 BY MR. ANWAR:

2 Q. And if you turn to page Roman
3 numeral III again, the Foreword. The almost
4 identical language is included as in the Tarawa
5 Terrace report, and I'll read it. It says:

6 ATSDR "is conducting epidemiological
7 studies to evaluate the potential for health
8 effects from exposures to volatile organic
9 compounds (such as PCE, TCE, and benzene) in
10 drinking (finished) water at U.S. Marine Corps
11 Base Camp Lejeune, North Carolina. Historical
12 exposure data needed for the epidemiological
13 studies are limited. To obtain estimates of
14 historical exposures, ATSDR is using
15 water-modeling techniques and the process of
16 historical reconstruction to quantify
17 concentrations of particular contaminants in
18 finished water and to compute the level and
19 duration of human exposure to contaminated
20 drinking water."

21 Did I -- did I read that correctly?

22 A. Yes.

23 Q. Okay. And again here in the
24 Foreword, it's stating that the historical

1 exposure data needed for epidemiological studies;
2 correct?

3 MR. DEAN: Object to the form
4 of the question.

5 THE WITNESS: Can you repeat
6 the question?

7 BY MR. ANWAR:

8 Q. It's stating here historical
9 exposure data is needed for the epidemiological
10 studies that ATSDR is performing; correct?

11 A. Yeah.

12 Q. Okay. And that was the purpose of
13 the Hadnot Point/Holcomb Boulevard model; correct?

14 MR. DEAN: Object to the form
15 of the question. Mischaracterizes prior
16 testimony.

17 THE WITNESS: Well, my
18 understanding is -- is the purpose of the
19 model was to reconstruct or to estimate
20 how concentrations of these contaminants
21 varied in time and space.

22 BY MR. ANWAR:

23 Q. For the epidemiology --
24 epidemiological studies; right?

1 MR. DEAN: Object to the form
2 of the question.

3 THE WITNESS: Well, I think
4 that's stated here that that's the
5 ultimate goal, but, again, the model
6 itself doesn't know or care what the
7 purpose of the use of the output would
8 be.

9 BY MR. ANWAR:

10 Q. And, again, if we turn to page A182.

11 A. What page?

12 Q. A182.

13 MR. DEAN: A182? It only goes
14 to A164.

15 MR. ANWAR: Oh, I'm sorry. I
16 must have put the wrong one there.
17 Sorry.

18 BY MR. ANWAR:

19 Q. Okay. We can skip that. That's
20 fine.

21 And earlier you talked about the
22 conception or earlier we discussed the sentence in
23 your book about the importance of the conceptual
24 model, forming the conceptual model in relation to

1 efficiency and accuracy of the model.

2 Do you recall that?

3 A. I do.

4 Q. Okay. And the conceptual model, to
5 be clear, for both of the ATSDR models, Tarawa
6 Terrace and Hadnot Point, was to estimate monthly
7 contaminant concentration levels for EPI studies?

8 MR. DEAN: Object to the form
9 of the question.

10 Last time. I'm going -- next
11 time I'm going to instruct him not to
12 answer your question because you've asked
13 it now, according to my calculations, at
14 least 110 times, and his first answer is
15 all that you needed.

16 So if you don't like his
17 answer, move on to some different
18 subject, but this is the last time. I'm
19 going to let him answer it, but next time
20 I'm going to ask him to instruct him not
21 to continue answering your questions.

22 BY MR. ANWAR:

23 Q. The answer is correct; right?

24 MR. DEAN: Object to the form.

1 THE WITNESS: Can you repeat
2 the question?

3 MR. ANWAR: Okay. And your --
4 Kevin, I'm going to say, your objection
5 is noted. You know as well as I do the
6 rules with issues to objections to form
7 in a non-suggestive manner. I'm going to
8 ask you to limit your speaking
9 objections. You keep making speaking --

10 MR. DEAN: Well, we can call
11 the court because I can have this court
12 reporter read me how many times you've
13 asked that same question, and we can get
14 the judge on the phone and ask him how
15 many times you get to ask him that
16 question. It's the same one.

17 MR. ANWAR: During -- during
18 the next break --

19 MR. DEAN: Do you dispute
20 you've asked him the same question more
21 than 10 times?

22 MR. ANWAR: During the break,
23 I'm happy to do that. Let me focus on my
24 questioning.

1 BY MR. ANWAR:

2 Q. The question is the conceptual
3 model -- you would agree the conceptual model,
4 as -- as confirmed by the statements we've just
5 read from the -- from the actual reports, the
6 conceptual model for ATSDR's Tarawa Terrace model
7 and Hadnot Point model was to estimate contaminant
8 concentration levels for EPI studies; right?

9 MR. DEAN: Object to the form
10 of the question.

11 THE WITNESS: No.

12 BY MR. ANWAR:

13 Q. What was -- what was the conceptual
14 model then?

15 A. The conceptual model is your idea of
16 how the system works, how the flow system works.
17 Your understanding of what constitutes an aquifer
18 versus a confining layer.

19 The conceptual model is relevant to
20 how you structure the model. It's not -- it's not
21 a description of the purpose of the model.

22 Q. Okay. And that's -- that's a -- I
23 appreciate that clarification.

24 The conceptual model that was

1 developed for the purpose of the ATSDR Tarawa
2 Terrace and Hadnot Point/Holcomb Boulevard models
3 was developed in mind of the actual purpose for
4 which the model was being used, which was exposure
5 estimates for EPI study; correct?

6 MR. DEAN: Object to the form
7 of the question.

8 I'm not sure if anybody would
9 understand that question.

10 THE WITNESS: I don't know
11 what was in their mind when they
12 developed the conceptual model.

13 BY MR. ANWAR:

14 Q. Okay. Now, in your report, you give
15 a couple examples of other instances where --
16 well, let me back up for a second.

17 As it relates to the Hadnot
18 Point/Holcomb Boulevard model, can you point me to
19 any statement in the ATSDR reports stating that
20 that model was intended to be used for exposure
21 determinations in individuals in the real world?

22 MR. DEAN: Object to the form.

23 THE WITNESS: I would have to
24 reread the whole report carefully and see

1 if it says that. I...

2 BY MR. ANWAR:

3 Q. Having read the reports in
4 preparation for your deposition, as you sit here
5 today, can you -- can you -- are you aware of any
6 such statement in the reports?

7 MR. DEAN: Object to the form.

8 THE WITNESS: Well, I believe
9 that the Foreword that we just went over
10 describes that the ultimate purpose is to
11 evaluate the potential for health effects
12 from exposure to volatile organic
13 compounds.

14 BY MR. ANWAR:

15 Q. Okay. Can you point me to anywhere
16 in the -- in the Hadnot Point/Holcomb Boulevard
17 reports that states that particular model was
18 intended to be used in litigation as part of a
19 causation analysis for individual plaintiffs?

20 MR. DEAN: Object to the
21 form --

22 THE WITNESS: I --

23 MR. DEAN: -- of the question.

24 THE WITNESS: I don't recall

1 seeing anywhere in the reports that
2 litigation was mentioned. So I would
3 have to say no.

4 BY MR. ANWAR:

5 Q. Okay. Now, in your rebuttal report,
6 you identified two examples of hindcasting models;
7 correct? Other examples of hindcasting models;
8 correct?

9 A. I think I identified two models
10 where that had been done but had never been called
11 hindcasting.

12 Q. Okay.

13 A. And that wasn't -- that was just
14 done as part of the modeling exercise, as part of
15 the model output. It just wasn't the main purpose
16 of those models, and it was just a consequence of
17 the modeling, but in effect that's what was done.

18 Q. And that was the Rocky Mountain
19 Arsenal in Colorado example; correct? One of
20 them?

21 A. One of two examples was from the
22 Rocky Mountain Arsenal, which I'm very familiar
23 with because I had done the modeling and I had
24 written the reports about it.

1 Q. And the other one is the Lawrence
2 Livermore National Laboratory example; correct?

3 A. Correct.

4 Q. Now, the Rocky Mountain Arsenal
5 examples wasn't about reconstruction --
6 reconstructing contaminant concentrations to
7 determine exposures in individuals; right?

8 A. The issue of determining exposures
9 has nothing to do with the model, in the sense
10 that you're trying to develop a model that
11 simulates the system based on your understanding
12 of the physical and chemical --

13 THE VIDEOGRAPHER: Counsel,
14 could please fix your mic. I'm not
15 picking up your questioning.

16 BY MR. ANWAR:

17 Q. Earlier you mentioned that you had
18 been deposed related to the Rocky Mountain --

19 A. Yeah, I'm not sure I finished
20 answering the previous question --

21 Q. Okay.

22 A. -- because of the interruption.

23 But I think what I was going to add
24 was that the assessment of health effects is

1 external to the development of the model. It's
2 not in the groundwater flow and transport models.
3 It has no impact on the groundwater flow and
4 transport model.

5 You're doing the best you can to
6 develop the models that simulates -- reproduces
7 the historical distributions, but that model
8 development should not be influenced by what the
9 output might be used for.

10 MR. ANWAR: Okay. I am
11 handing you what is being marked as
12 Exhibit 10.

13 (Document marked for
14 identification as Konikow Exhibit 10.)

15 BY MR. ANWAR:

16 Q. Now, this is the article that you
17 wrote about the Rocky Mountain Arsenal study;
18 correct?

19 A. Yes.

20 Q. Okay. And in the Rocky Mountain
21 Arsenal study -- and actually if you want to look
22 at your report for this, it's on page -- it's on
23 page 3 of your rebuttal report if you want to jump
24 back to -- to that.

1 A. This? Okay. Wait. The rebuttal
2 report? Page 3? Okay.

3 Q. You state at the start of the second
4 full paragraph:

5 Hindcasting was accomplished as a
6 part of a study at the Rocky Mountain Arsenal.
7 Contamination problem in which I developed and
8 calibrated the groundwater flow and transport
9 model. The Rocky Mountain Arsenal began
10 operations in or about 1943. Groundwater
11 contamination problem was recognized in 1954 and
12 1955."

13 Did I read that correctly?

14 A. Yes.

15 Q. Okay. And so to the extent that you
16 are estimating contaminant concentrations or
17 anything in the past, it was over that 12- or
18 13-year period from -- date from 1954, 1955 back
19 to 1943; right?

20 A. Yeah. Well, that was the first
21 period there was no data. There were several
22 other periods for which there were no data.

23 Q. Okay. And you say there were no
24 concentration data were available for the first 13

1 years of operation; correct?

2 A. Correct.

3 Q. And in Camp Lejeune for both the
4 Hadnot Point/Holcomb Boulevard and the Tarawa --
5 Tarawa Terrace models, those models are attempting
6 to reconstruct historical contaminant
7 concentrations over a 30-year period; right?

8 A. Yes.

9 Q. Okay. From observed data in 1982,
10 contaminant concentration level in 1982 till 1953
11 or earlier; correct?

12 A. Correct.

13 Q. Okay. So if we turn to the
14 Introduction, if we turn back to Exhibit 10, which
15 is your article on Rocky Mountain Arsenal, on
16 page 1, there's -- on page numerical 1, there's an
17 Introduction there; right?

18 A. Correct.

19 Q. Okay. And it says:

20 "The contamination of a ground-water
21 resource is a serious problem that can have
22 long-term economic and physical consequences that
23 might not be easily remedied. Although the
24 prevention of ground-water contamination provides

1 the most satisfactory result, the capability to
2 predict the movement of dissolved chemicals in
3 flowing ground water is also needed in order to
4 (1) plan and design projects to minimize
5 ground-water contamination."

6 Did I read that correctly?

7 A. Yes.

8 Q. So that -- that was one of the uses
9 for the model; correct?

10 A. That's potential use of models.

11 Q. Okay.

12 A. I don't believe I was talking
13 specifically about this model, but I was talking
14 about models in general.

15 Q. Okay. Number 2. "Estimate spatial
16 and temporal variations of chemical
17 concentrations."

18 Correct?

19 A. Yes.

20 Q. Number 3. "Estimate the traveltime
21 of a contaminant from its source to a ground-water
22 sink (a discharge point, such as a stream, spring,
23 or well."

24 Correct?

1 A. Yes.

2 Q. Number 4. "Help design an effective
3 and efficient monitoring system."
4 Correct?

5 A. Yes.

6 Q. And then number 5 is "Help physical
7 and economic feasibility of alternative
8 reclamation plans for removing contaminants from
9 an aquifer."

10 A. "Help evaluate."

11 Q. "Help evaluate." Thank you.

12 "Help evaluate physical and economic
13 feasibility of alternative reclamation plans for
14 removing contaminants from an aquifer and (or)
15 preventing the contaminants from spreading."

16 Right?

17 A. Right.

18 Q. And those were the purposes of this
19 model; correct?

20 A. Well, those -- those were listed as
21 general purposes for groundwater models --
22 groundwater contamination models. I don't think
23 those six bullet points -- five bullet points were
24 meant to be narrowly applied to the Rocky Mountain

1 Arsenal. It was more of a general introduction,
2 but yeah, that certainly would apply to the Rocky
3 Mountain Arsenal model.

4 Q. If you turn to page 40 of the model.

5 A. 40?

6 Q. Excuse me. 40 of the exhibit of
7 your study.

8 THE VIDEOGRAPHER: Sir, please
9 try and be professional. It's making
10 very muddy record.

11 MR. ANWAR: Okay.

12 BY MR. ANWAR:

13 Q. And so 40 there's a Summary and
14 Conclusions; correct?

15 A. Yes.

16 Q. The Summary and Conclusions, if you
17 go down to the third full paragraph.

18 A. Which paragraph?

19 Q. Third full paragraph.

20 A. Okay.

21 Q. "The predictive accuracy of the
22 model is most limited by adequacy of the input
23 data."

24 Did I read that correctly?

1 A. You did.

2 Q. And do you agree with that
3 statement?

4 You wrote it.

5 A. Yeah, I think I do. Yeah. Yeah.

6 Q. Okay.

7 A. Yeah, I wrote it 50 years ago. So
8 I'm just making sure I still agree with it.

9 Q. Those are the questions I have about
10 that exhibit.

11 A. Okay.

12 Q. And so the other example you gave
13 was for the Lawrence Livermore National Laboratory
14 site; is that right?

15 A. Yes.

16 Q. And I think in the -- in your
17 rebuttal report, you reference it as a study in
18 groundwater authored by Rogers; is that right?

19 A. That was Rogers, who's with the
20 Lawrence Livermore National Laboratory, or at
21 least he was when he wrote the article.

22 MR. ANWAR: Okay. I'm going
23 to go ahead and mark this as Exhibit 11.

24 (Document marked for

1 identification as Konikow Exhibit 11.)

2 BY MR. ANWAR:

3 Q. Is this the article by Rogers that
4 you were referring to --

5 A. Yes.

6 Q. -- in your report?

7 A. Yes.

8 Q. And in the Abstract there, it states
9 that:

10 "Failure to incorporate retardation
11 factors in solute transport predictions can lead
12 to serious miscalculations of the degree of
13 contamination and the time required for
14 remediation."

15 Did I read that correctly?

16 A. Yes.

17 Q. And do you still -- do you agree
18 with that?

19 A. Well, yeah, I mean, retardation
20 factors would certainly be considered if a
21 particular constituent is being retarded by
22 chemical reactions or biological reactions of any
23 kind.

24 Q. And under Introduction, it says:

1 "A ground-water model can only
2 be -- can be only as accurate as useful -- and
3 useful as the degree to which the modeled flow and
4 transport mechanisms completely represent the
5 significant characteristics of the system."

6 Do you agree with that?

7 A. Yeah, in general. Sure. Yeah.

8 Q. Now, the modeling for the Lawrence
9 Livermore National Laboratory site in California,
10 it wasn't attempting to estimate historical
11 contaminant concentrations for exposure
12 determinations in individuals; right?

13 A. Well, for one thing, the purpose of
14 the model and what it's used for has nothing to do
15 with how well the model is calibrated. That's
16 something that comes after the model. So to me
17 that just seems irrelevant to assessing the model.

18 Q. But the purpose of this Lawrence
19 Livermore National Laboratory site model wasn't to
20 attempt historical contaminant concentration
21 exposure levels in individuals; right?

22 A. The model -- the purpose of the
23 model was to reproduce what was going on in the
24 system. So.

1 Q. And what was being -- what was
2 -- what was --

3 A. So as a natural consequence, this
4 was a problem that had many analogies to Hadnot
5 Point/Holcomb Boulevard. The contamination based
6 on the historical understanding is believed to
7 have started in the early 1940s, 1942 or '43, and
8 a contamination problem was recognized decades
9 later. And the first time for which there is any
10 measurements of concentrations was around 1982 to
11 '85. So I don't remember the exact year.

12 Q. The --

13 A. So to run the model to analyze what
14 was there now -- we're in 1992 when it was done --
15 they had to start from that initial condition, a
16 period of -- I don't know what -- 30 years when
17 there was no data available and then calibrate to
18 the later data. But part of that is your -- the
19 model is in effect historically reconstructing the
20 distribution during that time in which it.

21 So in principle, it's very similar
22 to what was done in Tarawa Terrace.

23 Q. But the information that this model
24 produced wasn't used for exposure estimates --

1 A. I don't --

2 Q. -- in individuals?

3 MR. DEAN: Object to the form
4 of the question.

5 THE WITNESS: I have no idea
6 what it was used for.

7 BY MR. ANWAR:

8 Q. Can you point to -- can you direct
9 me to anywhere in the -- the article where the
10 purpose is identified as estimating concentration
11 levels for exposure determinations in individuals?

12 MR. DEAN: Object to the form.

13 THE WITNESS: I don't think
14 so.

15 MR. ANWAR: Okay. You can set
16 that aside.

17 We've been going for a little
18 while. Now might be a good time to take
19 a lunch break.

20 MR. DEAN: How long you want
21 to take? 30 minutes?

22 MR. ANWAR: What do you guys
23 think? 30? 45?

24 MS. SILVERSTEIN: I think 45.

1 MR. ANWAR: Okay. Yep.

2 MR. DEAN: See you back 1:30.

3 MR. ANWAR: Sounds good.

4 THE COURT REPORTER: We are
5 going off the record. The time is 12:46
6 PM.

7 (Whereupon, at 12:46 p.m., a
8 luncheon recess was taken.)
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AFTERNOON SESSION

(1:43 p.m.)

LEONARD KONIKOW, PHD

called for continued examination and, having been previously duly sworn, was examined and testified further as follows:

EXAMINATION (CONTINUED).

THE VIDEOGRAPHER: We're back

on the record. The time is 1:43 PM.

BY MR. ANWAR:

Q. Good afternoon, Dr. Konikow.

A. Good afternoon.

Q. Hope you had a good lunch. We are back on the record from a lunch break.

Are you okay to continue?

A. Yes.

Q. Okay. During your lunch break, did you discuss the substance of your testimony with your lawyers at all?

A. No.

Q. Okay. When we left off prior to the lunch break, I had asked you some questions about the Rocky Mountain Arsenal study that you had worked on.

1 Do you recall that?

2 A. Yes.

3 Q. I wanted to ask you. You mentioned
4 that you sat for a deposition related to that
5 work.

6 Do you recall what year that
7 deposition took place?

8 A. No, I don't. It -- I looked to see
9 if I had any records of it, and I couldn't find
10 any. It was probably in the early to mid-'80s.
11 It could have been earlier. It could have been a
12 little later. I don't. I know where it was, but
13 I don't know even what year it was.

14 Q. Where did the deposition take place?

15 A. It was in the Sheraton Hotel in
16 Reston.

17 Q. Oh, in Reston out here.

18 A. Yeah.

19 Q. Okay. Thank you.

20 I wanted to ask you about some of
21 the opinions in your report.

22 So if you want to direct your
23 attention back to Exhibit 2, which is your
24 rebuttal report, and I wanted to start by focusing

1 on page 6 of your rebuttal report, which is
2 Opinion 1.

3 A. Okay.

4 Q. And there, you know, I don't want to
5 read the whole thing, but there -- there you offer
6 some opinions about in response to
7 Dr. Spiliotopoulos, and it concludes by saying, in
8 the third paragraph you say:

9 "Dr. Spiliotopoulos overstates the
10 lack of data for the Camp Lejeune groundwater
11 system."

12 Is it your opinion that
13 Dr. Spiliotopoulos overstated the lack of
14 historical concentration data available for
15 ATSDR's water modeling efforts related to Camp
16 Lejeune?

17 A. Well, that doesn't say concentration
18 data. It says he overstates the lack of data. So
19 I take that mean to all data related to the model
20 including hydraulic data, water data, and he's
21 implying or stating that there is a lack of data.

22 Q. Is it your opinion that there was a
23 lack of historical concentration data available
24 for ATSDR's modeling efforts at Camp Lejeune or

1 related to Camp Lejeune?

2 A. Well, as far as I know, it's factual
3 that there was no data between 19 -- are we
4 talking Tarawa Terrace or the other one or all of
5 them?

6 Q. For concentration -- observed data
7 for concentration levels, let's start with Tarawa
8 Terrace and then Holcomb Boulevard?

9 A. Prior to 19 -- yes, there were no --
10 best of my knowledge, there were no concentration
11 data available prior to 1982.

12 Q. Okay. And you'd agree that the
13 concentration level data for any of the VOCs at
14 issue at Camp Lejeune -- TCE, PCE, vinyl chloride
15 benzene -- prior to 1982 does not exist in terms
16 of real-world data; correct?

17 MR. DEAN: Objection.

18 THE WITNESS: In terms of
19 what?

20 BY MR. ANWAR:

21 Q. So you'd agree that prior to 1982,
22 concentration level data for any of the VOCs at
23 issue at Camp Lejeune -- TCE, PCE, vinyl chloride,
24 benzene -- it doesn't exist?

1 MR. DEAN: Object to the form
2 of the question.

3 THE WITNESS: Well, my answer
4 would be, I don't know for sure that it
5 doesn't exist, but I have not seen any
6 and I saw no reference to any.

7 MR. ANWAR: Okay. I'm going
8 to mark an exhibit.

9 Mark this as Exhibit 12.

10 (Document marked for
11 identification as Konikow Exhibit 12.)

12 BY MR. ANWAR:

13 Q. This is -- so this is Volume II of
14 the transcript from the 2005 ATSDR expert panel.

15 Would you agree with that?

16 A. Yes.

17 Q. Okay. And on the front of
18 the -- the front of the transcript, it states that
19 the meeting review -- meeting peer review panel
20 was held at Century Boulevard in Atlanta, Georgia
21 on Tuesday, March 29, 2005.

22 Do you see that?

23 A. Yes.

24 Q. Okay. And is that consistent with

1 your understanding about when the peer --

2 A. Well, I don't remember the address,
3 but, you know, that seems to be when the meeting
4 was held.

5 Q. Okay. And you don't have any reason
6 to disagree with that; right?

7 A. No.

8 Q. Okay. Now, when you -- when you
9 participated in both the 2005 and the 2009 expert
10 peer review panels, were you aware that the
11 conversations were being transcribed?

12 A. I probably was.

13 Q. Were you aware that these
14 transcripts now exist?

15 A. Yes.

16 Q. And is it fair to assume that
17 whatever discussion that took place both in
18 2000 -- at the 2005 expert panel and the 2009
19 expert panel, those were your -- your honest
20 thoughts at that time?

21 A. I would think so.

22 Q. Okay. You wouldn't have any reason
23 to attend an expert peer review panel and lie or
24 make anything up; right?

1 A. Absolutely not.

2 Q. Okay. So I wanted to have you turn
3 to page 47, and then at the bottom of 47 line 25
4 it starts by saying -- and then it will go on to
5 page 48:

6 "DR. KONIKOW: Well, you have very
7 limited data against which to calibrate your
8 model. Okay. And you know, in the period that
9 you were collecting data, the wells were
10 contaminated. Okay. So if you're going to run
11 the groundwater model, it's a question of how do
12 you get from zero to that level of concentration
13 that you're calibrating. You start with an
14 initial condition of no PCE in 1954. Okay."

15 Did I read that paragraph correctly?

16 A. You read it correctly, yeah.

17 Q. Okay. And when you said, "Well, you
18 have very limited data against which to calibrate
19 your model," those -- those were your words;
20 correct?

21 A. Apparently.

22 Q. Okay. And do you have any reason to
23 disagree with those -- those words?

24 MR. DEAN: Object to the form

1 of the question.

2 And you're also providing
3 him -- not providing the context in which
4 the -- his comments are for the several
5 pages before that.

6 BY MR. ANWAR:

7 Q. Do you have any reason to disagree
8 with what you said?

9 A. (Reviews document.)

10 Well, yeah, they were talking about
11 the calibration. No, I don't disagree with it.

12 Q. And it says "You start with an
13 initial condition of no PCE in 1954" --

14 A. Yeah, that --

15 Q. -- we're talking about Tarawa
16 Terrace; right?

17 A. Yeah. Maybe that should have been
18 '53. I don't remember the time.

19 Q. And then the next paragraph you
20 state:

21 "And then you start your model
22 running. And there's going to be speculation upon
23 assumption built into that, and you'll get a range
24 of responses. My hypothesis or my guess would be

1 that all roads will lead to contamination by 1968.
2 You may want to do the modeling to demonstrate it.
3 Maybe I'm wrong."

4 Did I read that correctly?

5 A. You read it correctly.

6 Q. And you said "there's going to be
7 speculation upon assumption built into that";
8 right?

9 A. That's what it says.

10 Q. What did you mean by "speculation
11 upon assumption built into that"?

12 A. Well, I assume that I was talking
13 about the boundary conditions and other
14 assumptions built into the model. In other words,
15 get the model run, it has to have specific numbers
16 for where fluid comes into the system, where it
17 leaves the system, where solute mass is added to
18 the system and so on.

19 And for the period where there was,
20 you know, no record, you know, that those
21 estimates have to be reconstructed from the best
22 data available.

23 So for recharge to the aquifer, you
24 look at precipitation records and maybe the

1 estimates of soil properties that you could, and
2 you make a reasonable estimate of recharge but,
3 you know, it's not an observation.

4 And, you know, the same with the
5 mass loading. You know, for Tarawa Terrace, they
6 knew where the source was, but, you know, there
7 was no one recording the people dumping the PCE.
8 So you had to make an assumption or approximation
9 about an average rate, and even with an average
10 rate, you don't know the specific rates.

11 It may have been higher one week and
12 lower the next week, and there's no way to get
13 that variability. So you would do your best to
14 estimate long-term average rates.

15 Q. Got it.

16 And in that second paragraph, you go
17 on to state:

18 "My hypothesis or my guess would be
19 that all roads will lead to contamination by
20 1968."

21 Right?

22 A. That's what it says, yes.

23 Q. Okay. And when you said 1968,
24 you're referring to 1968 as the start of the

1 epidemiological study that ATSDR was wanting to
2 perform; right?

3 A. I presume so. Again, this was 20
4 years ago. I don't remember exactly what my
5 thoughts were.

6 Q. And you go on in the third paragraph
7 to say:

8 "But you want -- the only possible
9 outcome that would differ would be a later
10 arrival, and that may be the first few years
11 there's no exposure. I think that's unlikely, but
12 that's what you want to evaluate, and that's
13 probably best -- the best you could hope from --
14 from all of these models."

15 Did I read that correctly?

16 A. You read it correctly.

17 Q. Okay. When I -- when I read this
18 section of the transcript, it -- it appears to me
19 that the question that you're addressing is
20 whether -- in terms of mass loading whether PCE
21 would have contaminated the aquifers by the start
22 of the EPI study.

23 Is that -- is my understanding
24 correct?

1 A. Well, that's my under --

2 MR. DEAN: Object to form.

3 THE WITNESS: I'm sorry. Did
4 you?

5 MR. DEAN: I just --
6 objection.

7 THE WITNESS: Okay. My, you
8 know, understanding at the time and from
9 the preliminary documents I read this, I
10 thought as a reviewer my obligation was
11 to question pretty much everything about
12 the groundwater flow and transport
13 models.

14 I don't think I really thought
15 that there would be an arrival later than
16 1968. I was just giving them a probing
17 question.

18 BY MR. ANWAR:

19 Q. Okay. Do you know for a fact --
20 well, let me -- let me back up.

21 When you say in the third paragraph,
22 "the only possible outcome that would differ would
23 be a later arrival, and that may be the first few
24 years there's no exposure," you're acknowledging

1 there the possibility that the PCE -- that Tarawa
2 Terrace was not contaminated on day one in 1953;
3 right?

4 A. On day one?

5 Q. Yeah.

6 A. I don't know that that's
7 acknowledging it, but I think it -- the first day
8 it's probably not contaminated. It takes time.
9 If they're dumping this in a drain or on the land
10 surface, it takes time to get down to the aquifer.

11 Q. Contaminants, you know, if you're
12 pumping PCE onto a land surface, it doesn't
13 immediately go into the aquifer; correct?

14 A. Correct.

15 Q. It needs to travel through the
16 subsurface; correct?

17 A. Through the unsaturated zone.

18 Q. Okay. Of the subsurface; correct?

19 A. Yes.

20 Q. Do you have any understanding of
21 how -- how long it takes for PCE to travel
22 generally or -- let's start generally.

23 A. You know --

24 MS. BAUGHMAN: Objection.

1 THE WITNESS: -- it's hard to
2 generalize, but it depends on the
3 individual circumstances.

4 BY MR. ANWAR:

5 Q. Was -- did any discussion take place
6 in the context of Camp Lejeune at the expert peer
7 panel -- peer review panel about how long it would
8 take PCE to travel from the ground through --
9 through the subsurface into the aquifer?

10 A. I don't recollect that, but I would
11 expect that the issue was mentioned and discussed
12 somewhere. But I don't recall it.

13 Q. And in your -- in the transcript
14 here, you're saying it could be a few years later
15 after ABC Cleaners started operating; right?

16 A. No, I don't think that's the case.

17 Whatever is said there, I thought
18 that was an extremely unlikely but, theoretically
19 possible, outcome. But, no, I thought from the
20 time they started dumping it, you're talking about
21 days to weeks before it reaches the water table,
22 at most a month or two.

23 I mean, because you're talking about
24 disposable of a dense nonaqueous base liquid.

1 That substance is going to sink pretty fairly --
 2 pretty quickly towards the water table. Some of
 3 it getting dissolved on the way down and, you
 4 know, we're talking mostly about how it's moving
 5 in solution, not as a dense separate phase.

6 Q. Okay. We'll return to mass loading.
 7 If you could turn to -- I think your
 8 might already there, but I'm looking at page 49
 9 line 14 through 19.

10 And it starts "DR. KONIKOW."
 11 Are you with me?

12 A. Yes.

13 Q. Okay.

14 "DR. KONIKOW: But I'm guessing the
 15 outcome is still going to be, from the start of
 16 your epidemiological study to the end, Tarawa
 17 Terrace residents were exposed, which, if you
 18 could support that, it kind of mediates the need
 19 for more refined modeling because it's not going
 20 to yield anything more."

21 Did I read that correctly?

22 A. You read it correctly.

23 Q. And here in -- in the 2005 expert
 24 peer review panel, the focus of the discussion

1 appears to be what you need for the -- the type of
2 information you need for the ATSDR epidemiology
3 -- epidemiological study that was -- was going to
4 be performed; right?

5 A. Well, I think the focus was on the
6 development of the transport model to compute the
7 concentrations needed for that, but I think the
8 focus of the modeling of our discussions that I
9 was commenting on was not the epidemiological
10 studies or the exposure. It was on the transport
11 model. You know, there were comments about the
12 epidemiological study, but that only in the sense
13 of that that's what the results were going to be
14 used for.

15 Q. So, and if we read it again:
16 "But I'm guessing the outcome is
17 still going to be, from the start of your
18 epidemiological study to the end, Tarawa Terrace
19 residents were exposed, which, if you could
20 support that, it kind of mediates the need for
21 more refined modeling because it's going to
22 yield -- it's not going to yield anything more."

23 Those are your words --

24 A. Yes.

1 Q. -- correct?

2 A. Yes.

3 Q. And when you say, "if you could
4 support exposure at the start of the EPI study, it
5 kind of mediates the need for more refined
6 modeling because it's not going to yield anything
7 more than that," what did you mean?

8 A. I'm not sure. Looking at this, I'm
9 not sure what I meant by "more refined modeling."
10 Yeah, I'm not sure. I don't remember.

11 But -- yeah. I don't know. You
12 know, I didn't read carefully the several pages
13 before this to look for context of that comment.

14 Q. Okay. But you're not denying
15 that -- when you say -- scratch. Strike that.

16 When you say "because it's not going
17 to yield anything more than that," what did you
18 mean?

19 A. I assume that it meant it would
20 yield the concentration distributed over time and
21 from that the concentration in the water supply
22 wells and that's -- that's what you'd expect from
23 it.

24 Q. Okay.

1 A. Certainly these models were not
2 going to assess human health effects from these
3 models themselves. That's a totally other
4 different thing that has to be used. But these
5 models provide the input to that type of
6 assessment.

7 Q. I will say, aren't you saying
8 here -- so as an outside observer or someone who
9 didn't participate in this panel, what it looks
10 like you're saying here is that the best that the
11 TT model -- the Tarawa Terrace modeling can do is
12 determine whether the population at Tarawa Terrace
13 would have been exposed or not?

14 MR. DEAN: Object to the form
15 of the question.

16 THE WITNESS: No, that's not
17 what I --

18 BY MR. ANWAR:

19 Q. Because you say --

20 A. -- meant.

21 Q. -- "it's not going to yield anything
22 more than that"?

23 A. I meant the concentration at the
24 location of the water supply wells is I think what

1 I was referring to. By, you know, "more refined
2 modeling," perhaps I meant with a finer grid or a
3 finer time step or something, but, again, I don't
4 recall exactly what I meant by that term.

5 Q. Okay. So it's your testimony today
6 that you have no recollection of what your words
7 here mean?

8 A. Well, I wouldn't say that.
9 The specific term "more refined
10 modeling," I don't recall what I was thinking at
11 that point, but the general gist there I think is
12 still clear and I would agree with.

13 Q. If you were asked to describe a more
14 refined model in present day terms, how does a
15 more refined model compare to a simpler model?

16 A. Well, a more refined model could be
17 solving the same governing equations but do it
18 over a much finer grid with a much better
19 definition of hydraulic properties.

20 Hydraulic properties is something
21 you don't have to go back in time to get because
22 they remain constant in time. So you could drill
23 more wells, get more pumping tests, get a better
24 definition, maybe use a new geophysical method,

1 get a better definition of the porosity
2 distribution, and that would be a more refined
3 model with possibly smaller grid spacing and
4 better definition of hydraulic parameters.

5 A more refined model might be one
6 that includes more processes that weren't included
7 in the transport model. I'm not sure what exactly
8 that would be, but maybe instead of using a
9 retardation factor, it tried to represent the
10 actual chemical and biogeochemical processes more
11 accurately than the simplified approximation of
12 using the retardation factor.

13 So you could have a more refined
14 model in terms of the processes that affect the
15 concentration as it's being transported, but, you
16 know, the use of a retardation factor is a common,
17 standard way of simplifying all the reaction
18 terms.

19 Q. When -- when you start developing a
20 new model, do you start with a more refined model
21 or do you start with a simpler model and then
22 build towards a more refined model?

23 A. Well, we try to start as, you know,
24 after we build the conceptual model of what's

1 going on, we'll try to build as simple as possible
2 and see if we need to, you know, refine the grid
3 spacing, add more processes, anything like that.

4 So yeah, general rule is, you know,
5 you develop a conceptual model about what the
6 governing processes are, what needs to be
7 considered, and then you develop a model.

8 You discretize it at some grid
9 spacing that seems reasonable based on your
10 judgment and experience, and you assess whether or
11 not that's adequate one way or another, usually
12 through numerical experiments. And if it's not,
13 use a finer grid, and if it's adequate, you either
14 stick with it or maybe even based on computational
15 efforts you might decide to use a coarser grid to
16 reduce the computational time.

17 Q. Does the term -- and I may -- may
18 mispronounce this, but does the term "parsimony"
19 mean anything to you?

20 A. Parsimony.

21 Q. Parsimony?

22 A. Yeah. It's basically a fancy way of
23 talking about the simplicity or complexity of the
24 model. Parsimony implies you use the simplest

1 possible approach. You want a parsimonious model.

2 Q. Okay. Why is that?

3 A. Well, the more complex a model is,
4 the harder it is for the modeler and the analyst
5 to understand what the model is doing. And you
6 want to -- it's obviously better if you understand
7 what the model does. The simpler the model is,
8 the more you can understand what is going on in
9 the model mathematically.

10 If you have a multitude of reaction
11 terms and transport terms and all in the same
12 model and something unexpected happens or
13 something showing up, you're not sure exactly why
14 that's happening. There's too many things to do,
15 to look at.

16 So, you know, you always want to use
17 the simplest possible model, but the difficulty is
18 always assessing how do you know that it's not too
19 simple. And there's judgment calls in there and
20 discussions with colleagues and so back and forth.

21 It's not just a perfectly objective
22 type of assessment. You need some judgment calls
23 and decisions as to what level of complexity to
24 build in. It's not necessarily that one is wrong

1 or one is better, but sometimes there's, you know,
2 in modeling, particularly in the older days, there
3 was always a trade-off with computer resources
4 because you were much more limited 20, 30 years
5 ago in terms of computer capabilities than you are
6 today. So that always factored into it in terms
7 of efficiency versus, let's say, complexity and
8 accuracy.

9 Q. Okay. In terms of adding complexity
10 to a model, are there circumstances under which
11 adding complexity to a model could increase the
12 uncertainty or decrease the accuracy of the model?

13 A. I suppose. I mean, if you add more
14 and more processes, then you're going to require
15 more and more parameters that need to be defined.
16 And if you don't have good ways to measure those
17 parameters, then you're in effect adding more
18 uncertainty even though you're representing more
19 processes.

20 So it's not always a good thing to
21 do, and, again, it may mask what's really
22 happening in terms of what's causing things to
23 happen.

24 Q. Okay. Thank you.

1 On page 7 of your rebuttal report,
2 Exhibit 2. I'm going to be jumping --

3 A. What page?

4 Q. It's --

5 A. 7?

6 Q. I'm going to be jumping back and
7 forth between your rebuttal report and probably
8 the transcript. So it might be good to have both
9 side by side or -- or I can tell you. Let me do
10 it this way.

11 There is a reference in your report,
12 it's in Opinion 2, where you mention that
13 Dr. Spiliotopoulos -- Spiliotopoulos says that the
14 results are conservative. You said:

15 "Dr. Spiliotopoulos says this
16 results in conservative estimates of estimated
17 monthly contaminant concentrations. It is not
18 clear what is meant by 'conservative' or why that
19 is not a good trait. He also says the results are
20 biased high."

21 If you'd like to read it, it's in
22 Opinion 2 page 7.

23 But do you recall that portion of
24 your opinion?

1 A. Yeah, I'm looking at it now. Yes.

2 Q. Okay. And so if you go back to the
3 transcript that we were just looking at, the 2005
4 transcript.

5 A. Yeah.

6 Q. On page 49. You question in your
7 report:

8 "It is not clear what is meant by
9 'conservative' or why that is not a good trait."

10 And right after 14 and 19, the
11 discussion we were just having about your
12 comments, Mr. Maslia responds:

13 "Then from the standpoint of being
14 conservative from a public health standpoint,
15 let's assume we refine our groundwater
16 understanding and we get" -- and then he goes on.

17 When we're talking about -- sort of
18 as reflected in Mr. Maslia's statement there, when
19 we're talking about conservative in terms of
20 ATSDR's Camp Lejeune modeling, we're talking about
21 from a public health standpoint; right?

22 MR. DEAN: Object to form.

23 THE WITNESS: I -- I don't
24 recall what he was talking about, but he

1 says "from a public health standpoint."

2 BY MR. ANWAR:

3 Q. What does "conservative" mean to you
4 from a public health standpoint?

5 A. To me that implies being very
6 careful and safe on what you're doing and not
7 going beyond the basis of the data and supporting
8 modeling studies. You know, it could mean other
9 things.

10 Q. Would you agree that conservative
11 from a public health standpoint could mean being
12 health protective?

13 MR. DEAN: Object to the form.

14 THE WITNESS: I'm -- yeah,
15 you know, I'm not a health expert or an
16 epidemiologist. So I'm not sure what
17 common usage of that means, but that
18 sounds okay.

19 BY MR. ANWAR:

20 Q. Because, I mean, we've discussed
21 this.

22 The modeling was being used for --
23 to produce information for an EPI study; right?

24 MR. DEAN: Object to form of

1 the question.

2 THE WITNESS: Yeah.

3 MR. DEAN: You asked 122.

4 BY MR. ANWAR:

5 Q. Okay. And from a public health or
6 safety standpoint, wouldn't you err on the side of
7 making assumptions and using inputs that you
8 consider sort of results of exposure that's at
9 greater risk to the public?

10 A. I guess I think I need a more
11 specific example, but maybe repeat the question.

12 Q. So, for instance --

13 A. Yeah.

14 Q. -- we were talking about mass
15 loading a moment ago; right?

16 A. Yeah.

17 Q. And there was a question whether
18 mass loading started on -- for Tarawa Terrace
19 whether it started in 1953, the day that ABC
20 Cleaners opened; correct?

21 A. Yeah.

22 Q. Okay. And I think at least in the
23 passage that we discussed, there was a discussion
24 about whether or not the mass could have

1 traveled -- it would have taken a couple years for
2 the mass to travel through the aquifer so that --

3 A. To where?

4 Q. In Tarawa Terrace. The mass. We're
5 talking about the Tarawa Terrace model.

6 A. To travel from where to where?

7 Q. From the dumping on the ground from
8 the dry cleaner to the subsurface into the
9 aquifer.

10 A. No, we did not say.

11 I said that it would probably take
12 days to weeks, maybe a month or two. That's what
13 I would -- that I would estimate was the travel
14 time from disposal by the dry cleaners into the
15 land surface until it reaches the water table,
16 which I would think was on the order of 20 feet
17 below the land surface.

18 Q. Okay. Let's -- let's take what
19 you're saying out. We'll return to your
20 statements.

21 But let's say, for instance, the
22 question was whether you decide the concentration
23 started mass loading immediately into the aquifer
24 in 1953 or 1960.

1 And if you were deciding between
2 those two start dates, from a public health
3 standpoint, isn't it more health protective to
4 assume -- to assume more people were exposed than
5 less to protect those people?

6 MR. DEAN: Object to form.

7 THE WITNESS: I'm not
8 qualified to answer that.

9 But what I will say, from the
10 perspective of the model, being
11 protective of public health really should
12 not enter into your assessment of mass
13 loading, hydraulic properties, or
14 anything else related to the model should
15 not be influenced by any perception of
16 health effects. That would not be sound
17 application of groundwater modeling.

18 BY MR. ANWAR:

19 Q. And are you saying that -- well, why
20 not?

21 A. The development of a groundwater
22 model should be based on your understanding of the
23 hydrogeologic framework of the boundary
24 conditions. Mass loading is one type of boundary

1 condition, and it should be based on
2 hydrogeological and hydrochemical evidence.

3 You know, basically I don't see why
4 you would, you know, in developing, doing your
5 best scientific engineering efforts to develop a
6 sound model, a reliable model, what you put into
7 that data set of input parameters, or input data
8 sets, should reflect your understanding of the
9 aquifer system and the stresses on it.

10 And it should not -- that by itself
11 should not be influenced by what you think the
12 outcome might be or how you might protect human
13 health. Protection of human health is not a
14 component of groundwater modeling.

15 Q. Are you saying that ATSDR, as a
16 public health agency and performing this -- this
17 modeling related to Camp Lejeune, didn't account
18 for protecting human health?

19 MR. DEAN: Object to the form
20 of the question.

21 THE WITNESS: In my mind and
22 in my recollection of everything that was
23 described, there was an impartial
24 scientific objective assessment to get

1 the best estimates of the input
2 parameters, and I could -- I did not see
3 any evidence that the selection of
4 parameters, boundary conditions, initial
5 conditions were influenced by ATSDR's
6 health mandates.

7 BY MR. ANWAR:

8 Q. Why would a public health agency
9 perform groundwater modeling for estimating
10 contaminant concentrations without considering its
11 mission to protect public health?

12 MR. DEAN: Object to the form
13 of the question.

14 THE WITNESS: I would hope
15 that they would want to get the best
16 possible scientific estimate of how those
17 contaminants move through the ground.

18 The estimate of the truth --
19 and, again, it's clearly estimating what
20 had happened historically -- is what
21 needs to be known.

22 They don't need to know an
23 estimate that would be protective of
24 human health. They need an estimate of

1 what actually happened.

2 BY MR. ANWAR:

3 Q. Okay. Based on this conversation
4 that we've been having, are there any parameters
5 that you would consider undesirable? Let's start
6 generally.

7 A. Undesirable with respect to what?

8 Q. Well, let me strike that.

9 Are there any parameters that in
10 evaluating ATSDR's water models that you
11 determined to be undesirable?

12 A. Again, I'm not sure what you mean by
13 "an undesirable parameter."

14 I mean, there are parameters in the
15 model which basically reflect coefficients in the
16 governing equations. They're all there because
17 it's believed they're part of the governing
18 processes. So a characteristic of desirability
19 just is inappropriate and irrelevant.

20 Q. Now, I want to turn back to the
21 opinion or critique you offered of
22 Dr. Spiliotopoulos in terms of overstating the
23 lack of historical concentration data available.

24 Could you please turn to page 193 of

1 the transcript that you're looking at.

2 A. This is from the 2005? Volume II
3 from 2005?

4 Q. Correct.

5 A. Repeat the page.

6 Q. 193.

7 A. 193?

8 Q. Correct.

9 A. Okay.

10 Q. And in the middle of the page
11 starting at line 11, you're sort of concluding --
12 it's towards of the panel. You can see the
13 transcript. It's towards the end of the
14 transcript.

15 "DR. KONIKOW: Well, again, I second
16 all the comments that have been made up to now. I
17 again just reiterate what the groundwater modeling
18 and the transport modeling that ultimately we're
19 limited in what we can do in terms of the
20 available data. I mean, you know, we don't have
21 concentration data before 1980 or '82, and so
22 everything we do for looking at distribution
23 before then is going to be a little fuzzy."

24 Did I read that correctly?

1 A. Yes.

2 Q. And those are your words; right?

3 A. Yes.

4 Q. What did you mean by "and so
5 everything we're going we do" -- so -- strike
6 that.

7 What did you mean by "and so
8 everything we do for looking for at distribution
9 before then is going to be a little fuzzy"?

10 A. Talking about before 1982 or so, the
11 period in there. That the modeling -- when I say
12 a little fuzzy, but what that means is you're
13 going to make some prediction, decide, you know,
14 your best calibration, your best fit.

15 But you have to recognize that
16 there's confidence limits about that and there may
17 be a band of uncertainty and that you have to, you
18 know, assess that and consider that and, you know,
19 not take the one prediction of mean as the gospel,
20 but you have to consider -- and this is some of
21 the things that ATSDR did.

22 They present many graphs with a band
23 about their best fit calibration, and this is a
24 way to reflect -- well, I use the term "a little

1 fuzzy," which is not really a scientific term but,
2 you know, it recognizes that you have to -- that
3 there's uncertainty in the estimate. There's
4 uncertainty in the results. Your best fit model
5 gives you, you know, a precise estimate, but you
6 have to recognize that it could be above it or
7 below it.

8 Q. And --

9 A. And I think that's kind of the
10 consideration of that was followed with good
11 practices by ATSDR and presented their results
12 clearly showing, well, in that term "fuzziness"
13 but they really showed a band about the estimate
14 for different sources of uncertainty.

15 Q. And there's uncertainty in the
16 results prior to '82 because, as you say there,
17 "we don't have concentration data before 1980 or
18 '82"; right?

19 MR. DEAN: Object to the form
20 of the question. I'm not sure what the
21 question was.

22 BY MR. ANWAR:

23 Q. Correct?

24 A. We have a very, I believe, high

1 confidence at the start of the period that there
2 was initial conditions and initial concentrations
3 that were, zero and then we have no data until
4 about 1982 or so, and so that's what the model was
5 used to reconstruct how that might be.

6 And the model basically is saying
7 that there are certain processes we know govern
8 the fate and transport of dissolved constituents
9 and the movement of groundwater, and the way we
10 make our estimation or calculation of the
11 concentration there, we do it in a way that is
12 consistent with everything we know about the
13 physics.

14 Q. You just described uncertainty, and
15 I just want to confirm.

16 That uncertainty exists because
17 there isn't concentration data before 1982?

18 A. It exists for more reasons than
19 that. It exists because the uncertainty in the
20 definition of the hydraulic conductivity. There's
21 some uncertainty in porosity. There's some
22 uncertainty -- well, every parameter there's some
23 uncertainty. Nothing is known exactly.

24 The KDs and RFs, the retardation

1 factor, these are all engineering approximations
2 for the processes that in reality are much more
3 complex. They're not a true and precise
4 representation of all the processes that that
5 causes.

6 It's an engineering process
7 that -- approximation that is very common in
8 modeling and very well accepted and it's almost,
9 you know, it's there because it's a necessity. It
10 helps keep the model as simple as possible. It
11 keeps you towards parsimony, but we know it's an
12 approximation.

13 The real processes that control
14 retardation are probably nonlinear, they're not
15 instantaneous, and they vary in space and they
16 could vary in time. If you look at a retardation
17 factor or a KD for one constituent, it may
18 actually depend and vary depending on the
19 concentration of a different constituent.

20 And, you know, all these -- none of
21 those complexities are incorporated into the RF or
22 into a KD. So they're simple -- simplifying
23 approximations, and that's what we do in effect to
24 some degree or another with everything in the

1 model.

2 MR. ANWAR: Understood. Thank
3 you.

4 Give me one second. I'm going
5 to grab a document.

6 Let's go off the record for
7 one second.

8 THE VIDEOGRAPHER: We're going
9 off the record. Time is 2:28.

10 (A recess was taken.)

11 THE VIDEOGRAPHER: We're back
12 on the record. The time is 2:45 PM.

13 BY MR. ANWAR:

14 Q. We're back on the record after a
15 very short break.

16 Thank you for bearing with me,
17 Dr. Konikow.

18 I am handing you -- well, are you
19 okay to continue?

20 A. Yes.

21 Q. And did you speak about the
22 substance of your testimony with your --

23 A. No.

24 Q. Okay. With your lawyers during the

1 break?

2 A. With what?

3 Q. With your lawyers during the break?

4 A. No.

5 MR. ANWAR: Okay handing you
6 what's being marked as Exhibit 13.

7 (Document marked for
8 identification as Konikow Exhibit 13.)

9 BY MR. ANWAR:

10 Q. And sort of still on the topic of
11 Dr. Spiliotopoulos's -- well, still on the topic
12 of your criticism about Dr. Spiliotopoulos's
13 -- Spiliotopoulos's statement on the lack of
14 historical data, I've handed you the expert panel
15 summary from 2009.

16 Would you agree with that?

17 A. Yes.

18 Q. Okay. The title on the document is
19 "Expert Panel Assessing ATSDR's Methods and
20 Analyses for Historical Reconstruction of
21 Groundwater Resources and Distribution of Drinking
22 Water at Hadnot Point, Holcomb Boulevard, and
23 Vicinity, U.S. Marine Corps Base Camp Lejeune,
24 North Carolina."

1 Did I read that correctly?

2 A. Yes.

3 Q. And the date of the expert panel is
4 identified -- the 2009 panel as April 29 to 30,
5 2009; correct?

6 A. Yes.

7 Q. Okay. So I'd like you to turn to
8 page 99.

9 Page 99 is labeled "Appendix E" to
10 this, the expert panel summary that I just
11 handled -- handled -- handed you.

12 Do you see that there?

13 A. Yeah.

14 Q. Okay. And it -- I'll represent to
15 you that it appears to be comments submitted by
16 you. I'm not sure if it was before or after the
17 expert panel.

18 Do you recognize this document?

19 A. My recollection is that these were
20 questions submitted before the panel before we
21 met.

22 Q. Okay.

23 A. And the answers were prepared before
24 we met, not with all the information given at the

1 panel.

2 Q. Okay. And so I wanted to turn your
3 attention to the middle of the page -- page
4 starting "CHARGE TO PANEL" in all bold.

5 Do you see that there?

6 A. "CHARGE TO PANEL"? Yes.

7 Q. Okay. And the question is: "Do the
8 data analysis and computational methods provide an
9 adequate level of accuracy and precision?"
10 Correct?

11 A. Yes.

12 Q. Okay. And your comment there
13 states:

14 "The approach taken appears to be
15 quite reasonable, as far as can be told from the
16 available information and with exceptions noted or
17 discussed below, but indeed the level of accuracy
18 and precision may still not be adequate because of
19 the paucity of data and complexity of contaminant
20 sources during the time period when the history is
21 to be reconstructed."

22 Did I read that correctly?

23 A. Yes.

24 Q. Okay. And then you go on to say:

1 "The adequacy will depend in large
2 part on the reliability and soundness of the
3 groundwater flow and transport models that will be
4 developed (but which have not been adequately
5 described in the reviewed documents). As noted in
6 comments below, the approach used to estimate
7 reaction rates appears to lack a firm theoretical
8 basis for providing confidence in the accuracy and
9 precision of calculated values."

10 Did I read that correctly?

11 A. You read it correctly.

12 Q. Okay. And these are your words;
13 correct?

14 A. Apparently.

15 Q. And you said you submitted this
16 before -- these -- these comments before the
17 panel -- expert panel in 2009?

18 A. Before we met, yes.

19 Q. Okay. And they were specifically in
20 response to questions that were issued before you
21 met for the 2009 panel?

22 A. As I recall, before we met, they
23 sent us a short list of -- I don't remember --
24 four, five, six questions that they requested we

1 answer as best we could based on the knowledge we
2 had. And I think they had sent us some documents
3 to review ahead of time, but it was not a
4 comprehensive presentation of everything done at
5 the site.

6 Q. Do you recall what documents they
7 sent you to review ahead of time?

8 A. I do not.

9 Q. This summary report was published
10 after the expert panel had taken place, though;
11 right?

12 A. Yes.

13 Q. Okay. And your comments were
14 attached as an appendix; correct?

15 A. Apparently, yes.

16 Q. Okay. And so in that first
17 sentence, you say:

18 "But indeed the level of accuracy
19 and precision may still not be adequate because of
20 the paucity of data and complexity of contaminant
21 sources during the time period when the history is
22 to be reconstructed."

23 When you say "the level of accuracy
24 and precision may still not be adequate because of

1 the paucity of data," what do you mean by "paucity
2 of data"?

3 A. I think -- and, again, this is from
4 15 years ago. I think I was referring to the
5 source terms and the lack of observed
6 concentration values in the, you know, 30-year
7 period or so.

8 But the source term, you know, is an
9 obvious, important characteristic for the model or
10 probably for the model parameter. And it was
11 clear that for the Hadnot Point/Holcomb Boulevard
12 area, there were many more sources -- potential
13 sources of contamination than there were for the
14 previous Tarawa Terrace -- Tarawa Terrace models.

15 And I thought that added more
16 complexity and uncertainty to the -- what would be
17 the overall model results.

18 Q. Do you recall how many sources there
19 were for Hadnot Point/Holcomb Boulevard?

20 A. I thought there were tens of
21 potential sources, dozens of sources, individually
22 numerous storage tanks, industrial areas where
23 things were going on, different buildings had
24 different activities. There were just a multitude

1 of potential sources.

2 Q. The last sentence in that paragraph:

3 "As noted in comments below, the
4 approach used to estimate reaction rates appears
5 to lack a firm theoretical basis for providing
6 confidence in the accuracy and precision of the
7 calculated values."

8 What did you mean by that?

9 A. I don't recall. I assume the
10 "reaction rates" is referring to either absorption
11 reactions and/or the degradation term. I don't
12 recall what exactly I meant there.

13 Q. If you turn the page to page 100,
14 there is a second question there that starts with
15 an ellipses "reconstructing historical contaminant
16 concentrations."

17 Do you see that there?

18 A. Number 2?

19 Q. Yes.

20 A. I see it.

21 Q. Okay. And 2a there states
22 "anticipated data analysis and model modeling
23 complexities?"

24 That was the question; right?

1 A. I guess, yeah.

2 Q. And your response there:

3 "Overall, the task at hand is an
4 enormously difficult and challenging one, and
5 there are numerous difficulties confronting a
6 successful completion. There are numerous sources
7 of uncertainty both in the data analysis and the
8 modeling results. Attempts should be made
9 throughout the course of the project to quantify,
10 as well possible, the degree of uncertainty in
11 each stage of the work. In the transport
12 modeling, the issue of estimating the appropriate
13 magnitude of the dis --

14 A. Dispersivity.

15 Q. -- dispersivity -- thank you --
16 coefficients is a difficult one for which there is
17 no simple answer or standard. This will certainly
18 be clouded by the use of the finite-difference
19 solution method in the MT3D transport model, and
20 the effects of numerical dispersion on calculated
21 early arrivals and breakthroughs, as well as on
22 peak concentrations, must be carefully considered
23 and evaluated, and alternative solution methods
24 and discretizations considered."

1 Did I read that correctly?

2 A. You did.

3 Q. Can you elaborate a little bit here
4 on what you meant by "the task at hand is an
5 enormous -- enormously difficult and challenging
6 one, and there are numerous difficulties
7 confronting a successful completion"?

8 A. Well, you know, I think in any
9 groundwater model, flow model or transport model,
10 that's ever been developed, they face an
11 enormously difficult challenge in representing the
12 hydrogeologic framework in a mathematical way, as
13 well as defining all the stresses on the system
14 and so on.

15 In that sense, all the problems I
16 faced here are problems that every groundwater
17 model ever made over real system faces the same
18 challenges. The degree of data available just
19 varies.

20 I emphasize again that my answers to
21 these questions were done before we had any
22 presentation by the technical people at
23 ASTDR -- ATSDR on what they actually did.

24 We had some preliminary draft

1 documents, which I don't recall what they were,
2 but these answers that are prepared were prior to
3 receiving any feedback or any answers on the
4 questions.

5 So I had questions, but this was
6 before I got any answers, but these are all issues
7 that every modeler -- groundwater modeler always
8 faces.

9 You know, here, particularly at the
10 Hadnot Point, there was, you know, probably a more
11 complex set of source terms than in many studies,
12 not in all studies but in many problems.

13 Any specific comment you want me to
14 address in a little more detail?

15 Q. Sure.

16 Before I ask you about specific
17 comments you made, I think you stated that every
18 groundwater model faces sort of these challenge.

19 Does every groundwater model
20 estimate contaminant concentrations that are now
21 used -- that are now being attempted to be used to
22 determine exposure on individuals?

23 A. I doubt it but, you know, again,
24 that end use of the modeling results really should

1 not influence the development of the model to any
2 degree. The model -- the people who develop
3 groundwater models are going to look at the
4 hydrogeologic framer, the stressors, all the
5 parameters in the model and do the best possible
6 job they can to define the input data.

7 And the definitions of the input
8 data for the model should not be affected by what
9 they perceive as the ultimate use of the model,
10 and many descriptions of groundwater models in the
11 literature describe the groundwater model, the
12 reliability, sensitivity, all of those things, but
13 they very often do not describe what the model
14 results may have been used for by other people.

15 Q. I understand that you're saying now
16 that the -- the model results really -- and you
17 should correct me if I'm misunderstanding your
18 testimony.

19 What the model results are used for
20 are really not relevant to performing the model;
21 is that right?

22 A. They're all -- they're only relevant
23 to the extent that you want to make sure the model
24 will yield results that are relevant to the people

1 paying for the model development.

2 In other words, if you know they're
3 going to use it for health studies based on what
4 you predict in the -- the concentration history in
5 water supply wells, if that's, you know, what it
6 will be used for, then you want to, you know, kind
7 of make sure anything related to that gets special
8 emphasis in being as reliably estimated as
9 possible.

10 So it's just a very general sense
11 that that would have feedback into the model but,
12 you know, in general, the standard of practice in
13 developing a groundwater model anywhere is you
14 make your best effort at every parameter that goes
15 into it.

16 But where it might influence, well,
17 if you know this, then you might say, we have to
18 drill a couple more wells or we have to invest
19 more money and, you know, that kind of feedback
20 that you would do to do a better study.

21 But if you don't have that
22 opportunity to, you know, spend another five years
23 drilling test wells and so on, you do the best you
24 could and that's the standard. Do the best you

1 could based on your understanding and knowledge of
2 the principles, the governing equation, and the
3 mathematics.

4 Q. Okay. And the reason I was asking
5 that was because sort of going back to the section
6 Chapter 20 of your -- your book chapter, in the
7 section discussing model design development and
8 application, the first sentence of that section
9 is:

10 "The first step in model design and
11 application is to define the nature of the problem
12 and purpose of the model."

13 Isn't that right?

14 A. That's what I said. I still think
15 that's reasonable.

16 Q. So when you're designing a model,
17 isn't it unreasonable to -- to divorce how the
18 results of the model will be used from the
19 developing the actual model itself?

20 A. Well, you don't want -- you don't
21 want to divorce it in the sense of being totally
22 ignorant of what it is. Because that may
23 affect -- if you know the model will be used and
24 the results will rely on your estimates of

1 concentration in a water supply well, you're going
2 to design your grid, your spatial discretization
3 grid for the model to make sure it's fine enough
4 around those observation -- around those water
5 supply wells to feel that you will get a
6 reasonably accurate result in those water supply
7 wells.

8 Whereas, if your purpose is to look
9 at regional flow and what might get into the river
10 at the end, you wouldn't worry so much about
11 having to find enough grid around the supply
12 wells. You'd be okay instead of 50 feet okay 200
13 feet, you know, things like that.

14 So in the sense of being aware of
15 the use of it, you want to know what the
16 ultimate -- the end users need and what they're
17 going to need, and that certainly can affect how
18 you design the model.

19 It should not influence your
20 selection of parameter values. It should not
21 influence your selection of boundary, but it might
22 influence your grid space and your time step. You
23 know, if -- if the end user only is interested in
24 how things change on a yearly basis, well, then

1 you use annual time steps. If they're interested
2 in a monthly basis, you might use monthly time
3 steps. So in that sense, it affects how you
4 design the model.

5 Q. Understood.

6 So turning to -- back to the 2009
7 expert summary comments, your comments, 2b there
8 says:

9 "Which modeling methods do panel
10 members recommended ATSDR use for reliable monthly
11 mean concentration results for exposure
12 calculations?"

13 Your comments are:

14 "The proposed modeling methods
15 appear to be quite reasonable and appropriate to
16 the task, although given the complexity and the
17 uncertainty in the underlying database, there is
18 no guarantee about the accuracy and reliability of
19 the results; those will need to be assessed as the
20 work progresses. Within the broad framework of
21 using MODFLOW and MT3D, details of the approach
22 and implementation must be carefully evaluated,
23 and alternatives considered, to assure the maximum
24 chance of achieving reliable results."

1 Did I read that correctly?

2 A. You did.

3 Q. Okay. And what did you mean there
4 by, although in the first sentence, "The proposed
5 method -- the proposed modeling methods appear to
6 be quite reasonable and appropriate to the task,"
7 and then you go on, "although given the complexity
8 and uncertainty in the underlying database, there
9 is no guarantee about the accuracy and reliability
10 of the results"?

11 What did you mean by "the complexity
12 and the uncertainty in the underlying database"?

13 A. Well, I mean, I think we've said
14 this several times already that there's a period
15 in which there were no observations of
16 concentration over a period of a number of years
17 until the early '80s.

18 The hydrogeologic framework
19 everywhere always has uncertainty in it for every
20 case, not just Camp Lejeune.

21 There's multiple sources, you know,
22 it's a complex subsurface environment. For the
23 Hadnot Point, you had very complex source terms,
24 at least in the sense that they were in many

1 areas, and there were no direct observations that
2 I recall of what leaked when. They had to make
3 assumptions.

4 And I was just, you know, again,
5 this is before we had the presentations, and I was
6 cautioning, you know, be careful, be as accurate
7 as possible, evaluate the uncertainty and, you
8 know, consider alternative approaches and
9 alternative considerations.

10 It was just these are just, you
11 know, good general warnings and guidelines for any
12 important modeling project, and, you know, this
13 was before I heard what they did or saw their end
14 results.

15 Q. Okay. So is it your testimony that
16 your -- so we've looked at a number of statements
17 from the 2005 transcript, as well as now the 2009
18 expert panel summary document where you raised --
19 you pointed to the lack of historical data and
20 questioned -- raised questions about uncertainty
21 and whether accuracy could be obtained.

22 And you've noted that this was
23 before you actually sat through the 2009 expert
24 panel.

1 Do you no longer hold the concerns
2 that are reflected in all, you know, in your own
3 words in the transcripts and in the summary
4 documents?

5 A. Some of my concerns -- all my
6 concerns, I mean, these, all the issues that were
7 brought up were responded to. I had concerns
8 about numerical dispersion because in the MT3D
9 model they used a central finite-difference scheme
10 to solve the governing equations.

11 The reason for doing this is that
12 that's much more numerically efficient computer.
13 The simulations will take less real time with the
14 finite-difference method than with the TVD method,
15 and so I cautioned them to assess alternatives and
16 be aware of the numerical dispersion as a
17 possibility.

18 And I saw in the later reports that
19 they followed up on that, and they did testing and
20 they compared it with a method of characteristics
21 model and with a TVD model. And these refer to
22 just the specific numerical methods used to solve
23 the solute transport equation. That's a governing
24 equation. There's nothing different in the

1 equation.

2 So just alternative numerical
3 methods that were available at that time, and
4 they -- they, I guess, took my advice and they
5 made assessments. And I looked at the results,
6 you know, later on or recently reviewing the
7 documents, and I was very impressed at how little
8 difference it made.

9 Everything I saw. So. Oh, sorry.
10 Okay. I was drifting off the record.

11 Q. Okay.

12 A. Everything I saw showed that there
13 was negligible effect of the solution method,
14 indicating that numerical dispersion was not a
15 problem.

16 Q. When you say after sitting through
17 the expert panel and when you looked at the final
18 product again that they addressed your concerns.

19 When did you look at the final
20 reports again?

21 A. The final reports were -- I don't
22 know -- sometime after 2013, whenever they were
23 published, but I, you know, I looked at them again
24 in the last month or two. I don't remember

1 exactly when I first saw the final products.

2 Q. So you looked at -- you looked at
3 the reports again after you had been retained as a
4 litigation expert; correct?

5 MR. DEAN: Objection to the
6 form.

7 THE WITNESS: You mean
8 recently I've --

9 BY MR. ANWAR:

10 Q. Correct.

11 A. Yes, I -- I looked at every one of
12 the reports for both Tarawa Terrace and Hadnot
13 Point. I read -- reread some of them in more
14 detail and more slowly and some of them in less
15 detail less slowly, but I did go every one of
16 them.

17 Q. Is there any document or anything
18 that you can point to reflecting that your
19 concerns that you raised at the expert panels and
20 that's reflected in the summary -- the summary
21 report, is there any document you can point to
22 prior to your retention as an expert reflecting
23 that the concerns had been addressed?

24 A. Yeah. I think the content is in the

1 reports, that they did tests for grid spacing to
 2 look at the possible effects of oscillations and
 3 numerical dispersion in the solution. They -- I
 4 don't remember which report it's in, but I did
 5 -- I do recall seeing it that they tested it and,
 6 you know, there was not a problem there in terms
 7 of any substantive effect on the accuracy of the
 8 solution with the method that they did use. And
 9 I'm talking about the numerical accuracy of the
 10 solution.

11 Q. I guess what I'm asking --

12 MS. BAUGHMAN: Wait. Were you
 13 finished?

14 THE WITNESS: I was going to
 15 say a little more but, you know, --

16 MR. DEAN: Go ahead.

17 THE WITNESS: -- I was
 18 essentially finished.

19 BY MR. ANWAR:

20 Q. Go ahead if you'd like to say
 21 anything more.

22 A. Well, and I can't remember, again,
 23 where it was but, you know, the whole issue of
 24 numerical dispersion as it might be influenced by

1 a Courant number being exceeded or a Peclet number
2 being exceeded. These are one of the ways to look
3 at it and control to make sure your grid spacing
4 and time stepping is not so big that it creates
5 inaccuracies in the solution and, you know, I
6 raised it as a question.

7 I didn't know that. I had no
8 assessment that there were numerical deficiencies
9 there, but I raised it as a question. They
10 addressed it. It's in described in some of the
11 reports -- I don't remember which ones -- and
12 everything looked fine.

13 They describe that their Courant
14 number was consistently less than 1 and the Peclet
15 number consistently less than 2, and these are
16 kind of standard criteria that you want to see met
17 in solving the transport equation for groundwater.

18 Q. I guess what I'm asking is: Can
19 you -- can you point to any document or anywhere
20 where you expressed that your concerns had been
21 addressed prior to your retention as an expert in
22 this litigation?

23 MR. DEAN: Objection to the
24 form.

1 THE WITNESS: Where I -- you
2 mean where I said they were addressed?

3 BY MR. ANWAR:

4 Q. Correct.

5 A. No. I mean, I felt they were
6 addressed, but I would have no reason to write
7 that anywhere once my service on the panel was
8 done.

9 Q. And --

10 A. Which was done after my service on
11 the panel that they prepared, and so I was never
12 asked for anything until I was hired for this
13 litigation.

14 Q. And now your feelings are reflected
15 in your -- your rebuttal expert report; is that
16 right?

17 A. No. My rebuttal report is
18 commenting on Spiliotopoulos and Hennet's report.
19 It's not commenting on my original concerns.

20 Q. Okay. I noted that in a number of
21 places -- well, let me start.

22 I want to turn your attention back
23 to your -- your rebuttal report, and on page 2
24 sort of the end of your Introduction section, you

1 state:

2 "I hold these opinions to a
3 reasonable degree of scientific certainty."

4 A. At the top of the page?

5 Q. Correct.

6 Do you see that?

7 A. Yeah. Yes, I do.

8 Q. And my question is to you: What do
9 you mean there by a "reasonable degree of
10 scientific certainty"?

11 MR. DEAN: Object to the form.

12 It calls for legal conclusion.

13 THE WITNESS: Well, let me

14 read --

15 BY MR. ANWAR:

16 Q. Sure.

17 A. -- the background.

18 (Reviews document.)

19 Okay. I think to summarize what I
20 meant is that the opinions I express in here in
21 terms of critiques or reviews of what was said in
22 those expert reports, I stand behind them. I
23 think there's a scientific basis for my comments
24 and they're based on my, you know, 50 years of

1 experience as a hydrogeologist and groundwater
2 modeler and that, yeah, I stand behind these
3 opinions that are in this report.

4 Q. Okay. Are you opining that the
5 simulated monthly contaminant concentrations
6 produced by the two ATSDR models, Tarawa Terrace
7 and Hadnot Point/Holcomb Boulevard, are accurate
8 to a reasonable degree of scientific certainty?

9 MR. DEAN: Object to the form.

10 THE WITNESS: I -- I think
11 they're accurate to a reasonable degree.
12 I think they're as likely as not to
13 represent what happened.

14 There's, you know, there's a
15 band of uncertainty about the results
16 that their or the calculations by their
17 best fit parameters and best fit model,
18 but the calibrated results, I think, are
19 scientifically defensible based on
20 state-of-the-art modeling and standard
21 practices in the field of groundwater.

22 BY MR. ANWAR:

23 Q. You mention the phrase "as likely or
24 not."

1 What does that term mean to you?

2 A. It means, as far as I could tell, I
3 mean, I think I've seen that somewhere in all the
4 documents I've been reading.

5 You know, it means this could be
6 exact or maybe it's not, you know, exactly what
7 happened. But in assessing the likelihood of this
8 being right, it's just as likely to be highly
9 accurate or -- or not. It may be off, but
10 everything is done with a recognition of
11 uncertainty.

12 But these are the best estimates and
13 they're consistent with standard practices and,
14 you know, that's -- we don't know with certainty
15 that it's accurate and precise and represents
16 exactly what happened, but there's a good chance
17 that it is.

18 Q. It sounded like you were saying it's
19 as likely as it's right as it is wrong.

20 Is that what you're saying?

21 A. Well --

22 MR. DEAN: Object to the form.

23 THE WITNESS: I don't know if
24 that's exact. I won't say that's exact.

1 What I meant is, well, these
2 are good estimates and they're based on
3 scientifically defensible approaches with
4 state-of-the-art tools. There's no
5 reason not to believe them.

6 BY MR. ANWAR:

7 Q. So the phrase "as likely or not" is
8 a phrase that actually comes from the statute that
9 created this litigation.

10 A. Okay.

11 Q. And I'm just wondering: Have you
12 ever used that phrase before prior to -- to
13 your -- your expert work in this litigation?

14 A. Not that I remember. It's possible
15 I did, but I don't recall.

16 Q. Where did your understanding about
17 "as likely or not" come from?

18 A. The words. What it sounds like it
19 means.

20 Q. Did you understand that's a legal
21 standard in the statute that we're litigating?

22 A. I did not know it was a term in a
23 statute, no.

24 Q. And you're not a lawyer; right?

1 A. Absolutely not.

2 Q. And you're not offering any sort of
3 legal opinions; correct?

4 A. Nope. That's correct.

5 Q. I wanted to -- let's -- let's turn
6 to the page 32 of your report.

7 MR. DEAN: Page what?

8 MR. ANWAR: 32.

9 MR. DEAN: 32.

10 MR. ANWAR: Correct.

11 BY MR. ANWAR:

12 Q. Let's focus on -- so this is the
13 Conclusions section of your report.

14 Do you see that?

15 A. Yes.

16 Q. Okay. And that second paragraph
17 states:

18 "Although Dr. Spiliotopoulos
19 repeatedly questions the accuracy of the ATSDR
20 model and its calibration, I don't see any
21 evidence that it is unacceptably inaccurate."

22 What do you mean by "unacceptably
23 inaccurate"?

24 A. That there would be obvious errors

1 in or results that are based on errors in the
2 calibration of the model or in the use of
3 parameter values.

4 Q. Are there acceptable inaccuracies?

5 A. Sure.

6 Q. What are some of the acceptable
7 inaccuracies?

8 A. Well, I mean, if you say the
9 hydraulic conductivity is 10 feet per day, but
10 somehow our measurement says it's 12 feet per day
11 or 8 feet per day, that's an acceptable
12 inaccuracy.

13 First of all, you would never really
14 know what the true value is, and it depends on
15 many things in how you measure it, the method of
16 measurement the scale of the measurement and so
17 on. So let's say the truth is a little elusive.

18 Q. But there are inaccuracies; right?

19 MR. DEAN: Object to form of
20 the question.

21 THE WITNESS: Every model is
22 a simplification of complex reality. It
23 involves approximation, assumptions, and
24 averaging.

1 So yes, there's -- there's
2 always uncertainty and certainly errors
3 in every model, and what you try to do in
4 standard practice is assess how serious
5 those errors might be, how they might
6 affect the results.

7 You do sensitivity tests and
8 uncertainty analysis to help assess what
9 confidence you should have in the model
10 because we recognize that the model is
11 not the reality.

12 BY MR. ANWAR:

13 Q. At the bottom of the Conclusions,
14 that last paragraph that spills onto the next
15 page, you start:

16 "In my opinion, ATSDR has done an
17 admirable job in completing a challenging task of
18 using hindcasting with a calibrated model to
19 reconstruct credible concentration distributions
20 in time and space prior to the availability of
21 data from chemical analyses of groundwater samples
22 in the mid-1980s. In the face of missing
23 historical data, the ATSDR's models provide useful
24 input to epidemiological studies."

1 Did I read that correctly?

2 A. Yes.

3 Q. I think earlier we had discussed
4 -- I had asked you the purpose -- I had asked you
5 questions about the purpose of ATSDR's model and
6 the fact that the data, the information would be
7 used for epidemiological studies.

8 Do you recall that?

9 MR. DEAN: 123 now. Yeah.

10 MR. ANWAR: Okay.

11 MR. DEAN: We all do.

12 THE WITNESS: Yes, I do.

13 BY MR. ANWAR:

14 Q. And in response to some of those
15 questions, you -- you made clear you're not an
16 epidemiologist; right?

17 A. Yes.

18 Q. So what is the basis for your
19 opinion there "the ATSDR models provide useful
20 input to epidemiological studies"?

21 A. My understanding was the
22 epidemiological studies required first
23 concentrations in the water supply wells, but
24 ultimately concentrations in the water treatment

1 plants. That was my understanding of what was
2 needed, and that's my understanding of what the
3 modeling provided.

4 Therefore, I said, well, that's
5 useful. It's providing useful input. That's why
6 they wanted the models and the model -- the models
7 provided that. So my inference was that was
8 useful.

9 Q. And so if we skip a couple lines
10 ahead, there is -- starting with the fourth line
11 down, there is --

12 A. Which page?

13 Q. The last page, page 33.

14 A. Okay.

15 Q. It says:

16 "There is uncertainty in the
17 calibrated models (as there always is in such
18 models) and in the hindcasted results, and that is
19 clearly recognized and evaluated. The uncertainty
20 is not so large or unexpected as to preclude the
21 use of the model results in the epidemiological
22 studies or for providing mean monthly -- monthly
23 mean concentrations for use by health
24 professionals to estimate past exposure of

1 residents on 'as likely than not' or 'more likely
2 than not' basis."

3 Did I read that correctly?

4 A. Yes.

5 Q. Did you -- did you write that
6 sentence?

7 A. I did and those --

8 Q. Why did you -- go ahead.

9 A. You know, those terms "as likely as
10 not" or "more likely" I probably heard from the
11 lawyers and so that was -- I felt, yeah, that was
12 a good description, but they did not tell me what
13 to write or how to write it or anything like that.

14 I mean, that's probably -- I'm sure
15 I heard those terms from the lawyers, and so I
16 felt it appropriate to use it --

17 Q. Okay.

18 A. -- with, you know, my perception of
19 what that meant.

20 Q. Got it.

21 And you say:

22 "The uncertainty is not so large or
23 unexpected as to preclude the use of the model
24 results in the epidemiological studies."

1 And we talked about the
2 epidemiological studies, but then you go on to
3 say:

4 "Or for providing monthly mean
5 concentrations for use by health professionals to
6 estimate past exposure of residents on an 'as
7 likely as not' or 'more likely than not' basis."

8 You're not a health professional;
9 correct?

10 A. Correct.

11 Q. So what is -- what is the basis for
12 your opinion that the simulated concentrations
13 from the ATSDR models are -- do not preclude the
14 use by health professionals to estimate past
15 exposure of residents?

16 A. Well, from the health perspective, I
17 have no basis for saying that.

18 But from the modeling perspective, I
19 felt that the mean monthly concentrations were
20 estimated on the basis of reasonable, adequate
21 models and so that they could be relied on for
22 other purposes. But it's certainly not meant to
23 imply I understood the health studies.

24 Q. Are you offering the opinion that

1 the simulated concentrations produced by ATSDR
2 models are sufficiently accurate for health
3 professionals to rely upon?

4 A. I think they're the best that could
5 be come up with. From -- I think they're
6 reasonably accurate. I think they're reasonably
7 reliable. I think there's uncertainty associated
8 with them.

9 I think the uncertainty is clearly
10 expressed in the analyses produced by ATSDR, and
11 then it would be up to the health professionals to
12 decide with that level of uncertainty is it good
13 enough for them to use. That would not be
14 something I would say. So yeah.

15 Q. Earlier we had a discussion or an
16 exchange where I was asking you about the intended
17 purpose or use of particular models, and I believe
18 you told me, as a modeler, the use of the model
19 isn't really your focus or your concentration for
20 purposes of developing the model; is that right?

21 MR. DEAN: Object to form of
22 the question.

23 THE WITNESS: I would design
24 a model, develop the model, calibrate the

1 model according to best practices in my
2 understanding, regardless of what the
3 downstream use of that model might be.

4 Although as I said before, I
5 might refine the grid or do something
6 particular to help meet the needs of the
7 people paying for the model.

8 BY MR. ANWAR:

9 Q. But you're not -- and we -- we
10 talked -- you're not a health professional
11 yourself; correct?

12 A. Correct.

13 Q. Did you -- in forming this opinion,
14 did you speak with any health professionals?

15 A. No.

16 Q. So it's your opinion, as a modeler,
17 that the simulated concentrations from the ATSDR
18 models are -- are good enough for health
19 professionals?

20 A. Well --

21 Q. And when I say "good enough," I mean
22 accurate enough.

23 A. I think they're reasonably accurate.
24 Again, I'm not a health professional. So I

1 really -- I really shouldn't comment on whether
2 it's good enough for a health professional.

3 Q. Well, if you don't feel comfortable
4 commenting on the results being good enough for a
5 health professional, why do you feel comfortable
6 commenting on the results being accurate enough
7 for a health professional?

8 MR. DEAN: Objection to form
9 of the question. It mischaracterizes his
10 testimony 100 percent.

11 BY MR. ANWAR:

12 Q. You can answer.

13 A. Excuse me?

14 Q. You can answer.

15 A. Well, as a hydrogeologist and an
16 experienced modeler, I felt that these results
17 were reasonably reliable, and I could think of no
18 reason that they shouldn't be used in light, you
19 know, with consideration of the uncertainty, why
20 they shouldn't be used for any purpose after that.

21 Q. How many -- if you had to estimate,
22 how many groundwater and/or transport models have
23 you developed yourself or evaluated throughout
24 your career?

1 A. Probably on the order of half a
2 dozen comprehensive, detailed studies and model
3 developments that I've done. And in terms of
4 reviewing or assessing others, probably many tens,
5 if not well over a hundred different cases,
6 probably even more.

7 Q. Of all those models, are ATSDR
8 models -- are ATSDR's models the only one you're
9 aware of that are -- that estimate -- that are
10 attempting to be used to estimate exposure --
11 monthly contaminant concentrations for exposure
12 determinations in individuals?

13 MR. DEAN: Object to the form.
14 BY MR. ANWAR:

15 Q. You can answer.

16 A. Well, as I mentioned earlier, the
17 analyses for the Waste Isolation Pilot Plant used
18 models for 10,000 years into the future, and that
19 was for the purpose of health exposure of a
20 potential hypothetical future farmer and so it was
21 used for health assessments. I don't recall what
22 the health assessment studies were or how they
23 were done, but it was used. That was one of the
24 purposes of that modeling.

1 There are many other models that I
2 reviewed with similar characteristics, but most
3 often I say they do not describe what the sponsors
4 of the modeling effort were going to do with it.
5 So a lot of times.

6 So I guess my answer is, they may or
7 may not have been used for health exposure
8 studies. I don't know because I wasn't always
9 aware of what the ultimate purpose of the model
10 was.

11 Q. Okay. There are places in your
12 report -- and I can give you examples if you'd
13 like -- where you -- so, for instance, on the page
14 we were just looking at, the last line of your
15 report, you state:

16 "The methods were rigorous and
17 scientifically sound."

18 Correct?

19 A. Yes.

20 Q. And then there are other places
21 throughout your report where you refer to
22 scientifically valid methods being used and/or the
23 models being scientifically valid, the ATSDR
24 models.

1 Do you recall that?

2 A. I don't recall saying they were
3 scientifically valid, but I may have said that.

4 Q. Okay. Well, why don't we -- why
5 don't you turn to page 30 of your report.

6 A. 30?

7 Q. Yeah.

8 A. Okay.

9 Q. Sorry. I might have put the wrong
10 page on. Give me a second.

11 Oh, I'm sorry. Yeah. It is
12 starting on 30.

13 At the bottom of 30, that last
14 paragraph has a section heading "Section 3.3 and
15 scientific validity of ATSDR model -- ATSDR's
16 models," and you quote an opinion offered by
17 Dr. Spiliotopoulos there where he -- he opined:

18 "I do not think their results were
19 scientifically valid because" -- or I think you
20 quote Dr. Waddill, actually.

21 A. Yes.

22 Q. And it says:

23 "I do not think their results ...
24 were scientifically valid because, you know,

1 science needs to be based on real-world
2 observations and analysis ... and there were just
3 not enough real-world measurements for this to
4 count as scientifically valid."

5 And you disagree there.

6 And then on the next page, on page
7 31, the second line:

8 "Therefore, I would counter
9 Dr. Waddill's statements by noting that in
10 developing and applying the ATSDR groundwater
11 models, that scientifically valid methods were
12 used, and the models were based on sound hydraulic
13 and physical principles that themselves have been
14 tested and shown to be accurate and reliable
15 approaches to describing and predicting
16 groundwater flow and contaminant transport."

17 Did I read that correctly?

18 A. Yes.

19 Q. Okay. Is it your opinion that
20 ATSDR's Camp Lejeune water models are
21 scientifically valid?

22 A. Yes.

23 Q. Why do you say that?

24 A. The models are based on a

1 mathematical representation of the processes that
2 govern fluid flow in porous media and the movement
3 of dissolved chemicals. These equations are well
4 accepted throughout the scientific and engineering
5 worlds.

6 There's common practice, standard
7 practice. There may be some debate in the
8 scientific circles, particularly about the
9 governing solute transport equation, what it
10 should look like but, nevertheless, it is a
11 standard form. And these equations and the
12 numerical methods to solve them are widely
13 accepted as being scientifically valid and
14 appropriate and useful.

15 So these -- these are the models and
16 methods that ATSDR used and applied and, you know,
17 I think what they do is estimate how water fluxes
18 and water levels and solute concentrations, how
19 they change over time in a way that is consistent
20 with the widely accepted principles reflected in
21 the governing equations.

22 This is -- this is valid science.
23 This is, you know, well accepted. You know,
24 there's very few people that would argue with

1 that, you know. So I think, yes, it is
2 scientifically valid.

3 MR. ANWAR: Okay. I'm going
4 to hand you an exhibit that I'm marking
5 as Exhibit 14.

6 (Document marked for
7 identification as Konikow Exhibit 14.)

8 BY MR. ANWAR:

9 Q. This is an editorial that was
10 coauthored by you and a J.D. -- you pronounced it
11 earlier -- Bredehoeft?

12 A. Bredehoeft.

13 Q. Bredehoeft. Entitled "Ground-Water
14 Models: Validate Or Invalidate"; correct?

15 A. Correct.

16 Q. And we can -- we can read through
17 this a little bit, but the first bolded section
18 there -- so it was originally -- let me take a
19 step back.

20 This editorial was originally
21 published in 1993; correct?

22 A. The editorial? It says reprinted
23 from 1993. The ideas expressed in here are really
24 based on a more comprehensive analysis and article

1 that Bredehoeft and I published in, I believe,
2 1992.

3 Q. Okay. What is the name of that
4 publication?

5 A. I think it was "Advances in Water
6 Resources" is the name of the journal.

7 Q. And then this editorial was
8 republished in "Groundwater" in 2012; correct?

9 At the bottom note.

10 A. Yes.

11 Q. So the first paragraph focuses on
12 validation and it states:

13 "The word validation has a clear
14 meaning to both the scientific community and the
15 general public. Within the scientific community
16 the validation of scientific theory has been the
17 subject of philosophical debate."

18 And then you reference Karl Popper.
19 Going to the second paragraph there,
20 you state:

21 "To the general public, proclaiming
22 that a ground-water model is 'validated' carries
23 with it an aura of correctness that we do not
24 believe many of us who model would claim. We can

1 place all the caveats we wish, but the public has
2 its own understanding of what the word implies.
3 Using the word 'valid' with respect to models
4 misleads the public; 'verification' carries with
5 it similar connotations as far as the public is
6 concerned.

7 "Our point is this: using the terms
8 'validation' and 'verification' are misleading, at
9 best. These terms should be abandoned by the
10 ground-water community."

11 Did I read that correctly?

12 A. Yes.

13 Q. And so when you're describing
14 ATSDR's model as scientifically valid --

15 A. I never said that their model was
16 valid. I never said it was validated. I never
17 said anything about validation of the models.

18 I said the -- I try to avoid using
19 the term "valid" or "validation." I used it once
20 or twice in terms of overall broad scientific
21 validity reflecting that it's a widely accepted
22 method.

23 Q. I think I just asked you the
24 question, is it your opinion that ATSDR's models

1 are scientifically valid, and your response was
2 yes.

3 Is it?

4 A. Well, okay, but, you know, if you
5 read the paper, what I don't want to imply is that
6 the model is perfect or that there is no other
7 model within the realm of infinite possibilities
8 of combinations of parameters that would not do as
9 well in terms of accuracy.

10 So it's not a unique model. It's
11 valid in a broad sense of that term, but there is
12 no exercise that validated their model. But it's
13 valid scientifically in the sense of using
14 state-of-the-art methods.

15 Q. What do you mean "there was no
16 exercise that validated ATSDR's models"?

17 A. They went through a calibration,
18 which involved history matching, and that
19 calibration yields a best fit to the parameters,
20 but it's not the only possible fit. History
21 matching by itself does not prove that the model
22 was valid, that it was the absolute truth.

23 We know it's not. That's why we do
24 uncertainty analysis and sensitivity analyses.

1 Q. Your -- your report is directed to
2 an audience of people that are not modelers;
3 correct?

4 A. Which report are you referring to?

5 Q. I'm sorry. Your rebuttal expert
6 report in this case; correct?

7 It's directed towards an audience
8 that all aren't necessarily modelers; correct?

9 A. Yeah. I mean, it's aimed at you and
10 others that aren't hydrogeologists, as well as
11 aimed at technical experts in hydrogeology.

12 Q. Isn't using the terms "valid
13 methodology" or "scientifically valid" or
14 describing the model as "valid," isn't that, as
15 you state in your own words here, misleading?

16 MR. DEAN: Object to the form
17 of the question.

18 THE WITNESS: Well --

19 MR. DEAN: Mischaracterizes
20 his prior testimony. He's already
21 answered that question.

22 THE WITNESS: Let me
23 emphasize that bringing up this topic of
24 validity was not mine. It was brought

1 up -- I'm quoting from Spiliotopoulos.
2 He raised the issue and so I'm trying to
3 address it.

4 It is not -- it's not a
5 terminology that I would normally use for
6 the very reasons we discussed and
7 summarized in that editorial.

8 BY MR. ANWAR:

9 Q. And the first sentence of that
10 second paragraph:

11 "To the general public, proclaiming
12 that a ground-water model is 'validated' carries
13 with it an aura of correctness that we do not
14 believe many of us who model would claim."

15 "Using the word 'valid' with respect
16 to models misleads the public."

17 Isn't describing ATSDR's models as
18 scientifically valid or the methodology they used
19 as scientifically valid, isn't that intended to
20 carry with it an aura of correctness that you
21 acknowledge?

22 A. I don't think they ever said that
23 they validated their model. I don't think that
24 terminology was ever used with respect to their

1 modeling of the results.

2 The ATSDR is very clear and very
3 transparent about recognizing uncertainty in the
4 results.

5 Q. They -- go ahead.

6 A. So they're not anywhere in my
7 reading implying that they have the right truth or
8 model or that they validated it in the sense of it
9 being the ultimate pinnacle of correctness. I
10 don't think they ever implied that. They
11 certainly never say that, and I think that's why
12 we use.

13 What they've done clearly in many,
14 many, many plots of results, they show the
15 calculations based on their best fit calibrated
16 model, and they show upper and lower bounds about
17 that that reflect some range of consideration of
18 uncertainty in one or more parameters.

19 So I think they're very clear in
20 expressing that they have not validated the model
21 in the sense that people could misinterpret it to
22 mean that they have an aura of correctness and
23 certainty about their results.

24 Q. ATSDR didn't validate their model

1 because they couldn't validate their model; right?

2 MR. DEAN: Object to the form
3 of the question.

4 BY MR. ANWAR:

5 Q. There wasn't sufficient data to
6 validate their model; correct?

7 MR. DEAN: Object to the form.

8 THE WITNESS: That's very
9 misleading as I read it because there is
10 never ever any groundwater model for
11 which there is sufficient data to say
12 (indicates) you've validated it. It just
13 doesn't exist.

14 There is always uncertainty.
15 Every model ever developed for
16 groundwater has uncertainty associated
17 with it, and no competent hydrogeologist
18 would claim that they have the truth.

19 BY MR. ANWAR:

20 Q. What is your understanding of why
21 ATSDR didn't validate their models?

22 MR. DEAN: Object to the form
23 of the question.

24 THE WITNESS: Repeat the

1 question.

2 BY MR. ANWAR:

3 Q. What -- having reviewed the reports,
4 the Tarawa Terrace reports and the Hadnot
5 Point/Holcomb Boulevard reports in preparing for
6 your deposition and offering expert opinion in the
7 case, why didn't ATSDR just validate their two
8 models?

9 A. Well, the title of the paper I
10 published in 1992 with John Bredehoeft is
11 groundwater models cannot be validated. That did
12 not refer to ATSDR or Camp Lejeune. It referred
13 to every groundwater model ever developed or
14 potentially developed in the future.

15 It's in our opinion -- and not
16 everyone agrees, but in our opinion, no
17 groundwater model could be validated in the sense
18 that the public might perceive the term to imply
19 that you have the right model to the exclusion of
20 any other possibility.

21 So if ATSDR had claimed that they
22 validated the model, I would have come down on
23 them very hard, severely criticized them for
24 saying that, but I think they knew better than to

1 say that.

2 Q. Okay. Describing a groundwater --
3 groundwater model as scientifically valid or the
4 methodology that was used as being scientifically
5 valid doesn't mean that the output, in this -- in
6 this case the simulated concentrations produced by
7 ATSDR's models, are accurate; right?

8 MR. DEAN: Object to the form.

9 THE WITNESS: It depends how
10 you mean "accurate." They're not
11 precisely the truth because we don't know
12 the truth. They're not, you know,
13 they're reasonable and they represent
14 what's going on, but there's uncertainty
15 about it.

16 It could be a little higher.
17 It could be a little lower. This is the
18 best estimate in the middle. It's a
19 moving trend based on a very reasonable
20 model that solves the governing
21 equations.

22 The equations for which we
23 know represent the processes, but the
24 coefficients in the equation are not

1 known precisely, and they are never known
2 precisely or accurately.

3 BY MR. ANWAR:

4 Q. Okay. I think you stated or I
5 believe it's listed on your reliance materials
6 that you reviewed Jones and Davis's original
7 postaudit report; correct?

8 A. I read it. It was probably a couple
9 of weeks ago. I didn't give it a technical review
10 in great depth, but I did. I looked at it, yeah.

11 Q. Did you also look at their -- I
12 can't recall, so I apologize if I asked you this
13 already.

14 Did you also look at their rebuttal
15 expert report submitted in this case?

16 A. I think I did, yes.

17 Q. There is a portion in their report
18 where they state:

19 "Based on this postaudit, we can
20 find no significant evidence that would invalidate
21 the analysis performed by ATSDR with the original
22 model."

23 Are they using the term "invalidate"
24 then incorrectly?

1 MR. DEAN: Object to the form.

2 THE WITNESS: Well, I would
3 assume so. You know, the general belief,
4 John Bredehoeft and I and many others
5 believe that you can invalidate a model,
6 but you cannot validate it. And by
7 invalidating, you show that there are
8 significant errors from what's going on.

9 So if you -- the basic
10 reasoning -- I'm not sure who said this
11 first but, you know, if you have a model,
12 you have best fit, your history match,
13 and all of that. That builds confidence
14 in the model, but it doesn't prove you
15 have a valid model.

16 If you make a prediction and
17 that prediction turns out to be wrong by
18 some substantial degree, you have in
19 effect invalidated the model and you try
20 to get a better model.

21 But if the next prediction,
22 you know, that prediction you made turned
23 out to be really close, that builds more
24 confidence, but it still doesn't prove

1 that you validated the model because the
2 very next prediction might be erroneous.

3 So the kind of philosophy --
4 philosophical argument is that you can
5 never validate the model in any kind of
6 literal sense, but you can invalidate it
7 by showing that it was inaccurate.

8 BY MR. ANWAR:

9 Q. Isn't validation a history matching,
10 a form of history matching?

11 A. What I would argue is that they are
12 not equivalent. History -- if you match history
13 very well, that doesn't mean you validated the
14 model. It means you have more confidence in the
15 model. The model is probably pretty good.

16 Q. If you have history matched very
17 well, why does that not validate the model?

18 A. Because the next prediction could be
19 off. You may not have data for a particular point
20 or thing where it may have been an error. You
21 never have enough to say, this is the perfect
22 model and it's a valid model or you validated it.
23 Because you make a prediction, that could turn out
24 to be wrong.

1 So the general cautiousness that you
2 want to say is that you've got a good model, a
3 reasonable model. We've matched the history, the
4 historical data that we have. We have a good
5 calibration, and we think this is an appropriate
6 model, a reasonable model for the purposes that
7 we're using it.

8 But we don't say that it's validated
9 because I would argue that you can never validate
10 a model because you never, you know, you just
11 don't know what will happen in the future.

12 Q. So my understanding of calibration
13 and validation is -- and you should correct me if
14 I'm wrong -- is essentially that you -- when
15 you're calibrating the model, you're attempting to
16 adjust parameters to match observed parameters
17 such that the simulated results matches closely as
18 possible observed values that you're running the
19 model against.

20 And validation is taking a set of
21 observed values that you didn't use as part of the
22 calibration and then comparing the simulated
23 models against sort of a separate set of observed
24 data.

1 Is my understanding right?

2 A. I would say it's not right, but it
3 matches the perception of many other people. You
4 know, I think there are people who believe that.

5 I would counter that in groundwater
6 systems, you can almost never have independent
7 data sets. If you have, you know, your
8 observations say, well, let's save this for the
9 (indicates) what you might call validation, you're
10 not blind to that data. You know what it is.
11 It's not.

12 You know, in drug approval, they
13 would never say that that's acceptable for a drug
14 test because you are aware of what those values
15 were. You weren't blind to them, and they're not
16 an independent set of data.

17 You never have an independent set of
18 data in a historical groundwater. Everything is
19 linked and in groundwater systems, even if you can
20 compare it with surface water systems, surface
21 water, without the issue of validation, you could
22 get a fairly independent set of responses in a
23 river flow data if you go down a year or two in
24 time in response to different precipitation

1 events.

2 In groundwater systems, the
3 responses are much more buffered and much more
4 slower, and the behavior of a groundwater system a
5 year in the future depends to a large degree on
6 what it was at the start of that year.

7 You don't get independence and that
8 restricts your ability to even talk about
9 validation with an independent data set because
10 it's so difficult to get in groundwater system
11 anything that approaches an independent data set,
12 and I would argue that still revealed validation
13 if you had.

14 Q. I guess the reason I asked -- part
15 of the reason I asked that question: If it's your
16 opinion that you can't validate a model ever under
17 any circumstance, how can you ever calibrate a
18 model? How can you say that any model --

19 A. The calibration has nothing to do
20 with validation in the sense. You can calibrate.
21 What you do in model calibration is adjust
22 parameters and boundary conditions and maybe some
23 other processes, maybe your numerical grid, maybe
24 your time step. You adjust lots of things so that

1 the results match the historical changes that
2 you've seen. You could do this. It doesn't
3 depend on any condition (indicates) called
4 validation.

5 It's the process of model
6 calibration is the process of parameter
7 restoration in effect, and that's why automatic or
8 automated parameter estimation models are so
9 useful because they make the whole process faster
10 and more efficient to adjust parameters to get
11 what could be a statistically best fit.

12 Q. Is it possible to adjust the
13 parameters in a model in such a way that
14 the -- that you successfully -- let me -- let me
15 start -- strike that.

16 Talk to me about the concept of
17 nonuniqueness.

18 MR. DEAN: Object to form.

19 THE WITNESS: Excuse me?

20 MR. DEAN: Object to form.

21 BY MR. ANWAR:

22 Q. What is nonuniqueness in modeling?

23 A. Well, that's basically the concept
24 that when you calibrate a model, you have a set of

1 parameters that you feel give you the best fit but
2 that may not be the only combination of parameters
3 that give you approximately an equally good fit.

4 You know, there's, you know, if
5 you -- if your result is a sum of 10, 5 plus 5
6 gives you 10 or 6 plus 4 gives you 10, and in
7 terms of the fit, they're both equally good.

8 Q. And so when we're talking about
9 calibrate -- adjusting parameters to calibrate a
10 model, there -- there are many different
11 possibilities of combinations of parameters that
12 could calibrate the model in the sense that the
13 simulated values match the observed values;
14 correct?

15 A. As well as possible. What you do
16 that -- I mean, it's not an unbounded process.
17 What you do is you consider the -- how good the
18 fit is and the quality and the errors and the mean
19 error and all the other statistical measures of
20 the fit. And you adjust parameters until that
21 error measure gets smaller and smaller, and
22 continued changing of parameters basically yields
23 no improvement, no further improvement in fit, and
24 that's why you say, well, that's as good as we

1 could do.

2 Q. And simply calibrating a model or --
3 excuse me -- simply adjusting parameters in a way
4 that to calibrate a model doesn't mean the model
5 is good or accurate if the input parameters are
6 unrealistic; correct?

7 A. Well, one of the guidelines for
8 adjusting parameters during history matching
9 during calibration is you have to keep those
10 bounded within reasonable limits. You know,
11 that's, you know, whether you're doing by trial
12 and error or with an automated method, you don't
13 have an unlimited range to adjust parameters.

14 You can't have a negative value of
15 hydraulic conductivity. You know, you have to be
16 consistent with principles and your geologic
17 knowledge and other maybe more subjective
18 criteria, but it's not an unbounded universe.

19 Q. The statistical analysis that you're
20 talking about to -- to ensure that the model is
21 appropriately calibrated and the parameters fall
22 within a certainty bound, ATSDR didn't do that
23 statistical analysis for the Hadnot Point/Holcomb
24 Boulevard model; right?

1 A. I'm not sure what you mean. I mean,
2 they did a model calibration. They were measuring
3 the goodness of fit. They -- my understanding is
4 that they used the PEST software to help with the
5 calibration and parameter. That PEST
6 automatically calculates all those measures of fit
7 and that's how it does the calibration, by
8 minimizing some objective function that's related
9 to the error.

10 Q. Okay. Why don't we take a quick
11 break.

12 A. Sure.

13 MR. ANWAR: A short break.

14 THE VIDEOGRAPHER: Going off
15 the record. The time is 3:51 PM.

16 (A recess was taken.)

17 THE VIDEOGRAPHER: We're back
18 on the record. The time is 4:05 PM.

19 BY MR. ANWAR:

20 Q. We are back on the record from a
21 short break.

22 Dr. Konikow, are you okay to
23 continue?

24 A. Yes.

1 Q. Okay. And did you speak with your
2 lawyers about the substance of your testimony?

3 A. No.

4 Q. Okay. I wanted to ask you.
5 Can a postaudit be used to validate
6 a model?

7 A. No.

8 Q. Why not?

9 A. Because a model can't be validated.

10 Q. And looking back at your -- this
11 editorial, it is, I think, Exhibit 13.

12 A. 14.

13 Q. 14. Thank you.

14 If you turn to the next page, there
15 is a section on Postaudits, and you state there:

16 "Several postaudits have been
17 performed to evaluate the accuracy of predictions
18 made using -- sorry, lost my place -- made using
19 supposedly validated -- 'validated' models.
20 Compared to the number of model studies, the
21 number of postaudits is small. There are numerous
22 problems in examining past predictions; often the
23 stress placed on the system was quite different
24 from that used in the model analysis.

1 "The results of the current set of
2 postaudits suggests that extrapolations into the
3 future were rarely very accurate. There are
4 various problems with the models: the period of
5 history match was too short to capture an
6 important element of the model, or the conceptual
7 model was incomplete, or the parameters were not
8 well-defined, etc. Our experience suggests that
9 models are more useful as tools used by the
10 hydrologist to understand the system rather" -- it
11 says "that" but I think it's -- "than as tools to
12 predict future response. Our record of
13 'validating' models is not encouraging."

14 Did I read that correctly?

15 A. Yes.

16 Q. Okay. So you can use a postaudit to
17 evaluate the accuracy of the predictions of a
18 model; correct?

19 A. No.

20 MR. DEAN: Object to form.

21 THE WITNESS: That's not
22 correct.

23 BY MR. ANWAR:

24 Q. Okay.

1 A. You could use the postaudit to
2 assess the accuracy of the predictions made by the
3 model, how good the model was, but it just would
4 not prove that you had a valid model.

5 Q. Okay. And why -- why wouldn't it
6 prove that you have a validated model?

7 A. Because if you use the model, the
8 same model to predict another year into the
9 future, that may be very wrong. That prediction
10 may be wrong and, therefore, that would prove you
11 had an invalid model. It would invalidate the
12 model.

13 So when you use a postaudit to
14 assess the accuracy of the prediction, if it turns
15 out -- which doesn't always happen -- if it turns
16 out that the prediction was fairly reliable and
17 acceptably accurate, it helps build confidence in
18 the model. You're building confidence in the
19 model. You feel better about the model.

20 You just have not proved that it is
21 a valid model. You have not validated the model
22 because the next prediction could be very much in
23 error with the same model, and that would
24 invalidate the model.

1 Q. Okay. Understand.

2 Can you pull up Exhibit 12. It is
3 the 2005 transcript of the expert summary, day 2.

4 A. Which one is 12?

5 Q. It's the transcript of the expert
6 panel. I think we have only given you one of
7 those so far. Should be one of the thick ones.

8 A. Yeah, thick ones. This is 9. 13.

9 Q. There you go.

10 A. 12. Okay.

11 Q. Could you turn to page 46?

12 A. Okay.

13 Q. Okay. So just for frame of
14 reference purposes, the 2005 expert panel was
15 focused on ATSDR's Tarawa Terrace model; correct?

16 A. Yes.

17 Q. And so starting at line 14, there's
18 a discussion going on and you chime in at line 14.
19 You say:

20 "But the point -- one of the points
21 is that you really -- your study isn't starting
22 until 1965."

23 And Maslia says '68 and you say '68.

24 "That gives you 14 years from the

1 time ABC Cleaners started. So the value in doing
2 the groundwater flow and transport model will be
3 to, you know, start as best as we -- or as best we
4 know. They were introducing contaminants into the
5 soil at least through the septic tanks very
6 shortly after they started, maybe a year, maybe
7 instantly, maybe a year, maybe two years at most.
8 That gives you 12 years for it to reach the water
9 table and spread."

10 "The" -- going into the next page.

11 "The groundwater flow and transport
12 models accounting for uncertainty" --

13 A. I'm not sure where you're reading
14 from now.

15 Q. On page 47 line 1.

16 A. Okay. Okay.

17 Q. Just continuing from where we were
18 reading.

19 "The groundwater flow and transport
20 models accounting for uncertainty, heterogeneity,
21 and so on will give you a range of arrival times,
22 but I'm guessing the bulk of your realization will
23 get contaminant reaching the wells in that 14-year
24 period."

1 Did I read that all correctly?

2 A. Yes.

3 Q. And it sounds like in this exchange,
4 you're talking about here mass loading at Tarawa
5 Terrace; correct?

6 A. Well, we're talking about, yeah, the
7 solute load. Yeah, when the source got to the
8 water table and then spread down to TT-26 and so
9 on.

10 Q. And the way I read your comments
11 here is that, you know, you say:

12 "ABC Cleaners, they were introducing
13 contaminants into the soil at the very least
14 through the septic tanks very shortly after they
15 started, maybe a year, maybe instantly, maybe a
16 year, maybe two years at most. That gives you 12
17 years for it to reach the water table and spread."

18 You're discussing --

19 A. I did not mean that it would take 12
20 years to reach the water table.

21 Q. Okay.

22 A. I meant that it would reach the
23 water table, and then it had 12 years to spread.
24 Until that, you know, 1968 time.

1 Q. It does sound like you're saying
2 here, though, that the contaminants wouldn't reach
3 the water table on day one; right?

4 A. On day one? Probably not.

5 Q. And you indicate that "maybe a year,
6 maybe two years at most"?

7 A. Yeah, I really think it would be
8 less than that.

9 Q. But at this time, you stated "maybe
10 a year, maybe two years at most"; right?

11 A. Yeah, that's what I said. Yeah.

12 Q. And, again, when you're referencing
13 1968, you're talking about the starting point of
14 the EPI study that ATSDR was performing; right?

15 A. I believe so.

16 MR. ANWAR: Okay. I'm going
17 to hand you what I'm marking as
18 Exhibit 15.

19 (Document marked for
20 identification as Konikow Exhibit 15.)

21 BY MR. ANWAR:

22 Q. This is the transcript from day 1 of
23 the 2009 expert panel; right?

24 A. Apparently, yes.

1 Q. And it's dated April 29, 2009 there;
2 correct?

3 A. Yes.

4 MS. BAUGHMAN: Did you hand us
5 one?

6 MR. ANWAR: Yeah, it's right
7 there.

8 BY MR. ANWAR:

9 Q. I'd like you to turn to page 89.
10 And in the middle of the page there,
11 your name is highlighted starting on line 7.

12 Do you see that?

13 A. Line 7.

14 Q. On page 89?

15 A. Yes.

16 Q. You see that?

17 A. Yes.

18 Q. It says:

19 "DR. KONIKOW: The Tarawa Terrace
20 with the first arrival in November '57, if that
21 was actually several years later, maybe even four
22 or five years later, would that have any effect on
23 the health study since the health study is '68 to
24 '85?"

1 Did I read that correctly?

2 A. You read it correctly.

3 Q. And so you're -- you're raising
4 whether an even later contaminant mass loading
5 date would impact the -- the EPI study that ATSDR
6 was performing; correct?

7 MR. DEAN: Object to the form.

8 THE WITNESS: I seem to be
9 talking about the first arrival, and I am
10 inferring that might be talking about
11 TT-26, but I don't see. I haven't
12 carefully read right now the preceding
13 several pages.

14 So when I said "first
15 arrival," I'm inferring that meant at
16 TT-26, but I'm not positive that's what
17 we were talking about.

18 BY MR. ANWAR:

19 Q. Okay. TT-26, was that the -- was
20 that the primary source in Tarawa Terrace?

21 A. I believe so.

22 Q. Or that was the source was ABC
23 Cleaners, but the TT-26 was the most contaminated
24 well; correct?

1 A. Most contaminated well, yes.

2 Q. Okay. And so if we go on to read,
3 Mr. Maslia states:

4 "We actually did, Mustafa Aral did
5 some well scheduling optimization and did
6 different scenarios with different wells other
7 than the ones that we calibrated for the model.
8 And you could shift from '57 to '60, but during
9 the course of the study it did not significantly
10 affect at all the higher concentrations.

11 "They all tended towards that level
12 of that chart, the graph that shows in the
13 finished water that all that it shifted was, other
14 than if you shut down, for example, TT-26. If you
15 shut down TT-26, both the data and the model would
16 show that your finished water went down to
17 practically no contamination at Tarawa Terrace.
18 But if you shifted the cycling so that it didn't
19 hit or arrive or pass the MCL, say, as you said,
20 59, 60, 61, whatever, did not significantly affect
21 the higher concentrations in the finished water."

22 Did I read that correctly?

23 A. Yes.

24 Q. Okay. And because TT-26 was the --

1 I guess the most contaminated well, it sounds like
2 he's saying -- Mr. Maslia -- that if you shut it
3 down, the contamination levels went to nearly
4 zero; correct?

5 A. He said that they would. He didn't
6 say they shut it down. He said -- I believe he
7 implied if you shut down TT-20 -- TT-26. That was
8 because that was the main source, not the only but
9 the main source, of contaminated water to the
10 Tarawa Terrace Water Treatment Plant. If that
11 wasn't pumping, then there would be few, very few
12 contaminants showing up in the Water Treatment
13 Plant.

14 I think that's what was implied
15 there.

16 Q. Do you recall the extent of data
17 available about the pumping history for TT-26?

18 A. I recall seeing it. I can't recite
19 the details of it, but I know they had a graph
20 showing when it was operating, and there was
21 another graph showing estimated pumping rates from
22 that and other wells. So yeah.

23 Q. Would you agree that there was
24 incomplete data about the pumping history of

1 TT-26?

2 MR. DEAN: Object to form.

3 THE WITNESS: To the best of
4 my knowledge, there was not a complete
5 record of when the well was pumping and
6 how much it was pumping. That had to be
7 reconstructed also.

8 BY MR. ANWAR:

9 Q. And one of the assumptions that
10 ATSDR made was to assume that the well was pumping
11 unless there was a historical record confirming
12 that the well was not pumping; correct?

13 A. Well, I don't know exactly what they
14 assumed but, you know, certainly in terms of, they
15 had methods to estimate what the average monthly
16 pumping rate was. And if the well is shut down
17 for a day or two during a particular month, then
18 maybe your average withdrawal for that month would
19 be a little lower.

20 But for the model, you would still a
21 sum -- assume that it's pumping at that slightly
22 lower rate but over the whole month, and it
23 wouldn't make any significant difference in the
24 results.

1 But as I recall, there were only two
2 extended periods of non-operation of TT-26 before
3 it was finally shut down, but I don't think that
4 implied that it was never shut down. I think
5 there was some statement that typically they cycle
6 through all the different wells that supplied
7 water, and so it was routine for any individual
8 well to be shut down for a short period of time.

9 I think that's normal when you have
10 multiple wells in a well field supplying it. I
11 think it's normal to cycle through using different
12 ones to meet the demands at the time.

13 Q. Okay. And so your recollection of
14 the way ATSDR handled -- handled the model with
15 respect to missing pumping history is that they
16 cycled through?

17 A. No, that wasn't part of the
18 reconstruction. That was part of the operation.

19 That the normal operation of wells,
20 I believe, included cycling through different
21 combinations of well pumping at any time, any
22 particular time during the whole history, in other
23 words.

24 So no one is saying that, the

1 Department of the Navy or anyone. They're not
2 saying that TT-26 pumped continuously from the
3 beginning to end of their pumping period before
4 there was, you know, a longer break for servicing.

5 The normal operation includes short
6 sequences in which the well is turned off, maybe
7 minor servicing, but that's normal and it doesn't
8 affect the model.

9 Q. How did ATSDR handle TT-26 for
10 purposes of the historical reconstruction period?

11 A. You mean --

12 Q. The pumping. How did ATSDR handle
13 the pumping schedule for TT-26 for purposes of the
14 historical reconstruction period dating back to
15 1953?

16 A. I don't have a precise recollection
17 of method they used, but it was well-documented in
18 the report. I had read it. I just don't recall
19 the details of it, but my recollection is that
20 there was some estimates based on water demand,
21 you know, how much the water treatment plants
22 needed, and how that might have been apportioned
23 among the different wells supplying it.

24 So there was some correlation,

1 regression analysis and reconstruction, and it
2 is -- let me emphasize again that in all
3 groundwater models, you require an estimate of the
4 pumpage from all wells in the area and it is, I'd
5 say, beyond common, it's almost in every case the
6 models have to reconstruct the pumping history and
7 make estimates of it.

8 Q. Understood.

9 A. It is rare that over a historical
10 period you would have very precise records of
11 pumpage.

12 Q. Let's turn to page 201, and starting
13 at line 6 your name is highlighted there for
14 comments you made; correct?

15 A. Yes.

16 Q. Okay. So it says:

17 "DR. KONIKOW: So then the question
18 is how do you go, you'll calculate a mass, but
19 then how do you go back in time and use that to
20 estimate what the mass loading rate is over the
21 duration of the model? The Tarawa Terrace
22 situation you had essentially a point source with
23 a known location and a fairly constant -- constant
24 over time disposal rate. Here I'm not sure how

1 you're going to reconstruct the history of mass
2 loading."

3 You're referring to Hadnot Point and
4 Holcomb Boulevard; right?

5 A. I believe so.

6 Q. Why are you not sure how they're
7 going to reconstruct the history of mass loading
8 at Hadnot Point and Holcomb Boulevard?

9 A. Well, I wasn't sure because there
10 were multiple sources. There was very little
11 record. There were underground storage tanks that
12 were leaking. They could discover where they were
13 but not necessarily when they started leaking.

14 There were aboveground storage
15 tanks. There were poor practices in industrial
16 facilities. There was -- there were, you know,
17 just multiple potential sources, and this was a
18 logical question, I thought. How are you going to
19 reconstruct it?

20 Well, I mean, they went ahead and
21 reconstructed it, and they documented the methods
22 they used and, you know, I mean, they did it.
23 There's uncertainty associated with that.

24 MR. ANWAR: All right. Okay.

1 I'm going to hand you a different
2 exhibit. Fortunately, it's another one
3 of these big transcripts. I am marking
4 this exhibit as Exhibit 16.

5 (Document marked for
6 identification as Konikow Exhibit 16.)

7 BY MR. ANWAR:

8 Q. Now, in your report, quickly jumping
9 back to Exhibit 2, on page 9, it is -- yeah, on
10 page 9, you include a graphic F16 from the Tarawa
11 Terrace reports.

12 Do you see that there?

13 A. Yes.

14 Q. Why did you include that graphic?

15 A. (Reviews document.)

16 Well, reading back, it looks like
17 Dr. Spiliotopoulos included that in his report,
18 and I wanted to discuss it. So I thought it might
19 be of value. I didn't include too many figures in
20 my report, but this is one I thought was worth
21 including.

22 It --

23 Q. Go ahead.

24 A. Do you want me to comment on that

1 figure or...

2 Q. Sure.

3 A. Well, as I say here, he's commonly
4 talking about the model being biased high or that
5 the estimates were biased high in it. You know, I
6 think he, you know, sort of cherry-picking results
7 that emphasize that and ignoring the results that
8 might counter it.

9 To me this, the figure that
10 apparently he used in his report, is really the
11 kind of results you want to see. The simulated
12 results at the time of five of these observations
13 falls right about a level of 800 when the
14 observations range from about -- I don't know -- 3
15 or 30 up to about almost 1600. That is the
16 simulated value falls right in the middle of that
17 range, and to me that's a good estimate of -- a
18 good illustration of where the model is doing a
19 really good job.

20 It's -- that's, you know, when
21 you're faced with the variability in the observed
22 data over such a short time at one point in time,
23 which sometimes it's hard to explain but,
24 nevertheless, there it is. You can't expect the

1 model with monthly time steps to match every
2 single one of those values. You want it to match
3 the central tendency of those values, and that it
4 did almost perfectly.

5 Q. Is it your opinion that this F16
6 figure shows a well-calibrated model?

7 A. Well, that it seems to be. It
8 certainly is not evidence of anything being biased
9 high.

10 And one of the things to note is
11 that this is the record at TT-26, which was the
12 most important water supply well in terms of
13 contributing contaminants to the Water Treatment
14 Plant.

15 If you could have said, without
16 seeing the simulated results, where would you have
17 wanted the model to be at that point in time, I
18 would say right at 800.

19 Q. And so it's your opinion that --
20 just to be clear, it's your opinion that Figure 16
21 shows TT-26 at least -- let me -- let me ask that
22 again.

23 Is it your opinion that with respect
24 to TT-26 the model -- this figure demonstrates the

1 model is calibrated well?

2 A. At least at that point. Again, it
3 doesn't prove there's a perfect match everywhere.
4 It's just at this point, boy, you couldn't do any
5 better. That's an important point. That location
6 is an important location.

7 Q. Okay. Let's -- is it your opinion
8 that ATSDR's Tarawa Terrace model does not
9 overestimate contaminant concentrations?

10 A. I think there was evidence at some
11 locations that it was too high, particularly
12 TT-23. It was not a good match at that location,
13 but in, you know, it's a model. You know,
14 calibration yields some, you know, it's a best
15 fit. Best fit by definition means at some point
16 it's too high. At some points it's too low.

17 In this case, you know, for the
18 Tarawa Terrace model, I think, you know, that's
19 certainly true. In some places, it's too high.
20 In some places, it's too low. It may be a little
21 too high at more places than you'd like. So there
22 is a slight, but I think it's not. I think
23 Spiliotopoulos overstated the degree to which it
24 overestimates.

1 Q. Turning back to -- I forget --
2 Exhibit 16, which is the transcript I handed you.
3 This is day 2 of the transcript -- excuse me.

4 This is the transcript for day 2 of
5 the 2009 expert panel.

6 A. Yes.

7 Q. Do you see that?

8 A. Yes.

9 Q. Okay. It's dated April 30, 2009;
10 correct?

11 A. Yes.

12 Q. Okay. If you turn to page 216 in
13 the transcript.

14 A. 2-1-6?

15 Q. Correct.

16 Are you there?

17 A. Yes.

18 Q. Okay. Your name is highlighted
19 there in the middle starting on line 5.

20 A. Yes.

21 Q. It states:

22 "You kind of mentioned earlier that
23 you have quite a lot of variability over short
24 periods of time in the observed concentration."

1 Which is what I think you were just
2 talking about?

3 A. Yes.

4 Q. And the next line is:

5 "That's really going to be a big
6 obstacle to calibrating the model."

7 Did I read that correctly?

8 A. That's what I said at the time.

9 Q. Okay. And those are your words;
10 correct?

11 A. Apparently.

12 Q. And Mr. Faye responds:

13 "It was and it is."

14 And you respond:

15 "Look at Figure F-16" the one we
16 just discussed in your report. You say:

17 "Look at Figure F-16 in your Tarawa
18 Terrace report. You have this simulated curve
19 that's coming up, a nice smooth curve, and then
20 there's one point in, I guess, 1985, where you
21 have five frequently, sampled -- you have five
22 frequently, samples collected over a short period
23 of time."

24 And then you go on to say:

1 "And they have a range much greater
2 than the long period of the --"

3 And then Mr. Faye cuts you off:

4 "I know. I know, Lenny. Let me
5 make a comment on that. In part -- in part of my
6 comment I'll reference, for example, the Table
7 C-7, if you want to check that out."

8 And then he goes on to explain a lot
9 the reasons for variability of concentration data.

10 I just wanted to confirm it.

11 As -- as of the 2009 expert panel,
12 it was your belief that the figure that we were
13 looking at demonstrated that calibrating the model
14 was going to -- it was going to be a big obstacle
15 to calibrate the model; right?

16 MR. DEAN: Objection to the
17 form.

18 Read the next few pages of the
19 transcript for him in context, not just a
20 section on it.

21 MS. BAUGHMAN: You can read as
22 much of it as you want before you answer.

23 BY MR. ANWAR:

24 Q. Well, let me ask this.

1 A. Okay.

2 Q. On page 216, the quote from lines 5
3 to 9, those are your words; right?

4 A. Yes.

5 Q. Okay. That's -- we can move on from
6 that.

7 A. I assume I was talking about the
8 Hadnot Point/Holcomb Boulevard model there.

9 Q. Why do you assume you were talking
10 about the --

11 A. Because this was an expert panel on
12 the Hadnot Point/Holcomb Boulevard model.

13 Q. Why would you immediately then refer
14 to F16?

15 A. By "immediate," I'm not sure what
16 you mean by immediately, but this is page 216 on
17 the second day. So it wasn't immediate.

18 Q. No. I guess I mean: You make the
19 comment about being a big obstacle to calibrating
20 the model. Mr. Faye responds "It was and it is"
21 and then you say "Look at F-16 in your Tarawa
22 Terrace report."

23 A. That refers to Tarawa Terrace.

24 Q. Okay.

1 A. I can't -- I can't say that the
2 previous comment was about Tarawa Terrace.

3 Q. Okay. So the -- the obstacle to
4 calibrating the model was at Hadnot Point/Holcomb
5 Boulevard?

6 A. I --

7 MR. DEAN: Object to the form.

8 THE WITNESS: I'm not sure,
9 but that's -- without reading back, I
10 think that's what we were talking about,
11 but I'm not positive.

12 BY MR. ANWAR:

13 Q. Okay. Fair enough.

14 MS. BAUGHMAN: Just for the
15 record, he didn't have time to read the
16 pages before and after for context.

17 MR. ANWAR: The record may
18 reflect that.

19 I'm going to hand you what I'm
20 marking as Exhibit 17.

21 (Document marked for
22 identification as Konikow Exhibit 17.)

23 THE WITNESS: Thank you.

24 BY MR. ANWAR:

1 Q. Exhibit 17 is a copy of Chapter F
2 for the Tarawa Terrace model; correct?

3 A. Yes.

4 Q. And so I wanted you to turn to page
5 33. It's page F33, and on page F33 there's a
6 figure, Figure F12; correct?

7 A. Yes.

8 Q. And Figure F12 is comparing observed
9 PCE concentration versus simulated PCE
10 concentration for the Tarawa Terrace model;
11 correct?

12 A. Yes.

13 Q. And would you agree that Figure F12
14 shows the model to be overpredicting PCE
15 concentrations?

16 MR. DEAN: Object to form.

17 THE WITNESS: I would agree
18 that there are more data points above the
19 solid line than below it, but what I
20 would note is that at the real critical
21 important high concentrations, the fit is
22 very good.

23 I would also note that there
24 are many or at least several duplicative

1 samples in here that really present a
2 little bit of an unfair picture in that
3 they're, you know, they reflect samples
4 collected within a day or two at the same
5 location and, therefore, shouldn't be
6 plotted in a way that seems to give equal
7 weight to each value.

8 BY MR. ANWAR:

9 Q. If you --

10 A. I think I discuss that in my expert
11 report.

12 Q. But you would agree that F12
13 demonstrates that the model overpredicts. TT
14 model is overpredicting; correct?

15 MR. DEAN: Object to form.

16 Asked and answered.

17 THE WITNESS: It's a limited
18 number of points. There are some points
19 there that probably shouldn't be there.
20 It doesn't include the agreement at
21 locations or for data points where there
22 were non-detects reported.

23 But in terms of what's shown
24 in Figure 12, there are more data points

1 above, but that's not -- this is just for
2 a limited number of observation points.
3 It's not a reflection of the
4 reasonableness of the whole model.

5 BY MR. ANWAR:

6 Q. Would you agree that calibration
7 targets are subjective?

8 A. Targets?

9 Q. Yeah.

10 A. I would say so.

11 Q. And then, therefore, whether a model
12 is calibrated is a subjective assessment as well?

13 A. Partly subjective. I mean, as a
14 hydrogeologist, you would have a good sense as to
15 whether or not you have a reasonable calibration,
16 but that assessment is certainly at least in part
17 subjective.

18 Q. What does the location of the
19 observed concentrations relative to the line in
20 Figure 12 tell you about the calibration and the
21 fit of observed versus simulated concentrations?

22 A. Tells me at the high concentrations,
23 the model did a really good job. Knowing some of
24 the basis of some of the data, I think some of the

1 points probably should be lumped together and not
2 shown as separate independent points. They're not
3 independent samples.

4 It's a very -- relative to the
5 number of calculations done in the model, this is
6 an extremely, extremely small sample. But that's
7 part of the problem that there just aren't that
8 many observed concentrations certainly over time.

9 But yeah, I -- yeah, I mean, this
10 table shows more values above that line of a
11 perfect match than below it.

12 Q. And there in the text right above
13 the last paragraph on F33, it says:

14 "Both results indicate that
15 simulated PCE concentrations moderately to
16 substantially overpredicted observed
17 concentrations at water-supply wells."

18 Correct?

19 A. That's what it says.

20 Q. Okay. So ATSDR in its report
21 indicated that the PCE concentrations were
22 moderately to substantially overpredicted, right,
23 at the water supply wells?

24 A. Well, what they said what you read

1 there. I would argue that they themselves gave
2 equal weight to those points, and I argue in my
3 expert report I point out that they should really
4 consider the overall accuracy at each of the
5 observation wells, which gives you a different
6 picture. Not a perfect picture, but it gives you
7 a different picture of the nature of the
8 overprediction and the calibration.

9 And in my expert -- expert report, I
10 think pointed out at 73 percent of the locations,
11 the fit was within their calibration targets as
12 opposed to the image given by in the report itself
13 and as pointed out by Dr. Spiliotopoulos.

14 Q. Did you say 73 percent fell within
15 the calibration standard?

16 A. In terms of the location, the
17 individual wells. I can look in the report and
18 see exactly what I said, but I think that's what I
19 said.

20 Q. Okay. It's okay.

21 A. Yeah.

22 Q. We can -- we can come back to that.

23 Would you agree that groundwater
24 data gets more independent the further apart the

1 data sets are in time?

2 MR. DEAN: Object to form.

3 THE WITNESS: I'm not sure I
4 understand the question.

5 BY MR. ANWAR:

6 Q. Okay. Scratch that. We'll come
7 back to that.

8 I guess the reference to that -- so
9 let me -- let me backtrack to that -- that last
10 question quickly.

11 I think you said -- and you correct
12 me if I'm wrong -- that data points are -- the
13 data points for -- it was F16 that we were looking
14 at -- were not independent because they were too
15 close in time; correct?

16 A. I don't remember if I said that they
17 weren't independent. I said, you know, in
18 Figure -- F-16 we're talking about?

19 Q. Correct.

20 A. I said they're close in time and
21 they have a very large spread or a large variance
22 in the values. The individual. The five values
23 that are collected at this scale it looks like
24 within a few days or so of each other show a large

1 range in concentration from close to 1600 to, you
2 know, 10 or 20 or 30, very low value.

3 And that's a degree of change that I
4 would not have expected in such a short period of
5 time in the same location, and yet there it is.
6 So I don't doubt that it happened. It's certainly
7 been observed in other areas where you get such a
8 big change in concentration.

9 So I don't understand the reference
10 to independence, but each of those five samples
11 were collected at the same location at slightly
12 different times and they showed widely varying
13 values.

14 MR. ANWAR: Okay. I'm going
15 to hand you what is being marked as
16 Exhibit 18.

17 (Document marked for
18 identification as Konikow Exhibit 18.)

19 BY MR. ANWAR:

20 Q. This is an article that you
21 published in "Groundwater" in 1986; right?

22 A. Yes.

23 Q. It's entitled "Predictive Accuracy
24 of a Ground-Water Model - Lessons from a

1 Postaudit"?

2 A. Yes.

3 Q. I just had a couple questions about
4 this article.

5 A. Okay.

6 Q. If you could turn to page 178.

7 A. 178?

8 Q. Correct.

9 A. Okay.

10 Q. There is Figure 8 there.

11 A. Yes.

12 Q. And you describe it as:

13 "Relation between predicted and
14 observed changes in water level in the
15 Tempe-Mesa-Chandler area of the Salt River basin,
16 Arizona, 1964 to '74. Solid line shows where
17 predicted equals observed values."

18 Did I read that correctly?

19 A. Yes.

20 Q. Okay. And it's very similar to --
21 understandably different site, different model,
22 but the presentation itself is very similar to the
23 figures we just looked at for -- for Tarawa
24 Terrace; correct?

1 MR. DEAN: Objection to form.

2 THE WITNESS: In a certain
3 sense, yeah.

4 BY MR. ANWAR:

5 Q. It's comparing observed versus
6 predicted --

7 A. Yeah.

8 Q. -- values?

9 A. Yeah.

10 Q. And so if you -- underneath there,
11 there is text under Assessment and Prediction.

12 Second paragraph states:

13 "The relationship between the
14 predicted and observed changes in water levels is
15 illustrated in Figure 8. If the predictions were
16 relatively accurate, the data should plot along
17 (or close to) the 45 degree line connecting equal
18 values of predicted and observed changes.

19 Instead, data from all but three wells fall below
20 that line, indicating poor accuracy and the
21 presence of bias in the model predictions."

22 Did I read that correctly?

23 A. Yes.

24 Q. And in this article, you stated that

1 the model indicated poor accuracy due to the fit
2 of the simulated concentrations, the observed
3 versus simulated on the line; is that right?

4 A. Can you say that again?

5 Q. Sure.

6 In this article, you said because
7 the simulated or predicted values fell below the
8 45 degree line --

9 A. Yes.

10 Q. -- that it indicated poor accuracy
11 and presence of bias in the model predictions;
12 correct?

13 A. Yes.

14 Q. And why is that?

15 A. The scatter was very large and the
16 magnitude of the errors of the differences was
17 very large. Much larger than in the example from
18 Tarawa Terrace.

19 Here you have where the observed
20 water level -- let's see -- some of the points
21 where it's observed at zero change, they observed
22 a drawdown or a negative change of more than 160
23 feet.

24 And errors in the groundwater flow

1 model, you know, more than 50 feet to 100 feet is
2 really large, and here there were quite a few that
3 were really very large in terms of the magnitude
4 of the error. But, you know, clearly, you know,
5 this would reflect a bias.

6 Q. Okay. Those -- those are the
7 questions I have about that document.

8 Let's take a quick two-minute break.
9 Thank you.

10 A. Sure.

11 THE VIDEOGRAPHER: We're going
12 off the record. The time is 4:54.

13 (A recess was taken.)

14 THE VIDEOGRAPHER: We're back
15 on the record. The time is 5:01 PM.

16 BY MR. ANWAR:

17 Q. We're back on the record from a
18 short break.

19 Dr. Konikow, are you okay to
20 continue?

21 A. Yes.

22 Q. Okay. I wanted to ask you a couple
23 questions about -- about each of the two models.

24 So for Tarawa Terrace, ATSDR used a

1 simple mixing flow-weighted average model to
2 compute PCE concentrations delivered to the Tarawa
3 Terrace Water Treatment Plant; right?

4 A. Yes.

5 Q. And that was from all active supply
6 wells and subsequently to the Tarawa Terrace water
7 supply network.

8 Does that sound right to you?

9 A. That sounds right, yes.

10 Q. Okay. And they did the same thing
11 for Hadnot Point, correct, used a simple mixing
12 model?

13 A. I believe that's what they did.

14 Q. And so you'd agree that ATSDR didn't
15 model -- or strike that. Let me ask.

16 You'd agree that neither the Tarawa
17 Terrace nor the Hadnot Point/Holcomb Boulevard
18 models included calculations for contaminant
19 losses during storage treatment or distribution;
20 right?

21 A. I believe so.

22 Q. Meaning you'd agree?

23 A. Yes.

24 Q. Okay. So the models don't take

1 into -- neither Tarawa Terrace model nor the
2 Hadnot Point/Holcomb Boulevard model take into
3 account VOC losses during the water distribution
4 process; correct?

5 A. My recollection of the expert peer
6 panels is that there were experts there in
7 volatilization and water treatment processes, and
8 they stated, as best I could recollect, that there
9 was not significant volatilization or losses of
10 the VOCs for these particular water treatment
11 plants. And so seemed to me as an expert reviewer
12 of the work that that seemed like a reasonable
13 assumption.

14 Q. So -- so the models don't take into
15 account VOC losses; correct?

16 A. The inference was that there are no
17 VOC losses to account for.

18 Q. So they don't take into account
19 losses that they don't account for; correct?

20 MR. DEAN: Object to the form.

21 THE WITNESS: They don't take
22 into account losses that don't exist.

23 BY MR. ANWAR:

24 Q. Okay. I think earlier you mentioned

1 reviewing Sabatini's rebuttal report; correct?

2 A. Let's say I read it. I, you know,
3 in the sense reviewing it in the sense of having
4 read it, but it was not a technical review of
5 Sabatini's report.

6 Q. And Dr. Sabatini acknowledges that
7 VOC losses do occur in the water distribution
8 process; right?

9 A. Very small. You know, he was
10 talking about maybe, as I recall, maybe a 6
11 percent loss, but it was -- he implied that this
12 was pretty negligible, as I recall.

13 Q. And you would agree whether it's 6
14 percent, or some other number, the ATSDR models
15 don't take into account those losses; correct?

16 A. The groundwater flow and solute
17 transport models that I reviewed did not include
18 the Water Treatment Plant. So what was done to
19 the water distribution model I did not look
20 closely at, but I know that they did not include a
21 volatilization loss in that model.

22 You know, the data from the Water
23 Treatment Plant, in effect, they were computing
24 what it was, but that didn't go into the model

1 calibration. It really was a -- I mean, what they
 2 ended up doing in the end is increasing the
 3 confidence in the groundwater flow and transport
 4 models because there was a pretty good match
 5 between their estimated concentrations in the
 6 Water Treatment Plant and what was actually
 7 observed there. So, but that was without
 8 considering volatilization.

9 Q. Okay. Thank you.

10 I wanted to talk to you a little bit
 11 about the retardation factor. You addressed that?

12 A. Yeah.

13 Q. You addressed some of
 14 Dr. Spiliotopoulos's -- Spiliotopoulos's -- it's
 15 been a long day --

16 A. Yeah.

17 Q. -- opinions --

18 A. Yes.

19 Q. -- about the retardation factor and
 20 the variables in calculating the retardation
 21 factor; correct?

22 A. Yes.

23 Q. Okay. Can you explain to me what a
 24 retardation factor is?

1 A. Okay. The retardation factor
2 reflects that some constituents, like PCE, are
3 somewhat reactive with the solid grains of the
4 aquifer, and they would tend to sorb or ion
5 exchange onto the solid grains.

6 This means as a net, the net average
7 velocity -- because of sorption and desorption
8 reaction going on, the net velocity of that
9 constituent can be slower than the net average
10 velocity of the water itself.

11 So you could constituent, you know,
12 it's moving in with the groundwater due to
13 advection. It's spreading a little due to
14 dispersion. But at the same time, some of it gets
15 sorbed and some keeps moving. And then that sorb
16 thing may come off again, desorb and then start
17 moving.

18 And the net effect of all the
19 sorption, desorption, ion exchange, all the other
20 things going on, reactions or the complex
21 reactions, the net effect is assume that you can
22 on the average represent it with a retardation
23 factor that really represents the ratio of the
24 average velocity of the constituent to the average

1 velocity of the water. So that if a retardation
2 factor is 3, the constituent moves at one-third
3 the velocity of the water.

4 Q. Okay. Would it be fair to say the
5 higher -- and you should correct me if I'm
6 misunderstanding this -- but the higher the
7 retardation factor, the longer it takes for the
8 contaminant to travel through the water or the
9 subsurface in the water?

10 A. I think that's fair.

11 Q. Okay. And the same sort of
12 relationship exists between bulk density, which is
13 a variable of the retardation factor; correct?

14 A. I'm not sure I understand the
15 question.

16 MR. DEAN: Object to form.

17 BY MR. ANWAR:

18 Q. Sure.

19 So bulk density is a variable of the
20 calculation for the retardation factor; correct?

21 MR. DEAN: Object to form.

22 THE WITNESS: It's one of the
23 factors that go into estimating the
24 retardation factor if you want to

1 calculate it based on other factors. I
2 mean, it really comes down to the fact
3 that the retardation factor is a
4 component of the transport equation.

5 The bulk density, the KD, and
6 the other terms in there are not directly
7 in the governing equation. They're not
8 in the model.

9 The model kind of externally,
10 you know, it asks for input of KD and
11 bulk density, and then it calculates the
12 retardation factor, and then the solution
13 of the transport equation is based on the
14 retardation factor.

15 So the, you know, the bottom
16 line is that, you know, the parameter to
17 be calibrated on, the parameter to be
18 estimated really is the retardation
19 factor, not -- not individual estimates
20 of bulk density or KD.

21 BY MR. ANWAR:

22 Q. I guess what I was getting at is:
23 If the bulk density increases, doesn't the
24 retardation factor necessarily increase as well,

1 assuming the other variables remain constant, KD
2 and --

3 A. Well, sure, but you can't assume
4 that. You know, again, it's -- the parameter that
5 counts is RF. So, you know, for the calibrated
6 model, if you want to say the bulk density is
7 higher, you have to say the KD is lower in a
8 compensating way.

9 Q. Okay. Dr. Spiliotopoulos pointed
10 out to two errors in ATSDR's Tarawa Terrace model
11 in calculating the retardation factor; correct?

12 A. He pointed out an error in
13 estimating the bulk density using a wet bulk
14 density instead of a dry. That, and I think they
15 acknowledged. They agreed that that was an error.

16 Q. And didn't he point out an error in
17 KD as well?

18 A. I don't recall that but that's...

19 Q. So if we go to page 10 of your
20 report.

21 A. Okay.

22 Q. In the middle of the page under the
23 first paragraph of Opinion 3, middle paragraph you
24 talk about the error that Dr. Spiliotopoulos

1 caught relating to bulk density, correct, for bulk
2 density?

3 A. Yes.

4 Q. Okay. I think maybe I'm
5 misremembering.

6 But in any event, the middle of the
7 page a little further down it says:

8 "However, as Dr. Spiliotopoulos
9 himself admits, this significant impact on RF does
10 not actually occur because the calibration process
11 compensates for an overestimate of PB by
12 estimating a value for KD that appears to be too
13 low. Recall that neither of these two parameters
14 are used directly in the transfer model."

15 Did I read that correctly?

16 A. Yes.

17 Q. And so I think what -- if I'm
18 understanding you, you acknowledge that the bulk
19 density was overestimated; correct?

20 A. And I'm also saying it didn't make
21 any difference.

22 Q. I understand that.

23 But you agree that the bulk density
24 was overestimated; correct?

1 A. Yes, for the Tarawa Terrace.

2 Q. And you agree that the KD was too
3 low; correct?

4 A. Well, in the sense that the model
5 was calibrated to RF, and so if row B was too
6 high, then KD had to be too low. This is the
7 whole concept of compensating errors. That's the
8 essence of a model calibration.

9 Q. But the errors exist is my point;
10 correct?

11 A. Yes.

12 Q. And I understand that it's your
13 opinion that they offset each other, so it's not
14 an issue; correct?

15 A. Well, I think it's -- yeah, it's my
16 opinion. It would also be the opinion of others.

17 Q. Now, the values used for -- the
18 parameter values used for the retardation factor
19 calculation -- and I think you acknowledge this in
20 your report. I can find the precise place if I
21 need to.

22 But the values -- the parameter
23 values used to calculate the retardation factor
24 differ between the Tarawa Terrace model and the

1 Hadnot Point/Holcomb Boulevard model; correct?

2 A. I believe there was a small
3 difference. Yeah. I think one was 2.9 and the
4 other is 3.3 or something on that order. A small
5 difference but, yeah, a difference.

6 Q. And that's even though Tarawa
7 Terrace and Hadnot Point were both on Camp
8 Lejeune; correct?

9 A. Nothing wrong with that. That's a
10 small difference. If you look at the hydraulic
11 conductivity maps, you see much bigger differences
12 over much shorter distances. This is not
13 unexpected in a geologic environment or geologic
14 framework.

15 Q. And I can pull out the report if you
16 need me to show it to you, but ATSDR states in its
17 report in the Hadnot Point/Holcomb Boulevard study
18 that -- excuse me -- it states in -- yeah, in the
19 Hadnot Point report, Holcomb Boulevard report that
20 sorption in the Hadnot Point/Holcomb Boulevard
21 study area is assumed to be similar to sorption in
22 the study area of -- for Tarawa Terrace.

23 A. In terms of the process?

24 Q. Okay.

1 A. Yeah.

2 MS. BAUGHMAN: Object to
3 the -- you didn't show him the document,
4 right? You need to show him the document
5 before he answers that.

6 THE WITNESS: So I think -- I
7 mean, it sounds to me like you're saying
8 they're saying sorption process is
9 sorption process in both areas.

10 BY MR. ANWAR:

11 Q. Okay. And wouldn't that dictate
12 that the parameter values for -- wouldn't that
13 suggest that the parameter values between Tarawa
14 Terrace and Hadnot Point/Holcomb -- and Holcomb
15 Boulevard should -- should --

16 A. Be the same?

17 Q. -- be similar, the same?

18 A. Well, they are similar, but they're
19 not the same, and it does not imply that they
20 would be identical.

21 Q. Okay.

22 A. Or necessarily close. I mean,
23 again, if you look at the hydraulic conductivity
24 map, for which there are a fair number of aquifer

1 tests and slug tests and so on, you find much
2 better. You see a much bigger variability between
3 Tarawa Terrace and Hadnot Point in terms of the
4 precise estimates of hydraulic conductivity.
5 Another important parameter.

6 MR. ANWAR: Okay. I'm going
7 to hand you what I'm marking as
8 Exhibit 19.

9 (Document marked for
10 identification as Konikow Exhibit 19.)

11 BY MR. ANWAR:

12 Q. This is one of the documents that
13 was produced to us last night that was in your
14 possession --

15 A. Yeah.

16 Q. -- Dr. Konikow; is that right?

17 A. That's correct.

18 Q. Okay. And it is a letter to you
19 from Morris Maslia on behalf of ATSDR providing
20 Mr. Maslia or I guess -- yeah -- ATSDR's responses
21 to your review comments; correct?

22 A. It's Bob Faye's responses.

23 Q. Bob Faye's responses. Okay. Thank
24 you.

1 And I think earlier you had
2 indicated that -- we had a discussion about the
3 issues you raised with respect to limited data for
4 both the models that ATSDR performed and other
5 concerns that were raised, and I think you said
6 that you reviewed the reports recently and those
7 issues had been addressed; correct?

8 A. The issues had been addressed, and I
9 think some of the details of those are expressed
10 by Bob Faye in this response letter.

11 Q. Now, in this response letter, Bob
12 Faye, on behalf of ATSDR, doesn't agree with all
13 of the concerns that were expressed; correct?

14 A. That's correct. That's normal.

15 Q. And so is it your testimony that
16 this response or this response along with your
17 recent review of the ATSDR reports is what
18 satisfies your -- your belief that the -- your
19 concerns were addressed?

20 A. Yeah, I think they -- I think they
21 seriously considered every comment and suggestion
22 that I had made and that the expert panel had
23 made, but that doesn't mean they have to accept
24 every one. It's just that I think they did

1 seriously consider every one of them.

2 And, again, you know, they're the
3 ones who worked for years on the site. I only
4 looked at it for a few hours.

5 Q. The major concerns that are listed
6 here, are these the major concerns you raised?

7 A. This is an outcome of my review of
8 the Chapter F draft report. So yeah, these are
9 issues that I raised, I believe.

10 Q. And number 1 there is:

11 "The lumping of two aquifers and one
12 confining unit into the superficial model
13 layer 1."

14 Correct?

15 A. Correct.

16 Q. What was your concern? What was the
17 concern you raised there?

18 A. Well, I was concerned that -- I
19 mean, it's always -- in developing a model,
20 there's always a conflict between lumping and
21 dividing in a general sense, you know. How much
22 do you want to lump? How much do you want to
23 divide?

24 My concern was that if there was a

1 continuous low permeability confining layer lumped
2 in the middle of a single model layer, it might
3 not adequately reflect the vertical velocities
4 through the system.

5 The responses were, I think,
6 alleviated my concerns, pointing out that the
7 material above the confining layer was generally
8 typically for most of the time unsaturated and
9 really would not be included in the model, and if
10 it had been, would have generated numerical
11 difficulties.

12 They pointed out that the confining
13 layer is discontinuous, that it's sandy, and that
14 material would -- there was good hydraulic
15 connection through that layer.

16 And considering everything, I
17 thought, okay, that's a reasonable explanation.

18 Q. Okay. Is there any part of Robert
19 Faye's response to your concern number 1, major
20 concern number 1 that you disagree with?

21 A. (Reviews document.)

22 No. It's an explanation of things
23 that I hadn't fully appreciated at the time I did
24 the review.

1 Q. Number 2 of your major concerns:
2 "The use of a finite-difference
3 method to solve the governing transport equation
4 (which causes substantial numerical dispersion,
5 especially if time steps are too large)."

6 What was your concern there?

7 A. My concern was that just the
8 finite-difference numerical solution itself can
9 cause calculated concentrations to increase, to
10 spread where it's not related to the physical
11 process of dispersion, and that was my concern.
12 That's a recognized issue sometimes with the
13 finite-difference numerical method for solving the
14 transport equation.

15 So that was a concern. I think it
16 was a reasonable concern to make sure that they
17 had considered this, evaluated it, and that it
18 wasn't a significant issue.

19 Q. Did this response satisfy you?

20 A. Yes. The response, I mean, I think
21 it pointed out that they did carefully consider
22 the Peclet number and the Courant number and that
23 they did testing for grid spacing and time
24 stepping.

1 Some of this is shown on page 16
2 where they compared calculations at two wells at
3 three different times for using a one day time
4 step compared with their one month time step that
5 was actually used in the model, and it's an
6 incredibly small difference.

7 So that is telling me that this is
8 not a problem. It's not an issue. I mean, the
9 differences are in the, you know, 4th significant
10 figure, which is just --

11 Q. The first --

12 A. -- not one to be concerned with.

13 Q. The first sentence of the response
14 to number 2 about the finite -- finite-difference
15 method is:

16 "First of all the reviewer probably
17 has no idea whether or not using a code based on
18 finite-difference methods caused substantial --
19 'substantial' or insubstantial numerical
20 dispersion during solution of the Tarawa Terrace
21 fate and transport model."

22 Would you agree that you had no idea
23 whether or not using a code based on
24 finite-difference methods caused "substantial" or

1 insubstantial numerical dispersion during solution
2 of the Tarawa Terrace fate and transport model?

3 A. For the case of the Tarawa Terrace
4 model, I did not know whether or not it caused
5 substantial numerical dispersion, which is why I
6 was -- and I suspected he didn't know either, and
7 this is why I brought the issue up.

8 Because in the literature, the issue
9 of numerical dispersion related to
10 finite-difference solutions is in the literature,
11 and that it can under certain circumstances cause
12 substantial numerical dispersion.

13 By "substantial" I'm not sure
14 exactly what that means, but it can cause
15 numerical dispersion due to the solving of the
16 equation rather than due to the physical
17 processes. This is a recognized issue in solute
18 transport modeling and solving the equation.

19 As a reviewer, I felt he had
20 to -- because they were using the
21 finite-difference method, I felt he had to address
22 it more carefully than he had.

23 Q. Okay. Number 3 on the next page,
24 page 4 states:

1 "The reliability of the estimate of
2 the biodegradation rate constant based on the
3 assumption that concentration declines observed at
4 one location over a period of several years can be
5 explained solely by biodegradation."

6 What was your concern there?

7 A. I don't remember all the details of
8 that concern, but I think the way they estimated
9 biodegradation rates. I'm not positive. I think
10 they looked at some condition where the
11 concentration decreased over time, and they used
12 that as a basis for estimating the degradation
13 rate.

14 And I was raising a concern that how
15 well could they isolate the degradation due to
16 biodegradation versus a reduction in concentration
17 due to advection and dispersion, and, you know, I
18 don't remember in detail what -- how they actually
19 did that calculation. I just don't remember.

20 Q. And the first line of the response
21 there on number 3 is:

22 "The authors never claimed that the
23 biodegradation rate computed using field data was
24 reliable or the sole reason for the observed

1 decline in PCE concentration."

2 Did I read that correctly?

3 A. Yes.

4 Q. So is Robert Faye saying here that
5 the biodegradation rate computed using field data
6 wasn't reliable?

7 MR. DEAN: Object to form.

8 THE WITNESS: What I think the
9 implication is, the bottom line is that
10 he's saying that it's a parameter that
11 had to be estimated with the calibration
12 process. It's a parameter, just like the
13 retardation factor.

14 It's a parameter that you
15 couldn't rely completely on the
16 calculation. You had to use it as a
17 parameter in the calibration method.

18 It's a parameter that had to
19 be estimated just like the retardation
20 factor, and you adjust the values of
21 these within some reasonable range to
22 yield the best fit for the overall
23 simulation.

24 And I think what he's saying

1 here is that he recognizes that this is a
2 parameter to be adjusted during the
3 calibration.

4 BY MR. ANWAR:

5 Q. To your knowledge, did ATSDR test
6 higher biodegradation rates for TT, for Tarawa
7 Terrace?

8 A. I believe they did.

9 Q. Did you evaluate the range of
10 biodegradation rates that ATSDR considered?

11 A. I -- I'm sure I looked at it, but I
12 didn't do a detailed evaluation of it. I'm pretty
13 sure I did not, but I think certainly at the time
14 I did the review, I was aware of what they did.

15 Q. Do you recall the biodegradation
16 rate that they ended up using for Tarawa Terrace?

17 A. Yeah. Yeah. I mean, here they're
18 talking about .0005 in that range, and so I assume
19 they went up and down from 0005 to a higher value
20 and a lower value. I don't recall exactly what
21 the range was.

22 Q. Number 4 on page 4 states:

23 "The exclusion of concentration data
24 collected in monitoring wells from the calibration

1 basis."

2 Why was it a major concern to you to
3 exclude concentration data collected in monitoring
4 wells for calibration?

5 A. I'm not sure if it was a major
6 concern compared with some other things. It was a
7 concern, and I didn't understand why if they had
8 concentration data from a monitoring well or from
9 a point, why they would not use that in the
10 calibration.

11 I'm -- I'm, you know, he gave an
12 answer, but I'm still not sure why. If I was
13 doing it, I probably would have used those values,
14 with the recognition that it's a sample from a
15 point rather than a pumping well that brings in
16 lots of water.

17 So I think that was kind of his
18 basis for not using it is that it was sampling an
19 extremely small volume of the aquifer.

20 I would have, you know, I, you know,
21 if I was doing it, I would say, well, it's still a
22 point within the volume and I would have -- I
23 would have looked at it and, you know, I might --
24 unless I saw some reason not to, I would have used

1 it in the calibration.

2 But he had a reason for not and, you
3 know, we may disagree on that.

4 Q. Okay. So that may be at least one
5 area where you disagree in terms of these
6 comments?

7 A. Well, to some extent. You know,
8 it's certainly not a fatal flaw in the
9 calibration. It's a -- it's his way of looking at
10 it and I, you know, he had experience in the area.
11 He worked it for years.

12 I only, you know, spent two days
13 reviewing it. So, you know, that's -- I didn't
14 have the hands-on experience he did, but -- but
15 from what I, you know, I probably would have used
16 the monitoring well data as part of the
17 calibration.

18 Q. Okay. The number 5 there on page 5
19 identifies as a concern that you had:

20 "The use of a much larger mass
21 loading rate than apparently was indicated by the
22 field data in order to improve model calibration."

23 Tell me about that concern.

24 A. I don't remember the details of why

1 I said that. I can't remember.

2 Except that there must -- there
3 probably was some indication or initial estimate
4 of what the mass loading rate was, and it was
5 adjusted in the model calibration to achieve the
6 best fit, and that calibration indicated a much
7 higher mass loading rate.

8 And, you know, it's -- it's an
9 issue, again, I don't recall the details of.

10 Q. So Robert Faye in his response
11 starts by saying:

12 "First of all please note that field
13 data did not indicate a mass loading rate. The
14 computations of PCE mass in the saturated and
15 unsaturated zones described in the report were the
16 result of a highly interpretative, somewhat
17 subjective calculation using field data."

18 Do you see that there?

19 A. Yes.

20 Q. What is -- what was your reaction to
21 that response to the concern you had expressed?

22 A. You know, I don't remember my
23 reaction at the time but, you know, you're looking
24 at it now. He's explaining what he did, maybe a

1 little more clearly than was in the report.

2 You know, he's saying that there's
3 some subjectivity and approximations that went
4 into that calculation, which itself is not
5 surprising considering the nature of the sources.

6 Q. Did you disagree at all with the
7 mass loading rate ATSDR chose to use?

8 A. Not per se, no. No.

9 Q. Do you disagree with the start date
10 for contamination that ATSDR chose to use for
11 Tarawa Terrace?

12 A. No, it seemed reasonable.

13 Q. Between the Tarawa Terrace model and
14 the Hadnot Point and Holcomb Boulevard model, do
15 you view one model as better or more accurate than
16 the other?

17 MR. DEAN: Object to form.

18 THE WITNESS: Both models, I
19 think, are reasonable, using well
20 accepted state-of-the-art methods. I
21 think both models are quite acceptable.
22 I think their predictions are reasonable,
23 with the recognition of uncertainty.

24 The Tarawa Terrace model

1 clearly had a better defined source term
2 and that, you know, probably yields a
3 little more confidence in that model. A
4 little more confidence in the results.

5 But the numerical solutions I
6 think are good numerical solutions in
7 both cases given the assumptions about
8 the stresses on the system and the
9 parameters.

10 I mean, they're basically the
11 same model in the sense that they're both
12 using MODFLOW and MT3D, which are both
13 good models.

14 BY MR. ANWAR:

15 Q. The Hadnot Point/Holcomb Boulevard
16 site was more complex to model than Tarawa
17 Terrace; right?

18 A. In the sense of source terms and
19 mass loading, yes. Other than that, I think
20 they're equivalent.

21 Q. There were more sources at Hadnot
22 Point; correct?

23 A. Yes. Yes.

24 Q. There were -- were there more wells

1 to examine in Hadnot Point/Holcomb Boulevard?

2 A. Probably a few more. I think
3 -- yeah, I think there were more. I don't recall
4 the numbers, though, but...

5 Q. Was Hadnot Point/Holcomb Boulevard a
6 generally larger area to model?

7 A. It was somewhat larger, yeah, and
8 also they -- for the transport, they broke it down
9 into two separate MT3D models. One focusing on
10 the landfill area and another focusing on the
11 industrial area. So there wasn't one MT3D model
12 for the Hadnot Point/Holcomb Boulevard. There's
13 one flow model.

14 Q. The Holcomb Boulevard/Hadnot Point
15 model also included a water distribution model to
16 simulate connections between Hadnot Point and
17 Holcomb Boulevard; right?

18 A. I believe so.

19 Q. And that was an additional
20 complexity introduced into the Hadnot
21 Point/Holcomb Boulevard modeling; correct?

22 A. I guess you could say that. I don't
23 think that was a major complexity, but yeah, it
24 was an additional factor.

1 Q. Could you turn to page 10 of this
2 document.

3 A. Okay.

4 Q. In the middle of the page, so page
5 46 to 49.

6 A. 59?

7 Q. 59. Excuse me. Thank you.

8 It looks like Robert Faye agrees
9 with a suggestion you made, and it says "A
10 sentence has been added to the report."

11 Do you see that?

12 A. Yes.

13 Q. And then underneath that, he
14 discusses biodegradation rate again and he says:

15 "Disagree. This criticism was
16 previously addressed under Major Concerns, item
17 #3," which we just discussed. "The reviewer's
18 suggestion to simulate PCE concentrations using a
19 degradation rate of zero and adjust the field data
20 by simulated changes is not accepted. Adjustments
21 to field data using such simulated changes would
22 not add any additional certainty -- any
23 additional -- would -- excuse me -- adjustments to
24 field data using such simulated changes would add

1 additional uncertainty to an already uncertain
2 process."

3 Do you agree with what he's saying
4 there?

5 A. I think it's a reasonable
6 perspective and so, yeah, I certainly would accept
7 that comment.

8 Q. You had suggested, according to this
9 document, "to simulate PCE concentrations using a
10 degradation rate of zero and adjust the field data
11 by simulated change -- and adjust the field data
12 by simulated changes."

13 What did you mean by that?

14 A. First of all, I don't remember
15 precisely what I suggested. I don't have that
16 original comment in front of me.

17 But just from what it says here, I'm
18 assuming I had suggested whatever biodegradation
19 rate he used, I said rerun it with zero and
20 assess, you know, see what difference is. What --
21 what -- assess at least qualitatively what the
22 impact of that biodegradation is.

23 But I don't recall it precisely or
24 at all exactly what I said there, but it was a

1 suggestion. He didn't. He disagreed, and I think
2 that's fine.

3 Q. Okay. On -- if you skip down a
4 couple of the page 59 comment.

5 A. Yeah.

6 Q. It says "Mass loading" and Robert
7 Faye says:

8 "Disagree. See comments under Major
9 Concerns, item #5. The reviewer seems to assign a
10 high degree of accuracy and credibility to the PCE
11 mass computation that is unwarranted. As
12 explained previously, the computation of PCE mass
13 was a highly interpretative and somewhat
14 subjective -- highly interpretative and somewhat
15 subjective process frequently based on
16 questionable data."

17 Did I read that portion correctly?

18 A. You read it correctly.

19 Q. Do you have any understanding of
20 what means when he says "the computation of PCE
21 mass was a highly interpretative and somewhat
22 subjective process frequently based on
23 questionable data"?

24 MR. DEAN: Object to the form.

1 THE WITNESS: You know,
2 I'm -- right now I'm not sure what he
3 meant. I don't recall at the time if I
4 understood what he meant. I'm just
5 -- I'm just not sure.

6 Except that he's -- he's
7 saying that the computation of PCE mass,
8 there's a lot of uncertainty there seems
9 to be what he's saying, and I certainly
10 don't disagree with that.

11 I don't -- I don't recall
12 assigning a high degree of accuracy to
13 it, but he seems to imply that I did or
14 at least he inferred that I did. I don't
15 think I would have, but I don't know.

16 BY MR. ANWAR:

17 Q. That's what the document states;
18 right?

19 A. Yeah.

20 Q. He goes on to say in the rest of
21 that:

22 "Field data applied to the PCE mass
23 computation were limited both spatially and
24 vertically. The computation was accomplished

1 regardless of data limitations to provide an
2 estimate of a minimum mass loading rate to use to
3 begin model calibration."

4 Is that right?

5 A. Okay. Tell me again which paragraph
6 you're reading. The first paragraph on page 59 or
7 the second one under that? Sorry. I lost track.

8 Q. No, it's okay. It's okay. I think
9 you -- you addressed what I was asking you.

10 MR. ANWAR: Let's take a short
11 break. I think I'm close to wrapped up.
12 I just want to check my notes.

13 THE VIDEOGRAPHER: We're going
14 off the record. The time is 5:43 PM.

15 (A recess was taken.)

16 THE VIDEOGRAPHER: We're back
17 on the record. The time is 5:51 PM.

18 BY MR. ANWAR:

19 Q. Okay. A few more questions for you,
20 Dr. Konikow.

21 A. Okay.

22 Q. I appreciate you're willingness to
23 speak with us. I know it's been a long day.

24 I wanted to ask you.

1 In terms of parameter estimation or
2 determining parameters as inputs in the model,
3 generally speaking, is it better -- is a parameter
4 that reflects the real world better than one that
5 doesn't?

6 A. That seems like a reasonable
7 statement.

8 MR. ANWAR: Okay. Okay. I'm
9 handing you what I'm marking as
10 Exhibit 20.

11 (Document marked for
12 identification as Konikow Exhibit 20.)
13 BY MR. ANWAR:

14 Q. And I will just represent to you
15 that this is ATSDR's response to a critique that
16 the Navy offered about the Tarawa Terrace
17 modeling.

18 Have you seen this before?

19 A. Not that I recall.

20 Q. Okay. Did you review the Navy's
21 critique of the Tarawa Terrace model in forming
22 your -- the opinions in your rebuttal report?

23 A. No, I don't remember seeing this.

24 Q. Okay. If you could turn to

1 page -- I'm going to have to identify it by the
2 Bates ranges. It's the page ending 33271.

3 A. Say that again.

4 Q. So at the bottom, there's a little
5 Bates stamp that says "CLJA_WATERMODELING."

6 A. Yes.

7 Q. And then there's a number. It's the
8 one at the end that says 33271.

9 A. 33271?

10 Q. Correct.

11 It's in the middle of the page,
12 there is a comment from the Navy labeled 7.1.
13 Do you see that?

14 A. Yeah.

15 Q. Okay. And so I just wanted for
16 context to provide you the -- or show you the
17 comment that ATSDR was responding to.

18 The Navy stated:

19 "However, all comparisons did not
20 fall within the calibration range. At the Water
21 Treatment Plant, 12% of the simulated PCE
22 concentrations failed the calibration standard ...
23 at the water supply wells, a majority (53%) of the
24 simulated concentrations fell outside of the

1 outside the calibration standard."

2 Did I read that correctly?

3 A. You read it correctly.

4 Q. Is that consistent with your
5 understanding of the calibration for the Tarawa
6 Terrace model?

7 MR. DEAN: Objection to the
8 form of the question.

9 THE WITNESS: I'm not sure,
10 but I've seen that 53 percent number, I
11 think, in Alex Spiliotopoulos' in his
12 report, and I disagree that that was a
13 fair assessment of the accuracy.

14 BY MR. ANWAR:

15 Q. Okay. If you turn the page, ATSDR
16 responds -- well, ATSDR starts responding on the
17 prior page, but their response goes on to the next
18 page.

19 So on the page ending 33272, I just
20 wanted to ask you about a portion of their
21 response.

22 A. Okay.

23 Q. The very last paragraph there
24 states:

1 "To address the issue of the
2 intended use of the water-modeling results by the
3 current ATSDR epidemiological study, the
4 Department of Navy should be advised that a
5 successful epidemiological study places little
6 emphasis on the actual (absolute) estimate of
7 concentration and, rather, emphasizes the relative
8 level of exposure. That is, exposed individuals
9 are, in effect, ranked by exposure level and
10 maintain their rank order of exposure level
11 regardless of how far off the estimated
12 concentration is to the true -- 'true' (measured)
13 PCE concentration. This rank order of exposure
14 level is preserved regardless of whether the mean
15 or the upper or lower 95% of simulated levels are
16 used to estimate the monthly average contaminant
17 levels. It is not the goal of the ATSDR health
18 study to infer which health effects occur at
19 specific PCE concentrations -- this task is for
20 risk assessment utilizing approaches such as
21 meta-analysis to summarize evidence from several
22 epidemiological studies because a single
23 epidemiological study is generally insufficient to
24 make this determination."

1 And then it goes on:

2 "The goal of the ATSDR
3 epidemiological analysis is to evaluate
4 exposure-response relationships to determine
5 whether the risk for a specific disease increases
6 as the level of the contaminant (either as a
7 categorical variable or continuous variable)
8 increases."

9 Did I read that correctly?

10 A. I think you read it correctly, yeah.

11 Q. What do you understand ATSDR to be
12 saying in this response?

13 MR. DEAN: Object to the form
14 of the question.

15 You want him to comment on
16 what ATSDR is saying, right?

17 MR. ANWAR: Isn't that what
18 he's doing anyway?

19 MR. DEAN: No. Object to
20 form.

21 MR. ANWAR: That's his role as
22 an expert.

23 THE WITNESS: I think what
24 they're saying is that the exposure

1 levels are considered in terms of a
2 ranking based on how -- where it is in
3 the scale and that it's not based on the
4 actual concentration value.

5 So it's like a high, low,
6 medium or, you know, some -- something on
7 that scale rather than 95.3 to 89.9 or
8 anything like that.

9 So but, again, I'm, you know,
10 I'm certainly not an expert in
11 epidemiological studies, so I'm not sure
12 what all the implications here are.

13 BY MR. ANWAR:

14 Q. It appears to me he's saying, for
15 the purpose of a successful epidemiological study,
16 at least the one ATSDR was conducting, and I'm
17 quoting, it says:

18 "Places little emphasis on the
19 actual (absolute) estimate of concentration" and
20 then it goes on to say "regardless of how far off
21 the estimated concentration is to the 'true'
22 (measured) PCE concentration."

23 Based on that, it appears to me he's
24 saying that for this model for the purpose that it

1 was intended for in terms of providing information
 2 for epidemiological studies, it doesn't matter
 3 what the absolute concentrations levels are
 4 produced by the model and it doesn't matter if
 5 they're inaccurate.

6 Do you agree with that?

7 MR. DEAN: Object to the form.

8 THE WITNESS: Well, it depends
 9 what you mean by "inaccurate" because if
 10 you, you know, you still want it accurate
 11 in the sense of what's high is high and
 12 what's low is low, what's in the middle
 13 is in the middle.

14 You know, the actual
 15 concentration level we already know has
 16 uncertain -- that's computed we know has
 17 uncertainty associated with it.

18 So there's, you know, it's
 19 naturally going to be imprecise and, you
 20 know, you can't say it's going to be 99.5
 21 micrograms per liter because it might be
 22 higher or lower because of all the
 23 uncertainty in the model.

24 But you certainly want

1 consistency in the model. You want the
2 model to, you know, have a good mass
3 balance. You want, you know, the
4 numerical solution should be accurate for
5 the conditions in terms of solving the
6 equation.

7 I think all of those
8 conditions are met.

9 What exactly they mean by a
10 rank order I'm not precisely sure, but I
11 would imply that some -- this is somehow
12 related to exposure levels, but I don't
13 completely understand that.

14 BY MR. ANWAR:

15 Q. Does this response change or inform
16 anything that you've stated today about the -- the
17 accuracy of the model predictions, the simulated
18 contaminant concentrations produced by the ATSDR
19 models?

20 A. No. No. I mean, I'm not evaluating
21 the model from a perspective of the health
22 exposure studies.

23 I'm evaluating it in terms of the
24 solution to the equation for the initial

1 conditions, the boundary conditions, the estimated
2 parameters, and everything related to that.

3 So, you know, the concentrations in
4 the Water Treatment Plant, to the best of my
5 knowledge, were not used for the calibration but
6 served as a way to increase confidence in the
7 model.

8 These were computed by the mixing
9 model that you mentioned a few minutes ago, which
10 was really subsequent to the MT3D modeling.

11 So it's kind of like a next -- I
12 wouldn't call it independent, but it's a -- it's a
13 kind of standalone process that estimated the
14 concentrations in the Water Treatment Plant based
15 on what the computed results of the model.

16 And these were not part of the
17 calibration, to my best recollection, but it
18 certainly served to increase confidence in the
19 model because those, you know, where they did have
20 observed data, it generally looked reasonably good
21 in terms of matching the -- you know, what this
22 mixing model did to estimate the concentrations in
23 many cases agreed closely with what was observed.

24 Q. Okay. As a -- those are the

1 questions I had about this document.

2 As a member of the National Academy
3 of Engineering and as someone that has served on
4 National Research Council committees in the past,
5 were you aware that the National Research Council
6 also issued a report on ATSDR's water modeling
7 efforts?

8 A. I believe it was 2009?

9 Q. Correct.

10 A. Yes, I was aware of that.

11 Q. The report itself addressed sort of
12 epidemiology -- epidemiological and broader
13 issues, but there was a portion focused on --

14 A. Yeah.

15 Q. -- exposure assessment and the water
16 modeling.

17 Were you aware of that?

18 A. I -- I read the charge of the
19 committee, and the charge of the committee really
20 focused on epidemiological studies and health
21 effects. The charge to the committee did not --
22 actually did not mention the groundwater modeling
23 at all, but obviously the groundwater modeling was
24 what led to the estimates. So that was a

1 legitimate domain for their discussions.

2 But, you know, the committee, I
3 looked at the committee membership. You know, I
4 think there were 10 or 11 members. There was only
5 one who had any expertise in groundwater. The
6 rest were medical and health effects and
7 epidemiologist experts because that was the main
8 charge to the committee.

9 Q. Who was the one expert that was the
10 groundwater modeler?

11 A. Professor Clement.

12 Q. Okay. And what are your opinions
13 about -- so let me back up.

14 Are you aware of what the NRC said
15 about ATSDR's water modeling efforts?

16 A. I looked at that report. I don't
17 recall their exact comments.

18 Q. Do you have any opinion about the
19 National Research Council's comments on the ATSDR
20 water modeling efforts?

21 A. I think I had a few comments because
22 Spiliotopoulos made some comments about it. So I
23 think I had some comments in my rebuttal report
24 about it.

1 Q. Do you remember what those comments
2 are?

3 (Mr. Dean no longer present).

4 A. I see that it's not a huge report.
5 I can probably find it pretty quickly.

6 One of my comments was that of all
7 the members of the panel, there was only one who
8 was an expert in groundwater, and that's a really
9 minority on an NRC panel.

10 What I recall about Clement
11 publishing an article in "Groundwater" about model
12 complexity, and he was using the case study of
13 ATSDR, I presume based on his experience on the
14 NRC panel, and he was critical of the ATSDR model
15 and then that was in the published article.

16 Then Morris Maslia published a very
17 detailed response that was published in the
18 journal to his comments, and I thought he did an
19 excellent job countering all of the criticisms.

20 And then Dr. Clement had a reply to
21 the responses, in which the first thing he said
22 was that "My analysis should not be considered a
23 review of the ATSDR modeling," which to me
24 countered everything he had said in the first

1 article about what he did say was that the purpose
2 of his article was to generate discussion about
3 model complexity in general and he did not intend
4 to, you know, as a criticism.

5 What he implied to me is that he did
6 not do a technical in-depth, detailed review of
7 the ATSDR models, which was very disappointing.

8 His response, the first words pretty
9 much wanted to set aside any criticism and concern
10 about the ATSDR models. He backed off of with
11 what, I think, were his criticisms. He couldn't
12 defend them.

13 Q. Do you -- do you know Professor -- I
14 think is it -- Prabhakar Clement?

15 A. I have met him occasionally. I have
16 had a few e-mail discussions with him. When I was
17 an editor of "Groundwater Journal," he had
18 submitted a discussion article and so we discussed
19 that.

20 Q. Have you spoken with him at all
21 about Camp Lejeune?

22 A. No, not that I recall. No, I don't
23 think so.

24 Q. Do you have any opinion of Professor

1 Clement?

2 A. Not really. I don't know his work
3 that well. He hasn't published as much as other
4 people in the groundwater field, but I know he,
5 you know, he certainly is trained as a groundwater
6 specialist.

7 Q. And in order to -- to have served on
8 the role on for the National Research Committee,
9 he had to have been elected as a member of NRC by
10 his peers; right? Or no?

11 A. No, absolutely not.

12 Q. Okay.

13 A. You -- most people who serve on NRC
14 committees are not members of the Academy.

15 Q. Okay. Do you know if he is?

16 A. And all those committees that are, I
17 was not a member of the Academy when I served on
18 those committees, and most of the people on the
19 committees were not members. So it's kind of two
20 different things.

21 Q. Okay. Understood. That makes
22 sense.

23 Do you by chance, do you know if
24 he's been elected to --

1 A. I am 99.9 percent sure that he was
2 not.

3 MR. ANWAR: Okay. I'm going
4 to hand you one last exhibit.

5 (Document marked for
6 identification as Konikow Exhibit 21.)

7 BY MR. ANWAR:

8 Q. Exhibit 21, and I'll just represent
9 to you this is the chapter about "Exposure to
10 Contaminants in Water Supplies at Camp Lejeune"
11 from the NRC report. The larger report from --
12 from -- about Camp Lejeune.

13 Have you seen this before?

14 A. This is the 2009 report?

15 Q. Correct.

16 A. Well, I looked at the 2009 report,
17 but I, you know, I don't specifically recall
18 seeing this.

19 Q. Okay. I just wanted to ask you a
20 few questions about --

21 A. Sure.

22 Q. -- some of the conclusions they made
23 at the end.

24 If you turn to the second to last

1 page of the document. It's ending in 516.

2 A. Okay.

3 Q. The second paragraph states:

4 "ATSDR applied best practices and
5 cutting-edge modeling approaches to predict the
6 complex groundwater-contamination scenario at
7 Tarawa Terrace."

8 Would you agree with that statement?

9 A. Yes, sounds like a compliment.

10 Q. "The ultimate outcome of the
11 modeling was average monthly predictions of the
12 concentrations of contaminants in the water supply
13 to which people could have been exposed. Although
14 ATSDR recognized and tried to account for the
15 limitations and uncertainties associated with
16 developing its models, it is extremely difficult
17 to obtain quantitative estimates of historical
18 levels of PCE -- excuse me -- exposure to PCE and
19 its degradation products reliably on a monthly
20 basis."

21 Do you agree with those statements?

22 MS. BAUGHMAN: Objection.

23 Form.

24 THE WITNESS: Well, I mean, I

1 thought it was a challenging exercise and
2 difficult also, but they did it.

3 BY MR. ANWAR:

4 Q. It goes on to state:

5 "Reporting such model predictions
6 without clear error bounds gives the impression
7 that the exposure of former residents and workers
8 at Tarawa Terrace during specific periods within a
9 given year can be accurately defined."

10 Would you agree with that statement?

11 A. Well, I don't -- I disagree that the
12 predictions were presented without clear error
13 bounds. I thought pervasive in all the ATSDR
14 reports was -- were discussions of error bounds,
15 uncertainty, you know, how the results could vary
16 under a different range of assumptions.

17 So I thought they did a nice job
18 presenting clear error bounds.

19 Q. Can I ask you.

20 I guess for someone who may have
21 been at Camp Lejeune, a former service member or a
22 resident there, who was interested in looking at
23 ATSDR's simulated concentrations, looked at the
24 reports or turned to the reports.

1 Based on your experience, would a
2 layperson be able to understand the concepts and
3 the uncertainty analysis presented in ATSDR's
4 report?

5 MS. BAUGHMAN: Object to the
6 form.

7 THE WITNESS: I'm not sure
8 what a layperson would understand or get
9 from it. I think it's just highly
10 variable with a person depending on how
11 much background they have in statistics
12 and math and geology, if they have any
13 background at all or how much. You know,
14 I think that understandability in the
15 public would be highly variable.

16 BY MR. ANWAR:

17 Q. "It is the committee's
18 judgment" -- so this paragraph goes on.

19 "It is the committee's judgment that
20 ATSDR's model is suitable only for estimating
21 long-term exposure quality. From that
22 perspective --"

23 MS. BAUGHMAN: Qualitatively.

24 MR. ANWAR: "Qualitatively."

1 Thank you. I'm sorry.

2 BY MR. ANWAR:

3 Q. I'll read that again.

4 "It is the committee's judgment that
5 ATSDR's model is suitable only for estimating
6 long-term exposure qualitatively. From that
7 perspective, a single exposure category of
8 'exposed' appears to be applicable for persons
9 residing or working at Tarawa Terrace at any time
10 during 1957 to 1985."

11 Do you agree with that statement?

12 MS. BAUGHMAN: Object to the
13 form.

14 THE WITNESS: I -- I -- I
15 don't. No, I don't think I do because,
16 you know, you know, there they seem to be
17 relating it to either exposed or not
18 exposed and ignoring any of the scale of
19 variability in the concentrations.

20 So I think the ATSDR models
21 were better than that.

22 BY MR. ANWAR:

23 Q. Okay. That last paragraph on that
24 portion says:

1 "Efforts at historical
2 reconstruction of exposures at Hadnot Point will
3 be even more problematic. The contamination
4 scenario at Hadnot Point is so complex that the
5 committee judges that only crude estimates of
6 contaminant concentrations in the water supply can
7 be obtained."

8 Do you agree with that statement?

9 MS. BAUGHMAN: Objection.

10 Form.

11 THE WITNESS: Not completely
12 and, again, I point out that before I
13 served on the Hadnot Point/Holcomb
14 Boulevard expert peer review panel, I was
15 quite skeptical myself and, in that
16 sense, at that time maybe I would have
17 agreed with this statement.

18 But I learned a lot. They
19 explained a lot. I saw the final
20 reports. I think they did a good job
21 modeling, a reasonable. Modeling results
22 are reasonably reliable.

23 I think there's certainly more
24 uncertainty there than probably in the

1 Tarawa Terrace model, but I think -- I
2 think they were successful in putting
3 together a reasonable model.

4 They explained all their
5 assumptions and approximations, and there
6 clearly are assumptions and
7 approximations underlying the models,
8 underlying that. So that, you know, it's
9 there, but it's a good model.

10 BY MR. ANWAR:

11 Q. When we're talking about successful
12 in terms of putting together a good model, ATSDR,
13 do you think they were successful in putting
14 together a good model for providing information to
15 an epidemiology -- EPI study, epidemiological
16 study?

17 MS. BAUGHMAN: Object to the
18 form.

19 THE WITNESS: In recognition
20 that the epidemiological study did not
21 make an assessment based on the actual
22 concentration level in the calibrated
23 model, but rather a ranked form that kind
24 of removes some of that.

1 But, you know, without any
2 understanding of their epidemiological
3 studies, it seemed like the output from
4 the models provided something that would
5 be useful for them.

6 BY MR. ANWAR:

7 Q. Okay. And when you say the model
8 was successful, ATSDR was successful, and it was a
9 good model, are you saying that it was successful
10 and a good model for the purpose of estimating
11 exposure in individuals?

12 A. I don't know.

13 MS. BAUGHMAN: Objection.
14 Form.

15 THE WITNESS: I don't know
16 how it was used for exposure. I didn't
17 look at the exposure studies or the
18 epidemiological studies. So I really
19 can't --

20 BY MR. ANWAR:

21 Q. Okay.

22 A. -- say.

23 Q. Last question.

24 Do you -- what -- what is your

1 opinion of Robert Faye?

2 A. Of Robert Faye?

3 Q. Yeah.

4 A. He seems to be a competent
5 hydrogeologist, primarily in the, you know, in the
6 practical application end of hydrogeology. He's
7 not an academic in the sense of producing papers
8 on research and theory, but I think he has a lot
9 of experience and knowledge in terms of field
10 applications, studies, the reality of geology and
11 the hydrogeologic framework and the use of models.

12 Q. When is the last time you spoke to
13 him?

14 A. Way more than 10 years ago.

15 Q. Okay. I really appreciate your time
16 today and your patience with my questions. I
17 think that's all I have. I'll pass the witness.

18 A. Thank you.

19 EXAMINATION

20 BY MS. BAUGHMAN:

21 Q. Dr. Konikow, I just have a few
22 questions for you.

23 A. Yeah.

24 Q. You were just asking -- asked

1 questions about what you meant by successful in
2 terms of the ATSDR models.

3 Do you have an opinion about whether
4 ATSDR was successful in estimating the mean
5 monthly concentrations of contaminants at Tarawa
6 Terrace?

7 A. At Tarawa Terrace? I think those
8 were reasonably reliable. Again, always
9 reasonable in light of the uncertainty and the
10 error bounds about it. I think the calibrated
11 models were provided -- they were successful in
12 providing estimates and in assessing the
13 uncertainty in those estimates. So I think that,
14 yeah, I would say they were successful.

15 Q. And do you have the same opinion for
16 Hadnot Point?

17 A. I do. Again, there it was a more
18 complicated problem and, you know, many people
19 probably would have thrown their hands up and
20 said, we can't do it. But they did it and, you
21 know, I think the important thing is they
22 carefully documented all of their assumptions, how
23 they got at mass loading, pumping rates, pumping
24 schedules, and assessing uncertainty in those as

1 well as uncertainty -- assessing uncertainty in
2 many of the physical parameters.

3 Q. Okay. If an end user wants to use
4 the mean monthly concentrations for an
5 epidemiology study versus an individual exposure,
6 right, how if at all would that change -- (cell
7 phone) -- let me -- let me start over.

8 If an end user wanted to use the
9 mean monthly concentrations to estimate an
10 individual's exposure as opposed to for purposes
11 of an epidemiology study, how if at all would that
12 change how the model would be developed?

13 And I'm asking you in your expertise
14 as a hydrogeologist.

15 MR. ANWAR: Object to form.

16 BY MS. BAUGHMAN:

17 Q. In other words, if you're using the
18 mean monthly concentrations for individual
19 exposure as opposed to an epidemiology study, does
20 that change how you develop the model?

21 A. It should not. You know, again, I
22 think I said it earlier, maybe this morning.

23 But what the end user does or
24 intends or wants really should have minimal impact

1 on the development of the model, other than to
2 make, you know, if the end user, who's paying for
3 the model study, says, I need an estimate at this
4 point in space, then, okay, you make sure that you
5 calculate it at that point in space.

6 But the model itself should not be
7 affected by the end use of it. In other words,
8 the model should do the best job they can. Get
9 the most accurate result they could. Calibrate
10 the model, document the model and its accuracy,
11 and then use the results whatever you want to use
12 it.

13 Q. And just to be clear, if -- if a
14 medical doctor wanted to use the mean monthly
15 concentrations to calculate an individual's
16 exposure as opposed to for some other purpose,
17 like an epidemiology study, would that change how
18 the hydrogeologist gets to what the mean monthly
19 concentrations are?

20 MR. ANWAR: Object to form.

21 BY MS. BAUGHMAN:

22 Q. From a modeling perspective?

23 A. Should not, no.

24 Q. Okay.

1 A. I don't think it would.

2 Q. Okay. Is there a difference between
3 the words "valid" and "validated" or "validation"
4 in terms of hydrogeology and water modeling?

5 A. These are terms that not everyone
6 agrees on their meaning or intent, but it's very
7 common that just using the word "valid" by itself
8 is generally okay. You're saying that it's
9 appropriate for what it's being used for.

10 The word "validated" it has, I
11 think, more of an implication that you've got the
12 right model and you prove that you got the right
13 model, and that's generally not accepted in
14 science that, you know, for all the reasons in my
15 published paper.

16 Q. So if when you use the phrase
17 "scientifically valid," is that another way of
18 saying that ATSDR adhered to generally accepted
19 methodologies?

20 A. That's -- yeah. You're using
21 standard practices, common practices, well
22 accepted, well-documented methods and approaches
23 that are well accepted, in other words, yeah.

24 MS. BAUGHMAN: Okay. Thank

1 you. I have no other questions for you.

2 MR. ANWAR: I have nothing
3 either.

4 Thank you for your time today.

5 MS. BAUGHMAN: You're
6 finished.

7 THE WITNESS: Okay. Thank
8 you all.

9 THE VIDEOGRAPHER: Please
10 stand by.

11 We're off the record at 6:23
12 PM. This concludes today's testimony
13 given by Dr. Konikow.

14
15 (Signature not waived, the
16 deposition concluded at 6:23 p.m.)

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I declare under penalty of perjury that I have read the entire transcript of my Deposition taken in the captioned matter or the same has been read to me, and the same is true and accurate, save and except for changes and/or corrections, if any, as indicated by me on the DEPOSITION ERRATA SHEET hereof, with the understanding that I offer these changes as if still under oath.

Signed on the _____ day of _____, 2024.

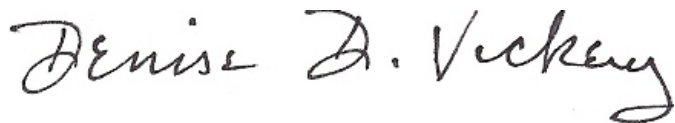
LEONARD KONIKOW, PHD

1 CERTIFICATE OF REPORTER
2 COMMONWEALTH OF VIRGINIA)

3 I, Denise Dobner Vickery, a
4 Registered Court Reporter and Notary Public of
5 the Commonwealth of Virginia, do hereby certify
6 that the witness was first duly sworn by me.

7 I do further certify that the
8 foregoing is a verbatim transcript of the
9 testimony as taken stenographically by me at the
10 time, place and on the date herein set forth, to
11 the best of my ability.

12 I do further certify that I am
13 neither a relative nor employee nor counsel of
14 any of the parties to this action, and that I am
15 neither a relative nor employee of such counsel,
16 and that I am not financially interested in the
17 outcome of this action.

18
19 
20

21 DENISE DOBNER VICKERY, CRR,RMR
22 Notary Public in and for the
23 Commonwealth of Virginia

24 My Commission expires: March 31, 2026

Notary Registration No. 126014

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EXHIBIT 13

IN RE: CAMP LEJEUNE)
WATER LITIGATION,)
)
Plaintiff,)
) No. 7:23-CV-00897
vs.)
)
UNITED STATES OF)
AMERICA,)
)
Defendant.)

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1 February 14, 2025

9:13 a.m.

2 P R O C E E D I N G S

3 THE VIDEOGRAPHER: Good
4 morning. We are going on the record
5 at 9:13 a.m. on February 14, 2025.
6 This is Media 1 deposition recording
7 of Dr. Norman Jones, In the Matter of
8 Camp Lejeune Water Litigation filed in
9 the District Court for the Eastern
10 District of North Carolina, Case
11 Number 7:23-CV-00897.

12 This deposition is being held
13 at the Attorney General's Office in
14 Salt Lake City, Utah.

15 My name is McKayla Largin. I'm
16 the videographer. And Vickie Larsen
17 is the court reporter.

18 Will counsel please state who
19 they represent for the video record.

20 MR. ANTONUCCI: Giovanni
21 Antonucci for the United States.

22 MS. SILVERSTEIN: Kailey
23 Silverstein for the United States.

24 MR. ANWAR: Haroon Anwar for
25 the United States.

1 MS. BAUGHMAN: Laura Baughman
2 for the plaintiffs.

3 MS. BOLTON: Devin Bolton for
4 the plaintiffs.

5 THE VIDEOGRAPHER: Will the
6 court reporter please swear in the
7 witness.

8 NORMAN L. JONES,
9 called as a witness, having been duly sworn,
10 was examined and testified as follows:

11 EXAMINATION

12 BY MR. ANTONUCCI:

13 Q. All right. Good morning.

14 A. Good morning.

15 Q. Please state your full name.

16 A. Norman Lovell Jones.

17 Q. And can you please state your
18 current address.

19 A. 4174 North 430 East, Provo,
20 Utah.

21 Q. Well, good morning, Dr. Jones.
22 My name is Giovanni Antonucci, as you just
23 heard. I'm an attorney for the Department of
24 Justice. I represent the United States in
25 the Camp Lejeune Water Litigation that's

1 currently pending in the District Court for
2 the Eastern District of North Carolina.

3 Dr. Jones, have you ever had
4 your deposition taken before?

5 A. Yes.

6 Q. How many times have you had
7 your deposition taken before?

8 A. Once.

9 Q. And what was the nature of the
10 case in which you were deposed?

11 A. I was the class representative
12 on a class action lawsuit against the Traeger
13 company. And I can't remember the exact
14 date, a year and a half, two years ago, I had
15 a seven-hour deposition as part of that.

16 Q. Is the Trager company the same
17 company that manufactures grills?

18 A. Yes.

19 Q. Okay. All right. We'll come
20 back to discuss that, but I'd like to get
21 through a few more sort of ground rules, if
22 that's all right with you.

23 A. Sure.

24 Q. So you just took an oath;
25 right?

1 A. Right.

2 Q. Do you understand the nature of
3 that oath?

4 A. Yes.

5 Q. That oath requires you to fully
6 answer each question. If you're not sure of
7 an answer or don't have a complete answer,
8 you must still answer the question to the
9 extent that you can.

10 Do you understand?

11 A. Yes.

12 Q. As you can see, a court
13 reporter is taking down everything that we
14 say. Because she can only record words, it's
15 important that you answer questions verbally.

16 For example, you must say "yes"
17 are or "no" rather than shaking or nodding
18 your head. Do you agree to do that?

19 A. Understood, yes.

20 Q. Please speak at a slow pace so
21 that the court reporter can record
22 everything. I will do my best to do the
23 same.

24 We should also try not to
25 interrupt one another; otherwise, our court

1 reporter will not be able to record us
2 accurately.

3 Please wait until I finish my
4 question before you start to answer, and I
5 will not interrupt you while you are
6 speaking.

7 Sound good?

8 A. Sounds great.

9 Q. Once the deposition is
10 complete, you'll be given an opportunity to
11 read a transcript of your testimony and make
12 any corrections. You will then be asked to
13 sign it.

14 Is that all right with you?

15 A. Sounds great.

16 Q. Dr. Jones, only you are
17 testifying today. You must answer to the
18 best of your ability and you may not ask
19 others for their help.

20 Do you understand?

21 A. Yes.

22 Q. If you don't understand one of
23 my questions, please let me know and I will
24 try to clarify. However, if you don't ask
25 for clarification, I will assume that you

1 understood the question; is that fair?

2 A. Yes.

3 Q. During the deposition you may
4 hear other attorneys say "objection" and
5 state an objection. Unless you've been
6 instructed not to answer the question, please
7 answer the question after the objection has
8 been made.

9 Do you understand?

10 A. Understood, yes.

11 Q. Is there any reason why you're
12 unable to give your most truthful and
13 accurate testimony today?

14 A. No.

15 Q. Is there any reason your memory
16 might be impaired today?

17 A. No.

18 Q. Have you taken or do you intend
19 to take today any medication that might
20 affect your ability to testify accurately or
21 honestly?

22 A. No.

23 Q. Dr. Jones, you can ask for a
24 break at any time. Please don't hesitate to
25 ask for breaks. All I ask is that you answer

1 any question that's pending before we go on
2 the break.

3 Does that sound good?

4 A. Sounds good.

5 Q. Am I correct that you've been
6 retained by plaintiff's leadership group as
7 an expert witness in the In Re: Camp Lejeune
8 Water Litigation pending in the United States
9 District Court for the Eastern District of
10 North Carolina?

11 A. Yes.

12 Q. When were you hired as an
13 expert witness?

14 A. September of 2024.

15 Q. Do you remember the specific
16 date?

17 A. I don't remember the exact
18 date. Earlier in the month, I believe.

19 Q. And who hired you?

20 A. The -- the Bell Legal Group, I
21 think it's called.

22 Q. Okay. Were you dealing with
23 attorney Kevin Dean at that time?

24 A. Yes.

25 Q. Before you were retained, had

1 you ever heard about Camp Lejeune?

2 A. I'd heard of it, yes.

3 Q. Had you heard of the existence
4 of the camp in general, or more specifically
5 the water contamination issues?

6 A. I'd heard -- I was aware of the
7 existence of the camp, and I was aware that
8 there was some groundwater contamination at
9 the camp, and there was some -- there was --
10 yeah, I was aware that it was being studied
11 and analyzed.

12 Q. How did you become aware of the
13 water contamination?

14 A. You know, I -- I'm not sure I
15 remember. One of those things that I recall
16 knowing vaguely about it, but I never
17 investigated it deeply prior to that time.

18 Q. Do you recall when you first
19 learned about the water contamination issues
20 at Camp Lejeune?

21 A. No, I don't.

22 Q. Was it prior to 2022?

23 A. I don't think so, but I can't
24 be sure.

25 Q. Is it possible you learned

1 about the issues from attorney advertising?

2 MS. BAUGHMAN: Objection.

3 Form.

4 THE WITNESS: I can't say. I
5 don't remember.

6 Q. BY MR. ANTONUCCI: Sure. Had
7 you heard about Camp Lejeune in your
8 professional capacity?

9 A. Again, I -- I don't recall. I
10 didn't know a lot about it, so it's hard for
11 me to pin down where I -- where I heard about
12 it. Just was vaguely aware that there was a
13 groundwater contamination issue there.

14 MR. ANTONUCCI: Okay. I am
15 going to ask that Exhibit 1 be marked
16 for identification.

17 (Exhibit 1 was marked for identification.)

18 Q. BY MR. ANTONUCCI: Dr. Jones,
19 please take a moment to look that over.

20 A. Okay.

21 Q. Have you finished reviewing
22 Exhibit 1?

23 A. Yes.

24 Q. Have you seen this document
25 before?

1 A. Yes.

2 Q. When have you seen it before?

3 A. It was sent to me, I believe,
4 by email a few weeks ago.

5 Q. Okay. I'll represent to you
6 that that's the notice of deposition and
7 subpoena that I issued for your testimony
8 here today.

9 A. Okay.

10 Q. Does that generally comport
11 with your understanding?

12 A. That is what I would have
13 guessed, yes.

14 Q. Okay. I'd appreciate it if you
15 could turn to Attachment A, which is towards
16 the end of the document.

17 So Attachment A states
18 "Pursuant to Federal Rules of Civil Procedure
19 39(b)(2) and 45, the United States makes the
20 following requests for the production of
21 non-privileged documents, communications, and
22 materials, including but not limited to, any
23 electronically stored information, data,
24 technical files, and photographs, within your
25 possession, custody, or control:

1 "Number 1. All emails,
2 letters, correspondence, text messages,
3 conversations, chats, voicemails, data,
4 technical files, or other communications
5 pertaining to Camp Lejeune sent or received
6 prior to your retention as an expert in this
7 matter, including but not limited to, from,
8 or with:

9 "Morris Maslia, Robert Faye,
10 Jason Sautner, David Savitz, Rene
11 Suarez-Soto, Susan Martel, Scott Williams,
12 Frank Bove, Mike Partain, Jerry Ensminger,
13 Lori Freshwater."

14 Did I read that correctly?

15 A. I believe so, yes.

16 Q. Do you have any emails,
17 letters, correspondence, text messages,
18 conversations prior to your retention with
19 any of those individuals?

20 A. Not related to Camp Lejeune.

21 Q. Do you have any emails,
22 letters, correspondence, text messages,
23 conversations, chats, voicemails, data,
24 technical files or other communications
25 pertaining to Camp Lejeune prior to your

1 retention -- excuse me -- not pertaining to
2 Camp Lejeune from prior to your retention
3 with any of those individuals?

4 A. Yes.

5 Q. May I ask who?

6 A. Morris Maslia.

7 Q. Okay. What sort of
8 communications had you had with Mr. Maslia
9 prior to your retention as an expert in this
10 case?

11 A. So -- so for several years he
12 and I both served together on a peer-review
13 panel for a research project at the
14 University of Alabama, and I was the chair of
15 that expert panel and Morris was a member of
16 the panel.

17 So in the context of reviewing
18 that research project, we had correspondence.

19 Q. Okay. Before we discuss that
20 more, is there anyone else on that list with
21 whom you've had any communications prior to
22 your retention as an expert in this case?

23 A. No.

24 Q. Other than your dealings with
25 the expert panel and Mr. Maslia, do you have

1 any other communications with him prior to
2 your retention as an expert?

3 A. No.

4 Q. Okay. So you mentioned that
5 your work with Mr. Maslia was through the
6 University of Alabama; is that right?

7 A. Yes. There's a -- a National
8 Science Foundation-funded project where the
9 principal investigators at the University of
10 Alabama, it also involves other universities,
11 Louisiana State University, University of
12 Mississippi, Auburn, a number of other
13 smaller universities.

14 Q. And you mentioned serving on
15 an -- or excuse me -- serving as the chair of
16 an expert panel on which Mr. Maslia also
17 served; is that right?

18 A. That's correct.

19 Q. What were you evaluating?

20 A. So based on the rules and
21 protocols for that grant established by the
22 National Science Foundation, they were
23 required to, every year, bring in an outside
24 panel to review their work to give feedback,
25 make sure they're following good research

1 standards and making good progress.

2 And so once a year we would
3 read the report that they had generated, and
4 then we would travel to Alabama and
5 participate in a two-day workshop,
6 presentations, and then we would write a
7 report with recommendations and observations
8 we make during the review process, and we did
9 that three times.

10 Q. Okay. So you've mentioned
11 providing feedback, ensuring good research
12 standards, and good progress?

13 A. Yes.

14 Q. What is the project that you
15 were evaluating for those criteria?

16 A. It was a very broad project,
17 but the primary objective was to do research
18 on groundwater in -- in the Southeast United
19 States. Looking at groundwater recharge,
20 looking at evaluating groundwater storage
21 change, things like that.

22 And they also used, developed,
23 and applied some groundwater models as part
24 of the project.

25 Q. So my understanding of recharge

1 and storage change is that those are
2 parameters that pertain to the amount of
3 water contained in an aquifer; is that right?

4 A. Yeah, recharge is typically the
5 water that comes from rainfall that as a
6 portion of that eventually percolates down
7 and enters the aquifer. It's the primary
8 source of water to an aquifer.

9 And then the storage change
10 is -- it's dependent on the water balance,
11 how much water is coming in versus how much
12 water is being discharged to springs and
13 streams and being pumped out by wells.

14 Q. And you mentioned this was the
15 Southeast United States. Was this the
16 Floridian aquifer?

17 A. They studied, I know, aquifers
18 in Mississippi and Alabama, and there was a
19 very large model built in the state of
20 Louisiana by the researchers from Louisiana
21 State University.

22 Q. What was the purpose of the
23 applied groundwater models that they were
24 developing?

25 A. Partially to look at storage

1 change and aquifer sustainability. And,
2 again, determination of recharge rates was
3 one of the things that was studied.

4 And they're also looking at, I
5 believe, innovative numerical algorithms and
6 methods for analyzing aquifers, determining
7 recharge rates.

8 For example, the -- they used
9 not just in-situ data from monitoring wells,
10 but earth observations from satellite data.

11 Q. So I'd like to sort of break
12 that down a little bit more with you.

13 A. Sure.

14 Q. You mentioned that the purpose
15 of evaluating storage change and recharge is
16 to evaluate aquifer sustainability; am I
17 stating that correctly?

18 A. That's one of the purposes,
19 yes.

20 Q. Okay. What are the other
21 purposes?

22 A. To -- water resource planning.
23 When your -- groundwater is one of our most
24 significant sources of fresh water. For
25 example, in a drought when the stream flow is

1 low, sometimes you pump more groundwater to
2 make up that deficit, so it's a -- it's a
3 large, underground reservoir.

4 So much of the work we do in
5 groundwater studies is to assess how our
6 groundwater storage is changing over time and
7 how to characterize that and how to predict
8 how it will respond in the future, and that
9 happens to be one of my -- one of my areas of
10 research as well.

11 Q. So if I'm understanding
12 correctly, the purpose of this project at the
13 University of Alabama was, at least in part,
14 to assess sustainability for planning
15 purposes; is that right?

16 A. That's one of the objectives,
17 that's right.

18 Q. Okay. Can you please list the
19 other objectives.

20 A. You know, it's been almost two
21 years since our last review, so I'm not sure
22 I could add much beyond what I've stated in
23 terms of detail without looking up the
24 reports and reviewing it.

25 Q. Sure.

1 A. You know, and a big part of the
2 project is also public education and
3 outreach. So they -- they had a lot of
4 funding to -- to work with K through 12 and
5 provide high school science teachers, for
6 example, with material and understanding
7 aquifers and aquifer dynamics.

8 And so it -- it was a -- it was
9 a very broad project. They looked at machine
10 learning algorithms for different kinds of
11 data analysis related to groundwater data.
12 It was very broad.

13 They had, I think, maybe as
14 many as 80 people on this project. It was
15 one of the bigger research projects I've ever
16 seen.

17 Q. What was the process like to be
18 selected as the chair of the expert panel?

19 A. I -- so I was the princ- --
20 this grant was through what's called the
21 EPSCoR project, E-P-S-C-O-R, the EPSCoR
22 program through the National Science
23 Foundation.

24 And from 2010 to 2014 I
25 happened to be the principal investigator of

1 an EPSCoR grant, a \$6 million EPSCoR grant
2 featuring Brigham Young University,
3 University of Utah, Utah State University,
4 and University of Wyoming.

5 And the -- the principal
6 investigator of the project centered in
7 Alabama. It was an associate of mine and he
8 was aware of that and thought that my
9 experience and also my general background and
10 experience in groundwater would -- would make
11 me a -- a good pick for that role.

12 Q. And do you know how any of the
13 other panel members were selected?

14 A. They were selected by the --
15 they were asked to serve on behalf of the
16 principal investigator of that project, which
17 is Prabhaker Clement.

18 Q. You mentioned previously that
19 part of the objective of the expert panel was
20 to provide feedback, evaluate research
21 standards, and ensure good progress?

22 A. Yeah.

23 Q. Am I stating that correctly?

24 A. Right.

25 Q. What kinds of -- of research

1 standards were you looking for in this
2 project?

3 A. Well, they would make
4 presentations on -- on their findings and the
5 methodologies they were using, review journal
6 articles that they had published or in the
7 process of working on and, you know, in some
8 cases we would give advice on -- on
9 methodology, suggestions on -- on different
10 kinds of computer algorithms to help, you
11 know, based on our experience.

12 But, overall, it was a very
13 impressive project and they -- they've been
14 doing excellent work.

15 Q. You mentioned --

16 A. So we didn't -- we didn't -- I
17 don't recall any highly critical feedback
18 that we gave. Fortunately, it's a really --
19 really well-run project.

20 Q. So you just mentioned
21 evaluating the methodology; is that correct?

22 A. Yeah.

23 Q. How did you go about evaluating
24 the methodology of this groundwater modeling
25 project?

1 A. We would review the reports
2 that they provided, the papers that they
3 were -- that they had -- they were either
4 preparing to submit or publishing, and two
5 days of presentations that they would make
6 each year.

7 Q. Were you provided with the
8 modeling files to evaluate?

9 A. No.

10 Q. Did you perform a post-audit of
11 any kind of their work?

12 A. No.

13 Q. I'd like for you to sort of
14 walk me through the process of evaluating the
15 methodology of a groundwater modeling
16 project --

17 A. Sure.

18 Q. -- if that's all right.

19 A. Yeah.

20 Q. I guess maybe we can start with
21 the conceptual model.

22 A. Yeah.

23 Q. My understanding is that's kind
24 of where modeling begins; is that right?

25 A. That's right.

1 Q. So what did you do to evaluate
2 the conceptual model of this project from the
3 University of Alabama?

4 A. Well, there's not one model,
5 there were -- there were multiple models.
6 The -- they provided a general description of
7 the conceptual model, and for the Louisiana
8 model there was a presentation and some
9 written material where they described the
10 basic components of the conceptual model.

11 Q. Did your evaluation of the
12 conceptual model involve evaluating the
13 purpose for which the model was designed?

14 A. They -- they described the
15 purpose, I believe, that -- in -- in -- for
16 the Louisiana model, it was to look at water
17 availability and long-term, again,
18 sustainability, water balances.

19 Q. And, again, that's for planning
20 purposes; right?

21 A. But that's -- I'm going by
22 memory. I'm quite sure that's what it was,
23 but it's been a while.

24 Q. Of course. Completely
25 understandable.

1 The -- what you just stated,
2 the evaluating sustainability and planning
3 purposes. My understanding is that your
4 primary memory of what the projects are for
5 as it stands today is that it was a planning
6 project; is that right?

7 A. They -- I -- what -- from what
8 I recall, it's been a while, it was develop a
9 very sophisticated model of the aquifers in
10 Southern Louisiana to characterize the
11 groundwater flow and the long-term changes in
12 groundwater storage --

13 Q. And it was --

14 A. -- and then the dynamics of the
15 aquifer.

16 Q. Excuse me. I didn't mean to
17 cut you off.

18 That was to determine the
19 future availability of groundwater?

20 A. It's one of the objectives, I
21 believe, yes.

22 Q. Okay. And you can't remember
23 any other objectives today?

24 A. No.

25 MS. BAUGHMAN: Objection.

1 Form.

2 Q. BY MR. ANTONUCCI: All right.
3 You mentioned there were multiple models that
4 you were evaluating. Can you provide a
5 general overview of what those models were.

6 A. I don't remember the other
7 cases as well. I'm not sure there were
8 models as much as aquifer studies. That's
9 the one I remember most, because it was the
10 most significant model, Louisiana model. I'm
11 not sure I could comment on the others. My
12 memory is more fuzzy with regard to that.

13 Q. Okay. Moving on from the
14 conceptual model. Did you evaluate their
15 selection of a mathematical model?

16 A. I know they -- they used
17 MODFLOW.

18 Q. Okay. Are there different
19 options for equations -- governing equations
20 that can be used in MODFLOW?

21 A. No. There's one governing
22 equation that the model is built around.

23 Q. Okay. Did you evaluate the
24 process of model calibration?

25 A. That was part of what they

1 presented, yes.

2 Q. Okay. What factors did you
3 look at when evaluating calibration?

4 A. Just -- I -- I don't remember
5 the details. I remember they -- they did an
6 extensive calibration process, but it seemed
7 fairly standard, as I recall.

8 Q. Do you know if they used
9 perimeter estimation tools?

10 A. I don't remember for sure, but
11 I believe they did. It's fairly typical to
12 use automated parameter estimation on a large
13 model like that.

14 Q. Is it also typical to do some
15 manual parameter estimation as well?

16 A. Oh, yes. Yeah, always.

17 Q. Do you generally start with
18 manual parameter estimation?

19 A. In general --

20 MS. BAUGHMAN: Objection.

21 Form.

22 THE WITNESS: It's generally
23 good practice to start with manual
24 calibration before you engage the use
25 of software to help calibrate a model.

1 Q. BY MR. ANTONUCCI: My
2 understanding is that one of those software
3 codes is called PEST for parameter
4 estimation; is that right?

5 A. That's correct.

6 Q. That was created by John
7 Doherty?

8 A. That's correct.

9 Q. Do you know if the model you
10 evaluated used the PEST code?

11 A. I don't recall.

12 Q. What other factors did you
13 evaluate for in your analysis of their
14 calibration?

15 A. I don't recall.

16 Q. Did you evaluate the
17 sensitivity analysis performed by the
18 investigators of the study?

19 A. I don't recall.

20 Q. Is it typical to analyze the
21 sensitivity analysis of a groundwater model
22 when reviewing the methodology?

23 MS. BAUGHMAN: Objection.

24 Form.

25 THE WITNESS: Will you state

1 that again.

2 Q. BY MR. ANTONUCCI: Sure.

3 I'll -- I'll restate my question.

4 When you are evaluating a
5 groundwater model's methodology, is it
6 typical to evaluate the sensitivity analysis?

7 MS. BAUGHMAN: Objection.

8 Form.

9 THE WITNESS: If -- if they
10 performed a sensitivity analysis, you
11 would review that, yes.

12 Q. BY MR. ANTONUCCI: Okay. So
13 based on that answer, it seems like it's not
14 a guarantee that a sensitivity analysis will
15 be done for every model; is that right?

16 A. Not necessarily.

17 Q. Okay.

18 A. Yeah.

19 Q. How about uncertainty analysis?
20 Is that typically done for most models?

21 A. It is done for some models.

22 Q. Okay. What factors do you look
23 at when you're evaluating uncertainty
24 analysis?

25 MS. BAUGHMAN: Objection.

1 Form.

2 THE WITNESS: When I'm -- when
3 you're performing a sensitivity
4 analysis on the model? Is that the
5 question?

6 Q. BY MR. ANTONUCCI: I'm asking
7 now about as a peer reviewer --

8 A. Yeah.

9 Q. -- when you're evaluating the
10 methodology of a groundwater model, you're
11 looking at the uncertainty analysis. What
12 factors do you look at?

13 MS. BAUGHMAN: Objection.

14 Form.

15 THE WITNESS: The methodology
16 they use to perform the uncertainty
17 analysis.

18 Q. BY MR. ANTONUCCI: Can you
19 elaborate on that? What -- what are the sort
20 of --

21 A. Well --

22 MS. BAUGHMAN: Objection.

23 Form.

24 THE WITNESS: There are
25 different ways one can go about an

1 uncertainty analysis, but the general
2 process is typically basically the
3 same from one case to another.

4 Q. BY MR. ANTONUCCI: Okay. Can
5 you explain that general process.

6 A. Well, typically one would first
7 calibrate a model to come up with a best
8 estimate of the parameters of the model and
9 the features of the model that reproduce
10 the -- the behavior exhibited by the aquifer
11 in the field.

12 And then -- then you look at
13 your parameters and for -- for the selected
14 set of parameters, you look at the
15 uncertainty in that parameter typically with
16 the use of a probability distribution
17 function.

18 And then to perform the
19 uncertainty analysis, you generate a large
20 number of model instances, versions of the
21 model. In each case where -- for the
22 parameters you've selected, you perturb the
23 parameter value within the range of values
24 you determined would be reasonable to expect
25 for that parameter.

1 And that gives you a -- a
2 number of models. And if you do it right,
3 each of those models are considered equally
4 probable.

5 And then you run your
6 simulation for each of those, and then you
7 evaluate the outcome you're looking at, and
8 then you can get that -- that allows you to
9 get a probability of a certain outcome or a
10 confidence interval for a range of outcomes,
11 and this is often called a Monte Carlo
12 process.

13 Q. The uncertainty analysis is
14 evaluating the probability of all possible
15 model solutions; is that right?

16 A. Of a range of model solutions
17 that are considered to be likely or probable
18 as being -- or considered to be possible.
19 Variations of the model.

20 Q. All right. Thank you. I
21 didn't mean to sidetrack the discussion so
22 much with that. I appreciate you providing
23 that information. You can put Exhibit 1 to
24 the side, please.

25 What did you do to prepare for

1 your deposition today, Dr. Jones?

2 A. I primarily reviewed the -- the
3 ATSDR reports and our model reports.

4 Q. I see that you have some stacks
5 of paper in front of you; is that right?

6 A. Yeah.

7 Q. What are those?

8 A. I have Chapter A, ATSDR
9 Chapter A. Chapter F. And then I have a
10 copy of the rebuttal report that Jeff Davis
11 and I submitted in January of this year.

12 Q. And I see those are tabbed with
13 sticky notes; is that right?

14 A. That's correct.

15 Q. What sections did you tab in
16 Chapter A?

17 A. I put some tabs in for some
18 figures that I thought -- primarily figures I
19 thought might be useful that I think are
20 important in the -- in the analysis -- in the
21 review of the work, one of which is
22 Figure A18, Chapter A. Another of which is
23 A26 in Chapter A.

24 And in Chapter F I have tagged
25 Figure F12, the scatter plot simulated versus

1 observed for the MT3DMS model. Page F34
2 which shows the -- the time series of PCE at
3 Well TT-26 versus the observed values. And
4 F43, which is the simulated and observed
5 concentrations at the Tarawa Terrace water
6 treatment plant.

7 Q. Did you make any handwritten
8 notes in those?

9 A. No.

10 Q. Did you make any highlights?

11 A. No.

12 Q. Did you do anything other than
13 tab those documents?

14 A. No.

15 Q. And I see you also have the
16 rebuttal report; is that right?

17 A. Yes. In the rebuttal report I
18 have tagged the "Summary of Opinions" page, I
19 have tagged at the beginning of the figures
20 page and -- or excuse me -- the figure
21 section in case I want to refer to some of
22 the figures. Specifically Figure 2 and
23 Figure 5.

24 And then I've tagged the --
25 where the maps of the contaminant plumes

1 begin in the Appendix A7.

2 Q. Did you make any notes in your
3 copy of the rebuttal report?

4 A. No.

5 Q. Did you make any highlights?

6 A. No.

7 Q. Did you do anything other than
8 tab the pages you just mentioned?

9 A. No.

10 Q. So, Dr. Jones, I'm sorry to do
11 this, but I'm going to ask you to put those
12 to the side to --

13 A. Okay.

14 Q. -- ensure we're looking at the
15 same copies of the documents today.

16 A. That's fine.

17 Q. Thank you. I appreciate that.

18 MS. BAUGHMAN: But obviously if
19 he wants to refer to his copies, he
20 can.

21 MR. ANTONUCCI: We're going to
22 use the copies that were produced.

23 MS. BAUGHMAN: He can refer to
24 his tabbed copies if he wants to.

25 MR. ANTONUCCI: We can tab the

1 produced copies at a break.

2 MS. BAUGHMAN: Norm, you can --
3 you can look at your version if you
4 want to, if it's helpful. It's the
5 same thing.

6 MR. ANTONUCCI: All right, then
7 I'm going to ask that those be marked
8 as exhibit.

9 MS. BAUGHMAN: That's fine.

10 MR. ANTONUCCI: All right.

11 Q. So other than reviewing those
12 documents which you've tabbed, have you done
13 anything else to prepare for your deposition?

14 A. Just discussed with the legal
15 team the format and what to expect. The
16 procedure and methodology.

17 Q. When you say "legal team," are
18 you referring to Ms. Baughman and Ms. Bolton?

19 A. That's correct.

20 Q. Are you also referring to
21 Mr. Dean?

22 A. No -- there were -- I guess he
23 was briefly involved in some of the
24 discussions, yeah. Yeah, he was involved.

25 Q. Were there any other attorneys

1 you spoke with?

2 A. Not that I recall, no.

3 Q. Was anyone else present at
4 those meetings?

5 A. Jeff Davis.

6 Q. Was Mr. Davis present for every
7 meeting you had with the legal team?

8 A. No. Most of them.

9 Q. Other than Mr. Davis, was
10 anyone else present?

11 A. No.

12 Q. Approximately how many times
13 did you meet with the legal team to prepare
14 for this deposition?

15 A. We met on Monday -- or excuse
16 me, I'm sorry -- Wednesday of this week. We
17 had dinner on Tuesday night. Had dinner last
18 night.

19 Q. Approximately how long was your
20 Wednesday meeting?

21 A. Six or seven hours, I would
22 guess.

23 Q. Okay. What did you discuss in
24 that meeting?

25 A. Again, what to -- how -- how a

1 deposition works. What -- what types of
2 questions would -- we would expect to be
3 asked. Don't talk over the question when
4 it's being asked. Allow time for -- don't
5 start speaking too soon. Allow time to make
6 an objection, if necessary.

7 A lot of procedural coaching
8 like that.

9 Q. Was there anything else?

10 A. Just a general review of the
11 case and rebut- -- our opinions, and so
12 forth.

13 Q. Were you provided with any
14 documents in those meetings?

15 A. I don't recall, no.

16 Q. All right. Have you reviewed
17 any of the other depositions taken in this
18 case?

19 A. I reviewed the prelim- -- the
20 draft transcript of the Mustafa Aral
21 deposition that was taken recently. And I
22 was on the Zoom yesterday. I watched most,
23 but not all, of the Jeff Davis deposition.

24 Q. Have you reviewed any other
25 depositions that have been taken in the Camp

1 Lejeune Justice Act litigation?

2 A. No.

3 Q. So you mentioned testifying in
4 a deposition. I'm interested, have you ever
5 testified at trial?

6 A. I testified at a court hearing
7 in the -- in Carson City, Nevada, in front of
8 the state engineer as part of a water rights
9 dispute on two occasions where I was put
10 under oath and questioned as an expert
11 witness.

12 Q. Did you prepare a report in
13 those cases?

14 A. Yes.

15 Q. But you weren't deposed?

16 A. I was not deposed, no.

17 Q. So you mentioned it was a water
18 rights dispute. Can you --

19 A. Yes.

20 Q. -- explain in laymen's terms
21 what that means.

22 A. So the -- the City of Las Vegas
23 back in the 1980s decided that they needed to
24 do something to ensure long-term water
25 availability, and this organization later was

1 renamed The Southern Nevada Water Authority,
2 it represents primarily Las Vegas, but also
3 surrounding cities.

4 And they decided to pursue a
5 groundwater development project where they
6 would drill a series of deep production wells
7 in some valleys in East Central Nevada, and
8 build 300 miles of large pipe to pump that
9 water south to Las Vegas.

10 It would have been a
11 \$15 billion project, would have taken
12 estimated 27 years to build. Would have been
13 the largest inter basin transfer in history,
14 the largest groundwater development project
15 in history, and it would, as you can imagine,
16 extract a significant amount of water from
17 these valleys.

18 And I represented a significant
19 landholder. I was -- I was retained as an
20 expert witness for a landholder in Spring
21 Valley that was one of several parties that
22 were protesting the groundwater project.

23 And, yeah, we did a bunch of
24 modeling simulations and wrote a series of
25 reports related to the impact that project

1 would potentially have on the water rights,
2 springs and streams and wells in the -- in
3 this valley.

4 Q. How long ago was that?

5 A. I started in 2010 and the
6 project -- it went on for ten years until it
7 was concluded in 2020.

8 Q. Okay. So you already mentioned
9 that you were deposed in a class action
10 lawsuit where you served as a class
11 representative. Is that suit ongoing?

12 A. It -- they've -- have --
13 there's been a settlement in the last few
14 months, so it's -- I think it's over.

15 Q. Okay. Other than that class
16 action, have you ever been involved in any
17 other litigation personally, not as an
18 expert?

19 A. Involving me? No.

20 Q. And you mentioned starting work
21 for the landholder in Spring Valley in 2010.
22 Was that your first time serving as an expert
23 witness?

24 A. No.

25 Q. When did you serve as an expert

1 witness prior to that?

2 A. Several years prior to that I
3 was retained as -- to do a review of a case
4 in Montana that a colleague of mine was
5 involved with as the primary expert witness
6 involving groundwater contamination at a --
7 at a railroad facility.

8 Q. Who was that colleague?

9 A. Willis Weight.

10 Q. And do you recall which party
11 you represented in that -- or excuse me --
12 for which party you served as a witness in
13 that case?

14 A. So Willis was hired as an
15 expert to -- on the side of some plaintiffs
16 who lived adjacent to a railroad facility,
17 Burlington Northern and Santa Fe, and their
18 contention was that contaminants had leached
19 from an unlined pond or a poorly lined pond
20 on the railroad facility and migrated under a
21 neighborhood where they -- they had some
22 drinking water wells, and that had caused
23 some -- some health damages.

24 And so Willis built a MODFLOW
25 and MT3D model simulating the migration of

1 the plume over to the property, and that was
2 entered as evidence in the case.

3 And then the railroad hired
4 Papadopoulos & Associates to -- to represent
5 their side, and they -- the expert from
6 Papadopoulos did a critical review of Willis'
7 model.

8 So I was hired to review
9 Willis' work and the Papadopoulos critique of
10 his work and then write a report, which I
11 believe became an affidavit that was entered
12 in the case.

13 Q. So that I can understand, were
14 you hired as an independent expert by the
15 court or were you hired by --

16 A. No, I was hired by the
17 plaintiff attorneys.

18 Q. Okay. So you submitted an
19 affidavit in support of the plaintiff's
20 reports; is that right?

21 A. It was based on my review of --
22 of his modeling and the critique of that,
23 yeah.

24 Q. Other than that Montana case,
25 have you served as an expert witness in any

1 other cases?

2 A. Not that I recall.

3 Q. Do you know who specifically
4 from S.S. Papadopoulos & Associates was the
5 expert in that case?

6 A. I don't. It's been a number of
7 years. No, I don't recall his name. He was
8 one of their lead modelers, very well
9 respected, I remember that.

10 Q. What was the contaminant of
11 concern in that case? The Montana case.

12 A. Boy, it's been a long time. I
13 know that it was a degreasing facility, but
14 it might have been creosote. I wish I could
15 remember. It's been probably 15, 20 years,
16 yeah.

17 Q. Do you have an opinion about
18 S.S. Papadopoulos as a firm?

19 MS. BAUGHMAN: Objection to
20 form.

21 THE WITNESS: No.

22 Q. BY MR. ANTONUCCI: And you
23 mentioned that your -- your colleague,
24 Mr. Willis, simulated the flow of
25 contamination through the -- through the

1 groundwater; is that right?

2 A. That's correct.

3 Q. And that was from the poorly
4 lined pond to water supply wells; is that
5 correct?

6 A. To the -- yes, to the area
7 downgradient from the railroad facility where
8 the water was pumped out, yeah.

9 Q. How far away from the pond were
10 the water supply wells?

11 A. It -- it wasn't a great
12 distance, but I -- I don't remember the exact
13 distance.

14 Q. Do you know the total size of
15 the area that was modeled?

16 A. I don't recall.

17 Q. And do you know what
18 information was used to, for example, to
19 select boundary conditions in that model?

20 A. I don't recall.

21 Q. Do you know what information
22 was available in terms of heads and flow
23 data?

24 A. I don't recall specifics.

25 Q. Do you know if there was heads

1 and flow data available to Mr. Willis?

2 A. I -- I believe there were, yes.

3 Q. Why do you believe that?

4 A. I -- if -- if there were not
5 any data -- I know they had concentrations at
6 the -- at the location where the water was
7 being pumped out. That was the whole basis
8 of the suit was they measured contaminants in
9 their drinking water.

10 Q. When you say "the location
11 where the water was pumped out," are you
12 referring to the supply wells, the water
13 treatment plant, or the tap?

14 A. I don't believe a water
15 treatment plant was involved. There were --
16 I -- from -- from what I recall, there were
17 some small wells. I believe it was actually
18 a -- part of a -- an Indian reservation, and
19 they had some small water supply wells they
20 were using.

21 Q. So it sounds like those samples
22 were taken at the supply wells?

23 A. Yes, I believe so.

24 Q. Do you know approximately what
25 time span those samples covered?

1 A. I don't recall.

2 Q. Was it more than a year?

3 A. I don't recall.

4 Q. Was it less than a year?

5 A. I don't recall.

6 Q. Do you know approximately how
7 many data points they had?

8 A. I don't recall.

9 Q. Did they have -- strike that.
10 With regard to the -- the head
11 and flow data that you assumed that they had
12 available, do you know how much of that was
13 available?

14 A. I don't recall.

15 Q. Where do you -- in these kinds
16 of cases, where do modelers normally get head
17 and flow data from?

18 MS. BAUGHMAN: Objection.

19 Form.

20 THE WITNESS: Head and flow
21 data? Well, you track down water
22 level measurements from observation
23 wells. In some cases, aquifers
24 interact with streams, either
25 discharge to streams or streams leak

1 water into the ground.

2 Sometimes you can look at
3 gauges on the stream to get an
4 estimate of -- of how much water's
5 being gained or lost, but that is a
6 fairly standard part of the data
7 collection phase on the modeling
8 project is to gather all the data you
9 can find.

10 Q. BY MR. ANTONUCCI: Okay. And
11 you mentioned that it was a lawsuit brought
12 on behalf of the individuals who drank the
13 water from those wells; is that correct?

14 A. That's correct.

15 Q. Do you know if the purpose of
16 the model was to determine the absolute
17 amount of contaminants that these individuals
18 were exposed to?

19 MS. BAUGHMAN: Objection to
20 form.

21 THE WITNESS: I don't recall.
22 I know part -- at least part of the
23 purpose was to determine if, presuming
24 water leaked from the pond, would it,
25 given the groundwater flow directions

1 and the timing, is it probable that it
2 traveled -- that the contaminants were
3 transported to that location where
4 they could potentially be pumped out.

5 Q. BY MR. ANTONUCCI: So that's
6 kind of a yes-or-no question, right? Like,
7 could the contamination have gotten to the
8 well in that time period or not; right?

9 A. Yeah.

10 Q. Okay. And that's the only
11 purpose that you recall from that report?

12 MS. BAUGHMAN: Objection.
13 Form.

14 THE WITNESS: That is a purpose
15 that I recall.

16 Q. BY MR. ANTONUCCI: What other
17 purposes do you recall?

18 A. I -- I don't recall other
19 purposes.

20 Q. Okay. Okay. So prior to that
21 Montana case, had you ever served as an
22 expert witness before that?

23 MS. BAUGHMAN: In litigation?

24 MR. ANTONUCCI: Yes, in
25 litigation.

1 MS. BAUGHMAN: Object to the
2 form.

3 MR. ANTONUCCI: Have you --
4 excuse me. I'm going to ask my
5 question again.

6 Q. Prior to the Montana case, had
7 you ever served as an expert witness in
8 litigation?

9 A. I don't believe so. Not that I
10 recall.

11 Q. Okay. Do you have a list of
12 all the times you've served as an expert
13 witness somewhere?

14 A. No.

15 MR. ANTONUCCI: Okay. All
16 right. Actually, before we move on,
17 I'm going to ask that the copies that
18 you brought of the rebuttal report and
19 Chapters A and F be marked for
20 identification for Exhibits 2, 3,
21 and 4.

22 (There was a discussion held off the record.)

23 (Exhibits 2-4 were marked for
24 identification.)

25 MR. ANTONUCCI: Thank you for

1 that.

2 And now I'm going to hand you
3 another document. I'll ask that this
4 be marked for identification as
5 Exhibit 5.

6 (Exhibit 5 was marked for identification.)

7 Q. BY MR. ANTONUCCI: Please let
8 me know when you've had a chance to review
9 that document.

10 A. I'm ready.

11 Q. Okay. Do you recognize
12 Exhibit 5?

13 A. Yes.

14 Q. Okay. What is Exhibit 5?

15 A. This is the CV that I
16 submitted.

17 Q. Okay. So if you turn to Page 1
18 of Exhibit 5, it looks like this document is
19 titled "Norman L. Jones, PhD, Professor,
20 Department of Civil & Construction
21 Engineering, Brigham Young University"; is
22 that right?

23 A. Correct.

24 Q. Is this a complete and accurate
25 copy of your resum??

1 A. Yes.

2 Q. Is there anything that you
3 would like to change or add to this copy of
4 your resum??

5 A. Can you clarify what you mean
6 by "complete"?

7 Q. Sure. Is -- is this the most
8 updated iteration of your resum??

9 A. This is the resum? -- resum?
10 that I am currently using when my resum? is
11 requested.

12 Q. Okay. So I'm inferring from
13 your question that there's some things that
14 are probably left off of this resum?; is that
15 right?

16 A. That's correct. It's not
17 100 percent inclusive of everything I've done
18 in my professional career.

19 Q. Sure. What kind of things are
20 currently listed on your resum? that's marked
21 as Exhibit 5?

22 A. Oh, heavens. Consulting
23 projects, expert witness work, workshops and
24 courses I've taught, things like that.

25 Q. Have you served as a consulting

1 expert in litigation?

2 MS. BAUGHMAN: Objection to
3 form.

4 THE WITNESS: A consultant --
5 not beyond the cases we've described.

6 Q. BY MR. ANTONUCCI: Okay. Your
7 resum? mentions a bachelor's, master's, and
8 PhD in civil engineering. Did you have any
9 specialization or concentration in those
10 programs?

11 A. Yes. My master's degree and
12 PhD at the University of Texas, I specialized
13 in geotechnical engineering.

14 Q. And is there a list of your
15 peer-reviewed publications from the last ten
16 years on Page 3 of this resum??

17 A. Yes.

18 Q. How many of these publications
19 deal with groundwater flow modeling?

20 A. You'll have to give me a
21 minute. I would say of these, six are --
22 five or six are directly related to a
23 groundwater flow model and -- but a large
24 number of them are for characterizing
25 groundwater conditions, groundwater

1 sustainability.

2 Q. And how many of those deal with
3 contaminant fate and transport modeling?

4 A. I'm not sure in this period --
5 I got to read them again. I can see at least
6 one.

7 Q. So just the one?

8 A. I believe so.

9 Q. Would it be fair to say that
10 you focus more on groundwater flow modeling
11 than contaminant fate and transport modeling?

12 MS. BAUGHMAN: Objection.
13 Form.

14 THE WITNESS: In terms of my
15 publications, yeah, I've -- my -- I've
16 done more research on -- well, in the
17 last ten years, the focus of my
18 research has been more shifted to
19 using earth observations and machine
20 learning and data analytics to analyze
21 aquifers.

22 MR. ANTONUCCI: I'd like to
23 talk to you about that more later in
24 the deposition. For now, it's been
25 about an hour, would you like to take

1 a break?

2 THE WITNESS: Sure.

3 MR. ANTONUCCI: Okay.

4 MS. BAUGHMAN: If you're -- if
5 you're willing to keep going, we can.
6 We don't have to. That's up to you.

7 THE WITNESS: I can keep going.

8 MR. ANTONUCCI: Well, I'd like
9 to take a break.

10 THE WITNESS: Sure. All right.

11 THE VIDEOGRAPHER: Off the
12 record. The time is 10:18.

13 (There was a break taken.)

14 THE VIDEOGRAPHER: We're back
15 on the record. The time is 10:28.
16 This is Media Number 2.

17 Counsel may proceed.

18 MR. ANTONUCCI: All right. I
19 am going to hand you what is being
20 marked for identification as
21 Exhibit 6.

22 (Exhibit 6 was marked for identification.)

23 MR. ANTONUCCI: Sorry, I just
24 noticed my microphone wasn't on.

25 Q. I just handed you what was

1 marked for identification as Exhibit 6.

2 Dr. Jones, this is your initial
3 expert report and materials considered;
4 right?

5 A. Correct.

6 Q. And looking at that first page,
7 the cover page, title is Tarawa Terrace Flow
8 and Transport Model Post-Audit prepared for
9 Bell Legal Group. A couple lines down,
10 prepared by Norman L. Jones, R. Jeffrey
11 Davis.

12 Is that your signature there?

13 A. Yes.

14 Q. Okay. How do you know
15 Mr. Davis?

16 A. He was a former graduate
17 student of mine when I was a young professor
18 at Brigham Young University. And then I
19 hired him to be a staff member in our
20 research laboratory where we were developing
21 groundwater modeling software.

22 And then I worked with him in
23 that capacity for several years, and then
24 even after he left the university I -- we
25 worked together on consulting projects and

1 teaching groundwater and contaminant
2 transport modeling short courses.

3 Q. So it's fair to say that you've
4 worked together before your work on this
5 case?

6 A. Yes.

7 Q. And it appears that you
8 co-wrote this expert report; is that correct?

9 A. That's correct.

10 Q. Did you participate in the
11 drafting process with Mr. Davis?

12 A. Drafting?

13 Q. I guess can you explain to me
14 your -- your role in the preparation of this
15 report.

16 A. Yes. We decided it would be
17 beneficial to team up. I have certain
18 limitations on my time given that I'm a
19 full-time university professor, and we
20 decided that we would work together, we could
21 share the workload.

22 And so he did most of the
23 modeling work in terms of entering the data
24 into the GMS MODFLOW MT3DMS software and
25 running the model simulations.

1 I did a lot of the
2 post-processing and data analysis. Together
3 we -- we reviewed the -- the data, reviewed
4 the -- the prior publications from ATSDR, and
5 then we -- together we drafted and edited and
6 finalized this report.

7 This report also -- in the
8 preparation of the report we utilized staff
9 at Integral Consulting. For example, the --
10 the figures with the maps. We provided the
11 model results to staff members at Integral
12 and they helped do a lot of the formatting.

13 There was also a professional
14 copy editor that reviewed the documents
15 before we submitted them.

16 Q. A moment ago you mentioned that
17 Mr. Davis used GMS, which I believe
18 incorporates MODFLOW and MT3DMS; is that
19 right?

20 A. That's correct. It's what we
21 call a pre and post processing for MODFLOW
22 and MT3DMS. It -- the input files to MODFLOW
23 and MT3DMS are very large and complicated and
24 synthesize a lot of data. And so GMS was
25 developed to streamline and simplify that

1 process and encapsulate it in what we call a
2 graphical user interface.

3 It -- you can -- you can modify
4 the input files through the GMS interface,
5 for example, save the modified files, run --
6 and then GMS will then launch MODFLOW and/or
7 MT3D, and then they generate a set of output
8 files which are ingested to GMS for -- for
9 visualization plotting.

10 Q. And you and Mr. Davis developed
11 GMS for the Department of Defense; is that
12 right?

13 A. That's correct. We were -- it
14 was developed, yeah, in the early part of my
15 career.

16 Q. Okay. Turning your attention
17 back to Exhibit 6, your initial report. And,
18 by the way, if I refer to this --

19 A. Okay.

20 Q. -- as your initial report, will
21 you understand what I'm saying?

22 A. Sure.

23 Q. Okay. Do you agree with all of
24 the opinions and statements made in
25 Exhibit 6?

1 A. Yes.

2 Q. And then I'd appreciate it if
3 you could turn to the back, because I've
4 appended your materials considered list.

5 So is this a fair and accurate
6 copy of your initial report and materials
7 considered list?

8 A. Yes.

9 Q. Okay. Thank you, Dr. Jones.
10 You can put that to the side.

11 I'm now going to hand you what
12 will be marked for identification as
13 Exhibit 7.

14 (Exhibit 7 was marked for identification.)

15 MS. BOLTON: For the record, a
16 revised copy of this materials list,
17 it was served after this initial one.

18 MR. ANTONUCCI: For the
19 rebuttal report?

20 MS. BOLTON: No. This is the
21 October 2024 report, so for the
22 initial report.

23 MR. ANTONUCCI: Okay.

24 MS. BAUGHMAN: Do you want us
25 to send that to you so that you can

1 mark it or?

2 MS. BOLTON: Yeah, it includes
3 all of those, plus additional.

4 MR. ANTONUCCI: That's right.
5 Yes, if you could send it, that would
6 be great.

7 MS. BOLTON: Okay.

8 Q. BY MR. ANTONUCCI: Okay.
9 Dr. Jones, I showed you what's been marked
10 for identification as Exhibit 7. This is a
11 report titled "Rebuttal Report Regarding
12 Tarawa Terrace Flow and Transport Model
13 Post-Audit"; is that right?

14 A. That's correct.

15 Q. Is this the -- if I refer to
16 this as your rebuttal report, will you
17 understand that I'm referring to Exhibit 7?

18 A. Yes.

19 Q. Okay. And, again, it looks
20 like it says "Prepared by Norman L. Jones"
21 with your signature on the front page; is
22 that right?

23 A. Yes.

24 Q. And, again, I appended the
25 materials considered to the end of this

1 report.

2 A. Yes.

3 Q. Did you participate in the
4 drafting of this report in the same way as
5 with your initial report?

6 A. Yes.

7 Q. Were there any changes in how
8 you and Mr. Davis divided labor?

9 A. No.

10 Q. So it's fair to say you
11 undertook substantially the same process to
12 draft both reports?

13 A. That's correct.

14 Q. Do you agree with all of the
15 opinions made in Exhibit 7?

16 A. Yes.

17 Q. Do you hold every opinion in
18 Exhibit 6, that's your initial report, as
19 your own opinion?

20 A. Yes.

21 Q. Do you hold every opinion in
22 Exhibit 7, your rebuttal report, as your own
23 opinion?

24 A. Yes.

25 Q. Is there anything in either

1 report that you believe is incorrect or needs
2 updating?

3 A. Well, there were some -- can
4 you clarify what you mean by that? You mean
5 in how it's written?

6 Q. I think you might be referring
7 to the changes that were made to the
8 post-audit --

9 A. Correct.

10 Q. -- in between the initial and
11 rebuttal report; is that right?

12 A. Correct.

13 Q. So other than those changes, is
14 there anything incorrect in either report?

15 A. Not that I can think of.

16 Q. Okay. Is there anything that
17 needs to be updated in either report?

18 A. Not that I can think of.

19 Q. Is any portion of either report
20 incomplete?

21 MS. BAUGHMAN: Objection.

22 Form.

23 THE WITNESS: Not that I can
24 think of.

25 Q. BY MR. ANTONUCCI: Okay. So

1 Exhibit 6 and 7, your initial and rebuttal
2 reports, do these include all of the opinions
3 you hold regarding ATSDR's groundwater flow
4 and transport models for Marine Corps Base
5 Camp Lejeune?

6 MS. BAUGHMAN: Objection.

7 Form.

8 THE WITNESS: Can you clarify
9 what you mean by that.

10 Q. BY MR. ANTONUCCI: Do you have
11 any opinions on ATSDR's water modeling
12 efforts at Camp Lejeune that are not
13 contained in either Exhibit 6 or Exhibit 7?

14 MS. BAUGHMAN: Objection.

15 Form.

16 THE WITNESS: Yeah, I -- I'm
17 not sure I'm comfortable saying I
18 would never have any other opinions
19 than what are contained here.

20 Q. BY MR. ANTONUCCI: Sure. In
21 what sort of circumstances would -- would you
22 have a new opinion?

23 MS. BAUGHMAN: Objection.

24 Form.

25 THE WITNESS: Well, if you were

1 to ask me about specific questions
2 related to different parts of the
3 modeling that's done in Chapter A and
4 Chapter F by ATSDR, there may be
5 specific opinions about that, which
6 I'd be happy to share that it may not
7 be 100 percent included in these
8 reports.

9 Q. BY MR. ANTONUCCI: Do you
10 intend to offer any opinions that are not in
11 this case -- strike that.

12 Do you intend to offer any
13 opinions in this case that are not contained
14 in Exhibit 6 or Exhibit 7?

15 MS. BAUGHMAN: Objection.
16 Form.

17 THE WITNESS: In the context of
18 this deposition?

19 Q. BY MR. ANTONUCCI: I'm
20 referring to the entire case.

21 Do you intend to offer any
22 other opinions in this case that are not
23 contained in either Exhibit 6 or Exhibit 7?

24 MS. BAUGHMAN: Objection.
25 Form.

1 THE WITNESS: If requested by
2 our legal team, I would be willing to
3 provide additional opinions.

4 Q. BY MR. ANTONUCCI: As you sit
5 here today, do you have any additional
6 opinions about ATSDR's water modeling efforts
7 at Camp Lejeune that are not contained in
8 either Exhibit 6 or Exhibit 7?

9 MS. BAUGHMAN: Objection.
10 Form.

11 THE WITNESS: Yes, there are
12 things about their initial report that
13 I -- I would be happy to proffer as
14 opinions in this deposition that
15 aren't necessarily contained in this
16 report.

17 Q. BY MR. ANTONUCCI: Okay. Can
18 you list those for me, please.

19 A. Well, what I'm saying is in the
20 context of -- of this discussion, there may
21 be specific features in the context of the
22 Monte Carlo simulation, the -- the confidence
23 interval, the calibration exercise that may
24 not -- I'm uncomfortable saying every opinion
25 I have is exclusively contained in this.

1 Q. So -- so to be clear, then, the
2 answer is no, all of your opinions are not
3 contained in your reports?

4 MS. BAUGHMAN: Objection.

5 Form.

6 THE WITNESS: In the context of
7 what I just described, yes. I'm
8 hesitant to say everything, all of my
9 opinions are here, and then later be
10 told I can't render an opinion on
11 something because I was told all of my
12 opinions are in here, if you catch my
13 drift.

14 Q. BY MR. ANTONUCCI: Can you
15 explain why all of your opinions aren't in
16 your report?

17 A. These reports had a specific
18 purpose and we were asked to do a post-audit,
19 and then report the results of that. And
20 then we were asked to respond specifically to
21 a rebuttal to our post-audit offered by
22 Mr. Spiliotopoulos.

23 And we -- so the purpose of
24 these documents, to my understanding, was
25 very specific and focused.

1 Q. Dr. Jones, do you understand
2 that you've been retained as an expert in
3 this case?

4 A. Yes.

5 Q. Do you understand the Federal
6 Rules of Civil Procedure require you to
7 disclose a complete list of your opinions?

8 MS. BAUGHMAN: Objection.

9 Form.

10 THE WITNESS: I'm not aware of
11 that rule.

12 Q. BY MR. ANTONUCCI: Can you
13 provide me with a list of the opinions you
14 have that are not contained in your reports?

15 A. I don't have a list, no.

16 Q. Can you name a single opinion
17 you have that's not contained in your
18 reports?

19 A. I -- I would -- I would have to
20 think about that.

21 Q. Okay. We'll come back to this.

22 A. Okay.

23 Q. If you could, please turn to
24 Page 6-1 of Exhibit 6, that's your initial
25 report.

1 A. Sure.

2 Q. Page 6-1 of Exhibit 6 has the
3 heading "Conclusions"; is that right?

4 A. Correct.

5 Q. And there's a list of five
6 categories of conclusions on this page; is
7 that right?

8 A. Correct.

9 Q. Is this a complete list of all
10 the conclusions from your report?

11 MS. BAUGHMAN: Objection.

12 Form.

13 THE WITNESS: These are the
14 conclusions from our report, yes.

15 Q. BY MR. ANTONUCCI: Are there
16 any conclusions from your initial report,
17 Exhibit 6, that are not contained in this
18 list?

19 A. No.

20 Q. Am I correct in understanding
21 that this is not a complete list of all the
22 opinions you will render in this case?

23 A. It's a -- given the context of
24 what we're asked to do, this is a complete
25 list of the -- of the opinions relative to

1 this. And I've not been asked to formally
2 submit any additional opinions at this time.

3 Q. Okay. Does any part of this
4 list need to be updated?

5 A. Not --

6 MS. BAUGHMAN: Other than with
7 the rebuttal? I mean, I object to the
8 form.

9 THE WITNESS: No.

10 Q. BY MR. ANTONUCCI: Okay. And
11 now as we've already discussed, you've
12 provided a rebuttal report which modified
13 some of the conclusions from Exhibit 6; is
14 that right?

15 MS. BAUGHMAN: Object to the
16 form.

17 THE WITNESS: No, I don't
18 believe it modified the conclusions of
19 this report. I wouldn't state it that
20 way.

21 Q. BY MR. ANTONUCCI: Okay. There
22 were errors in Exhibit 6 that you corrected
23 in Exhibit 7; is that correct?

24 A. That's correct.

25 Q. Okay.

1 A. But I don't think any of those
2 errors were significant enough to change the
3 opinions rendered in the initial report.

4 Q. I understand.

5 So aside from those errors,
6 are -- is there anything else in Exhibit 6,
7 your initial report, sitting here today that
8 is incorrect?

9 A. Not that I can think of.

10 Q. Okay. All right. Now if you
11 could please flip to Page 1-1 of Exhibit 7,
12 that's the rebuttal report.

13 A. Sure.

14 Q. All right. Page 1-1 of
15 Exhibit 7, your rebuttal report, has the
16 heading "Summary of Opinions"; is that right?

17 A. Correct.

18 Q. And there's a list of six
19 opinions on Page 1-1 of Exhibit 6; right?

20 A. Correct.

21 Q. Is this a complete list of all
22 the opinions from your rebuttal report,
23 Exhibit 7?

24 MS. BAUGHMAN: Objection.

25 Form.

1 THE WITNESS: Yes.

2 Q. BY MR. ANTONUCCI: Do you have
3 any opinions regarding the content of ATSDR's
4 groundwater modeling efforts at Camp Lejeune
5 that are not contained in this list?

6 MS. BAUGHMAN: Objection.

7 Form. Asked and answered.

8 THE WITNESS: I don't think I
9 have any opinions that are
10 inconsistent with this list, no.

11 Q. BY MR. ANTONUCCI: All right.
12 Now, this is from the rebuttal report which
13 includes the corrections to your initial
14 report; is that right?

15 A. Say that again.

16 Q. We're looking at your rebuttal
17 report right now, and this --

18 A. Yes.

19 Q. -- report includes corrections
20 to your initial report; is that right?

21 A. Correct.

22 Q. Does any part of this report
23 need to be corrected?

24 A. Not that I can think of.

25 Q. Is any part of this report

1 incorrect?

2 A. Not that I can think of.

3 Q. Is there any part of this
4 report that needs to be updated?

5 A. No.

6 Q. You provided, I believe, three
7 lists of materials considered in this case;
8 is that right?

9 A. What are you referring to?

10 Q. So my understanding is that you
11 provided a list of materials considered with
12 your initial report, then an updated list of
13 materials considered with that same initial
14 report, and finally a list of materials
15 considered with your rebuttal report; is that
16 correct?

17 A. That sounds correct.

18 Q. Okay. Does that materials
19 considered list include all of the facts,
20 data, and information you considered in
21 rendering your opinions?

22 A. I believe so, yes.

23 Q. Did you review any facts, data,
24 or information not listed on your materials
25 considered lists in rendering these opinions?

1 A. Not that I recall.

2 Q. Okay. Did you review any
3 academic texts when preparing these opinions?

4 MS. BAUGHMAN: Objection.

5 Form.

6 You mean other than what's on
7 the lists?

8 Object to the form.

9 THE WITNESS: I don't recall.

10 Q. BY MR. ANTONUCCI: Are you not
11 sure if there's an academic text you've
12 referenced that aren't on your materials
13 considered list --

14 MS. BAUGHMAN: Objection.

15 Q. BY MR. ANTONUCCI: -- or in
16 your report?

17 A. I don't recall any other
18 references specifically considered that were
19 not cited in our report.

20 Q. Okay. Did you review any
21 course books or peer-reviewed articles in
22 rendering these opinions?

23 MS. BAUGHMAN: Object to the
24 form.

25 You mean other than what's

1 already referenced?

2 THE WITNESS: I -- in the
3 process of conducting the post-audit
4 and writing the review, I cited -- I
5 believe we cited all of the materials
6 that were directly referenced as part
7 of that process.

8 Now, were there other books and
9 articles through my career that I've
10 read that influenced this? Probably.
11 Things we specifically cited in terms
12 of writing this that were specifically
13 relevant, I believe we cited those.

14 Q. BY MR. ANTONUCCI: Can you
15 think of any books or articles you've read
16 through the course of your career that may
17 have influenced your opinions?

18 A. Oh, yeah, I would say I have
19 34 years of experience in groundwater and
20 contaminant transport modeling, and I've read
21 countless articles and books that form my
22 basis of knowledge and expertise in this
23 area.

24 Q. Is there any that stand out?

25 A. Not particularly.

1 Q. Okay. Have you reviewed or
2 otherwise considered any other expert reports
3 in this case?

4 A. Related to the case? I -- I've
5 reviewed the -- several other -- I've
6 reviewed the expert reports by Morris Maslia,
7 Mustafa Aral, Leonard Konikow, I believe
8 Sabatini is his name, the professor at
9 Oklahoma.

10 Those are the ones I recall off
11 the top of my head. And then of course
12 the -- the DOJ reports that were submitted.

13 Q. By "the DOJ reports that were
14 submitted," are you referring to the expert
15 report of Dr. Spiliotopoulos?

16 A. Correct.

17 Q. And the expert report of
18 Dr. Remy Hennet?

19 A. Yes.

20 Q. And the expert report of
21 Dr. Jay Brigham?

22 A. Yes.

23 Q. So you reviewed all three of
24 those?

25 A. Yes.

1 Q. You mentioned reviewing the
2 expert report of Morris Maslia; is that
3 correct?

4 A. Yes.

5 Q. Morris Maslia submitted two
6 reports in this case. Did you review both of
7 those?

8 A. Yes.

9 Q. Beginning with his initial
10 report, that was the report disclosed
11 October 25th of 2024. Do you agree with all
12 of the opinions in Mr. Maslia's report?

13 MS. BAUGHMAN: Object to the
14 form.

15 THE WITNESS: As far as I can
16 recall.

17 Q. BY MR. ANTONUCCI: And with
18 regard to Mr. Maslia's rebuttal report, that
19 was the report disclosed January 14th of
20 2025. Do you agree with all of the opinions
21 in that report?

22 MS. BAUGHMAN: Objection.
23 Form.

24 THE WITNESS: Yes.

25 Q. BY MR. ANTONUCCI: What's your

1 opinion of Mr. Maslia?

2 A. I think he's a -- a very
3 competent and experienced expert in the field
4 of groundwater flow and transport modeling.

5 Q. What's his reputation in the
6 field of groundwater flow and transport
7 modeling?

8 A. As far as I know, he's
9 respected.

10 Q. Turning to the expert report of
11 Dr. Mustafa Aral, October 25, 2024, do you
12 agree with all of the opinions in that
13 report?

14 MS. BAUGHMAN: Object. Form.

15 THE WITNESS: I believe so. I
16 can't think of anything specific that
17 I would disagree with.

18 Q. BY MR. ANTONUCCI: What's your
19 opinion of Dr. Aral?

20 A. He's a very accomplished and
21 widely respected expert in this field.

22 Q. And do you agree with all of
23 the opinions in Dr. Sabatini's report?

24 MS. BAUGHMAN: Objection.

25 Form.

1 THE WITNESS: Yes.

2 Q. BY MR. ANTONUCCI: What is your
3 opinion of Dr. Sabatini?

4 A. I don't know him very well.

5 Q. Do you know his reputation in
6 the field of groundwater modeling?

7 A. Not independent of this
8 project. I reviewed his resum? and his
9 experience and it seems very impressive.

10 Q. And did you -- did you agree
11 with the opinions stated in the expert report
12 of Dr. -- Dr. Leonard Konikow?

13 MS. BAUGHMAN: Objection.
14 Form.

15 THE WITNESS: Yes.

16 Q. BY MR. ANTONUCCI: And what's
17 your opinion of Dr. Konikow?

18 A. Well, he's -- he's one of the
19 most widely respected experts in groundwater
20 modeling.

21 Q. Okay. So would you say he has
22 a generally good reputation in the field of
23 groundwater modeling?

24 A. He has an exceptional
25 reputation.

1 Q. Okay. I'd appreciate if you
2 could turn back to Exhibit 7, and I'd like
3 for you to look at the materials considered
4 list that's at the end of Exhibit 7.

5 A. Sure.

6 Q. So I understand that there's a
7 sort of intermediate materials considered
8 list for your initial report. However, this
9 is your rebuttal report; right?

10 A. Correct.

11 Q. Is this the final materials
12 considered list for your rebuttal report?

13 A. These are the materials that we
14 cited specifically in writing the report.

15 Q. Does it also include the
16 materials you considered in review -- in
17 rendering your opinions?

18 A. No, not necessarily. For
19 example, this -- this doesn't include the --
20 the specific list at the back doesn't include
21 the DOJ reports.

22 Q. Okay. Other than the DOJ
23 reports, are there any other materials you
24 considered in rendering your opinion that's
25 not included on this list?

1 A. Not that I can think of.

2 Q. Okay. So according to this
3 list, you considered ATSDR's Tarawa Terrace
4 Chapters A, F, and C; is that correct?

5 A. Correct.

6 Q. Did you review any other
7 chapters of ATSDR's Tarawa Terrace reports?

8 A. I skimmed through some of the
9 others, but not in the same detail that I
10 read Chapters A, C, and F.

11 Q. Do you remember which others
12 you skimmed?

13 A. I don't recall.

14 Q. Do you remember the subject
15 matter of the other reports that you skimmed?

16 A. The -- I believe it may have
17 included a more detailed dive into the
18 uncertainty analysis, but I -- I can't -- I
19 couldn't specifically tell you which one. I
20 just know I looked through the others.

21 Q. Okay. You remember discussion
22 of the uncertainty analysis in the other
23 reports. Do you remember the subject matter
24 of any others?

25 A. I'm not positive on that, but I

1 believe that's the topic of one of the
2 others. I -- I couldn't specifically cite
3 the topics of the others, yes.

4 Q. Did you review others or just
5 the uncertainty analysis chapter?

6 A. Like I say, I believe I skimmed
7 through all of them, but -- just to see what
8 was there, but I -- I did not do a -- as
9 thorough a reading of those chapters as I did
10 of A, C, and F.

11 Q. Okay. So you didn't thoroughly
12 review Chapter B: Geologic Framework of the
13 Castle-Hayne Aquifer System; correct?

14 A. Correct.

15 Q. You did not thoroughly review
16 Chapter E: Occurrence of Contaminants in
17 Groundwater; is that right?

18 A. Correct.

19 Q. You didn't thoroughly review
20 Chapter G: Simulation of Three-Dimensional
21 Multispecies Multiphase Mass Transport of
22 Tetrachloroethylene (PCE) and Associated
23 Degradation Byproducts; is that right?

24 A. Correct.

25 Q. You didn't closely review

1 Chapter H: Effective Groundwater Pumping
2 Schedule Variation on Arrival of
3 Tetrachloroethylene (PCE) at Water Supply
4 Wells and Water Treatment Plants; is that
5 correct?

6 A. Correct.

7 Q. And you didn't thoroughly
8 consider or thoroughly review Chapter I:
9 Parameter Sensitivity, Uncertainty, and
10 Variability Associated With Model Simulations
11 of Groundwater Flow, Contaminant Fate and
12 Transport, and Distribution of Drinking
13 Water; is that right?

14 A. I -- I believe I may have read
15 that a little more carefully than the others,
16 but certainly not to the same depth of
17 analysis as I did to the other chapters.

18 Also, Chapter A is kind of a
19 comprehensive summary, as I understand it, of
20 all of the work that was done, including what
21 was put in those other chapters. And so I
22 felt like I had a reasonably good exposure to
23 the overall methods and processes that were
24 used and then described in more detail in
25 those chapters.

1 But for the purpose of the
2 post-audit which we were hired to do,
3 certainly the most important chapters would
4 be A, C, and F.

5 Q. Why are A, C, and F the most
6 important chapters for the post-audit you
7 were hired to do?

8 A. Because A is a -- is a
9 comprehensive summary, a detailed summary of
10 the entire modeling project. It was very
11 helpful in getting an overview of all of the
12 work that was done.

13 Chapter C provided a very
14 detailed description of the construction and
15 calibration of the MODFLOW flow model.

16 And Chapter F was a very
17 detailed description of the construction and
18 calibration, uncertainty analysis associated
19 with the contaminant transport model.

20 And we were asked to, in -- in
21 conducting the post-audit, to -- to perform
22 simulations using both the flow and transport
23 model. So they were clearly the most
24 relevant chapters for our work.

25 Q. So you weren't asked to review

1 all of the Tarawa Terrace chapters?

2 A. They were provided to us and,
3 you know, we -- we were -- we quickly
4 determined which chapters would be most
5 relevant. And it's a matter of, you know,
6 where you focus your time and effort.

7 Q. Were you provided with ATSDR's
8 reports on their water modeling efforts at
9 Hadnot Point and Holcomb Boulevard?

10 A. Yes.

11 Q. Did you review any of those?

12 A. Yes.

13 Q. Is there a particular reason
14 none of them are on your materials considered
15 list?

16 A. Because our primary focus was
17 Tarawa Terrace in terms of the -- what we
18 were asked to do with the -- with the
19 post-audit.

20 Q. Did you perform as close of a
21 reading on the Hadnot Point/Holcomb
22 Boulevard chapters as you did with Tarawa
23 Terrace Chapters A, C, and F?

24 A. I wouldn't say it was as
25 equally careful because it was less relevant,

1 but I did, as I recall, read the entire
2 report on the Hadnot Point/Holcomb Boulevard
3 report --

4 Q. Did you --

5 A. -- just to be familiar with the
6 overall project.

7 Q. And you said that you read
8 those. Did you skim through them or did you
9 read them carefully?

10 A. I read them completely.

11 Q. Is there a reason that you
12 skimmed through the Tarawa Terrace reports
13 but not the Hadnot Point reports?

14 MS. BAUGHMAN: Objection to
15 form.

16 THE WITNESS: I read through
17 the portions of the -- carefully the
18 Tarawa Terrace reports that I felt
19 were most critical for the work we
20 were asked to do.

21 Q. BY MR. ANTONUCCI: What about
22 the Hadnot Point reports was critical for
23 your Tarawa Terrace post-audit?

24 A. I -- I wouldn't classify it as
25 critical. I partially read that out of

1 interest. Curious to -- to kind of see and
2 compare the work that was done there versus
3 the work that was done at Tarawa Terrace.

4 Q. Do you have any opinions on the
5 Hadnot Point or Holcomb Boulevard chapters
6 that ATSDR published?

7 MS. BAUGHMAN: Objection.

8 Form.

9 THE WITNESS: A general opinion
10 that the work that was done there
11 seemed to be rigorous and followed
12 what I would consider good -- good
13 practices, sound practices.

14 Q. BY MR. ANTONUCCI: And -- I'm
15 sorry, go ahead.

16 A. I can't think of anything more
17 specific than that, I would say.

18 Q. What is that opinion based on?

19 A. Just my reading the document
20 and my experience and the processes they
21 appeared to follow.

22 Q. Do you have any other opinions
23 about ATSDR's Hadnot Point/Holcomb Boulevard
24 modeling efforts other than that they were
25 rigorous and followed good practices?

1 A. Not that I can think of at the
2 moment.

3 Q. So you provided a post-audit
4 for the Tarawa Terrace models; is that right?

5 A. Correct.

6 Q. You did not provide a
7 post-audit for the Hadnot Point/Holcomb
8 Boulevard model; is that right?

9 A. That's correct.

10 Q. Why did you not provide a
11 post-audit for Hadnot Point or Holcomb
12 Boulevard?

13 A. We were not asked to do so.

14 Q. Okay. Have -- are you familiar
15 with the text Modeling Groundwater Flow and
16 Contaminant Transport by Jacob Bear and
17 Alexander H.-D. Cheng?

18 A. I've heard of it.

19 Q. Have you ever reviewed it?

20 A. Not carefully, no.

21 Q. Do you have any opinion on the
22 reputation of Dr. Bear or Dr. Cheng?

23 A. I know Dr. Bear is a
24 well-known, widely respected groundwater
25 expert. I'm not as familiar with the other

1 author.

2 Q. Do you consider Modeling
3 Groundwater Flow and Contaminant Transport to
4 be a reliable authority in the field of
5 groundwater modeling?

6 MS. BAUGHMAN: Objection.
7 Form.

8 THE WITNESS: What do you mean
9 by "authority"?

10 Q. BY MR. ANTONUCCI: How would
11 you define "authority"?

12 MS. BAUGHMAN: Objection.
13 Form. He's asked you to clarify your
14 question.

15 THE WITNESS: I would just say
16 it's a -- it's a book in the field of
17 groundwater I'm familiar with, written
18 by a well-known groundwater expert.

19 Q. BY MR. ANTONUCCI: Do you
20 consider it to be a reliable book?

21 MS. BAUGHMAN: Objection.
22 Form.

23 THE WITNESS: I -- like I say,
24 I -- I don't -- I haven't read it. I
25 may have skimmed it earlier in my

1 career, so I -- I don't -- I'm not
2 comfortable rendering an opinion on
3 the book.

4 Q. BY MR. ANTONUCCI: Okay. Are
5 you familiar with the text Applied
6 Groundwater Modeling Simulation of Flow and
7 Advective Transport by Mary Anderson, William
8 Woessner and Randall Hunt?

9 A. Yes.

10 Q. My understanding is that there
11 are two editions of that text; is that right?

12 A. That's correct.

13 Q. 1992 and 2015?

14 A. Correct.

15 Q. Have you reviewed both editions
16 of that text?

17 A. Yes.

18 Q. Did you consult that text in
19 rendering the opinions in your reports?

20 A. Only in the basis that those
21 texts, along with hundreds if not thousands
22 of other documents, have formed my general
23 background and expertise in groundwater
24 modeling. Not -- not specifically to the
25 point where I would feel it needs to be

1 cited, that I can recall.

2 Q. Sure. So you consider the
3 Anderson, Woessner, and Hunt text to be a
4 reliable authority in the field of
5 groundwater modeling?

6 MS. BAUGHMAN: Objection.
7 Form.

8 THE WITNESS: I believe it's
9 a -- a -- a valuable and informative
10 book in the area of groundwater
11 modeling.

12 Q. BY MR. ANTONUCCI: What do you
13 mean by "valuable and informative"?

14 A. Meaning it has useful content
15 that is helpful in forming understanding of
16 groundwater modeling principles.

17 Q. Okay. In your experience as a
18 professor, have you ever used that text?

19 A. I teach a graduate course on
20 groundwater modeling, and I believe there
21 were times in the past where I listed
22 Anderson, Woessner as a -- as an optional
23 textbook that -- but I haven't used it as a
24 required textbook ever.

25 Q. Okay.

1 A. That I recall.

2 Q. Would you make an optional
3 text -- would you list an optional text on
4 your syllabus if it -- you considered it
5 unreliable?

6 MS. BAUGHMAN: Objection.
7 Form.

8 THE WITNESS: I'm not sure what
9 you mean by "unreliable." I think
10 it's a valuable and instructive book
11 on the general concepts of groundwater
12 modeling.

13 Q. BY MR. ANTONUCCI: Okay. Other
14 than listing it on your syllabus as an
15 optional text for your students, have you
16 used it in any other capacity as a professor?

17 A. One of the things that --
18 there's a -- early in the book there's, I
19 believe, a chapter on the groundwater
20 modeling process, talks about forming
21 conceptual models or the different steps in a
22 modeling project, and if I ever refer to that
23 text I often reference that as a -- as a good
24 overview of the groundwater modeling process
25 in general.

1 When I -- when I teach my
2 course, I present it in a similar fashion.

3 Q. Okay. And that's because it's
4 valuable, informative, and instructive;
5 right?

6 MS. BAUGHMAN: Objection.
7 Form.

8 THE WITNESS: It's -- it's an
9 instructive textbook, yes.

10 Q. BY MR. ANTONUCCI: Is it
11 valuable?

12 MS. BAUGHMAN: Objection.
13 Form.

14 THE WITNESS: I'd consider it
15 valuable, yeah.

16 Q. BY MR. ANTONUCCI: Is it
17 instructive?

18 A. It's instructive.

19 MR. ANTONUCCI: All right. I
20 am going to mark for identification
21 Exhibit 8.

22 (Exhibit 8 was marked for identification.)

23 Q. BY MR. ANTONUCCI: All right,
24 Dr. Jones, do you recognize this?

25 A. Yes, I do.

1 Q. What is it?

2 A. These are lecture notes used in
3 my graduate course on a Groundwater Modeling
4 CE 547.

5 Q. Okay. Did you create -- it
6 looks like this is a PowerPoint presentation;
7 is that right?

8 A. Correct.

9 Q. Did you create this yourself?

10 A. I did.

11 Q. Okay. And is this a fair and
12 accurate copy of your lecture notes from your
13 graduate course in groundwater modeling?

14 A. It appears to be, yes.

15 Q. Okay. I'd like for you to turn
16 to Page 2 and Slide 3.

17 A. Yes.

18 Q. I think this might be what you
19 were referencing earlier with regard to the
20 model development protocol from Anderson and
21 Woessner; is that correct?

22 A. Woessner.

23 Q. Excuse me. Thank you.

24 A. Yeah.

25 Q. So --

1 A. Excuse me. Yes, this is
2 precisely what I was discussing earlier.

3 Q. Okay. So you use the Anderson
4 and Woessner text to discuss the model
5 development protocol; is that right?

6 A. Yes.

7 Q. Okay. Did you adapt this flow
8 chart from the Anderson and Woessner --
9 Woessner text?

10 A. Yes.

11 Q. Okay. And then sort of
12 flipping through the other sections of this
13 PowerPoint, it looks like you continue to use
14 it throughout the lecture; is that right?

15 A. Well, the purpose of this
16 lecture is to provide an overview of the
17 model development protocol, and so the
18 different slides here are explaining each of
19 the different steps involved in the model
20 development process, and thus it relates to
21 the different items on that -- on that flow
22 diagram.

23 Q. Is that a yes?

24 A. Yes.

25 Q. Okay. Are you familiar with

1 the text Guidelines for Evaluating
2 Groundwater Flow Models by Thomas Reilly and
3 Arlen Harbaugh?

4 A. I'm aware of that, yes.

5 Q. Do you consider that text to be
6 a reliable authority in the field of
7 groundwater modeling?

8 A. Again, I -- I --

9 MS. BAUGHMAN: Object to the
10 form.

11 THE WITNESS: I think it's a
12 helpful book.

13 Q. BY MR. ANTONUCCI: Okay. How
14 about the text Calibration and Uncertainty
15 Analysis For Complex Environmental Models by
16 John Doherty; are you familiar with that?

17 A. Yes.

18 Q. And John Doherty is the
19 individual who developed the PEST code; is
20 that right?

21 A. That's correct.

22 Q. Do you consider Calibration
23 Uncertainty Analysis For Complex
24 Environmental Models to be a reliable
25 authority in groundwater modeling?

1 MS. BAUGHMAN: Object to the
2 form.

3 THE WITNESS: I think it's a --
4 it's a good reference for calibration.

5 Q. BY MR. ANTONUCCI: Okay. And
6 earlier you -- you mentioned working with
7 Dr. Prabhaker Clement on a grant or some --
8 the project at the University of Alabama; is
9 that right?

10 A. That's correct.

11 Q. Dr. Clement is the principal
12 investigator of that project?

13 A. That's correct.

14 Q. What's your opinion of
15 Dr. Clement?

16 A. Dr. Clement and I have worked
17 together professionally since the earliest
18 days of my career. I consider him a very
19 good researcher and also a close personal
20 friend. And he and I are also currently
21 co-investigators on a NOAA-funded research
22 grant.

23 Q. All right. I'm going to sort
24 of refocus attention on the ATSDR reports
25 which you were asked to provide opinions

1 about.

2 That's correct, that you were
3 asked to provide opinions on ATSDR's Tarawa
4 Terrace reports; right?

5 MS. BAUGHMAN: Object to the
6 form.

7 THE WITNESS: I'm not sure I
8 would phrase it that way. We were
9 asked to conduct a post-audit and
10 render opinions relative to that
11 post-audit, and -- and that
12 involved -- I'm going to take that
13 back.

14 Yes, we did render opinions on
15 these reports.

16 Q. BY MR. ANTONUCCI: Okay. These
17 reports deal with, at a very basic level,
18 groundwater models; right?

19 A. What do you mean by "a very
20 basic level"?

21 Q. I don't mean to say that the
22 reports themselves are basic. I guess I
23 should say, like, essentially they deal with
24 groundwater models; is that correct?

25 A. That's correct.

1 Q. Okay. Groundwater models are
2 simplified versions of reality; right?

3 A. That's correct.

4 Q. And we should never expect a
5 groundwater model to perfectly reproduce
6 subsurface conditions; is that correct?

7 MS. BAUGHMAN: Object to the
8 form.

9 THE WITNESS: That's correct.
10 I would not expect any model to
11 perfectly replicate the real-world
12 system that it is meant to simulate.

13 Q. BY MR. ANTONUCCI: Okay. If
14 you could please turn your attention back to
15 Exhibit 8. That's the PowerPoint.

16 A. Sure.

17 Q. I'd like you to turn to
18 Slide 14.

19 A. Yes.

20 Q. Okay. There are two quotes on
21 this slide; right?

22 A. Correct.

23 Q. The first one says "One of the
24 most insidious and nefarious properties of
25 scientific models is their tendency to take

1 over, and sometimes supplant, reality." That
2 quote is attributed to Erwin Chargaff?

3 A. That's correct.

4 Q. Did I read that correctly?

5 A. Uh-huh.

6 Q. And that was quoted in J.J.
7 Zuckerman, The Coming Renaissance of
8 Descriptive Chemistry, Journal of Chemical
9 Education in 1986?

10 THE REPORTER: In what year?

11 MR. ANTONUCCI: 1986.

12 Q. Is that correct?

13 A. Yes.

14 Q. The next quote on the page
15 says, quote, "... all models are
16 approximations. Essentially, all models are
17 wrong, but some are useful." And that quote
18 is attributed to George E.P. Box.

19 Did I read that correctly?

20 A. Correct.

21 Q. And that's from George E.P. Box
22 and Norman R. Draper, Empirical
23 Model-Building and Response Surfaces 2007; is
24 that right?

25 A. Correct.

1 Q. This is the last slide of your
2 lecture.

3 A. That's correct.

4 Q. Why did you choose to end your
5 lecture with these quotes?

6 A. Because it's a -- it's a fun
7 launching pad for a discussion in the class.
8 I read these quotes and I ask the students,
9 What do you think of these statements? If
10 models are wrong, why are you taking this
11 class?

12 And that leads to a --
13 typically to a very constructive discussion
14 of what's kind of captured in Box's quote
15 there that, yeah, you should never expect a
16 model to be a perfect replication of reality;
17 however, models are extremely valuable as
18 an -- as an interpretive tool, a historical
19 reconstruction tool, and in many cases
20 they're the best and only tool we have.

21 And so, again, it's meant to
22 stimulate a discussion where I then talk
23 about the benefits of modeling, I talk about
24 all the different cases in -- in groundwater
25 management and analysis where models are

1 critical.

2 Q. You agree that all models are
3 approximations?

4 A. Yes.

5 Q. You agree that all models are
6 wrong?

7 MS. BAUGHMAN: Object to the
8 form.

9 THE WITNESS: Wrong in the
10 sense that they're all simplifications
11 of reality. That's the context of his
12 statement here.

13 Q. BY MR. ANTONUCCI: So we can't
14 expect a model to be a perfect representation
15 of reality; right?

16 A. That's correct.

17 Q. You can put Exhibit 8 aside
18 now.

19 So I understand that you were
20 asked to provide a post-audit of ATSDR's
21 Tarawa Terrace groundwater flow and transport
22 model; is that correct?

23 A. Correct.

24 Q. Were you asked to do any other
25 evaluation of ATSDR's Tarawa Terrace flow and

1 transport model?

2 MS. BAUGHMAN: Object to the
3 form.

4 THE WITNESS: What do you mean
5 by "evaluation"?

6 Q. BY MR. ANTONUCCI: Did you do
7 anything -- strike that.

8 Were you asked to do anything
9 other than the post-audit?

10 MS. BAUGHMAN: Object to the
11 form.

12 THE WITNESS: Jeff and I were
13 asked to perform some additional
14 simulations using the models to --
15 with respect to how the model output
16 varies as a function of retardation
17 factor.

18 The -- the beginning simulation
19 time or the -- excuse me -- the --
20 when the contaminants were released.
21 And both of those, the results of that
22 were included in Morris Maslia's
23 rebuttal report.

24 In other words, we were asked
25 to run the models and post process the

1 results and generate some of the
2 graphics that Morris then relied on in
3 his report, and then we were -- most
4 recently we -- we did an analysis
5 where we varied the reaction rate and
6 determined how sensitive the model was
7 to the reaction rate.

8 Q. BY MR. ANTONUCCI: Is reaction
9 rate a synonym for biodegradation rate?

10 A. It includes the biodegradation
11 rate, yeah.

12 Q. Are there other -- so is it
13 correct that reaction rate and biodegradation
14 rate are not the same thing?

15 A. In general, the -- the reaction
16 rate can include any kind of decay of the
17 contaminant. Most commonly that's a result
18 of biodegradation.

19 But, you know, in the grand
20 scope of transport modeling, for example, if
21 you're simulating a radioactive contaminant
22 then it would simulate the half-life and
23 decay of the contaminant.

24 Q. So you performed a sensitivity
25 analysis varying the --

1 A. The reaction --

2 Q. -- reaction rate; is that
3 right?

4 A. Correct.

5 Q. You did not vary the
6 biodegradation rate?

7 A. Well, the reaction rate is
8 inclusive of the biodegradation rate in this
9 case.

10 Q. Does it include anything else?

11 A. I -- I believe that's
12 predominantly what it's meant to represent in
13 this case.

14 Q. Okay. And when were you asked
15 to perform that sensitivity analysis?

16 A. Couple of weeks ago, maybe.

17 Q. Was it more than a month ago?

18 A. No.

19 Q. Was that after you had
20 disclosed your rebuttal report?

21 A. Yes.

22 Q. Other than the figures that you
23 created for Mr. Maslia's rebuttal report and
24 the sensitivity analysis that we've already
25 discussed, were you asked to do any other

1 evaluation of ATSDR's Tarawa Terrace
2 groundwater flow and transport model?

3 A. No.

4 Q. Did you review the data mining
5 techniques that ATSDR employed to generate
6 their groundwater flow and transport model?

7 MS. BAUGHMAN: Object to the
8 form.

9 THE WITNESS: I recall reading
10 about what Morris referred -- or what
11 was referred to as the data mining
12 process, but I'm not sure I could
13 recall specific details.

14 Q. BY MR. ANTONUCCI: So is it
15 fair to say you didn't thoroughly evaluate
16 the data mining process that ATSDR undertook?

17 MS. BAUGHMAN: Object to the
18 form.

19 THE WITNESS: I -- I reviewed
20 what was in, I believe, Chapter A --
21 A, C, and F.

22 Q. BY MR. ANTONUCCI: Okay. Did
23 you review the conceptual model for the
24 Tarawa Terrace groundwater flow and transport
25 model that ATSDR created?

1 A. Yes.

2 Q. Can you describe that review,
3 please.

4 A. Well, the -- the conceptual
5 model was described in the Chapters A, C, and
6 F, and I reviewed it as I -- in that context.

7 Q. Did you undertake any other
8 review of the conceptual model, apart from
9 your review of the reports?

10 A. No.

11 Q. Did you note any flaws in the
12 conceptual model?

13 A. I don't recall anything that
14 stood out to me as being flawed or a bad
15 assumption, no.

16 Q. Okay. If you had noted any
17 flaws, would you have included that in your
18 report?

19 A. Depending on the magnitude of
20 the flaw, I suppose, yes.

21 Q. How big would a flaw have to be
22 to be included in your report?

23 A. Well, one of the opinions in
24 our report was the -- the methods that they
25 followed were sound and followed good

1 scientific and engineering practices and,
2 yeah, I just -- I did not find anything
3 that -- that I was -- would consider to be an
4 error in their process.

5 Q. If you had noted a flaw in
6 ATSDR's conceptual model, do you believe that
7 recalibration of the models using the
8 post-audit data would have yielded
9 substantive changes in ATSDR's original
10 results?

11 MS. BAUGHMAN: Object to the
12 form. Incomplete hypothetical.

13 THE WITNESS: Can you say that
14 again.

15 Q. BY MR. ANTONUCCI: Sure.
16 Suppose you had noted a flaw in
17 ATSDR's conceptual model. Do you believe
18 that recalibration of the ATSDR models using
19 your post-audit data would have yielded
20 substantive changes in ATSDR's original
21 results and conclusions?

22 MS. BAUGHMAN: Object to the
23 form.

24 THE WITNESS: I think their
25 conceptual model was -- was sound and

1 consistent with the hydrogeologic
2 conditions at Tarawa Terrace, and I
3 think the model was well calibrated.

4 Q. BY MR. ANTONUCCI: Do you have
5 any opinion about whether or not a --
6 Mr. Maslia or Dr. Aral should have reran the
7 model using your post-audit data?

8 A. Yes.

9 Q. What is that opinion?

10 A. So the -- the objective of the
11 post-audit was to take the original MODFLOW
12 and MT3D models and evaluate the performance
13 of the model with additional data which was
14 not available to them at the time they built
15 the model.

16 And when they built the model,
17 they had two sets of data. They had PCE --
18 well, they had a large set of head and flow
19 data that they used to build a
20 well-calibrated flow model, which is the
21 foundation of the transport model.

22 To calibrate the transport
23 model, they had a set of PCE concentrations,
24 I believe there were 36 at -- at different
25 points in time at monitoring well locations.

1 And then they had some concentrations of
2 water at the water -- Tarawa Terrace water
3 treatment plant.

4 The objective, as I understand
5 it, the original study was to do historical
6 reconstruction of the concentration of the
7 water at the water treatment plant based on
8 the -- the migration of the plume through the
9 Tarawa Terrace aquifer.

10 And when they did their
11 calibration, the -- if you look specifically
12 at the PCE -- measured PCE -- observed PCE
13 concentrations at the observation wells,
14 there was a high bias for observed
15 concentrations in the lower range, but where
16 there was high, observed concentrations, the
17 simulated concentrations matched quite
18 closely.

19 That's significant because that
20 means that in the center of the plume where
21 the concentrations are the greatest, the
22 model did a good job predicting the
23 concentrations.

24 Now, that happens to correspond
25 to Well TT-26, which as the model showed was

1 the primary contributor of contaminated water
2 to the Tarawa Terrace water treatment plant.

3 After they did their initial
4 calibration --

5 INTERCOM SYSTEM: Hi everyone.
6 Trina and her dog are in her office.
7 If you want to go over there and say
8 hi to -- to the dog and also to Trina
9 if you want, please head over there.
10 Thank you.

11 THE WITNESS: The -- they --
12 they -- the -- the model simulated
13 concentrations at the water treatment
14 plant matched the observed
15 concentrations at the water treatment
16 plant extremely well.

17 So when we did our post-audit
18 work, we had an additional 318
19 measured concentrations, observed
20 concentrations. A much richer set
21 that they didn't have in the original
22 case.

23 So -- but what we didn't have
24 is, you know, additional
25 concentrations at the water treatment

1 plant, of course, because they stopped
2 pumping due to the contamination.

3 So when we did our post-audit,
4 we found that the -- if you look at
5 the simulated versus observed
6 concentrations from the extended
7 simulation we constructed in the
8 post-audit, there's a significant
9 amount of variance in the observed
10 concentrations.

11 And that variance caused
12 some -- some high fluctuations in the
13 area -- in the error. However, the
14 errors seemed to be well balanced,
15 meaning the model did a good job at
16 simulating the primary trajectory of
17 the plume.

18 In fact, if you look at the
19 bias, the bias we got from the
20 extended simulation with the
21 additional data was -- was smaller
22 than the bias they had with the
23 initial concentrations at the
24 observation wells, which I believe
25 strengthens the evidence supporting

1 the accuracy of the additional model.

2 And, therefore, I -- there's no
3 reason for me to believe, based on the
4 results of the post-audit, that the
5 initial model was wrong, especially
6 when it comes to the concentrations at
7 the water treatment plant.

8 It did an excellent job and
9 there's nothing in the post-audit that
10 would warrant, I believe, that would
11 be strong evidence to say, hey,
12 there's something wrong with the
13 original model.

14 Q. BY MR. ANTONUCCI: Well, thank
15 you, Dr. Jones, I appreciate that. But my
16 question was whether they should have reran
17 the model using the newly available data?

18 MS. BAUGHMAN: Object to the
19 form. Asked and answered.

20 THE WITNESS: We did rerun the
21 model. That's part of the -- that's
22 what we did in the post-audit, is we
23 ran the model.

24 Are you asking me if they
25 should have recalibrated it or if they

1 should have rerun the model?

2 Q. BY MR. ANTONUCCI: Should they
3 have recalibrate the model using newly
4 available data?

5 A. We -- well, before you
6 recalibrate it, you would do an analysis
7 precisely in the fashion that we did. You
8 would test the original model using the new
9 data.

10 And if in that process there
11 was some evidence that there was a major flaw
12 with the original model or that you would get
13 significantly different answer, then that may
14 warrant a reevaluation. But we did not find
15 any evidence to that.

16 MR. ANTONUCCI: Okay. I'd like
17 to clarify for the record. In my
18 previous question I used the term
19 "they." I was referring to Morris
20 Maslia and Dr. Aral and their expert
21 reports.

22 All right. I would -- I would
23 like to discuss a new document, so I
24 am going to mark for identification
25 Exhibit 9.

1 (Exhibit 9 was marked for identification.)

2 Q. BY MR. ANTONUCCI: All right.
3 Dr. Jones, Exhibit 9 is the document titled
4 "Analyses of Groundwater Flow, Contaminant
5 Fate and Transport, and Distribution of
6 Drinking Water at Tarawa Terrace and
7 Vicinity, U.S. Marine Corps Base Camp
8 Lejeune, North Carolina: Historical
9 Reconstruction and Present-Day Conditions
10 Chapter A: Summary of Findings."

11 And for the record, this
12 document has the Bates range beginning
13 CLJA_WATERMODELING_09-0000615638 and ends
14 with the Bates number ending in 615753.

15 And when I say "Bates number,"
16 Dr. Jones, do you know what I'm referring to?

17 A. My understanding is it's a --
18 it's a systematic way of referring to content
19 that's been submitted in litigation.

20 Q. Right. It's the numbers at the
21 bottom; right?

22 A. Right.

23 Q. Okay. So I would appreciate if
24 you could turn to Page A48 of Exhibit 9, and
25 that page ends in Bates Number 615699.

1 Okay. So the caption
2 underneath the figure on Page A48 says
3 "Figure A21. Sensitivity of
4 tetrachloroethylene concentration in finished
5 water at the water treatment plant to
6 variation in water-supply well operations,
7 Tarawa Terrace, U.S. Marine Corps Base Camp
8 Lejeune, North Carolina. [PCE,
9 tetrachloroethylene; see text for discussion
10 of points A-I]."

11 You're familiar with this
12 figure; right, Dr. Jones?

13 A. Yeah, I've seen it before.

14 Q. This is one of the figures you
15 had tabbed in your copy of the report; right?

16 A. No, it was not.

17 Q. Okay. Well, this is a graph
18 from ATSDR's sensitivity analysis of the
19 Tarawa Terrace model; isn't that right?

20 A. Correct.

21 Q. And this shows the change in
22 PCE concentrations in finished water based on
23 different well pumping schedules; is that
24 right?

25 A. Correct.

1 Q. And, Dr. Jones, you're aware
2 that ATSDR used the pumping and schedule
3 optimization system tool to simulate
4 otherwise unknown supply well pumping rates;
5 right?

6 A. Yes.

7 Q. And in this graph, all of the
8 simulations assumed a constant mass loading
9 rate of 1,200 grams per day; is that right?

10 A. Yes, I assume so.

11 Q. And that constant rate of
12 1,200 grams per day is the same mass loading
13 rate that you used when conducting the
14 post-audit; right?

15 A. Correct, we did not change the
16 model.

17 Q. Okay. So looking at Figure A21
18 on Page A48 of Exhibit 9, we see that all of
19 these use a mass loading start date of
20 January 1953; is that correct?

21 A. Where are you reading that?

22 Q. Strike that.

23 All of the -- ATSDR's model
24 assumed a PCE mass loading start date of
25 January 1953; is that right?

1 A. As far as I know, yes.

2 Q. Okay. And that's the same mass
3 loading start date that you used in your
4 post-audit?

5 A. Correct.

6 Q. Okay. So on Figure A21, that
7 blue line that's -- it's labeled A.
8 Do you see that?

9 A. Yes.

10 Q. This blue line shows the
11 earliest arrival of PCE at the water
12 treatment plant under the maximum pumping
13 schedule; right?

14 A. Correct.

15 Q. Okay. And so that blue line
16 shows a concentration of 0.001 micrograms per
17 liter of PCE starting just before
18 January 1955; is that right?

19 A. That looks correct, yes.

20 Q. Okay. Now, there's also a red
21 line here, and that one is labeled B.
22 Do you see that?

23 A. Yes.

24 Q. And that is the calibrated
25 model; right?

1 A. Correct.

2 Q. Okay. That's the same -- that
3 model used the same parameters that you used
4 in your post-audit; is that right?

5 A. Yes.

6 Q. So that red line, the
7 calibrated model, shows a concentration of
8 0.001 micrograms per liter of PCE starting on
9 or about January 1955; right?

10 A. Correct.

11 Q. Okay. Next I'd ask that you
12 look at the black line. That one is labeled
13 C.

14 A. Yes.

15 Q. So this shows the late arrival
16 of PCE at the water treatment plant under the
17 Minimum Schedule Number 2; is that right?

18 A. That looks correct.

19 Q. Okay. And under the Minimum
20 Schedule 2, TT-26 is operated at at least
21 25 percent capacity; right?

22 A. Yes.

23 Q. And that black line that's
24 line -- letter C shows a concentration of
25 0.001 micrograms per liter of PCE starting

1 sometime after January 1955; right?

2 A. Yes.

3 Q. All right. Now, finally
4 there's the green line, and that one is, I
5 believe, split into D and G.

6 Do you see what I'm referring
7 to?

8 A. Yes -- well, let's see. The
9 black -- oh, yes, the -- Well TT-26 not
10 operated January '62 to February 1976, hence
11 there's a gap, yes.

12 Q. Okay. So that green line, that
13 shows the arrival -- excuse me -- it shows
14 the latest arrival of PCE at the water
15 treatment plant under Minimum Schedule 1;
16 right?

17 A. That's -- that looks correct,
18 yeah.

19 Q. Okay. And minimum -- Minimum
20 Schedule 1 is where Well TT-26 is not
21 operated between January of 1962 and February
22 of 1976?

23 A. That's correct.

24 Q. Okay. So that green line shows
25 a concentration above 0.001 micrograms per

1 liter of PCE starting sometime between
2 January 1955 and January of 1960; right?

3 A. Starting, yes.

4 Q. Okay. And then there's sort of
5 a gap where the green line is not represented
6 on the figure, and then it restarts again
7 sometime between January 1970 and
8 January 1975; is that right?

9 A. Yes.

10 Q. Okay. So in general, that blue
11 line, that shows the highest PCE
12 concentrations over time; right?

13 A. Yes.

14 Q. Then that red line there, that
15 shows the next highest PCE concentrations
16 over time; right?

17 A. Yes.

18 Q. Then the black line shows the
19 next highest PCE concentrations over time?

20 A. Yeah, I think that's fair.

21 Q. Okay. And, finally, that green
22 line shows the lowest PCE concentrations over
23 time; right?

24 A. Correct.

25 Q. Okay. So the arrival of PCE at

1 the water treatment plant is dependent on
2 when PCE contamination arrived at the supply
3 wells; right?

4 A. Can you say that again.

5 Q. Of course.

6 The arrival of PCE at the water
7 treatment plant is dependent on when PCE
8 contamination arrived at the supply wells;
9 right?

10 A. Correct.

11 Q. The concentration of PCE
12 simulated by the model is dependent on when
13 PCE contamination arrived at the supply
14 wells; right?

15 A. The concentration at the
16 treatment plant. You said -- I'm sorry, can
17 you state that one more time.

18 Q. Of course.

19 The concentration of PCE
20 simulated by the model is dependent on when
21 PCE contamination arrived at the supply
22 wells; right?

23 MS. BAUGHMAN: Object to the
24 form.

25 THE WITNESS: Yeah, I -- I

1 think you're not clear in how you
2 formulated that question. Do you mean
3 the concentration at the water
4 treatment plant?

5 Q. BY MR. ANTONUCCI: As opposed
6 to?

7 A. You just said "the
8 concentration."

9 Q. Sure. Yes. Let's say -- I'll
10 rephrase the question.

11 A. Okay.

12 Q. The concentration of PCE
13 simulated by the model at the water treatment
14 plant is dependent on when PCE contamination
15 arrived at the supply wells; right?

16 A. Correct.

17 Q. Okay. And to be clear, the
18 contamination at the water treatment plant
19 was assumed to be the same level at the tap
20 in consumer's homes; right?

21 A. Would you state that again.

22 Q. Sure.

23 The ATSDR assumed that
24 contaminations of PCE at the water treatment
25 plant were the same as those after the water

1 had gone through the water distribution
2 system and was at the point of use by the
3 consumer; is that right?

4 A. Yeah, I'm not sure on that.

5 Q. Do you know if -- I mean,
6 should there be a different contamination
7 concentration at the water treatment plant
8 versus at the tap?

9 A. I know that one of the areas
10 that's been debated in the -- in the
11 rebuttals and the expert report is how much
12 the concentration changes through the water
13 treatment process, and I know that was
14 reviewed by the expert panel and others.

15 I'm generally familiar with
16 that discussion that that volatilization
17 issue was addressed by Sabatini. That is not
18 my area of expertise.

19 I will say that what the model
20 simulates is the water that would be pumped,
21 the concentration of the water as it's pumped
22 out of the aquifer, that's what -- the model
23 does not inherently explicitly include the
24 treatment process as part of the model.

25 Q. Okay.

1 A. It's simply how the
2 contaminants move through the aquifer through
3 the wells.

4 Q. Do you agree that there would
5 be losses of contamination to volatilization
6 during the treatment process?

7 MS. BAUGHMAN: Object to the
8 form.

9 THE WITNESS: That is not my
10 area of expertise.

11 Q. BY MR. ANTONUCCI: Okay.
12 However, the model -- the model doesn't take
13 that into account --

14 MS. BAUGHMAN: Object to the
15 form.

16 Q. BY MR. ANTONUCCI: -- correct?

17 A. The model does not explicitly
18 simulate volatilization.

19 Q. Does the model implicitly
20 simulate volatilization?

21 A. It potentially could.

22 Q. Can you please elaborate.

23 A. Sure. Suppose that the
24 concentrations used to calibrate the model
25 were concentrations taken from treated water.

1 If the model is then calibrated to predict
2 accurate concentrations at the water
3 treatment plant based on observed
4 concentrations of treated water, then you
5 could argue that it implicitly includes the
6 effects of any volatilization.

7 Q. Did the model calibrate to
8 treated water samples?

9 A. I know some of the samples --
10 from what I've read, it's believed some of
11 the samples may have been post-treated water,
12 and -- but I don't know if there's any
13 conclusion on the majority of the samples.

14 Q. Okay. Well, it's fair to say
15 that concentrations of PCE at the water
16 treatment plant that's simulated by the model
17 is dependent on when PCE contamination began
18 entering the aquifer; right?

19 A. Yeah.

20 Q. Based on your review of the
21 reports, is it your understanding that ATSDR
22 assumed PCE contaminants started leaking when
23 ABC Cleaner started operating in 1953?

24 A. Yes.

25 Q. Hypothetically, if ABC Cleaners

1 opened later than 1953, would that impact the
2 arrival time of contaminants at the water
3 treatment well?

4 A. It would --

5 MS. BAUGHMAN: Object to the
6 form. Incomplete hypothetical.

7 Go ahead.

8 THE WITNESS: It makes a small
9 difference in the concentrations at
10 the water treatment plant.

11 Q. BY MR. ANTONUCCI: Okay. So
12 let's say that the --

13 MS. BAUGHMAN: Were you
14 finished answering?

15 THE WITNESS: Let me clarify.

16 I know some different dates
17 have been proposed, argued by the DOJ
18 experts as a more accurate start date.

19 Having run the model at both
20 start dates, I -- I believe that the
21 differing start dates as proposed by
22 the DOJ experts does not make a
23 substantial difference in the
24 concentrations that are simulated at
25 the water treatment plant.

1 Q. BY MR. ANTONUCCI: Okay. So it
2 doesn't make a substantial difference; right?

3 A. No, that was part of Morris
4 Maslia's rebuttal report.

5 Q. Is that a yes?

6 A. Yes.

7 Q. Okay. Does it make any
8 difference?

9 A. It makes some difference.

10 Q. Okay. Hypothetically, let's
11 ignore the start dates proposed by differing
12 experts.

13 A. Okay.

14 Q. Let's say that the
15 contamination began in 1970. How big of a
16 difference would that make?

17 MS. BAUGHMAN: Object to the
18 form.

19 THE WITNESS: If the
20 contamination started in 1970 --

21 Q. BY MR. ANTONUCCI: Let's say --
22 what would the impact on 1981 data be?

23 MS. BAUGHMAN: Object to the
24 form. Are you asking in terms --
25 wait, in 1981?

1 Are you asking in terms of the
2 concentration or the arrival time? I
3 object to the form. I don't
4 understand the question.

5 THE WITNESS: So if --

6 MS. BAUGHMAN: It's also
7 outside the scope.

8 THE WITNESS: If the
9 contamination was not released until
10 1970, and that was simulated in the
11 model, yeah, I would suspect that
12 would lead to a much more significant
13 difference in the results.

14 Q. BY MR. ANTONUCCI: Okay. If
15 you were to -- to dispose of dry cleaning
16 solvents improperly -- which I know you never
17 would -- they would be -- you would -- let's
18 assume you would dump them on the ground.

19 Do you understand where my
20 hypothetical is so far?

21 A. Okay, yeah, sure.

22 Q. If you were to just pour dry
23 cleaning solvents on the ground outside,
24 would the PCE from that solvent enter the
25 aquifer immediately?

1 MS. BAUGHMAN: Object to the
2 form. Incomplete hypothetical.
3 Foundation.

4 THE WITNESS: Immediately, no.

5 Q. BY MR. ANTONUCCI: Okay. Can
6 you elaborate?

7 A. Well, if you -- for example, if
8 you had a really high water table, the water
9 table's close to the surface, it would enter
10 it very rapidly. Or if you had highly
11 permeable materials between the ground
12 surface and the aquifer, that contamination,
13 again, could happen very rapidly, so it's --
14 depends on the context.

15 Q. Sure. I guess is the inverse
16 true? If you had a low water table or low
17 permeability materials?

18 MS. BAUGHMAN: Object to the
19 form.

20 THE WITNESS: There are
21 conditions where it would take longer
22 to get to the groundwater, yes, if
23 it's starting at the ground surface.

24 Q. BY MR. ANTONUCCI: Okay. So
25 from the ground surface to the aquifer it has

1 to travel through something; right?

2 A. Yeah.

3 Q. And that takes time, depending
4 on different conditions; right?

5 A. Yeah, another factor is the
6 precipitation. How -- and snow melt,
7 precipitation, how much water is -- is
8 traveling through -- we call that the vadose
9 zone between the ground surface and the water
10 table.

11 And, you know, there are
12 conditions that are a variety of conditions
13 that would impact the -- the -- the rate of
14 transport from the ground surface to the
15 aquifer.

16 Q. Okay. Does MT3DMS model
17 contaminant transport through the vadose
18 zone?

19 A. No.

20 Q. Does TechFlowMP?

21 A. I believe it does, yes.

22 Q. And then for my own
23 understanding, the vadose zone and the
24 unsaturated zone, are those the same concept?

25 A. Yeah, same thing.

1 Q. If -- if the DOJ experts are
2 correct, would you agree that it makes a
3 substantial difference for calculating
4 exposure to someone at Tarawa Terrace prior
5 to DOJ's start but after ATSDR's mass loading
6 start?

7 MS. BAUGHMAN: Object to the
8 form.

9 THE WITNESS: I don't
10 understand the question.

11 Q. BY MR. ANTONUCCI: Not sure I
12 do either.

13 So say the true start date of
14 contaminant mass loading at Tarawa Terrace is
15 sometime between when ATSDR said it started
16 and when DOJ said it started.

17 You on board?

18 A. So January '53 is when ATSDR
19 said it started. To my understanding the DOJ
20 said maybe June '54 or July '54? Does that
21 sound right?

22 Q. Sounds about right.

23 A. Okay.

24 Q. Sometime in between there.

25 A. Okay.

1 Q. If that was when mass loading
2 started, would it make a substantial
3 difference for calculating exposure for
4 someone who was at Tarawa Terrace?

5 MS. BAUGHMAN: Object to the
6 form.

7 THE WITNESS: Your question is
8 not -- you said "if that is when." We
9 just talked about two different dates
10 or -- can you restate the question?

11 Q. BY MR. ANTONUCCI: Sure.

12 Let's say contaminant mass
13 loading started in December 1953. Would --

14 A. One year later, roughly, yeah.

15 Q. Would that make a substantial
16 difference for calculating exposure to
17 someone at Tarawa Terrace?

18 MS. BAUGHMAN: Object to the
19 form.

20 THE WITNESS: No, I think one
21 of the dates that we simulated may
22 have been January 1954, which is one
23 month off from that, and kind of
24 between the January '53 and July '54
25 dates and, no, none of those changes

1 in the date made a substantial
2 difference in the concentration of the
3 water at Well TT-26 or in the
4 concentration of the water at the
5 Tarawa Terrace water treatment plant
6 over the majority of the time frame.

7 Q. BY MR. ANTONUCCI: Okay. How
8 far apart were the simulated concentrations
9 from this experiment that you did for
10 Mr. Maslia's report?

11 MS. BAUGHMAN: Object to the
12 form.

13 THE WITNESS: Well, if -- if
14 you have the copy of the Maslia
15 rebuttal I could -- we could look at
16 the graph.

17 MR. ANTONUCCI: Okay.

18 THE WITNESS: It -- in my
19 opinion, there -- there was a minor
20 difference through a majority of the
21 simulation period.

22 Q. BY MR. ANTONUCCI: Were there
23 major differences at any time in the
24 simulation period?

25 MS. BAUGHMAN: Object to the

1 form.

2 THE WITNESS: Not that I would
3 consider significant. There was -- if
4 you -- during the very early years,
5 there was maybe a larger gap between
6 the curves, but that is where the
7 concentrations are really low.

8 And once the -- you get a few
9 years later where the concentrations
10 are higher, those curves -- the
11 distance between those curves narrowed
12 significantly and through most of the
13 period from, you know, '60s, '70s,
14 through the '80s, there's very little
15 difference.

16 Q. BY MR. ANTONUCCI: Do you
17 recall the magnitude of the difference at any
18 time?

19 MS. BAUGHMAN: Object to the
20 form.

21 THE WITNESS: Numerical
22 magnitude, no.

23 Q. BY MR. ANTONUCCI: What
24 numerical magnitude would you consider
25 significant?

1 MS. BAUGHMAN: Object to the
2 form.

3 THE WITNESS: That depends on
4 the context.

5 Q. BY MR. ANTONUCCI: What -- what
6 numerical difference would you consider
7 minor?

8 A. Depends on the context.

9 Q. What would impact your
10 consideration there?

11 A. Well, for example, in this case
12 for the majority of the range the -- the
13 concentrations are at a very high rate well
14 over the MCL level of five.

15 And qualitatively looking at
16 that, it seemed like the model was highly
17 insensitive or relatively insensitive to
18 the -- to the start date given the start
19 dates that were considered.

20 Q. Okay. And earlier you
21 mentioned that the model is perhaps better at
22 calculating concentrations at TT-26 than over
23 the wider area. Am I -- is that correct?

24 MS. BAUGHMAN: Object to the
25 form.

1 THE WITNESS: That's not how I
2 would characterize what I said.

3 Q. BY MR. ANTONUCCI: Can you
4 please repeat it for me.

5 A. Sure.

6 MS. BAUGHMAN: Object to the
7 form.

8 What's the question? I
9 don't -- let's make sure there's a
10 question.

11 THE WITNESS: Do you want me to
12 restate what I said earlier relative
13 to simulated concentrations at
14 observation wells versus -- sure.

15 As I mentioned earlier, I
16 believe the concentration data used to
17 calibrate and evaluate the performance
18 of the original flow and transport
19 model consisted of two types of data.

20 One of which was PCE
21 concentrations that were sampled at
22 observation wells; and the other is
23 a -- was a series of measured
24 concentrations at the water treatment
25 plant.

1 When you have an individual
2 sample taken at an observation well,
3 it's a small amount of water from a
4 very small part of the aquifer, a
5 specific point location, and -- and it
6 has -- it's more susceptible to
7 sampling errors and -- and the impact
8 of local scale heterogeneities.

9 And when they -- when they
10 calibrated to that, they had a good
11 match where the simulated observed
12 concentrations were high, and a bias
13 where the observed concentrations were
14 low.

15 The concentrations that were
16 measured -- or that were observed at
17 the water treatment plant are
18 different because that involves the
19 collection of water from a variety of
20 wells over a period of time, and the
21 water pumped through those wells comes
22 from a -- a much broader part of the
23 aquifer than when you take a simple
24 sample.

25 And those -- the contaminant is

1 then brought in and it's mixed and
2 averaged. And so it has much less
3 variation and sampling error than
4 you'd get with the individual error.

5 So I would consider that to be,
6 I would say, the gold standard of --
7 of data for calibrating the original
8 model. And it matched, in my opinion,
9 the model-simulated results matched
10 those observed concentrations at the
11 water treatment plant quite well.

12 Q. BY MR. ANTONUCCI: Okay.

13 Before this deposition began, when speaking
14 to counsel, you used the phrase "dilution is
15 the solution to pollution"; right?

16 A. Yeah.

17 Q. That's kind of what we're
18 talking about here, isn't it?

19 MS. BAUGHMAN: Object to the
20 form.

21 Q. BY MR. ANTONUCCI: There were
22 multiple wells, some were presumably pumping
23 clean water, some were presumably pumping
24 contaminated water, mixing and diluting at
25 the water treatment plant; right?

1 MS. BAUGHMAN: Object to the
2 form.

3 THE WITNESS: Yeah -- well, the
4 context are a little different. We
5 were talking about dirty air being
6 blown out of the valley.

7 But when you calculate the --
8 the concentration of water at the
9 water treatment plant, you have to
10 consider the -- the pumping rate for
11 each of the supply wells to the water
12 treatment plant, and then the
13 concentration of the water coming in.

14 So there's a mixing process
15 that's represented in the equation we
16 use to come up with those
17 concentrations.

18 It weights the -- the overall
19 concentration by the product of the
20 individual concentrations and the
21 individual pumping rates.

22 So there's a mixing and, yeah,
23 there's a dilution process. For
24 example, the -- the water coming in in
25 Well TT-26 has a higher concentration

1 than the water you measure at the
2 water treatment plant because it's
3 mixed with water from other supply
4 wells that have generally a lower
5 concentration.

6 Q. BY MR. ANTONUCCI: Okay. So --
7 all right. Thank you for answering that.

8 If you could turn to Page A2 of
9 Exhibit 9. I think this will maybe tie up
10 what we were discussing earlier. And that is
11 the page ending in Bates Number 615653.

12 So the footnote on this page,
13 Footnote 6 says "For this study, finished
14 drinking water is defined as groundwater that
15 has undergone treatment at a water treatment
16 plant and is delivered to a person's home.
17 The concentration of contaminants in treated
18 water at the water treatment plant is
19 considered the same as the concentrations in
20 the water delivered to a person's home. This
21 assumption is tested and verified in the
22 Chapter J report (Sautner et al. in press
23 2007). Hereinafter, the term 'finished
24 water' will be used."

25 Did I read that correctly?

1 A. Yes.

2 Q. So I will represent to you that
3 Chapter J was never published. However, a
4 draft of Chapter J was produced in this
5 litigation with the Bates Number
6 CLJA_WATERMODELING_05-22 -- excuse me --
7 212246 through 212309.

8 Have you reviewed the draft of
9 Chapter J?

10 A. No.

11 Q. Do you know whether any testing
12 was done to compare the concentrations of
13 contaminants delivered to the water treatment
14 system with the concentrations of
15 contaminants delivered to a person's home?

16 A. Not that I'm aware of.

17 Q. Okay. Please turn to Page A13
18 of Exhibit 9. That's the page ending in
19 Bates Number 615664.

20 A. Got it.

21 Q. Okay. So there's a sort of
22 list of paragraphs on this page. One of them
23 starts with the Number 4.

24 Do you see that?

25 A. Yes.

1 Q. So this says "The monthly
2 concentrations of PCE assigned to finished
3 water at the Tarawa Terrace WTP were
4 determined using a materials mass balance
5 model (simple mixing) to compute the
6 flow-weighted average concentration of PCE.
7 The model is based on the principles of
8 continuity and conservation of mass (Masters
9 1998).

10 Did I read that correctly?

11 A. Yes.

12 Q. Do you know what a materials
13 mass balance model is?

14 A. I know what they're describing
15 here, yes.

16 Q. So you agree that simple mixing
17 flow-weighted average has no calculation
18 simulating processes where contaminants are
19 lost during storage, treatment, or
20 distribution?

21 A. That's correct. It's simply
22 taking the -- the pumping rates and
23 concentrations of the supply wells to
24 determine what the resulting concentration of
25 the mixed water would be at the water

1 treatment plant.

2 Q. So a simple mixing
3 flow-weighted average wouldn't explicitly
4 take into account something like sorption or
5 volatilization?

6 MS. BAUGHMAN: Object to the
7 form.

8 THE WITNESS: That's not what
9 it's meant to do, no.

10 Q. BY MR. ANTONUCCI: It's true
11 that ATSDR's Tarawa Terrace model did not
12 include a calculation simulating contaminant
13 losses during storage, treatment, or
14 distribution; right?

15 A. Not that I'm aware of.

16 Q. You agree that ATSDR's Tarawa
17 Terrace model simulated PCE concentrations as
18 equivalent to the mixture of water straight
19 out of the wells?

20 A. Yes.

21 Q. And ATSDR assumed continuity
22 and conservation of mass in its simple mixing
23 model; right?

24 A. Yes.

25 Q. Do you agree that some losses

1 during treatment, storage, and distribution
2 are inevitable?

3 MS. BAUGHMAN: Object to the
4 form. Outside the scope.

5 THE WITNESS: That is not my
6 area of expertise. I don't have an
7 opinion on that.

8 MR. ANTONUCCI: Okay. I'd like
9 to break for lunch now.

10 THE WITNESS: Great.

11 THE VIDEOGRAPHER: We're off
12 the record. The time is 12:10.
13 (The lunch break was taken from
14 12:10 p.m. until 1:13 p.m.)

15 THE VIDEOGRAPHER: We're back
16 on the record. The time is 1:13.
17 This is Media Number 3.

18 Counsel may proceed.

19 Q. BY MR. ANTONUCCI: All right.
20 Dr. Jones, I remind you that you are still
21 under oath.

22 Have you discussed the
23 substance of your testimony with anyone
24 during the break?

25 A. Only superficially.

1 Q. Can you describe what you mean
2 by that, please.

3 A. Hey, Norm, you're doing a good
4 job.

5 Q. Okay. Did you discuss it --
6 did you discuss it any further?

7 A. No.

8 Q. All right. A couple of things
9 I want to circle back on from before the
10 break. First is going to be this document,
11 which I will mark as Exhibit 10.

12 (Exhibit 10 was marked for identification.)

13 THE WITNESS: Okay.

14 Q. BY MR. ANTONUCCI: All right.
15 Dr. Jones, do you know what this is?

16 A. Yes.

17 Q. What is it?

18 A. It appears to be the model
19 simulation results based on varying the
20 reaction coefficient over three different
21 values, and it shows the resulting
22 concentrations at the water treatment plant
23 and at Well TT-26.

24 Q. Okay. What are the three
25 different values that you used to perform

1 this analysis?

2 A. One of which was the -- the --
3 the middle line. The red line is the .005,
4 which was what was used in the original ATSDR
5 model. And one of those, as I understand,
6 was a .004 value that was suggested or used
7 by Faye. And then another one was a .006
8 value, which was suggested by -- by Dr. Aral.

9 Q. Okay. And for all of those
10 values, those are different values of
11 reaction rates; is that right?

12 A. Yeah, so the only thing that
13 was changed in the model was the reaction
14 rate, and then we looked at what impact that
15 had on the simulated concentrations for these
16 two outputs.

17 Q. Okay. And when did you perform
18 this analysis?

19 A. A week or two ago.

20 Q. Okay. So there are two graphs
21 here. I want to make sure we're looking at
22 the same one. There's one that has a caption
23 that says "MT3DMS," "Calibrated," and
24 "TechFlowMP" in the top right. Then there's
25 one that has the sort of legend in the middle

1 of the page; is that right?

2 A. Top left, yeah.

3 Q. Excuse me, thank you.

4 A. Yep.

5 Q. So what you just described, was
6 that the version of the document with the
7 legend in the center of the page or the left?

8 A. So the one with the legend in
9 the center is the simulated concentrations at
10 the Tarawa Terrace water treatment plant, and
11 the one with the legend in the upper left
12 corner is the simulated concentrations at
13 Well TT-26.

14 Q. Understood.

15 And are the reaction rates the
16 same for the different categories in both
17 graphs?

18 A. Yes. Yeah, they're both based
19 on the same model results, yeah.

20 Q. And then you also in front of
21 you should have a series of spreadsheets.

22 Do you see those?

23 A. Yes.

24 Q. What -- what do these show?

25 A. So the first column are the

1 monthly dates through the simulation period,
2 and then for each month the second column
3 would be the -- the concentrations at --
4 resulting from -- well, let me back up a
5 little bit.

6 This -- I believe this
7 spreadsheet represents the concentrations at
8 the water treatment plant.

9 Q. Dr. Jones, when you say "this
10 spreadsheet," are you referring to the one
11 with the Bates number ending in 302 or
12 document name ending in 302 up at the top?

13 A. 299.

14 Q. 299, okay.

15 All right. I'm on the Page 1
16 of the spreadsheet with the title
17 CL_PLJ-EXPERT_DAVIS_0000000299.xlsx. Is that
18 where you are?

19 A. Yes.

20 Q. And this is what you were
21 describing in your last answer?

22 A. Yeah, so the first column or
23 the simulated concentrations resulting
24 from -- or excuse me -- the first column
25 after the date it says r00004_orig, that

1 would be the concentrations resulting from
2 the simulation featuring a reaction rate of
3 .004.

4 Likewise, the next column would
5 be the results featuring a reaction rate
6 labeled as -- or corresponding to .0005. And
7 the last column would be the results with a
8 simulation with a reaction rate of .0006.

9 In other words, it's the actual
10 numbers used to generate the plots.

11 Q. Okay. I will ask you to take a
12 look through CL_PLJ-PLG-EXPERT_DAVIS_299 and
13 ask if you're familiar with the data
14 contained in this spreadsheet?

15 A. Yes, I am. I generated it.

16 Q. Okay. I'm interested in the
17 difference between the values in the three
18 columns, the Robert Faye column, the ATSDR
19 column, and the Dr. Aral column.

20 If I refer to them that way, do
21 you understand what I mean?

22 A. Yeah.

23 Q. Okay. What -- where is the
24 smallest discrepancy between the three data
25 points? At what time?

1 A. The beginning.

2 Q. Okay. Is that because they all
3 simulate a concentration of 0 micrograms per
4 liter?

5 A. That's partly why.

6 Q. Okay. Where is the largest
7 discrepancy between any two columns on this
8 spreadsheet?

9 A. On the spreadsheet, I -- I'm
10 not sure. If I had the spreadsheet in front
11 of me I could use an Excel function to find
12 that, but looking at the graphs, it appears
13 that the -- the -- the spread between the
14 curves increases until roughly late '60s and
15 then it stays relatively constant after that
16 in terms of the log-log plot.

17 Overall, they're -- in my
18 opinion, they're really close. In terms of a
19 model result, this is what I would call the
20 models being highly insensitive to changes in
21 the reaction rate.

22 Q. Did you just use the phrase
23 "log-log plot"?

24 A. A log plot. So that means the
25 vertical axis is based on the log of the

1 concentrations.

2 Q. Okay. And both of these graphs
3 use a logarithmic scale for the Y axis; is
4 that right?

5 A. That's correct.

6 Q. You I think stated that the
7 concentrations, the spread between the
8 concentrations seems to stabilize around the
9 late '60s; is that what you said?

10 A. Well, there's -- there's
11 actually a reason for that.

12 Q. Okay.

13 A. Well, there's a reason why the
14 curves are closer together in the early
15 years, and that's because, for example, the
16 TT-26 plot, this is the model simulated
17 concentrations at Well TT-26, and the source
18 of the contaminants at the ABC Cleaners is
19 some distance away from Well TT-26.

20 And so it takes time for the
21 results to get down that far. And it's --
22 you're looking at -- there is a -- an early
23 arrival, but it's at a really small
24 concentration as a function of the dispersion
25 coefficients used in the model.

1 So just the fact -- and then
2 the Tarawa Terrace water treatment plant
3 concentrations, those are a function of
4 supply wells which are all downgradient.

5 The point being, it takes time
6 for the contaminants to reach those wells
7 after it leaves the source and, therefore,
8 there's not much spread.

9 And you can see the same
10 narrowing of the band in the -- in the
11 probabilistic -- or excuse me -- the
12 uncertainty analysis results, which is
13 results from the same phenomenon I'm
14 describing.

15 Q. Okay. If you could please turn
16 to Page 5 of that same spreadsheet, which has
17 the title ending in 299.xlsx. I'm just sort
18 of looking at the bottom row. The date is
19 February 1, 1967.

20 Do you see that?

21 A. Yeah.

22 Q. So it looks like under the
23 point I think 004 reaction rate, the PCE
24 concentration in micrograms per liter is
25 67.16, and then many further digits; is that

1 right?

2 A. Correct.

3 Q. Okay. And for the ATSDR value,
4 that's the 0.005, it's 60.37; is that right?

5 A. Correct.

6 Q. And for the Aral value, and
7 that's the .006, it's 54.3; right?

8 A. Correct.

9 Q. By my math, that's a -- in
10 terms of percentages, it's a pretty
11 widespread, don't you think?

12 MS. BAUGHMAN: Object to the
13 form.

14 THE WITNESS: In terms of
15 contaminant concentrations which are
16 log normally distributed, I would
17 consider that a relatively small
18 chance spread of values.

19 Q. BY MR. ANTONUCCI: Okay. What
20 do you mean by contaminant concentrations are
21 log normally distributed?

22 A. Sure. That means there's a --
23 a statistical analysis you can run on data.
24 When a parameter is log normally distributed
25 means the values cover a very broad range of

1 values over several orders of magnitude.

2 And if you refer to the
3 rebuttal report, Exhibit 7, this is where I
4 can -- let's see. Give me a second to find
5 the page I'm looking at.

6 MS. BAUGHMAN: You can use
7 these, too, if that helps.

8 THE WITNESS: Okay, I got it
9 right -- okay. Figure 3 of the
10 rebuttal report. In this case I took
11 the 318 observed PCE concentrations
12 and ran a statistical analysis to
13 generate a histogram. And if a
14 parameter is log normally distributed,
15 you see that classic bell-shaped
16 curve.

17 And so this clearly indicates
18 that the PCE values are log normally
19 distributed, which is very typical of
20 concentration data, and, therefore --
21 that's one of the reasons why people
22 almost always show when they plot
23 concentration data, use a log scale
24 for the concentrations.

25 Q. BY MR. ANTONUCCI: When you

1 plot concentrations on a logarithmic scale
2 like you've done here --

3 A. Yeah.

4 Q. -- numbers that are -- what's
5 the benefit of using a logarithmic scale?
6 Can you explain that to me?

7 A. It captures -- given that
8 there's a high variability in concentration
9 data and the fact that they are log normally
10 distributed, it is considered to be the
11 proper way to -- to show them.

12 And so, yeah, it will -- it
13 also allows you to -- one of the benefits is
14 it doesn't compress the lower part of the
15 plot. So it allows you to get a level of
16 detail on the very small concentrations that
17 you wouldn't get in a -- in a -- in a non --
18 in a normal arithmetic scale.

19 Q. At the higher concentrations,
20 would the lines be further apart if you had
21 used an arithmetic scale here?

22 A. Yes.

23 MR. ANTONUCCI: All right. I'm
24 going to ask that you please mark
25 Exhibit 11 for identification.

1 (Exhibit 11 was marked for identification.)

2 Q. BY MR. ANTONUCCI: Okay.

3 Dr. Jones, this is ATSDR's Analyses of
4 Groundwater Flow, Contaminant Fate and
5 Transport, and Distribution of Drinking Water
6 at Tarawa Terrace and Vicinity, U.S. Marine
7 Corps Base Camp Lejeune, North Carolina:
8 Historical Reconstruction and Present-Day
9 Conditions Chapter F: Simulation of Fate and
10 Transport of Tetrachloroethylene (PCE).

11 Have you seen this before?

12 A. Yes.

13 Q. And for the record, this
14 document has the Bates range
15 CLJA_WATERMODELING_01-0000093047 through
16 93114.

17 Dr. Jones, could you please
18 turn to Page F28 of this report. That's the
19 page with Bates number ending in 93086.

20 A. Sure.

21 Q. Thanks very much.

22 All right. So I am reading on
23 the last full paragraph of Page F28. This
24 says "The PCE concentrations at water-supply
25 Well TT-26 on September 25, 1985, and

1 July 11, 1991, were 1,100 and 350 micrograms
2 per liter, respectively, and the elapsed time
3 was 2,151 days (Table F2). Applying these
4 data to Equation 3 yields a degradation rate
5 of 0.00053 per day. Potentiometric levels
6 shown on Figure F7 and F8 indicate that Well
7 TT-26 is located on a direct advective
8 pathway from ABC One-Hour Cleaners. Thus,
9 PCE mass migrates downgradient toward and
10 away from Well TT-26. To the extent
11 migration of PCE mass toward and away from
12 Well TT-26 occurred at about equal rates from
13 1985 to 1991, the compound degradation rate
14 of 0.00053 per day approximates a long-term
15 average degradation rate. On the other hand,
16 if a significant quantity of the PCE degraded
17 in the vicinity of Well TT-26 was replaced by
18 advection, then a degradation rate computed
19 using Equation 3 is probably a minimum rate.

20 "Half-lives of PCE reported in
21 the literature range from about 360 to
22 720 days (Lucius and others 1990). Applying
23 these half-lives to Equation 3 yields
24 first-order degradation rates ranging between
25 .001 and .002 per day, about twice to four

1 times the rate computed using concentrations
 2 at water-supply Well TT-26. An initial
 3 first-order degradation rate of 0.00053 per
 4 day was applied to the MT3DMS model uniformly
 5 to every layer for all stress periods. The
 6 final calibrated degradation rate was 0.00050
 7 per day, similarly applied."

8 Did I read that correctly?

9 A. Yes.

10 Q. So it seems that Robert Faye,
 11 the author of this report, is saying that a
 12 higher degradation rate here could be
 13 warranted; is that right?

14 MS. BAUGHMAN: Object to the
 15 form.

16 THE WITNESS: It looks to me
 17 like he's -- if that's who wrote this,
 18 explaining the logic that was used to
 19 calculate the degradation rate that
 20 was used in the model, .0005.

21 Q. BY MR. ANTONUCCI: Is there a
 22 reason that you did not calculate -- or
 23 perform sensitivity analysis using the values
 24 from this portion of Chapter F?

25 MS. BAUGHMAN: Object to the

1 form.

2 THE WITNESS: We were asked to
3 perform an evaluation using the three
4 values specified.

5 Q. BY MR. ANTONUCCI: Who asked
6 you to do that?

7 A. The legal team.

8 Q. All right. You can put that to
9 the side. Thanks, Dr. Jones.

10 All right. Dr. Jones, did you
11 review the model parameters that ATSDR
12 subjected to probabilistic analysis?

13 A. Yes, I read a summary of their
14 probabilistic analysis. I'm not sure I
15 remember all the details, but I did review
16 that.

17 Q. Beyond reading the summary, did
18 you -- beyond reading the summary, did you
19 otherwise evaluate the model parameters ATSDR
20 subjected to probabilistic analysis?

21 MS. BAUGHMAN: Object to the
22 form.

23 THE WITNESS: No.

24 Q. BY MR. ANTONUCCI: You used all
25 the same model parameters in your post-audit

1 that ATSDR used in the calibrated model; is
2 that right?

3 A. Correct.

4 Q. Did you perform any independent
5 evaluation of the appropriateness of those
6 parameters?

7 A. No.

8 Q. Okay. Dr. Jones, are you aware
9 of any critiques of ATSDR's Tarawa Terrace
10 model?

11 A. Yes.

12 Q. Okay. Well, first, which
13 critiques are -- are you aware of?

14 A. The critiques first and
15 foremost by the Department of Justice experts
16 we reviewed earlier.

17 Q. Are you aware of any other
18 critiques of ATSDR's Tarawa Terrace model?

19 A. I know that there was a review
20 by an NRC panel. There was a review by a --
21 a peer review by a panel of experts. I'm not
22 sure I would call those critiques, but
23 they're reviews. And I'm aware of -- of a
24 paper published by Prabhaker Clement in The
25 Groundwater Journal.

1 Q. Are you familiar with critiques
2 that the Department of the Navy has made of
3 ATSDR's Tarawa Terrace model?

4 A. Yes, I've seen reference to
5 those as well.

6 Q. Okay. Are you aware of any
7 other critiques of ATSDR's Tarawa Terrace
8 model?

9 A. Not that I can think of at the
10 moment.

11 MR. ANTONUCCI: All right. I
12 am going to mark for exhibit -- for
13 identification Exhibit 12.
14 (Exhibit 12 was marked for identification.)

15 Q. BY MR. ANTONUCCI: For the
16 record, this document has the Bates range
17 CLJA_HEALTHEFFECTS-0000000479 through 517.

18 Can you look up at me,
19 Dr. Jones, after you've finished looking
20 through that.

21 A. Sure.

22 MS. BAUGHMAN: Did you want him
23 to read it or just flip through it?

24 Q. BY MR. ANTONUCCI: Dr. Jones,
25 you've mentioned you're aware of the NRC

1 critique of -- or the NRC's review of the
2 Camp Lejeune modeling done by ATSDR; is that
3 right?

4 A. That's correct.

5 Q. Have you read this before?

6 A. I have skimmed through it, and
7 I can't say I've read every part of it, no.

8 Q. You cited to this in your
9 rebuttal report, didn't you?

10 A. Yes.

11 Q. How did you decide which
12 portions to read carefully and which portions
13 to skim?

14 A. I -- there were in the -- I
15 remember reading in the documents somewhere a
16 rebuttal to this from Morris Maslia, and so
17 I -- I read -- I was aware with -- of some of
18 the concepts in -- in this document and in
19 the rebuttal.

20 And in the context of the -- of
21 the post-audit that we did, there were some
22 sections that seemed relevant to things we
23 were discussing.

24 Q. Okay. Dr. Jones, you agree
25 that the basis used for setting the values of

1 calibration targets was unclear for ATSDR's
2 TT model?

3 A. Yes.

4 Q. I ask that you turn to Page 49
5 of the Exhibit 12.

6 A. Okay.

7 Q. I am looking at the one, two,
8 three, fourth bullet point from the top.

9 Do you see that? The sentence
10 starting with "The PSOpS."

11 A. Uh-huh.

12 Q. This says "The PSOpS modeling
13 study is based on the premise that an
14 optimization model can be used to evaluate
15 pumping stresses. Without site-specific
16 pumping data and water-quality data, the
17 results will be nonunique and uncertain."

18 Did I read that correctly?

19 A. Yes.

20 Q. That's a correct statement,
21 isn't it?

22 MS. BAUGHMAN: Object to the
23 form.

24 THE WITNESS: I'm not familiar
25 enough with the context to say with

1 certainty whether that's a correct
2 statement or not.

3 Q. BY MR. ANTONUCCI: Okay. Is
4 this one of the sections that you skimmed or
5 one of the sections you reviewed carefully?

6 A. I don't -- I don't recall
7 reading this specific bullet point.

8 Q. Okay. On the next bullet point
9 down the last sentence says "The difference
10 indicates that the real system is highly
11 transient and that the model did not account
12 for temporal and spatial averaging effects."

13 That's a correct statement,
14 Dr. Jones, isn't it?

15 MS. BAUGHMAN: Object to the
16 form.

17 THE WITNESS: I'm not willing
18 to say whether or not that's correct
19 or not.

20 Q. BY MR. ANTONUCCI: Why not?

21 A. You just read one sentence at
22 the end of a paragraph, so I'm --

23 Q. Okay.

24 A. Asking me whether to say
25 whether it's true or not, I would need to

1 explore the full context of what they're
2 describing before I could have an opinion as
3 to whether or not that's a true statement.

4 Q. Sure. I'll start from the
5 beginning of that bullet point there. That's
6 the fifth from the top.

7 It says "Review of water
8 quality monitoring data indicates substantial
9 temporal variability even at a single well."

10 You agree with that statement,
11 don't you, Dr. Jones?

12 A. Yes.

13 Q. Okay. "For example, the seven
14 measurements taken on Well TT-26 from January
15 to September 1985 indicates that the
16 concentrations at this well varied from 3.8
17 to 1,580 micrograms per liter (see Table
18 2-8). The model predictions for the same
19 time frame range from 732 to 804 micrograms
20 per liter."

21 Did I read that correctly?

22 A. Yes.

23 Q. "The difference indicates that
24 the real system is highly transient and that
25 the model did not account for temporal and

1 spatial averaging effects."

2 Did I read that correctly?

3 A. Yes.

4 Q. Now that you've seen the full
5 paragraph, are you willing to offer an
6 opinion about the validity of the last
7 sentence?

8 MS. BAUGHMAN: Object to the
9 form.

10 THE WITNESS: I'm not sure what
11 they mean by "temporal and spatial
12 averaging effects." The fact that the
13 simulated concentrations differ from
14 the observed concentrations which vary
15 quite significantly is a phenomenon
16 that we've discussed at length in
17 our -- both our post-audit report and
18 our rebuttal document.

19 There's a -- there are very
20 good reasons why one wouldn't expect
21 an exact match between the simulated
22 and observed values and why there
23 would be much greater variance in the
24 observed values versus the simulated
25 values.

1 Q. BY MR. ANTONUCCI: Okay. We'll
2 get into all of those reasons a little bit
3 later. I'd like to continue reading. This
4 is the second-to-last bullet point on Page 49
5 of Exhibit 12.

6 It says "Reporting absolute
7 predicted concentrations of PCE and its
8 biodegradation byproducts in finished water
9 delivered by the Tarawa Terrace water-supply
10 system with a precision of up to five
11 significant figures without any error bounds
12 (for example, Jang and Aral [2008] report
13 concentrations of PCE at 102.10 micrograms
14 per liter, TCE at 4.33 micrograms per liter,
15 DCE at 13.75 micrograms per liter, and vinyl
16 chloride at 7.50 micrograms per liter)
17 provides an unwarranted sense of certainty.
18 Such reporting can contribute to
19 misconceptions by the public and the
20 epidemiology-research community such that
21 water-modeling efforts can produce a specific
22 value for contaminant concentration. Posting
23 such precise point estimates for PCE, TCE,
24 DCE, and vinyl chloride concentrations on
25 public web pages (www.atsdr.cdc.gov/sites/

1 lejeune) and encouraging former Camp Lejeune
2 marines and their families to find the
3 estimated exposure concentrations of these
4 contaminants leads to a misleading perception
5 that reactive transport models can make
6 accurate predictions."

7 Dr. Jones, is it your opinion
8 that providing numbers such as the ones
9 mentioned in this paragraph without error
10 bars can provide an unwarranted sense of
11 certainty?

12 MS. BAUGHMAN: Object to the
13 form. Outside the scope.

14 THE WITNESS: I think that
15 depends on the context.

16 Q. BY MR. ANTONUCCI: Okay. The
17 last bullet point on this page, that's
18 Page 49 of Exhibit 12, says "In the absence
19 of data, historical reconstruction efforts
20 that use groundwater models can only provide
21 a general conceptual framework for what
22 happened at the site and why. At best, such
23 models may be used only to estimate a range
24 of possible concentrations. Without
25 historical geochemical data, the uncertainty

1 associated with many of the input parameters
2 (such as the biodegradation parameters) could
3 be very high. In addition, current
4 understanding of subsurface reactive
5 transport processes is inadequate, so"
6 reactive -- excuse me -- "so transport models
7 cannot be expected to provide definitive
8 concentration estimates especially for
9 biodegradation by products."

10 Did I read that correctly?

11 A. Yes.

12 Q. Okay. That's a true statement,
13 isn't it, Dr. Jones?

14 MS. BAUGHMAN: Object to the
15 form. That's about five statements,
16 it's not one.

17 THE WITNESS: Yeah, well, I
18 think this, as is the case with some
19 of the reviews, may tend to
20 overestimate, overstate the absence of
21 data. I think they did have quite a
22 bit of data to use to build the flow
23 and transport model. Certainly enough
24 to make it a reasonable and valuable
25 model.

1 And I think they did a
2 reasonable job of simulating or
3 estimating the uncertainty in the
4 model through their Monte Carlo
5 analysis and presenting that to the
6 public in their reports.

7 Q. BY MR. ANTONUCCI: Do you agree
8 that in the absence of data, historical
9 reconstruction efforts that use groundwater
10 models can only provide a general conceptual
11 framework for what happened at the site and
12 why?

13 MS. BAUGHMAN: Object to the
14 form.

15 THE WITNESS: No, I don't agree
16 with that.

17 Q. BY MR. ANTONUCCI: Why not?

18 A. I think it -- it's -- I --
19 where's the part you read again?

20 Q. That's the first sentence of
21 the last bullet point on --

22 A. Okay.

23 Q. -- Page 49 of Exhibit 12.

24 A. I think they can go beyond
25 providing a general conceptual framework, as

1 was done in the case here.

2 I think what they did with the
3 historical reconstruction is a perfectly
4 valid application of groundwater and
5 contaminant transport model.

6 Q. What's your understanding of
7 what the NRC is?

8 MS. BAUGHMAN: Object to the
9 form.

10 THE WITNESS: National Research
11 Council. It's a -- it's part of the
12 National Academy of Sciences.

13 Q. BY MR. ANTONUCCI: Is the NRC a
14 well respected institution?

15 MS. BAUGHMAN: Object to the
16 form.

17 THE WITNESS: Generally it --
18 they -- they use experts in their
19 work.

20 Q. BY MR. ANTONUCCI: Are you
21 aware that Dr. Clement served as a reviewer
22 for this report?

23 A. Yes.

24 Q. Earlier you mentioned you're
25 familiar with a critique of ATSDR's water

1 modeling efforts from -- by Dr. Clement; is
2 that right?

3 A. That's correct.

4 Q. Do you have any opinions on
5 that article?

6 A. I do.

7 Q. Okay. What are they?

8 A. Well, as I mentioned, Professor
9 Clement is a good friend of mine and he has a
10 habit of writing thought -- thought-provoking
11 issue papers. And he has a number of these
12 over the years that are meant to push buttons
13 and stimulate conversations.

14 He typically asks me to review
15 his draft manuscripts of his issue papers and
16 we have a lot of fun discussing the issues,
17 and he enjoys getting reactions and getting
18 people to talk about things.

19 I did not review this
20 particular article when he published it, nor
21 have we had extensive conversations about it,
22 but it certainly follows the pattern. And if
23 you read his response to Morris' response, in
24 the opening paragraphs he does indicate that
25 one of his objectives was to stimulate

1 conversation with that.

2 That being said, when I read
3 the paper, it seemed that a lot of his
4 critiques were -- were directed at the
5 TechFlow -- use of the TechFlowMP model in
6 the modeling study. And in fact he -- I
7 recall he suggested that a better approach
8 would be to stick perhaps with MODFLOW and
9 MT3DMS, which is what we've done in this
10 study and what I think the -- you know,
11 certainly what's documented in Chapters C
12 and F.

13 And I also think he made some
14 fundamental logical errors in his critique of
15 the -- of the modeling effort.

16 For example, he stated that
17 with a hindcasting model, the farther you go
18 back in time, the greater the uncertainty.
19 And I -- I do not agree with that, because
20 probably the most certain state of this model
21 is 1953 when it started. That's a point in
22 time when you have a definitive
23 representation of what the model should look
24 like.

25 So they -- they had

1 concentration data at the water treatment
2 plant in the -- in the mid '80s. They had
3 concentrations at the wells. And so you
4 could argue that there's -- there's less
5 uncertain -- there's data at that point.

6 So you're going to from a
7 state -- a known state to another known
8 state. And so there's uncertainty along that
9 path, but you're simulating between two
10 relatively precise states.

11 Another issue I had with the
12 model with his analysis is he pointed to
13 the -- the uncertainty band of the simulated
14 concentrations at well -- at the Tarawa
15 Terrace water treatment plant, and he looked
16 at the -- the narrow band of uncertainty in
17 the early years of the results as we were
18 discussing a little bit earlier in this
19 deposition.

20 And he said this is wrong
21 because it implies that -- that there's no --
22 there's very little uncertainty at that point
23 in time, which is wrong. And I believe
24 Spiliotopoulos made the same critique about
25 the narrow band there.

1 And as I explained earlier,
2 there's a very important reason why the band
3 is narrow. The -- the -- that plot shows the
4 concentrations at the water treatment plant,
5 which is derived from concentrations at
6 supply wells that are a significant distance
7 away from the source.

8 So no matter what -- no matter
9 what perturbations or variation you had in
10 the model in those early stages, you would
11 get very small concentrations downgradient
12 during the first few years.

13 So it has -- has nothing to do
14 with falsely representing the uncertainty.
15 That -- the fact that that band is narrow is
16 a natural mathematical byproduct of the -- of
17 the geometry and the -- and the physics at
18 the site.

19 Q. Okay. Do you have any other
20 fundamental logical errors that you'd like to
21 point out?

22 A. No.

23 Q. All right. When was the last
24 time you reviewed the Clement article?

25 A. I -- a couple of weeks ago,

1 maybe.

2 Q. And you said that you haven't
3 discussed it with Dr. Clement; is that right?

4 A. That's correct.

5 Q. Why not?

6 A. I figured it would be best as
7 I'm serving as an expert on this case and
8 knowing his past involvement to -- to not
9 have that conversation. Save it for a later
10 time.

11 Q. You don't think he'd want to
12 engage with you in a controversial
13 discussion?

14 A. Oh, I'm sure he would. But I
15 don't want that to -- my personal
16 relationship with him to impact my -- my --
17 my work and my conclusions on this.

18 Q. You mentioned that many of
19 Dr. Clement's critiques were directed at the
20 use of TechFlowMP; is that correct?

21 A. In my reading of the article,
22 that's the -- that's the sense I got. For
23 example, he -- one of his critiques was we
24 shouldn't use cutting-edge research -- we
25 should be careful or reluctant to use

1 cutting-edge research models developed in
2 academic institutions that haven't been
3 thoroughly vetted. That certainly would not
4 apply to -- to MODFLOW and MT3D.

5 Q. Understood.

6 But is it -- is it your opinion
7 that TechFlowMP has not been thoroughly
8 vetted?

9 MS. BAUGHMAN: Object to the
10 form.

11 THE WITNESS: I don't -- I
12 don't -- I don't think it's been
13 vetted to the same degree as MODFLOW
14 or MT3D. That doesn't mean it's not
15 a -- a -- an accurate and valuable
16 model.

17 Q. BY MR. ANTONUCCI: Do you have
18 any opinion on the accuracy and validity of
19 results generated using TechFlowMP?

20 A. No.

21 Q. You have no opinion either way?

22 A. I haven't studied the
23 TechFlowMP results. We focused mainly on the
24 MODFLOW and MT3DS -- MS as -- within the
25 context of the work were asked to do. Was

1 not asked to evaluate TechFlowMP or study it.

2 Q. Okay. It's my understanding
3 that TechFlowMP was generated at the Georgia
4 Institute of Technology by Dr. Aral?

5 A. That's correct.

6 Q. Okay. And that was done for
7 the purpose of the Camp Lejeune study; right?

8 MS. BAUGHMAN: Object to the
9 form. Foundation.

10 THE WITNESS: I'm not sure what
11 it was -- if that's why it was
12 developed or not. I'm just not -- I'm
13 not aware.

14 Q. BY MR. ANTONUCCI: Okay. How
15 many other groundwater modeling projects have
16 you evaluated that use TechFlowMP?

17 A. I don't recall seeing any
18 other.

19 Q. This is the only one you've
20 evaluated that's used TechFlowMP?

21 A. That's correct.

22 Q. Okay. How about published
23 studies, things you've reviewed in the
24 literature. Have you seen TechFlowMP used
25 anywhere else?

1 A. Not that I recall.

2 Q. Okay. All right. I would like
3 to discuss hindcasting.

4 When I say the word
5 "hindcasting," what does that mean to you?

6 A. Using a model to look back in
7 time and characterize what happened in the
8 past in an aquifer.

9 Q. Okay. ATSDR's groundwater flow
10 and transport models are hindcasting models;
11 right?

12 A. That's what they were primarily
13 developed for, yes, to do a historical
14 reconstruction is another term for
15 hindcasting.

16 Q. So the -- would you consider
17 those terms, "historical reconstruction" and
18 "hindcasting" to be synonyms?

19 A. Yeah.

20 Q. Have you ever constructed a
21 historical reconstruction or hindcasting
22 model?

23 A. Yes.

24 Q. Okay. I think we discussed a
25 few of those at the beginning of the

1 deposition; is that right?

2 A. Correct.

3 Q. Are there any others that we
4 didn't already mention?

5 A. Yeah. One in particular, you
6 may or may not be familiar with the -- with
7 the Woburn case near Boston, Massachusetts.

8 Early in my career I became
9 interested in that case after reading the
10 book A Civil Action and learning about the --
11 at that site they had PCE contamination in
12 the groundwater, which then traveled to some
13 municipal supply wells resulting in a cluster
14 of childhood leukemia and other things, I
15 believe, in the -- in the Woburn
16 neighborhood.

17 And I became very interested in
18 the case and I read up on it and I contacted
19 a lot of -- I knew some of the experts who
20 had been involved in the study, such as
21 George Pinder, and I contacted a number of
22 the people who were involved and asked if
23 they had any data they could share with me.

24 And so I collected a wide
25 variety of data on the site, which I then put

1 into a website, Woburn hydrogeologic data, or
2 something I think I called it.

3 And then as I was teaching a
4 graduate course on contaminant -- on
5 groundwater modeling, I ended up developing a
6 series of exercises where each time I teach
7 the class, we study the case and I have the
8 students build groundwater models, and then
9 take opposing sides in the case and critique
10 each other's models and -- and estimate
11 the -- whether or not the contaminant would
12 have reached the wells within a certain time
13 frame and answer questions like that.

14 I was able to travel to a
15 symposium at Harvard Law School on the case
16 and interact with a lot of the people
17 involved with it, and over the years a number
18 of other university courses have adapted this
19 same set of exercises and materials and
20 content that I developed for this particular
21 model.

22 MR. ANTONUCCI: I'm showing you
23 what I will have marked for
24 identification as Exhibit 19.

25 THE REPORTER: 19?

1 MR. ANTONUCCI: Excuse me, 13.

2 Thank you.

3 (Exhibit 13 was marked for identification.)

4 Q. BY MR. ANTONUCCI: Dr. Jones,
5 do you recognize this?

6 A. Yes, I do.

7 Q. How do you recognize this?

8 A. This is a part of the Woburn
9 case study that I just described to you.
10 This is one of the pieces of information that
11 I provide to my students.

12 Q. Is this a page from the CE 547
13 website?

14 A. Yes, it is.

15 Q. Did you -- did you create this
16 web page?

17 A. Yes, I did.

18 Q. Okay. And have you visited it
19 in the past?

20 A. Yes.

21 Q. Okay. Have you read the
22 contents of this web page before?

23 A. Yeah, I wrote this web page.

24 Q. Okay. And do you currently
25 remember the contents of this web page?

1 A. Yes.

2 Q. Okay. I'd like for you to look
3 at the italicized text in the center which
4 starts with the word "First"?

5 A. Yes.

6 Q. This says "First: Had the
7 plaintiffs established by a preponderance of
8 the evidence that any of the following
9 chemicals - TCE, perc, and 1,2
10 transdichloroethylene - were disposed on the
11 Beatrice land after August 27, 1968 (in the
12 case of W.R. Grace, after October 1, 1964,
13 and the date Well G had opened), and had
14 these chemicals substantially contributed to
15 the contamination of the wells before May 22,
16 1979?"

17 Did I read that correctly?

18 A. Yes.

19 Q. That appears to be from the
20 jury instructions from Judge Skinner; is that
21 right?

22 A. Yes. And I took this from the
23 book A Civil Action published in 1995 by
24 Harr.

25 Q. Okay. So the question posed to

1 the groundwater modeling experts at Woburn
2 was whether or not contaminants could have
3 reached the pumping wells through the
4 groundwater flow within a certain time frame;
5 is that right?

6 MS. BAUGHMAN: Object to the
7 form.

8 THE WITNESS: Can you state
9 that again.

10 Q. BY MR. ANTONUCCI: The question
11 posed to the groundwater modeling experts at
12 Woburn was whether or not contaminants could
13 have reached the pumping wells through
14 groundwater flow in a certain time frame;
15 right?

16 MS. BAUGHMAN: Object to the
17 form.

18 THE WITNESS: Yeah, I think
19 that's accurate.

20 Q. BY MR. ANTONUCCI: Okay. Were
21 the groundwater modelers at Woburn asked to
22 determine the concentrations of contaminants
23 in the wells at different points in time for
24 determining an individual's potential
25 exposure to contaminants?

1 MS. BAUGHMAN: Objection.

2 Form. Foundation.

3 THE WITNESS: I don't recall.

4 Q. BY MR. ANTONUCCI: You don't
5 know if the groundwater modelers generated a
6 list of contaminant exposure doses?

7 A. As part of this initial case,
8 I -- I'm not sure.

9 Q. Okay.

10 A. I know that this -- after
11 this -- this civil action was concluded,
12 there was an extensive study by the -- by the
13 USGS, there was a model built. It also
14 became a Superfund site and, you know, there
15 were a lot of different kinds of analyses
16 that were performed.

17 I also became friends with a
18 professor at Ohio State University who
19 studied this extensively and did a number of
20 simulations, including calculating the
21 concentrations at the wells and then putting
22 those concentrations into a water
23 distribution model to simulate the
24 resulting -- the concentrations of water
25 delivered to different neighborhoods in

1 Woburn, and then he compared that to
2 incidents of leukemia in the children in
3 those neighborhoods who were in -- in utero
4 when they -- their mothers drank the water,
5 and found a really strong correlation. And
6 that study was then published in Nature, the
7 journal Nature and got a lot of recognition.

8 So my point is there -- there
9 are a lot of different modeling efforts and
10 analyses associated with this case. It's
11 been very highly studied.

12 Q. Okay. Specifically for the
13 question you ask your students --

14 A. Yes.

15 Q. -- the project you ask them to
16 recreate --

17 A. Yes.

18 Q. -- are they determining
19 specific concentrations of contaminants at
20 wells?

21 A. No. I have them focus purely
22 on travel time and whether or not the
23 contaminants -- it's more likely than not
24 that the contaminants would have reached
25 Wells G and H within the time frame

1 associated with this case.

2 Part of my objective is to --
3 is to frame a -- you know, the case study
4 around an amount of work that could
5 reasonably be done in the course of a
6 university semester.

7 Q. Sure. The other studies you
8 were discussing, the I think USGS and
9 others --

10 A. Yeah.

11 Q. -- those use a EPA net water
12 distribution system modeling software to
13 estimate the movement of contaminants through
14 the water distribution system; right?

15 A. I don't know about the USGS. I
16 know the study that was done at Ohio State
17 University did that.

18 Q. Okay. The -- the USGS study --
19 or what's -- how would you describe your
20 level of familiarity with that study?

21 A. I know that they -- they built
22 a groundwater model. I have copies of the
23 model. I've looked at the model and the
24 outputs. I looked at the boundary conditions
25 they found, the -- the conceptual model they

1 used and -- and that -- the manner in which
2 they built that model informed the guidelines
3 that I give my students to -- to recreate the
4 model each semester I -- I teach it. We use
5 the same basic conceptual model and boundary
6 conditions used by the USGS. And I believe
7 we may calibrate to the same data that they
8 had.

9 Q. The USGS study did not
10 determine specific concentrations of
11 contaminants individuals in Woburn were
12 exposed to; right?

13 A. I'm not sure. I don't recall.

14 Q. The USGS study bifurcated into
15 two parts; right?

16 A. The USGS? I'm -- not that I'm
17 aware of.

18 Q. The USGS study first looked at
19 whether contaminants could have possibly
20 reached the wells, then whether contamination
21 from the wells would have reached certain
22 neighbors in different proportions.

23 Does that sound like your
24 understanding of the USGS study?

25 MS. BAUGHMAN: Object to form

1 and foundation.

2 THE WITNESS: I think you may
3 be conflating some different things
4 here. But the -- the description in
5 this Exhibit 13 was based on the
6 evidence presented at the original
7 trial, and in that case there were
8 modeling -- a modeling expert for the
9 plaintiffs, another modeling expert to
10 defense. They had different models
11 and argued for the merits of each, and
12 that's the -- that was bifurcated as
13 described in this -- in this issue.

14 Now, the -- the other study I
15 was talking about at Ohio State, that
16 was purely, to my knowledge, an
17 academic study. He had a PhD student
18 that worked on that, and like me, he
19 became interested in the case and did
20 that more extensive analysis.

21 You know, one of the questions
22 in this case -- this was the late
23 '80s, early '90s at a time when our
24 understanding of chlorinated solvents
25 and their impact on health and how

1 they migrate and degrade in an aquifer
2 was not as well understood as it is
3 now, and so there -- that was one of
4 the -- that was one of the issues in
5 the case.

6 And -- and so, again, one of
7 the questions was does -- do these
8 contaminants cause the illnesses that
9 were reported in Woburn.

10 And so one of the objectives of
11 the Ohio State study was he was able
12 to take the -- recreate through the
13 model simulation the concentrations
14 that were reaching the supply wells,
15 and then the next question is once
16 they're in the supply wells, where did
17 they go, right?

18 Because -- and so the EPA net
19 model -- I believe he used EPA net --
20 it was a water distribution model
21 similar to EPA net, then simulated
22 where -- which specific neighbors and
23 houses that would go to. And then
24 they did statistical analysis of the
25 correlation between that water

1 delivery and the incidents of
2 childhood leukemia and found a very
3 strong statistical correlation.

4 Q. Understood.

5 You mentioned that your
6 students use the same calibration data that
7 was available to USGS; is that right?

8 A. That's -- I believe so. I
9 collected my calibration -- I was also in
10 contact with some of the original experts who
11 were involved in the litigation, and so I --
12 whether my calibration data came from the
13 USGS model or theirs, I'm not positive.

14 Q. Okay. Regardless of where it
15 came from --

16 A. Yeah.

17 Q. -- can you describe that data
18 to me?

19 A. Yeah. It -- it is measured
20 water levels at a number of observation wells
21 in the Woburn area, and also there's a --
22 there's a river or a stream that flows
23 through the -- the valley and the -- there
24 were some measure -- and I believe this one
25 was USGS data -- measured the change in flow

1 across that -- between a gauge at the top of
2 where the model is and a gauge at the bottom
3 to determine how much water in this case was
4 gained. There's water flowing from the
5 aquifer to the river, and the magnitude of
6 that was measured.

7 So the students calibrate the
8 MODFLOW model to the water levels at the
9 observation wells and to the stream
10 discharges. The discharges to the streams --
11 stream.

12 Q. Can you use the discharges to
13 the stream to determine the recharge rate of
14 the aquifer?

15 A. Yes, it's actually really
16 helpful because based on the -- the closed
17 nature of the -- of the site, there's only
18 one source of water to the aquifer, and
19 that's through recharge.

20 And then the water leaves the
21 aquifer by being pumped out through the wells
22 that are active at the specific point in
23 time, and also through discharge to the
24 stream.

25 So, in fact, I instruct my

1 students you can actually back calculate the
2 recharge in a spreadsheet using a simple
3 water balance method using that data.

4 Q. What time frame did the water
5 level data cover that you just discussed?

6 A. I don't recall. I would have
7 to go back and look and see. But we build a
8 steady-state model. We don't build a --
9 actually, I take that back. I have them
10 build both a steady-state model and then they
11 have the option to make a transient model,
12 but the calibration is the steady-state
13 conditions.

14 Q. Is that because you don't have
15 well pumping data?

16 A. No -- well, it's partly because
17 it's -- I don't believe we had water-level
18 data over a long period of time. And, again,
19 I have to construct the case study, it's
20 something that a set of students who are
21 brand new to groundwater modeling can do over
22 the course of a semester, so it's -- it's --
23 it's a small aquifer. It's a contained
24 system.

25 Q. Sure. Do you -- do you know if

1 that data is available, the well pumping
2 data?

3 A. Oh, so we have -- we use some
4 pumping data in -- in the case, yeah. There
5 are four wells; there are two industrial
6 wells and then Wells G and H and the pumping
7 data's described somewhere in my website.

8 Q. Do your students calibrate the
9 model to any contamination concentrations?

10 A. No.

11 Q. Were contaminant concentrations
12 available to the water modelers in the
13 lawsuit?

14 A. Yes, I believe so.

15 Q. Do you know roughly what time
16 period that data spanned?

17 A. I don't recall. I know once
18 they -- similar to the Camp Lejeune case,
19 once the chlorinated solvents were discovered
20 in the municipal wells, they -- they shut
21 down the wells and stopped pumping.

22 Q. Okay. So there wouldn't
23 be -- strike that.

24 I'm sorry, were you going to
25 continue?

1 A. Well, that -- there are two
2 types of concentrations data. There's the
3 concentration of the water coming out of the
4 well, which I know they measured that. But
5 then I think at a later point in time they
6 went in and started sampling water at
7 monitoring wells throughout the Aberjona
8 aquifer and collected a set of concentration
9 data from that, which was then used to build
10 the models that were used in the court case.

11 Q. Okay. Maybe zooming out from
12 Woburn --

13 A. Sure.

14 Q. -- talking about groundwater
15 modeling in general.

16 A. Sure.

17 Q. What are the types of data that
18 are required to create a historical
19 reconstruction groundwater model?

20 A. That depends on the context.

21 Q. Sure. Would you ideally have
22 precipitation data for use in creating a
23 hindcasting model?

24 A. Ideally, yes.

25 Q. Okay. And that would help you

1 determine the recharge rate; is that correct?

2 A. That does inform the recharge
3 rate, typically, yes.

4 Q. To calibrate the groundwater
5 flow model, would you say that you need water
6 level data?

7 A. Yes.

8 Q. And for the flow and transport
9 model, would you say that pumping schedules
10 and pumping rates are helpful in creating a
11 hindcasting model?

12 MS. BAUGHMAN: Object to the
13 form.

14 THE WITNESS: I would say,
15 yeah, any of the major, significant
16 what we call stresses, sources and
17 sinks of water you'd want to
18 characterize as best you can based on
19 the data that are available to you.

20 Q. BY MR. ANTONUCCI: How about
21 the properties of the aquifer, like porosity
22 or other parameters similar to that, would
23 that be helpful in generating a groundwater
24 model?

25 A. Yes.

1 MS. BAUGHMAN: Object to the
2 form.

3 Q. BY MR. ANTONUCCI: Ideally,
4 where do you get information about the
5 aquifer properties from?

6 MS. BAUGHMAN: Object to the
7 form.

8 THE WITNESS: It depends on the
9 aquifer properties that you're talking
10 about. One of the ways in which we
11 get hydraulic conductivity, for
12 example, is you can go to the site and
13 perform pump tests where you either
14 inject water or pump water out of the
15 aquifer and watch the -- the response
16 of the aquifer, and from that you can
17 back calculate or infer the hydraulic
18 conductivity in the region surrounding
19 the well.

20 And -- but in some cases we
21 start with our -- our best estimate
22 using scientific and engineering
23 judgment and experience on the
24 parameters, and then use the feedback
25 from the calibration data to help

1 inform those results.

2 For example, recharge is hard
3 to quantify, but once you start
4 running the model, if your recharge
5 rate is too high, the whole aquifer
6 floods and you know that's not
7 realistic; where if your recharge rate
8 is too low, your aquifer gets
9 dewatered.

10 So there are things that you
11 can do as part of the modeling
12 exercise to help narrow down a
13 reasonable range of parameters in your
14 model.

15 Q. BY MR. ANTONUCCI: Okay. I
16 would appreciate if you could please turn to
17 Exhibit 9, Page A27.

18 A. Okay.

19 Q. All right. Page A27 of
20 Exhibit 9, the title of the table is "Summary
21 of model-derived values and observed data of
22 tetrachloroethylene at water-supply wells,
23 Tarawa Terrace U.S. Marine Corps Base Camp
24 Lejeune, North Carolina; is that right?

25 A. That's correct.

1 Q. And it looks like this graph
2 shows the model-derived values versus the
3 observed data at Tarawa Terrace; is that
4 correct?

5 A. Correct.

6 Q. Is it your understanding that
7 this is all of the water supply well data
8 that ATSDR had available?

9 A. I would assume so.

10 Q. Okay. And this is 36 data
11 points; right?

12 A. Yes.

13 Q. Okay. And it looks like they
14 were taken in 1985 and 1991; correct?

15 A. Correct.

16 Q. Okay. Now I'd appreciate if
17 you could turn to Exhibit 6, that's your
18 initial report.

19 A. Okay.

20 Q. And if you could please look at
21 Page 7 in Roman Numerals vii, it's the
22 Executive Summary.

23 A. This is Exhibit 6?

24 Q. Yes.

25 A. Oh, sorry, I thought you said

1 7-I. Okay. Got it.

2 Q. Okay. I'm reading from the top
3 of Page 7, the sentence starting with the
4 word "Despite."

5 A. Yes.

6 Q. It says "Despite the inherent
7 challenges in simulating complex subsurface
8 conditions and dealing with incomplete data,
9 the model effectively simulates long-term
10 trends in contaminant migration."

11 Did I read that correctly?

12 A. Yes.

13 Q. What did you mean by "the
14 inherent challenges in simulating complex
15 subsurface conditions"?

16 A. I think I would probably use
17 this sentence to describe just about any
18 groundwater modeling project that I've been
19 familiar with over the course of my career.

20 When we're looking at
21 groundwater models, we always have -- we're
22 dealing with something that's underground,
23 that you can't directly touch and measure,
24 and so the whole process is based on building
25 the model as best you can from the available

1 data that you have and overcoming, in a
2 reasonable fashion, the -- the lack of more
3 continuous data.

4 Q. Okay. And what did you mean by
5 "dealing with incomplete data"?

6 A. What I just described. I --
7 there -- I've never in my 34 years in this --
8 in this profession and my career encountered
9 a case where someone built a model and said,
10 By golly, we had all the data we needed for
11 this project, right?

12 You're always dealing with
13 incomplete data. But there are standard,
14 established procedures on how to do that and
15 how to assess uncertainty in those cases and
16 how to -- again, I -- I previously -- I
17 mentioned that recharge, which is very hard
18 to measure directly.

19 And so we use indirect methods
20 to -- to pin down the -- the level of
21 recharge. That process is used in multiple
22 ways in building models.

23 MR. ANTONUCCI: Is this
24 Exhibit 14?

25 THE REPORTER: Yes.

1 MR. ANTONUCCI: Okay. I'm
2 handing you Exhibit 14.
3 (Exhibit 14 was marked for identification.)

4 Q. BY MR. ANTONUCCI: Dr. Jones,
5 have you seen this before?

6 A. It certainly looks familiar,
7 yes.

8 Q. Where have you seen this
9 before?

10 A. That would appear to be a
11 poster. I believe I presented this at the
12 American Geophysical Union meeting, annual
13 meeting.

14 Q. Could you please turn to the --
15 THE VIDEOGRAPHER: Sorry, can
16 you...

17 Q. BY MR. ANTONUCCI: Could you
18 please turn to the page with the title
19 "Augmenting Sparse Groundwater Level Data
20 With Earth Observations via Machine Learning"
21 with the multiple text box -- text boxes on
22 it.

23 A. Sure.

24 Q. I believe that's the second
25 page.

1 A. Oh, okay, yeah.

2 Q. If you could look at the box
3 entitled "Data Gaps"?

4 A. Yes.

5 Q. Here this says "Monitoring
6 wells are often samples at irregular or
7 sporadic intervals. It is not uncommon for
8 monitoring wells to be abandoned, or to have
9 quite brief periods of record. We may have
10 only one or two years of information from the
11 well. How can we use machine learning to
12 best make use of what little data we have?"

13 Did I read that correctly?

14 A. Yes.

15 Q. So according to this poster,
16 one or two years of information from a well
17 is a brief period of record; right?

18 MS. BAUGHMAN: Object to the
19 form.

20 THE WITNESS: Depending on the
21 context.

22 Q. BY MR. ANTONUCCI: Okay. Are
23 you currently researching ways to address the
24 issue of sparse groundwater level data and
25 groundwater modeling by using machine

1 learning?

2 A. Yes, although I would
3 characterize it as the -- the primary
4 objective of the research we're doing here
5 with this algorithm is to help scientists and
6 water managers accurately determine how their
7 groundwater storage is changing over time so
8 that they can determine if their groundwater
9 resources are being used sustainably.

10 And one of the challenges in --
11 in generating a time history of aquifer
12 storage change is we have to work with water
13 levels measured at wells, and some wells have
14 a -- a -- a relatively complete record over a
15 long period of time.

16 Other wells have -- may go
17 years between measurements or have
18 measurements that only cover a short time
19 span. And we're exploring machine learning
20 algorithms that combine the data you do have
21 with satellite data, earth observations to --
22 to intelligently infer the missing data so
23 that you can more accurately build an aquifer
24 storage versus time curve that can be used by
25 water managers to address aquifer

1 sustainability.

2 Q. Okay. And to be totally clear,
3 machine learning is not something that was
4 applied to ATSDR's Tarawa Terrace groundwater
5 flow or transport model; right?

6 A. Not to my knowledge.

7 Q. You can put that exhibit aside.
8 Thanks, Dr. Jones.

9 A. Sure.

10 Q. Is it fair to say that a
11 modeler's goal might be to keep a model
12 simple enough to be manageable yet complex
13 enough to be useful?

14 A. That's a -- that's a common
15 expression we use, yes.

16 Q. Okay. And would you agree with
17 the phrase that one should start simple and
18 build in complexity only as needed?

19 A. Yes, in general.

20 Q. Okay. That's sort of the
21 theory underpinning model parsimony; right?

22 MS. BAUGHMAN: Object to the
23 form.

24 THE WITNESS: Yeah, that's --
25 that -- model parsimony is having the

1 right level of -- the level of
2 complexity in your model warranted by
3 the purpose of the model and what it's
4 going to be used for and the -- the
5 nature of the site that you're
6 modeling.

7 Q. BY MR. ANTONUCCI:
8 Theoretically, it's true to say that there
9 are an infinite number of combinations of
10 model parameters that will calibrate the same
11 model; right?

12 MS. BAUGHMAN: Object to the
13 form.

14 THE WITNESS: It depends on the
15 context. Not in -- there are certain
16 circumstances where that could apply,
17 but it's not true as a general
18 statement.

19 Q. BY MR. ANTONUCCI: Okay. What
20 is the problem of nonuniqueness in the
21 context of groundwater modeling?

22 A. Depending on how a model is
23 built, if -- if you have -- for example, let
24 me refer back to the -- earlier I mentioned
25 that we can use stream flow data to pin down

1 our recharge value.

2 Suppose you have an aquifer
3 where all you have are water level
4 measurements and no -- no -- no estimates on
5 discharge, and that -- that could become a
6 little more problematic in pinning down your
7 recharge value.

8 And so there are certain
9 conditions where if a -- if the conceptual
10 model is overly simplistic or your boundary
11 conditions are not well posed, you can
12 achieve a mathematical situation where, for
13 example, you could plug in any value of
14 hydraulic conductivity and get the same heads
15 out of it.

16 So it's something that modelers
17 need to be aware of. It's something that I
18 teach in my groundwater modeling class. But
19 it -- it's -- I certainly would never say
20 that for any given model there are an
21 infinite number of parameters that would
22 reasonably calibrate it.

23 Q. It is fair to say, though, that
24 multiple sets of model input parameters could
25 calibrate to a single set of observed data;

1 right?

2 MS. BAUGHMAN: Object to the
3 form.

4 THE WITNESS: I -- again, it
5 depends on the context. I wouldn't
6 say that as a general statement.

7 MR. ANTONUCCI: I'm going to
8 introduce Exhibit 15.

9 (Exhibit 15 was marked for identification.)

10 Q. BY MR. ANTONUCCI: Dr. Jones,
11 you've seen this before, haven't you?

12 A. It looks like one of my exams,
13 yes.

14 Q. Okay. I'll represent to you
15 that I pulled this off the website for your
16 groundwater modeling class.

17 Are you familiar with the
18 content of this exam?

19 A. Yes, I am.

20 Q. Okay. You've seen it before?

21 A. Yes.

22 Q. And you currently know what the
23 information on this exam is; right?

24 A. Yes.

25 Q. Okay. I'd like you to look at

1 Question 4, please.

2 A. Yes.

3 Q. It reads "(calibration) Model
4 non-uniqueness occurs when:" Answer: "b.
5 Multiple sets of model input parameters will
6 calibrate to a single set of observed data."

7 Did I read that correctly?

8 A. That's correct.

9 Q. Okay. That means there could
10 be more than one calibrated model that fits a
11 given data set; right?

12 A. You notice the way that's
13 phrased, "model uniqueness occurs when."
14 That -- basically there are certain
15 conditions, depending on how the model was
16 built, where the model can end up being
17 nonunique. That doesn't mean that all models
18 are nonunique.

19 Q. So with regard to the ATSDR
20 model, theoretically a model that sits
21 outside the uncertainty range of their model
22 could still be a good fit to the post-audit
23 data; right?

24 MS. BAUGHMAN: Object to the
25 form.

1 THE WITNESS: Say that again.

2 Q. BY MR. ANTONUCCI:

3 Theoretically, there could be a model that
4 sits outside the uncertainty range of the
5 ATSDR model that is still a good fit to the
6 post-audit data set; right?

7 MS. BAUGHMAN: Object to the
8 form.

9 THE WITNESS: I'm sorry, one
10 more time. I got to make sure I get
11 the correct answer here.

12 Q. BY MR. ANTONUCCI:

13 Theoretically, there could be a model that
14 sits outside the uncertainty range of the
15 ATSDR model that is still a good fit to the
16 post-audit data set; right?

17 MS. BAUGHMAN: Objection.
18 Form.

19 THE WITNESS: Not necessarily.

20 Q. BY MR. ANTONUCCI: Dr. Jones,
21 is a non- --

22 MS. BAUGHMAN: Wait. Were you
23 finished answering?

24 THE WITNESS: Well -- no. So
25 from my understanding of what they did

1 is they calibrated the model and got a
2 set of parameters which best fit
3 the -- the observed heads and
4 concentrations, and then in the
5 uncertainty analysis, they perturbed
6 those over a wide range of values and
7 looked at the effect on the -- on the
8 outcome, the concentrations. That
9 means they explored a broad range of
10 models.

11 Now, whether outside of that
12 range there could be models that --
13 that would adequately calibrate, I
14 can't say.

15 Q. BY MR. ANTONUCCI: Okay. Is it
16 your opinion that the post-audit calibrated
17 model is the only model that could fit the
18 data ATSDR had?

19 A. Well, the -- the post-audit was
20 not a calibration exercise.

21 Q. Excuse me. I'll re-ask my
22 question.

23 Is it your opinion that ATSDR's
24 calibrated model is the only model that could
25 fit the data ATSDR had?

1 MS. BAUGHMAN: Object to the
2 form.

3 THE WITNESS: I think it's a
4 model that reasonably and accurately
5 fits the data that they had.

6 Q. BY MR. ANTONUCCI: Is it the
7 only one that reasonably and accurately fits
8 the data they had?

9 MS. BAUGHMAN: Object to the
10 form.

11 THE WITNESS: I can't say.

12 Q. BY MR. ANTONUCCI: Why not?

13 A. I think it's an overly
14 restrictive question.

15 Q. Can you explain what would need
16 to change for you to be able to answer your
17 question?

18 MS. BAUGHMAN: Object to the
19 form.

20 THE WITNESS: Well, I would
21 need you to explain more what you
22 mean. What are the circumstances that
23 you're talking about? If you could --
24 it's a general statement. That's why
25 I'm nervous about giving a definitive

1 answer.

2 Q. BY MR. ANTONUCCI: Dr. Jones,
3 is a nonunique model a useful predictive
4 tool?

5 MS. BAUGHMAN: Object to the
6 form.

7 THE WITNESS: A model that
8 is -- it depends on the level of
9 nonuniqueness. I would say with every
10 model there's -- there's some
11 variability in the calibration, right?

12 It's not a yes-or-no question
13 whether or not a model is unique.
14 There are levels of uniqueness. In
15 fact, there are actual numerical
16 analyses that you can do to analyze
17 uniqueness.

18 When I teach the calibration
19 section of my groundwater class, we
20 use the PEST model. And one of the
21 outputs from the PEST model is a
22 number, it's a set of eigenvalues and
23 you can look at that number and
24 determine its -- it's a measure of the
25 level of uniqueness.

1 So if that number is within a
2 certain range, you say there's good
3 evidence that the model is relatively
4 unique. If it's beyond a certain
5 range, then it's evidence that there's
6 nonuniqueness at play.

7 But it's not -- that's why I'm
8 not comfortable with your question, is
9 it's not a -- it's not a black and
10 white boundary between unique and
11 nonunique models. It's a spectrum.

12 Q. BY MR. ANTONUCCI: Sure. Did
13 you evaluate the ratio of eigenvalues that
14 the calibrated model ATSDR made?

15 A. No, I did not.

16 Q. Why not?

17 A. That would have required
18 running a PEST simulation. It was -- it was
19 not within the scope of work that we were
20 asked to do.

21 Q. Okay. How can a modeler make a
22 model more unique?

23 A. More data. And it's not just
24 the amount of data, it's the types of data
25 that you have. For example, with the ATSDR

1 model, the -- they had -- from what I, in my
2 judgment, was a pretty rich data set to -- to
3 calibrate the flow model.

4 Then for the transport model,
5 you know, the initial condition was zero
6 contaminants represents, you know, one bound.
7 And on the other end they had a combination
8 of -- of water levels -- or excuse me --
9 concentrations at the wells plus the water
10 treatment data.

11 The combination of the
12 concentrations at the water treatment plant
13 plus the concentrations simulated at the
14 observation wells, in my opinion, makes the
15 model more unique.

16 Now, I would also argue that at
17 this point in time we have another 318 point
18 observations at monitoring wells at a later
19 date, which I believe the model does a --
20 does a good job of simulating; therefore,
21 providing additional evidence for the -- for
22 the accuracy and uniqueness of the model.

23 Q. Dr. Jones, you agree that it's
24 impossible to fully characterize and
25 incorporate all parameters and complexities

1 of a real aquifer system into a discretized
2 computer model; right?

3 A. Correct.

4 Q. Okay. ATSDR had no
5 site-specific data for estimating the
6 distribution coefficient; right?

7 MS. BAUGHMAN: Object to the
8 form and foundation.

9 THE WITNESS: I'm not -- I
10 don't know. Not that I'm aware of.

11 Q. BY MR. ANTONUCCI: Would
12 reviewing Chapter F help you remember?

13 A. It could.

14 Q. Okay. I'd like you to turn to
15 Page F27.

16 A. Let's see, exhibit -- I'm
17 getting a stack here.

18 Q. Chapter F is Exhibit 11.

19 A. Okay. Okay.

20 Q. Okay. I am looking at the last
21 full paragraph on Page F27, starting with the
22 word "Estimates."

23 A. Yes.

24 Q. This says "Estimates of
25 retardation factors and distribution

1 coefficients for PCE migration within the
2 Tarawa Terrace aquifer or Castle Hayne
3 aquifer are unknown, and initial estimates
4 applied to the MT3DMS model were based on
5 literature sources."

6 Did I read that correctly?

7 A. Yep.

8 Q. That help you remember whether
9 they had data for the distribution
10 coefficient?

11 A. Yes.

12 MS. BAUGHMAN: Object.

13 Q. BY MR. ANTONUCCI: Okay. Did
14 they have site-specific data to estimate the
15 distribution coefficient for the ATSDR TT
16 model?

17 A. No.

18 Q. Okay. Instead, ATSDR reviewed
19 literature sources; right?

20 A. Correct.

21 MR. ANTONUCCI: All right. I'd
22 like to take a break now.

23 THE VIDEOGRAPHER: We're off
24 the record. The time is 2:42.

25 (There was a break taken.)

1 THE VIDEOGRAPHER: We're back
2 on the record. The time is 2:56.
3 This is Media Number 4.

4 Counsel may proceed.

5 Q. BY MR. ANTONUCCI: Dr. Jones,
6 what is your understanding of how the data
7 from ATSDR's Tarawa Terrace model was to be
8 used?

9 MS. BAUGHMAN: Objection.
10 Form. Foundation.

11 THE WITNESS: So are we through
12 with this discussion on the --

13 MR. ANTONUCCI: Yep, you can
14 put that to the side.

15 THE WITNESS: Okay. All right.

16 MR. ANTONUCCI: I'll ask again.

17 Q. What is your understanding of
18 how the data from ATSDR's Tarawa Terrace
19 model was to be used?

20 MS. BAUGHMAN: Objection. Form
21 and foundation.

22 THE WITNESS: From my
23 understanding, the primary objective
24 was to do a historical reconstruction
25 of the PCE concentrations at the

1 Tarawa Terrace water treatment plant
2 between 1953 and when the plant was
3 shut down.

4 Q. BY MR. ANTONUCCI: Okay. I'd
5 ask that you turn to Exhibit 9. That's TT
6 Chapter A Page A1.

7 A. Exhibit 2?

8 Q. Exhibit 9.

9 A. Did you say Chapter A?

10 Q. Yes. Exhibit 9 is also a copy
11 of Chapter A.

12 A. I'm sorry. Let me grab your
13 copy. What page again?

14 Q. A1. That's the page ending in
15 Bates Number 615652.

16 A. Okay.

17 Q. All right. In the column
18 underneath the word "Abstract," I'm reading
19 the third sentence starting with the word
20 "Because."

21 "Because scientific data
22 related to the harmful effects of VOCs on a
23 child or fetus are limited, the Agency for
24 Toxic Substances and Disease Registry
25 (ATSDR), an agency of the U.S. Department of

1 Health and Human Services, is conducting an
2 epidemiological study to evaluate potential
3 associations between in utero and infant (up
4 to one year of age) exposures to VOCs in
5 contaminated drinking water at Camp Lejeune
6 and specific birth defects and childhood
7 cancers. The study includes births occurring
8 during the period 1968 to 1985 to women who
9 are pregnant while they resided in family
10 housing at Camp Lejeune. Because limited
11 measurements of contaminant and exposure data
12 are available to support the epidemiological
13 study, ATSDR is using modeling techniques to
14 reconstruct historical conditions of
15 groundwater flow, contaminant fate and
16 transport, and the distribution of drinking
17 water contaminated with VOCs delivered to
18 family housing areas."

19 Did I read that correctly?

20 A. Yes.

21 Q. Please turn to Page A98. That
22 page ends in Page Number 615749.

23 A. Okay.

24 Q. All right. I am looking at the
25 last paragraph on this page. It looks like

1 it's a question and answer section. Here the
 2 question reads "ATSDR's historical
 3 reconstruction analysis documents that Tarawa
 4 Terrace drinking water was contaminated with
 5 PCE that exceeded the current maximum
 6 contaminant level (MCL) of 5 micrograms per
 7 liter during 1957 and reached a maximum value
 8 of 183 micrograms per liter. What does this
 9 mean in terms of my family's health?"

10 Did I read that correctly?

11 A. Oh, hang on, I was looking at
 12 the wrong paragraph.

13 MS. BAUGHMAN: Where -- just
 14 tell him -- where are you reading
 15 from?

16 THE WITNESS: The blue
 17 paragraph on the left. I think you
 18 might be on the wrong page. It's A98.

19 MS. BAUGHMAN: I thought he
 20 said 97, okay.

21 THE WITNESS: Okay, yes, I -- I
 22 believe you read that correctly.

23 Q. BY MR. ANTONUCCI: Okay. Now
 24 I'm looking at the paragraph in black text on
 25 the right next to what I just read.

1 Do you see that?

2 A. Yeah.

3 Q. It reads "ATSDR's exposure
4 assessment cannot be used to determine
5 whether you, or your family, suffered any
6 health effects as a result of past exposure
7 to PCE-contaminated drinking water at Camp
8 Lejeune."

9 Did I read that correctly?

10 A. Yes.

11 Q. It goes on to say "The study
12 will help determine if there is an
13 association between certain births defects
14 and childhood cancers among children whose
15 mothers used this water during pregnancy."

16 Did I read that correctly?

17 A. Yes.

18 MR. ANTONUCCI: Okay. I am now
19 going to hand you what will be marked
20 for identification as Exhibit 16.

21 (Exhibit 16 was marked for identification.)

22 Q. BY MR. ANTONUCCI: Okay. For
23 the record, Exhibit 16 has the Bates range
24 CLJA_WATERMODELING_01-09_0000033263 through
25 33326.

1 Dr. Jones, this document has
2 the title "Analyses of Groundwater Flow,
3 Contaminant Fate and Transport, and
4 Distribution of Drinking Water at Tarawa
5 Terrace and Vicinity, U.S. Marine Corps Base
6 Camp Lejeune, North Carolina: Historical
7 Reconstruction and Present-Day Conditions
8 Response to the Department of the Navy's
9 letter on: Assessment of ATSDR Water Modeling
10 for Tarawa Terrace."

11 Dr. Jones, have you seen this
12 before?

13 A. Yes, I have.

14 Q. Okay. I'm going to ask you to
15 turn to the page ending in Bates
16 Number 33272.

17 A. Okay.

18 Q. All right. Looking at the last
19 full paragraph on that page, this says "To
20 address the issue of the intended use of the
21 water-modeling results by the current ATSDR
22 epidemiological study" --

23 A. Excuse me, I think I might be
24 on the wrong page. What -- what was the page
25 number? Is it 33272?

1 Q. Yes, sir.

2 A. And which paragraph are you --
3 oh, the last paragraph. Okay, I gotcha.

4 Q. So the last paragraph on
5 Page 33272 of Exhibit 16 states "To address
6 the issue of the intended use of
7 water-modeling results by the current ATSDR
8 epidemiological study, the DON should be
9 advised that a successful epidemiological
10 study places little emphasis on the actual
11 (absolute) estimate of concentration and,
12 rather, emphasizes the relative level of
13 exposure. That is, exposed individuals are,
14 in effect, ranked by exposure level and
15 maintain their rank order of exposure level
16 regardless of how far off the estimated
17 concentration is to be 'true' (measured) PCE
18 concentration."

19 Did I read that correctly?

20 A. Yes.

21 Q. Okay. So, Dr. Jones, the
22 paragraph I just read states that a
23 successful epidemiological study places
24 little emphasis on the actual absolute
25 estimates of concentration; right?

1 A. Yes.

2 Q. Okay. In your report you opine
3 that the model remains a reliable tool for
4 understanding general trends of contaminant
5 migration in the Tarawa Terrace region, and
6 that you can find no significant evidence
7 that would invalidate the analysis performed
8 by ATSDR with the original model; right?

9 A. Correct.

10 Q. However, you're not offering an
11 opinion that the Tarawa Terrace model is a
12 sufficiently reliable model for determining
13 quantitative levels of contaminant exposure
14 for an individual; right?

15 MS. BAUGHMAN: Object to the
16 form. Foundation. Outside the scope.

17 THE WITNESS: I am not an
18 expert in epidemiology, so I don't
19 feel qualified to render an opinion on
20 that question.

21 Q. BY MR. ANTONUCCI: Okay. So
22 you're not offering the opinion that the
23 Tarawa Terrace model can be used to determine
24 quantitative levels of contaminant exposure
25 for individuals?

1 MS. BAUGHMAN: Object to the
2 form.

3 THE WITNESS: I don't believe
4 I've -- again, my answer's the same.
5 I'm not an epidemiological expert so I
6 can't comment on that.

7 Q. BY MR. ANTONUCCI: Can I have a
8 yes or a no?

9 MS. BAUGHMAN: No -- objection.
10 You do not have to answer yes
11 or no.

12 Q. BY MR. ANTONUCCI: Are you
13 offering the opinion or not?

14 MS. BAUGHMAN: Object to the
15 form. Asked and answered.

16 THE WITNESS: Could you restate
17 the question.

18 Q. BY MR. ANTONUCCI: You're not
19 offering the opinion that the Tarawa Terrace
20 model is a sufficiently reliable model for
21 determining quantitative levels of
22 contaminant exposure for an individual;
23 right?

24 MS. BAUGHMAN: Objection; form.
25 Objection; Foundation.

1 THE WITNESS: The -- the
2 opinions we've rendered on the model
3 was that in terms of the -- how the
4 model simulates concentrations at the
5 water treatment plant, it -- it is a
6 reasonably accurate model developed
7 using sound scientific and engineering
8 principles.

9 How that -- concentrations
10 resulting from that are then
11 incorporated in an epidemiological
12 study is outside my scope of
13 expertise -- expertise.

14 Q. BY MR. ANTONUCCI: So that is
15 not an opinion you're offering?

16 MS. BAUGHMAN: Objection.
17 Form.

18 THE WITNESS: No, that's not an
19 opinion I'm offering.

20 Q. BY MR. ANTONUCCI: Had you done
21 a post-audit prior to the Tarawa Terrace
22 post-audit?

23 MS. BAUGHMAN: Objection to
24 form.

25 THE WITNESS: In the sense of

1 running a model simulation and
2 comparing its output to field observed
3 values, I have done that countless
4 times.

5 Q. BY MR. ANTONUCCI: You just
6 described calibration, didn't you?

7 A. In a -- no. Calibration is
8 when you then take the results of that and go
9 back and change the input parameters.

10 But I would say what I just
11 described is a subset of what you do for
12 calibration. But simply comparing model
13 outputs to field observed values is -- is a
14 really simple and very common thing that I've
15 done countless times.

16 Q. Have you ever published a
17 post-audit before?

18 A. No.

19 Q. How long did it take you to
20 perform the Tarawa Terrace post-audit?

21 A. The initial post-audit we
22 started in, I believe, early September and
23 submitted it in late October of 2024.

24 Q. So roughly a month?

25 MS. BAUGHMAN: Objection to

1 form.

2 THE WITNESS: A little over a
3 month.

4 Q. BY MR. ANTONUCCI: And you did
5 both a qualitative and quantitative
6 assessment as part of your post-audit; is
7 that right?

8 A. That's correct.

9 Q. Are quantitative and
10 qualitative assessments terms of art applied
11 to post-audits?

12 A. Excuse me? Terms of art?

13 Q. Are those -- do those terms
14 have any special significance in the modeling
15 community?

16 A. Yeah, I would say it's a
17 relatively standard practice. For example,
18 one of the most common ways to assess the --
19 the results of a model calibration is to
20 visually examine a simulated versus observed
21 plot and see how close the points plot to
22 the -- to the -- the line of agreement, which
23 is what I would call a qualitative assessment
24 of the goodness of fit.

25 Q. Okay. There are also

1 quantitative assessment of goods of fit;
2 right?

3 A. Yes.

4 Q. That would include summary
5 statistics like mean error and mean absolute
6 error; right?

7 A. And -- yes, and geometric bias
8 is one of those, yes.

9 Q. Okay. I'd like to discuss
10 those error metrics in more detail, but first
11 you issued two reports in this case; right?

12 A. Correct.

13 Q. One was an initial report and
14 the other was a rebuttal; right?

15 A. Yes.

16 Q. In your rebuttal report you
17 corrected errors highlighted by
18 Dr. Spiliotopoulos in his expert report;
19 right?

20 A. Yes.

21 Q. That included truncation
22 errors, incorrect mass loading end date, and
23 an incorrect pumping rate for well RWC2;
24 right?

25 A. That's correct.

1 Q. After Dr. Spiliotopoulos
2 identified errors in your post-audit, did you
3 go back and confirm that the rest of the
4 post-audit had been done correctly?

5 A. We had -- I'm not aware of any
6 other reason to believe there were errors in
7 the initial post-audit.

8 Q. After Dr. Spiliotopoulos
9 identified errors, did you go back and check
10 for any others?

11 A. No.

12 Q. So you only corrected errors
13 that Dr. Spiliotopoulos pointed out?

14 A. That's correct.

15 Q. Are you aware of any other
16 model input errors in your post-audit?

17 A. No.

18 Q. Are you now confident that
19 you've found and resolved all model input
20 errors in your post-audit?

21 A. I believe so.

22 Q. Could there be more model input
23 errors in your post-audit?

24 MS. BAUGHMAN: Objection.

25 Form.

1 THE WITNESS: It's possible.

2 Q. BY MR. ANTONUCCI: Okay.

3 Please turn to your initial report, that's
4 Exhibit 6. Page 5-1.

5 A. Okay.

6 Q. All right. Are you looking at
7 the page that has the heading "Results"?

8 A. Oh, sorry. 5-1 did you say?

9 Q. Yes.

10 A. I have it now.

11 Q. Okay. I'm looking at the last
12 sentence of the first paragraph. It reads
13 "Before presenting the results, it is helpful
14 to remember that when simulating the
15 migration of a PCE contaminant plume using
16 MODFLOW and MT3DMS, achieving a close match
17 between simulated and observed concentrations
18 can be challenging for several reasons."

19 Did I read that correctly?

20 A. That's correct. And what I
21 was talk- -- what we were talking about in
22 this case is looking at individual observed
23 concentrations and expectations regarding how
24 well the model will reproduce those
25 concentrations in the simulation on a

1 point-by-point basis.

2 Q. Okay. With all due respect,
3 Dr. Jones, my question was did I read that
4 correctly. I need you to limit your answers
5 to my questions, okay?

6 A. Sorry. Will do.

7 Q. Thank you.

8 You go on to list reasons why
9 it's helpful to remember that achieving a
10 close match between simulated and observed
11 concentrations can be challenging; right?

12 A. Correct.

13 Q. Those four reasons include
14 complex subsurface conditions, temporal
15 variability, limitations in model resolution,
16 and measurement variability; right?

17 A. Correct.

18 Q. Okay. Under the subheading
19 "Complex Subsurface Conditions," that's
20 Number 1.

21 A. Yes.

22 Q. You wrote that "The subsurface
23 environment is inherently complex, with
24 variations in soil heterogeneity,
25 permeability, porosity, and hydraulic

1 conductivity. These properties vary
2 spatially in ways that are not fully captured
3 in the model, affecting how the contaminant
4 plume moves through the groundwater system."

5 Did I read that correctly?

6 A. That's correct.

7 Q. Next Number 2, "Temporal
8 Variability," you wrote "The concentration of
9 contaminants can change over time due to
10 factors like seasonal variations in
11 groundwater flow, biodegradation, chemical
12 reactions. Simulating these dynamic
13 processes accurately over the entire
14 simulation period is challenging."

15 Is that correct?

16 A. Correct.

17 Q. Okay. Number 3 says
18 "Limitations in Model Resolution: MODFLOW
19 and MT3DMS rely on discretizing the
20 subsurface into numerical grids consisting of
21 cells that represent a subset of the aquifer.
22 The resolution of these grids can limit the
23 model's ability to capture fine-scale
24 variations in plume behavior, particularly in
25 areas with sharp concentration gradients,

1 small-scale heterogeneities, or preferential
2 pathways."

3 Did I read that correctly?

4 A. Yes.

5 Q. Number 4 says "Measurement
6 Variability: The observed concentrations at
7 observation wells may contain some degree of
8 measurement error or uncertainty. Field data
9 collection is subject to variability, which
10 adds another layer of complexity with trying
11 to match it closely with model outputs. As
12 outlined above in Section 4.2, extreme
13 variations were observed in some of the
14 measured concentrations used in this
15 post-audit."

16 Did I read that correctly?

17 A. Yes.

18 Q. Okay. I'd like for you to turn
19 to your rebuttal report, Page 3-12. That's
20 going to be Exhibit 7.

21 A. What was the page again?

22 Q. 3-12.

23 A. 3-12. Okay.

24 Q. Okay. Dr. Jones, the second
25 paragraph on this page reads "We have also

1 generated new versions of each of the tables
2 and figures from our original post-audit"
3 reporting -- "report featuring simulated PCE
4 values, using the updated post-audit
5 simulation results, processed at full
6 precision. These results are presented in
7 Appendix A. The differences in the tables
8 and figures relative to the original report
9 are relatively minor overall. The
10 differences are summarized as follows:"

11 Did I read that correctly?

12 A. Yes.

13 Q. Dr. Jones, this section says
14 that the differences between the corrections
15 you made to your post-audit are relatively
16 minor overall; is that right?

17 A. That's correct.

18 Q. Okay. And the table below that
19 paragraph summarizes the list of changes to
20 the tables and figures of your report; is
21 that right?

22 A. That's correct.

23 Q. Okay. I'd like you to turn
24 back to your original report, Page vi, six in
25 Roman numerals. Again, your original report

1 is going to be Exhibit 6.

2 A. Okay.

3 Q. Are you looking at the
4 Executive Summary?

5 A. Yes.

6 Q. All right. I am looking at the
7 third paragraph from the bottom beginning
8 with the sentence -- the phrase "The
9 extended."

10 Do you see where I am?

11 A. Yes.

12 Q. This reads "The extended MT3DMS
13 model was found to perform well in simulating
14 PCE concentrations at monitoring wells across
15 the study area. The errors are remarkably
16 well balanced, indicating a good overall fit
17 between simulated and observed
18 concentrations."

19 Did I read that correctly?

20 A. Yes.

21 Q. Now, Dr. Jones, for the
22 purposes of evaluating fit between simulated
23 and observed concentrations you provided some
24 summary statistics; is that right?

25 A. Correct.

1 Q. Okay. What is residual error?

2 A. At a particular observation
3 well location it's the difference between the
4 model simulated concentration and the
5 observed concentration.

6 And the way we calculated it,
7 we took the simulated value minus the
8 observed value.

9 So if the model overestimates
10 the concentration, it would be a positive
11 residual error; if the model underestimated
12 the concentration, it would represent a
13 negative residual error.

14 Q. Okay. The mean error is the
15 average of the residual errors; right?

16 A. That's correct.

17 Q. And mean absolute error is the
18 average of the absolute value of the
19 residuals?

20 A. That's correct.

21 Q. The mean error of the initial
22 post-audit was 21 micrograms per liter;
23 correct?

24 A. That's correct.

25 Q. The mean absolute error of your

1 initial post-audit was 334 micrograms per
2 liter; correct?

3 A. That's correct.

4 Q. Dr. Jones, a negative mean
5 error indicates that a model under predicts
6 observed values; correct?

7 A. That's correct.

8 Q. A positive mean error indicates
9 that a model over predicts observed values;
10 correct?

11 A. Correct, on average.

12 Q. Mean absolute error is also a
13 metric that's used to evaluate overall fit
14 between simulated and observed
15 concentrations; correct?

16 A. It's -- it's a different
17 statistical measure used to fit -- to analyze
18 the calibration results, yes.

19 Q. Okay. And the mean absolute
20 error cannot be negative; right?

21 A. That's correct.

22 Q. For your updated post-audit,
23 the mean error was 48 micrograms per liter;
24 right?

25 A. Yes.

1 Q. That's an increase of
2 27 micrograms per liter from the original
3 post-audit results?

4 A. That's correct.

5 Q. Did you calculate the mean
6 absolute error for the updated post-audit?

7 A. I don't recall.

8 Q. Your groundwater modeling
9 software, GMS, provides the summary
10 statistics automatically, doesn't it?

11 A. Yes. But to calculate these
12 errors, we typically just took the -- the
13 simulated versus observed PCE concentrations
14 as shown, for example, in Table A1 of the
15 rebuttal report and did the error analysis
16 using Excel, Microsoft Excel. It's a very
17 simple equation.

18 Q. Okay. So you -- you did that
19 very simple equation for the initial report
20 but not the rebuttal report; is that right?

21 A. Well, I'm sure I have a
22 spreadsheet with that number in it. Whether
23 that number was reported in the rebuttal
24 report, I don't recall.

25 I would expect that number to

1 be roughly similar to the -- to the value
2 reported in the initial report, certainly
3 along the same scale, which is relatively
4 large considering a large -- indicating a
5 large variability in the PCE concentrations.

6 Q. But sitting here today, you do
7 not know the mean absolute error of your
8 updated -- or your rebuttal post-audit?

9 A. That's correct. I couldn't
10 tell it off the top of my head.

11 Q. Okay. Earlier you mentioned
12 geometric model bias as another summary
13 statistic that could be used to evaluated fit
14 between simulated and observed
15 concentrations; is that right?

16 A. That is correct.

17 Q. When a ratio of simulated PCE
18 concentrations is simulated to observed PCE
19 concentrations is less than one, that
20 indicates under-prediction by the model;
21 correct?

22 A. That's correct.

23 Q. And when the ratio of simulated
24 PCE concentration to observed PCE
25 concentrations equals one, that indicates

1 exact agreement; correct?

2 A. That's correct.

3 Q. When the ratio of simulated PCE
4 concentrations to observed PCE concentrations
5 is greater than one, that indicates
6 over-prediction by the model; correct?

7 A. Correct.

8 Q. The further the geometric model
9 bias is from a value of one, the worse the
10 agreement between simulated and observed
11 concentrations; correct?

12 A. That's correct.

13 Q. Okay. I would like to direct
14 your attention to Exhibit 9, Page A26. And
15 Exhibit 9 is the Tarawa Terrace Chapter A
16 report.

17 A. Okay. A26, got it.

18 Q. All right. Do you see Table A8
19 at the top of the page?

20 A. Yes.

21 Q. Okay. In the one, two -- third
22 column from the top, in the -- excuse me --
23 third row from the top in the Resulting
24 Calibration Statistics column, geometric
25 model bias is indicated as being equal to 5.8

1 backslash or 3.9.

2 Do you see that?

3 A. Yes.

4 Q. Okay. ATSDR calculated two
5 geometric model biases for the Tarawa Terrace
6 calibrated model; correct?

7 A. That's correct.

8 Q. One was the geometric model
9 bias that used data for TT-23; is that right?

10 A. Yes.

11 Q. And that was the 5.9 value?

12 A. 5.8. It says 5.8 in this
13 table.

14 Q. It does.

15 If you turn to Page A25. At
16 the top of the right-hand column I'm reading
17 the sentence that says "The inclusive
18 geometric model bias, using data for
19 water-supply Well TT-23, was 5.9."

20 A. Okay.

21 Q. See that?

22 A. Sure.

23 Q. "The selected geometric model
24 bias, omitting data for supply Well TT-23 was
25 3.9."

1 A. Yes.

2 Q. "Both results, however,
3 indicate over-prediction by the model."
4 Did I read that correctly?

5 A. Yes.

6 Q. Dr. Jones, I would like you to
7 turn to Exhibit 7, that's your rebuttal
8 report, Figure A2.

9 A. Yes.

10 Q. Okay. And here we're looking
11 at a graph. On the Y axis we have simulated
12 PCE concentrations in micrograms per liter,
13 the X axis we have observed PCE
14 concentrations in micrograms per liter;
15 right?

16 A. That's correct.

17 Q. That dashed line in the middle
18 is where the simulated and observed
19 concentrations are equal; right?

20 A. That's correct.

21 Q. Okay. Earlier you indicated
22 that a scatter plot like this one can be used
23 for a qualitative assessment of the goodness
24 of fit of a model; is that right?

25 A. Yes.

1 Q. And that's because you can
2 visually examine how far the points are from
3 the one to one line; is that right?

4 A. Yes, and also the clustering
5 and -- and distribution.

6 Q. Okay. Please turn to Figure 5
7 of your rebuttal report. And that's
8 Exhibit 7.

9 A. Okay.

10 Q. This figure shows the graph
11 that we were just looking at on the
12 right-hand side of the page; is that right?

13 A. Yes.

14 Q. And it shows a similar plot
15 from your initial report on the left-hand
16 side of the page; right?

17 A. Correct.

18 Q. In your rebuttal report you
19 state that while the numbers indicate a high
20 degree of variance, they're visually more
21 balanced than the results we originally
22 presented in the post-audit report; right?

23 A. Correct.

24 Q. Quantitatively the updated
25 post-audit indicates a small increase in the

1 bias compared to the initial post-audit;
2 right?

3 A. Say that again.

4 MS. BAUGHMAN: Object to the
5 form.

6 Q. BY MR. ANTONUCCI: The updated
7 post-audit indicates a small increase in the
8 bias compared to the initial post-audit?

9 A. Based on the mean error, yes.

10 Q. I'd like you to turn to
11 Page 3-5 of your rebuttal report. I am
12 looking at the one, two -- third paragraph
13 from the top of the page beginning with "In
14 Section 3.1.2."

15 Do you see where I am?

16 A. Yes.

17 Q. All right. About halfway down
18 the paragraph a sentence starts with "For the
19 original post-audit."

20 Do you see that?

21 A. Yes.

22 Q. "For the original post-audit
23 results we calculated a mean error value
24 equal to 21 micrograms per liter, indicating
25 an extremely balanced fit with only a small

1 high bias. For the updated post-audit
2 results, the mean error equals 48 micrograms
3 per liter, indicating a small increase in the
4 bias, but still relatively well balanced
5 overall."

6 Is that correct?

7 A. That's correct. When you --
8 when you asked that before, I thought maybe
9 you were talking of the post-audit versus the
10 original report, so I apologize for the
11 misunderstanding. Excuse me, versus the
12 original model.

13 Q. Please turn to Table A2 in your
14 rebuttal report. Again, that's Exhibit 7.

15 MS. BAUGHMAN: What page did
16 you say?

17 MR. ANTONUCCI: Table A2.

18 Q. Are you looking at Table A2,
19 Dr. Jones?

20 A. Yes.

21 Q. Okay. So this table shows the
22 monitoring wells, the layer in the model
23 where the well is screened, mean error, mean
24 absolute error, and the mean absolute error
25 category; correct?

1 A. That's correct.

2 Q. Okay. Earlier you indicated
3 that the mean absolute error is the absolute
4 value of the mean error; correct?

5 A. No. It's the -- well, yes, you
6 can calculate it that way, sure.

7 Q. Okay. I'd like you to take a
8 look at Well C3.

9 A. Okay.

10 Q. Here the mean error is
11 indicated as being 98 micrograms per liter
12 and the mean absolute error is indicated as
13 being 124.5 micrograms per liter.

14 Do you see that?

15 A. Yes.

16 Q. Why are those numbers
17 different?

18 A. That is a great question. I'm
19 not sure.

20 Q. I'd like you to look at
21 Well C9. Here the mean error is negative
22 5.9 micrograms per liter, the mean absolute
23 error is 6 micrograms per liter.

24 A. Yes.

25 Q. Why are those numbers

1 different?

2 A. Because they're displayed using
3 different significant figures.

4 Q. Okay. I'd like you to look at
5 Well C13.

6 A. Okay.

7 Q. Here the mean error is negative
8 555 micrograms per liter, the mean absolute
9 error is 563.7 micrograms per liter.

10 A. Yes.

11 Q. Why are those numbers
12 different?

13 A. I'm not sure.

14 Q. Okay. Look at Well C17-D.
15 Here the mean error is negative 0.2, the mean
16 absolute error is 0.4.

17 Why are those numbers
18 different?

19 A. I'm not sure.

20 Q. Okay. If you look at
21 Well RWC-1, the mean error is 251.9, the mean
22 absolute error is 252.6; right?

23 A. Correct.

24 Q. Why are those numbers
25 different?

1 A. I'm not sure.

2 Q. If you look at Well RWS-3A, the
3 mean error is negative 83.8; correct?

4 A. Yes.

5 Q. The mean absolute error is
6 136.4; right?

7 A. Correct.

8 Q. Why are those numbers
9 different?

10 A. The -- well, you -- when you
11 calculate the mean error, you calculate the
12 average of all of the individual errors. To
13 calculate the mean absolute error, you don't
14 simply take the absolute value of that
15 number.

16 What you do is you take the
17 absolute value of the individual residuals
18 one by one and then calculate the mean of
19 those values. And I suspect the reason there
20 are some differences here is because of that
21 difference in how they're calculated. It is
22 not simply taking the absolute value of the
23 mean error.

24 Q. Okay. You did say that
25 earlier, though; right?

1 A. Excuse me?

2 Q. You said that the mean absolute
3 error is the absolute value of the mean
4 error?

5 A. Yes, but on an individual
6 basis. And so I'm -- I -- if -- if I stated
7 that misleadingly, then I'm correcting that
8 now.

9 Q. Okay. Why don't you take a
10 look at Well S2.

11 MS. BAUGHMAN: Were you -- were
12 you finished with your answer, Norm?

13 THE WITNESS: Yeah, I think so.

14 MS. BAUGHMAN: Okay.

15 Q. BY MR. ANTONUCCI: All right.
16 Well S2.

17 A. Uh-huh.

18 Q. Mean error negative 73.8.

19 A. Yes.

20 Q. Mean absolute error 111.6.

21 A. Right.

22 Q. Is that a rounding error?

23 A. No. These -- these are not --
24 these should not be expected to agree. And
25 let me explain why.

1 Suppose you had a circumstance
2 where you had a number of positive residual
3 errors and a number of negative residual
4 errors, but somehow they -- they balanced,
5 right?

6 They -- they -- let's say you
7 had a negative ten, a negative five, and a
8 positive ten and a positive five. If you
9 took the mean of those errors, that would
10 equal zero indicating a perfect balance.

11 But if you first took the
12 absolute value of those numbers and then took
13 the average of that, you'd be averaging ten,
14 five, ten, and five. And the mean of that
15 would be 7.5.

16 So, no, the mean absolute error
17 is not simply the absolute value of the mean
18 error.

19 Q. Okay. When you report the mean
20 absolute error in your -- when you reported
21 that in your initial report, which method of
22 calculating did you use?

23 A. What I just described. You
24 take the absolute value of the individual
25 residuals, and then calculate the average of

1 that. There are circumstances under which
2 your mean error will match the mean absolute
3 error.

4 For example, if all of your
5 errors are negative or if all of your errors
6 are positive, then your mean error and your
7 mean absolute error will match, and that's
8 why it matches in some of these cases but not
9 others.

10 Q. Okay. Okay. Another point of
11 clarification that I'd appreciate, if you
12 look at Table 1 of your initial report, and
13 that's going to be Exhibit 6.

14 A. Okay.

15 Q. This table shows various
16 publicly available rainfall data; is that
17 right?

18 A. Yes.

19 Q. Okay. And it shows publicly
20 available rainfall data from 1995 to 2009;
21 right?

22 A. Correct.

23 Q. At the Wilmington Airport,
24 Wilmington 7N, and New River MCAF stations;
25 is that right?

1 A. That's correct.

2 Q. Okay. Okay, I am going to mark
3 for identification Exhibit 17.

4 (Exhibit 17 was marked for identification.)

5 MR. ANTONUCCI: For the record,
6 this is the native spreadsheet version
7 of the document produced with Bates
8 Number CL_PLG --

9 MS. BAUGHMAN: Sorry, did you
10 give me one? I don't have one.

11 MR. ANTONUCCI: Dash
12 EXPERT_DAVIS_0000000203.XL -- excuse
13 me -- 203. That's the end of the
14 Bates number.

15 Q. Dr. Jones, are you familiar
16 with this?

17 A. It looks familiar.

18 Q. This is the rainfall data you
19 used to calculate the effective rainfall
20 recharge rate for the post-audit; right?

21 A. I believe so.

22 Q. Okay. Can you please look at
23 the year 1999.

24 A. Uh-huh.

25 Q. Is there data available there?

1 A. No.

2 Q. Okay. Can you look back at
3 Table 1 in your initial report.

4 A. Yes.

5 Q. Will you please look at the
6 year 1999.

7 A. Yes.

8 Q. Is there data available there?

9 A. Yes.

10 Q. For New River MCAF?

11 A. Yes.

12 Q. Can you explain the
13 discrepancy, please.

14 A. I cannot.

15 Q. Okay. How about the year 2000?
16 Can you look at the year 2000 on the
17 spreadsheet that you produced?

18 A. Yes.

19 Q. Is there data available there?

20 A. No.

21 Q. Okay. Can you look at the year
22 2000 on Table 1 of your initial report.

23 A. Yes.

24 Q. In the New River MCAF column,
25 is there a value there?

1 A. No -- or excuse me -- yes.

2 Q. It's 50.4; right?

3 A. That's correct.

4 Q. Inches per year?

5 A. Correct.

6 Q. Where did you get that data
7 from?

8 A. I -- I'm not sure why there's a
9 discrepancy here.

10 Q. Okay.

11 A. I'd have to investigate it.

12 MR. ANTONUCCI: I'd like to
13 take another break.

14 THE VIDEOGRAPHER: We're off
15 the record. The time is 3:47.

16 (There was a break taken.)

17 THE VIDEOGRAPHER: We're back
18 on the record. The time is 4:06.

19 Q. BY MR. ANTONUCCI: Dr. Jones,
20 you stated in your initial report that larger
21 errors tend to be concentrated in the center
22 of the plume where the simulated
23 concentrations are greater; is that right?

24 A. Yes.

25 Q. You also said that that's

1 somewhat expected because comparing larger
2 numbers organically results in larger
3 differences; right?

4 A. Yes.

5 Q. Concentrations are generally
6 higher in the center of a plume; right?

7 A. Yes.

8 Q. Could you please turn your
9 attention to Rebuttal Figure A9. That's
10 going to be Exhibit 7.

11 A. Okay.

12 Q. Please look at the center pane
13 of this figure, Model Layer 3. Are you
14 looking there?

15 A. Yes.

16 Q. Do you see model -- excuse
17 me -- do you see Well C5, the plot for
18 Well C5?

19 A. Yes.

20 Q. And that is within the
21 simulated PCE plume; right?

22 A. Correct.

23 Q. And it's in the portion of the
24 simulated PCE plume where concentrations are
25 greater than 500 to 5,000 micrograms per

1 liter; right?

2 A. That's correct.

3 Q. Okay. That's the center of the
4 plume; right?

5 A. Yes.

6 Q. I'd like you to turn to
7 Rebuttal Table A1.

8 A. Okay.

9 Q. And if you could please look at
10 the first two pages of Table A1 in Exhibit 7.

11 A. Which page number?

12 Q. So Page 1. The page number is
13 Page 1 of 7.

14 A. Okay.

15 Q. And...

16 A. I got it.

17 Q. All right. If you look towards
18 the bottom of Page 1 of 7, Table A1?

19 A. Yes.

20 Q. Well C5 is the last four rows
21 of this table; right?

22 A. Yes.

23 Q. And this shows observed versus
24 simulated concentrations with the error rate
25 and the absolute error rate; correct?

1 A. That's correct.

2 Q. All of the observed PCE
3 concentrations for Well C5 are below the
4 detection limit; isn't that right?

5 A. That's correct.

6 Q. Okay. And then continuing on
7 to Page 2 of Table A1, we're still looking at
8 Well C5. That's going to be the first seven
9 rows of this table?

10 A. Yes.

11 Q. All of the PCE observed
12 concentrations were below the detection limit
13 here as well; right?

14 A. That's correct.

15 Q. The calibrated model and the
16 post-audit both simulated high PCE
17 concentrations at that well, didn't they?

18 A. Yes.

19 Q. Still in Exhibit 7, your
20 rebuttal report, I'd like you to turn to
21 Page 3-13.

22 A. Okay.

23 Q. All right. Under Section 3.7,
24 Opinion 6 - Post-Audit Robustness. I am
25 looking at the second full paragraph.

1 Do you see that?

2 A. Yes.

3 Q. Okay. The last sentences of
4 that paragraph reads "These findings support
5 our original conclusion that the ATSDR model
6 was developed using a methodology that is
7 scientifically sound and accepted within the
8 scientific community, and it remains a
9 reliable tool for assessing the impacts of
10 PCE contamination at Tarawa Terrace."

11 Did I read that correctly?

12 A. Yes.

13 Q. Okay. Dr. Jones, in the
14 post-audit you used the model input
15 parameters that were provided to you by the
16 legal team; right?

17 A. Yes.

18 Q. And you did not independently
19 evaluate the suitability of those parameters;
20 correct?

21 A. The -- the parameters in the --
22 you mean as part of the post-audit? Can you
23 restate the question, I'm sorry.

24 Q. You did not evaluate the
25 appropriateness of the model input

1 parameters; correct?

2 MS. BAUGHMAN: Objection.

3 Form.

4 THE WITNESS: I wouldn't say
5 that.

6 Q. BY MR. ANTONUCCI: You used the
7 model input parameters that were provided to
8 you by the legal team; right?

9 MS. BAUGHMAN: Objection.
10 Form.

11 THE WITNESS: Yes, we did.

12 Q. BY MR. ANTONUCCI: Okay.
13 Dr. Jones, earlier in the deposition you
14 mentioned that you were present via Zoom for
15 the deposition of Mr. Davis yesterday; is
16 that correct?

17 A. That's correct.

18 Q. You mentioned that you weren't
19 present for the entire deposition; is that
20 right?

21 A. That's right.

22 Q. At what times were you watching
23 the deposition?

24 A. From about 9:00 to 9:25 a.m.,
25 and then I jumped on again about 10:50 a.m.

1 and watched the remainder of the deposition.

2 Q. Do you disagree with any of the
3 opinions that Dr. Jones expressed in his
4 deposition -- excuse me -- that Mr. Davis
5 expressed in his deposition?

6 MS. BAUGHMAN: Objection.

7 Form.

8 THE WITNESS: I -- I'm not
9 going to say that everything he said
10 was precise or exactly the way I would
11 have said it, but the general
12 statements he gave, I -- I think I
13 would agree with that.

14 Q. BY MR. ANTONUCCI: Were any of
15 the statements that Mr. Davis gave incorrect?

16 MS. BAUGHMAN: Objection.

17 Form.

18 THE WITNESS: I'm not prepared
19 to cite specific examples.

20 Q. BY MR. ANTONUCCI: Can you
21 think of a single instance where Mr. Davis
22 made an incorrect statement in his
23 deposition?

24 MS. BAUGHMAN: Objection.

25 Form.

1 THE WITNESS: Nothing
2 substantive.

3 Q. BY MR. ANTONUCCI: Can you
4 think of any non-substantive errors in
5 Mr. Davis' deposition testimony?

6 MS. BAUGHMAN: Objection to
7 form.

8 THE WITNESS: Not that I could
9 recite off the top of my head.

10 Q. BY MR. ANTONUCCI: What do you
11 mean by "substantive"?

12 A. Well, I -- I believe there was
13 one case where he was talking about the --
14 when we did the post-audit and he talked
15 about the calibration target relative to Well
16 TT-26.

17 In fact, we did not have any
18 observations at Well TT-26 during the
19 extended simulation period, so that was not a
20 correct statement. That's the one that I can
21 recall, and I believe he may have corrected
22 himself, but...

23 Q. Dr. Jones, how much have you
24 billed to date in this case?

25 MS. BAUGHMAN: Objection to

1 form. We've provided the bills.

2 THE WITNESS: I've billed the
3 amount shown in the invoices that we
4 submitted.

5 Q. BY MR. ANTONUCCI: Do you know
6 what that amount is?

7 MS. BAUGHMAN: Object to form.

8 THE WITNESS: I think through
9 the end of January it would be roughly
10 \$120,000, I believe.

11 Q. BY MR. ANTONUCCI: Does your
12 payment depend on the outcome of this case?

13 A. No.

14 MR. ANTONUCCI: Okay. I am
15 going to show you another exhibit.
16 This will be Exhibit 18.

17 (Exhibit 18 was marked for identification.)

18 Q. BY MR. ANTONUCCI: This
19 document has the title "An overview of
20 current applications, challenges, and future
21 trends in distributed process-based models in
22 hydrology"; is that right?

23 A. Correct.

24 Q. There's a list of several
25 authors here, one of them being Norm Jones.

1 Is that you?

2 A. That's me.

3 Q. Okay. Were you an author of
4 this study?

5 A. I was a co-author.

6 Q. Okay. Please turn your
7 attention to Page 5 of Exhibit 18.

8 A. Okay.

9 Q. I'm looking at the very last
10 sentence on the page starting with the word
11 "Although." It's -- it continues on to
12 Page 6.

13 A. Oh, okay, sure.

14 Q. Okay. So this says "Although
15 some of those process-based hydrological
16 models include numerous distinct processes,
17 the degree of complexity and quantity of
18 processes represented varies between models
19 and influences the suitability of a given
20 model for specific applications."

21 Did I read that correctly?

22 A. Yes.

23 Q. You'd agree that a model cannot
24 capture the complexity of aquifer conditions
25 completely; right?

1 A. Yes.

2 Q. That they don't necessarily
3 reflect all real-world conditions; right?

4 A. A model, as we've discussed
5 earlier, is a simplification of reality.

6 Q. Okay. Would it be possible for
7 you to have performed a post-audit on the
8 Hadnot Point/Holcomb Boulevard model?

9 A. Yes, I assume it would be
10 possible.

11 Q. Okay. And you did not do it
12 because you weren't asked to by the legal
13 team; right?

14 A. That's correct.

15 Q. Okay. Finally, I'd -- I'd like
16 to turn back to our earlier discussion of the
17 model's ability to predict contaminant
18 concentrations at TT-26 accurately.

19 Do you remember discussing
20 that?

21 A. I -- we've discussed that topic
22 quite a few times today. In general, yes, I
23 remember discussing that.

24 Q. Okay. It's true that the ATSDR
25 used a mass balance model for determining

1 concentrations at the water treatment plant;
2 right?

3 A. That's correct.

4 Q. Okay.

5 A. Based on the concentrations and
6 pumping rates at the supply wells.

7 Q. It's also true that you did not
8 have information on the pumping rates for all
9 times during this study period; correct?

10 MS. BAUGHMAN: Objection.

11 Form.

12 Q. BY MR. ANTONUCCI: Excuse me.

13 It's true that ATSDR did not
14 have information on pumping rates during all
15 times of the study period; correct?

16 MS. BAUGHMAN: Objection. Form
17 and foundation.

18 THE WITNESS: Yes, that is very
19 standard for groundwater modeling
20 projects.

21 Q. BY MR. ANTONUCCI: Okay. Would
22 the process of performing a post-audit for
23 Hadnot Point/Holcomb Boulevard be different
24 than performing a post-audit for Tarawa
25 Terrace?

1 A. The basic process would be the
2 same. It would be extended over a -- the
3 model inputs would be extended over a new
4 period. We would not change anything in the
5 original models, other than extending it, and
6 then run the simulations and compare the
7 predicted results of the extended model with
8 any new field observed value data that were
9 available, is the general process.

10 Q. The -- the -- ATSDR's
11 calibrated model's geometric model bias was
12 lower when considering Well TT-23; right?

13 A. That's correct.

14 Q. That's because the ATSDR's
15 calibrated model demonstrated a worse fit
16 between simulated and observed conditions at
17 that well?

18 A. I think that's safe to say,
19 yes. Well, actually, the reason why -- I'm
20 not comfortable saying they didn't consider
21 it because it had a worse fit. I would say
22 that the difference in the geometric bias
23 between the two, the fact that it goes down
24 if you don't include it would indicate that
25 it -- it has a high fit at that. But I -- I

1 recall there were -- there were a couple of
2 reasons why they argued why it may not be
3 considered, but they presented both values
4 for consideration, so...

5 Q. Okay. So then ATSDR's
6 calibrated model had a sort of variable fit
7 between observed and simulated data at
8 different supply wells; isn't that right?

9 A. Yes.

10 Q. Okay. Dr. Jones, I think we're
11 coming up on the end of my questions. Are
12 there any answers you've given to my
13 questions you wish to change before we end
14 this deposition?

15 A. Not that I can think of.

16 Q. Is there any information I
17 asked you about that you didn't recall at the
18 time but now remember?

19 A. No.

20 Q. Were there questions I asked
21 that you did not understand in which I was
22 unable to clarify?

23 A. Not that I recall.

24 Q. Once it's ready, you will be
25 provided with a transcript of this

1 deposition. We ask you carefully read,
2 correct, and sign it.

3 Do you understand that?

4 A. Yes.

5 MR. ANTONUCCI: Well, thank
6 you, Dr. Jones, for your patience in
7 answering my questions today.

8 I pass the witness.

9 THE WITNESS: Thank you.

10 MS. BAUGHMAN: Dr. Jones, I
11 just have a few questions for you.

12 EXAMINATION

13 BY MS. BAUGHMAN:

14 Q. First, let's go to Exhibit 6 of
15 your -- Exhibit 6, which is your original
16 post-audit. And if you could turn to
17 Page 5-1.

18 A. Sure.

19 Q. Okay. And I think you may
20 remember earlier that counsel for DOJ asked
21 you some questions about -- or he read parts
22 of Numbers 1 through 4 under your results and
23 asked if he'd read it correctly and if these
24 things were true.

25 Do you recall that?

1 A. Yes.

2 Q. Okay. And so what you have
3 here under Section 5 Results is you wrote
4 "Before presenting the results, it is helpful
5 to remember that when simulating the
6 migration of a PCE contaminant plume using
7 MODFLOW and MT3DMS, achieving a close match
8 between simulated and observed concentrations
9 can be challenging for several reasons:" And
10 you listed four reasons; correct?

11 A. Yes.

12 Q. Now, I'm going to ask about
13 each of them individually, but is your
14 observation that when simulating the
15 migration of a PCE contaminant plume using
16 MODFLOW and MT3DMS, when doing that achieving
17 a close match between simulated and observed
18 concentrations can be challenging, is that
19 limited to Camp Lejeune and the ATSDR's
20 modeling efforts?

21 A. No.

22 Q. What -- to what extent does
23 that apply to groundwater modeling?

24 A. The contaminant transport
25 modeling with MT3DMS, there's always -- or

1 there's typically a very high variability in
2 the observed concentration data. And the --
3 the model simulates a plume representing
4 average conditions over the grid cells and
5 using some simplifying assumptions.

6 And so you shouldn't expect it
7 to -- to precisely match the observed
8 concentrations at each instance, rather the
9 overall level of fit is what is most
10 important to analyze.

11 Q. And that's true whenever you're
12 modeling a plume using MODFLOW and MT3DMS;
13 right?

14 A. That's correct.

15 Q. Okay. So if we go to the first
16 factor, you wrote that "The subsurface
17 environment is inherently complex, with
18 variations in soil heterogeneity,
19 permeability, porosity, and hydraulic
20 conductivity. These properties vary
21 spatially in ways that are not fully captured
22 in the model, affecting how the contaminant
23 plume moves throughout the groundwater
24 system."

25 Is that observation specific to

1 Camp Lejeune and the ATSDR modeling efforts?

2 A. No.

3 Q. Is that statement regarding
4 complex subsurface conditions generally true
5 for groundwater modeling efforts using
6 MODFLOW and MT3DMS?

7 A. Yes.

8 Q. Okay. Or using any model?

9 A. Yes.

10 Q. Okay. Your second factor
11 listed is "Temporal Variability," and you
12 wrote "The concentration of contaminants can
13 change over time due to factors like seasonal
14 variations in groundwater flow,
15 biodegradation, and chemical reactions.
16 Simulating these dynamic processes accurately
17 over the entire simulation period is
18 challenging."

19 Is that observation specific or
20 unique to Camp Lejeune and the ATSDR's
21 modeling efforts?

22 A. It's a -- it's a general
23 statement that would be true of any
24 contaminant transport model.

25 Q. At any location?

1 A. Yes.

2 Q. By any modeler?

3 A. Yes.

4 Q. Okay. Your third reason listed
5 is "Limitations in Model Resolution." And
6 you wrote "MODFLOW and MT3DMS rely on
7 discretizing the subsurface into numerical
8 grids consisting of cells that represent a
9 subset of the aquifer. The resolution of
10 these grids can limit the model's ability to
11 capture fine-scale variations in plume
12 behavior, particularly in areas with sharp
13 concentration gradients, small-scale
14 heterogeneities, or preferential pathways."

15 Is that observation specific to
16 ATSDR's modeling efforts at Camp Lejeune?

17 A. No, it's a general statement,
18 and I think there's evidence of this
19 specifically at Camp Lejeune.

20 Q. But the limits in modeling --
21 limitations of model resolution that you've
22 described here is a limitation that would
23 apply whenever this type of modeling is done
24 with MODFLOW and MT3DMS?

25 A. Correct.

1 Q. Okay. And the fourth factor
2 you listed is "Measurement Variability," and
3 you wrote "The observed concentrations at
4 observation wells may contain some degree of
5 measurement error uncertainty. Field data
6 collection is subject to variability, which
7 adds another layer of complexity when trying
8 to match it closely with model outputs."

9 Is that observation unique to
10 ATSDR's efforts at Camp Lejeune?

11 A. No.

12 Q. Is it a general issue on
13 measurement variability that applies in all
14 groundwater modeling efforts?

15 A. That's correct.

16 Q. Okay. You were asked, I think,
17 on numerous occasions today by DOJ's counsel
18 for what purpose ATSDR's modeling effort can
19 be used, and I want to ask you this: Can
20 ATSDR's model be used to determine -- let me
21 strike that.

22 Is ATSDR's model or models used
23 for Camp Lejeune sufficiently reliable to
24 determine the mean monthly concentrations at
25 the water treatment plant at Tarawa Terrace

1 based on the work that you've done in this
2 case?

3 A. Yes, I believe so.

4 Q. And was it necessary for you or
5 for the ATSDR modelers to know how those mean
6 monthly concentrations would be used by any
7 health professional, including an
8 epidemiologist or a toxicologist or a medical
9 doctor, in order to conduct the modeling
10 efforts appropriately?

11 A. I can't think of any
12 circumstances in how they would be used that
13 would alter the modeling process that went
14 about building the model and generating those
15 simulated concentrations at the water
16 treatment plant.

17 Q. So, in other words, if a MD,
18 PhD, epidemiologist, medical doctor wanted to
19 use the mean monthly concentrations to
20 estimate an individual exposure as opposed to
21 a group exposure, would that change how you
22 or Morris Maslia or anyone else conducts the
23 modeling?

24 MR. ANTONUCCI: Objection.

25 THE WITNESS: No.

1 Q. BY MS. BAUGHMAN: You were
2 asked a number of questions by DOJ counsel
3 regarding -- about geometric bias.

4 Do you recall that?

5 A. Yes.

6 Q. Do you know what the geometric
7 bias was that was calculated for the
8 concentrations at the water treatment plant
9 for Tarawa Terrace?

10 A. Yes.

11 Q. What was that?

12 A. 1.5.

13 Q. And that's -- what's your
14 opinion of that in terms of, you know, good,
15 bad, accurate, inaccurate, do you have an
16 opinion?

17 A. I would say in the context of
18 contaminant transport modeling that would be
19 a slight high bias.

20 Q. Okay. And did you calculate
21 the geometric bias related to your post-audit
22 work?

23 A. Yes.

24 Q. And what was that geometric
25 bias?

1 A. I calculated geometric bias for
2 the 318 observations, and the geometric bias
3 was 2.1, which is substantially lower than
4 the 3.9 to 5.9 range that they got with the
5 original model.

6 And if you look solely at
7 observation -- observation -- concentrations
8 at observation wells that are greater than
9 5 micrograms per liter, that bias drops to
10 1.2.

11 Q. And remind me, 5 micrograms per
12 liter, why is that number significant?

13 A. It's the minimum -- it's the
14 MCL.

15 Q. Maximum contaminant --

16 A. Maximum contamination level,
17 yes.

18 Q. Set by the EPA?

19 A. That's correct.

20 MS. BAUGHMAN: Okay. I'll pass
21 the witness.

22 EXAMINATION

23 BY MR. ANTONUCCI:

24 Q. Dr. Jones, you just testified
25 that the geometric model bias at the Tarawa

1 Terrace water treatment plant was 1.5; is
2 that correct?

3 A. That's correct.

4 Q. Where did you get that value
5 from?

6 A. From the modeling reports.
7 ATSDR modeling reports.

8 Q. Okay. Can you tell me where
9 specifically in the modeling reports you got
10 that value from?

11 A. Well, earlier this afternoon
12 you had me read from a table, and it was in
13 that table and a discussion of that was in
14 the prior page. I believe it's in -- you can
15 find it in Chapter A, if I recall correctly.

16 Q. Okay. And you also testified
17 that the geometric model bias of your
18 post-audit was 2.1; is that correct?

19 A. That's correct.

20 Q. It's true that you calculated a
21 geometric model bias but not a mean absolute
22 error of your post-audit; is that right?

23 A. I -- there is a mean absolute
24 error calculated, I just can't remember what
25 it was off the top of my head.

1 Q. Okay. And it's not in your
2 report; correct?

3 A. No, we did not put it in the
4 report.

5 MR. ANTONUCCI: Okay. All
6 right. I pass the witness.

7 EXAMINATION

8 BY MS. BAUGHMAN:

9 Q. The geometric bias, is there --
10 is there a table or a figure in your report
11 from which one could easily calculate the
12 geometric bias for the post-audit work?

13 A. Yes. If you take the simulated
14 versus observed PCE concentrations at the 318
15 well locations, it's -- it's a simple
16 spreadsheet calculation.

17 Q. And all of the data necessary
18 to do that is in your report?

19 A. That's correct.

20 Q. Where? Where?

21 A. It's the -- well, the most
22 recent and correct version of that would be
23 in table -- Table A1 of the rebuttal report.

24 MS. BAUGHMAN: Okay. Thank
25 you.

1 I'll pass the witness.

2 MR. ANTONUCCI: All right.

3 Thank you, Dr. Jones, no further
4 questions.

5 THE WITNESS: Okay. Thank you.

6 MS. BAUGHMAN: I think we're
7 finished. Thank you.

8 THE VIDEOGRAPHER: We're off
9 the record. The time is 4:34.

10 (The deposition was concluded at 4:34 p.m.)

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Reporter's Certificate

State of Utah)
County of Salt Lake)

I, Vickie Larsen, Certified Court
Reporter and Registered Merit Reporter in the
State of Utah, do hereby certify:

THAT the foregoing proceedings were
taken before me at the time and place set
forth herein; that the witness was duly sworn
to tell the truth, the whole truth, and
nothing but the truth; and that the
proceedings were taken down by me in
shorthand and thereafter transcribed into
typewriting under my direction and
supervision;

THAT the foregoing pages contain a true
and correct transcription of my said
shorthand notes so taken.

IN WITNESS WHEREOF, I have subscribed
my name this 19th day of February, 2025.



Vickie Larsen, CCR/RMR
Utah License No. 109887-7801
Nevada License No. 966

I, NORMAN L. JONES, HEREBY DECLARE:
That I am the witness referred to in the
foregoing testimony; that I have read the
transcript and know the contents thereof;
that with these corrections I have noted this
transcript truly and accurately reflects my
testimony.

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-----	No corrections were made.	-----

I, NORMAN L. JONES, hereby declare under the penalties of perjury of the laws of the United States of America and the laws of the State of Utah that the foregoing is true and correct.

Dated this _____day of _____,
2025.

NORMAN L. JONES

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EXHIBIT 14

IN THE UNITED STATES DISTRICT COURT
FOR THE EASTERN DISTRICT OF NORTH CAROLINA
SOUTHERN DIVISION
Civil Action No. 7:23-cv-00897

IN RE: CAMP LEJEUNE WATER LITIGATION

THIS DOCUMENT RELATES TO:
ALL CASES

VIDEOTAPED

DEPOSITION OF: MORRIS MASLIA

DATE: March 13, 2025

TIME: 9:14 a.m.

LOCATION: BELL LEGAL GROUP
219 North Ridge Street
Georgetown, SC

TAKEN BY: Counsel for the Defendants

REPORTED BY: Lauren A. Balogh, RPR

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12 Leonard Konikow (via videoconference)

13 Deanna Havai, Motley Rice

14 (Via videoconference)

15 Alex Spiliotopoulos

16 (Via videoconference)

17 Timothy Thompson

(Via videoconference)

18 Bill Williams (via videoconference)

19
20
21 (INDEX AT REAR OF TRANSCRIPT)

1 THE VIDEOGRAPHER: The following will
2 be the videotaped deposition of Morris Maslia in re
3 Camp Lejeune Water Litigation versus United States
4 of America, File No. 7-23-CV-897. Today's date is
5 March 13th, 2025 and the time is 9:14 a.m. We are
6 here today at 219 Ridge Street, Georgetown, South
7 Carolina. The court reporter is Lauren Balogh and
8 the videographer is Jon Landau.

9 At this time I will ask all attorneys
10 present to please state their names and whom they
11 represent for the record.

12 MR. DEAN: Good morning. Kevin Dean
13 here on behalf of the PLG and the witness.

14 MR. BELL: Edward Bell on behalf of the
15 plaintiff.

16 MR. ANWAR: Haroon Anwar on behalf of
17 the United States.

18 MS. SILVERSTEIN: Kaylie Silverstein on
19 behalf of the United States.

20 THE VIDEOGRAPHER: Do you want the
21 people on the Zoom to do it?

22 MR. DEAN: It's up to you.

23 MR. ANWAR: The court reporter can take
24 it down. That's fine.

25 MR. DEAN: Yeah.

1 THE VIDEOGRAPHER: Okay. All right.
2 You may swear the witness, please.

3 MORRIS MASLIA
4 being first duly sworn, testified as follows:

5 EXAMINATION

6 BY MR. ANWAR:

7 Q. Good morning, Mr. Maslia.

8 A. Good morning.

9 Q. My name is Haroon Anwar. I am a lawyer
10 at the Department of Justice here on behalf of the
11 United States. We've met before at your prior
12 deposition in fall 2024, correct?

13 A. September 26th.

14 Q. September 26th of 2024. Thank you.

15 A. Yes.

16 Q. You may remember that experience. I'm
17 just going to go through -- go over a few rules for
18 the deposition just so we're on the same page, but
19 I'm going to ask you a number of questions today.
20 If I ask you a question that's vague or you don't
21 understand, please ask me to clarify. Otherwise,
22 I'm going to assume that you -- you understand my
23 question. Fair enough?

24 A. Fair enough.

25 Q. Okay. And the number one most

1 important rule for the deposition today, same as
2 before, is that you are under the oath to tell the
3 truth as if you were in an actual court of law. Do
4 you understand that?

5 A. Yes, I do.

6 Q. Okay. And is there any reason that
7 you'll be -- is there any reason today that you'd
8 be unable to testify truthfully?

9 A. No, there is not.

10 Q. The court reporter is transcribing
11 everything that we're taking down, so if we could
12 try not to speak over each other and perhaps give a
13 brief pause in case your lawyer needs to object, it
14 will make for a much cleaner transcript as well as
15 a much happier court reporter. Can we agree to try
16 to do that?

17 A. Yes.

18 Q. Okay. We will try to take breaks about
19 every hour. If you need to take a break sooner
20 than that, just let me know.

21 A. Okay.

22 Q. I'm happy to accommodate you. The only
23 stipulation I would put on that is if there's a
24 pending question, I would ask that you answer that
25 question and then we -- we can take a break. This

1 is not intended to be sort of a punishment, so to
2 speak.

3 A. Understood.

4 Q. So with that I wanted to start by
5 asking you what you did to prepare for today's
6 deposition?

7 A. I reviewed every single ATSDR Camp
8 Lejeune historical reproduction report that I was
9 involved with both for Tarawa Terrace, Hadnot
10 Point. I've also reviewed my expert report that
11 was submitted to you as well as my rebuttal report,
12 and I also reviewed some published journal
13 articles.

14 Q. What were the published journal
15 articles that you reviewed?

16 A. There was a series by -- that appeared
17 in Groundwater journal by Dr. Prabhakar Clement,
18 who I think you may know, and ATSDR exposure dose
19 reconstruction program staff responded to it, and
20 then they responded to -- to ours, so it's three
21 articles in Groundwater. His was 2010 and ours was
22 2012.

23 Q. Okay.

24 A. And then I've also reviewed just some
25 articles on uncertainly analysis. An article that

1 I published in 2004 on use of -- contained some
2 historical reconstruction of some smaller sites
3 using an analytical contaminant transport system
4 model and also contained the probabilistic
5 uncertainty analyses using Monte Carlo simulation.
6 So reviewed that as well as an article by
7 Dr. Clement in 2000 at Dover Air Force Base, which
8 is identical to Tarawa Terrace and came out with
9 identical values for some of the parameters, and I
10 would, in fact, like to add that to my expert
11 report if I can.

12 Q. Okay.

13 A. I've got a copy here, if you would like
14 to see that.

15 Q. Sure.

16 MR. DEAN: Yeah, I brought a copy.

17 MR. ANWAR: Thank you.

18 MR. DEAN: You're welcome.

19 BY MR. ANWAR:

20 Q. Thank you. So this -- we'll note this
21 for the record as an additional material --

22 A. Okay.

23 Q. -- on your -- your reliance list.

24 A. Yes, yes.

25 Q. For your expert report. Thank you.

1 Aside from the articles that you -- you mentioned,
2 the ATSDR reports and -- the ATSDR modeling reports
3 for Tarawa Terrace and Hadnot Point, Holcomb
4 Boulevard, and then your expert and rebuttal
5 report, did you review any other documents?

6 A. Just my deposition from September 26th.

7 Q. Okay.

8 A. And the exhibits that you provided.

9 Q. Oh, okay. During the September 26th --

10 A. Yes.

11 Q. -- 2024 deposition?

12 A. Yes.

13 Q. Did you review any of the other expert
14 reports in the case?

15 A. I reviewed Dr. Konikow's report. I
16 reviewed Dr. Sabatini's report. I reviewed
17 Dr. Jones and Mr. Davis's post-audit report and
18 rebuttal. And I also reviewed the defense's expert
19 reports by Dr. Spiliotopoulos, Dr. Hennet, and
20 Dr. Brigham.

21 Q. Understood. And I understand just from
22 attending the depositions of Dr. Aral, Mustafa
23 Aral, Dr. Davis, Dr. Jones, and then Dr. Konikow
24 about a week or so ago -- did you listen in to all
25 of those depositions as well?

1 A. Yes.

2 Q. Okay.

3 A. With Dr. Konikow I had to step out for
4 a couple of hours.

5 Q. Okay.

6 A. To do a medical run with my dad, so --
7 but I listened, I would say, to a majority of it.

8 Q. Did you review any of the transcripts
9 from those depositions?

10 A. I -- I read them. I guess
11 Dr. Konikow's transcript, because I wasn't there
12 for part of it, I read that in its entirety. Okay.
13 The other ones, just spot, you know, spot read
14 because I was watching the entire time.

15 Q. Understood. Did you do anything else
16 to prepare for today's deposition?

17 A. Only discuss with the plaintiff's
18 attorney the logistics, again, of, I believe, the
19 first time I was deposed as a fact witness versus
20 an expert witness to them.

21 Q. Understood. And I'm not asking about
22 the substance of your conversations with --

23 A. Right.

24 Q. -- the lawyers, just the circumstances
25 of the meeting. When did you meet with the lawyers

1 to prepare for the deposition today?

2 A. Yesterday, most of the day, and on
3 Tuesday afternoon.

4 Q. Okay. Who did you meet with yesterday?

5 A. Yesterday I met with Mr. Dean and also
6 Mr. Williams.

7 Q. Was there anyone else present in that
8 meeting?

9 A. Mr. Tim Thompson. He works with
10 Mr. Williams, and that's it.

11 Q. Okay. About how long did that meeting
12 last, the one yesterday?

13 A. Yesterday, we started about 9:30 and
14 ended about 4:30, 5.

15 Q. Did you review any documents during
16 yesterday's meeting?

17 A. Yes, the same ones that I had mentioned
18 to you, and spoke about wanting to place the
19 journal article as an addition to my materials in
20 my expert report.

21 Q. Understood.

22 MR. DEAN: Not to interrupt, but you
23 might want to ask him was anybody else in
24 attendance by Zoom. Because you asked in person
25 and he may have forgotten that.

1 MR. ANWAR: Sure.

2 BY MR. ANWAR:

3 Q. Were -- was anyone else in attendance?

4 A. Yes, another attorney, Laura Baughman.

5 Q. Okay.

6 A. With -- was in and out on Zoom.

7 Q. To the best of your knowledge, during
8 yesterday's meeting, it was only yourself and
9 attorneys for the plaintiffs attending, correct?

10 A. That's correct.

11 Q. And then on Tuesday's meeting, who was
12 present for that?

13 A. I believe that was Mr. Dean and
14 Mr. Williams and Mr. Thompson.

15 Q. And --

16 A. I don't recall if anyone was on Zoom or
17 not. I don't believe because I did not get here
18 until three o'clock p.m.

19 Q. To the best of your knowledge, the only
20 folks in attendance on Tuesday's meeting were
21 yourself and lawyers for the plaintiffs?

22 A. That is correct.

23 Q. Prior to yesterday's meeting and
24 Tuesday's meeting, were there any other meetings
25 with the lawyers to prepare for today's deposition?

1 A. No, no meetings.

2 Q. Dr. Konikow mentioned during his
3 deposition a meeting that took place. I think he
4 said it was in preparation for his deposition, but
5 you were present as well; is that right?

6 A. That's -- yes, yes, yes, now that I
7 recall, that was when -- I believe, if I'm not
8 mistaken, that was in February.

9 Q. Okay.

10 A. And I think I was supposed to be -- be
11 deposed that Thursday. That got postponed.

12 Q. Sure.

13 A. But Dr. Konikow and I were in that
14 meeting, yes.

15 Q. Aside from yourself and Dr. Konikow,
16 who else attended that meeting?

17 A. Mr. Dean, Mr. Williams, and I believe
18 Mr. Thompson.

19 Q. Any -- anyone other than yourself,
20 Dr. Konikow, and the plaintiffs' lawyers attend
21 that meeting?

22 A. Not that I recall.

23 Q. Have you -- did you attend any other
24 meetings in preparation for today's deposition?

25 A. No, I did not.

1 Q. Did you speak with anyone else in
2 preparation for today's deposition?

3 A. No, I did not.

4 Q. Did you speak with anyone from ATSDR in
5 preparation for today's deposition?

6 A. No.

7 Q. Now, you -- we have the -- the most
8 recent 2020 article from Clement that you're adding
9 to your -- your reliance list --

10 A. Yes.

11 Q. -- and have provided a copy here today.
12 You mentioned a couple of other articles that you
13 reviewed.

14 A. Right.

15 Q. And I was just wondering, the Clement
16 article and the other articles that you reviewed,
17 why did you review those articles?

18 A. Well, the article that I coauthored on
19 the analytical contaminant transport analysis
20 system, the ACT system, I think it was published in
21 2004, we reviewed that because it had a number of
22 historical reconstruction cases. One was for
23 20 years, a dry cleaner in New Mexico, and one was
24 -- I want to say it's Otis Air Force Base, EDB
25 contamination, and we did 65 years, and we used an

1 analytical contaminant fate and transport model and
2 conducted two-stage Monte Carlo simulation. So I
3 just wanted to refresh my memory as to what we did
4 and some of the parameters that -- contaminant fate
5 and transport parameters that we used in that.

6 In the Clement article I reviewed --
7 and I reviewed that one in specific detail because
8 Dover Air Force Base is very similar to Tarawa
9 Terrace. About the same size, 2.4 square miles.
10 They used a -- was testing out the RT3D model,
11 which is the reactive transport. So they went from
12 PCE to TCE to DCE to vinyl chloride in their
13 analysis, and a number of their parameters are
14 right where the parameter values that we calibrated
15 for Tarawa Terrace, so I thought it was a good
16 comparison article.

17 Q. The Clement article, I'll look at it
18 during the break.

19 A. Okay.

20 Q. But just based on your memory, what --
21 what did they use that model for?

22 A. I think the -- the purpose was to --
23 was it to -- well, there was historical
24 contamination at the Air Force base and they wanted
25 to look at how it advanced in time, and they wanted

1 to test out the RT3D code that Dr. Clement had
2 developed originally when he was at Lawrence
3 Livermore National Labs, and it was hooked in to
4 MT3DMS, and so they were testing that out, and
5 that's what basically I recall. And then when I
6 started reading the details of it, it appeared to
7 me that it was a very, very good comparison article
8 to what we did at Tarawa Terrace.

9 Q. Just quickly -- and I'll mark this as
10 an exhibit, actually.

11 A. Okay.

12 (DFT. EXHIBIT 1, article from Journal
13 of Contaminant Hydrology entitled "Natural
14 Attenuation of Chlorinated Ethene Compounds: Model
15 Development and Field-scale Application at the
16 Dover Site", was marked for identification.)

17 BY MR. ANWAR:

18 Q. Let's go ahead and mark this as
19 Exhibit 1, but I'll -- I'll mark it and then I'll
20 hand it to you after I have a chance to read it.
21 The 2020 Clement article on the Dover Air Force
22 Base site, in the abstract it states, "the
23 numerical model developed in this study is a useful
24 engineering tool for integrating field-scale
25 natural attenuation data within a rational modeling

1 framework. The model results can be used for
2 quantifying the relative importance of various
3 simultaneously occurring natural attenuation
4 processes."

5 Does that sound consistent with your
6 recollection?

7 A. Yes.

8 MR. DEAN: Object to the form of the
9 question. I think you misspoke about the data, the
10 article. I think you said 2020. If you said 2000,
11 I apologize, but I thought I heard 2020.

12 BY MR. ANWAR:

13 Q. Okay. And I understood you, Doctor, or
14 Dr. Maslia, Mr. Maslia, to state that this article
15 was published in 2020, but I perhaps misunderstood.

16 A. Okay. Okay. It is a 2000 article.

17 Q. 2000 article. Okay. So I'll reask my
18 question. This 2000 article -- and it looks like
19 on the first page of the article it actually says
20 it was accepted in October -- into the -- this
21 journal in October of 1999, but let's -- let's call
22 it the 2000 Clement article.

23 The abstract states, "the numerical
24 model developed in this study is a useful
25 engineering tool for integrating field-scale

1 natural attenuation data within a rational modeling
2 framework. The model results can be used for
3 quantifying the relative importance of various
4 simultaneously occurring natural attenuation
5 processes."

6 Is that consistent with your
7 recollection of the article?

8 A. Yes.

9 Q. To the best of your knowledge, was the
10 model discussed in this 2000 Clement article
11 estimating contaminant concentrations for
12 determining exposure in specific individuals?

13 A. The article did not go into what the
14 end use was, okay? I took it to mean that this was
15 the first stage or initial stage in developing a
16 model. It did not discuss exposure. In other
17 words, it was not an exposure assessment article.

18 Q. And to the best of your knowledge, was
19 this -- the model discussed in the 2000 Clement
20 article used for estimating contaminant
21 concentrations for the purpose of -- purpose of
22 determining exposure in individuals?

23 A. It was used for determining contaminant
24 concentrations.

25 Q. But as you sit here today, you're not

1 aware of it being used for the purpose of
2 determining exposure in individuals?

3 MR. DEAN: Object to the form of the
4 question.

5 THE WITNESS: I don't know what the end
6 use was.

7 BY MR. ANWAR:

8 Q. With respect to any -- the other
9 articles that you mentioned, were any of those
10 models -- strike that.

11 With respect to the other articles that
12 you mentioned, were any of the models discussed in
13 those articles used for estimating contaminant
14 concentrations that were used to determine exposure
15 in individuals?

16 A. The -- or the sites that we summarized
17 or did an analysis for in our 2004 paper, the
18 analytical containment transport analysis system,
19 one of them was at a dry cleaner in New Mexico and
20 the other one was Otis Air Force Base, which was
21 multimedia, meaning groundwater surface water and
22 -- and volatilization, and I know USGS has done
23 some work at Otis Air Force Base. It's been an
24 ongoing thing and I believe there are some
25 components from just the general topic of Otis Air

1 Force Base that look at exposure. It goes -- there
2 are people living downstream from the river that
3 goes through the Air Force base. I don't know the
4 details of the subsequent analysis of -- on -- on
5 that. I believe ATSDR did use the New Mexico site,
6 I think it's North Avenue Railroad site, if I
7 recall correctly, and I think they did a health
8 assessment there, okay, but I don't know the
9 specifics.

10 Q. Those other articles, are those
11 included on your -- either in your report or on the
12 reliance list?

13 A. Yes, the -- the 2004 is already on my
14 reliance list, 2004 by Maslia and Aral.

15 Q. And that's the one -- 2004 is focused
16 on Otis Air Force Base?

17 A. And -- and the New Mexico site.

18 Q. Okay. So it's just one article from
19 2004?

20 A. Yes.

21 Q. Besides that article and this 2000
22 Clement article, it sounded like you reviewed a
23 couple of other articles, perhaps related to
24 uncertainty analysis.

25 A. Right.

1 Q. Did any of those involve using
2 groundwater modeling to estimate contaminant
3 concentrations for the purposes of determining
4 exposure in individuals?

5 MR. DEAN: Object to the form.

6 THE WITNESS: Again, most of the
7 articles that I reviewed did not state the end
8 purpose of the -- they said the purpose of the
9 modeling to reconstruct or predict groundwater
10 contaminant concentrations using techniques,
11 different techniques, and also one of the articles
12 went into -- I think it was one of the earlier
13 applications of uncertainty analysis using Monte
14 Carlo simulation.

15 BY MR. ANWAR:

16 Q. So as you sit here today, you're not
17 aware of those other articles using models to
18 estimate contaminant concentrations for the purpose
19 of determining exposure in individuals, correct?

20 MR. DEAN: Object to the form.

21 THE WITNESS: Again, not having been
22 directly involved with the analysis, it's -- I
23 really can't answer what the results were used for.

24 BY MR. ANWAR:

25 Q. Okay.

1 A. The articles describe the process of
2 developing and/or calibrating models.

3 MR. DEAN: Object to the form. And
4 also add that if you're going to ask him about what
5 certain conclusions are in certain reports, that
6 the witness is entitled to see those reports, have
7 an opportunity to review them in detail, and then
8 properly respond.

9 MR. ANWAR: I'm going to mark the 2000
10 Clement article as Exhibit 1.

11 BY MR. ANWAR:

12 Q. Now, earlier we talked about the other
13 experts in the case and you having listened to
14 their depositions and read the deposition
15 transcripts, correct?

16 A. Right, yes, to -- some more detail than
17 others.

18 Q. Sure. One of those experts is doctor
19 -- professor -- or Dr. Mustafa Aral, correct?

20 A. Yes.

21 Q. Who is -- remind me, who is Mustafa
22 Aral?

23 A. Well, he was a professor at the Georgia
24 Institute of Technology. He was also director of
25 the multimedia environmental simulations laboratory

1 within the School of Civil and Environmental
2 Engineering. And he had or he was the principal
3 investigator on a cooperative agreement between
4 ATSDR and Georgia Tech.

5 Q. And the cooperative agreement between
6 ATSDR and Georgia Tech, was that in relation to the
7 Camp Lejeune water modeling?

8 A. Not specifically. That was a
9 multiyear-type agreement and it was for any site.
10 For example, the couple of sites that I mentioned
11 in the journal article, ACTS article, we did
12 cooperatively.

13 Q. Understood. So -- but it did include
14 the Camp Lejeune water modeling, correct?

15 A. Yes, it did.

16 Q. And if I understand your testimony
17 before correctly, Dr. Aral was a professor that you
18 had at Georgia Tech, correct?

19 A. Yes, yes, he was my -- my master's
20 thesis dissertation chair of that -- that
21 committee.

22 Q. Okay. And you know him personally,
23 correct?

24 A. I know him professionally. I don't
25 socialize with -- with -- with him, but I've known

1 him throughout the years professionally.

2 Q. Understood. What is your opinion of
3 Dr. Aral?

4 A. He's very qualified. I view him as a
5 mentor.

6 Q. Okay.

7 A. And can take his problems and analyze
8 them from a practical standpoint and also address
9 them through computational methods.

10 Q. Now, you also listened to the
11 depositions of Jeffrey Davis and Norman Jones,
12 correct?

13 A. Correct.

14 Q. Who is Jeffrey Davis?

15 A. I only -- I've never met him in person.
16 I met him, I assume, through Zoom and he's -- to my
17 understanding, he's a consulting engineer and
18 modeler.

19 Q. You mentioned you have spoken with
20 Mr. Davis on Zoom; is that right?

21 A. In a meeting, yes, in meetings.

22 Q. Was that during the course of preparing
23 expert reports in the case?

24 A. I believe he and Dr. Jones had some
25 questions about the Tarawa Terrace model input

1 files, and so I think that's where we had
2 discussions over Zoom.

3 Q. And it was in the context of the -- the
4 litigation, correct?

5 A. Yes.

6 Q. Had you met either Jeffrey Davis or
7 Norman Jones prior to being retained by plaintiffs
8 as an expert?

9 A. I have met Dr. Jones previously.

10 Q. Okay. You had not met Mr. Davis prior
11 to working -- or that call with him in the context
12 of the litigation, correct?

13 A. That is correct.

14 Q. Had you worked with Mr. Davis prior to
15 that Zoom meeting with him?

16 A. No, I have not.

17 Q. And it sounds like you don't know him
18 personally or socially, correct?

19 A. That is correct.

20 Q. Now, you mentioned having met Dr. Jones
21 in the past?

22 A. Right.

23 Q. When have you met Dr. Jones in the
24 past?

25 A. I served with Dr. Jones on a review of

1 a National Science Foundation grant for the
2 University of Alabama. And so he was the chair of
3 the panel. And I think every year, every other
4 year, they have to have a review status report like
5 that, so that's -- that's where I met him in
6 person.

7 Q. Around what time frame would that
8 meeting have taken place?

9 A. 2021, 2022, someplace around there.

10 Q. Have you met him on any other
11 occasions?

12 A. Not in person, but I do know of him.

13 Q. How do you know of him?

14 A. Early on or as part of the Tarawa
15 Terrace analyses we found out that the -- I believe
16 it was the U.S. Army Corps of Engineers or U.S.
17 Army Corps of -- Hydrologic Center were developing
18 a software platform called GMS. And while they
19 were beta testing it, since we were a federal --
20 sister federal agency, they wanted people to test
21 it out. So they provided us with a license, and I
22 believe Dr. Jones was one of the original
23 developers of the GMS software and platform.

24 Q. Do you remember around what time frame
25 that would have been developed?

1 A. I don't know the start of GMS, but
2 there's probably some letters in my files or
3 e-mails. I'm going to say 2005, '6, somewhere --
4 maybe 2004, right when we were modeling or --
5 modeling Tarawa Terrace.

6 Q. Did Dr. Jones directly work on the
7 model -- ATSDR's Camp Lejeune model for Tarawa
8 Terrace?

9 A. No.

10 Q. Okay. You just had the conversation
11 with him in the context of the GMS software?

12 A. No, I've never had --

13 Q. Oh, you didn't. Okay.

14 A. It was just his -- his name as the
15 developer --

16 Q. Understood. Understood.

17 A. -- when we were provided the executable
18 code by -- I think it was U.S. Army Corps of
19 Engineers Hydrologic Engineering Center, and so I
20 just saw it -- saw it through there, okay?

21 Q. Outside of the work with the University
22 of Alabama and then the Zoom meeting that you
23 described for the purpose of this litigation, have
24 you worked with Dr. Jones in any other context?

25 A. No.

1 Q. Do you have any opinion about either
2 Mr. Davis or Dr. Jones?

3 A. Both very well qualified. Very good
4 analysts and they know their way around the GMS
5 modeling platform. And I believe Dr. Jones is the
6 chair of the Brigham Young University School of
7 Civil and Environmental Engineering.

8 Q. What about David Sabatini, who is
9 Dr. Sabatini?

10 A. I understand he's a professor -- and I
11 forget the university, whether it's Texas or
12 Oklahoma. Reading his report, he is -- appeared to
13 me to be an expert in volatilization issues, and I,
14 again, only met him over Zoom.

15 Q. And that was in the context of this
16 litigation, correct?

17 A. Yes.

18 Q. Had you met him prior to the Zoom
19 meeting in this litigation?

20 A. No, I have not.

21 Q. Do you have any opinion about Dr. -- or
22 David Sabatini?

23 A. The same as the others, very competent
24 and understands volatilization issues. Was able to
25 assess them both from a scientific engineering

1 standpoint as well as present them to a layperson
2 who is not as technically knowledgeable.

3 Q. Thank you.

4 A. Can I get a drink of water here?

5 Q. Sure.

6 (DFT. EXHIBIT 2, deposition of Morris
7 L. Maslia dated June 30, 2010 Bates-stamped
8 CLJA_Healtheffects-00000494487 through 0000049712,
9 was marked for identification.)

10 BY MR. ANWAR:

11 Q. I'm handing you what I'm marking as
12 Exhibit 2. Here you go. And I asked you these
13 questions last time around --

14 A. Okay.

15 Q. -- in September, but I just want to
16 confirm.

17 A. Okay. Can I take the rubber band off?

18 Q. Sure. Actually, that's all -- I
19 actually gave you all the copies.

20 A. Oh.

21 Q. Feel free to give one to Kevin.

22 A. Okay. Who else?

23 Q. And I can take that one. Exhibit 2 is
24 a transcript from a deposition you gave in 2010 in
25 Laura Jones versus the United States, correct?

1 A. That is correct.

2 Q. Okay. And at that time you were
3 employed still with the ATSDR, correct?

4 A. That is correct.

5 Q. And you were, I think, in the midst of
6 working on the Hadnot Point/Holcomb Boulevard
7 model, correct?

8 A. That is correct.

9 Q. And the Laura Jones versus United
10 States case, that was a prior Camp Lejeune case,
11 correct?

12 MR. DEAN: Object to the form of the
13 question.

14 THE WITNESS: It was never explained to
15 me, either by the Office of the General Counsel or
16 DOJ or the plaintiffs' attorney, what -- what
17 exactly the case was for.

18 BY MR. ANWAR:

19 Q. The focus of your deposition, was it on
20 your work on the ATSDR water modeling for Camp
21 Lejeune?

22 MR. DEAN: Object to the form of the
23 question.

24 THE WITNESS: It was for Tarawa
25 Terrace, my understanding was.

1 BY MR. ANWAR:

2 Q. Okay. So the focus of the deposition
3 was the Tarawa Terrace model, correct?

4 MR. DEAN: Object to the form of the
5 question.

6 THE WITNESS: That's my --

7 MR. DEAN: Give me time to -- you can
8 answer.

9 THE WITNESS: Okay. That -- that was
10 my understanding.

11 BY MR. ANWAR:

12 Q. Okay. And you testified under oath
13 during that deposition truthfully, correct?

14 A. Yes, I did.

15 Q. And you had an opportunity to -- to
16 review the transcript and make corrections on an
17 errata sheet, correct?

18 A. That is correct.

19 Q. And I believe the last page of the
20 transcript is your signed errata sheet. You can
21 take a look.

22 A. Yes, yes, it is.

23 Q. Okay. And as you sit here today, do
24 you stand by your prior deposition testimony?

25 A. I will say I generally do. If there's

1 a specific item in -- in here that there's a
2 question about, I would have to see what that
3 technical issue is and then I could specifically
4 tell you.

5 Q. Okay.

6 A. Okay.

7 Q. As you sit here today, you don't have
8 any changes that you want to make to that
9 testimony?

10 MR. DEAN: Object to the -- object to
11 the form.

12 BY MR. ANWAR:

13 Q. You didn't come with changes, correct?

14 A. No, I did not come with changes.

15 Q. Okay. So I am handing you now what I'm
16 marking as Exhibit 3.

17 (DFT. EXHIBIT 3, deposition of Morris
18 Maslia dated September 26, 2024, was marked for
19 identification.)

20 BY MR. ANWAR:

21 Q. Here you go.

22 MR. ANWAR: Kevin, here you go, if you
23 would like a copy.

24 MR. DEAN: All right. Thanks.

25 BY MR. ANWAR:

1 Q. I'll represent to you this is a copy of
2 the transcript from your September 26th, 2024
3 deposition in this case. Would you agree with
4 that?

5 A. It appears to be, yes.

6 Q. And this is deposition you gave in this
7 case in your sort of capacity as a fact witness,
8 correct?

9 A. That is my understanding, yes.

10 Q. And this deposition took place after
11 you had been retained by the plaintiffs, but before
12 you had disclosed your expert report in the case,
13 correct?

14 A. Yes, that is correct.

15 Q. And you gave that deposition testimony
16 under the oath to tell the truth and testify
17 truthfully, correct?

18 A. That is correct.

19 Q. And you had an opportunity to review
20 and make corrections on an errata sheet for that
21 deposition transcript as well, correct?

22 A. Yes, I did.

23 Q. And I say that deposition transcript.
24 I mean the September 2024 transcript; is that
25 correct?

1 A. Yes.

2 Q. Okay.

3 (DFT. EXHIBIT 4, Acknowledgement of
4 deponent and errata sheets, was marked for
5 identification.)

6 BY MR. ANWAR:

7 Q. I'm handing you what I'm marking as
8 Exhibit 4, which I'll represent to you is a copy of
9 your signed errata sheet for the September 2024
10 deposition transcript. Would you agree with that?

11 A. Yes, it is.

12 Q. Aside from the changes on that errata
13 sheet, do you have any changes to your prior
14 deposition testimony?

15 A. Not that I recall at this time.

16 Q. Okay. Nothing that you came with to
17 the deposition, correct?

18 A. Excuse me? I don't understand the
19 question.

20 Q. You didn't come prepared to make
21 changes or offer changes to your past deposition
22 testimony as you sit here right now, correct?

23 A. No, I do not.

24 Q. Okay. I am going to hand you now what
25 I'm marking as Exhibit 5.

1 (DFT. EXHIBIT 5, Expert Report of
2 Morris L. Maslia, P.E., D.WRE, DEE, Fellow EWRI,
3 was marked for identification.)

4 BY MR. ANWAR:

5 Q. Here you go.

6 MR. ANWAR: Here's a copy for you.

7 BY MR. ANWAR:

8 Q. Mr. Maslia, this is a copy of your
9 expert report in this case dated October 25th,
10 2024, correct?

11 A. That is -- I'm looking for the date on
12 here. There's no date on this copy.

13 Q. I think it's at the bottom there in the
14 middle.

15 A. Oh, there it is, yes. Okay. That is
16 correct.

17 Q. And to the -- you had an opportunity to
18 sort of look through that. True and accurate copy,
19 to the best of your review?

20 A. The copy is correct.

21 Q. And aside from the articles that you --
22 we discussed this morning already, is the
23 materials-considered list on there complete and
24 accurate?

25 A. Yes, as far as I know.

1 Q. Is there anything on -- in that report
2 that you believe needs to be added that's not
3 reflected in the report?

4 A. No.

5 Q. I am handing you now what I'm marking
6 as Exhibit 6.

7 (DFT. EXHIBIT 6, Rebuttal Response to
8 Reports of Alexandros Spiliotopoulos, Remy, J.-C.
9 Hennet & Jay Brigham, was marked for
10 identification.)

11 BY MR. ANWAR:

12 Q. Mr. Maslia, is Exhibit 6 a true and
13 accurate copy of your rebuttal expert report
14 submitted in this case?

15 A. Yes, it is.

16 Q. And it's dated January 14, 2024?

17 A. Yes, it is.

18 Q. And aside from the articles that you
19 mentioned this morning, is there anything missing
20 from the materials-considered list or the
21 references provided with this report?

22 A. No.

23 Q. And in this report, as the title
24 indicates, is in response to the reports of DOJ
25 experts Dr. Spiliotopoulos, Dr. Hennet and Brigham?

1 A. That is correct.

2 Q. Do you know Dr. Spiliotopoulos, Hennet
3 or Brigham?

4 A. I do not know any of them and have
5 never met any of them.

6 Q. Do you know of any of them?

7 A. I know of Dr. Spiliotopoulos. I
8 believe his name appeared in -- as an observer at
9 at least one of the ATSDR expert panel meetings.

10 Q. Okay.

11 A. But I could not tell you exactly which
12 one, okay?

13 Q. Have you ever met Dr. Spiliotopoulos?

14 A. No.

15 Q. Have you -- so fair to assume if you
16 haven't met him, you've never worked with him,
17 correct?

18 A. That is correct.

19 Q. And same with Dr. Hennet?

20 A. That is correct.

21 Q. And I assume same with Dr. Brigham?

22 A. That is correct.

23 Q. Do you have any opinion about
24 Dr. Spiliotopoulos, Hennet or Brigham?

25 A. Not other than they are the DOJ's

1 expert witnesses.

2 Q. Okay. In your -- either your primary
3 expert report or the rebuttal report, is there
4 anything that you believe is incorrect?

5 A. I would -- in my expert report there
6 was -- and there was discussion during my
7 deposition about model bias and geometric biases.
8 And I believe that we -- or I went back and --
9 because there were a number of duplicate samples.
10 And because our model was only on a monthly time
11 frame, it really is not correct to try to match
12 daily or even weekly samples within monthly model
13 output.

14 So if you take the average within the
15 month of the actual sample data, you get a much
16 closer geometric bias to 1 -- 1.5. So we
17 overstated both in the ATSDR report, and I'm
18 talking about Tarawa Terrace, as well as my expert
19 report, which came from -- had that overstated or
20 provided a higher geometric bias both for the
21 supply wells and the water treatment plant than I
22 believe should actually be there.

23 Q. Is that currently reflected in your
24 expert report?

25 A. No, it's not.

1 Q. And it's not reflected in the ATSDR
2 reports, correct?

3 A. No, no.

4 Q. When --

5 A. I'm sorry.

6 Q. No, go ahead.

7 A. My expert report reflects or copies
8 exactly the tables out of the ATSDR reports
9 specifically for Tarawa Terrace with that.

10 Q. When did you do this analysis about the
11 geometric bias? And this is specifically for
12 Tarawa Terrace?

13 A. Yes, I would say within -- as I was
14 preparing my rebuttal report to the DOJ experts and
15 within last month sometime, I started just reading
16 more about nondetection of sample data and multiple
17 samples within a month, which we had at Tarawa
18 Terrace, Hadnot Point, and then realizing that our
19 model results -- we only had one result per month
20 because they were monthly time steps. So the
21 implication was that the model could reproduce
22 those daily or multiple monthly sampling, and they
23 -- it really can't if you only have a one-month
24 time step.

25 Q. Does it follow, then, the -- the model

1 certainly -- because the model produced monthly
2 estimated concentrations, correct?

3 A. That is correct.

4 Q. And the model was not intended to
5 produce daily estimated concentrations, correct?

6 A. Not the groundwater flow and
7 contaminant transport. It was produced -- we had
8 monthly time steps, so that would be 31, 30, 28 or
9 29 days, depending on which month it was, and our
10 assumption was that represented the last day of
11 each month, like January 31st, February 28th, and
12 so on, but that it was equally likely to occur on
13 any day of the month.

14 Q. So is it your opinion because you used
15 daily samples, but the model was producing monthly
16 simulated contaminant concentration estimates, that
17 you overestimated the geometric bias?

18 A. Yes.

19 MR. DEAN: Object to the form.

20 THE WITNESS: We computed a geometric
21 bias that was higher than if you had a one-to-one
22 correspondence, one -- one sample and one model
23 result for each month.

24 BY MR. ANWAR:

25 Q. Have you actually done the calculations

1 on that?

2 A. Yes, I have.

3 Q. I guess, based on the opinion that
4 you're offering now, what is -- what is, in your
5 opinion, the geometric bias for the Tarawa Terrace
6 model?

7 A. For the supply wells, I believe it
8 comes down to somewhere below 1.5 and recalling a
9 value of 1.0 would be an exact match, okay? And at
10 the water treatment plant, I believe it comes down
11 to almost 1.0.

12 Q. Do you -- when you said you did the
13 calculations, is that reflected in writing
14 anywhere?

15 A. I've got notes, but not with me.

16 Q. Okay. If we requested those notes to
17 be produced, would you be agreeable?

18 MR. DEAN: Object -- object to the form
19 of the question. I'll let you finish. I'm not
20 sure if you were finished.

21 BY MR. ANWAR:

22 Q. Well, we will request the notes from
23 your lawyer and the lawyers will work it out, but
24 if your lawyers ask you for the notes, would you be
25 agreeable to giving it to them?

1 A. Yes.

2 MR. DEAN: Object to the form of the
3 question.

4 BY MR. ANWAR:

5 Q. And outside of those notes, this
6 opinion that you're offering now, it's not
7 reflected in either your current expert report or
8 rebuttal report or the ATSDR reports themselves?

9 A. That is correct.

10 Q. And sort of my general high-level
11 understanding of sort of the thrust of your main
12 expert report at least is, is that the -- the ATSDR
13 models for Tarawa Terrace and the model for Hadnot
14 Point and Holcomb Boulevard are sufficiently
15 reliable and accurate to -- in estimating
16 contaminant levels for purposes of using them to
17 make exposure determinations in this case; is that
18 right?

19 A. I would say that the models produce
20 reliable results on a monthly basis, the
21 groundwater flow and contaminant transport models
22 for both Tarawa Terrace and Hadnot Point, and that
23 we met one of the objectives that we were required
24 to meet by the study epidemiologists of providing
25 mean monthly concentrations.

1 Q. You're serving as an expert in this
2 case, correct?

3 A. That is correct.

4 Q. On behalf of the plaintiffs, correct?

5 A. That is correct.

6 Q. And do you understand that the
7 plaintiffs are offering the model for purposes of
8 estimating exposure in individual plaintiffs in the
9 litigation?

10 MR. DEAN: Object to the form of the
11 question.

12 THE WITNESS: When we did the model, I
13 was not aware of the end use of it. I was
14 concerned with and what I have presented to the
15 plaintiffs is that it's reliable to provide monthly
16 mean concentrations. I'm not involved in, nor have
17 I ever been involved in, any use post-modeling
18 results.

19 BY MR. ANWAR:

20 Q. You understand the -- and if not, I'm
21 telling you now, the plaintiffs' lawyers are
22 offering the model as a way to estimate exposure --
23 estimated exposures in individual plaintiffs. Do
24 you understand that?

25 MR. DEAN: Object to the form of the

1 question.

2 THE WITNESS: I understand what you
3 have just said, yes.

4 BY MR. ANWAR:

5 Q. Okay. And do you believe the model is
6 sufficiently reliable and accurate for that
7 purpose?

8 A. The model is sufficiently reliable and
9 accurate for the monthly mean concentrations in
10 groundwater and in drinking water. I don't know
11 what analyses they are conducting with those --
12 with those values, nor I have ever known, even when
13 I was at ATSDR, what the epidemiologists or how
14 they were planning on -- on using them other than
15 in a general framework. But the epidemiologists at
16 ATSDR believe the model results were reliable and
17 accurate for their use.

18 Q. Sort of at a high level I understood
19 the purpose of your report as -- to be supporting
20 the use of the model in the litigation. Would you
21 agree with that?

22 MR. DEAN: Object to the form of the
23 question.

24 THE WITNESS: Could you clarify which
25 report you're speaking of?

1 BY MR. ANWAR:

2 Q. Sure. I understood the purpose of your
3 expert report that you submitted as a litigation
4 expert in the case for which you're consulting with
5 the plaintiffs on as advocating for or supporting
6 the use of ATSDR's Tarawa Terrace and Hadnot
7 Point/Holcomb Boulevard models in the litigation.

8 MR. DEAN: I'm sorry.

9 BY MR. ANWAR:

10 Q. Do I understand -- am I -- would you
11 agree with that?

12 MR. DEAN: Object to the form of the
13 question. You're asking him if he understands the
14 same thing you understand? That's...

15 THE WITNESS: My understanding was --

16 MR. DEAN: For the record, I do not
17 know, nor has Mr. Anwar provided sufficient
18 information about what his understanding is to get
19 in his head in order to be able to have anyone
20 properly be able to respond to that question, so I
21 object to the form.

22 MR. ANWAR: And I appreciate your
23 objections, Kevin. I would appreciate if you also
24 limit your objections to form within the rules and
25 limit your speaking objections. Mr. Maslia is the

1 one here to testify. This isn't your deposition.

2 MR. DEAN: You're familiar with the
3 rules of the road and the rules of depositions, and
4 if you follow those rules, then I will certainly
5 follow them as well.

6 MR. ANWAR: And I am sort of raising
7 this now because if this continues to be a problem,
8 we intend to take that to the Court, so...

9 BY MR. ANWAR:

10 Q. Mr. Maslia, I will ask you the question
11 again. So you submitted an expert report in this
12 case?

13 A. Yes.

14 Q. And you submitted an expert report as a
15 paid litigation expert, correct?

16 A. That is correct.

17 Q. And you did so on behalf of the
18 plaintiffs, correct?

19 A. That is correct.

20 Q. Did you do so with the understanding
21 that the plaintiffs are offering the model or the
22 -- and when I say "the model", I mean ATSDR's
23 Tarawa Terrace model and ATSDR's Hadnot
24 Point/Holcomb Boulevard model -- for use in the
25 litigation?

1 MR. DEAN: Object to the form.

2 THE WITNESS: I did so as the expert
3 and the person who oversaw the development of the
4 ATSDR models to any technical or scientific
5 questions pertaining specifically to the model,
6 model assumptions, model results that the
7 plaintiffs' attorneys may have.

8 BY MR. ANWAR:

9 Q. Okay. I just want to make sure I'm
10 crystal clear on this because as of now the Court
11 intends to hold a hearing on -- or the -- there's
12 discussion of a potential hearing being held on
13 issues related to water contamination in the case.
14 And I imagine if the Court does hold a hearing,
15 you'll be called to testify. And if you're asked
16 by a lawyer or one of the judges that -- whether or
17 not the Court should use the model for making
18 exposure determinations for individual plaintiffs
19 in the case, what would your answer be?

20 MR. DEAN: Object to the form of the
21 question.

22 THE WITNESS: My response would be,
23 from my standpoint, my professional and expert
24 standpoint, that the model results are reliable
25 based on our assessment of model calibration, model

1 results, and that the -- as long as the models are
2 sufficiently calibrated, in my mind, anyone can use
3 them for whatever purpose they want to use them
4 for. In other words, we did not calibrate the
5 models with the end result of exposure assessment.
6 Again, we were, at ATSDR, blinded to anything with
7 the epidemiology in terms of cases, controls,
8 people, anything like that, other than the five
9 objectives that I believe I listed in my expert
10 report as to what the epidemiologists requested us
11 to meet.

12 BY MR. ANWAR:

13 Q. Okay. Now, Appendix A, which is page
14 120 of your initial expert report.

15 A. 2020. Yes, I'm there.

16 Q. Is that a true and accurate copy of
17 your curriculum vitae?

18 A. Yes, it is.

19 Q. To the best of your knowledge, as you
20 sit here today, is it complete?

21 A. Yes, it is.

22 Q. And there's not anything that needs to
23 be updated as far as you're aware on that
24 curriculum --

25 A. Not that I'm aware of.

1 MR. DEAN: So there's someone who has
2 just joined with an area code 202 number. You're
3 not muted. Would you mind muting your phone,
4 please. Thank you.

5 BY MR. ANWAR:

6 Q. And on page 17 of your report it states
7 that "I'm being compensated an hourly rate of 400
8 for my work for preparing this report. My rate for
9 depositions and trial testimony is 2,000 per day."
10 Did I read that correctly?

11 A. Yes, you read that correctly.

12 Q. And is that what you're being
13 compensated in the case?

14 A. Yes, as it states right here.

15 Q. I'm handing you what is being marked as
16 Exhibit 7.

17 (DFT. EXHIBIT 7, M.L. Maslia Consulting
18 Engineer invoices Bates-stamped
19 CL_PLG-Expert_Maslia_0000000609 through 0000000680,
20 was marked for identification.)

21 BY MR. ANWAR:

22 Q. These are invoices that were produced
23 to us in response to a document, subpoena,
24 accompanying your -- your deposition notice.

25 A. Okay.

1 Q. Are these the invoices for the -- for
2 your expert work performed on behalf of the
3 plaintiffs in the case?

4 A. I haven't gone through all of them, but
5 they appear to be with my signature and the
6 billable hours and expenses that I submitted, yes.

7 Q. Okay. Do you have an estimate on how
8 much you've billed to date in the case?

9 A. No, I just submit it on a monthly
10 basis.

11 Q. Sure.

12 A. And you would have to ask the --
13 whoever the accountant is for the plaintiffs or my
14 CPA who is filing my taxes.

15 Q. Well, so I went through the invoices.

16 A. Right.

17 Q. According to my calculation and
18 let's -- let's call this rough, it looks like
19 you've billed a little over 1100 hours in the
20 amount of about \$346,000, just under \$347,000, for
21 your work in this case and that's for professional
22 services. Does that sound about right to you?

23 MR. DEAN: Object to the form.

24 THE WITNESS: It sounds high to me,
25 but, again, you'll have to add these up. If you're

1 basing them on -- on these, that's all --

2 Q. Okay.

3 A. It does sound high. The 300 number
4 sounds high.

5 Q. Okay. But if it's -- if that's what
6 the invoices add up to, you wouldn't dispute it?

7 A. No, I would not.

8 Q. And I noticed your invoices were
9 separated out for professional services and then
10 you had travel and related expenses, correct?

11 A. That is correct.

12 Q. Okay. And so the hours and the numbers
13 I read to you just now were what I calculated for
14 professional services. For travel and related
15 expenses, again, roughly I calculated 82.5 hours in
16 the amount of about \$16,000. Does that sound about
17 right to you?

18 A. It would be hard for me to answer that
19 right at this instant of time without going through
20 them and adding them up.

21 Q. Okay. If that's what they add up to in
22 the invoices, do you have any reason to dispute
23 that?

24 A. No, I do not.

25 Q. We've been going for about an hour.

1 Would you like to take a break or --

2 A. Sure. That would be good.

3 Q. Okay. Let's do that.

4 THE VIDEOGRAPHER: Okay. We're going
5 off record. The time is 10:14 a.m.

6 (A recess transpired.)

7 THE VIDEOGRAPHER: Okay. We're going
8 back on the record. The time is 10:25 a.m.

9 BY MR. ANWAR:

10 Q. We are back on the record from a short
11 break, Mr. Maslia. Are you okay to continue?

12 A. Yes, I am.

13 Q. Did you speak with your lawyers during
14 the break?

15 A. No, I did not.

16 Q. Okay.

17 A. There is one thing I would like to
18 clarify.

19 Q. Sure.

20 A. If I could do that. When we were
21 speaking about the improved and reanalysis of the
22 geometric biases, I got the original thought
23 reading Dr. Konikow's expert report where he had
24 mentioned about duplicate values in his report.

25 Q. Okay.

1 A. So I just wanted to give credit for the
2 initial thought about that.

3 Q. No, I appreciate that. You actually
4 anticipated my question. I was going to ask you
5 sort of as a follow-up when you decided to do that
6 analysis and it sounds like it was in the last
7 month or two; is that right?

8 A. That is correct.

9 Q. Okay. And it was in the context of
10 reading Dr. Konikow's report?

11 A. Yes.

12 Q. Okay. Would that have been after he
13 had disclosed his report?

14 A. Yes, yes, it was the -- I mean, what
15 was submitted to DOJ.

16 Q. Okay. And was there any particular
17 reason you decided to do the analysis or it was
18 just the thought popped up in reading his report?

19 A. Well, he mentioned that -- specifically
20 I believe it was in reference to well TT26 at
21 Tarawa Terrace where there were, like, five samples
22 within a short time period, like within a day or
23 week.

24 Q. Yeah.

25 A. And that the models could not really

1 reproduce that, okay, on a monthly basis. And so
2 that's when I looked at our tables that we had
3 published in the Tarawa Terrace Chapter A report
4 where we computed the model biases and the
5 geometric biases, and I went back and took that
6 suggestion and did the analysis.

7 Q. Okay. And you indicated you have some
8 notes about that, right?

9 A. That is correct.

10 Q. Okay.

11 MR. ANWAR: We will -- we will formally
12 request those notes be produced. We will just
13 formally on the record request that those notes be
14 produced and reserve the right to reopen the
15 deposition depending on what's in the notes.

16 MR. DEAN: That's right. And we
17 reserve all of our objections and -- but we will
18 take a look at it and provide a response back to
19 you.

20 MR. ANWAR: Okay. Sounds good.
21 Thanks, Kevin.

22 MR. DEAN: I don't have what he's
23 referring to here either, so...

24 MR. ANWAR: Okay. Understood.

25 BY MR. ANWAR:

1 Q. And then I wanted to ask you,
2 Mr. Maslia, when we were talking about expert
3 reports that you had reviewed, did you review
4 Dr. Longley's report as well?

5 A. No, I did not.

6 Q. Okay. Did you review it at any point?

7 A. I don't know who Dr. Longley is.

8 Q. Okay. I wanted to ask you a few
9 questions about the invoices. There were a couple
10 of references to discussions with -- with Robert
11 Faye. And it looks like you spoke with Robert Faye
12 in August of 2024. I'll call him Bob Faye.
13 Everyone calls him Bob Faye, it appears. And one
14 of the notes is -- provide Robert Faye, Bob Faye,
15 with verbiage on the use of probabilistic analysis
16 for Tarawa Terrace models, compose table listing,
17 ATSDR data discovery activities, and then review so
18 -- review 2005 expert report panel. And I can
19 direct you to where in the invoices that is if you
20 would like to take a look at it, but --

21 A. Yeah, if you could, please.

22 Q. Sure. It's the page ending 626.

23 A. 626. Okay. Ah, okay. Sure. What
24 date in particular?

25 Q. It's August 24.

1 A. Okay.

2 Q. Why did you speak to Robert Faye there?
3 What was that about?

4 A. Well, Bob Faye and I have known each
5 other professionally probably for 40 years.

6 Q. Four or 40?

7 A. 40. 40. 40 years, more or less. And
8 he was the person responsible for developing the
9 Tarawa Terrace groundwater flow and contaminant
10 fate and transport models as well as analyzing all
11 the hydrogeologic data. And so I had found out,
12 maybe through Bob, that he had been retained by the
13 plaintiffs' attorneys and I think there was a
14 question on -- on his part as to how to properly --
15 or how to word something containing probabilistic
16 analyses, which is what I did at ATSDR. Not only
17 did that, but I was familiar with -- with that on
18 numerous occasions of doing that, and so I think
19 that's what the discussion was about.

20 Q. Do you know when Bob Faye was retained?

21 A. I don't know the date.

22 Q. But as of this day, August 24th, 2024,
23 you spoke with him and he was retained; is that
24 right?

25 A. That is my understanding.

1 Q. Okay. And on that same page there is
2 an entry phone call with R. Faye about review of
3 ABC One Cleaners site data 2007 to 2012. Do you
4 remember what that conversation was about?

5 A. I think the question came up in some of
6 the production that DOJ provided to the -- the
7 plaintiffs about what documents we may have had at
8 ATSDR and what documents either the Department of
9 Navy provided us --

10 Q. Sure.

11 A. -- in conducting the Tarawa Terrace
12 reports. And so that ABC Weston 2007 report came
13 up.

14 Q. Okay. And then if you turn the page to
15 the page ending 640.

16 A. Okay.

17 Q. There are a couple of entries for
18 December 28th and 29.

19 A. Right.

20 Q. The 29th entry is, review R. Faye
21 rebuttal report, call with R. Faye. Do you recall
22 that conversation?

23 A. On the 28th?

24 Q. 29th.

25 A. 29th. I'm sorry. I don't specifically

1 recall that -- that phone call. I mean, I don't
2 know what exactly I was reviewing in his report.
3 He may have asked me my opinion of something he was
4 writing and being that he was retained and I was
5 retained, I probably provided an opinion.

6 Q. Okay. We have not received a rebuttal
7 report from Bob Faye. One has not been disclosed.
8 I'm just wondering if you knew why that was?

9 MR. DEAN: Object to the form of the
10 question. It's confidential attorney work product
11 and I would instruct the witness not to answer the
12 question.

13 BY MR. ANWAR:

14 Q. Do you know if Bob Faye intends to
15 testify in this case?

16 A. I've -- I'm not involved in that part
17 of being retained as to who does and does not
18 testify, so I do not know.

19 Q. Okay. Other than sort of what's
20 reflected on these invoices, have you spoken with
21 Bob Faye about any other aspect of your work on
22 this case?

23 A. Well, just in reviewing the original
24 ATSDR reports where he was the primary author,
25 making sure I understood what he was writing about

1 or what his intent was.

2 Q. Sure.

3 A. For example, the Chapter F, fate and
4 transport model, I wanted to clarify, you know,
5 technically clarify something.

6 Q. When would that have taken --
7 conversation taken place?

8 A. Last week sometime.

9 Q. I also noticed from some of the entries
10 on your invoices that you exchanged some e-mails
11 with Jerry Ensminger; is that right?

12 A. If you could -- can you point me to
13 exactly where they -- they are?

14 Q. I don't -- I don't -- I can look during
15 one of the breaks --

16 A. Okay. Okay.

17 Q. -- and point you directly, but do you
18 recall exchanging e-mails with Jerry Ensminger or
19 talking with him during the course of your work on
20 this case?

21 A. He has called me a couple of times.

22 Q. Okay.

23 MR. DEAN: I think you might have
24 marked some of that in the first depo, if I
25 remember correctly, just for what it's worth to

1 help him remember. I think you might have marked a
2 couple that were produced.

3 BY MR. ANWAR:

4 Q. When is the last time you spoke with
5 Mr. Ensminger?

6 A. Sometime this past month he called me.

7 Q. What was that conversation about?

8 A. He wanted to know my opinion of the
9 ATSDR models. He did mention geometric bias
10 specifically, but whether the models were, you
11 know, accurate, did they overpredict, underpredict.

12 Q. Do you know why he called you in the
13 last month about that, about whether the models
14 were accurate?

15 A. No, he never provides a reason why he
16 calls. He just calls me. I mean, in that sense.

17 Q. You know, just in reviewing the
18 documents in the case, it seems like -- and you
19 should correct me if I'm wrong -- throughout the
20 years Mr. Ensminger has had a number of
21 conversations with you and others on the ATSDR side
22 about work that was being performed related to the
23 models and the epi studies. Is that consistent
24 with your recollection?

25 A. Well, Mr. Ensminger was a member of the

1 Camp Lejeune camp.

2 Q. Yeah.

3 A. And he probably called or talked to me
4 in that capacity because when I was at ATSDR -- and
5 I don't know what the situation is now -- they
6 would have quarterly CAP meetings, okay, and it's
7 mostly when -- if I was going to present some
8 information or whatever, I called in his capacity
9 as the -- as a CAP member. That's what I recall.

10 Q. Okay. I was just wondering if you had
11 any insight on why he called you now. Because it
12 seems like he probably has a pretty good
13 understanding of the models just from the years of
14 working with you-all. If you have any insight on
15 why he decided to call in the last month.

16 MR. DEAN: Object to the form of the
17 question.

18 THE WITNESS: No, I do not know why --
19 why he would call me, because I had not heard from
20 him in a while. I mean...

21 BY MR. ANWAR:

22 Q. Sure. And did you-all specifically
23 discuss geometric bias during that call?

24 A. Not -- not that specific verbiage, but
25 the concept and what it means.

1 Q. Okay. Now --

2 A. Those were the values -- I need to
3 clarify. Those were the values relating
4 specifically to the report, not anything additional
5 that I had done.

6 Q. Understood. Have you had any other
7 conversations with Mr. Ensminger during the course
8 of your work in this case?

9 A. I believe there's one e-mail where he
10 wanted to know if I had an award certificate where
11 we were awarded the grand prize in research from
12 the American Academy of Environmental Engineers and
13 Science in 2015, and I believe I did provide him
14 with a couple of images.

15 Q. Sure. And if my understanding -- if my
16 recollection from your prior deposition is correct,
17 Mr. Ensminger is a Camp Lejeune activist, right?

18 MR. DEAN: Object to the form.

19 THE WITNESS: I assume there's
20 different definitions for activist. I have always
21 known him as a member of the CAP and a -- I'll just
22 leave it at that. That's where I first met him and
23 that's -- even when he calls today, I still think
24 of him in terms of the Camp Lejeune CAP.

25 BY MR. ANWAR:

1 Q. And are you aware that he's a plaintiff
2 in the lawsuit as well?

3 A. No, I'm not aware of anyone who's a --
4 who's in the lawsuit.

5 Q. Is Mr. Ensminger a water modeler?

6 A. No, he is not.

7 Q. Is he an epidemiologist?

8 A. No, he's not. Let me qualify that, to
9 my knowledge, I guess.

10 Q. Sure. I also noticed in the invoices
11 at some point during the course of your work as a
12 retained expert, you spoke with Chris Portier. Do
13 you recall that?

14 A. I don't ever recall speaking with
15 Dr. Portier once I was retained here.

16 Q. Okay.

17 A. I spoke to him -- or he spoke to me
18 when I was at ATSDR. That's the last -- last time,
19 actually, I recall speaking to Dr. Portier.

20 Q. Who is Chris Portier?

21 A. Dr. Portier is a former director of the
22 Agency for Toxic Substances and Disease Registry.
23 I'm not sure when he started. Maybe 2010, perhaps,
24 and retired, my understanding is, in 2013.

25 Q. Okay. And then I noticed on the

1 invoices there were some e-mails or conversations
2 that took place with Walter Grayman; is that right?

3 A. That is correct.

4 Q. First off, let me ask you, who is
5 Walter Grayman?

6 A. Walter Grayman I would consider a
7 mentor in water distribution system modeling and
8 probably one of the godfathers of water
9 distribution system modeling using computational
10 methods.

11 Q. And why did you speak with Walter
12 Grayman?

13 A. In my capacity here or -- I don't
14 understand --

15 Q. Sure.

16 A. -- the question.

17 Q. During the course of your retention --

18 A. Right.

19 Q. -- as a -- for the plaintiffs in the
20 litigation as an expert. I noticed his name on
21 some of the invoices. Why did you speak with him
22 during the course of the litigation?

23 A. My understanding is that he was also
24 retained as an expert witness.

25 Q. Okay.

1 A. But he is no longer that. But that was
2 my initial understanding. So he had some questions
3 about the water distribution system modeling
4 because he had assisted us in conducting field
5 studies and using the -- the model, and so that's
6 probably why I spoke with him, about that.

7 Q. Do you recall any other conversations
8 that you've had with Walter Grayman during the
9 course of the litigation?

10 A. No, no.

11 Q. I wanted to -- we talked -- some of
12 this is going to overlap with our discussion during
13 the last deposition. I'm trying --

14 A. Okay.

15 Q. -- my best not to duplicate too much.
16 We talked about, in your prior deposition, sort of
17 when you started working on the Camp Lejeune water
18 modeling at ATSDR and when it concluded. And I
19 noticed in Dr. Aral's report submitted in this
20 case, he makes a statement that over the 15-year
21 period from 2000 to 2015, I had my team members
22 work with essentially EDRP at ATSDR -- and, for the
23 record, the EDRP is exposure dose reconstruction
24 program. The statement is "from 2000 to 2015, I
25 and my team members worked with other team members

1 at EDRP at ATSDR to perform analysis of Tarawa
2 Terrace, Holcomb Boulevard, Hadnot Point studies
3 related to Camp Lejeune."

4 Does that time period, 2000 to 2015, is
5 that right in terms of the work for the water
6 modeling?

7 A. For Camp Lejeune?

8 Q. Correct.

9 A. No, that is not correct. We had a --
10 as I indicated previously, we had the cooperative
11 agreement that ran every five years, and Georgia
12 Tech was the cooperative agreement university
13 partner. And so on other sites, for example, I
14 mentioned the journal article that was published in
15 2004, so we would work on other sites. We did not
16 begin working in earnest until 2003 on Camp -- Camp
17 Lejeune, at which point, if they were still part of
18 the cooperative agreement, which they were, that's
19 when they would have started or we would have
20 started to have discussions about Camp Lejeune and
21 the approaches we should be taking and things of
22 that nature.

23 Q. And that's helpful in terms of the
24 start date. And then the end date he had in his
25 report as 2015. I noted that the -- I think the

1 last Hadnot Point/Holcomb Boulevard report was
2 published in 2013. Is that consistent with your
3 understanding?

4 A. The last report series was released in
5 March 2013.

6 Q. Did -- did the work related to the
7 Hadnot Point/Holcomb Boulevard modeling at ATSDR,
8 did it conclude in March 2013 or did it go on
9 another year until 2015?

10 A. The actual modeling activities and data
11 analysis activities and report publishing concluded
12 March 2013. I may have been asked by the
13 epidemiologists to forward them the final modeling
14 results after March of 2013, but I don't recall the
15 exact date.

16 Q. Were you doing any work on the modeling
17 in the ATSDR, I guess, either Tarawa Terrace or
18 Hadnot Point/Holcomb Boulevard models, in 2015?

19 A. No, I was not.

20 Q. Okay. So the -- the time frame is just
21 slightly off a little bit in his report, it sounds
22 like?

23 A. That is correct.

24 Q. Okay. I just wanted to clarify that.

25 So you -- you worked on the ATSDR

1 models for Tarawa Terrace and Holcomb
2 Boulevard/Hadnot Point -- Hadnot Point/Holcomb
3 Boulevard for just over a decade; is that right?

4 A. Yes, that would be correct, although
5 the initial work plan development probably was in
6 early 2003 or maybe 2002, internal, internal work
7 plan.

8 Q. Understood. You said 2002, 2003?

9 A. Yes.

10 Q. Okay. 11, 12-year time frame?

11 A. That is correct.

12 Q. For the 11, 12-year time frame for the
13 work that you and your colleagues at ATSDR did
14 related to the Tarawa Terrace and the Hadnot
15 Point/Holcomb Boulevard models, correct?

16 A. That is correct.

17 Q. Okay. And during that period of time,
18 you were ATSDR's project officer for the exposure
19 dose reconstruction program, correct?

20 A. That is correct. I was the project
21 officer from the beginning of the exposure dose
22 reconstruction program, which was probably 2004 or
23 '5.

24 Q. Okay. And then you were also the --
25 the lead or the project manager for ATSDR's water

1 models on Camp Lejeune, correct?

2 A. That is correct.

3 Q. Okay. Now, when you were employed
4 during this period of time by ATSDR working on the
5 Camp Lejeune modeling, you were a federal
6 government employee, correct?

7 A. That is correct.

8 Q. Do you remember what grade you were
9 sort of in the GS system in terms of employed?

10 A. It changed over time because I was
11 classified under the Office of Personnel
12 Management's research grade evaluation system.

13 Q. Sure.

14 A. So I was promoted twice from a GS-13,
15 which is where I came into ATSDR, applied to be
16 reclassified as -- under the research grade, and
17 then was promoted to a GS-14 and a GS-15.

18 Q. When were you promoted to a GS-15?

19 A. I would have to look at my electronic
20 personnel file.

21 Q. Sure. Were you a GS-15 by the time you
22 were working on the Camp Lejeune water models at
23 ATSDR?

24 A. Somewhere in there. Not necessarily at
25 the beginning.

1 Q. Okay. I am going to hand you what I'm
2 marking as Exhibit 8.

3 (DFT. EXHIBIT 8, Federal employee
4 profile for Morris L. Maslia, was marked for
5 identification.)

6 BY MR. ANWAR:

7 Q. I -- I looked you up on the federal
8 government employee lookup tool, and you're welcome
9 to look me up, too, as a federal employee. But
10 does this document I hand you accurately reflect
11 your GS grade and your salary while employed at
12 ATSDR between 2004 and 2018?

13 A. Well, it's incorrect because I retired
14 on December 31st, 2017.

15 Q. Okay. Aside from the 2018 year, for
16 the other years, does that generally look correct?

17 A. I don't recall being a GS-15 all the
18 way down to 2004 because I do recall them -- under
19 the research grade evaluation program, what they do
20 is, depending on the grade, but at the 13 and above
21 they should review you every four to five years,
22 maximum. So they would -- you -- they call in a
23 panel and have experts and then they score you on a
24 point basis. And then if you make above a
25 certain -- a certain point level, then the agency

1 has to say yes, we've got a GS-15 position
2 available or not, okay?

3 So again, I just don't recall it being
4 in 2004, but I would have to look at my own -- I
5 know you pulled this off the -- I've got my own
6 electronic personnel folder at home, or it was on
7 my ATSDR LAN drive, because they wanted everybody
8 to keep a copy of their personnel -- electronic
9 personnel folder when they went to digital versions
10 of it. So I could tell by those. I'm familiar
11 with the -- whatever it is, SF-171 form that tells
12 each year or whatever when you get promoted.

13 Q. Sure. Would the salary amounts, do
14 they look roughly right?

15 A. They -- they -- they look, from my
16 recollection, correct, yes.

17 Q. Okay. And so for that 11- or 12-year
18 period, would it be fair sort of roughly to
19 estimate that your total salary, cumulative salary,
20 during that period exceeded a million dollars,
21 correct?

22 A. I've never -- I've never added it up,
23 to be quite honest about it, so I would need to add
24 that up before...

25 Q. Okay. But if we added that up and I

1 told you it's over a million dollars, do you have
2 any reason to dispute that?

3 A. No.

4 Q. Okay. Besides your salary as an ATSDR
5 employee and the compensations and billings we've
6 discussed related to your retention or your role as
7 an expert in the litigation, have you received any
8 other compensation related to Camp Lejeune?

9 A. No, I have not, nor have I ever.

10 Q. Now, if I remember correctly -- and
11 you're welcome to refer to your CV as we're going
12 through this. It's page 121 in your expert report.
13 You started at ATSDR in 1992?

14 A. Let me just get there, so --

15 Q. Sure.

16 A. -- I'm on the page that you're
17 referring to. I started at ATSDR in 1992, that's
18 correct.

19 Q. And you retired in 2017, right?

20 A. December 31st, 2017.

21 Q. And as we just discussed, you worked on
22 ATSDR's Camp -- the water modeling related to Camp
23 Lejeune for Tarawa Terrace and Hadnot Point/Holcomb
24 Boulevard from about 2003 to 2013, 2014?

25 A. Probably. I want to say through 2013.

1 I was being funded in part at that time by the
2 Department of Navy, and so whatever they put in the
3 budget for 2014, it would not have been funded
4 by -- to my knowledge, by Camp Lejeune because the
5 modeling was completed, okay.

6 Q. Okay. And give or take, for a little
7 over -- for roughly a little over a decade, I think
8 we said 11 or 12 years, you worked on Camp Lejeune
9 water modeling at ATSDR, right?

10 A. That is correct. We did have, though,
11 again, because I was not only project chief or
12 scientific technical project officer for Camp
13 Lejeune, but I was also over the exposure dose
14 reconstruction program. We had other EDRP
15 activities and a couple of sites that we worked in,
16 not using Camp Lejeune money, but using the
17 agency's other funds.

18 Q. Okay. You started at ATSDR in '92.
19 You left in 2017, and you worked -- so that's,
20 what, roughly 25 years?

21 A. Yes.

22 Q. Okay. And you worked on Camp Lejeune
23 water modeling for close to half of that, is that
24 right, at ATSDR?

25 A. Did we say 10 or 11 years, yes.

1 Q. Okay.

2 A. Maybe slightly less. Maybe slightly
3 less, but...

4 Q. Understood. Was the water modeling for
5 Camp Lejeune a significant portion of your work
6 portfolio at ATSDR?

7 A. It was a substantial, but there were
8 other sites, as I said, prior to Camp Lejeune and a
9 couple of sites -- or a couple of analyses that
10 were not Camp Lejeune related.

11 Q. Focusing on that period between 2002,
12 2003 to 2013, what percentage of your work would
13 you say was related to the ATSDR's Camp Lejeune
14 modeling?

15 A. I'll start after about mid-2003. I
16 think that's when the ATSDR, I assume, got approval
17 from either the Marine Corps or the Navy to expend
18 the budget money on Camp Lejeune. I would say it
19 was probably 95 percent on different aspects of
20 Camp Lejeune.

21 Q. As I was looking at your -- your CV,
22 and specifically I was looking at your list of
23 publications, without looking each and every one
24 up --

25 A. Right.

1 Q. -- it's on page 130.

2 A. Okay. Okay. I'm there.

3 Q. I counted about nine or ten articles
4 that you've published related to the modeling work
5 you did on Camp Lejeune at ATSDR; is that right?

6 A. That sounds about right. It would be
7 agency reports. It would be journal articles and
8 there were some symposia presentations.

9 Q. Do you have any -- well, let me ask it
10 this way. Just ballpark, not holding you to any
11 specific number, how many publications, symposiums,
12 presentations, have you given related to the Camp
13 Lejeune water modeling?

14 A. I would really have to go and count
15 them up. I just don't feel answering truthfully if
16 I just picked a number out.

17 Q. Would you -- I think I identified nine
18 publications. Would you agree over ten?

19 A. Yes.

20 Q. Do you think over 20?

21 A. If you count some symposia
22 presentations where we had to actually submit a
23 manuscript, sometimes we did, and others we just
24 did, like, PowerPoint presentations, okay?

25 Q. So potentially over 20?

1 A. Right, yes.

2 Q. What about over 30?

3 A. That may come under other activities.
4 Like I was adjunct professor at the Emory
5 University Rollins School of Public Health, and so
6 I would give some case studies to my students using
7 what was publicly released from Camp Lejeune. And
8 I may have been asked by other ATSDR professionals
9 who were teaching other courses on statistics or
10 risk assessment at Emory to be a guest speaker for
11 my -- and I would give, again, things we had
12 already published or publicly released by the
13 agency about Camp Lejeune.

14 Q. Would you agree that the work you did
15 on the water modeling for Camp Lejeune at ATSDR was
16 a significant part of your career at ATSDR?

17 A. I would say it was substantial. It
18 would not be the complete time.

19 Q. And I saw on your CV that you, in 2015,
20 received the 2015 Excellence and Environmental
21 Energy Award, the grand prize, from the American
22 Academy of Environmental Engineers and Scientists;
23 is that right?

24 A. That is correct, sir.

25 Q. And was that related to the water

1 modeling work that you did at ATSDR on Camp
2 Lejeune?

3 A. Yes, it was.

4 Q. What is AEEES?

5 A. It's a professional organization, as
6 the name implies, of environmental engineers and
7 other engineers and scientists, and they run a
8 competition each year with different categories,
9 for example, consulting small projects, government
10 projects, and research projects.

11 Q. Okay.

12 A. And I mean, they put on webinars and
13 things of that nature, continuing education
14 courses.

15 Q. I saw the picture that you produced
16 holding the award. You looked very happy. What
17 did that award mean to you?

18 A. It meant -- it was especially
19 meaningful not just to me, but for our entire team
20 because an outside organization recognized the
21 significance of our work and contribution about
22 Camp Lejeune to the profession.

23 Q. Are you proud of that award?

24 A. Yes, I am.

25 Q. Would you describe it as one of the

1 highlights of your career?

2 A. Yes.

3 Q. How would you describe the work you've
4 done on the Camp Lejeune water modeling at ATSDR in
5 the context of your career?

6 A. I would say it was one of the similar
7 works that I have done, just like prior to Camp
8 Lejeune, Dover Township. Toms River, New Jersey
9 was also a similar piece of work. It was at the
10 U.S. Geological Survey, the work on the Floridian
11 RASA was also a similar piece of work.

12 Q. Now, in your prior deposition we
13 briefly discussed some e-mail exchanges that you
14 had with the Bell Legal Group in a 2009/2010 time
15 frame. Do you recall that?

16 A. In the September deposition?

17 Q. Correct.

18 A. I don't specifically recall that, but
19 if it's in the verbatim transcript, then we
20 discussed it.

21 Q. Okay. I'll show you one of them later.

22 A. Okay.

23 Q. And then you were retained by the Bell
24 Legal Group in July 2022 to serve as an expert in
25 this litigation, right?

1 A. That is correct.

2 Q. I was wondering what -- what led you or
3 how did you decide to serve as an expert witness in
4 this case?

5 A. Well, after I retired, of course, I --
6 I did a few consulting jobs just to keep in the
7 profession, keep my mind fresh. And then I was
8 approached and I felt because I had probably the
9 most internal knowledge -- not internal ATSDR, but
10 about the modeling I'm talking about, about what --
11 what we did, what the results meant, our confidence
12 in them, and that I could advise them on those
13 aspects of it.

14 Q. Are you -- how do I ask this? Is one
15 of the factors you considered in serving as an
16 expert in a litigation helping plaintiffs pursue
17 their claims related to exposure to Camp Lejeune
18 water?

19 A. That never -- that was never discussed
20 with me and that was never my -- my understanding,
21 but rather that I was a technical expert on water
22 modeling.

23 Q. Do you want to help the plaintiffs in
24 this case pursue their claims related to exposure
25 to Camp Lejeune water?

1 MR. DEAN: Object to the form of the
2 question.

3 THE WITNESS: That really would be a
4 legal question. I'm not really involved in legal
5 aspects other than being retained to explain what
6 we did, what I did, and the meaning of the work at
7 -- the water modeling that came from Camp Lejeune.

8 BY MR. ANWAR:

9 Q. And I guess I'm not asking you sort of
10 in the legal sense of whether your work is being
11 used to support the plaintiffs. I'm just asking
12 you personally, do you want to help the plaintiffs
13 in the litigation?

14 MR. DEAN: Object to the form of the
15 question.

16 THE WITNESS: When we did work at ATSDR
17 and even when I was at the USGS, we did what I
18 would classify as science in the public's interest,
19 okay? And so it's important to me that the public
20 understands what we did and how we did it, and if
21 it can help them come to a better understanding of
22 what occurred at Camp Lejeune or Toms River, Dover
23 Township, New Jersey, then that's a good -- good
24 use of my time, expertise, and the taxpayer's
25 money.

1 BY MR. ANWAR:

2 Q. So does your desire to -- or your
3 involvement in the litigation, does that stem from
4 a desire to explain the work that you did related
5 to Camp Lejeune at ATSDR?

6 A. Yes, yes.

7 Q. Do you feel like your work is under
8 attack in the litigation?

9 A. Not personally under attack. I believe
10 there's been mischaracterization of the work and
11 perhaps at different points misunderstanding of
12 what we were tasked with or charged with doing and
13 the reliability of the work.

14 Q. Do you --- is one of the motivating
15 factors in serving as an expert for the plaintiffs,
16 is it to defend your work?

17 MR. DEAN: Object to the form.

18 THE WITNESS: Well, I think if I'm
19 asked a question about our work, I'm defending
20 the -- the work, okay? So -- so but my objective
21 is not necessarily to be hired so I can defend what
22 we did. I would like to think that more of
23 explaining what we did and explaining, you know,
24 assumptions, limitations, and data analyses and
25 things of that nature.

1 BY MR. ANWAR:

2 Q. Aside from sort of the scientific
3 explanation portion of it or defending or
4 explaining your work, is money a motivating factor
5 at all serving as an expert?

6 A. Not at all, not at all.

7 Q. If the Court were to say, hey, the work
8 that you did at ATSDR was very fine, but we don't
9 -- we, the Court, don't believe it's appropriate
10 for use in this -- this case, how would that make
11 you feel?

12 A. Well, I would have to understand or be
13 there when someone said -- said that. That's sort
14 of a hypothetical. And I've never looked at the
15 work as defending it because the Court is going to
16 say, we don't believe it, okay? That's the best I
17 can answer.

18 Q. Okay. We'll talk a little bit more
19 about some of these other subjects later in the
20 deposition. Did you feel like you were defending
21 your work from the National Research Council?

22 MR. DEAN: Object to the form.

23 THE WITNESS: You mean, the results of
24 -- of their report?

25 BY MR. ANWAR:

1 Q. I guess, did you perceive -- let me ask
2 it differently. Did you perceive the National
3 Research Council's comments on the ATSDR Camp
4 Lejeune water modeling to be an attack?

5 MR. DEAN: Object to the form.

6 THE WITNESS: I believe and I believe
7 we have explained, on a couple of occasions,
8 internal documents as well as the published article
9 in Groundwater, that it was a mischaracterization
10 and misunderstanding and there was what appeared to
11 be -- because I requested additional meetings and
12 they would not meet with us. And I believe they
13 made their -- part of their decision -- I didn't
14 review the entire report, so I'm not talking about
15 the toxicology or the epi or the rest or anything
16 like that.

17 Q. Sure.

18 A. But they are all in conclusion that
19 they -- there was a misunderstanding,
20 mischaracterization, of some of the key things. So
21 yes, I mean, it's...

22 Q. Yes, it was an attack, is what
23 you're --

24 A. I wouldn't call it an attack, no. I
25 would say it was a mischaracterization and

1 misunderstanding.

2 Q. Okay. What about the Navy's critique
3 of the ATSDR water modeling for Camp Lejeune? How
4 did you perceive that?

5 A. I perceived that as a very usual
6 professional discourse that you have some work,
7 whether it's a model, data analyses or whatever,
8 and you publish it, whether it's a peer-reviewed
9 journal or peer-reviewed report, and the Navy had
10 some technical comments on the report, and so we
11 addressed them, in other words. So -- and until
12 this day, I still perceived it as a professional
13 exchange.

14 Q. What about Prabhakar Clement's --
15 Dr. Clement's article?

16 A. Right.

17 Q. How did you perceive that?

18 A. At the time it was published, which I
19 believe is 2010, it came right after the
20 publication of the NRC report. And again, I
21 thought there were some misunderstandings and
22 mischaracterizations. I do understand now that
23 part of it was sort of philosophical. In fact, he
24 mentioned that in his rebuttal to us. He was
25 looking at more philosophical issues, but I felt

1 the need to respond editorially to Dr. Clement's
2 article.

3 Q. Sure. Now, in the instance of the NRC
4 and the Navy and Dr. Clement, you did respond to
5 each one of those, correct?

6 A. The -- to the NRC we wrote or I -- I
7 oversaw an internal document, okay, and advised my
8 management chain and leadership that we needed to
9 respond to the NRC, I guess, agency, and they and
10 CDC quickly invoked the 11th commandment, thou
11 shall not critique the NRC.

12 Q. Why do you think that is?

13 A. I have no idea, but we point -- and
14 that internal document was very -- I mean, it was
15 very technically oriented in going -- I wouldn't
16 say line by line, but topic by topic and explaining
17 where we saw some issues with the NRC report. And
18 I do know that -- I believe it was Dr. Portier,
19 when he -- Dr. Portier in 2009 was not director of
20 ATSDR, but when he became director, I provided him
21 with a copy of that internal -- it's called
22 document, okay, it wasn't a memo or anything like
23 that. And he had a couple of topics in his letter
24 to -- and I forget who he wrote exactly to, but
25 about -- about our work, about the NRC report.

1 Q. If I'm understanding you correctly, you
2 wanted to respond to NRC, correct?

3 A. Yes.

4 Q. Okay. And you had put together a
5 response?

6 A. That is correct.

7 Q. But the response was kept, for whatever
8 reason, by CDC and ATSDR, internal, correct?

9 A. I know by ATSDR. I don't know if it
10 ever made it up to CDC --

11 Q. Okay.

12 A. -- that's over ATSDR, but it did make
13 it up through my management chain, okay?

14 Q. And it was kept internal, correct?

15 A. That is my understanding.

16 Q. Okay. And you did respond to the
17 Navy's comments or critiques, correct?

18 A. That is public information on the ATSDR
19 website, yes.

20 Q. Okay. That -- there's this ATSDR
21 report that's -- we'll look at it later, but it's
22 sort of named response to the Navy's letter. Did
23 you draft that response?

24 A. Yes.

25 Q. Okay. And then --

1 A. With assistance of team members and
2 some epidemiologists.

3 Q. Understood. And the article that you
4 published along with, I believe, Dr. Aral and some
5 of the other ATSDR colleagues, Jason Sautner, maybe
6 Rene, a response to Dr. Clement's article as well,
7 correct?

8 A. That is correct, yes, the team. I
9 listed all of the team. When I say team, from an
10 agency standpoint, so that's why there are some
11 epidemiologists that's coauthors on it as well.

12 Q. And when I say -- because we were
13 talking -- just for purposes of the record, because
14 we were talking about the 2000 Clement article,
15 when I'm talking about Dr. Clement's article now,
16 it's the article, I think, in the mid-2000s, 2010,
17 2011, focused on hindcasting, correct?

18 A. That is correct.

19 Q. Okay. Did you introduce the
20 plaintiffs' lawyers to -- in this case to
21 Dr. Konikow?

22 A. Yes, I did. When I say introduced, let
23 me clarify. I think they were looking for a name
24 of somebody who was nationally renowned in fate and
25 transport modeling, and so from my days at USGS, I

1 knew Dr. Konikow.

2 Q. Okay. So you connected Dr. Konikow
3 with the Plaintiffs' Leadership, correct?

4 MR. DEAN: Object to the form.

5 THE WITNESS: I just provided contact
6 information.

7 BY MR. ANWAR:

8 Q. Okay. Did you introduce or provide
9 contact information to the plaintiffs' lawyers in
10 this case for Rob -- Bob Faye?

11 A. Yes.

12 Q. When did you do that?

13 A. I really don't remember.

14 Q. Was -- was it in the last 30 days?

15 A. It was prior to that.

16 Q. Last 60 days?

17 A. I've been, as you said, involved in
18 this case since July of 2022.

19 Q. I won't hold you to a precise date.
20 Was it in 2025?

21 A. No, it was -- must have been sometime
22 in 2024.

23 Q. Do you recall whether it was before or
24 after the September 26th deposition, 2024?

25 A. It would have been before.

1 Q. Did you -- do you have Bob Faye's
2 contact information?

3 A. Yes, I do.

4 Q. What is it?

5 A. I've got a phone number and an e-mail.

6 Q. Okay.

7 MR. DEAN: Hold on. I have his info as
8 well. I don't mind -- he's a retained consulting
9 expert. He's not been disclosed as an expert. So
10 if you were to get his contact information, I would
11 request that you not talk to him -- talk to
12 Mr. Faye without me being present or on the phone.

13 MR. ANWAR: Okay.

14 MR. DEAN: If at all because he is,
15 again, a confidential consulting expert for the
16 PLG.

17 MR. ANWAR: Okay. We can discuss that
18 separately.

19 MR. DEAN: Sure.

20 BY MR. ANWAR:

21 Q. Did you introduce or provide contact
22 information for any of the other experts for the
23 plaintiffs?

24 A. Just the two that you have mentioned,
25 Dr. Konikow and Mr. Faye.

1 Q. In documents that we received from
2 Dr. Konikow, there was an e-mail in there between
3 you and Dr. Konikow. I think you were e-mailing
4 him, and it included a line, it said "don't know if
5 Kevin explained the politics of the case now, but
6 it's quite eye opening to me." Do you recall that?

7 A. I may have said that in the e-mail. I
8 mean, if I saw the e-mail, then we could see.

9 Q. Sure. What did you mean by the
10 politics of the case?

11 A. Well, Camp Lejeune has always been
12 surrounded, you know, from a political standpoint,
13 okay, because you have different parties, meaning
14 the Navy, the CAP, ATSDR, and so on, having
15 different points of view, so that makes it -- and
16 you're in public health, which is -- always has
17 politics associated with public health. And so
18 that's what -- and then they passed or perhaps I
19 was aware -- I was aware of the Janey Ensminger
20 Act, okay. That would have been political to get
21 that passed. And I believe at the time they had
22 already passed the PACT Act, which contained the
23 section -- I forget the exact number for Camp --
24 Camp Lejeune.

25 So that's what I was referring --

1 referring to, is most of the time I know the work
2 that -- I can't speak for Dr. Konikow, but the work
3 that I did at, say, USGS, okay, and even most of
4 the work that I did at ATSDR, with the exception of
5 Dover Township, Toms River, and Camp Lejeune, were
6 not -- did not have necessarily political aspects
7 to them in terms of legislation being passed.

8 Q. Understood.

9 A. Things like that.

10 Q. I -- and we talked about this in your
11 last deposition, and I know that you were part of a
12 group from ATSDR that testified to Congress,
13 correct?

14 A. That would have been in, like,
15 June 12th, 2007.

16 Q. Okay. And that was about Camp Lejeune,
17 correct?

18 A. Right.

19 Q. Was it a House Committee Hearing, if I
20 remember correctly?

21 A. It was a Senate Subcommittee Hearing.

22 Q. Oh, I'm sorry.

23 A. And I actually was -- did not provide
24 the testimony. I believe it was Dr. Tom Sinks. I
25 was just there, I guess, as a -- again, a technical

1 expert, but I was seated at the table.

2 Q. Okay. Have you had any direct
3 conversations -- have you directly had any
4 conversations with any Congress members about Camp
5 Lejeune?

6 A. No, I have not.

7 Q. You have a quote in your -- your e-mail
8 signature block currently from Nobel prize
9 physicist Richard P. Feynman. Do you know what I'm
10 talking about?

11 A. Dr. Feynman, yes, yes, I do.

12 Q. And I believe the quote is "I would
13 rather have questions that can't be answered than
14 answers that can't be questioned"; is that right?

15 A. That is correct.

16 Q. Okay. Who is Richard P. Feynman?

17 A. He's a Nobel -- he's since deceased,
18 but he was a very young Nobel prize winning
19 physicist. And the laypeople probably know him for
20 his participation on and his famous experiment on
21 the Challenger explosion.

22 Q. Okay.

23 A. And I believe that's where he put that
24 quote in, but I wouldn't swear -- swear to it, and,
25 in fact, I just bought a copy of -- of a book about

1 -- about him.

2 Q. Okay. Why did you include that quote
3 in your signature block?

4 A. I thought it's appropriate to
5 everything in -- in life. It's very succinct.
6 Don't be afraid to say you don't know the answer,
7 but that's better than saying don't ask me the
8 question.

9 Q. Would you agree that that quote is
10 applicable to all of the work that you've done as
11 an engineer or an environmental scientist?

12 A. I would say it's a more philosophical
13 statement, okay?

14 Q. One that would apply to -- and you said
15 any aspect of life, right?

16 MR. DEAN: Object to the form.

17 THE WITNESS: Well, that's how I am
18 interpreting it, okay? I wasn't there when
19 Dr. Feynman stated it or published it, so I don't
20 know what was in his mind, but it seemed to me,
21 from a philosophical standpoint, it, you know, it
22 resonates with me just philosophically.

23 BY MR. ANWAR:

24 Q. Okay. We have been going for a little
25 over an hour. Do you want to -- should we take

1 another break?

2 A. Sure, yes.

3 THE VIDEOGRAPHER: Okay. We're going
4 off record. The time is 11:23 a.m.

5 (A recess transpired.)

6 THE VIDEOGRAPHER: Okay. We are going
7 back on the record. The time is 11:32 a.m.

8 BY MR. ANWAR:

9 Q. We are back on the record from a short
10 break. Mr. Maslia, are you okay to continue?

11 A. Yes, I am.

12 Q. Okay. And did you speak with your
13 lawyer during the break?

14 A. No, I did not.

15 Q. Could you turn to page 145 of your
16 expert report?

17 A. Yes. Okay.

18 Q. 145 is a -- includes on it a figure or
19 a chart laying out the team that worked on the
20 ATSDR water modeling for Tarawa Terrace and Hadnot
21 Point/Holcomb Boulevard, their titles and sort of
22 their roles; is that right?

23 A. That is correct.

24 Q. Okay. And you've included Xs. A dark
25 green X for senior author of a report chapter. A

1 light green X for a contributing author of a report
2 chapter, and then a light red O for project
3 management and coordination; is that right?

4 A. That's correct.

5 Q. Okay. As I -- as I look at this
6 figure, is it fair to say that you were a senior
7 author or a contributing author or project managed
8 and coordinated every single chapter of the Tarawa
9 Terrace model reports and the Hadnot Point/Holcomb
10 Boulevard model reports?

11 A. I was the technical or scientific
12 project officer over all of the Camp Lejeune water
13 modeling.

14 Q. Okay.

15 A. It's just not shown on here. You can't
16 print three different colors on the same box, okay?
17 So -- and then where the dark Xs are, obviously I
18 was the senior author on that and contributed to
19 most of the reports, but there were some individual
20 chapters or supplements that I did not have
21 authorship of.

22 Q. But you still oversaw and managed,
23 correct?

24 A. Yes, yes.

25 Q. Coordinated, managed?

1 A. Yes.

2 Q. Okay. In coordinating and managing
3 every chapter of the two models, Tarawa Terrace and
4 Hadnot Point, would you have reviewed and approved
5 every chapter on each of those reports?

6 A. I would have reviewed and then said
7 it's ready to go to -- through the agency peer
8 review and then to external -- or if any review
9 comes back and then go out to external peer review.
10 It's ultimately up to the agency, I guess, Office
11 of Science and CDC Office of Science to give the
12 final release.

13 Q. Understood. Would you be the one to
14 make the decision it's ready to go to the next step
15 of the process, the peer review process?

16 A. Yes.

17 Q. And in making that final decision,
18 would you -- for each chapter or each report, would
19 you have an opportunity to review and comment and
20 suggest edits to particular chapters of either of
21 the model reports?

22 A. Yes.

23 Q. Okay. We talked about, at the
24 beginning of the deposition, the -- sort of the
25 most recent calculations you've run --

1 A. Yes.

2 Q. -- with respect to geometric bias.

3 A. Right.

4 Q. As to the Tarawa Terrace model,
5 correct?

6 A. Yes, yes.

7 Q. That was in the last month or so,
8 correct?

9 A. That is correct, sir.

10 Q. Aside from that, do you stand by every
11 chapter of the Tarawa Terrace model?

12 A. Yes.

13 Q. And is that also true -- do you stand
14 by every chapter of ATSDR's Hadnot Point model?

15 A. Yes.

16 Q. Again, aside from that geometric bias
17 discussion that we had, is there anything that
18 you're aware of that should be changed or corrected
19 in either the Tarawa Terrace set of model reports
20 or the Hadnot Point/Holcomb Boulevard set of model
21 reports?

22 A. There's issues brought up by the DOJ's
23 experts that I've responded to.

24 Q. Okay.

25 A. Okay. Absorption parameters, for

1 example, the results, and they do not impact at all
2 the results of the Tarawa Terrace analyses.

3 Q. Understood. In preparing your expert
4 report, either the primary -- the main one or the
5 rebuttal report, did you rerun either of the Tarawa
6 Terrace or the Hadnot Point and Holcomb Boulevard
7 model?

8 A. No.

9 Q. Were your reports, the main report and
10 the rebuttal report, were they based on the ATSDR
11 reports that are publicly available now?

12 A. You're talking about my expert report?

13 Q. Correct.

14 A. Yes, they were all -- whatever was
15 publicly available on the ATSDR website, which
16 would be all the Tarawa Terrace expert panel
17 reports, response to the Navy, and the Hadnot
18 Point/Holcomb Boulevard series of reports.

19 Q. Okay.

20 A. And that's what my expert report would
21 rely on.

22 Q. Okay. And I think you've clarified
23 that for me. Basically what I'm getting at is you
24 didn't, you know, go and put MODFLOW on your
25 computer and run the groundwater model again. You

1 didn't go and get MT3DMS and run the fate and
2 transport model again, correct?

3 A. Not at all, no, I do not have those on
4 my computer.

5 Q. And same with EPANET and the water
6 distribution model, you didn't --

7 A. I did not rerun it, although I do have
8 EPANET on my computer at home.

9 Q. Okay. Do you consider yourself an
10 expert in groundwater modeling generally?

11 A. Yes.

12 Q. Any particular aspects of groundwater
13 modeling that you consider yourself an expert or do
14 you consider yourself an expert in all of it?

15 A. I would consider myself an applied
16 researcher, so applying the available models that
17 have been developed by others to sites, okay, and
18 doing that as well as experience with
19 post-calibration analyses to assess the goodness of
20 fit of models.

21 Q. In terms of groundwater modeling, do
22 you consider yourself an expert in groundwater flow
23 modeling?

24 A. Yes.

25 Q. Do you consider yourself an expert in

1 contaminant fate and transport modeling?

2 A. I would consider myself very
3 knowledgeable.

4 Q. Okay. But not an expert?

5 MR. DEAN: Object to the form of the
6 question.

7 THE WITNESS: I mean, I'm an expert
8 from the standpoint that I've had courses in
9 contaminant fate and transport. I applied some and
10 -- but I don't do it -- I did not do it routinely,
11 but I have run contaminant fate and transport
12 models.

13 BY MR. ANWAR:

14 Q. Do you consider yourself an expert in
15 water distribution modeling?

16 A. Yes.

17 Q. Why do you consider yourself an expert
18 in water distribution modeling?

19 A. Well, we've applied -- when I say we,
20 at ATSDR, we applied water distribution system
21 modeling to a couple of sites: Dover Township,
22 Toms River, New Jersey as well as Camp Lejeune.
23 And we were -- for the Dover Township analysis, we
24 were actually awarded the best practice oriented
25 paper in 2000 by the Journal of Water Resources

1 Planning and Management based on the work in field
2 monitoring of the water distribution system in Toms
3 River, New Jersey. So yes, I would consider myself
4 an expert there.

5 Q. Okay. Let's turn to page 17 of your
6 report.

7 A. Of my expert?

8 Q. Your main report, yes.

9 A. Expert report?

10 Q. Correct.

11 A. Page 17. Okay.

12 Q. Page 17 contains a summary of your
13 opinions; is that right?

14 A. It has one item.

15 Q. Oh, I'm sorry. 17 and 18.

16 A. And 19.

17 Q. And 19. 17 through 19?

18 A. Yes.

19 Q. Starting on 17 is a section entitled
20 "summary of your opinions" and it concludes on page
21 19, right?

22 A. Yes.

23 Q. Okay. I wanted to focus on opinion
24 number three. It states, "the reconstructed
25 simulated monthly mean contaminant concentrations

1 of PCE, TCE, 1-2 DCE, vinyl chloride, benzene at
2 Tarawa Terrace, Hadnot Point and Holcomb Boulevard
3 are contained in ATSDR report appendices A-2 for
4 Tarawa Terrace, A-3 and A-7 for Hadnot Point, and
5 A-8 for Holcomb Boulevard." Did I read that
6 correctly?

7 A. Yes.

8 Q. Okay. And then opinion three goes on.
9 It says, "these reconstructed monthly mean
10 concentrations are also included in this report in
11 appendixes H, I, J and K" -- well, let me -- "these
12 reconstructed monthly mean concentrations are also
13 included in this report in appendixes H, I, J and
14 K, comma, are reliable and represent, within
15 reasonable scientific and engineering certainty,
16 the contaminant levels in selected water-supply
17 wells and in finished water at Camp Lejeune from
18 1953 to 1996." Did I read that correctly?

19 A. That is correct.

20 Q. Okay.

21 A. The ones for Hadnot Point probably go
22 to 2008. That's what the model runs did.

23 Q. Okay.

24 A. I'm not sure about the '96. That may
25 have been when the wells -- all the wells -- I --

1 but I do recall, because we had 2008 or 2006
2 through 2008, a remediation rate of Hadnot Point
3 that ran the model all the way out to 2008. So I
4 would...

5 Q. When you say there that the
6 reconstructed mean -- or reconstructed monthly mean
7 concentrations in the ATSDR reports are reliable
8 and represent, within reasonable scientific and
9 engineering certainty, what do you mean by
10 reasonable scientific and engineering certainty?

11 MR. DEAN: Object to the form.

12 THE WITNESS: When you conduct
13 scientific and engineering analysis application and
14 you come up with the value of -- that you believe
15 is the most likely value and -- then there's
16 always, you know, plus or minus a certain percent,
17 okay, and that's accepted. That's a pragmatic
18 engineering approximation to a modeling problem,
19 okay? You do the best you can and see if the level
20 of uncertainty is way beyond the information that
21 you have in terms of giving a reliable solution or
22 if it's within, then -- but there's always some --
23 some differences or errors in any of the solutions.

24 Q. When you say reliable there, what do
25 you mean? Is that --

1 A. Reliable, to me, means that -- and I'm
2 going to say for their ATSDR analyses, of course,
3 that are published -- somebody could pull that off
4 the shelf or off -- offline, I guess, now, and with
5 the model input files, duplicate what we did, okay?

6 Q. In this opinion, are you stating -- are
7 you opining that the reconstructed monthly mean
8 concentrations in the ATSDR reports are accurate
9 within a reasonable degree -- or reasonable
10 scientific and engineering certainty?

11 A. Yes.

12 Q. So it's your opinion that the simulated
13 monthly mean concentrations are accurate within
14 reasonable scientific and engineering certainty?

15 A. They are the most likely values to
16 occur.

17 Q. And --

18 A. Or to have occurred.

19 Q. When we're talking about reasonable
20 scientific and engineering certainty, help me
21 quantify that into a percentage. Are they
22 50 percent accurate, 75 percent accurate, 51
23 percent? Are they 90 percent likely to be
24 accurate?

25 MR. DEAN: Object to the form of the

1 question. Calls for legal conclusion.

2 THE WITNESS: Depending on the
3 application, not necessarily just on Camp Lejeune,
4 but in -- generally speaking, it depends on a lot
5 of factors. The quality of the field data. How
6 you constructed the model. What your calibration
7 targets may have been, or at least you try to
8 figure them out, and so each application will have
9 a different level of uncertainty, okay, and
10 reliability.

11 BY MR. ANWAR:

12 Q. What do you mean by depending on the
13 application?

14 A. Well, for example, we did water
15 distribution system modeling, okay? Water
16 distribution system modeling takes hour time steps,
17 not monthly, but hour time steps. And we measure
18 and we gather data because -- we personally
19 gathered them both in -- at Dover Township and at
20 Camp Lejeune. We had 15-minute readings per hour,
21 okay? So that's more data. So then you have to
22 assess that model based on the data that you have
23 and can you accept the difference between the
24 modeling results and the data that you -- that you
25 have and the way you interpret the data.

1 In other instances you may have monthly
2 data or sporadic data, and so the level of
3 reliability may change. And it also depends,
4 again, how you constructed the model. The size of
5 the grid, how you hydrogeologically conceptualized
6 the model. There's a lot of factors that go --go
7 into there, so you just can't -- I don't think it's
8 accurate to say on a blanket statement there's this
9 uncertainty in terms of percent or not percent, you
10 know.

11 Q. If the -- there is uncertainty to the
12 simulated monthly mean contaminant concentrations,
13 why were they -- those contaminant concentrations,
14 I'm just wondering, why were they produced in this
15 -- kind of this table format at the -- in multiple
16 places in the report, but do you know what I'm
17 referring to, at the end of Appendix A for Tarawa
18 Terrace, for instance?

19 MR. DEAN: Object to the form of the
20 question.

21 THE WITNESS: Can I just take a look at
22 Appendix A?

23 BY MR. ANWAR:

24 Q. Sure. Here, we'll go ahead and mark it
25 -- mark them both.

1 A. Okay. Oh, I've got a copy right here
2 that's unmarked. That's A. No, that's not A.
3 Here's Tarawa Terrace.

4 Q. Okay. I'll give you the one for the
5 court reporter.

6 MR. DEAN: Just use that.

7 THE WITNESS: Okay. Okay.

8 (DFT. EXHIBIT 9, Analyses of
9 Groundwater Flow, Contaminant Fate and Transport,
10 and Distribution of Drinking Water at Tarawa
11 Terrace and Vicinity, U.S. Marine Corps Base Camp
12 Lejeune, North Carolina: Historical Reconstruction
13 and Present-Day Conditions, Chapter A, Summary of
14 Findings, Bates-stamped
15 CLJA_Healtheffects-0000221172 through 0000221287,
16 was marked for identification.)

17 (DFT. EXHIBIT 10, Analyses and
18 Historical Reconstruction of Groundwater Flow,
19 Contaminant Fate and Transport, and Distribution of
20 Drinking Water Within the Service Areas of the
21 Hadnot Point and Holcomb Boulevard Water Treatment
22 Plants and Vicinities, U.S. Marine Corps Base Camp
23 Lejeune, North Carolina, Chapter A, Summary and
24 Findings Bates-stamped CLJA_Healtheffects-000022136
25 through 0000221535, was marked for identification.)

1 THE WITNESS: So based on the Appendix
2 2 in Tarawa Terrace?

3 BY MR. ANWAR:

4 Q. I am talking about Appendix A3 and A --
5 A3.

6 A. A -- in Tarawa Terrace it's Appendix
7 A3. It's questions and answers.

8 Q. Oh, I'm sorry. I have the wrong one.
9 You're probably right. A2, yeah.

10 A. Okay. A2. Okay. Could you repeat the
11 question?

12 Q. Sure. I guess given the uncertainty
13 and the -- the -- the application being important,
14 I was just wondering why were these concentrations
15 presented in the format that they were in A2?

16 A. By format, what do you mean?

17 Q. The summary -- I mean, you -- for
18 instance, can a person go on page A90 --

19 A. Okay. Hold on. A90. Okay.

20 Q. Stress period, 301, is for January of
21 1976 and the model simulated a PCE monthly mean
22 concentration of 73.96 micrograms per liter; is
23 that right?

24 A. That's directly, yes, from the model
25 output.

1 Q. Sure.

2 A. Okay.

3 Q. Do you know for sure that's what the
4 PCE concentration was in micrograms per liter in
5 January of 1976?

6 A. I would say the most likely value was
7 74 micrograms per liter, just rounding.

8 Q. Okay.

9 A. Most likely.

10 Q. Didn't a moment ago you say there are
11 sort of -- there's uncertainty associated with the
12 model outputs and there's a range --

13 A. Yes.

14 MR. DEAN: Let him finish the question
15 and then if I have an objection.

16 THE WITNESS: Okay. Okay. Oh, okay.
17 No problem.

18 MR. DEAN: Can you --

19 BY MR. ANWAR:

20 Q. Didn't you say that a moment ago?

21 MR. DEAN: Object to the form of the
22 question.

23 THE WITNESS: A moment ago I said
24 there's -- yes, I also said there's uncertainty
25 with the data; there's, you know, uncertainty

1 exists, okay?

2 BY MR. ANWAR:

3 Q. Why wasn't this numerical data
4 presented with the uncertainty, the range, and the
5 potential error bands for the data?

6 MR. DEAN: Object to the form of the
7 question.

8 THE WITNESS: I believe it was in
9 figure -- let me see if I can find the figure here.
10 Figure -- on page A60, figure -- the figure there,
11 A26, it's presented in terms of the 95 percent
12 confidence.

13 Q. Okay. Let's turn to page -- well, let
14 me -- let me ask some just for purposes of the
15 record questions. When we're talking about Camp
16 Lejeune water modeling, we're really talking about
17 two separate water models, correct? And what I
18 mean by that is there was a model that related to
19 Tarawa Terrace and then there was a separate model
20 that related to Hadnot Point and Holcomb Boulevard,
21 correct?

22 A. I'd say there was an analysis related
23 to Tarawa Terrace.

24 Q. Sure.

25 A. And then there were subsequent analyses

1 because of the complexity of Hadnot Point and
2 Holcomb Boulevard and the interconnection related
3 to those areas.

4 Q. Was the model for the analyses for
5 Tarawa Terrace, did that actually consist of two
6 separate models?

7 A. For Tarawa Terrace? Consisted of
8 MODFLOW and MT3DMS and then a mixing model. That
9 would be three models.

10 Q. Understood. And MODFLOW is a
11 groundwater flow model -- modeling software,
12 correct?

13 A. That is correct.

14 Q. And MT3DMS is a contaminant fate and
15 transport model, correct?

16 A. That is correct.

17 Q. For Tarawa Terrace, rather than running
18 a -- sort of a water distribution model, you used
19 the simple mixing model, correct?

20 A. No, that's -- that's mixing apples and
21 oranges, okay? Let's separate off water
22 distribution system modeling. For the groundwater
23 flow analyses we ran MODFLOW, which generated
24 groundwater flow velocities of different layers.
25 That's directly imported into MT3DMS. And then we

1 applied a flow-weighted mixing because you had
2 different wells turning on and off. And then we
3 used the mixing model, which was described on page
4 A40 in equations one and two, and that was because
5 all the wells mixed at the water treatment plant,
6 and that was the final output to which we compared
7 available samples that were collected at the water
8 treatment plant.

9 Q. Understood. So you assumed in the
10 Tarawa Terrace model that the -- the water from the
11 treatment plant was the same water that the end
12 user received, correct?

13 A. Yes.

14 Q. Now, I think that's what I was getting
15 at. The -- now, the Tarawa Terrace analysis was
16 completed in 2009, right?

17 A. The last chapter was published in 2009.

18 Q. Chapter A was published roughly 2007,
19 is that...

20 A. In -- because of the -- excuse me.
21 Because of the Senate Subcommittee Hearing, there
22 was an executive summary released June the 12th,
23 2007.

24 Q. Okay.

25 A. And then the full Chapter A, summary of

1 findings, was released in July of 2007. But other
2 work had been done. Again, it was a summary
3 document, so obviously it had results in here from
4 -- it was just a matter of finalizing the reports.

5 Q. And then the Hadnot Point/Holcomb
6 Boulevard analysis, that was completed in 2013,
7 right?

8 A. March 2013, the Chapter A, summary of
9 findings, and in that situation, rather than
10 individual additional chapters, the agency decided
11 to make supplements for the other contributing
12 analyses described in the summary of findings.

13 Q. You would agree that when running a
14 groundwater flow model using, for instance,
15 MODFLOW, there is some level of uncertainty,
16 correct?

17 A. Yes, yes.

18 Q. And when you run a fate and transport
19 model using, for instance, MT3DMS, there is also
20 some level of uncertainty associated with the fate
21 and transport aspect, correct?

22 A. Yes, but there are different types of
23 uncertainty, okay? In other words, there's what's
24 referred to as scenario uncertainty, and that is
25 your understanding or conceptualizing the system

1 that can be an error before you ever get to the
2 model. There's model uncertainty. For example,
3 someone were to try to apply an analytical model,
4 which assumes constant flow field in the
5 groundwater, constant velocities, then that would
6 be uncertain -- model uncertainty.

7 Q. And so when you're -- when you're using
8 a groundwater flow model, a MODFLOW, and then
9 taking the results and putting them into a fate and
10 transport model, an MT3DMS, doesn't that certainty
11 then accumulate because you're combining
12 uncertainty -- uncertain results with even more
13 uncertain results?

14 MR. DEAN: Object to the form of the
15 question.

16 THE WITNESS: That's -- actually, if
17 you read some papers published and all of that,
18 it's a common mistake is to linearly add up
19 uncertainty. It doesn't work that way, okay? It
20 may compound it. It may get reduced or whatever,
21 but you just can't add that you've got a 10 percent
22 uncertainty or a 95 percent confident band on the
23 flow model. You just can't say, okay, well, the --
24 the transport model has 90 percent, add the two
25 together and call it 92 and a half. It doesn't --

1 it doesn't work like that.

2 BY MR. ANWAR:

3 Q. And I think you just said it could
4 compound it, though, right?

5 A. You would have to look at the -- again,
6 the specific application, the specific site that
7 you're looking at, the specific model that
8 you're -- you're applying.

9 Q. And I'm just quoting back your words.
10 You would agree, though, it could compound it?

11 MR. DEAN: Object to the form of the
12 question.

13 THE WITNESS: I would not necessarily
14 say it would compound it. You would have
15 uncertainty associated with each of the models that
16 you applied as well as uncertainty in the data,
17 okay, that you're calibrating to. And so that's
18 why it's, I think, critical after you complete --
19 in our case it was a four-stage calibration, to try
20 to -- or even after a third-stage, try to assess
21 the goodness of fit of the model to data. To look
22 at sensitivity analyses, to look at uncertainty
23 analyses, and probabilistic uncertainty analyses to
24 quantify that, okay?

25 BY MR. ANWAR:

1 Q. Now, let's turn to page Roman numeral
2 three.

3 A. Chapter A?

4 Q. Chapter A, correct, of Tarawa Terrace,
5 which is, for the record, Exhibit 9.

6 A. Oh, okay. I'm sorry. Roman -- the
7 foreword?

8 Q. Correct. Okay. And you would agree
9 with me, there it says, in the foreword, "the
10 ATSDR, an agency of HHS, is conducting an
11 epidemiological study to evaluate whether in utero
12 and infant, up to one year of age, exposures to
13 volatile organic compounds in contaminated drinking
14 water at U.S. Marine Corps Base Camp Lejeune,
15 North Carolina, were associated with specific birth
16 defects and childhood cancers." Did I read that
17 correctly?

18 A. Yes, you did.

19 Q. Okay. And it goes on to say "the study
20 includes births occurring during the period 1968 to
21 1985 to women who were pregnant while they resided
22 in family housing at the base." Did I read that
23 correctly?

24 A. Yes, you did.

25 Q. Then if you go to the next paragraph,

1 "historical exposure data needed for the
2 epidemiological case-control study are limited. To
3 obtain estimates of historical exposure, ATSDR is
4 using water modeling techniques and the process of
5 historical reconstruction. These methods are used
6 to quantify concentrations of particular
7 contaminants in finished water and to compute the
8 level and duration of human exposure to
9 contaminated water." Did I read that correctly?

10 A. To contaminated drinking water.

11 Q. Contaminated drinking water. Thank
12 you.

13 A. Yes, yes.

14 Q. And so you would agree with me, and I
15 think you have before, that the Camp Lejeune water
16 modeling for Tarawa Terrace was performed to
17 provide data for this epidemiological study,
18 correct?

19 A. It was conducted to address five
20 questions, as I've put in my expert report. Number
21 one was which contaminants you needed to look at.
22 These are questions posed by the epidemiologist.
23 You know, whether it's volatile organics, I mean,
24 volatiles, pesticides. Another conclusion, it's a
25 military base, so there's a numerous one. Number

1 two, when the contaminants arrived at water-supply
2 wells, monthly mean. And then number three, what
3 was the concentration in the wells. Number four,
4 what was the concentration in the water distributed
5 throughout, in this case, Tarawa Terrace. And
6 number five was what were the range of the values.
7 And we interpret that, from a modeling stance, is
8 some type of sensitivity or uncertainty analyses.

9 Those were -- those -- those were
10 always from -- I guess when we first had our first
11 kickoff meeting with the Marine Corps and Navy and
12 all of that in October of 2003, that's what we
13 presented to them.

14 Q. And that was in support of this
15 epidemiological study that was --

16 A. Yes, it was in support of.

17 Q. Of the epi study, correct?

18 A. Yes.

19 Q. Okay. And if you turn to A98.

20 A. Okay. I'm there.

21 Q. There is a -- so A98 is a page of a
22 question and answer section of Chapter A, Tarawa
23 Terrace report, which is identified as Appendix A3.
24 The question is "ATSDR's historical reconstruction
25 analysis documents that Tarawa Terrace drinking

1 water was contaminated with PCE that exceeded the
2 MCL" --

3 A. I'm not -- I'm not following where you
4 are. You said you were on A96?

5 Q. A98.

6 A. A98. And the --

7 Q. The last question --

8 A. Oh, okay. Okay. Okay.

9 Q. -- is about the results of the model,
10 "what does this mean in terms of my family's
11 health?"

12 A. Right.

13 Q. The response is "ATSDR's exposure
14 assessment cannot be used to determine whether you
15 or your family suffer -- suffered any health
16 effects as a result of past exposure to PCE
17 contaminated drinking water at Camp Lejeune",
18 correct?

19 A. That's what it says there, yes.

20 Q. And you -- your -- in the chart that we
21 looked at earlier, you're the -- the primary author
22 of Chapter A, correct?

23 A. Yes.

24 Q. Okay. And so you wrote these words,
25 correct?

1 A. I wrote these -- this section -- let me
2 go back -- the questions and answers, okay. When I
3 was at ATSDR they required you, if you conducted a
4 technical analyses modeling or whether it was epi,
5 whatever, to provide the public with a layperson's
6 understanding, okay? So I drafted these. They
7 were reworded by the Office of Communications and
8 then sent back down to me to see if I agreed with
9 their edits, which there were many. And then they
10 were published as that appendix.

11 Q. Okay. And you're the primary author?
12 You're listed first?

13 A. Yes.

14 Q. And you would stand by what's in this
15 report today, correct?

16 A. Yes.

17 Q. Okay. Now, if you would take a look at
18 Exhibit 10, which is Chapter A for Hadnot Point.

19 A. Okay. I've got a copy here. Okay.
20 Here we go. Okay. Yes, it's unmarked.

21 Q. Okay. If we turn to page three again,
22 foreword, Roman numeral three.

23 A. Okay.

24 Q. And again. There it says "ATSDR is
25 conducting epidemiological studies to evaluate the

1 potential health effects from exposures to volatile
2 organic compounds such as PCE, TCE, and benzene in
3 drinking finished water at U.S. Marine Corps Base,
4 Camp Lejeune, North Carolina." Did I read that
5 correctly?

6 A. Yes.

7 Q. Okay. "Historical exposure data needed
8 for the epidemiological studies are limited. To
9 obtain estimates of historical exposures, ATSDR is
10 using water modeling techniques in the process of
11 historical reconstruction to quantify
12 concentrations of particular contaminants in
13 finished water and to compute the level of duration
14 of human exposure to contaminated water." Did I --
15 "drinking water." Did I read that correctly?

16 A. That is correct.

17 Q. Okay. And you're also the principal
18 author of Chapter A for Hadnot Point/Holcomb
19 Boulevard, correct?

20 A. That is correct.

21 Q. Okay. And these are your words,
22 correct?

23 A. Yes.

24 Q. Okay. And so again, the -- the -- the
25 model for Hadnot Point and Holcomb Boulevard were

1 -- was done in support of an epidemiological study,
2 correct?

3 MR. DEAN: Object to the form of the
4 question. Asked and answered, too.

5 THE WITNESS: It was done to address
6 the five objectives or questions that the
7 epidemiologists asked us to -- to address.

8 BY MR. ANWAR:

9 Q. Okay. In support of the
10 epidemiological studies, correct?

11 MR. DEAN: Object to the form of the
12 question. I'll let him answer it one more time.
13 The same thing happened recently in another depo.

14 MR. ANWAR: Please --

15 MR. DEAN: You keep asking the same
16 question.

17 MR. ANWAR: If we need to get Judge
18 Jones on -- I'm going to ask you to stop making
19 speaking objections and coaching the witness.

20 BY MR. ANWAR:

21 Q. Doctor, it's a yes-or-no question. The
22 question is --

23 A. Well, no, it's not because you're
24 asking me about what the epidemiologists did. And
25 what I can tell you is I'm not an epidemiologist.

1 I don't know how they used the information, but I
2 do know that they asked us to address five
3 objectives. And one of the objectives was to
4 provide monthly mean concentrations in drinking
5 water that was delivered to residents, in this case
6 it would be Hadnot Point/Holcomb Boulevard, and
7 also express some range of confidence.

8 Q. And it was for the epidemiological
9 studies? That's what it says here.

10 MR. DEAN: Object to the form of the
11 question. The document speaks for itself.

12 THE WITNESS: That's what it says in --
13 in the report, but I would like to be clear that I
14 am not an epidemiologist, so how it's being used
15 from once we provided -- we provided -- all we
16 provided were the monthly mean concentrations.

17 BY MR. ANWAR:

18 Q. You're not an epidemiologist, but you
19 felt comfortable serving as a primary author in
20 this report that says that, right?

21 A. I felt confident because these were
22 water modeling reports and water modeling analyses,
23 yes.

24 Q. Okay. Let's go to page A182.

25 A. Okay. Okay.

1 Q. And this is Appendix A-9, another Q and
2 A section --

3 A. Yes.

4 Q. -- for the Hadnot Point and Holcomb
5 Boulevard report, correct?

6 A. That is correct.

7 Q. And per the modeling results -- in
8 terms of the modeling results, "what does this mean
9 in terms of my family's health." It again states,
10 "ATSDR's exposure estimates cannot be used alone to
11 determine whether you or your family suffered any
12 health effects as a result of past exposure to TCE
13 contaminated drinking water at U.S. Marine Corps
14 Base Camp Lejeune." Did I read that correctly?

15 A. Yes, you did.

16 Q. You have both Chapter As in front of
17 you?

18 A. Yes.

19 Q. And for the Tarawa Terrace Chapter A
20 and the Hadnot Point/Holcomb Boulevard Chapter A --

21 A. Excuse me, the mike fell off.

22 Q. Oh, no problem.

23 A. Okay. Am I okay? Okay. Sorry.

24 Q. No, it's okay. In either of the two
25 Chapter A reports for the Tarawa Terrace analysis

1 or the Hadnot Point/Holcomb Boulevard analysis, can
2 you point me to any statement in, I guess, Chapter
3 A or any of the reports that the models were
4 intended to be used for exposure determinations in
5 specific individuals?

6 MR. DEAN: Object to the form of the
7 question.

8 THE WITNESS: The purpose of these
9 reports were to document model analyses, data,
10 calibrations, to provide epidemiologists with mean
11 monthly concentrations. How they intended to use
12 it, their epidemiological studies, or how anyone
13 else intended to use it is -- does not disqualify
14 the model and is not a model limitation. The text
15 that you have read both in Chapter -- Appendices
16 Chapter A and that, that is a statement of agency
17 policy because ATSDR's a public health agency and
18 they do not conduct, to my knowledge, at least when
19 I was there, individual analyses.

20 BY MR. ANWAR:

21 Q. And so --

22 A. Right? So that's a statement that --
23 but what people can do, what anyone else wants to
24 do with -- with these models -- we had the same
25 situation when we did Dover Township. In fact, we

1 had consultants call ATSDR and wanted to know,
2 well, can you estimate for us what our exposure was
3 at, you know, 123 Main Street -- I'm making that
4 up.

5 Q. So I think -- go ahead.

6 MR. DEAN: Let him finish his answer.

7 BY MR. ANWAR:

8 Q. I think the --

9 A. The answer -- so -- and the answer was
10 from an agency policy standpoint, no.

11 Q. No, none of the reports say that the
12 models were intended or should be used to determine
13 exposure to contaminated water in specific
14 individuals, correct?

15 MR. DEAN: Object to the form of the
16 question. Can we go off the record and have you
17 step out of the room, please, sir.

18 THE WITNESS: Sure.

19 MR. DEAN: Thank you.

20 THE VIDEOGRAPHER: Okay. Going off
21 record. The time is 12:14 p.m.

22 (Off the record.)

23 THE VIDEOGRAPHER: We're going back on
24 record. The time is 12:16 p.m.

25 BY MR. ANWAR:

1 Q. We are back on the record, Mr. Maslia.
2 In order to expedite things a little bit, I'm going
3 to ask you this question. It's going to be similar
4 to at least the prior question, but it is a
5 different question, for the record.

6 In any of the ATSDR modeling reports
7 for Tarawa Terrace, Hadnot Point or Holcomb
8 Boulevard, any of the expert panel summaries that
9 you put together, any of the transcripts from the
10 expert panels, 2005 and 2009, can you point me to a
11 single statement from any of those experts at the
12 time or in any of your reports, the numerous
13 voluminous reports, stating that the results of the
14 models are sufficiently reliable and accurate to be
15 used for exposure determinations in specific
16 individuals?

17 MR. DEAN: Object to the form of the
18 question.

19 THE WITNESS: We express in numerous
20 places that they are reliable, acceptable. Again,
21 we were not asked or -- nor were we ever asked to
22 apply them to individuals.

23 BY MR. ANWAR:

24 Q. Okay. Let's -- I'm going to show you
25 another exhibit.

1 (DFT. EXHIBIT 11, Appendix 15
2 Bates-stamped CLJA_Healtheffects-0000061127 through
3 0000061136, was marked for identification.)

4 THE WITNESS: Okay.

5 BY MR. ANWAR:

6 Q. I'm going to represent to you -- do you
7 recognize this document -- I've handed you what
8 I've marked as Exhibit 11 -- Mr. Maslia?

9 A. It says Appendix I-5. Let me just find
10 -- well, that's not it. Chapter I. Oh, okay.
11 Okay. Yes, that's the sensitivity -- that's the
12 Tarawa Terrace Chapter I report.

13 Q. Okay. This is an appendix to the
14 Tarawa Terrace Chapter I report, correct?

15 A. Yes.

16 Q. Okay. And there at the -- the second
17 paragraph in the appendix is a disclaimer, right?

18 A. I don't recall putting that there, but
19 -- can I look at my full chapter on it?

20 Q. Sure.

21 A. It's not on my Chapter I.

22 Q. Yeah. And that's one of my questions
23 to you. It's on ATSDR's website currently and it's
24 been produced in the litigation. It is attached as
25 part of a table to Chapter I, but not directly

1 included in the reports. And on the table we
2 discussed earlier, you're the primary author of
3 Chapter I, correct?

4 A. Yes.

5 Q. Okay.

6 MR. DEAN: Let me object to the form of
7 the question because I think the witness just said
8 it was not attached to his -- or you may have said,
9 I misunderstood, that this document Appendix I-15
10 is not a part of the report that was released, but
11 is now on the website; is that what you said?

12 MR. ANWAR: It's available on the
13 website.

14 THE WITNESS: I don't know anything
15 about that. When I left ATSDR, the only things on
16 the website were the published reports in 2017. So
17 no, I have never seen that disclaimer.

18 BY MR. ANWAR:

19 Q. Right. Let's -- let's read through the
20 disclaimer together.

21 A. Okay.

22 Q. It starts "the water modeling analysis
23 results presented herein are provided as a service
24 to the public for informational purposes. All
25 analyses and computer simulation results have been

1 reviewed for accuracy and completeness based on
2 available information and current modeling
3 assumptions."

4 A. It says "all data, analyses, and
5 computer-simulations."

6 Q. Okay. "All data, analyses and
7 computer-simulation results have been reviewed for
8 accuracy and completeness based on available
9 information and current modeling assumptions." Did
10 I read that correctly?

11 A. Yes.

12 Q. Then it goes on to say "the results,
13 however, may not reflect the actual exposure of
14 specific individuals to contaminants in the water
15 system." Did I read that correctly?

16 A. Yes.

17 Q. "In addition, more updated information,
18 if and when obtained, may change interpretations
19 presented herein. For details pertaining to
20 assumptions and limitations, the public should
21 refer to the aforementioned reference list above."
22 Did I read all of that correctly?

23 A. Yes.

24 Q. I most wanted -- most importantly I
25 wanted to focus on -- it states, "the results,

1 however, may not reflect the actual exposure of
2 specific individuals to contaminants in the water
3 system." Did I read that correctly?

4 MR. DEAN: Well, you can answer that.
5 I don't have an objection to that question.

6 THE WITNESS: Okay. Yes, you read that
7 correctly.

8 BY MR. ANWAR:

9 Q. And is it your testimony that you've
10 never seen this before?

11 A. No, it is my testimony I have never
12 seen this before.

13 Q. Were you involved in any way in
14 drafting it?

15 A. Not that I recall.

16 MR. DEAN: Object to the form of the
17 question. He just told you he didn't know anything
18 about it.

19 THE WITNESS: I don't know when it went
20 on the website. The last time I checked, which was
21 not recently, maybe two years ago or whatever, I
22 don't recall seeing it.

23 BY MR. ANWAR:

24 Q. Do you know why this disclaimer is
25 included as part of an appendix in Chapter I and

1 not in Chapter A?

2 MR. DEAN: Object to the form of the
3 question. Asked and answered.

4 THE WITNESS: It's not in -- in the
5 published report, okay? It's -- so I don't know
6 why or who put the disclaimer there or when it went
7 on there. As I said, to my best knowledge, when I
8 left in -- or retired in December of 2017, the only
9 thing on the website were these complete reports.
10 And I would not -- I don't understand why they
11 would pull just this out and put it like that on
12 the website. That may -- again, somebody at ATSDR
13 must have made a decision, but I was not involved
14 in that, nor was this ever -- the reference
15 citation is correct, but the disclaimer I've never
16 seen.

17 BY MR. ANWAR:

18 Q. Okay.

19 MR. BELL: At a good stop -- good point
20 for a break or not?

21 MR. ANWAR: I have a little bit more
22 questioning and then we can take a lunch break.

23 MR. BELL: Yeah, the chef out there
24 won't ring the bell for the employees until we go
25 get our food because y'all are the guests of the

1 day. I'll leave it up to you.

2 MR. DEAN: Well, give him five more
3 minutes if that's okay.

4 MR. BELL: No problem.

5 (DFT. EXHIBIT 12, Analyses of
6 Groundwater Flow, Contaminant Fate and Transport,
7 and Distribution of Drinking Water at Tarawa
8 Terrace and Vicinity, U.S. Marine Corps Base Camp
9 Lejeune, North Carolina: Historical Reconstruction
10 and Present-Day Conditions Disclaimer Bates-stamped
11 CLJA_Watermodeling_01-0000938451, was marked for
12 identification.)

13 BY MR. ANWAR:

14 Q. Okay. I am handing you what I'm
15 marking as Exhibit 12.

16 A. Okay.

17 Q. Exhibit 12 is a redline of the
18 disclaimer that we just looked at.

19 A. Okay.

20 Q. Would you agree with that?

21 MR. DEAN: Object to the form of the
22 question.

23 THE WITNESS: It looks like a big
24 difference to me, redlined.

25 BY MR. ANWAR:

1 Q. It's been redlined, correct?

2 A. Well, I know. I'm -- it's...

3 Q. And so this is a redlined version
4 reflecting changes that were made to, I guess, the
5 original disclaimer -- well, let me -- let me reask
6 that question.

7 This is -- so the redlined language in
8 here is what made it into the final disclaimer that
9 we just looked at in Exhibit 11, correct?

10 MR. DEAN: Object to the form of the
11 question.

12 THE WITNESS: No, that's the wrong
13 sign. There's differences here. For example --
14 I'll just give a quick -- it says "the documents,
15 graphs, and water modeling analyses." It says the
16 water modeling analyses.

17 BY MR. ANWAR:

18 Q. I've got you. Okay.

19 A. Okay.

20 Q. Have you seen this before?

21 A. I don't recall seeing it.

22 Q. Okay. I will represent to you that the
23 meta analysis indicates that ATSDR is a custodian
24 and you're the author.

25 A. Okay.

1 Q. And it's dated May 23rd, 2007. Do you
2 recall this document?

3 MR. DEAN: I -- object to the form of
4 the question, not that we don't accept your
5 representation, and asked and answered.

6 THE WITNESS: This seems to me to be
7 two different documents because this, the one that
8 you handed me, Exhibit 11, okay, the appendix stuff
9 is from the Chapter I, not -- not the cover, not
10 the cover page. The reference is correct, but not
11 that. If you're saying -- and Chapter I probably
12 came out in 2009. I can take a look at the date.
13 February 2009. Okay.

14 BY MR. ANWAR:

15 Q. Do you remember --

16 A. The fact that it may have been in under
17 my ATSDR land or wherever you obtained it from, I
18 don't know how -- how these documents are obtained
19 by DOJ. It could have been sent as an e-mail
20 attachment or Office of Communication or even an
21 epidemiologist, Office of the Director, anybody
22 saying this is what we want to use, but, whatever,
23 I -- you know, honestly do not remember these
24 disclaimers.

25 Q. Okay. It is attached to an e-mail and

1 I will pull that e-mail during the break. We can
2 talk through that e-mail.

3 A. Okay.

4 Q. The one that you're -- you're included
5 on.

6 A. Thank you.

7 MR. ANWAR: Let's take a break for
8 lunch and --

9 MR. DEAN: 45?

10 MR. ANWAR: That's fine.

11 THE VIDEOGRAPHER: Okay. We're going
12 off record. The time is 12:29 p.m.

13 (A luncheon recess transpired.)

14 THE VIDEOGRAPHER: We're going back on
15 record. The time is 1:24 p.m.

16 BY MR. ANWAR:

17 Q. Good afternoon, Mr. Maslia. We are
18 back on the record from a lunch break. Are you
19 okay to continue?

20 A. Yes, I am.

21 Q. Okay. Did you speak with your -- with
22 the counsel about your testimony during the break?

23 A. No, I did not.

24 Q. Okay. Thank you. Before we went on
25 the lunch break, we were discussing what I had

1 marked as Exhibit 12, which is a redlined version
2 of Exhibit 11, Exhibit 11 being a disclaimer and
3 Exhibit 12 being the redline of that disclaimer.

4 A. Okay.

5 Q. I'm going to show you another document
6 that I'm marking as Exhibit 13.

7 (DFT. EXHIBIT 13, e-mail correspondence
8 Bates-stamped CLJA_ATSDR_BOVE-0000157167 through
9 0000157170, was marked for identification.)

10 BY MR. ANWAR:

11 Q. I will represent to you Exhibit 13 is
12 an e-mail exchange from 2007 with you and Deb Tress
13 from ATSDR and Frank Bove from ATSDR. And the
14 e-mail includes an attachment with -- which is a
15 redline of the disclaimer that we were discussing
16 before the break. Take -- take a minute to look at
17 it, but would you agree with that?

18 A. Agree that this is an e-mail about
19 this -- yes.

20 Q. Okay. And so if we start at the
21 beginning of the chain, it looks like you sent an
22 e-mail on May 23rd, 2007 to Deborah Tress and the
23 subject is disclaimer for website. And in it you
24 write, "Deborah, I need a disclaimer that will come
25 up when a person enters the Camp Lejeune water

1 modeling website. Here's my attempt. Can you
2 please review and provide correct legal verbiage?
3 Thanks, Morris." Did I read that correctly?

4 A. Yes, yes.

5 Q. What -- what water modeling website are
6 you referring to?

7 A. Thinking back to 2007, 15 years ago or
8 whatever, I'm looking at the date. It's May 23rd.
9 The -- neither the executive summary or the Chapter
10 A report had come out yet because they were
11 June 2007, is when they came out. And the only
12 thing I can think of is someone above me, my
13 supervisor or the division, were thinking that just
14 like with other ATSDR documents, they wanted to put
15 results on the website, but they wanted a
16 disclaimer, an agency policy-type -- type
17 disclaimer. That's the only thing I can, I mean,
18 recall this many years back, okay?

19 Q. Okay. And I think this came up in your
20 2010 deposition. I realize that's now 15 years
21 ago.

22 A. Okay.

23 Q. But at one point, did the ATSDR website
24 contain a page or have a page that allowed an
25 individual to go in and enter sort of when they

1 were at Camp Lejeune and it produced numbers from
2 the model?

3 A. Yes.

4 Q. Okay. Can you tell me about that?

5 A. Well, as part of our Tarawa Terrace
6 analyses -- at that time it was just Tarawa
7 Terrace. And, of course, ATSDR is focused on
8 providing information to the public on their
9 health, so we requested -- we were working with the
10 U.S. Geological Survey. They had some web
11 developer guys, so we requested an app that someone
12 who resided at Lejeune or someone who didn't reside
13 at Lejeune could put in dates, dates of service,
14 and get an estimate, a quantitative estimate of
15 exposure -- when I say exposures, concentrations of
16 PCE.

17 Q. Okay.

18 A. Okay. And so the web application did
19 go on the website. I'm trying to figure out how --
20 I think you showed me -- it was with this table,
21 because that was Chapter I. That was the last
22 chapter being -- I'm not saying we didn't have the
23 numbers, but anyway, and at some point after it
24 went on the website, I know I got a call and I'm
25 sure my supervisor or the agency got a call from

1 the Department of Navy that they were not pleased
2 with it at all.

3 Q. The website itself?

4 A. You have to pull it down, yes.

5 Q. Okay.

6 A. Pull the application down off your
7 website.

8 Q. What do you recall about the
9 conversation -- about the call with the Department
10 of the Navy?

11 A. Only that it gave quantitative
12 estimates of mean concentrations, and my point --
13 it's the team's point -- was that it's contained in
14 the report and it was just an easier way to present
15 if someone didn't want to read the entire report to
16 do it, and that's all I remember, is that there was
17 some conversations with the Department of Navy.
18 And then our web guys said there was something
19 about security or whatever and the web -- that
20 application never got put back on -- on the web.
21 So my assumption is the agency just wanted to go
22 with tabular values right out of the reports.

23 Q. Okay. We'll get back to the website.

24 A. Okay.

25 Q. I wanted to focus on the e-mail

1 exchange and the -- the redline disclaimer --

2 A. Okay.

3 Q. -- that was attached. So it's -- based
4 on this first -- the first thread on the chain, it
5 sounds like you attempted to draft the disclaimer
6 and you sent it to Deborah Tress, correct?

7 MR. DEAN: Object to the form of the
8 question. Mischaracterizes the document.

9 THE WITNESS: I don't know. If I
10 recall, I was probably asked to produce the table,
11 okay, here because someone wanted it up on the
12 website, okay? And then someone probably said,
13 well, we need to have a disclaimer, okay? I don't
14 know who. I don't know who, but -- and so I
15 attempted to draft a disclaimer not being an
16 attorney, okay --

17 Q. Okay.

18 A. -- or agency policy person.

19 Q. Okay. And so the next exchange is an
20 e-mail from Deb Tress responding to you saying, "so
21 does the website help them estimate their own
22 exposure to the contaminated water?" Did I read
23 that correctly?

24 A. Yes.

25 Q. And then you respond to that further up

1 in the chain. You say, "yes, but they cannot
2 modify our numbers. It just provides results of
3 modeling based on the dates they enter to a website
4 and they can also download a graph and table as a
5 PDF." Did I read that correctly?

6 A. Yes, that's what I just said about
7 getting the tables from the report, okay?

8 Q. And now going further up on the chain
9 to the first page of the exhibit, Deb Tress's
10 response to you on May 23, 2007 says, "how about
11 this? I'm not totally clear how this is being
12 presented, so please edit as needed. I'm not that"
13 -- it says considered, but I think I might be
14 concerned "with liability by ATSDR for the use of
15 the tool, so I took out that type of language."

16 A. Okay.

17 Q. "Thanks". Did I read that correctly?

18 A. Yes.

19 Q. Okay. And then you forward that on to
20 Frank Bove, correct?

21 A. That is correct.

22 Q. And that's the first e-mail on the
23 page, the top of the chain. It says, "Frank,
24 attached is a disclaimer that will appear on the
25 water modeling website. It's been edited by Deb

1 Tress. Let me know if you agree to it and then I
2 will send to our web gurus." Did I read that
3 correctly?

4 A. That is correct.

5 Q. Okay. So earlier you indicated you --
6 you at least couldn't recall having seen this
7 disclaimer before?

8 A. That is correct, yes.

9 Q. But based on this e-mail -- this is
10 your e-mail address and you would have received the
11 disclaimer, correct?

12 A. Yes, yes.

13 Q. Okay.

14 A. That's -- I mean, as I said, it was a
15 lot of things going on around May 2007 with the
16 prep for the subcommittee hearing and trying to get
17 reports approved by the Office of Science and the
18 Office of Director and stuff and...

19 MR. DEAN: So for the record, so we
20 just clarify that Bates stamp numbers ends in one
21 -- Bove 167 and goes through 170. I haven't gone
22 to look, but I presume the document attached is
23 what you're saying is the document that is attached
24 that -- that he sent to Frank Bove?

25 MR. ANWAR: The last document on this

1 chain --

2 MR. DEAN: 170.

3 MR. ANWAR: -- 170 is the attachment to
4 that e-mail thread.

5 MR. DEAN: Okay. Thank you.

6 BY MR. ANWAR:

7 Q. You didn't recall it earlier, but you
8 would have received it and you were involved in the
9 drafting process, correct?

10 A. It's got my e-mail address on it and,
11 again, it looks like Office of General Counsel,
12 Deborah Tress, edited it, okay?

13 Q. Okay.

14 A. And probably -- and sent it back to me
15 and then I -- I didn't accept or reject the
16 redline. It's blue on here, but that's fine. I
17 just sent it on, as you can see by the title of the
18 attachment, is disclaimer underscore MLMOGC
19 reviewed.

20 Q. Okay.

21 A. Okay. So that's -- I forwarded it on
22 to Dr. Bove.

23 Q. Okay. And Exhibit 11, which we
24 discussed before the break, was the Chapter I,
25 Appendix I-5 document. Do you recall that?

1 A. It's the table from Appendix I-5.

2 Q. Yes.

3 A. Again, the final version of the report
4 -- the numbers are the same, but the final version
5 of the complete report was not published until
6 February of 2009, so this must have been -- I
7 can -- I can only surmise that once this was
8 published in 2009, they went back and replaced the
9 original tables. Same numbers, but original
10 tables, okay? We had completed the Monte Carlo
11 simulation, but we had not had the Chapter I report
12 approved, okay? So it's, you know, I guess I'm
13 confused as to -- because the e-mail is dated 2007.

14 Q. Yeah.

15 A. The report is not -- typically we would
16 get a report approved and then if we wanted to pull
17 a table or a PDF or a figure or whatever from it,
18 we would do it that way. So it's the same table.
19 I've checked the numbers, or spot-checked the
20 numbers, and it's the same -- same table. So maybe
21 it was -- the report wasn't drafted when we went
22 ahead and put that, you know, forwarded that to
23 Dr. Bove.

24 Q. Do you have any idea why the disclaimer
25 didn't make it into Chapter I itself, the full

1 report?

2 A. No, that's -- that's a mystery to me.
3 I will say to give credit to ATSDR leadership and
4 management, they did believe in the peer review and
5 expert review panels that we put together, and
6 every report went through at least two peer
7 reviews, one internal and one external, and so I
8 think that's why none of the reports really -- with
9 the -- we'll get to Hadnot Point in a minute, but
10 none of the reports contained any disclaimers like
11 -- like you're showing here. So I don't know what
12 prompted the disclaimer, but...

13 Q. Well, I will -- I will represent to you
14 that -- and you're, obviously, welcome to go look
15 for it yourself. The Appendix I disclaimer is
16 still included on the website as part --

17 A. On the website.

18 Q. -- of the table -- as part of a table
19 document. In the disclaimer where it says "the
20 results, however, may not reflect the actual
21 exposure of specific individuals to contaminants in
22 the water system" --

23 A. Are you referring to the redline or
24 blue line -- I mean, blue line or redline?

25 Q. On Exhibit 11.

1 A. Okay. I'm sorry. Okay. Okay. Go
2 ahead.

3 Q. The final version that's on the website
4 now.

5 A. Okay.

6 Q. In the middle of the disclaimer, it
7 says, "the results, however, may not reflect the
8 actual exposure of specific individuals to
9 contaminants in the water system." Do you agree
10 with that statement?

11 MR. DEAN: Object to the form of the
12 question.

13 THE WITNESS: I would say it has to say
14 that because what we're presenting is a Monte Carlo
15 simulation result, so you've got the calibrated
16 value, the probability at 2.5 percent, the
17 probability at 50 percent, and the probability at
18 97.5 percent. So your exposure may be someplace in
19 the middle there in between those ranges. So from
20 that standpoint, that's a correct statement
21 because, you know, a person's individual exposure
22 could be within that range anywhere.

23 Q. Okay.

24 A. And can I just qualify something?

25 Q. Go ahead.

1 A. When I use the words from my standpoint
2 of exposure, I'm talking about the estimated value
3 of the contaminated drinking water. I'm not
4 referring to exposure like ingestion, inhalation,
5 thermal exposure, okay? I'm just -- so I'm using
6 the word exposure in that sense.

7 Q. You're using exposure in -- in the
8 sense of drinking water?

9 A. Drinking water. Drinking water. But
10 the definition of exposure -- exposure assessment
11 is you have to really look at which pathway or
12 multiple pathways, okay, someone may -- may have
13 been or may be exposed.

14 Q. Understood. Let's turn back to your
15 rebuttal report, which is Exhibit 6.

16 A. This is 5.

17 Q. I know, a lot of documents.

18 A. Four. I've got a copy here, if that's
19 okay.

20 MR. DEAN: Yeah.

21 THE WITNESS: The tabs are just
22 typographical edits. Not technical, typographical.

23 BY MR. ANWAR:

24 Q. That's your version of --

25 A. Yeah, that's my version of my response

1 report.

2 Q. Okay. Your rebuttal report?

3 A. Yes.

4 Q. Which is -- I've marked as Exhibit 6.

5 A. Yeah, it's here someplace.

6 Q. Do you have any, like, markings or
7 writing in that?

8 A. I only corrected -- due to the
9 Maslia-genetic OCD, you know, like, I referenced
10 date is incorrect, but nothing technical. No
11 technical changes or technical reinterpretations on
12 here.

13 Q. Okay. Just like a typo?

14 A. Yes, yes, yes.

15 Q. Okay. Let's -- let's turn to page 27.

16 A. Okay. Okay.

17 Q. Page 27, at the bottom of it, contains
18 a section in your rebuttal report, Section 4.3,
19 excuse me, volatilization of VOCs during water
20 treatment process, correct?

21 A. Yes.

22 Q. And this is a response to the opinions
23 of DOJ's expert Remy Hennet about VOC losses that
24 would have occurred during the water treatment and
25 distribution process at Tarawa Terrace and Hadnot

1 Point, correct?

2 A. It would have occurred only during the
3 water treatment process. It's not possible for it
4 to occur during the distribution because you're
5 dealing with closed pressurized pipes.

6 Q. Okay. You would agree during the water
7 treatment process, correct?

8 A. Well, that's -- yeah, that's -- yes.

9 Q. So I don't want to necessarily read
10 this line by line.

11 A. Okay.

12 Q. Unless you want to direct me to a
13 specific portion, but I'll start more generally.

14 A. Okay.

15 Q. For much of this it appears that you
16 are restating Dr. David Sabatini's opinion on how
17 VOC losses are calculated and the extent of the VOC
18 losses that would have occurred; is that right?

19 A. That is correct.

20 Q. Okay. And do you defer to Mr. --
21 Dr. Sabatini on those opinions?

22 A. Yes, the calculations that he did, the
23 interpretations that he did, I defer to him.
24 That's his area of expertise.

25 Q. Okay. You're not doing any independent

1 calculations on VOC losses, correct?

2 A. No, I'm not.

3 Q. And you're not doing any independent
4 interpretation of those calculations of VOC losses,
5 correct?

6 A. I'm doing comparisons.

7 Q. You're comparing Dr. Hennet's opinion
8 with Dr. Sabatini's opinion, correct?

9 A. And -- and the Marine Corps'
10 consultant, AH Environmental.

11 Q. Okay.

12 A. And our experts who served on the
13 expert panels.

14 Q. Determining VOC losses or calculating
15 them, that's not your expertise, correct?

16 A. That is correct.

17 Q. Okay. So turning to page 30 in your
18 report.

19 A. Okay.

20 Q. Actually, it might be 29. Sorry about
21 that.

22 A. Okay.

23 Q. Okay. I misspoke again. I'm sorry.
24 It's page 31.

25 A. 31?

1 Q. Yeah.

2 A. Okay. I'm there.

3 Q. Okay. So in the -- in the second
4 paragraph there, the first large paragraph, you go
5 on to discuss -- it says, "additionally, in
6 contrast to Remy Hennet's contention that ATSDR
7 ignored or did not account for VOC losses during
8 storage treatment and distribution"...

9 A. I'm there. I'm following.

10 Q. "This issue, including the results of
11 the AH Environmental Consultants report, was
12 discussed in detail with the expert panels convened
13 by ATSDR in 2005 and 2009." Did I read that
14 correctly?

15 A. Yes, yes, you did.

16 Q. Okay. And a little further down it
17 says, "excerpts from the verbatim transcript are
18 provided in Appendix A", and you're talking about
19 the expert panel. "The consensus was there was
20 negligible volatilization, at most 10 percent, from
21 the spiractors." And -- so -- and then you quote,
22 "so although we said it's probably negligible and I
23 agree with Tom's number here, at 90 percent what's
24 going in is coming out on the other end." Did I
25 read that correctly?

1 A. Yes, and then it references Appendix A
2 at the end of the sentence.

3 Q. Correct.

4 A. Okay. To be clear, that's not my
5 quotation.

6 Q. Correct. That's from the expert panel,
7 correct?

8 A. Yes.

9 Q. And that's Dr. Pommerenk?

10 A. Yes.

11 Q. Okay. And the last sentence there is,
12 "in light of the conclusions of AH Environmental
13 Consultants, 2004, and the recommendations of its
14 expert panels, ATSDR made the decision to consider
15 any potential VOC losses from storage, treatment
16 and distribution as negligible." Did I read that
17 correctly?

18 A. Yes.

19 Q. And I believe you reference in it in
20 your report, but I'll pull out the actual document
21 as well.

22 A. In which report? The expert report?

23 Q. It's in your expert report, but let me
24 -- I'm going to pull out the -- the AHE report for
25 you. Hang on a second.

1 (DFT. EXHIBIT 14, ATSDR Support
2 Estimation of VOC Removal report from AH
3 Environmental Consultants Inc., Bates-stamped
4 CLJA_Watermodeling_010000071446 through 0000071512,
5 was marked for identification.)

6 BY MR. ANWAR:

7 Q. I'm handing you what I'm marking as
8 Exhibit 14. Exhibit 14 is the 2004 environmental
9 -- or AH Environmental Consultants report, correct?

10 A. That is correct.

11 Q. It's the one that you reference in your
12 rebuttal report, correct?

13 A. Yes.

14 Q. If you turn to page 4-4.

15 A. Which page? Oh, report page four?

16 Q. Report page 4-4. Thank you.

17 A. Okay.

18 Q. At the top of the page there it states,
19 "based on these observations, there is some
20 uncertainty in removal estimates from the effluent
21 pipes. Additional uncertainties are introduced by
22 varying head losses in the pipes caused by calcium
23 carbonate scale built-up and manual clearing --
24 cleaning. However, it is estimated that PCE and
25 TCE removals due to aeration at the spiractor

1 effluent pipes are likely to be no larger than
2 15 percent." Did I -- Did I read that correctly?

3 A. Yes, yes.

4 Q. So AHE's report determined up to or no
5 larger than 15 percent, correct?

6 MR. DEAN: Object to the form of the
7 question.

8 BY MR. ANWAR:

9 Q. And let me -- let me repeat the
10 question. This AHE report determined that PCE and
11 TCE losses or VOC loss due to aeration at the
12 spiractor effluent pipes are likely to be no larger
13 than -- no, to be -- than 15 percent?

14 A. That's what it states.

15 Q. Okay.

16 A. That's what the report states.

17 Q. And looking back at page 31 of your
18 rebuttal report, that last -- that paragraph we
19 were just looking at, the last sentence is, "so in
20 light of the conclusions of the AHE consultants,
21 2004, and the recommendations of the expert panels,
22 ATSDR made the decision to consider any potential
23 VOC losses from storage, treatment, and
24 distribution as negligible." Did I read that
25 correctly?

1 A. Yes.

2 Q. Whether it's 10 percent VOC losses or
3 up to 15 percent VOC losses, is it your opinion
4 that 10 or 15 percent is negligible -- a negligible
5 percent of losses?

6 A. Yes, compared with the differences, for
7 example, in water sampling or the quality sampling,
8 the uncertainties associated with well scheduling
9 operations. And you've got to look at, you know,
10 everything, not just isolate on -- on the water
11 treatment plant, but considering everything 10
12 percent -- percent, we assumed and we were, I
13 believe, justified in assuming it was negligible,
14 okay? That is an -- the approach we took was a
15 pragmatic engineering approximation through a
16 modeling issue.

17 Q. For purposes of determining exposure in
18 an individual, is a 10 or 15 percent VOC loss --
19 would you consider that to be negligible?

20 A. You would have to speak with the
21 epidemiologist or toxicologist, okay? I couldn't
22 say on an individual level, okay?

23 (DFT. EXHIBIT 15, Analyses of
24 Groundwater Flow, Contaminant Fate and Transport,
25 and Distribution of Drinking Water at Tarawa

1 Terrace and Vicinity, U.S. Marine Corps Base Camp
2 Lejeune, North Carolina: Historical Reconstruction
3 and Present-Day Conditions Response to the
4 Department of the Navy's Letter on: Assessment of
5 ATSDR Water Modeling for Tarawa Terrace,
6 Bates-stamped CLJA_Watermodeling_01_09_0000033263
7 through 0000033326, was marked for identification.)

8 BY MR. ANWAR:

9 Q. I'm handing you what I'm marking as
10 Exhibit 15.

11 A. Okay. Response. Okay.

12 Q. And I wanted to direct your attention
13 to page six, I believe, of the report.

14 A. Okay. The pages, I don't believe, are
15 numbered.

16 Q. I think they're on the top left. Well,
17 and let me --

18 A. Can you give me a Bates number because
19 this doesn't have a report page number.

20 Q. Before I begin, let me -- let me start
21 by asking you a few questions.

22 A. Sure.

23 Q. This is the ATSDR response to the
24 Department of Navy's letter or their critiques on
25 the Tarawa Terrace modeling, correct?

1 A. That's -- yes, this is --

2 Q. And it's entitled, on the first page
3 there, response to the Department of Navy -- to the
4 Department of the Navy's letter on quote -- colon,
5 assessment of ATSDR water modeling for Tarawa
6 Terrace, correct?

7 A. That's correct.

8 Q. Okay. Did you write this response?

9 A. Again, other reports, I wrote parts of
10 it and I coordinated other people's response. I
11 may have asked them for input and if they could
12 respond to a certain section or not, but I
13 coordinated the overall report.

14 Q. Okay. So in coordinating it, similar
15 to the other reports that you oversaw and
16 coordinated, would you have reviewed and had an
17 opportunity to review the -- to comment on the
18 report?

19 A. Yes.

20 Q. And ultimately, what was decided, would
21 you have had an opportunity to sign off on the
22 report?

23 A. It would have come from me in going up
24 through the clearance process, report clearance
25 process of the agency, okay? And so I would have

1 been the one that put it into the clearance process
2 at the first stage once I was satisfied with the
3 report.

4 Q. So you would have -- you would have
5 approved it and then pushed it up the chain,
6 correct?

7 A. Yes.

8 Q. Okay.

9 A. Well, technically a report is only
10 approved by either the Office of the Director or
11 the Office of Science at CDC, okay? An author
12 cannot approve an agency report. They can submit
13 it, they can comment on it and all of that, but
14 it's only those two, Office of Director and Office
15 of Science at CDC, when I was there.

16 Q. And perhaps "approve" is a bad term
17 because it may be a term of art --

18 A. Right.

19 Q. -- within an agency, but you would have
20 had an opportunity to review, comment and sign up
21 -- sign off on it and then send it up the chain to
22 be approved, correct?

23 A. Yes, that is correct.

24 Q. Okay. So on the page with the Bates
25 ending in 33272, if you could turn there.

1 A. Yeah, yeah. 272?

2 Q. Correct.

3 A. Okay. I'm there, 33272.

4 Q. Okay. And then the page before, 33271,
5 it's a Department of Navy comment statement 7.1 and
6 it's an excerpt from their letter. It says,
7 "however, all comparisons did not fall within the
8 calibration range. At the water treatment plant,
9 12 percent of the simulated PCE concentrations
10 failed the calibration standard at the water supply
11 wells, a majority, 53 percent, of the simulated
12 concentrations fell outside the calibration
13 standard."

14 A. Correct.

15 Q. Did I read that correctly?

16 A. Yes.

17 Q. Okay. And so then ATSDR responds. And
18 if you turn the page, as part of the response on
19 the last page there it states, "to address the
20 issue of the intended use of the water modeling
21 results by the current ATSDR epidemiological study,
22 the DON, Department of Navy, should be advised that
23 a successful epidemiological study places little
24 emphasis on the actual or absolute estimate of
25 concentration and, rather, emphasizes the relative

1 level of exposure. That is, exposed individuals
2 are, in effect, ranked by exposure level and
3 maintain their rank order of exposure level
4 regardless of how far off the estimated
5 concentration is to the, quote, true measured PCE
6 concentration." Did I read that correctly?

7 A. Yes.

8 Q. Were you involved in -- did you -- did
9 you write that section?

10 A. No, I did not.

11 Q. Okay. But you reviewed it and you
12 signed off on the response before you sent it off
13 to the appropriate --

14 A. I did not. It seems to me, looking at
15 the language or the verbiage in that last
16 paragraph, that that was written by an
17 epidemiologist, and what I would have done as we
18 were preparing this report -- as I said, we had a
19 team. I may have forwarded it to the
20 epidemiologists of the study and asked them
21 specifically would they review it and care to add
22 anything to it.

23 Q. But you oversaw the response and you
24 reviewed it?

25 A. Yes.

1 Q. And you signed off and sent it up the
2 chain to be approved, correct?

3 A. That is -- that is correct.

4 Q. Okay. And so as I understand it, as
5 I'm reading this, it's -- and this is coming as
6 part of a response to a concern, so maybe you wrote
7 about -- raised about the accuracy of the model
8 based on the calibration. As far as -- it sounds
9 like for purposes of the epidemiological study that
10 was being conducted in which the modeling was
11 supporting, the absolute concentration values
12 produced by the model didn't matter; would you
13 agree with that?

14 MR. DEAN: Object to the form.

15 THE WITNESS: Well, it doesn't say
16 didn't matter. It says little emphasis is placed
17 on it.

18 BY MR. ANWAR:

19 Q. Okay.

20 A. And again, it's from -- I would
21 interpret this, because I know I did not write this
22 section, that that's -- you really need to ask an
23 epidemiologist on the epidemiological
24 interpretation of that.

25 Q. What it says is that that is

1 successful -- that the -- the intended use of the
2 water modeling results by the current
3 epidemiological study places little emphasis on the
4 actual absolute estimate of concentration and
5 rather emphasizes the relative level of exposure,
6 right?

7 A. That's what it says.

8 Q. All right. And then it says, "that is,
9 exposed individuals, in effect -- are, in effect,
10 ranked by exposure level and maintain their rank
11 order of exposure level regardless of how far off
12 the estimated concentration is to the true measured
13 PCE concentration", correct?

14 A. That's what that -- that sentence that
15 you just read says.

16 Q. Okay. So if in that context for the --
17 of the water modeling and what was happening at the
18 time, when you-all were -- so let's turn back to
19 the discussion in your rebuttal report about the
20 VOC losses --

21 A. Okay.

22 Q. -- and ATSDR's characterization of 10
23 or 15 percent of VOC losses as negligible. If
24 ATSDR was performing an epidemiological study that
25 was ranking exposure level and maintaining the rank

1 order of individuals, does it matter -- it doesn't
2 matter whether the VOC losses are 10 percent,
3 15 percent, 25 percent, does it?

4 A. It's an epidemiology question or
5 toxicology or a combination of both, okay? Again,
6 in the response, again, I can tell that's not the
7 way I write. It was written by an epidemiologist
8 in there and I just -- I'm not comfortable
9 answering an interpretation from one or the other,
10 okay?

11 Q. The point I'm getting at is that
12 whatever the concentration level, you know, we're
13 talking about is produced by the model, let's say
14 100, across the board for individuals, the same
15 amount is coming off the top for the VOC losses, so
16 10 percent, 15 percent, it doesn't change the rank
17 of the order -- the rank of individuals for
18 purposes of the epi study, right?

19 MR. DEAN: Object to the form of the
20 question.

21 THE WITNESS: Again, that's an
22 epidemiological analysis. I've never done one of
23 those. I've never ranked, okay, so I don't know
24 what assumptions they are using to put into there.
25 I know they are using the mean monthly

1 concentrations that we reconstructed, but that's as
2 far as I can go.

3 BY MR. ANWAR:

4 Q. ATSDR made the decision -- treated VOC
5 losses as negligible because the water modeling was
6 supporting an epi study, right?

7 A. No.

8 MR. DEAN: Object to the form of the
9 question.

10 THE WITNESS: One has nothing to do
11 with the other. I think we're comparing apples and
12 oranges here. The VOC potential volatilization was
13 geared towards our water modeling and taking the
14 results of the simple mixing model and then putting
15 it through the water treatment process. We did not
16 model the water treatment process and, you know,
17 distributing the -- the water to wherever,
18 locations within Camp -- Camp Lejeune.

19 If -- back up. Based on -- again, I'm
20 referring to the AH report, our experts. We had
21 one of our distribution system experts, and it was
22 our conclusion that 10 percent, 15 percent, was
23 well within engineering applications. That is
24 typically done in -- in engineering applications.
25 You go from theory -- from contaminant fate and

1 transport equation, groundwater flow, and then you
2 have to make some assumptions, okay, some
3 simplifying assumptions or pragmatic --

4 SIRI: I'm sorry. I didn't quite catch
5 that. Can you please say that again?

6 BY MR. ANWAR:

7 Q. Siri wants you to repeat it.

8 A. Okay. I didn't know someone was
9 listening, but -- and so that -- that's what our
10 focus is. Our focus was never on how the
11 epidemiology were going to interpret or use the
12 results other than that the most likely estimates
13 were mean monthly concentrations.

14 Q. When you're building a model and you're
15 -- you're starting with the conceptual model, isn't
16 part of the -- developing the conceptual model
17 understanding what the purpose and the model will
18 be used for?

19 A. No, the purpose is to get -- in terms
20 of, if we can get specific, a groundwater flow
21 model, for example, your conceptual model would be
22 how does water move through the different aquifers
23 or different layers. And contaminant transport, if
24 there's a contaminant source or sources, how do
25 those contaminants then mix or move with

1 groundwater, and then how are they mixed with the
2 different wells that may or may not intercept
3 contaminated water, and then how they're
4 distributed, okay?

5 And so your groundwater flow has
6 specific equations with some parameters that you
7 have to make assumptions on. The contaminant fate
8 and transport has equations that we have to make
9 some engineering approximations or simplifications,
10 and the treatment process we -- we said after
11 looking also at the data, the data, the sampling
12 data that was provided by whoever did the lab
13 analyses that came -- provided to us by our points
14 of contact at Camp Lejeune, but somebody did the
15 analyses, that there was very little negligible
16 indication of any kind of VOC loss from the
17 untreated, where all the raw water went in, to the
18 treated. And that's -- I put that in -- is this
19 the rebuttal report? I put that in the rebuttal
20 report. We had some sampling data that showed
21 that.

22 Q. I guess one of the things I -- and this
23 is just me, like, leveling --

24 A. Right.

25 Q. -- and not, you know, taking off the

1 lawyer hat. One of the things I sort of struggle
2 with is this idea that when the modeling was being
3 performed, that the purpose for which the model was
4 being used is somehow divorced from the decisions
5 that were made with respect to building the actual
6 model. And I'm saying candidly, like, reading the
7 e-mails, the documents --

8 A. Right.

9 Q. -- it's all over the paperwork and the
10 documents at the time that the modeling was built
11 to support the epi study. And I think -- it sounds
12 like, to me, you're saying that when you're
13 building the model, you just had no idea what they
14 were doing with the -- the model results.

15 MR. DEAN: Object to the form of the
16 question. You can answer.

17 THE WITNESS: As I said before, if you
18 look at the start of the project, the start, they
19 asked us -- they saw what we did with Toms River,
20 New Jersey and came to us and said, well, can you
21 do the same thing with Camp Lejeune, meaning
22 monthly concentrations or monthly -- yeah, monthly
23 water concentrations. And so that's where we
24 started and there were, again, the five objectives
25 that I've stated previously, and that's how we

1 designed the model, is to be able to reconstruct
2 concentrations to meet those five objectives and
3 to, you know, express some reliability, uncertainty
4 associated with them.

5 How the epidemiology side or toxicology
6 side of -- of the agency would then take those and
7 what analyses they would do, as I said, we were
8 blinded to that, okay? I could never tell you --
9 to this day, I do not know who was classified as a
10 case, who was a controlled, where they lived, what
11 -- how they served, when they served or anything
12 like that. Because in developing these -- the
13 models for historical reconstruction, they should
14 be, as I termed it, robust, meaning anyone, not
15 just the epidemiologists, anyone should be able to
16 take the results of your model and apply them as
17 they see fit given the uncertainties, the
18 limitations of modeling.

19 BY MR. ANWAR:

20 Q. Frank Bove was the epidemiologist
21 performing the studies, correct?

22 A. He was the senior epidemiologist.
23 There was also -- now it's Dr. Perri Ruckart.

24 Q. Okay.

25 A. Those are the two people I interacted

1 with.

2 Q. Dr. Bove and Dr. Ruckart, correct?

3 A. Yes.

4 Q. And if you were developing the model,
5 you were certainly communicating with Dr. Bove,
6 correct?

7 A. There were e-mails, but not -- he was
8 not questioning us and what assumptions we were
9 making. They would more communicate with us on two
10 aspects. One, there's a CAP meeting and we need an
11 update on the modeling and, two, when are we going
12 to have some final results that we can use for the
13 epi study, okay?

14 Q. Okay. You were communicating with
15 Dr. Bove when building the model, though, correct?

16 MR. DEAN: Object to the form of the
17 question.

18 THE WITNESS: When you say building,
19 are you talking about calibrating the model or
20 doing the conceptual groundwater flow model and
21 what type of code we were going to use?

22 BY MR. ANWAR:

23 Q. Any aspect of developing either of the
24 Tarawa Terrace model or the Hadnot Point/Holcomb
25 Boulevard model. During the course of it, you were

1 discussing what Dr. Bove's needs were, correct?

2 MR. DEAN: Object to the form of the
3 question. Mischaracterizes his prior testimony.

4 THE WITNESS: We communicated about
5 what results they would need, the epidemiologists
6 would need, and could we provide them. They
7 indicated that they would need, at one point,
8 trimester information. So if we could give them
9 monthly, that would -- they would be comfortable
10 with -- with monthly values.

11 BY MR. ANWAR:

12 Q. Was Dr. Bove permitted the opportunity
13 to weigh in on modeling decisions? So, for
14 instance, parameter inputs that you decided on and
15 assumptions that were made?

16 A. I may have copied him if I sent out a
17 group e-mail, if we were discussing modeling
18 things, but he would not come back and say, no, you
19 should use, you know, 100 or 30 or whatever
20 parameter. We never had those kinds of
21 discussions. He left that strictly to the water
22 modeling team.

23 Q. So turning back to your rebuttal
24 report.

25 A. Okay.

1 Q. I think it's page 31.

2 A. Okay.

3 Q. There -- actually, I may have told you
4 the wrong page again. Give me one second. Okay.
5 It's page 30, actually. I'm sorry.

6 A. Okay.

7 Q. At the top of that page it starts, "in
8 addition, Remy Hennet's assertion that" --

9 A. Wait. Page 30.

10 Q. 30 of your rebuttal.

11 A. This says rebuttal.

12 Q. It's the first full sentence.

13 A. Oh, okay. I see it. Okay.

14 Q. It states, "in addition Remy Hennet's
15 assertion that ATSDR did not account for such VOC
16 losses is incorrect." And then it goes on, "first
17 ATSDR analyzed sampling data of water from both
18 pretreatment and posttreatment." And then you list
19 in a table sampling data for the Hadnot Point water
20 treatment system?

21 A. Correct.

22 Q. And the rest of that is a discussion
23 about the sampling data from the Hadnot Point water
24 treatment system. I don't see anywhere in that
25 paragraph any discussion about Tarawa Terrace. And

1 it's true that the Tarawa Terrace model didn't
2 account for VOC losses at all, right?

3 A. No, we said they were negligible at
4 each treatment facility. It's just that at Hadnot
5 Point we actually had sampling data, okay? A pair
6 and a triplet, okay? And, for example, for
7 July 27th, 1982 for TCE, we have -- the untreated
8 water is 19 micrograms per liter and that same day
9 -- I can't say what time it was taken at, but we've
10 got treated water at 21 micrograms per liter,
11 allowing for measurement error. It appears to me
12 that there is no VOC loss and that is in sampling
13 data that -- and so, again, you can calculate using
14 equations, but the sampling data showed no VOC
15 loss.

16 Again, on here there is -- at the top
17 of page 31 it says "at the Tarawa Terrace water
18 treatment plant there's triplet measured data taken
19 on July 28th, 1982." And in this -- in this one
20 it's classified as finished, untreated, and treated
21 water. So 104 micrograms per liter finished water,
22 76 untreated, and 82 treated water, okay?

23 Q. Those --

24 A. Now, again, you have variations like
25 this in water -- water samples, but it does not

1 seem to me that there are any VOC losses.

2 Q. So we'll turn to the sampling data as
3 it relates to Hadnot Point --

4 A. Okay.

5 Q. -- because that discussion is all about
6 Hadnot Point, correct?

7 A. No, no, I just said this is Tarawa
8 Terrace. I just -- the triplet is data from Tarawa
9 Terrace. The TTWTP is our acronym for that.

10 Q. What page are you looking?

11 A. Page 31 at the top.

12 Q. Now, when you were comparing the
13 sampling data to determine no VOC losses, so for
14 both Hadnot Point and Holcomb Boulevard, did you
15 take into account whether or not the -- the wells,
16 the contaminated wells, for those two treatment
17 systems had been pumping?

18 A. We do not have information on sampling
19 data, I believe, on any of the sampling data,
20 whether the wells were pumping or not -- not
21 pumping. We may be able to make some judgments
22 based on before and after if it's at the same --
23 same -- same well, whether the well was pumping or
24 not, but we had no information on the pumping
25 status of the well, but that would not have -- you

1 would not have lost any VOCs in the well because
2 it's not that you have air space in there. The
3 well is screened down through the aquifer, okay?
4 It's completely filled with water.

5 Q. Well, you're -- you're basing the
6 conclusion at the top of page 31 as it relates to
7 Tarawa Terrace, and I think for Hadnot Point as
8 well, you're comparing finished water samples
9 versus untreated water samples, and you're reaching
10 the conclusion, it seems to me, that in comparing
11 those, just the -- the sampling results, there were
12 no VOC losses, right?

13 A. Well, the data indicate that and then
14 taking that in addition to what our expert panel
15 said, maybe 10 percent or so, that leans you
16 towards the minimum for the negligible losses
17 because I would expect if there were VOC losses,
18 and let's say 10 percent, I would expect to see
19 that in the sampling data to be reduced for the
20 sampling data from the untreated water, which is
21 probably the raw water tank where all the wells mix
22 in together, go through the treatment process, and
23 then they put it into a treated water tank either
24 elevated or underground. I would have expected to
25 see some losses.

1 Furthermore, I might add, in the period
2 January 28th through February 8th, 1984, there was
3 an eight-day period when they had to shut down the
4 Holcomb Boulevard water treatment plant. Holcomb
5 Boulevard was never served with -- did not -- the
6 treatment plant was -- never had contaminated
7 water, but when they shut down during that
8 eight-day period, the distribution system going
9 into Holcomb Boulevard received contaminated Hadnot
10 Point water. And if you just look at some of the
11 values, and I put the ranges in there. I believe
12 there's a CLW document that lists them all the way
13 from 24.1 to over 1100. So again, I'm going to ask
14 again, where are the losses?

15 Q. So for instance, for Tarawa Terrace,
16 the -- the source or the primary contaminated well
17 was TT26, right?

18 A. That -- that was the main well, yes.

19 Q. And there's statements in the reports,
20 and we'll look at them, that -- but would you agree
21 that when TT26 was pumping, the -- the contaminant
22 concentration levels were higher?

23 A. Yes.

24 Q. And when TT26 was not pumping, the
25 contaminant concentration levels decreased, and I

1 think you stated in your expert panel that -- in
2 one of the expert panels that the concentration
3 levels went down to almost zero?

4 A. Well, that's shown in our Chapter A
5 report, too. When they shut the well down for
6 maintenance, okay, so it was not pumping, the
7 concentrations at the water treatment plant went
8 down to near -- near zero, and that also is what
9 proved to us that TT26 was the driving force or the
10 driving well in that whole -- whole system.

11 Q. So the only point I'm trying to make
12 with respect to comparing finished samples from
13 finished water versus untreated water at Tarawa
14 Terrace and at Hadnot Point, I mean, simply --
15 context matters. Simply comparing samples from
16 untreated water and finished water doesn't tell you
17 whether the well was pumping, whether the
18 contaminants were increasing, whether the well --
19 whether the well had stopped pumping and the
20 contaminants were decreasing, you can't make a
21 determination on VOC losses solely by comparing a
22 finished water sample and an untreated water
23 sample?

24 MR. DEAN: Object to the form of the
25 question. Compound. Complex.

1 BY MR. ANWAR:

2 Q. You can answer.

3 A. Okay. I think you are confusing -- and
4 I don't mean that as a personal attack.

5 Q. Sure. No offense taken.

6 A. Confusing different mechanisms and
7 different aspects of the entire process of
8 delivering, obtaining water from the aquifer to the
9 delivery point, okay? The samples -- there's some
10 samples at TT26, okay, that's at the well, and that
11 -- that says nothing about -- and honestly, that
12 says nothing about the treatment process. The
13 treatment process occurs after all the wells mix in
14 in the entry to the water treatment plant, okay?

15 So if I take a sample, and let's say
16 untreated water, which will be the raw water tank,
17 okay, and I get a -- a value, a concentration, and
18 then I take a similar sample and I'm assuming they
19 are using the same testing methodology at the
20 treated end, which would be on the other side of
21 the spiractors, the other side, and I don't see
22 any -- any losses, any changes, decreases in
23 concentration, excuse me, can I -- then what I am
24 saying is it's a good assumption, a good
25 engineering assumption, that even -- whatever

1 losses there are are so negligible that we're not
2 able to measure them. Or the people that measured
3 them, the same -- the ATSDR did not actually
4 measure those -- those samples, okay? And that's,
5 again -- and everything that we do in modeling and
6 interpretations and all of that, it's sort of a
7 weight of evidence approach.

8 Q. Sure.

9 A. Okay? So we've got the AH report.
10 We've got our expert panel. We've got -- these
11 members actually did water distribution system
12 testing at various -- not at Camp Lejeune, but at
13 various locations, and we've got sampling data. So
14 you've got to take it all -- all together, okay?

15 Q. I just have a few more questions on
16 this topic --

17 A. Sure.

18 Q. -- and then we'll take a break.

19 A. Okay.

20 Q. Now, using Tarawa Terrace again as the
21 example, TT26 was the main well that was
22 contaminated, correct?

23 A. That is -- that is correct. There was
24 some contamination at TT23, which is referred to as
25 the TT new well. It only ran for about nine months

1 maybe. When it was put in, it was put in to a
2 contaminated aquifer, okay, so that's why its
3 concentrations are high immediately. But again,
4 TT26 was the major contributor.

5 Q. TT26 and TT23 weren't the only wells
6 providing water in Tarawa Terrace, right?

7 A. That is correct.

8 Q. And the wells at Camp Lejeune,
9 including Tarawa Terrace, were cycled, right, in
10 terms of the usage?

11 A. They recycled, yes, yes.

12 Q. And so simply comparing a finished
13 water sample versus an untreated water sample
14 doesn't tell you anything about which well the
15 water was coming from, right?

16 A. Well, we knew that based --

17 MR. DEAN: Object to the form.

18 THE WITNESS: We knew that based on the
19 modeling, okay, the contaminant fate and transport
20 model. The output of the contaminant fate and
21 transport model were the concentrations at specific
22 wells, okay? And you have to look in the model
23 output and you can see which wells were turned on
24 or off during which month. And then we had, again,
25 a simple mixing model.

1 BY MR. ANWAR:

2 Q. And --

3 A. And the key is the simple mixing model
4 mixed all -- all the wells together, okay, for
5 conservation of mass and continuity. And so when
6 we get a monthly concentration out of the mixing
7 model, okay, that's what we said went into the
8 water treatment plant.

9 Q. In -- in comparing finished water
10 samples and untreated water samples for purposes of
11 your rebuttal report in offering opinions about VOC
12 losses --

13 A. Right.

14 Q. -- at Hadnot Point and Tarawa Terrace,
15 did you go back and look to see what time frame the
16 samples came from, whether the wells -- which wells
17 were turned on and off, what information was
18 available?

19 A. Let's see what this is. I looked at
20 the treatment process, okay, because that's -- that
21 was the focal point of those claiming there were
22 major VOC losses versus negligible. And so I
23 looked -- you have to look at the treatment
24 process, okay? The treatment process starts at the
25 mixing of all the wells into the raw water tank.

1 And the assumption, engineering assumption, is that
2 there's instantaneous mixing, and we prove that in
3 the Chapter I report because we run parallel
4 models. We run the full-blown EPANET model, which
5 is water distribution, and we run the mixing model.
6 And after a week or ten days, they are equivalent
7 to the -- out to the four decimal places. So that
8 means you have -- the mixing model in addition to
9 what our expert panel told us, all the wells were
10 mixing at the water treatment plant in the raw
11 water tank and there was instantaneous mixing
12 compared to our monthly concentration needs.

13 Q. Okay. I think my last question on
14 this, so just taking the Tarawa Terrace example
15 here in your report at the top of page 31 where
16 you're comparing the 104 microgram per liter
17 unfinished water versus the 76 microgram per liter
18 in untreated water and the 82 microgram per liter
19 in treated water --

20 A. Right.

21 Q. -- I don't see it anywhere in your
22 report, but -- and so I think you would agree that
23 you don't know what percentage of water in the
24 untreated, treated, and finished water samples at
25 Tarawa Terrace came from TT26, right?

1 MR. DEAN: Object to the form.

2 THE WITNESS: You -- you could -- you
3 could actually compute that because the process to
4 get the mixing model results would be is you take
5 the well's capacity for a given month, how much
6 it's pumping, what the concentration is -- let me
7 back up. Hold on. Get the chapter right. It's
8 easier for me to explain the Chapter A here. Here.
9 Okay. It's -- it's a model here. Okay. Page A40
10 in Chapter A, equations one and two. Concentration
11 of PCE in finished water, okay? So we have all of
12 the information. You see it's summing over however
13 many wells were pumping versus whether they are
14 contaminated or not. So, yes, we do know, but the
15 assumption was -- in agreement with what our expert
16 panel recommended -- is that you could assume
17 instantaneous was a CSTR, continuously stirred tank
18 reactor model, for the mixing model. And so the
19 minute the wells hit the raw water tank, they all
20 mixed. And to us instantly was anything less -- a
21 good portion less than a month. And that's shown
22 in the Chapter I report. I can tell you exactly
23 where in a minute.

24 Q. Why don't we go ahead and take a break
25 if you're --

1 A. Okay.

2 THE VIDEOGRAPHER: Okay. We're going
3 off. Record the time is 2:33 p.m.

4 (A recess transpired.)

5 THE VIDEOGRAPHER: Okay. We are going
6 back on record. The time is 2:43 p.m.

7 THE WITNESS: Is it possible to qualify
8 or continue with where we left off?

9 BY MR. ANWAR:

10 Q. Sure. Did you have something you
11 wanted to --

12 A. Yes.

13 Q. -- correct or --

14 A. I would like you to turn to the Hadnot
15 Point/Holcomb Boulevard Chapter A report.

16 Q. Sure. What page are you --

17 A. Page A38, Figure A15.

18 Q. A38, A15.

19 A. Yes.

20 Q. Okay.

21 A. Okay. This is the same mixing model
22 that we talked about at the Tarawa Terrace. You'll
23 notice the equations on page -- the next, page A1
24 and A2 are the same equations one and two in Tarawa
25 Terrace report in Chapter A.

1 Q. Okay.

2 A. What I want to point out to is -- and
3 this is a conceptual or a schematic. If you look
4 at the distribution network of pipes on the
5 left-hand part of the Figure A -- mixing model
6 approach is the title of that section.

7 Q. Okay.

8 A. You'll see that there are little --
9 towards the right there's HPWTP, that tank
10 represents HP, and you've got contaminated, meaning
11 red, or uncontaminated, blue, symbols there mixing
12 into the -- into the HPWTP. Now, we did not do
13 step-by-step treatment process. What the
14 assumption is, and a correct assumption, an
15 approximation, is that they all instantaneously
16 mixed in the raw water tank. Once they mixed in
17 the raw water tank, if, in fact, there's this
18 massive VOC loss, you would see it in the samples,
19 and we didn't. And so our assumption was that
20 there was negligible losses within the treatment
21 process, and so what -- the concentration in the
22 tank through the mixing model is the same as the
23 contamination anywhere throughout the distribution
24 system.

25 Q. Okay. But you're talking sort of --

1 you're talking in the context of model -- still the
2 model, right?

3 A. That's exactly correct, yes.

4 Q. And at the end of the day, a model is
5 an approximation of reality, right?

6 A. Yes.

7 Q. There is no way to perfectly replicate
8 reality, right?

9 A. No, a model is an approximation. Some
10 are closer approximations and some are -- are not
11 as close, but it is an approximation. But at the
12 end of the day, if we are going to test the model
13 out, I'm speaking generically now of the model,
14 then that's where we go and gather some field
15 information or sampling information and see if it,
16 in fact, proves or supports -- that's probably a
17 better word -- supports the assumptions that we
18 made using this model.

19 Q. The pumping data for Tarawa Terrace and
20 TT26, the wells in Tarawa Terrace and TT26 in
21 particular, that was limited, right?

22 A. The pumping data? We had -- we had
23 monthly data. We had some early on in the --
24 early, early '50s or '40s. We had some annual
25 pumpage data. And then in -- I believe from about

1 -- for Hadnot Point from about 1998 through 2008,
2 we had daily pumping values.

3 Q. You said from 1998 to 2008?

4 A. That's my recollection, yes, we had
5 daily -- daily values.

6 Q. Well -- and those values are sort of
7 outside the time period we're -- we're interested
8 in, right?

9 A. No. Again, you've got the
10 epidemiological study, which goes from '68 to '85,
11 but we're using -- and I'm going to limit this
12 right now to groundwater flow and contaminant fate
13 and transport models; those are boundary-valued
14 problems. So you've got to take them out or start
15 them from a period of known water level, a period
16 of known concentration, and run them out until you
17 get back to a period of known information.

18 We -- at Hadnot Point we had some known
19 information because they were doing remediation
20 pumping so that the models there went out all the
21 way to 2008 because it was another set of data in
22 addition to the 1980s data that could get -- build
23 confidence, substantial confidence, in the modeling
24 results. So the models went out or started based
25 on hydrogeologic and modeling concepts and

1 frametimed where -- and part of the model went
2 through the epidemiologic study period, the two --
3 in other words, the epidemiology did not control
4 when we started or ended the model.

5 Q. 1998 is after 1987, right?

6 A. Yes.

7 Q. And --

8 A. If you're interested in building
9 confidence in your model and testing out the
10 goodness of fit of your calibration, if you've got
11 another set of information past the epidemiology --
12 again, the epidemiology doesn't impact how we're
13 calibrating or developing the model -- then you
14 want to use that.

15 Q. I guess more broadly speaking, you
16 know, we can debate the points of the actual
17 modeling, which, you know, you're an expert on it
18 and I'm not. But if ATSDR's modeling accounted for
19 VOC losses, why was it necessary to make a
20 statement that the VOC losses were -- were
21 negligible and, you know, why was it necessary to
22 make that -- that determination?

23 A. Okay. Because you needed to somehow
24 quantify, I felt, what he meant by negligible. He
25 does not say zero. He said negligible, okay? And

1 I'm speaking again in terms of pragmatic
2 engineering applications doing modeling; you make
3 these kinds of assumptions, okay? He also had
4 wanted to make sure someone -- when we say
5 negligible, if they read the expert panel and saw
6 Dr. Pommerenk, who is, I believe, AH consultant for
7 the Marine Corps who sat on our expert panel
8 saying, well, less than 10 percent, then someone
9 reading our reports would say, okay, negligible 10
10 percent -- even if there's VOC losses, there's
11 somewhere less in that -- in that range, and now
12 I'm looking at sampling data and it doesn't appear
13 to be from the sampling data any -- even 10 percent
14 loss anywhere, so negligible is a good
15 approximation.

16 Q. You -- and coming out of the expert
17 panel, you-all landed on 10 percent, right?

18 A. That's what the expert panel said,
19 okay? And that's when we got together either in a
20 team meeting, not part of the expert panel, but,
21 you know, subsequent, because the expert panel made
22 many recommendations, which we typically either
23 generally followed, and we, you know, we would just
24 say, oh, well, it's 10 percent, that's negligible
25 compared to the variation and all the other

1 parameters. Sampling data, aquifer properties, and
2 things of that -- well operations, things of that
3 nature. So we were confident with the -- had
4 confidence in assuming negligible VOC losses.

5 Q. And the AEE report said up to
6 15 percent, right?

7 A. Yes.

8 Q. And so when -- when we're talking about
9 negligible in terms of the decision ATSDR made in
10 determining VOC losses were negligible, we're
11 talking about between 10 and 15 percent, right?

12 MR. DEAN: Object to the form of the
13 question. Mischaracterizes the prior testimony.

14 THE WITNESS: I would say it was 10
15 percent because the representative of AH Consulting
16 Dr. Pommernek, who was also representing the
17 Department of Navy, U.S. Marine Corps on the expert
18 panel then -- then said, well, you know, I'll give
19 you that 90 -- there's a 90 percent passthrough, so
20 that's 10 percent. And then we also had other
21 water distribution system experts on there and --
22 like Dr. Walski, Dr. Grayman, Dr. Clark, and they
23 indicated in their experience that there would be
24 even less than 10 percent negligible.

25 Q. Okay.

1 A. And they have done analyses with other
2 water distribution systems like Tucson, Arizona,
3 Redlands, California and so on.

4 Q. Let's turn to Exhibit 10, which is
5 Chapter A for Hadnot Point and Holcomb Boulevard.

6 A. Okay. Oh, I've got it open right here.
7 Okay.

8 Q. And let's turn to page A1.

9 A. Okay.

10 Q. So just -- just so the record is clear,
11 we're now discussing the analysis for Hadnot
12 Point/Holcomb Boulevard, right?

13 A. That is correct, summary of findings.

14 Q. And footnote number seven on the first
15 page states, "for this study, finished water is
16 defined as groundwater that has undergone treatment
17 at a water treatment plant and was subsequently
18 delivered to a family housing unit or other
19 facility. Throughout this report and the Hadnot
20 Point/Holcomb Boulevard report series, the term
21 finished water is used in place of terms such as
22 finished drinking water, drinking water, treated
23 water or tap water." Did I read that correctly?

24 A. Yes.

25 Q. So ATSDR modeled -- ATSDR said it

1 modeled water that had undergone treatment at a --
2 at a water treatment plant at Hadnot Point,
3 correct?

4 A. That's not what that says, or that's
5 not what I interpret that to say. What that is is
6 trying to define what finished water is, okay?
7 There are different names. Some people would say
8 potable water, okay? It's not the same as potable
9 water. It's not the same as groundwater. It's
10 treated water, but that statement does not say we
11 modeled the treatment process. And I've -- I've
12 never maintained that we modeled the treatment
13 process.

14 Q. Okay.

15 A. And our expert panel in 2005 also said
16 that the treatment process did not have to be
17 modeled.

18 Q. Let's turn to page A33.

19 A. Okay. Okay. I'm there.

20 Q. Looking at number nine.

21 A. Okay.

22 Q. It states, "reconstructed simulated
23 monthly mean concentrations of PCE, TCE, 1-2-DCE,
24 and vinyl chloride and benzene for finished water
25 at the Hadnot Point water treatment plant were

1 determined by using a materials balance model
2 simple" --

3 A. Materials mass balance.

4 Q. Excuse me. "Materials mass balance
5 model, simple mixing, to compute the flow-weighted
6 average concentration of the aforementioned
7 contaminants. This computational method is based
8 on the principals of continuity and conservation of
9 mass, Masters 1998. The use of the materials mass
10 balance method is justified because all raw water
11 from water supply wells within the Hadnot Point
12 water treatment plant service area was mixed at the
13 Hadnot Point water treatment plant prior to
14 treatment and distribution." And then it says,
15 "details of this method are described in a
16 subsequent section of the report." Did I -- did I
17 read all that correctly?

18 A. Yes.

19 Q. Would you agree that what ATSDR called
20 finished water at the Hadnot Point water treatment
21 plant was based on a material mass balance model,
22 simple mixing, to compute flow-weighted average
23 concentrations of contaminants?

24 A. Yes.

25 Q. And agree that mass -- a mass balance

1 -- agree it was a mass balance model based on
2 continuity and conservation of mass?

3 A. Yeah, that's what equations A1 and A2
4 in this report and equations one and two in the
5 Tarawa Terrace Chapter A report -- the first
6 equation is continuity. The second one is
7 conservation of mass.

8 Q. Agree that continuity and conservation
9 of mass means the simple mixing model assumed that
10 mass of all contaminants entering the water
11 treatment plant were conserved through the water
12 treatment plant?

13 A. Yes.

14 Q. Okay. And they continued, correct?

15 A. What do you mean?

16 MR. DEAN: Objection to form.

17 BY MR. ANWAR:

18 Q. It assumed that they continued the --

19 A. You mean the flow continued?

20 Q. The mass of the contaminants.

21 A. I'm not following you. Are you asking
22 did the concentration from one -- once it's mixed
23 at the raw water tank is the same as the
24 concentration in the finished water tank?

25 Q. I think you answered my question.

1 Let's -- would you agree ATSDR modeled influent to
2 the water treatment plant as having the same
3 contaminant concentrations as the effluent from the
4 water treatment plant?

5 A. No, we modeled -- the influent, to me,
6 by definition, would be the different wells coming
7 into the raw water treatment tank. If you look at
8 the water distribution system utility maps, you'll
9 -- you'll see that the raw water from wells were
10 typically piped over to the raw water tank through
11 concrete pipes, okay, underground pipes. So once
12 all the wells fed into there, in the raw water
13 tank, I assumed there was instantaneous mixing, as
14 the mixing model does, okay, and then that -- that
15 would equal the finished water concentration.

16 Q. Okay. Let's look at A62.

17 A. What? I'm sorry?

18 Q. A62.

19 A. On HP report?

20 Q. Yes.

21 A. Page 62. Okay. Okay.

22 Q. Looking -- focusing on Table A18, you
23 would agree that Table 18 shows, among other
24 things, measured TCE concentrations at the Hadnot
25 Point water treatment plant?

1 A. Yes.

2 Q. Looking at TCE, you would agree there
3 are only a few measurements each of treated and
4 untreated water?

5 A. Yes.

6 Q. Agree the data is insufficient to
7 conclude no treatment losses, right?

8 MR. DEAN: Object to form.

9 BY MR. ANWAR:

10 Q. You can answer.

11 A. Okay. Using the data that we have, you
12 always want more data as a modeler, okay, always.
13 That's -- okay. So if you're asking me as a
14 modeler would I want more data than this, yes, but
15 we were working with the data that we had and that
16 was presented to us. And given this data, I see,
17 again, July 27th, treated -- or let me see the
18 exact wording, untreated and treated, footnote five
19 and six, they are approximately the same value.
20 That's the data I referenced in my rebuttal report.
21 So you use that data because that's what we have.

22 Q. Direct me to that again.

23 A. On page A62, if you go to 7/27/82, the
24 first listing has a footnote five which says
25 untreated. The second listing, 7/27/1982, under

1 TCE, it says 21.

2 Q. You said 7/27/1982?

3 A. Yes.

4 Q. TCE. And then the listing underneath
5 it, you're saying is --

6 A. It gives the treatment status.

7 Q. And your -- your opinion is that the
8 model indirectly accounted for treatment losses
9 based on those two points of data?

10 A. Based on those two points. Based on,
11 also, the January 28th through February 4th, 1985
12 shutdown of the Holcomb Boulevard treatment plant
13 where we just saw huge slugs of TCE within the
14 Holcomb Boulevard treatment system -- not
15 treatment, but distribution system. So again, we
16 used a weight of evidence approach. And then,
17 again, referring back to the expert panel report
18 that said, well, we did 10 percent, we -- we said
19 that justified the assumption of negligible.

20 Q. For the samples that you're -- that
21 we're discussing, the 7/27/1928 for TCE.

22 A. Yes, uh-huh.

23 Q. ATSDR didn't know if HP651 was pumping
24 on that day, right?

25 A. We could go back to the reconstructed

1 -- reconstructed pumping schedule and -- and figure
2 out if it was pumping or not. I would have to look
3 -- I would have to look at our pumping schedule.

4 Q. Okay. But that's a reconstructed
5 pumping schedule, correct?

6 A. It's still the only thing close to
7 reality that we have.

8 Q. But it's not reality, right?

9 MR. DEAN: Object to form.

10 THE WITNESS: It's what we used to
11 reconstruct and then compare these values to -- to
12 that. So it was -- it was pumping in the model.

13 BY MR. ANWAR:

14 Q. For -- in the absence of pumping data
15 for Tarawa Terrace, at least --

16 A. Right.

17 Q. -- ATSDR assumed that a well was
18 pumping unless you had evidence affirmatively
19 disproving that it was pumping, correct?

20 A. That is correct. And we then tested
21 that out through an uncertainty analysis by varying
22 the pumping through a Monte Carlo-type uncertainty
23 analysis, but the calibrated model assumed
24 continuous pumping unless it was shut down for
25 maintenance purposes.

1 Q. And with respect to the samples that
2 we've been discussing, the July 27, 1982, ATSDR
3 didn't know if HP651 was pumping the day before
4 either, right?

5 A. No, there's no indication as to the
6 status of the water supply wells feeding the raw
7 water tank. These are taken at the treatment
8 plant, not at the wells, if I'm -- yes, these are
9 taken at the treatment plant. So the wells have
10 already mixed, on, off, whatever.

11 Q. When you say no indication, what do you
12 mean?

13 A. There's no -- this table here is from
14 the water treatment plant, okay?

15 Q. Yeah.

16 A. So it does not contain an indication as
17 to which wells were on, which wells were
18 contaminated, which wells were on and not
19 contaminated, and which wells were off, okay?
20 This -- this particular table, okay? This is a
21 result of applying the -- a mixing model, a
22 flow-weighted mixing model.

23 Q. When you say this is the result, what
24 do you mean "this?"

25 A. Well, if you look under the

1 reconstructed column, the middle column there.

2 Q. Yeah.

3 A. Okay. That's what -- once we got the
4 concentrations out of the model for each of the
5 Hadnot Point wells --

6 Q. Yeah.

7 A. -- and we can tell which ones were
8 operating, which ones were not and have a zero
9 there, and then we knew what the reconstructed
10 concentration is, so then we would tabulate those
11 into an Excel spreadsheet, do the flow-weighted
12 mixing in the Excel spreadsheet.

13 Q. And, you know, I'm talking about not
14 the reconstructed schedule, but about real-world
15 data?

16 A. I understand that, but, again, as I
17 think we've discussed real early on, if my
18 recollection is correct, these are one point in
19 time samples, okay? And we are -- we are doing
20 monthly simulations, monthly results. So that's,
21 you know, just -- you need to keep that in mind
22 when you're looking at data versus modeling
23 results.

24 Q. Agree -- you would agree that you don't
25 know the percentage of water in those samples that

1 came from HP651?

2 A. Not in the -- not in the samples, but I
3 would know -- I would have to tabulate it, but I
4 would know in the reconstructed column.

5 Q. But the reconstructed column is a
6 simulation, right?

7 A. That's our best estimate, most likely
8 estimate.

9 Q. Okay. And that's because you don't
10 know the real-world data on whether -- what
11 percentage of water in those samples came from
12 HP651?

13 A. Not from the sampling data. However,
14 you do have the previous table, I think, or
15 somewhere in here, it's early on, there is a table
16 -- let's see. Here you go. Page A48.

17 Q. So I wanted to actually change topics a
18 little bit.

19 A. Oh, sure. Okay.

20 Q. Shift gears a little bit. You would
21 agree that it takes time for water to get through
22 the -- the water treatment plant, right?

23 A. Compared to the groundwater system,
24 it's instantaneous. I'm talking about hours or
25 maybe even minutes compared to days or months or

1 longer than that, you know. That's -- I think, as
2 I said previously, water distribution system models
3 use an hour time step, and you typically would
4 measure pressures. If you had any concentrations,
5 you would measure those at, say, at 15-minute
6 intervals, so you're talking about a much more
7 rapid process.

8 Q. Similar to our discussion on TT26 for
9 Hadnot Point, you would agree that whether --
10 whether HP651 was pumping had a significant impact
11 on the concentration of TCE entering the Hadnot
12 Point water treatment plant, right?

13 A. Yes.

14 Q. And you would agree that when HP651
15 stops pumping or stopped pumping, concentration of
16 TCE entering the Hadnot Point water treatment plant
17 would go down very quickly?

18 MR. DEAN: Object to the form.

19 THE WITNESS: Well, we could look at
20 the graph on page A63 in Chapter A here, Figure
21 A27. And you do see up and down with -- of TCE at
22 the water treatment plant, which is indicative of
23 cycling on and off of HP651. But unlike TT26, the
24 only time it goes to zero or close to zero is after
25 they completely turned the well -- the well off.

1 Q. But when HP651 stops pumping,
2 concentration of TCE entering the HP -- the Hadnot
3 Point water treatment plant goes down, right?

4 A. It -- it gets reduced, but because
5 there were so many -- there were other wells
6 pumping and contributing to the water treatment
7 plant and supplied -- supplied water, some of those
8 other wells, if they were contaminated, would --
9 would, you know, add to the concentration at the
10 water treatment plant.

11 Q. You would agree that when HP651 stops
12 pumping, at that very moment water coming out of
13 the Hadnot Point water treatment plant entered into
14 it with TCE concentrations from when HP651 was
15 pumping, correct?

16 A. Could you repeat the question again?
17 I'm sorry. I didn't follow.

18 Q. Sure. So when -- when HP651 stops
19 pumping, the water that was pumping into the Hadnot
20 Point water treatment plant doesn't immediately go
21 away, right?

22 A. That is correct.

23 Q. That water that had been pumping from
24 HP651 continues through the water treatment plant,
25 correct?

1 A. Yes. Again, the pipes are pressurized
2 and water is flowing full, okay? A storage tank is
3 not pressurized like the distribution pipeline, but
4 it's full, and so it's not that you have no water
5 stopped at 651 and then the raw water tank has no
6 more water in it. It's still filled with the
7 previous day's concentration, and if 651 was not
8 pumping on a particular day, you would still have
9 contaminated water in that raw water tank.

10 Q. And so carrying that through to
11 conclusion, if 651 stopped pumping and that water
12 -- but the water that had been pumping from 651
13 into the Hadnot Point water treatment plant entered
14 into it and then continued to be distributed, the
15 finished water sample from -- from that water that
16 pumped through 651 -- or excuse me, from the 651
17 water that had pumped through the Hadnot Point
18 water treatment plant would reflect that
19 contaminated water, right?

20 MR. DEAN: Object to form.

21 THE WITNESS: Okay. Could you clarify
22 that?

23 BY MR. ANWAR:

24 Q. Sure. So a moment ago you agreed with
25 me that when HP651 stops pumping, at that precise

1 moment the water that had been pumping into the
2 water treatment plant at Hadnot Point doesn't go
3 away, right?

4 A. That is correct.

5 Q. It -- that water that had been pumping
6 from 651 remains in the water treatment plant,
7 correct?

8 A. Yes, the water that's there the
9 previous day when HP651 was pumping, let's say --
10 for argument's sake let's say it's still there,
11 okay, but over a day's period it probably moved
12 through the treatment process.

13 Q. And a moment ago we -- we discussed
14 that ATSDR treated or used a mixing model for
15 purposes of finished water, correct?

16 A. That is correct.

17 Q. And so -- well, let's -- let's --
18 stepping away from the model, that water in the
19 Hadnot Point treatment plant from 651, that doesn't
20 immediately disappear, that still ends up in the
21 finished water, correct?

22 A. That is correct.

23 Q. Okay. And then 651 is now stopped and
24 other wells are pumping water to it, correct?

25 A. They are compensating for the loss of

1 the volume of the well, okay? Because at the end
2 of the day, when we were there in 2004 and
3 historically, having spoken with past operators,
4 they had to keep their tanks, finished water tanks
5 nearly filled for fire protection, okay, so they --
6 you would have had to compensate for HP651 with
7 other -- other wells.

8 Q. And those other wells pumping into the
9 HP treatment plant could include wells that weren't
10 contaminated, right?

11 A. That is correct.

12 Q. So in that case, if you were to take an
13 untreated sample and compare it to the treated
14 sample from the -- the HP651 water that went
15 through the system, the treated water would be
16 higher, likely, than the -- the untreated water
17 sample taken at the water treatment plant?

18 A. Again, I think we need to view this in
19 terms of the historical reconstruction that we did
20 on a monthly basis. Even though -- even though the
21 distribution system does the EPANET model, you can
22 do hourly calculations, meaning you can do daily
23 calculations. The output from the contaminant fate
24 and transport model and the mixing model are valid
25 on a monthly basis. So over a month, you would

1 have seen 651 come back on.

2 Q. But again, we're talking about the
3 model simulation world and not the real world?

4 A. But that's what we did at ATSDR. I
5 mean, that's -- that's the whole concept of
6 historical reconstruction or modeling in general,
7 is that we used models and applied models where we
8 may not have information, real data, and you build
9 confidence by the calibration process to use -- use
10 those models. We took, at ATSDR, the sampling data
11 that was provided to us by the Marine Corps,
12 Department of Navy or other -- other water quality
13 labs and that's the data that -- that we had.

14 Q. I'm going to hand you what I'm marking
15 as --

16 MR. ANWAR: I'm sorry. Can you remind
17 me, is this 15? I forgot to write one down. 16.

18 (DFT. EXHIBIT 16, Analyses and
19 Historical Reconstruction of Groundwater Flow,
20 Contaminant Fate and Transport, and Distribution of
21 Drinking Water Within the Service Areas of the
22 Hadnot Point and Holcomb Boulevard Water Treatment
23 Plants and Vicinities, U.S. Marine Corps Base Camp
24 Lejeune, North Carolina, Chapter A-Supplement 2,
25 Development and Application of a Methodology to

1 Characterize Present-Day and Historical Water
2 Supply Well Operations, was marked for
3 identification.)

4 BY MR. ANWAR:

5 Q. Did I actually hand you the exhibit?

6 A. No.

7 Q. Sir, do you have the exhibit?

8 A. No, you didn't tell me what 16 was.

9 Q. Sorry. I just put the sticker on it
10 and I lost my train of thought. I'll just put
11 another sticker on it.

12 Okay. I'm handing you what I've marked
13 as Exhibit 16.

14 A. Supplement 2. Okay.

15 Q. Can you turn to page -- so for
16 starters, this is part of the Hadnot Point/Holcomb
17 Boulevard analysis, correct?

18 A. Yes, it's Supplement 2 of Chapter A.

19 Q. Okay. And the title is "development
20 and application of a methodology to characterize
21 present-day and historical water-supply well
22 operations", correct?

23 A. That is correct.

24 Q. Okay. If you could turn to page S2.2.

25 A. 2.2. Okay. 2.2. Okay. Background?

1 Q. Yeah.

2 A. Okay.

3 Q. And so at the top of that page on the
4 right-hand side --

5 A. Right.

6 Q. -- paragraph starting "detailed daily
7 data."

8 A. Let me just take a look. Okay. I'm
9 there.

10 Q. Okay. So it starts by stating,
11 "detailed daily data pertaining to the pumping
12 schedule of the wells are available subsequent to
13 January 1998", correct?

14 A. That's -- yes, that's what we
15 previously discussed.

16 Q. Sure. And then "prior to 1998, data
17 pertaining to wells operation are limited or
18 unavailable", correct?

19 A. That is correct.

20 Q. And then it goes on to state,
21 "similarly, daily water treatment plant raw water
22 samples are available" --

23 A. Raw water volumes.

24 Q. Volumes. Excuse me, are -- let me
25 reread that.

1 A. Okay.

2 Q. "Prior to, similarly, daily water
3 treatment plant raw water volumes are available
4 after December 1994", correct?

5 A. That is correct.

6 Q. "And then between 1980 and 1994,
7 monthly raw water volumes are available. Yearly
8 volumes are available for some times -- for some
9 years prior to 1980. A trendline was used to
10 estimate raw water flows for years prior to 1980
11 when no data exist. Monthly raw water flow
12 percentages were then calculated using known
13 monthly data for the period 1980 to 2004. These
14 values are used to estimate monthly raw water flows
15 prior to 1980. This methodology is based on two
16 assumptions: Similar characteristics of the
17 operational patterns of the wells and water
18 treatment plants for the periods of time before and
19 after January 1998 and, two, the quality between
20 total water volume delivered to the water treatment
21 plant from the operating wells and the water
22 treatment plant raw water volume data at all
23 times." Did I read that correctly?

24 A. Yes, you did.

25 Q. Okay. Agree -- you'd agree that prior

1 -- based on this, prior to 1998, data pertaining to
2 well operations was limited or unavailable?

3 A. Yes, that's what that says.

4 Q. Agree that according to this, that
5 there were daily water treatment plant raw water
6 volumes available after 19 -- after December 1994,
7 correct?

8 A. Yes.

9 Q. Agree there were monthly raw water
10 volumes available for 1980 to 1994, right?

11 A. Yes.

12 Q. And then there were some yearly volumes
13 prior to 1980, right?

14 A. That is correct.

15 Q. ATSDR had to estimate pumping schedules
16 due to the lack of this data, right?

17 A. We had to estimate pumping schedules to
18 get the operational -- I'm equating operational and
19 pumping schedules to be able to code them in -- on
20 a monthly basis to the -- to the model, to the
21 groundwater flow and contaminant fate and
22 transport.

23 Q. And so if we go on to the next
24 paragraph, data availability.

25 A. Okay.

1 Q. "Four types of data sources pertinent
2 to water supply well operation -- operational
3 records and water treatment plant raw water records
4 are used in this supplement." It says "these are
5 daily operational records, January 1998 to
6 June 2008. Number two, Camp Lejeune historic
7 drinking water consolidated document repository
8 records. Number three, Camp Lejeune water
9 documents. Number four, U.S. Geological Survey.
10 Using these data sources, operational chronologies
11 for 1996" -- excuse me.

12 A. Wait.

13 Q. "Using these data sources operational
14 chronologies for 96 wells supplying groundwater, in
15 parentheses, raw water, to the Hadnot Point water
16 treatment plant and Holcomb Boulevard water
17 treatment plant were developed." Did I read that
18 correctly?

19 A. Yes, yes.

20 Q. You would agree that ATSDR didn't use
21 pumping data from the '80s, but used data from
22 pumping schedules after 1998 to estimate pumping
23 schedules during 1953 to 1987?

24 A. The way the methodology that's
25 described in Supplement 2, there was a training

1 period and then a predictive period. So the
2 training period typically went from 1998 to 2008
3 because that was known information on a daily
4 basis. And once we obtained the characteristics of
5 the operating wells based on that, then we could go
6 out and where we either had partial data or missing
7 data, use the prediction from there and apply the
8 prediction to the data gaps.

9 Q. So for Hadnot Point/Holcomb Boulevard
10 analysis and the model, you used predictions based
11 on pumping schedules after 1998, correct, to -- to
12 let me ask that again.

13 So based -- for Hadnot Point/Holcomb
14 Boulevard you used pumping schedules from after
15 1998 and predicted backwards the pumping schedules
16 during 1953 to 1987, right?

17 MR. DEAN: Object -- object to the
18 form.

19 THE WITNESS: Again, it says -- I think
20 it was up -- yeah, we also used -- for data we're
21 missing a trendline, which is an accepted
22 statistical approach in engineering. And the
23 algorithm developed by who is now Dr. Telci, the
24 first author on here. At the time he was with
25 Georgia Tech, used the training period for periods

1 of known water supply operations and then used the
2 predictive period for when we had to predict the
3 operations. So you have a combination of both
4 training and prediction.

5 BY MR. ANWAR:

6 Q. And that's training and prediction, but
7 that's -- that's both simulated pumping schedules,
8 correct?

9 A. No, well, the training was based on
10 daily data, okay, and all we're interested in is
11 monthly.

12 Q. The training was based on pumping
13 schedule data after 1998, correct?

14 A. Yes, yes.

15 Q. And then the simulated is the pumping
16 schedule from 1953 to 1987, right?

17 A. It would go through '98, actually. I
18 mean, for -- Hadnot Point/Holcomb Boulevard didn't
19 come online until '72, so you have different
20 periods there, but, yes, it would -- that's the
21 predictive period, is where you had either limited
22 -- because you might have a month information here
23 and there and stuff like that, but that's -- or
24 unknown information that you would use the
25 predictive values that came out for each well, each

1 certain well.

2 Q. Let's turn to page S12.

3 A. Okay. Okay.

4 MR. DEAN: S2.12 or just S12?

5 MR. ANWAR: I'm sorry. It's S2.12.

6 MR. DEAN: Okay.

7 MR. ANWAR: I've been staring at these
8 documents too long.

9 BY MR. ANWAR:

10 Q. And at the top of the left-hand --

11 A. Right.

12 Q. -- page it says, historical
13 reconstruction period, 1942 to 2007, prediction
14 process, correct?

15 A. Right.

16 Q. And this is the -- the training and the
17 -- this -- this paragraph in this section is
18 addressing the training and the prediction process
19 you were just describing, correct?

20 A. I believe it is. This shows the start
21 of prediction process. There should be another
22 flow chart somewhere, I seem to recall.

23 Q. I wanted to just ask you about some of
24 the language in the first paragraph.

25 A. Okay. Sure, sure. Go ahead.

1 Q. It says, "similar to the training
2 process, the prediction process, PP, is structured
3 as a series of calculations and checking steps.
4 The results of the steps were placed in separate
5 sheets of a Microsoft Excel workbook." And then
6 that last sentence, "because some wells did not
7 physically exist during the training period,
8 surrogate wells were selected to represent these
9 untrained wells." Did I read that correctly?

10 A. Yes, yes.

11 Q. And so you would agree in the training
12 process for reconstructing historical well pumping
13 schedules, ATSDR used surrogate wells for wells
14 that were untrained?

15 A. No, for wells that -- wells that did
16 not physically exist, okay? If you look at Figure
17 S2.2 on page S2.4.

18 Q. 2.4?

19 A. Yes. It's a full-page figure.

20 Q. Okay. Oh, I see. It's 2.4 --

21 A. S2.4, Figure S2.2.

22 Q. Okay. Yeah, I'm looking at 2.40. Go
23 ahead.

24 A. Okay. For example, you can take an
25 example here, let's just look at -- coming down,

1 HP604, okay? It stops operations at about 1960,
 2 but then you've got HP637. So HP604 may be -- or
 3 HP637 may be a surrogate well because HP604 no
 4 longer exists. And I think we list the --
 5 somewhere in here there's a table -- oh, there you
 6 go. The surrogate wells, okay. Table S2.2 on page
 7 S2.13, there's a list.

8 Q. Okay. So --

9 A. And looking at those wells and looking
 10 at that figure, you can see which wells were
 11 surrogate for wells that were no longer operating.

12 Q. On S2.13.

13 A. Yes.

14 Q. Table S2.2.

15 A. Right.

16 Q. Just looking at that, the surrogate
 17 wells include -- let me double-check. Surrogate
 18 wells were used for HP651, HP634, HP602, HP603 and
 19 HP608, right?

20 A. 608, yes.

21 Q. You would agree that ATSDR modeled
 22 reconstructed pumping schedules for these wells --
 23 strike that.

24 Okay. You would agree that ATSDR
 25 modeled reconstructed pumping schedules for these

1 wells based on 1998 to 2008 pumping schedules for
2 different wells, correct?

3 A. Say that -- say that again.

4 Q. Sure. So a moment ago we talked -- you
5 know, we -- we went through a list of the wells,
6 651, 634, 602, 603, 608, for which surrogate wells
7 were -- were used, right?

8 A. Yes.

9 Q. And to determine the pumping schedule
10 for these wells, 651, 634, 602, 603, 608, ATSDR
11 reconstructed the pumping schedule for surrogate --
12 based on surrogate wells from 1998 to 2008,
13 correct?

14 A. Yes.

15 Q. Okay.

16 A. That was the training period.

17 Q. Let's go back to Exhibit 10, which is
18 Chapter A for Hadnot Point/Holcomb Boulevard.

19 A. Okay. I'm right here. Yes.

20 Q. Give me a second and I will catch up
21 with you. Turn to page A84, please.

22 A. Okay. A84. Okay. Where it says
23 "trichloroethylene source release date sensitivity
24 analysis?"

25 Q. Correct.

1 A. Okay.

2 Q. So this is a discussion in Chapter A
3 for Hadnot Point/Holcomb Boulevard about TCE's
4 source release date and the sensitivity analysis
5 that was performed, correct?

6 A. Yes.

7 Q. Okay. So I wanted to start by reading
8 from that first paragraph on the left.

9 A. Okay.

10 Q. Which starts, "historical records
11 delineating the timing and volume of inadvertent
12 releases of solvents during routine -- routine
13 operations from leaking" -- it says "UST". Those
14 are underground storage tanks, right?

15 A. That's correct.

16 Q. Okay. "From leaking UST systems or
17 from disposal solvent waste, spent dry cleaning
18 filters or other materials, were not available for
19 the Hadnot Point/Holcomb Boulevard study area."
20 Did I read that correctly?

21 A. Yes.

22 Q. "For modeling purposes, a median source
23 release date of nine years from the date of the
24 underground storage tank system installation or
25 site development, in the case of the HPLF area",

1 which is a Hadnot Point landfill area, "was used in
2 the contaminant fate and transport models." Did I
3 read that correctly?

4 A. Yes.

5 Q. "This source release date formulation
6 is consistent with empirical data indicating that
7 the median time frame for leak development in
8 underground storage tank systems, typically in
9 piping and joint components, is nine years from
10 installation date." And there's a source to an EPA
11 document and another cite source. Did I read that
12 correctly?

13 A. That is correct.

14 Q. Okay. Then it goes on to state, "UST
15 systems were not the source of contaminants in the
16 Hadnot Point landfill area. However, given the
17 lack of historical information, a similar source
18 release time frame, in this case seven years from
19 site development, was applied to the Hadnot Point
20 landfill area sources within the model." Did I
21 read that correctly?

22 A. Yes.

23 Q. Would you -- you'd agree, based on this
24 paragraph, that historical records delineating or
25 providing information about the time and volume of

1 solvent contaminant releases from underground
2 storage tank systems, disposal of solvent waste,
3 spent dry cleaning filters or other materials
4 wasn't available for the Hadnot Point area?

5 A. That is correct. And that is why we
6 went to external references or other references
7 like the ones that we -- we cited, the EPA report
8 '6/'87 and the Gangadharan, et al., '87. I think
9 they discussed something like over 12,000 tanks
10 that they analyzed that -- and so we -- we felt
11 that was a good source of information to use.

12 Q. ATSDR -- still based on this paragraph,
13 you would agree ATSDR, the Hadnot Point/Holcomb
14 Boulevard model, assumed all underground storage
15 tank systems began releasing contaminants nine
16 years after the system was installed, right?

17 A. It's -- typically it was the piping
18 joints, okay? I think we say in there the actual
19 tank did not necessarily leak, but it was at the
20 pipe joints because of the construction methods
21 back then in the '40s and '50s and '60s, unlike
22 today where you have to have a concrete pad, solid,
23 and then you put the tank on. They just dug the
24 hole, put the tank on, then when they -- and
25 connected the pipes. And when the tank filled up,

1 then the pipes flexed, and that's where you got the
2 leakage.

3 Q. So it -- ATSDR, the Hadnot
4 Point/Holcomb Boulevard model assumed that the
5 piping joints for underground storage systems began
6 releasing contaminants nine years after
7 the systems --

8 A. Yes, based -- based --

9 Q. -- were installed?

10 A. -- on the references that we cited.

11 Q. Okay. And as you indicated, based on
12 references, that was based on an EPA study on
13 underground storage tank system leaks, that
14 following nine years was the median time frame for
15 leak development?

16 A. Yes.

17 Q. ATSDR assumed contaminant sources in
18 Hadnot -- in the Hadnot Point landfill started
19 seven years --

20 A. Yes.

21 Q. -- after site development, right?

22 A. Yes.

23 Q. Okay.

24 A. That's because the landfill, to our
25 knowledge, was unlined and it was not tanks. It

1 was just disposal of landfill material,
2 contaminated landfill material.

3 Q. And it was necessary to make these
4 assumptions about sort of the contaminant start
5 dates because the information of when the
6 underground storage tanks and the Hadnot Point
7 landfill began releasing contaminants, that's not
8 available, right?

9 A. You're talking about the Hadnot Point
10 industrial area or the landfill?

11 Q. Well, let's -- let's break them up.

12 A. Okay.

13 Q. So the assumption was made about
14 underground storage tanks systems beginning to
15 release contaminants nine years after the system
16 was installed, right?

17 A. Yes, that would be the Hadnot Point
18 industrial area.

19 Q. And -- but that's because -- and that
20 assumption was made because the data available
21 precisely identifying or pinning down when the
22 underground storage tanks began releasing
23 contaminants does not exist?

24 A. That is correct.

25 Q. Okay. And the same is true for the --

1 the Hadnot Point landfill assumption, correct?

2 A. Right. And we used a shorter time
3 period, again, because there were not underground
4 storage tanks, per se. It was a landfill, most
5 likely unlined, okay, and not individual tanks, but
6 just waste thrown or disposed of into the landfill.
7 So we assumed it would have a, you know, two-year,
8 short period until it started leaking for the
9 modeling purposes.

10 Q. But -- okay. Understood. But in terms
11 of real-world data, in terms of the actual data,
12 precisely pinning down when the Hadnot Point
13 landfill started releasing contaminants, that
14 doesn't exist, right?

15 A. Not to my knowledge, but that, again,
16 is part of the model -- model calibration process,
17 okay? That makes the source, then, a calibration
18 parameter both in terms of strength and in terms of
19 duration.

20 Q. Okay. And if -- turning to the next
21 page, A85.

22 A. Yes.

23 Q. That's the calibration you're -- you're
24 referencing, right?

25 A. That's a sensitivity -- you're in the

1 sensitivity analysis section, which is part of the
2 uncertainty analysis. We wanted to see the impact
3 of varying, again, the source release date.

4 Q. And that's what I meant. So this -- as
5 I read the sensitivity analysis, you varied the
6 release source -- the source release date from a
7 period of -- let's see -- minus nine years, meaning
8 nine years before the calibrated source release
9 date, to plus nine years, meaning nine years after
10 the calibrated release source date, correct?

11 A. That is correct.

12 Q. And in all of these scenarios, nine
13 years before the release -- calibrated source
14 release date, the model was still able to -- well,
15 strike that.

16 Well, can you remind me, what was the
17 calibrated source release date?

18 A. Hold on. Let me see. I have to go
19 back to off the top of my head. Well, the model
20 started in 1942 for Hadnot Point.

21 Q. Sure.

22 A. Hadnot Point landfill industrial, 1942,
23 I believe. So nine -- nine years after that would
24 be 1951, so that would be the calibrated.

25 Q. Okay. I've got you. Let's -- looking

1 -- returning back to the sensitivity analysis.

2 A. Okay.

3 Q. As -- you agree that this shows the
4 effect of the calibrated model of varying the start
5 date of contaminant sources, right?

6 A. Yes. What it does not show, as any
7 sensitivity analysis, it doesn't show whether
8 that's realistic or not. These are numerical,
9 okay? In other words, it just shows numerically
10 how the concentrations would shift forward or
11 backwards depending on the release date.

12 Q. In all of these scenarios, nine years
13 earlier than the calibrated source release date --

14 A. Right.

15 Q. -- five years earlier than the
16 calibrated source release date, the actual
17 calibrated source release date, which I see there,
18 it appears to be 1951, 1952?

19 A. Yeah, that's what we said, yeah.

20 Q. Yeah. Five years after the calibrated
21 release source date --

22 A. Right.

23 Q. -- nine years --

24 A. Right.

25 Q. -- after the calibrated release source

1 date, they all seem to converge during the period
2 of the epidemiological study. Do you see that?

3 A. Yes.

4 Q. And so based on the sensitivity
5 analysis, it's possible any one of these ranges
6 could have been the release source date?

7 A. No, because we assumed, as we did with
8 Tarawa Terrace, that we had a -- the calibrated
9 parameters would be your most likely to have
10 occurred, okay? And then these others are just
11 seeing the impact on -- on the model, I mean,
12 that's, you know, a five-year or nine-year change
13 is a pretty major, major change --

14 Q. Don't these --

15 A. -- of the release date, okay, so -- but
16 the most likely one is the calibrated one. I think
17 that's important to understand.

18 Q. I understand that the -- the most
19 likely is the -- you know, it's your opinion the
20 most likely --

21 A. Yes.

22 Q. -- is the calibrated?

23 A. Yes.

24 Q. But doesn't the sensitivity analysis
25 show that plus or minus nine years or five years

1 from the calibrated source release date, that it's
2 possible?

3 A. It's a possibility.

4 MR. DEAN: Object to the form.

5 THE WITNESS: It's a possibility, but,
6 again, that's -- typically, when you're conducting
7 sensitivity analyses and uncertainty analyses, you
8 want to get an understanding of how the system is
9 reacting to changes in -- in this case, it's a
10 single parameter.

11 Q. I'm going to mark another exhibit.

12 (DFT. EXHIBIT 17, Analyses and
13 Historical Reconstruction of Groundwater Flow,
14 Contaminant Fate and Transport, and Distribution of
15 Drinking Water Within the Service Areas of the
16 Hadnot Point and Holcomb Boulevard Water Treatment
17 Plants and Vicinities, U.S. Marine Corps Base Camp
18 Lejeune, North Carolina, Chapter C: Occurrence of
19 Selected Contaminants in Groundwater at
20 Installation Restoration Program Sites, was marked
21 for identification.)

22 BY MR. ANWAR:

23 Q. I'm handing you what I'm marking as
24 Exhibit 17.

25 A. Chapter C. Okay.

1 Q. This is Chapter C for the Hadnot
2 Point/Holcomb Boulevard analysis, correct?

3 A. That's correct.

4 Q. I would like you to turn to C98.

5 A. C98. Okay. Well, okay. Let's -- let
6 me rearrange the clip so I can...

7 Q. What's that?

8 A. Let me rearrange the clip.

9 Q. Sure.

10 A. Okay. C98. Okay. Table C8.

11 Q. Yes, Table C8. And Table C8 is
12 entitled -- or titled "summary of analysis for
13 benzene, toluene, ethylbenzene and total xylene and
14 water samples collected at Hadnot Point water
15 supply wells, Camp Lejeune", right?

16 A. Right.

17 Q. Okay. I wanted -- directing your
18 attention to HP602.

19 A. Okay.

20 Q. It has concentrations there for one,
21 two, three, four, five, six, seven, eight dates
22 there between 1984 to 1981, correct?

23 A. Yes, with two below detection limits.

24 Q. Correct, so two below detection limits
25 for HP602?

1 A. Yes.

2 Q. And then the other five above detection
3 limits with some value?

4 A. No, there's six.

5 Q. Oh, there's six. Excuse me.

6 The other six are above the detection
7 limit with some value and they are all ranging from
8 1984 to 1991, correct?

9 A. That is correct.

10 Q. And it appears five of the samples, the
11 -- for benzene there at HP602 are from '84?

12 A. Is that a question? I'm sorry.

13 Q. Yeah, is that right?

14 A. Okay. I've got one from '84, one, two,
15 three, four. Four above detection limits are from
16 1984.

17 Q. Okay. And then there's one from '85,
18 one from '86, then one from '91, correct?

19 A. Yes, that's correct.

20 Q. And then if we go down to HP608.

21 A. Okay.

22 Q. There are four samples between '84 and
23 '86, correct?

24 A. Yes.

25 Q. And one appears to be below the

1 detection limit?

2 A. Right.

3 Q. Okay. You would agree that this table,
4 it summarizes the measurements of benzene at the
5 Hadnot Point water supply -- water supply wells,
6 right?

7 A. Yes.

8 Q. And agree that benzene -- you would
9 agree that benzene at the Hadnot Point source wells
10 found only benzene above the detection limit at
11 HP602 and HP608, correct?

12 A. 608, yes. Let me -- 608, that's
13 correct, and then -- yes, above -- yeah, above the
14 detection levels, yes.

15 Q. And the samples at 602, the
16 concentration levels of benzene and the samples at
17 602 are much higher than the samples at 608, right?

18 A. Yes.

19 Q. For instance, the highest sample there,
20 at 602, is 720 micrograms per liter, right?

21 A. Yes.

22 Q. And the highest sample at 608 appears
23 to be four micrograms per liter?

24 A. Yeah, yes.

25 Q. Okay. So you would agree that the

1 driving source of benzene contamination at the
2 Hadnot Point water treatment plant was HP602,
3 right?

4 A. I would actually like to look at my
5 graphs here because we really need to look at --
6 okay. Benzene. HP602, yes.

7 Q. That was the --

8 A. Yes.

9 Q. -- driving source of benzene
10 contamination for that Hadnot Point water treatment
11 plant, right?

12 A. That's -- that's the measured data that
13 we have, so yes.

14 Q. Okay.

15 A. Based -- based on the measured data.

16 Q. Okay.

17 A. And the -- and the supply list.

18 Q. Let's turn back to -- I'm jumping
19 around a little bit -- Chapter A for Hadnot Point,
20 which is Exhibit 10.

21 A. For Hadnot Point? Yeah, I've got it
22 right here.

23 Q. Actually it's Supplement 1 for --

24 A. Okay. I don't have Supplement 1. I've
25 got Supplement 2 that you gave me.

1 Q. Okay. Let me mark it, then.

2 THE VIDEOGRAPHER: Sir, I'm going to
3 need to change the media when you get to a stopping
4 point.

5 MR. ANWAR: Sure. Let's stop right
6 now.

7 THE VIDEOGRAPHER: All right. Going of
8 record. The time is 3:59 p.m.

9 (A recess transpired.)

10 THE VIDEOGRAPHER: Okay. We are going
11 back on record. The time the 4:10 p.m.

12 BY MR. ANWAR:

13 Q. We are back on the record from a short
14 break, Mr. Maslia. Are you okay to continue?

15 A. Yes.

16 Q. Okay. Did you speak with your counsel
17 outside or during the break?

18 A. No, I did not.

19 Q. Okay. Thank you.

20 I'm handing you what I'm marking as
21 Exhibit 18.

22 (DFT. EXHIBIT 18, Analyses and
23 Historical Reconstruction of Groundwater Flow,
24 Contaminant Fate and Transport, and Distribution of
25 Drinking Water Within the Service Areas of the

1 Hadnot Point and Holcomb Boulevard Water Treatment
 2 Plants and Vicinities, U.S. Marine Corps Base Camp
 3 Lejeune, North Carolina, Chapter A-Supplement 1,
 4 Descriptions and Characterizations of Data
 5 Pertinent to Water-Supply Well Capacities,
 6 Histories, and Operations, was marked for
 7 identification.)

8 BY MR. ANWAR:

9 Q. Okay. This is Chapter A, Supplement 1
 10 for the Holcomb Boulevard/Hadnot Point analysis --
 11 or the Hadnot Point/Holcomb Boulevard analysis.

12 A. Right, that's correct.

13 Q. And it's titled "descriptions and
 14 characterizations of data pertinent to water-supply
 15 well capacities, histories and operations", right?

16 A. Yes.

17 Q. Okay. If you could turn to page S117.

18 A. Okay. I'm there.

19 Q. S117 is a figure for well HP602, right?

20 A. It's a table, yes.

21 Q. Table. You'd agree that this table
 22 shows what ATSDR concluded about HP602 operating
 23 history and capacity history, right?

24 A. Yes.

25 Q. Okay. You'd agree that well HP602 had

1 a relatively small capacity, right?

2 A. I would say -- I would say it'd
3 probably have an average capacity. I mean, there's
4 some -- like 69 goes down to 50 or 30, it looks
5 like. They then redeveloped the well. So I would
6 say it's average. It's average capacity.

7 Q. If you compare it to HP well 608 on
8 page S126.

9 A. HP608. Okay.

10 Q. Would you agree that the capacity for
11 well HP602 was less than, generally speaking, the
12 capacity for well HP608?

13 A. Yes.

14 Q. And focusing back on HR602 on S117.

15 A. Okay.

16 Q. Would you agree that the capacity
17 fluctuated significantly?

18 A. Yes, it fluctuated.

19 Q. Okay. And it fluctuated in a range
20 from 30 GPM on September 4th, 1969 --

21 A. Right.

22 Q. -- to 154 GPM on October 24, 1984,
23 right?

24 A. Yes.

25 Q. Looking at the table for HP602, you

1 would agree that HP602 was out of service multiple
2 times, correct?

3 MR. DEAN: Object to the form.

4 THE WITNESS: No, it's only out of
5 service one, two, three -- three times.

6 BY MR. ANWAR:

7 Q. I see -- it was out of service April of
8 1979?

9 A. Yes, that's one. Oh, out four times.
10 Out.

11 Q. It was out of service in October of
12 1981?

13 MR. DEAN: Which well? 60 --

14 THE WITNESS: 602.

15 MR. DEAN: Okay.

16 BY MR. ANWAR:

17 Q. You agree with that?

18 A. Yes, yes -- well, no, it says out.
19 Again, these records are directly from either the
20 water utility at Camp Lejeune or the well driller
21 or whatever. So it says out. It does not say out
22 of service. I don't know if that means -- if that
23 means it was just out on that date or whatever, but
24 the rest of them say out of service.

25 Q. Okay. It was -- it says out of service

1 on October 1981, correct?

2 A. Yes.

3 Q. So there's an October 1981 that says,
4 quote, out, and then the following entry on the
5 table is October 1981, out of service, right?

6 A. Yes, to me indicates we had, at least
7 on that one, a multiple record or two different
8 sources of records.

9 Q. And then November 30th, 1984, it was
10 out of service as well, right?

11 A. Yes.

12 Q. So it was out of service at least three
13 times, correct?

14 A. Yes.

15 Q. And then as of November 30th, 1984, it
16 was permanently closed or terminated, right?

17 A. Well, service was terminated and then
18 abandonment would be in '94, permanently closed.

19 Q. What -- what do you understand the
20 distinction to be between service terminated and
21 abandoned?

22 A. Service terminated would indicate they
23 just stopped using it, but it might still be
24 available for emergency purposes, whereas,
25 abandonment would mean that they would, I would

1 say, pull the well screen out, pull the pump out,
2 and maybe they seal it up with bentonite, concrete,
3 the hole up.

4 Q. Okay.

5 A. That's the difference. There's an
6 example for -- at Tarawa Terrace for TT23 that --
7 it says it was out of service, but, in fact, we
8 have records that show during April of '85 they
9 actually used it because they were short of water,
10 okay? So unless it's abandoned, the well casing
11 pulled and then concrete up -- that's what service
12 terminated means to me, is that it's not being
13 used.

14 Q. Okay. Based on the information in the
15 table, which I assume comes from the available
16 data, HP602 wasn't used after November 30th, 1984,
17 right?

18 A. That's what that indicates.

19 Q. Okay.

20 A. We have no -- no data between -- or
21 there's -- yeah, no data listed in the table
22 between -- after November 30th, 1984 and June 1994.
23 So just looking at those two pieces of data, it's
24 terminated in '84 and then abandoned in '94.
25 There's no indication on here as to whether it was

1 used for emergency purposes or other things like
2 that.

3 Q. Okay.

4 A. Which is always a possibility with a
5 well that's not abandoned.

6 Q. Turning the page back to S16 -- excuse
7 me, S126. Looking at the table on HP608.

8 A. Yes. Okay.

9 MR. DEAN: S?

10 THE WITNESS: 26. 1.26.

11 MR. DEAN: I guess I don't have that
12 one.

13 THE WITNESS: Is this Supplement 1?

14 BY MR. ANWAR:

15 Q. You'd agree that ATSDA -- ATSDR
16 determined capacity of HP608 ranged from 115 GPM to
17 230 GPM?

18 A. Yes.

19 Q. And as we discussed a few moments ago,
20 compared to 60 -- HP602 --

21 A. Wait. Hold on just a second. It
22 continues on page S127. It's got a capacity of 226
23 on 1983 -- March 21st, 1984.

24 Q. I see that. So my question was, do you
25 agree that the range for -- ATSDR determined the

1 capacity of HP608 to be in the range of 115 GPM on
2 the low end and 230 GPM on the high end?

3 A. Yes.

4 Q. And --

5 A. I just wanted to make sure we had the
6 full table in front of us.

7 Q. No, I appreciate that. Compared to --
8 and we discussed a moment ago, and you're welcome
9 to turn back to look if you would like, but for
10 HP602 the range was 30 GPM to 154 GPM?

11 A. Yeah, that's correct.

12 Q. Okay. You agree that the table on --
13 for HP608 on page S127 shows that service was
14 terminated for HP608 on December 6, 1984, correct?

15 A. Yes, that's what it states.

16 Q. Okay. I would like to turn back to
17 Chapter C.

18 A. Chapter C. Okay.

19 Q. For the Hadnot Point/Holcomb Boulevard
20 analysis.

21 A. Yes. Okay. Chapter C.

22 Q. If I could direct you to page 108.

23 A. 108. Okay.

24 Q. Page C108, there's a Table C12 on it,
25 right?

1 A. Yes.

2 Q. Okay. So there are three entries
3 there, November 19, 1985, where benzene was
4 detected at 2500 micrograms per liter, right?

5 A. Yes.

6 Q. And then there's an entry December 10,
7 1985 where benzene was detected, 38 micrograms per
8 liter, right?

9 A. Yes.

10 Q. And then there is an entry just below
11 it, December 18, 1985, where benzene was detected,
12 one microgram per liter, right?

13 A. That's correct.

14 Q. Okay. Outside of those three entries
15 in November 1985 and December 1985, according to
16 this table, benzene was never detected above the
17 detection limit at the Hadnot Point water treatment
18 plant, right?

19 MR. DEAN: Object to the form.

20 THE WITNESS: Based on the sample data?
21 We're talking about the data in this table?

22 BY MR. ANWAR:

23 Q. Yeah.

24 A. With the exception of those three
25 readings that you cited, everything else was below

1 the detection limit.

2 Q. And just for the record, the -- we're
3 looking at Table C12. It's entitled "summary of
4 analyses for benzene, toluene, ethylbenzene and
5 total xylene in water samples collected at the
6 Hadnot Point water treatment plant at Camp
7 Lejeune", right?

8 A. Yes.

9 Q. Okay. So these are samples collected
10 at the Hadnot Point water treatment plant?

11 A. Right.

12 Q. Okay. And so a moment ago -- so for --
13 still focusing on C12 on -- Table C12 on
14 November 19, 1985, December 10, 1985, and
15 December 1985. Do you see that?

16 A. Yes.

17 Q. A moment ago we looked at tables with
18 the operating and pumping histories for HP602 and
19 HP608. Do you recall that?

20 A. Yes.

21 Q. So at the time of these three
22 detections for benzene, HP602 and HP608 were shut
23 down, right?

24 MR. DEAN: Object to the form.

25 THE WITNESS: I need to -- let's see.

1 Supplement 1, I'm guessing, yeah.

2 BY MR. ANWAR:

3 Q. Yeah, and if you want to --

4 A. Share the dates.

5 Q. -- go look over it, it was -- the 608
6 is on S126 and 27.

7 A. Okay. November 19th, '85.
8 November 19th, '85.

9 Q. HP608 --

10 A. Yes, yes, it was not, according to this
11 table, not operating, not in service.

12 Q. Yeah. And according to the table, it
13 was terminated in December, December 6th, 1984,
14 right?

15 A. Right.

16 Q. So almost -- it had been shut down for
17 almost a year --

18 A. Right.

19 Q. -- by the time the benzene was
20 detected --

21 A. Uh-huh.

22 Q. -- at the Hadnot Point water treatment
23 plant, right?

24 A. That's correct.

25 Q. Okay. Then 602, which is page 17,

1 S117.

2 A. Okay. I'm there.

3 Q. And we discussed this service was
4 terminated November 30th, 1984?

5 A. Yes.

6 Q. And it, likewise, had been shut down
7 almost a year by the time benzene was detected at
8 -- above detection limits at the --

9 A. Right.

10 Q. Or strike that.

11 It too -- the HP602 was -- also had
12 been shut down in November 30th, 1984, which was
13 about a year after benzene was detected at the
14 Hadnot Point water treatment plant, correct?

15 A. No, we've got '85 at the water
16 treatment plant. Is that what you're speaking
17 with, the benzene detections at the water treatment
18 plant?

19 Q. Correct.

20 A. That was in November '85 and it says
21 service terminated November 30, 1984.

22 Q. So almost a year had passed, right?

23 A. Yes.

24 Q. Okay. Would you agree that -- well,
25 strike that. Let me ask it this way. Residual

1 benzene from HP602 or HP608 used -- before
2 December 1984 was not the source of benzene in the
3 November and December 1985 samples we just looked
4 at, right?

5 MR. DEAN: Object to the form.

6 THE WITNESS: Again, this well says
7 service terminated. There's always the possibility
8 that they were operated and not recorded as
9 operated. I'm saying we observed at that Tarawa
10 Terrace, but -- and for the 2500 part per billion,
11 if you go to the Chapter C report, it might be in
12 this report also, we noted that the base chemist,
13 Elizabeth Betz, noted on that one that it was not
14 representative, okay? She did not say -- the
15 samples don't say that that's not a valid sample.
16 It said it was just not representative.

17 And we actually had a phone interview
18 with her and there's some documentation, with
19 Elizabeth Betz, to ask her did that mean that
20 sample was, you know, not valid and all of that. I
21 asked the question and she answered to me that, no,
22 she just meant that benzene sample -- especially
23 benzene samples would go up and down, up and down
24 until there was no regularity to the
25 concentrations.

1 BY MR. ANWAR:

2 Q. Well, in that conversation, was she
3 referring to the 2500 micrograms per liter?

4 A. I specifically asked her about that,
5 yes.

6 Q. And your understanding is -- from her
7 is that that sample from Hadnot Point water
8 treatment plant was not representative?

9 A. Yes, but I asked her -- that's marked
10 on the JTC lab reports. It's not -- and it's also
11 marked in our Chapter C.

12 Q. Sure.

13 A. Just to be clear. And I asked her what
14 was meant or what was her understanding of not
15 representative, and she said that -- and it's
16 recorded in the notes or meeting notes that we had
17 with her, phone conference, that she meant that
18 there was just -- the benzene sampling data would
19 go up and down, up and down by a large amount, and
20 so that's why it was not representative. She did
21 not say -- I asked her and she said she -- because
22 I asked if she meant that she would consider that
23 sample or, you know, or it was an erroneous sample,
24 and she definitely said, no, she just -- her
25 meaning was that it was -- the sampling data went

1 high and low, high and low.

2 Q. As you sit here today, you don't have
3 any reason to believe that the residual -- residual
4 benzene from HP602 or HP608 used before December
5 1984 was the source of benzene samples in November,
6 December 1985?

7 A. We really did not do a residual
8 analysis and, as you know, benzene is a floater.
9 It floats on top of water, so like salad dressing
10 with oil and vinegar. When you shake it up, maybe
11 stir it up, and then it separates out. So we
12 really did not do a residual analysis to see you
13 know, that specificity.

14 Q. But you don't have any definitive data
15 demonstrating that it was residual benzene from
16 HP602 or HP608 used before December 1984 that was
17 the source of this November, December 1985 benzene
18 samples?

19 A. Well, we've got our reconstructed
20 values at the water treatment plant.

21 Q. Well, and we don't need to look at
22 those.

23 A. Okay.

24 Q. I'm just talking in terms of the
25 real-world data, not in terms of the model right

1 now.

2 A. Okay. So again, ask your question
3 again.

4 Q. Just some terms of real-world data, you
5 don't -- there isn't any real-world data available
6 or that exists demonstrating that HP602 -- residual
7 benzene from HP602 or HP 608 used before
8 December 1984, which is when those two wells
9 closed, was the source of the
10 November/December 1985 measurements in the Hadnot
11 Point water treatment plant?

12 A. I do not have data for those wells
13 after they went out of service.

14 Q. Now, Tarawa Terrace, if I remember
15 correctly, ATSDR didn't use nondetects in the
16 geometric bias; is that right?

17 A. What's published in the published
18 title, yes, that's correct, we did not ignore the
19 data. They're published in the table, but when we
20 went to compute the geometric bias, we did not
21 include the nondetects because there's a whole area
22 of analysis about nondetects value -- what value
23 should you include or what value should you assign
24 or not assign and things of that nature.

25 Q. And in the published data you didn't --

1 ATSDR didn't use nondetects in the geometric bias,
2 which was used to assess calibration, right?

3 A. That is correct.

4 Q. Okay.

5 A. But we did publish it in the tables
6 accompanying -- accompanying that, okay, for both
7 the wells and -- supply wells and the treatment
8 plant.

9 Q. And as I understand it, from the very
10 beginning of our conversation today, it sounds like
11 you've done some additional work with respect to
12 geometric mean -- or geometric bias?

13 A. Yes.

14 Q. Okay. And was that only for Tarawa
15 Terrace?

16 A. It was for Tarawa Terrace and I'd have
17 to look at my notes. I might have done it for the
18 Hadnot Point water treatment plant.

19 Q. That would be reflected in your notes?

20 A. Yes.

21 Q. And do you intend to offer that opinion
22 if called to testify at trial?

23 A. That we -- that I reassessed the
24 computation?

25 Q. Yes.

1 A. Yes. Well, I mean, I will defer to the
2 attorneys on that, but I have notes that I'll turn
3 over to the attorneys.

4 Q. Okay. How --

5 MR. DEAN: Well, I mean, you should
6 answer his question fully because you can update
7 and amend your opinions pursuant to the rules in
8 the deposition if he asked. So if you've completed
9 your answer, fine. If you didn't, finish answering
10 his question.

11 THE WITNESS: No. I mean, I looked
12 again, as we discussed earlier today, after reading
13 Dr. Konikow's report, and he discussed the issue of
14 using duplicate samples or triplicate samples
15 within the same day or same month when the model
16 results only provide you one value per month. So
17 then I went back and recomputed using that
18 approach. So if we had two samples in a month,
19 then I would take an average. If you had three, I
20 would take an average, so I would compare one to
21 one.

22 Q. Okay. I have to find my place again.
23 Okay. How did ATSDR assess calibration of the
24 Hadnot Point mixing model for benzene with only --
25 or primarily nondetect data points?

1 A. Let me get to Chapter C and in table --
2 on Table A18 on page A62, we've got supply well.

3 Q. Is this on Chapter A or Chapter --

4 A. Chapter A. I'm on Chapter A, yes.
5 Chapter A of Hadnot Point.

6 Q. Okay. What -- what page were you
7 looking at?

8 A. I was on page A62. Okay. I misspoke.
9 That was the water treatment plant, okay? We had
10 measured data and then we had reconstructed data.
11 So I may have computed a geometric mean just, like,
12 on scratch paper, but I did not publish it as part
13 of the Chapter A for Hadnot Point/Holcomb Boulevard
14 report.

15 Q. Why did you treat that differently than
16 for Tarawa Terrace?

17 A. I really don't -- don't know. I know
18 we were under a timeline crunch to get it out and
19 it just may have been that it was not -- that I
20 looked at -- I just looked at visually the values,
21 reconstructed versus measured, and said, you know,
22 that was, you know, provided a good fit. And also
23 looked at the wells on page -- well, they're graphs
24 and stuff like that, but also there's a table
25 earlier on. Somewhere there's a table. And just

1 said that I was satisfied with -- with the -- with
2 the fit or the goodness of fit of the calibrated
3 results with the available water treatment plant
4 data.

5 It was also -- with Tarawa Terrace we
6 had just PCE, okay, one constituent. Whereas here
7 we had multiple constituents and I may have -- I
8 said, well, maybe we need to look into each one
9 individually or something like that. It was a
10 little more complex computation, and so it did not
11 end up in -- in the published report.

12 Q. Would you agree that not assessing
13 geometric bias affects uncertainty and reliability
14 for the Hadnot Point model?

15 A. Not necessarily because, again,
16 geometric bias just gives me an estimate; is the
17 model way over or way under or it's in the
18 ballpark, okay? And again, I'm looking at the
19 plot. A graphic is just as good as a geometric
20 bias. A geometric bias is putting a quantitative
21 estimate on a graphic, okay? Had this graphic, and
22 so it was just a computation that was not done for
23 this -- this analysis. You can go back and -- and
24 do it. I mean, as I said, I've got my notes.

25 Q. Okay. If you could turn back to

1 Chapter C on page C106.

2 A. 106?

3 Q. Yeah.

4 A. 106. Okay. I've got it.

5 Q. On C106 there's a Table C11, right?

6 A. Yes.

7 Q. It states, "summary analyses for PCE,
8 TCE, 1-1-DCE, trans-1-2-DCE, 1-2-DCE" -- it says,
9 "1-2-DCE, total 1-2-DCE, and vinyl chloride in
10 water samples collected at the Hadnot Point water
11 treatment plant, Camp Lejeune", correct?

12 A. Yes.

13 Q. Okay. I just wanted to ask you a few
14 questions about this.

15 A. Sure.

16 Q. You'd agree that this table summarizes
17 measured PCE and degradation product observations
18 at the Hadnot Point water treatment plant?

19 A. Yes.

20 Q. You'd agree that vinyl chloride was
21 never detected above the reporting limit at Hadnot
22 Point water treatment plant?

23 A. There's -- on February '85 the value --
24 estimated value of 2.9.

25 Q. Where are you looking? February --

1 A. C11, February 5th, 1985 all the way
2 across the last column. It says 2.9J.

3 Q. Okay. Aside from that one time, would
4 you agree that vinyl chloride was not detected
5 above the detection limit?

6 A. Let me make sure this goes -- is this
7 the same -- Table C10, C11. You're just talking
8 about Table C11, right?

9 Q. Correct.

10 A. Yes, that would be --

11 Q. You would agree that aside from that --
12 that one time in -- on February 5th, 1985, that
13 vinyl chloride was never detected above the
14 detection limit?

15 A. Yes.

16 Q. And this is for that Hadnot Point water
17 treatment plant, right?

18 A. That's correct.

19 Q. Okay. And then you would agree that
20 DCE was rarely detected above the detection limit
21 at the Hadnot Point water treatment plant?

22 MR. DEAN: Object to the form.

23 THE WITNESS: No, where there's a
24 trans-DCE, 1-2-DCE on February 5th, again, 1985, of
25 150 micrograms per liter.

1 BY MR. ANWAR:

2 Q. So that's that one time?

3 A. Yes.

4 Q. Would you agree, aside from that one
5 time, that DCE was not detected above the reporting
6 limit at the Hadnot Point water treatment plant?

7 MR. DEAN: Object to the form.

8 THE WITNESS: Yes.

9 BY MR. ANWAR:

10 Q. Okay. Let -- jumping around. Let's
11 turn back to Chapter A for Hadnot Point/Holcomb
12 Boulevard.

13 A. Okay. Okay.

14 Q. I would like to direct your attention
15 to A46.

16 A. Page A46?

17 Q. Correct.

18 A. Okay.

19 Q. There are a series of graphs there
20 entitled Figure A18, correct?

21 A. A18, yes.

22 Q. And A18 is titled "reconstructed or
23 simulated and measured concentrations of TCE at
24 selected water supply wells within the Hadnot Point
25 industrial area." Did I read that correct?

1 A. Yes.

2 Q. Okay. And the wells reflected on these
3 graphs are HP602, HP608, HP634, and then there's
4 well HP601 and, slash, HP660, correct?

5 A. That is correct.

6 Q. Would you agree that these -- this
7 figure shows calibrated model values at HP well
8 601, 602, 608 and 634?

9 A. They show the -- yes, the red line is
10 the simulated values.

11 Q. Okay.

12 A. Or reconstructed values, and the black
13 dots are the measured.

14 Q. So the -- for instance, at HP602 there
15 are one, two, three, four, five, six measured
16 values reflected on the graph, right?

17 A. Yes.

18 Q. For HP601 it looks like there are three
19 measured values on the graph, right?

20 A. Yes, they are measured for HP660, which
21 was the replacement well.

22 Q. For 601, right?

23 A. Yes.

24 Q. For HP608, it looks like there are four
25 values reflected on the graph?

1 A. Yes.

2 Q. And for HP634 it looks like there is
3 one value reflected on the graph?

4 A. Yes.

5 Q. Those are the measured values we're
6 talking about, correct?

7 A. That is correct.

8 Q. And then the -- that red -- the red
9 line is what the model is simulating as estimated
10 concentrations?

11 A. Yes, that's correct.

12 Q. These graphs show some measured values,
13 but they show none of the nondetect values,
14 correct?

15 A. That's correct.

16 Q. And you would agree that if we turn to
17 -- you might keep this page open --

18 A. Okay.

19 Q. -- but also turn to Chapter C, C95.

20 A. Right. C95?

21 Q. Correct.

22 A. Okay. I'm there. Table C7.

23 Q. Yes.

24 A. Okay.

25 Q. C7, "summary of analyses, PCE, TCE, DCE

1 and vinyl chloride for water samples collected at
2 Hadnot Point water treatment plant", right?

3 A. Right.

4 Q. Okay. For HP634 there, there are four
5 values below the nondetect limit, right -- or
6 excuse me, there are four -- four nondetects?

7 A. In Table C9 -- I mean, on Table C7?

8 Q. Yes.

9 A. For 634 there's -- yes, that's correct.

10 Q. And if you go back and look at A46,
11 there's one measured value reflected there, right?

12 A. That's correct.

13 Q. But those -- those four nondetects are
14 not reflected?

15 A. That's correct. The issue with trying
16 to graphically represent nondetects gets back to
17 what value are you going to use. If we use the
18 detection limit, then someone can argue, well, you
19 don't know that definitively because it was
20 nondetect. If you want to use half the detection
21 limit, again, that's just an estimate. There are
22 some other complex methods where people -- Dennis
23 Helsel and others who have worked in the nondetect
24 area, that you can estimate and quantify the
25 nondetects, but for our purposes we used the

1 graphics in the reports as -- and companions to the
2 tables. So if someone wanted to see what all the
3 values were, they could go to the -- to the table
4 and see that we had nondetects and we also had
5 above detection limits.

6 Q. Okay. Let's -- let's look at -- and
7 let me mark it. Let's switch gears a little bit.

8 A. Okay.

9 Q. I'm going to hand you what I'm marking
10 as Exhibit 19.

11 (DFT. EXHIBIT 19, Analyses and
12 Historical Reconstruction of Groundwater Flow,
13 Contaminant Fate and Transport, and Distribution of
14 Drinking Water Within the Service Areas of the
15 Hadnot Point and Holcomb Boulevard Water Treatment
16 Plants and Vicinities, U.S. Marine Corps Base Camp
17 Lejeune, North Carolina Chapter A-Supplement 6,
18 Characterization and Simulation of Fate and
19 Transport of Selected Volatile Organic Compounds in
20 the vicinities of the Hadnot Point Industrial Area
21 and Landfill, was marked for identification.)

22 THE WITNESS: Okay.

23 BY MR. ANWAR:

24 Q. Here you go.

25 A. Supplement 6. Okay.

1 Q. Exhibit 19 is a Hadnot Point/Holcomb
2 Boulevard Chapter A-Supplement 6, right?

3 A. That is correct.

4 Q. Okay. And it's titled
5 "characterization and simulation of fate and
6 transport of selected volatile organic compounds in
7 the vicinities of the Hadnot Point industrial area
8 and landfill", right?

9 A. That is correct.

10 Q. Okay. Can I have you turn to page
11 S645?

12 A. Okay. 645. Okay.

13 Q. And S645 includes a discussion of --
14 it's entitled discussion and limitations, correct?

15 A. That is correct.

16 Q. And that's of the Hadnot Point/Holcomb
17 Boulevard analysis and model, correct?

18 A. Yes, yes.

19 Q. Okay. Looking over on the right-hand
20 side, second paragraph, it starts, "for contaminant
21 fate and transport modeling reported herein,
22 however, insufficient water quality data existed to
23 conduct a statistical analysis for assessment of
24 model calibration fit. In addition, specific data
25 pertinent to the timing of initial deposition of

1 contaminants to the ground or subsurface
2 chronologies of waste disposal operations such as
3 dates and times when contaminants were deposited in
4 the Hadnot Point landfill or descriptions of the
5 temporal variation of contaminant concentrations in
6 the subsurface generally are not available."

7 Did I read that all correctly?

8 A. Yes.

9 Q. Okay. And then it goes on,
10 "determining these types of source identification
11 and characterization data became part of the
12 historical reconstruction, whereby the contaminant
13 fate and transport model was used to test source
14 locations, varying concentrations, and beginning
15 and ending dates for leakage and migration of
16 source contaminants to the subsurface and the
17 underlying groundwater flow system." Did I read
18 that correctly?

19 A. That's correct.

20 Q. Okay. So then the next starts,
21 "conducting a robust uncertainty analysis using
22 Monte Carlo analysis requires simulating thousands
23 of realizations. When using available
24 computational equipment, the Hadnot Point
25 industrial area and the Hadnot Point landfill

1 models have a simulation time of about six to
2 eight hours for each simulation. The lengthy
3 simulation times and the substantial data
4 limitations therefore make a comprehensive
5 uncertainty analysis computationally prohibitive
6 based on available resources and time limitations.
7 Thus, the ranges of values presented in the
8 sensitivity analysis section of this report assess
9 a limited number of input and output model
10 parameters. The results, in other words, range of
11 concentration presented in the sensitivity analysis
12 reported herein, should not be considered or
13 interpreted as the results of a robust and
14 comprehensive uncertainty analysis, but do provide
15 insight into parameter sensitivity and uncertainty
16 in a qualitative sense."

17 Did I read that all correctly?

18 A. Yes.

19 Q. Based on the two paragraphs we just
20 read together, you would agree that ATSDR did not
21 conduct a statistical analysis to assess model
22 calibration and fit at Hadnot Point because there
23 wasn't sufficient water quality data, right?

24 MR. DEAN: Object to the form of the
25 question and misstates and mischaracterizes the

1 document.

2 THE WITNESS: I'm just seeing where we
3 said that on this -- I'm sure I'm --

4 MR. BELL: Are y'all allowed to have
5 candy bars?

6 MR. ANWAR: Sure.

7 MR. BELL: I know it's late in the day.
8 Someone said, well, don't give him anymore.

9 THE WITNESS: Yeah, it's -- as it
10 states in the report, insufficient water quality
11 data and the statistical analysis for assessment of
12 model calibration is not -- was not conducted,
13 okay? I believe they were referring to -- this was
14 the -- this was the groundwater flow -- the
15 contaminant fate and transport groundwater model,
16 not necessarily the mixing model and -- at the
17 Hadnot Point water treatment plant, okay? That may
18 have been able to have been computed.

19 BY MR. ANWAR:

20 Q. But you agree statistical analysis to
21 assess model calibration fit wasn't conducted
22 because -- because there was insufficient water
23 quality data, right?

24 A. Yes, that's what it says.

25 Q. Okay. And in this paragraph, when it's

1 referencing water quality data, you would agree
2 that means measurements of contaminant
3 concentrations, right?

4 MR. DEAN: Object to the form.

5 THE WITNESS: That's what I would
6 interpret it to mean.

7 BY MR. ANWAR:

8 Q. Okay. So earlier, just, I think, a few
9 minutes ago, we talked about geometric bias at the
10 Hadnot Point mixing model?

11 A. Right.

12 Q. Would you agree this says one wasn't
13 done?

14 A. Again, I'm looking at -- this is
15 strictly a groundwater contaminant fate and
16 transport. It would have been done or could have
17 been done in the summary chapter, Chapter A, but I
18 do not see it there, so it was not conducted.

19 Q. One was --

20 A. It was not computed. Let me just -- it
21 was not computed like it was computed for Tarawa
22 Terrace.

23 Q. One wasn't computed for the fate and
24 transport model for Hadnot Point, correct?

25 A. One was not computed for the water

1 supply wells at Tarawa Terrace -- let's go back.
2 We computed geometric bias for the water supply
3 wells and then we also computed a geometric bias
4 for the water treatment plant, okay? So Supplement
5 6 is strictly the groundwater flow model, so there
6 was not one conducted -- computed for the supply
7 wells at Hadnot Point and Holcomb Boulevard.

8 Q. Okay. I just want to make sure. There
9 was not one computed for the supply wells, correct?

10 A. That is correct.

11 Q. And would you agree there was not one
12 conducted for fate and transport?

13 MR. DEAN: Object to the form.

14 THE WITNESS: That would -- that would
15 be the supply wells.

16 BY MR. ANWAR:

17 Q. Okay. I've got you.

18 A. Okay. The fate and transport model,
19 you would pull out the concentrations at the well
20 locations.

21 Q. Okay. That's what I wanted to make
22 sure I understood. Thank you.

23 And so now kind of looking back at the
24 paragraphs we just read.

25 A. Okay. Hold on. Go back there.

1 MR. DEAN: Page 45, 645. I think
2 that's where...

3 THE WITNESS: Yeah, I'm there.

4 BY MR. ANWAR:

5 Q. It says, you'd agree, "that specific
6 data pertinent to the timing of initial deposition
7 of contaminants to the ground or subsurface
8 chronologies of waste disposal operations such as
9 dates and times when contaminants were deposited in
10 the Hadnot Point landfill or descriptions of the
11 temporal variation of contaminant concentrations in
12 the subsurface generally were not available at
13 Hadnot Point", right?

14 A. That's what it says, yes.

15 Q. Okay. And you agree that historical --
16 quote, historical reconstruction, as used in the
17 paragraphs, had to include testing source
18 locations, varying concentrations, and beginning
19 and ending dates for leakage and migration of
20 source contaminants to the subsurface and the
21 underlying groundwater flow system?

22 A. That would be the calibration process.

23 Q. You'd agree that a comprehensive
24 uncertainty analysis wasn't done at Hadnot Point
25 because, as it states in the paragraph, "lengthy

1 simulation times and substantial data limitations
2 were computationally prohibited" --

3 A. Yes.

4 Q. "Prohibitive."

5 A. Yes, that's what it says.

6 Q. ATSDR did a sensitivity analysis, but
7 it said, results should not be considered or
8 interpreted as results of a robust and
9 comprehensive uncertainty analysis, correct?

10 A. Yes.

11 MR. DEAN: Object to the form.

12 BY MR. ANWAR:

13 Q. And your answer was yes, right?

14 A. Yes, I'm confirming what -- you read it
15 from the report.

16 Q. It's the last sentence of the last
17 paragraph. So ATSDR did a sensitivity analysis,
18 but said its results should not be considered or
19 interpreted as the results of a robust and
20 comprehensive uncertainty analysis, right?

21 MR. DEAN: We can stipulate you read
22 that sentence correctly.

23 BY MR. ANWAR:

24 Q. And you agree with that, right?

25 MR. DEAN: Object to the form.

1 THE WITNESS: It can be considered
2 qualitative. That's what we say in here, okay? We
3 did conduct sensitivity analyses.

4 BY MR. ANWAR:

5 Q. Let's jump ahead -- or let's jump to --
6 back to Supplement 6 -- or we are on Supplement 6.

7 A. Yes.

8 Q. So let's turn to page 44, S6.44.

9 A. 44, okay.

10 Q. So the page before.

11 A. Okay.

12 Q. On page S6 there is a Figure S6.23,
13 correct?

14 A. Yes.

15 Q. And the figure is titled "variations in
16 reconstructed simulated finished water
17 concentrations of TCE derived using a Latin
18 hypercube sampling methodology on water-supply well
19 monthly operational schedules for Hadnot
20 Point/Holcomb Boulevard study area", correct?

21 A. Yes.

22 Q. Okay. This is the -- the -- the figure
23 for the uncertainty analysis on the Hadnot
24 Point/Holcomb Boulevard model, right?

25 A. Yes, at the water treatment plant.

1 Q. Okay. At the water treatment plant.

2 And agree that the results of this
3 uncertainty analysis at the Hadnot Point water
4 treatment plant where reconstructed monthly well
5 operations -- okay. Let me ask that again.

6 You agree that the results of the
7 uncertainty analysis here were -- for reconstructed
8 monthly well operations schedules were varied?

9 A. Yes.

10 Q. And this -- this reflects the -- the
11 water-supply well monthly operational schedules,
12 correct?

13 A. Yes.

14 Q. It's an uncertainty analysis about the
15 water-supply well monthly operational schedules,
16 correct?

17 A. That is correct.

18 Q. Okay. And the uncertainty analysis
19 shows -- the uncertainty analysis was varied,
20 right?

21 MR. DEAN: Object to the form.

22 THE WITNESS: I'm not sure I understand
23 what you mean by the uncertainty analyses was
24 varied.

25 BY MR. ANWAR:

1 Q. The results of the uncertainty analysis
2 were varied, correct?

3 MR. DEAN: Object to the form.

4 THE WITNESS: The results were not
5 varied.

6 BY MR. ANWAR:

7 Q. I thought a moment ago you agreed they
8 were varied.

9 MR. DEAN: Object to the form.

10 THE WITNESS: You asked me about the
11 water-supply wells.

12 BY MR. ANWAR:

13 Q. Okay.

14 A. That's the parameter that was varied.

15 Q. Okay. Understood. Ah, yeah. And
16 you'd agree -- so let me -- just so the record is
17 clean, agree this -- the -- this uncertainty
18 analysis at Hadnot Point is where reconstructed
19 monthly well operations schedules were varied,
20 correct?

21 A. Yes.

22 Q. Okay. Thank you. And you agree that
23 the results of this uncertainty analysis suggests
24 that changes in pumping schedules produce very
25 different modeled monthly mean contaminant

1 concentrations, right?

2 MR. DEAN: Object to the form.

3 THE WITNESS: There's variation from
4 the mean to the high or low.

5 BY MR. ANWAR:

6 Q. There's significant variation, right?

7 MR. DEAN: Object to the form.

8 THE WITNESS: I don't know if I would
9 call it significant. If you compare it to the data
10 spread, it's not -- it's greater than at Tarawa
11 Terrace.

12 BY MR. ANWAR:

13 Q. You agree it is greater than Tarawa
14 Terrace, right?

15 A. Yes, but we still considered it to meet
16 our modeling objectives.

17 Q. You'd agree this was a Monte Carlo
18 simulation like in Tarawa Terrace, but unlike
19 Tarawa Terrace, only the one input parameter, well
20 pumping schedule, was varied, correct?

21 A. It was a Latin hypercube sampling,
22 which is a variant of Monte Carlo simulation when
23 Monte Carlo simulation becomes computationally
24 prohibitive. So it is a Monte Carlo, but it's
25 Latin hypercube sampling.

1 Q. A moment ago we were talking about the
2 degree of variation. Would you agree that the
3 variation is hundreds of micrograms per liter?

4 A. Once -- you're talking about the
5 reconstructed results or the sampling data?

6 Q. The -- the reconstructed results.

7 A. Once HP651 kicks in, yes, after July --
8 I think June or July of '72.

9 Q. That's where you see the -- on the
10 figure, Figure S623, dot 23, it spike up, correct?

11 A. Yes.

12 Q. Now, looking at this Figure S6.23, you
13 would agree the gray line show all of the Monte
14 Carlo simulations drawn on the same chart?

15 MR. DEAN: Object to the form of the
16 question.

17 THE WITNESS: They -- they show all the
18 Latin hypercube sampling results on -- on this
19 graph.

20 BY MR. ANWAR:

21 Q. Why not show the 95 percent realization
22 balance like ATSDR did for Tarawa Terrace?

23 A. It was not -- with Latin hypercube you
24 -- you had -- in this case we used ten equal
25 subdivision or sampling points, okay? That's the

1 definition of Latin hypercube, is you have an equal
2 probability within each sampling domain, which we
3 had ten. And so it was just not possible to
4 compute a confidence limit, but -- using -- using
5 that approach.

6 Q. Okay.

7 A. But it did give us both a quantitative,
8 in terms of high/low, and qualitative feeling of
9 the model results at the water treatment plant.

10 Q. Got it. I think we are in the home
11 stretch, about 40 minutes left, probably 40, 45.
12 Why don't we take a quick five or five or ten. I
13 would like to take a look at my notes and --

14 A. Okay. Sure.

15 MR. ANWAR: Thank you.

16 THE VIDEOGRAPHER: Going off record.
17 The time is 5:10 p.m.

18 (A recess transpired.)

19 THE VIDEOGRAPHER: Okay. We are going
20 back on record. The time is 5:23 p.m.

21 BY MR. ANWAR:

22 Q. We are back on the record from a short
23 break. Mr. Maslia, are you okay to continue?

24 A. Yes, I am.

25 Q. Did you speak to your lawyers during

1 the break?

2 A. No, I did not.

3 Q. Okay. I may bounce around a little
4 bit. I wanted to ask you a few questions about
5 your rebuttal report, your opinions in your
6 rebuttal report. Dr. Spiliotopoulos pointed out,
7 for the Tarawa Terrace model, that the KD values
8 and the bulk density values for the calculation of
9 the retardation factor contained errors. Do you
10 recall that?

11 A. He pointed out that the bulk density
12 did.

13 Q. Okay. And my -- my understanding of
14 your opinions about that are essentially that you
15 don't dispute the error, but it doesn't, in your
16 opinion, change the analysis much; is that right?

17 A. It's not so much of an error. What was
18 used originally was the wet bulk density, and it
19 was pointed out to us in 2009, by one of the
20 experts on the Hadnot Point/Holcomb Boulevard panel
21 when we had sent the Tarawa Terrace report, that we
22 had a wet bulk density. So we went back and
23 changed that value and, of course, you've got to
24 understand is that in the contaminant fate and
25 transport equations, bulk density and distribution

1 coefficient are not included. What's included is
2 retardation factor, okay? And we originally had a
3 retardation factor of 2.93. So if we adjusted the
4 bulk density to drop down, that means we could
5 adjust KD up. They are compensating, okay, because
6 they are calibration -- KD is a calibration
7 parameter.

8 Q. Sure.

9 A. And that resulted in the exact same
10 retardation factor of 2.93, and it resulted in
11 identical to the decimal place concentrations that
12 we had published in the Chapter A report.

13 Q. Okay. And thank you for -- for
14 explaining that. The -- if I'm understanding your
15 testimony correctly, it's not so much that the --
16 the difference of opinion about bulk density or the
17 error, as Dr. Spiliotopoulos has described it,
18 doesn't exist; it's that it's offsetting such that
19 it doesn't impact the retardation factor?

20 A. That is correct.

21 Q. Okay.

22 A. Our retardation factor was consistent
23 -- it was identical to what it was in the published
24 report, okay, but it was also very consistent with
25 existing literature values as well for PCE in this

1 type of terrain.

2 Q. Now, the retardation factors -- excuse
3 me, the bulk density and the KD value used for
4 Hadnot Point and Holcomb Boulevard model or
5 analysis is different than the one for the Tarawa
6 Terrace model, is that --

7 A. I would like to just compare the two so
8 we're --

9 Q. Sure.

10 A. -- comparing apples to apples here. So
11 let get me to Hadnot Point. Okay. There's -- I'm
12 looking at page A41 for the Hadnot Point report.
13 Ah, here you go. So you asked about bulk density.

14 Q. Yeah, the -- let's start with bulk
15 density.

16 A. Well, yes, but, again, as I said, we
17 corrected the one that was in Chapter A once we
18 realized that was a wet bulk density. The
19 corrected value came very close to 46,700 grams per
20 cubic foot.

21 Q. Okay.

22 A. Which is what we used in the Hadnot
23 Point.

24 Q. But the values for the actual
25 calculation -- for the actual -- how you calculated

1 the retardation factor between Tarawa Terrace and
2 for Hadnot Point, can you direct me to the page
3 that you're looking?

4 A. Okay. I'm on page A41 of the Hadnot
5 Point/Holcomb Boulevard report.

6 Q. Sure.

7 A. And then also page A29 of the Tarawa
8 Terrace report.

9 Q. Okay. Okay. Let's come back to that.

10 A. Okay.

11 Q. I'm going to mark what is, I think,
12 Exhibit 20 now.

13 (DFT. EXHIBIT 20, letter dated February
14 21, 2007 from Morris Maslia to Dr. Leonard F.
15 Konikow Bates-stamped
16 CL_PLG-Expert_Konikow_0000000006 through
17 0000000021, was marked for identification.)
18 BY MR. ANWAR:

19 Q. Here you go. This -- the first page of
20 Exhibit 20 is dated February 21, 2007, correct?

21 A. Yes.

22 Q. And it is a letter from you to
23 Dr. Leonard Konikow enclosing feedback to comments
24 that Dr. Konikow had raised about the Tarawa
25 Terrace analysis, correct?

1 A. Yes, he was a peer-reviewer, external
2 peer-reviewer --

3 Q. Okay.

4 A. -- on that particular chapter for
5 Tarawa Terrace.

6 Q. Now, these -- these responses to
7 Dr. Konikow's concerns or what are identified as
8 major concerns were drafted by Bob Faye, correct?

9 A. Yes.

10 Q. Did you have a chance to review these
11 before they were sent out?

12 A. I -- I reviewed it. It's been a while
13 since I've seen these, but I did -- did review it.

14 Q. Would you have discussed the responses
15 with Bob Faye before they were sent back to
16 Dr. Konikow?

17 A. Not necessarily discussed it. If I had
18 an issue with the response, I may have talked to
19 him.

20 Q. Okay.

21 A. And asked him, but I typically -- my
22 approach was not to micromanage the modelers,
23 right? So since Bob Faye was the primary author on
24 Chapter F, I assume that's what this chapter is --
25 yes, then I would allow him to develop the

1 responses. And, of course, he was a subcontractor
2 to ATSDR through Eastern Research Group, so that's
3 -- that's who he would send the responses to and
4 they would provide me with a copy.

5 Q. Okay. So on -- let's call it the page
6 ending in Bates label 08.

7 A. Okay. Okay.

8 Q. Actually, let's go to 09.

9 A. Okay.

10 THE WITNESS: Do you need a copy? Do
11 you need a copy?

12 MR. DEAN: I have one.

13 THE WITNESS: Oh, okay. Okay.

14 BY MR. ANWAR:

15 Q. Number three, Dr. Konikow raised as a
16 major concern, "the reliability of the estimate of
17 the biodegradation rate constant based on the
18 assumption that concentration declines" -- excuse
19 me. Let me read that again.

20 Number three of Dr. Konikow's major
21 concerns reads, "the reliability of the estimate of
22 the biodegradation rate constant based on the
23 assumption that concentration declines observed at
24 one location over a period of several -- several
25 years can be explained solely by biodegradation."

1 Did I read that correctly?

2 A. Yes, you read that correctly.

3 Q. Okay. And it looks like Bob Faye's
4 response there was "the author never claimed that
5 the biodegradation rate computer using field data
6 was reliable or the sole reason for the observed
7 decline in PCE concentration." Did I read that
8 correctly?

9 A. Yes.

10 Q. Okay. Do -- do you agree with that
11 statement?

12 A. That's Mr. Faye's opinion as the person
13 who did the -- the model in response to
14 Dr. Konikow's question or comment, but, you know,
15 what is generally being said is that some of these
16 transport parameters, like biodegradation rate,
17 that's very limited field -- field data, and so,
18 you know, there could be any possibilities for the
19 decline in the concentration. And I think that's
20 what Dr. Konikow was raising as well.

21 Q. And the next sentence says, "rather,
22 the computed rate was presented as an approximate
23 value useful to begin model calibration." Did I
24 read that correctly?

25 A. Yes. And I would agree with that.

1 Q. So if you go on, the rest of it reads,
2 "well TT26 is located on a direct migration, slash,
3 advective pathway from the PCE source at ABC
4 One-Hour Cleaners." Did I read that correctly?

5 A. Yes.

6 Q. Do you agree with that?

7 A. Yes.

8 Q. Okay. And then it says, "to the extent
9 that migration of PCE mass towards and away from
10 supply well TT26 occurred at about equal rates
11 during 1985 to 1991, the computed degradation rate
12 of 0.00053 per day approximates a long-term average
13 degradation rate." Did I read that correctly?

14 A. Yes.

15 Q. It goes on to say, "on the other hand,
16 if a significant quantity of the PCE degraded in
17 the vicinity of supply well TT26 was replaced by
18 advection, then the degradation rate computed using
19 equation three is probably a minimum rate,"
20 correct?

21 A. Yes, that's what you read.

22 Q. Okay. And do you agree with that?

23 A. I agree with that concept, yes. He's
24 basically saying we had two data points at TT26 in
25 '85 and '91, and so that's what was used to compute

1 the initial -- to start model calibration.

2 Q. And then it goes on to say, "the report
3 does not state or indicate that the decline in PCE
4 mass at supply well TT23 is due entirely to
5 biodegradation rate -- biodegradation. Rather, the
6 report indicates that the computed first-order
7 degradation rate is an estimate used as a basis to
8 begin model calibration," correct?

9 A. Yes. It's important to understand that
10 the value that we ended up for the calibrated rate,
11 which is five times ten to the minus four per day,
12 0.0005, compares extremely favorably with the
13 values that Dr. Clement came up with in his model
14 for his paper.

15 Q. That who came up with?

16 A. Dr. Clement.

17 Q. Okay. And you're talking about the
18 Dover Air Force Base model?

19 A. Yes, yes, very similar lithology. We
20 did have a gravel zone in there, but, again, he
21 came up with -- I think it was somewhere around one
22 to four times ten to the minus four. I would have
23 to look at the paper and see.

24 Q. That's okay.

25 A. But that's, you know...

1 Q. I wanted to turn your attention to the
2 Bates page ending now in 15.

3 A. Yeah, could I just make sure I gave you
4 the right numbers?

5 Q. Sure.

6 A. Here we go. Okay. Here you go. The
7 estimated -- the field estimated apparent reaction
8 rates range from 3.5 to seven times ten to the
9 minus four per day for PCE, and we're smack dab in
10 the middle with five times ten to the minus four.

11 Q. Let's turn to the page ending in 15.

12 A. Okay.

13 Q. There is a comment about -- towards the
14 bottom of -- about mass loading. Starting page 59,
15 it says, "mass loading, disagree, see my comments
16 under major concerns item five. The reviewer seems
17 to assign a high degree of accuracy and credibility
18 to the PCE mass computation that is unwarranted."
19 Did I read that correctly?

20 A. Yes.

21 Q. And then it says, "as explained
22 previously, the computation of PCE mass was highly
23 interpretive and somewhat subjective process
24 frequently based on questionable data." Did I read
25 that correctly?

1 A. Yes.

2 Q. Do you agree with that?

3 A. Not necessarily. We had data from ABC
4 Dry Cleaners, PCE data, and we used a technique
5 that was published in Groundwater journal that's
6 documented in the Chapter E and the Chapter F -- F
7 report in -- the key fact takeaway, and I mentioned
8 this in -- I believe it was my expert report, is
9 that the mass computed using the field data and the
10 mass determined from the MT3DMS model were the same
11 order of magnitude, which gave us -- it's almost
12 another calibration check, okay?

13 Q. The comment goes on to say, "field data
14 applied to the PCE mass computation were limited
15 both spatially and vertically," right?

16 A. Right.

17 Q. And that's a true statement, right?

18 A. That is. They were limited, but they
19 were still field data available.

20 Q. And then, "the computation was
21 accomplished regardless of data limitations to
22 provide an estimate of a minimum mass loading rate
23 to begin model calibration." Did I read that
24 correctly?

25 A. Yes.

1 Q. Okay. Now, for the Tarawa Terrace
2 model, ATSDR assumed mass loading on January 1,
3 1953, correct?

4 A. That is correct.

5 Q. And I think, was it -- without pulling
6 up the report, was it 1300 -- or no, 1200?

7 A. That was the calibrated value, is 1200.
8 We started at 200. And again, that is a
9 calibration parameter that you're free to adjust
10 during the model calibration process. We're
11 adjusting, you know, conductivity. You're
12 adjusting reaction rate. You're adjusting a number
13 of parameters. And so it was adjusted and the best
14 fit value came up to, I believe, 1200 grams per
15 day.

16 Q. Okay. And I understand that DOJ's
17 expert has offered a -- well, let me -- let me ask
18 you this: You reviewed Dr. Spiliotopoulos's
19 report, correct?

20 A. Yes.

21 Q. Okay. And you saw that his opinion
22 that the -- the later start date for ABC Cleaners,
23 correct?

24 A. Right, correct.

25 Q. Of July 1954, correct?

1 A. That is correct.

2 Q. Okay. And in the ATSDR Tarawa Terrace
3 model, the start date was assumed to be January 1,
4 1953, correct?

5 A. That is correct.

6 Q. And on day one, the calibrated mass
7 loading rate is 1200 micrograms per liter, correct?

8 A. No, grams per day.

9 Q. Per day. I'm sorry.

10 A. Yeah, grams. The way it was input to
11 the model as a source loading rate, so it would be
12 grams per day.

13 Q. Thank you for that. It was assumed to
14 be a constant 1200 micrograms per day, correct?

15 A. The calibrated value.

16 Q. For Tarawa Terrace?

17 A. Yes.

18 Q. Okay. In the real world, if
19 contaminants on the surface were to start leaking,
20 would they immediately reach the aquifer?

21 A. They would within, in this case,
22 probably a couple of years.

23 Q. So in -- in -- for Tarawa Terrace it's
24 your opinion that whenever ABC Cleaners released
25 PCE into the -- onto the ground, it would have

1 taken a couple of years for it to reach the
2 aquifer?

3 A. To reach any of the supply wells
4 pumping. In other words, it would have gone
5 vertically horizontal and, of course, the -- say
6 TT26 is pumping, is putting tremendous gradient,
7 vertical gradient, down right near to the well, so
8 it would have fallen horizontal and then vertically
9 down into the well -- a well casing or a well
10 screen and been pulled -- pulled up. And the
11 assumption was, again, the engineering assumption,
12 that it started on January 1st, 1953 when ABC
13 Cleaners started operations.

14 Q. Okay. So you assumed the constant --
15 the calibrated constant mass loading rate on day
16 one, but you agree in the real world it may have
17 taken a couple of years for contaminants from ABC
18 Cleaner to actually get to the supply wells,
19 correct?

20 A. It may have, but we did not do -- you
21 would have to do an unsaturated zone modeling or
22 analysis to actually quantify that.

23 Q. Why did you-all decide to assume a
24 constant mass loading rate on day one?

25 A. Because if we did not assume a constant

1 value, that would be, to me, indicative that we
2 must have had some additional data to say that, you
3 know, it was a certain rate this day, a different
4 rate in another day, and so on. So we did not have
5 that information, so in keeping with accepted model
6 calibration practice, we assumed the constant rate
7 that we computed -- we computed initial, which was
8 a minimum value, and then through the calibration
9 process increased it using calibration to check
10 results for the available contaminant concentration
11 data at the wells.

12 (DFT. EXHIBIT 21, e-mail correspondence
13 Bates-stamped CLJA_Watermodeling_05-0000021184
14 through 0000021188, was marked for identification.)
15 BY MR. ANWAR:

16 Q. I'm handing you what I'm marking as
17 Exhibit 21.

18 A. Okay.

19 Q. I hope that's right, 21. We were just
20 talking about mass loading with respect to Tarawa
21 Terrace. I would like to shift gears to -- to sort
22 of mass loading with respect to Hadnot
23 Point/Holcomb Boulevard.

24 A. Okay.

25 Q. And this is an e-mail from Barbara

1 Anderson to you dated -- the first e-mail -- well,
2 I guess the chain, both of them, are dated
3 September 26th, 2011, correct?

4 A. It's September 26, 2011, yes.

5 Q. Okay. And this e-mail is discussing
6 mass loading of benzene, correct, or, I guess,
7 LNAPL, light non-aqueous phase liquid?

8 A. I believe this is discussing the LNAPL
9 that's dissolved because -- it says LNAPL on it, so
10 I'll leave it at that right now.

11 Q. The third paragraph states, "the first
12 scenario is a simple step function. The second
13 scenario incorporates some information we have
14 about the Hadnot Point fuel farm area and
15 conceptualizes the source strength LNAPL area as
16 increasing over time. In reality, the LNAPL
17 footprint grew and spread as the UST system leaks
18 and releases progressed. At some point in time the
19 LNAPL footprint grew to be the size that -- that GT
20 calculated from the free product data, 1988 to
21 1999, but it was not that size from the beginning
22 start date. This is shown in scenario two."

23 Did I read that correctly?

24 A. Yes.

25 Q. And do you agree with Barbara Anderson

1 that in reality the LNAPL footprint grew and spread
2 as the underground storage tank system leaks and
3 releases progressed?

4 A. Conceptually, yes, I would agree with
5 that.

6 Q. And scenario two shows a -- the leaks
7 and releases progressing over time, correct?

8 A. That is correct.

9 Q. Whereas, the scenario one is a step
10 function that shows immediate mass loading or
11 release right away, correct?

12 A. That is correct.

13 Q. And for the Hadnot Point/Holcomb
14 Boulevard model as it relates to LNAPL, ATSDR used
15 scenario one, correct?

16 A. I would have to go back and read -- the
17 LNAPL was rather complicated because we had the
18 folks at the multi-environmental simulations lab at
19 Georgia Tech looking at the volume and then the
20 movement within the saturated zone to the water
21 table. And then we had the other people, like
22 Barbara and Mr. Elliott Jones, who did the fate and
23 transport part, looking at it moving the water
24 table.

25 So I would have to go back and -- and

1 look at how each one characterized the mass loading
2 rate or the source -- source rate and -- but I know
3 Barbara was our data analyst, and I think the task
4 here was to look at two different
5 conceptualizations for how mass loading at the
6 Hadnot Point industrial area and fuel farm could
7 have occurred.

8 Q. Okay. And scenario two is more
9 realistic, right, in the real world?

10 MR. DEAN: Object to the form.

11 THE WITNESS: Again, that's -- I think
12 that's an data analysis engineering call as to what
13 it could be.

14 BY MR. ANWAR:

15 Q. Okay.

16 A. You know, where it's almost -- you'd
17 have to run a sensitivity analyses on here and see
18 which one provided you closer agreement.

19 Q. Okay. As you, Mr. Maslia, sit here
20 today, are you planning to amend or supplement your
21 expert report in the case?

22 A. Well, we mentioned about the geometric
23 bias. I don't know if that amends my report or --
24 and we included that extra paper reference --

25 Q. Okay.

1 A. -- from Clement, so that definitely, I
2 think, should be in there. And, you know, I don't
3 have any intentions of any major changes based on
4 additional modeling that I'm -- I'm doing. I'm not
5 planning on doing any.

6 Q. When you say no intent on major
7 changes --

8 A. Right.

9 Q. -- are you planning to -- and when I
10 say supplemental disclosure, are you planning to
11 provide, like, another written document with
12 additional or updated opinions --

13 MR. DEAN: So --

14 BY MR. ANWAR:

15 Q. -- major or minor?

16 MR. DEAN: Let me -- let me take over
17 here and answer for the witness, if it's okay. And
18 that is, as you know, DOJ recently belatedly
19 produced a bunch of photos from Dr. Hennet without
20 any sort of a disclosure of what it is. So we
21 can't respond to our experts until we sort of know
22 some explanation as to what that is. So that could
23 potentially, depending on Mr. Hennet's deposition,
24 trigger something from him, but he nor any of our
25 experts at this time can answer your question about

1 additional thoughts or opinions or whatever. And,
2 of course, there's been some correspondence about
3 this. Mr. Bain has sent a letter and we've
4 responded. So we just -- he's reserving that right
5 as to that stuff.

6 MR. ANWAR: Okay. Well, we will wait
7 to see -- we'll wait to receive the documents
8 related to the geometric bias and we will reserve
9 our right to keep the deposition open or to reopen
10 it. And I think I only have a few minutes left, so
11 thank you for your time. I'll reserve those final
12 minutes. Thank you for your time today.

13 THE WITNESS: Okay. Thank you.

14 MR. DEAN: Okay. Let's go off the
15 record, if it's okay, for maybe about ten minutes.
16 Take a break. Let me get my thoughts together.
17 I've got some questions. They won't be long, but
18 I've got a few questions.

19 THE VIDEOGRAPHER: Okay. Going off
20 record. The time is 5:56.

21 (A recess transpired.)

22 THE VIDEOGRAPHER: Okay. We are going
23 back on record. The time is 6:15 p.m.

24 EXAMINATION

25 BY MR. DEAN:

1 Q. All right. Mr. Maslia, I just have a
2 few questions, so I don't think we'll be long,
3 okay?

4 A. Okay.

5 Q. Oh, there we go. So earlier you were
6 shown Exhibit 9, which is the Chapter A Tarawa
7 Terrace report, and I want to ask you if you can
8 look at your version and turn to page -- I believe
9 it's A -- excuse me. You were shown Chapter C.

10 A. Hadnot Point?

11 Q. Hadnot Point, page C98. So it looks
12 like it's Chapter C.

13 A. Yeah, I'm trying to find...

14 Q. Can you tell me what that exhibit
15 number was?

16 MS. SILVERSTEIN: 17.

17 THE WITNESS: I've got Exhibit 17.

18 BY MR. DEAN:

19 Q. Okay. So take a look at Exhibit 17;
20 put it in front of you.

21 MR. ANWAR: What page are you on?

22 MR. DEAN: Page C98.

23 THE WITNESS: Okay. C98. Okay. I'm
24 at C98.

25 BY MR. DEAN:

1 Q. Do you remember Mr. Anwar asking you
2 quite a few questions about the sampling for
3 benzene at Hadnot -- or HP602?

4 A. Yes, I do.

5 Q. Okay. And y'all went over -- spent
6 quite a while on reviewing those different sampling
7 results. Do you remember that?

8 A. Yes.

9 Q. Now, can I have exhibit number --
10 MR. DEAN: Do we just want to continue
11 the same number sequence?

12 MR. ANWAR: Whatever you want, yes.

13 (DFT. EXHIBIT 22, Appendix A5
14 Bates-stamped CLJA_Watermodeling_010000942748
15 through 0000942750, was marked for identification.)
16 BY MR. DEAN:

17 Q. I'm just going to use this just to
18 shortcut it. I believe it's the end of -- this is
19 Appendix I-5, Exhibit 22.

20 A. Okay. That's from the Chapter A report
21 for Hadnot Point/Holcomb Boulevard.

22 Q. Correct. Now, you -- you were also
23 asked some questions about the same time -- y'all
24 were having a discussion about when the well was on
25 and when was well was off. Do you remember that?

1 A. Yes.

2 Q. Okay. Can you explain to me as it
3 concerns those sampling that was done post-turning
4 off of the well, what the significance would be for
5 those test results as it concerns the existence of
6 the continuing contamination?

7 MR. DEAN: Object to the form.

8 THE WITNESS: Well, what these plots
9 show, show early time, '51, the contamination in
10 '68, the wells are pumping. November '84, the
11 wells are pumping and shut off. And then it shows
12 the plume -- this is the benzene plume, I believe,
13 yes, benzene. It still shows it migrating under
14 the hydraulic gradient, which is heading east to
15 northwest, okay?

16 Q. Okay. And what is the significance of
17 that with regard to the validity of any of the
18 either calibration or contaminant testing
19 concentrations after the well was shut off?

20 MR. DEAN: Object to the form.

21 THE WITNESS: What that indicates to
22 me, and I think we had this discussion, is even
23 though the tables that we have based on information
24 provided by the Marine Corps for the Navy shows a
25 well shut off, if you're still observing benzene

1 concentrations in the water treatment plant, there
2 had to be some wells pumping, okay? Maybe not
3 continuously, but the plume is still moving past
4 the well. I'm looking at well -- well 602 there,
5 and even in 2008 there's still a plume over there.
6 So if that well was ever turned on again, even
7 though it says out of service, you would -- it
8 would -- you would get benzene.

9 Q. Sorry.

10 A. This is similar to what we observed at
11 Tarawa Terrace with TT26, and even though they shut
12 down TT26, the plume kept moving.

13 Q. Okay. And were samples taken for
14 concentrations in the area of the wells after those
15 wells were shut down?

16 A. Were they?

17 Q. Yes.

18 A. I would have to look and see on the
19 Chapter C report.

20 Q. Now, the Prabhakar Clement article that
21 was previously -- I believe it was marked as an
22 exhibit, the 2000 paper.

23 A. Yes, that one.

24 Q. Okay. Exhibit 1.

25 A. Okay.

1 Q. When did you locate that paper?

2 A. I would say within the last six months.

3 Q. When you were giving your 2010
4 deposition and responding to a question from the
5 plaintiff's lawyer in that case -- well, strike
6 that.

7 Before I go there, who was defending
8 you during that 2010 deposition?

9 A. Mr. Adam Bain from the Department of
10 Justice.

11 Q. Okay. And did you meet with him and
12 prepare for that deposition in -- in -- either by
13 phone or in person?

14 A. I met with him in the afternoon along
15 with attorneys for CDC's Office of General Counsel
16 on the 29th, the day before, for a few hours in the
17 afternoon.

18 Q. Okay.

19 A. And since I had never been deposed
20 before, he went over the ground rules and --

21 Q. And during that meeting or any other
22 conversations y'all had, did Mr. Bain ever question
23 the validity of your work at -- for which you were
24 about to testify to?

25 A. No, he did not.

1 Q. Now, you -- he asked -- excuse me, not
2 he. The plaintiff's lawyer in that case asked a
3 question to which you responded something -- I'm
4 using the word mob, do you remember that?

5 A. Yes.

6 Q. Referring to the work or some of the
7 work that was done here. Were you aware at -- in
8 2010, or had you seen Dr. Clement's paper at that
9 time?

10 A. I had not seen this particular journal
11 article.

12 Q. All right. I'm going to show you
13 Exhibit 23.

14 (DFT. EXHIBIT 23, Author's reply by T.
15 Prabhakar Clement from Ground Water,
16 January-February 2012 Bates-stamped
17 CLJA_Watermodeling_010000092109 through 0000092111,
18 was marked for identification.)

19 MR. ANWAR: And I'm just going to note
20 for the record that conversations that took place
21 when you were an employee of ATSDR and the
22 Department of Justice are privileged.

23 THE WITNESS: Okay.

24 MR. DEAN: And I'm not sure I agree,
25 but I don't think it matters, just for the record.

1 You know what, I don't think I have an extra copy
2 of this. I'll show it to you. I don't have an
3 extra copy of it.

4 MR. ANWAR: I have a copy.

5 MR. DEAN: It's the response to...

6 BY MR. DEAN:

7 Q. So I'm going to show you Exhibit No.
8 23. And can you tell me what that document is?

9 A. This looks like Dr. Clement's response
10 to our editorial review or editorial comment on his
11 2010 paper about hindcasting.

12 Q. And can you read the first -- let me
13 see. I think it's just the first full sentence.

14 A. I believe I've got a copy if you want
15 me to just use my copy and then...

16 Q. Yes, it's -- it's actually the first
17 full sentence. It's a rather long sentence, but...

18 A. Yeah, I got --

19 Q. You can just use this one.

20 A. Oh, okay. Okay. Okay.

21 Q. Can you read into the record --

22 A. The first full sentence?

23 Q. Yes, sir. Now, let's give it a little
24 context. What is Dr. Clement responding to?

25 A. Dr. Clement published an article in

1 Groundwater, in the same journal, I believe it was
2 in 2010, about basically hindcasting, historical
3 reconstruction to us, when is enough enough, and
4 used the Camp Lejeune project as a case study or an
5 example.

6 Q. Okay. And who is Dr. Clement as it
7 concerns his relationship with any of the Camp
8 Lejeune work? What -- what role, if any, did he
9 play at any point in time with regard to Camp
10 Lejeune work?

11 A. Dr. Clement was the hydrogeologist and
12 modeler expert on the National Research Council
13 that assessed ATSDR's Camp Lejeune work.

14 Q. So when people refer to the 2009 NRC
15 report, he was the water modeler that was -- served
16 as one of those panel members?

17 A. He was the only water modeler.

18 Q. Okay. So later on he must have written
19 an article in 2010 about additional information
20 about Camp Lejeune?

21 A. Yes.

22 Q. Okay. And can you read into the record
23 what he said in his response to ATSDR's response?

24 A. Okay. In the response to our
25 editorial.

1 Q. Yes.

2 A. Okay. "The goal of my article was not
3 to review the Camp Lejeune, in parentheses, CLJ,
4 modeling studies." Do you want me to continue?

5 Q. You can -- you can read the next line.

6 A. Okay. "Rather it was to use the CLJ
7 problem as an example to highlight issues related
8 to model complexities and to speak -- and to spark
9 an open debate on when, where, and why we should
10 limit model complexity."

11 Q. Okay. Now, you spent a lot of time,
12 both you and Mr. Anwar, using a word,
13 "uncertainty?"

14 A. Yes.

15 Q. Okay. And of course, lawyers and the
16 general public may use the word "uncertainty"
17 differently than water modelers; is that correct?

18 A. Yes.

19 Q. So what -- when you were referring --
20 using the word with -- uncertainty in responding to
21 questions that used the word "uncertainty", can you
22 explain to the Court and jury what is an
23 uncertainty -- what is uncertainty definition or an
24 uncertainty analysis as you're using it in this
25 deposition?

1 A. I'm using it in this deposition and the
2 modeling analyses.

3 Q. Is uncertainty unusual in water
4 modeling work?

5 A. Not at all.

6 Q. And explain that to the Court, sir.

7 A. Again, that -- that was -- I'll say
8 that was one of our primary concerns and
9 disagreement with the NRC report because it -- it
10 described the uncertainty about data about
11 modeling. We never disagreed that there was
12 uncertainty. An example being you have a sample
13 measurement and, you know, you can have a lower
14 value or a higher value. And so the uncertainty
15 would be that range in there in terms of numerical
16 analysis, like Monte Carlo gives you upper band, a
17 mean, and a lower band. And so that band is the
18 uncertainty or the confidence, okay? So when we're
19 talking about uncertainty, we're also talking about
20 the confidence that we have in the results.

21 Q. Okay. And you expect to see the word
22 "uncertainty" in any -- everyday garden variety of
23 water modeling project?

24 MR. DEAN: Object to form.

25 THE WITNESS: They should. If you look

1 at some of the earlier modeling procedures or
2 protocols of models -- when I say earlier, prior to
3 1980, prior to 19 -- you might see sensitivity
4 analysis and that's part of uncertainty analysis,
5 but good modeling practice would include both
6 sensitivity analysis and an uncertainty analysis.

7 BY MR. DEAN:

8 Q. All right. Let's go to one other area
9 real quick. I don't know the exhibit number. It's
10 the e-mail related to the disclaimer.

11 A. Oh, okay. Here, 11.

12 Q. Okay.

13 MS. SILVERSTEIN: The e-mail is
14 Exhibit 13.

15 THE WITNESS: Here you go. 13.

16 BY MR. DEAN:

17 Q. 13, yes.

18 A. The exhibit is 12.

19 Q. Yeah, the disclaimer. So with regard
20 to Exhibits 12 and 13 having to do with this issue
21 that arose, it appears, in May of 2007, do you
22 remember having a conversation of questions back
23 and forth with Mr. Anwar?

24 A. Yes, I do.

25 Q. Okay. And -- but I didn't hear him

1 ask, nor did I -- or maybe I missed it, but did you
2 -- did someone reach out to you and complain or did
3 some -- something come to you from another
4 department or agency upset about what was being
5 posted on the website that generated the need for a
6 disclaimer on the website?

7 MR. DEAN: Object to form.

8 THE WITNESS: I recall that it was
9 conveyed to me in the source sent to me, the
10 Department of Navy, where or who -- I'm not sure,
11 it could have been a representative at Camp Lejeune
12 that -- my point of contact, but the message was
13 that the Navy was upset about anyone being able to
14 access values on the ATSDR website.

15 Q. And calculate for their own benefit
16 specific numbers?

17 A. Yes, yes, yes.

18 Q. Okay. So up until the time, based on
19 your information from a source that it's the Navy
20 that made this complaint, there was not any
21 consideration for the need for a waiver; is that
22 fair?

23 MR. DEAN: Object to form.

24 THE WITNESS: We -- we did not have
25 that in our protocol so to speak --

1 BY MR. DEAN:

2 Q. Sure.

3 A. -- that we needed to put up a
4 disclaimer.

5 Q. It still today doesn't show up in the
6 written published reports, bound, produced reports,
7 other than on the website?

8 A. No, no, it does not appear in the
9 reports.

10 Q. And when you were communicating with
11 the lawyer about a form of a disclaimer,
12 Ms. Deborah Tress in May 2007, do you know whether
13 or not she was communicating with Adam Bain and the
14 Department of Justice at the same time with regard
15 to this disclaimer?

16 MR. DEAN: Object to form.

17 THE WITNESS: I do not know. We were
18 just told --

19 BY MR. DEAN:

20 Q. And for the record, Ms. Deborah,
21 Debbie, Tress, she's a lawyer, in-house lawyer,
22 employed by the federal government working for the
23 ATSDR CDC in-house counsel?

24 A. At the time of that e-mail, she was the
25 CDC in the CC Office of the General Counsel and we

1 were told she would be the one handling any Camp
2 Lejeune-type issues.

3 Q. Okay.

4 A. From a legal standpoint.

5 Q. So late this afternoon, probably in the
6 last hour or so, you answered some questions with
7 regard to timing of contaminants to Tarawa Terrace
8 TT26. Do you remember that?

9 A. Yes.

10 Q. And I believe it is Alex
11 Spiliotopoulos's report where he has some
12 suggestions and a graph where he has the
13 contaminants going -- instead of going through the
14 water column, dropping into the ground -- are you
15 familiar with what I'm referring to?

16 A. Yes, I am.

17 Q. Okay. How is the most reasonable way
18 in which you expect contaminants that get into the
19 water column -- are they going to continue in the
20 water table or are they going to drop in the
21 ground, is my first question?

22 A. Well, they're going to go along a
23 pathway, a horizontal pathway. And as I put in my
24 rebuttal report and Dr. Konikow explained, they'll
25 -- they'll go horizontally almost until they reach

1 the well, and that's because you've got a cone of
2 depression around the well as the well is pumping,
3 and then go very rapidly vertically into the --
4 into the well.

5 Q. And scientifically, why does -- why --
6 why is that? Why does that occur, in your opinion?

7 A. Because the groundwater is -- velocity
8 is flowing with the gradient. So the gradient is
9 decreasing or the water level is decreasing as you
10 approach the well.

11 Q. Okay. And is the contaminants -- is
12 the -- traveling in the water table versus reaching
13 the well itself, is one faster than the other?

14 A. Yes, the -- the last, let's call it,
15 the few -- few feet or where the cone of depression
16 of the well is going to much more rapidly pull in
17 any contaminants, and the time is going to be much
18 more shortened because of the high velocities at
19 the well and within the cone of depression.

20 Q. I'm sorry. My dog is -- they can't
21 find my -- my wife can't find my dog, so I told her
22 where he was at.

23 Okay. Let's give this back.

24 A. Okay.

25 Q. Between the time -- when did you --

1 remind me when you retired?

2 A. December 31st, 2017.

3 Q. Okay. When you retired on January the
4 -- January of 2018 until the unfortunate time when
5 I gave you a call in '22, did you do any work on
6 Camp Lejeune during that time frame?

7 A. No, I did not.

8 Q. Okay.

9 A. Nor did I speak to anyone.

10 Q. Okay. Let me ask a -- the timing
11 question, let me ask one last different way. For
12 purposes of the timing of contaminants to reach the
13 aquifer, is that different from the time for it to
14 reach the water table?

15 A. Well, conceptually, the aquifer in
16 Tarawa Terrace that we modeled starts at the water
17 table, okay? And we didn't look at -- we didn't on
18 MODFLOW, MT3DMS, did not look above the water
19 table. It was maybe about 10 feet, 15 feet of
20 saturated zone. And so we looked at everything --
21 all our models assume it's at the water table, and
22 that the timed travel through the unsaturated zone,
23 so typically down vertically, would be minimal.

24 MR. DEAN: All right. I believe that's
25 all the questions I have. Thank you.

1 MR. ANWAR: I just have a couple of
2 follow-up questions in my --

3 THE WITNESS: Sure.

4 MR. ANWAR: -- few remaining minutes.

5 EXAMINATION

6 BY MR. ANWAR:

7 Q. Mr. Dean showed you, I think, what was
8 marked as Exhibit 22.

9 A. Yes.

10 Q. If you would like to take a look. My
11 only question about this is Exhibit 22 is the
12 depiction of plumes at Hadnot Point -- the
13 contaminant plume at Hadnot Point, correct?

14 A. Yes, yes, yes. It's the -- you're
15 talking about benzene?

16 Q. For the benzene plume, correct?

17 A. Yes, yes. Let's see, what -- what page
18 you're on?

19 Q. It's A146.

20 A. A146. Okay. Okay. I'm there.

21 Q. My only question about it is that what
22 we're seeing here is a visual depiction of the
23 reconstructed plume based on the model, right?

24 A. That is correct.

25 Q. Okay. I'm going to mark one exhibit.

1 (DFT. EXHIBIT 24, e-mail correspondence
2 Bates-stamped CLJA_ATSDR_BOVE-0000108607 and
3 0000108608, was marked for identification.)

4 BY MR. ANWAR:

5 Q. I'll hand it to you, Exhibit 23. 24.
6 I'm sorry. Let me fix that. I can't count. I
7 will represent to you this is an e-mail exchange
8 that starts between you and Dr. Clement and then
9 that you forward on to the ATSDR team in February
10 of 2008. Would you agree with that?

11 A. Yes.

12 Q. Okay. And in the -- the e-mail
13 exchange -- the e-mail from Clement, Dr. Clement,
14 to you at the bottom of the chain, he's offering
15 some -- some -- his sort of feedback and some
16 compliments about the work that you-all did with
17 respect to the Tarawa Terrace analysis, correct?

18 A. It does not specifically say Tarawa
19 Terrace. However, given the date of that, it would
20 have been Tarawa Terrace because we would not have
21 probably even started on Hadnot Point.

22 Q. Sure. And the subject says sensitivity
23 analysis on well --

24 A. Oh, okay. Okay.

25 Q. -- TT26, right?

1 A. Okay. Yes.

2 Q. Okay. And he says, "yesterday I read
3 most of your report and I found them to be very
4 thoughtfully organized. It is a complex problem,
5 but you guys did the best possible job a modeler
6 can. They are lucky to have you guys as a modeling
7 team. Thanks for your support." Did I read that
8 right?

9 A. Yes.

10 Q. Okay. And then you forward it to your
11 team and you say, "look at the second paragraph
12 from Dr. Clement, a member of the National Research
13 Council committee on contamination of drinking
14 water at Camp Lejeune. It's nice to get words of
15 praise from unbiased and technically competent
16 colleagues about our abilities and work." Did I
17 read that correctly?

18 A. Yes.

19 Q. Okay. And I understand that
20 subsequently the NRC report was published, correct,
21 in 2009?

22 A. That's correct, that's correct.

23 Q. And after the NRC report, Dr. Clement
24 published his -- his article on hindcasting, and
25 then you-all -- you and Dr. Aral and the ATSDR team

1 had a response, and then he published sort of a
2 response to your response, correct?

3 A. Right, that's correct.

4 Q. Okay.

5 A. That's typically what's done in the
6 journal article type.

7 Q. Sure. Do you -- in your view, as you
8 sit here today, is Dr. Clement still an unbiased
9 and technically competent colleague?

10 MR. DEAN: Object to the form.

11 THE WITNESS: Yes, I never -- I never
12 said he was biased. We always said it was the NRC
13 report, the final -- the final report. Again, I
14 think we discussed this in my previous deposition,
15 that that is what really caught the entire team by
16 surprise because we were providing information and
17 data to Dr. Clement. I think we also provided it
18 to Dr. Knuckles and some other people.

19 Q. Sure.

20 A. And the feedback was this is, you know,
21 great -- great stuff, great job and all of that.
22 And the report -- and especially the -- I guess,
23 what is it, the public summary or whatever, really
24 just took a 180-degree opposite turn.

25 Q. Okay.

1 A. Okay.

2 MR. ANWAR: Those are all the questions
3 I have. Thank you.

4 EXAMINATION

5 BY MR. DEAN:

6 Q. Mr. Maslia, he's -- I'm just focusing
7 on Exhibit 24, and Mr. Anwar is pointing out the --
8 your use of the word "unbiased" --

9 A. Right.

10 Q. -- with respect to the reference to
11 Dr. Clement on February 21st, 2008. Do you see
12 that?

13 A. Yes, I do.

14 Q. At the time that e-mail was sent and
15 words that you're issuing, the NRC report had not
16 been issued yet, right?

17 A. Yes, you're correct.

18 Q. And it had not been issued until July
19 -- I think it's July 2009.

20 A. June 2009.

21 Q. June 2009. Have you now read Susan
22 Martel's deposition and all of the exhibits that
23 are attached to it?

24 A. Yes.

25 Q. And do you have an opinion as to

1 whether or not the NRC was, in fact, biased or
2 unbiased in the issuance of that final report?

3 A. The NRC report, I believe, contained
4 numerous -- numerous -- it contained -- it
5 contained mistakes, mischaracterizations, and it
6 appeared to us to be -- and I'm talking about the
7 project team, including the epidemiologists and
8 whatever toxicologist, that it was a biased report.

9 MR. DEAN: Thank you. I have no
10 further questions.

11 MR. ANWAR: Nothing from me. Thank
12 you.

13 THE WITNESS: Thank you.

14 THE VIDEOGRAPHER: Okay. Then we're
15 going off record the time is 6:49 p.m. This
16 concludes today's deposition.

17 (The witness, after having been advised
18 of his right to read and sign this transcript, does
19 not waive that right.)
20
21
22
23
24
25

CERTIFICATE OF REPORTER

I, Lauren A. Balogh, Registered Professional Reporter and Notary Public for the State of South Carolina at Large, do hereby certify that the foregoing transcript is a true, accurate, and complete record.

I further certify that I am neither related to nor counsel for any party to the cause pending or interested in the events thereof.

Witness my hand, I have hereunto affixed my official seal this 18th day of March, 2025 at Myrtle Beach, Horry County, South Carolina.



Lauren A. Balogh
My Commission expires
March 19, 2030

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1	Application at the Dover		
2	Site",		
3	DFT. EXHIBIT 2, deposition of	29	6
4	Morris L. Maslia dated June		
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2 DFT. EXHIBIT 8, Federal 70 3
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24 the Hadnot Point and Holcomb
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IN THE UNITED STATES DISTRICT COURT
FOR THE EASTERN DISTRICT OF NORTH CAROLINA
SOUTHERN DIVISION
Civil Action No. 7:23-cv-00897

IN RE: CAMP LEJEUNE WATER LITIGATION

THIS DOCUMENT RELATES TO:
ALL CASES

VIDEOTAPED

DEPOSITION OF: MORRIS MASLIA

DATE: March 13, 2025

TIME: 9:14 a.m.

LOCATION: BELL LEGAL GROUP
219 North Ridge Street
Georgetown, SC

TAKEN BY: Counsel for the Defendants

REPORTED BY: Lauren A. Balogh, RPR

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10 ALSO PRESENT:

11 Jon Landau, Videographer

12 Leonard Konikow (via videoconference)

13 Deanna Havai, Motley Rice

14 (Via videoconference)

15 Alex Spiliotopoulos

16 (Via videoconference)

17 Timothy Thompson

(Via videoconference)

18 Bill Williams (via videoconference)

19
20
21 (INDEX AT REAR OF TRANSCRIPT)
22
23
24
25

1 THE VIDEOGRAPHER: The following will
2 be the videotaped deposition of Morris Maslia in re
3 Camp Lejeune Water Litigation versus United States
4 of America, File No. 7-23-CV-897. Today's date is
5 March 13th, 2025 and the time is 9:14 a.m. We are
6 here today at 219 Ridge Street, Georgetown, South
7 Carolina. The court reporter is Lauren Balogh and
8 the videographer is Jon Landau.

9 At this time I will ask all attorneys
10 present to please state their names and whom they
11 represent for the record.

12 MR. DEAN: Good morning. Kevin Dean
13 here on behalf of the PLG and the witness.

14 MR. BELL: Edward Bell on behalf of the
15 plaintiff.

16 MR. ANWAR: Haroon Anwar on behalf of
17 the United States.

18 MS. SILVERSTEIN: Kaylie Silverstein on
19 behalf of the United States.

20 THE VIDEOGRAPHER: Do you want the
21 people on the Zoom to do it?

22 MR. DEAN: It's up to you.

23 MR. ANWAR: The court reporter can take
24 it down. That's fine.

25 MR. DEAN: Yeah.

1 THE VIDEOGRAPHER: Okay. All right.
2 You may swear the witness, please.

3 MORRIS MASLIA
4 being first duly sworn, testified as follows:

5 EXAMINATION

6 BY MR. ANWAR:

7 Q. Good morning, Mr. Maslia.

8 A. Good morning.

9 Q. My name is Haroon Anwar. I am a lawyer
10 at the Department of Justice here on behalf of the
11 United States. We've met before at your prior
12 deposition in fall 2024, correct?

13 A. September 26th.

14 Q. September 26th of 2024. Thank you.

15 A. Yes.

16 Q. You may remember that experience. I'm
17 just going to go through -- go over a few rules for
18 the deposition just so we're on the same page, but
19 I'm going to ask you a number of questions today.
20 If I ask you a question that's vague or you don't
21 understand, please ask me to clarify. Otherwise,
22 I'm going to assume that you -- you understand my
23 question. Fair enough?

24 A. Fair enough.

25 Q. Okay. And the number one most

1 important rule for the deposition today, same as
2 before, is that you are under the oath to tell the
3 truth as if you were in an actual court of law. Do
4 you understand that?

5 A. Yes, I do.

6 Q. Okay. And is there any reason that
7 you'll be -- is there any reason today that you'd
8 be unable to testify truthfully?

9 A. No, there is not.

10 Q. The court reporter is transcribing
11 everything that we're taking down, so if we could
12 try not to speak over each other and perhaps give a
13 brief pause in case your lawyer needs to object, it
14 will make for a much cleaner transcript as well as
15 a much happier court reporter. Can we agree to try
16 to do that?

17 A. Yes.

18 Q. Okay. We will try to take breaks about
19 every hour. If you need to take a break sooner
20 than that, just let me know.

21 A. Okay.

22 Q. I'm happy to accommodate you. The only
23 stipulation I would put on that is if there's a
24 pending question, I would ask that you answer that
25 question and then we -- we can take a break. This

1 is not intended to be sort of a punishment, so to
2 speak.

3 A. Understood.

4 Q. So with that I wanted to start by
5 asking you what you did to prepare for today's
6 deposition?

7 A. I reviewed every single ATSDR Camp
8 Lejeune historical reproduction report that I was
9 involved with both for Tarawa Terrace, Hadnot
10 Point. I've also reviewed my expert report that
11 was submitted to you as well as my rebuttal report,
12 and I also reviewed some published journal
13 articles.

14 Q. What were the published journal
15 articles that you reviewed?

16 A. There was a series by -- that appeared
17 in Groundwater journal by Dr. Prabhakar Clement,
18 who I think you may know, and ATSDR exposure dose
19 reconstruction program staff responded to it, and
20 then they responded to -- to ours, so it's three
21 articles in Groundwater. His was 2010 and ours was
22 2012.

23 Q. Okay.

24 A. And then I've also reviewed just some
25 articles on uncertainly analysis. An article that

1 I published in 2004 on use of -- contained some
2 historical reconstruction of some smaller sites
3 using an analytical contaminant transport system
4 model and also contained the probabilistic
5 uncertainty analyses using Monte Carlo simulation.
6 So reviewed that as well as an article by
7 Dr. Clement in 2000 at Dover Air Force Base, which
8 is identical to Tarawa Terrace and came out with
9 identical values for some of the parameters, and I
10 would, in fact, like to add that to my expert
11 report if I can.

12 Q. Okay.

13 A. I've got a copy here, if you would like
14 to see that.

15 Q. Sure.

16 MR. DEAN: Yeah, I brought a copy.

17 MR. ANWAR: Thank you.

18 MR. DEAN: You're welcome.

19 BY MR. ANWAR:

20 Q. Thank you. So this -- we'll note this
21 for the record as an additional material --

22 A. Okay.

23 Q. -- on your -- your reliance list.

24 A. Yes, yes.

25 Q. For your expert report. Thank you.

1 Aside from the articles that you -- you mentioned,
2 the ATSDR reports and -- the ATSDR modeling reports
3 for Tarawa Terrace and Hadnot Point, Holcomb
4 Boulevard, and then your expert and rebuttal
5 report, did you review any other documents?

6 A. Just my deposition from September 26th.

7 Q. Okay.

8 A. And the exhibits that you provided.

9 Q. Oh, okay. During the September 26th --

10 A. Yes.

11 Q. -- 2024 deposition?

12 A. Yes.

13 Q. Did you review any of the other expert
14 reports in the case?

15 A. I reviewed Dr. Konikow's report. I
16 reviewed Dr. Sabatini's report. I reviewed
17 Dr. Jones and Mr. Davis's post-audit report and
18 rebuttal. And I also reviewed the defense's expert
19 reports by Dr. Spiliotopoulos, Dr. Hennet, and
20 Dr. Brigham.

21 Q. Understood. And I understand just from
22 attending the depositions of Dr. Aral, Mustafa
23 Aral, Dr. Davis, Dr. Jones, and then Dr. Konikow
24 about a week or so ago -- did you listen in to all
25 of those depositions as well?

1 A. Yes.

2 Q. Okay.

3 A. With Dr. Konikow I had to step out for
4 a couple of hours.

5 Q. Okay.

6 A. To do a medical run with my dad, so --
7 but I listened, I would say, to a majority of it.

8 Q. Did you review any of the transcripts
9 from those depositions?

10 A. I -- I read them. I guess
11 Dr. Konikow's transcript, because I wasn't there
12 for part of it, I read that in its entirety. Okay.
13 The other ones, just spot, you know, spot read
14 because I was watching the entire time.

15 Q. Understood. Did you do anything else
16 to prepare for today's deposition?

17 A. Only discuss with the plaintiff's
18 attorney the logistics, again, of, I believe, the
19 first time I was deposed as a fact witness versus
20 an expert witness to them.

21 Q. Understood. And I'm not asking about
22 the substance of your conversations with --

23 A. Right.

24 Q. -- the lawyers, just the circumstances
25 of the meeting. When did you meet with the lawyers

1 to prepare for the deposition today?

2 A. Yesterday, most of the day, and on
3 Tuesday afternoon.

4 Q. Okay. Who did you meet with yesterday?

5 A. Yesterday I met with Mr. Dean and also
6 Mr. Williams.

7 Q. Was there anyone else present in that
8 meeting?

9 A. Mr. Tim Thompson. He works with
10 Mr. Williams, and that's it.

11 Q. Okay. About how long did that meeting
12 last, the one yesterday?

13 A. Yesterday, we started about 9:30 and
14 ended about 4:30, 5.

15 Q. Did you review any documents during
16 yesterday's meeting?

17 A. Yes, the same ones that I had mentioned
18 to you, and spoke about wanting to place the
19 journal article as an addition to my materials in
20 my expert report.

21 Q. Understood.

22 MR. DEAN: Not to interrupt, but you
23 might want to ask him was anybody else in
24 attendance by Zoom. Because you asked in person
25 and he may have forgotten that.

1 MR. ANWAR: Sure.

2 BY MR. ANWAR:

3 Q. Were -- was anyone else in attendance?

4 A. Yes, another attorney, Laura Baughman.

5 Q. Okay.

6 A. With -- was in and out on Zoom.

7 Q. To the best of your knowledge, during
8 yesterday's meeting, it was only yourself and
9 attorneys for the plaintiffs attending, correct?

10 A. That's correct.

11 Q. And then on Tuesday's meeting, who was
12 present for that?

13 A. I believe that was Mr. Dean and
14 Mr. Williams and Mr. Thompson.

15 Q. And --

16 A. I don't recall if anyone was on Zoom or
17 not. I don't believe because I did not get here
18 until three o'clock p.m.

19 Q. To the best of your knowledge, the only
20 folks in attendance on Tuesday's meeting were
21 yourself and lawyers for the plaintiffs?

22 A. That is correct.

23 Q. Prior to yesterday's meeting and
24 Tuesday's meeting, were there any other meetings
25 with the lawyers to prepare for today's deposition?

1 A. No, no meetings.

2 Q. Dr. Konikow mentioned during his
3 deposition a meeting that took place. I think he
4 said it was in preparation for his deposition, but
5 you were present as well; is that right?

6 A. That's -- yes, yes, yes, now that I
7 recall, that was when -- I believe, if I'm not
8 mistaken, that was in February.

9 Q. Okay.

10 A. And I think I was supposed to be -- be
11 deposed that Thursday. That got postponed.

12 Q. Sure.

13 A. But Dr. Konikow and I were in that
14 meeting, yes.

15 Q. Aside from yourself and Dr. Konikow,
16 who else attended that meeting?

17 A. Mr. Dean, Mr. Williams, and I believe
18 Mr. Thompson.

19 Q. Any -- anyone other than yourself,
20 Dr. Konikow, and the plaintiffs' lawyers attend
21 that meeting?

22 A. Not that I recall.

23 Q. Have you -- did you attend any other
24 meetings in preparation for today's deposition?

25 A. No, I did not.

1 Q. Did you speak with anyone else in
2 preparation for today's deposition?

3 A. No, I did not.

4 Q. Did you speak with anyone from ATSDR in
5 preparation for today's deposition?

6 A. No.

7 Q. Now, you -- we have the -- the most
8 recent 2020 article from Clement that you're adding
9 to your -- your reliance list --

10 A. Yes.

11 Q. -- and have provided a copy here today.
12 You mentioned a couple of other articles that you
13 reviewed.

14 A. Right.

15 Q. And I was just wondering, the Clement
16 article and the other articles that you reviewed,
17 why did you review those articles?

18 A. Well, the article that I coauthored on
19 the analytical contaminant transport analysis
20 system, the ACT system, I think it was published in
21 2004, we reviewed that because it had a number of
22 historical reconstruction cases. One was for
23 20 years, a dry cleaner in New Mexico, and one was
24 -- I want to say it's Otis Air Force Base, EDB
25 contamination, and we did 65 years, and we used an

1 analytical contaminant fate and transport model and
2 conducted two-stage Monte Carlo simulation. So I
3 just wanted to refresh my memory as to what we did
4 and some of the parameters that -- contaminant fate
5 and transport parameters that we used in that.

6 In the Clement article I reviewed --
7 and I reviewed that one in specific detail because
8 Dover Air Force Base is very similar to Tarawa
9 Terrace. About the same size, 2.4 square miles.
10 They used a -- was testing out the RT3D model,
11 which is the reactive transport. So they went from
12 PCE to TCE to DCE to vinyl chloride in their
13 analysis, and a number of their parameters are
14 right where the parameter values that we calibrated
15 for Tarawa Terrace, so I thought it was a good
16 comparison article.

17 Q. The Clement article, I'll look at it
18 during the break.

19 A. Okay.

20 Q. But just based on your memory, what --
21 what did they use that model for?

22 A. I think the -- the purpose was to --
23 was it to -- well, there was historical
24 contamination at the Air Force base and they wanted
25 to look at how it advanced in time, and they wanted

1 to test out the RT3D code that Dr. Clement had
2 developed originally when he was at Lawrence
3 Livermore National Labs, and it was hooked in to
4 MT3DMS, and so they were testing that out, and
5 that's what basically I recall. And then when I
6 started reading the details of it, it appeared to
7 me that it was a very, very good comparison article
8 to what we did at Tarawa Terrace.

9 Q. Just quickly -- and I'll mark this as
10 an exhibit, actually.

11 A. Okay.

12 (DFT. EXHIBIT 1, article from Journal
13 of Contaminant Hydrology entitled "Natural
14 Attenuation of Chlorinated Ethene Compounds: Model
15 Development and Field-scale Application at the
16 Dover Site", was marked for identification.)

17 BY MR. ANWAR:

18 Q. Let's go ahead and mark this as
19 Exhibit 1, but I'll -- I'll mark it and then I'll
20 hand it to you after I have a chance to read it.
21 The 2020 Clement article on the Dover Air Force
22 Base site, in the abstract it states, "the
23 numerical model developed in this study is a useful
24 engineering tool for integrating field-scale
25 natural attenuation data within a rational modeling

1 framework. The model results can be used for
2 quantifying the relative importance of various
3 simultaneously occurring natural attenuation
4 processes."

5 Does that sound consistent with your
6 recollection?

7 A. Yes.

8 MR. DEAN: Object to the form of the
9 question. I think you misspoke about the data, the
10 article. I think you said 2020. If you said 2000,
11 I apologize, but I thought I heard 2020.

12 BY MR. ANWAR:

13 Q. Okay. And I understood you, Doctor, or
14 Dr. Maslia, Mr. Maslia, to state that this article
15 was published in 2020, but I perhaps misunderstood.

16 A. Okay. Okay. It is a 2000 article.

17 Q. 2000 article. Okay. So I'll reask my
18 question. This 2000 article -- and it looks like
19 on the first page of the article it actually says
20 it was accepted in October -- into the -- this
21 journal in October of 1999, but let's -- let's call
22 it the 2000 Clement article.

23 The abstract states, "the numerical
24 model developed in this study is a useful
25 engineering tool for integrating field-scale

1 natural attenuation data within a rational modeling
2 framework. The model results can be used for
3 quantifying the relative importance of various
4 simultaneously occurring natural attenuation
5 processes."

6 Is that consistent with your
7 recollection of the article?

8 A. Yes.

9 Q. To the best of your knowledge, was the
10 model discussed in this 2000 Clement article
11 estimating contaminant concentrations for
12 determining exposure in specific individuals?

13 A. The article did not go into what the
14 end use was, okay? I took it to mean that this was
15 the first stage or initial stage in developing a
16 model. It did not discuss exposure. In other
17 words, it was not an exposure assessment article.

18 Q. And to the best of your knowledge, was
19 this -- the model discussed in the 2000 Clement
20 article used for estimating contaminant
21 concentrations for the purpose of -- purpose of
22 determining exposure in individuals?

23 A. It was used for determining contaminant
24 concentrations.

25 Q. But as you sit here today, you're not

1 aware of it being used for the purpose of
2 determining exposure in individuals?

3 MR. DEAN: Object to the form of the
4 question.

5 THE WITNESS: I don't know what the end
6 use was.

7 BY MR. ANWAR:

8 Q. With respect to any -- the other
9 articles that you mentioned, were any of those
10 models -- strike that.

11 With respect to the other articles that
12 you mentioned, were any of the models discussed in
13 those articles used for estimating contaminant
14 concentrations that were used to determine exposure
15 in individuals?

16 A. The -- or the sites that we summarized
17 or did an analysis for in our 2004 paper, the
18 analytical containment transport analysis system,
19 one of them was at a dry cleaner in New Mexico and
20 the other one was Otis Air Force Base, which was
21 multimedia, meaning groundwater surface water and
22 -- and volatilization, and I know USGS has done
23 some work at Otis Air Force Base. It's been an
24 ongoing thing and I believe there are some
25 components from just the general topic of Otis Air

1 Force Base that look at exposure. It goes -- there
2 are people living downstream from the river that
3 goes through the Air Force base. I don't know the
4 details of the subsequent analysis of -- on -- on
5 that. I believe ATSDR did use the New Mexico site,
6 I think it's North Avenue Railroad site, if I
7 recall correctly, and I think they did a health
8 assessment there, okay, but I don't know the
9 specifics.

10 Q. Those other articles, are those
11 included on your -- either in your report or on the
12 reliance list?

13 A. Yes, the -- the 2004 is already on my
14 reliance list, 2004 by Maslia and Aral.

15 Q. And that's the one -- 2004 is focused
16 on Otis Air Force Base?

17 A. And -- and the New Mexico site.

18 Q. Okay. So it's just one article from
19 2004?

20 A. Yes.

21 Q. Besides that article and this 2000
22 Clement article, it sounded like you reviewed a
23 couple of other articles, perhaps related to
24 uncertainty analysis.

25 A. Right.

1 Q. Did any of those involve using
2 groundwater modeling to estimate contaminant
3 concentrations for the purposes of determining
4 exposure in individuals?

5 MR. DEAN: Object to the form.

6 THE WITNESS: Again, most of the
7 articles that I reviewed did not state the end
8 purpose of the -- they said the purpose of the
9 modeling to reconstruct or predict groundwater
10 contaminant concentrations using techniques,
11 different techniques, and also one of the articles
12 went into -- I think it was one of the earlier
13 applications of uncertainty analysis using Monte
14 Carlo simulation.

15 BY MR. ANWAR:

16 Q. So as you sit here today, you're not
17 aware of those other articles using models to
18 estimate contaminant concentrations for the purpose
19 of determining exposure in individuals, correct?

20 MR. DEAN: Object to the form.

21 THE WITNESS: Again, not having been
22 directly involved with the analysis, it's -- I
23 really can't answer what the results were used for.

24 BY MR. ANWAR:

25 Q. Okay.

1 A. The articles describe the process of
2 developing and/or calibrating models.

3 MR. DEAN: Object to the form. And
4 also add that if you're going to ask him about what
5 certain conclusions are in certain reports, that
6 the witness is entitled to see those reports, have
7 an opportunity to review them in detail, and then
8 properly respond.

9 MR. ANWAR: I'm going to mark the 2000
10 Clement article as Exhibit 1.

11 BY MR. ANWAR:

12 Q. Now, earlier we talked about the other
13 experts in the case and you having listened to
14 their depositions and read the deposition
15 transcripts, correct?

16 A. Right, yes, to -- some more detail than
17 others.

18 Q. Sure. One of those experts is doctor
19 -- professor -- or Dr. Mustafa Aral, correct?

20 A. Yes.

21 Q. Who is -- remind me, who is Mustafa
22 Aral?

23 A. Well, he was a professor at the Georgia
24 Institute of Technology. He was also director of
25 the multimedia environmental simulations laboratory

1 within the School of Civil and Environmental
2 Engineering. And he had or he was the principal
3 investigator on a cooperative agreement between
4 ATSDR and Georgia Tech.

5 Q. And the cooperative agreement between
6 ATSDR and Georgia Tech, was that in relation to the
7 Camp Lejeune water modeling?

8 A. Not specifically. That was a
9 multiyear-type agreement and it was for any site.
10 For example, the couple of sites that I mentioned
11 in the journal article, ACTS article, we did
12 cooperatively.

13 Q. Understood. So -- but it did include
14 the Camp Lejeune water modeling, correct?

15 A. Yes, it did.

16 Q. And if I understand your testimony
17 before correctly, Dr. Aral was a professor that you
18 had at Georgia Tech, correct?

19 A. Yes, yes, he was my -- my master's
20 thesis dissertation chair of that -- that
21 committee.

22 Q. Okay. And you know him personally,
23 correct?

24 A. I know him professionally. I don't
25 socialize with -- with -- with him, but I've known

1 him throughout the years professionally.

2 Q. Understood. What is your opinion of
3 Dr. Aral?

4 A. He's very qualified. I view him as a
5 mentor.

6 Q. Okay.

7 A. And can take his problems and analyze
8 them from a practical standpoint and also address
9 them through computational methods.

10 Q. Now, you also listened to the
11 depositions of Jeffrey Davis and Norman Jones,
12 correct?

13 A. Correct.

14 Q. Who is Jeffrey Davis?

15 A. I only -- I've never met him in person.
16 I met him, I assume, through Zoom and he's -- to my
17 understanding, he's a consulting engineer and
18 modeler.

19 Q. You mentioned you have spoken with
20 Mr. Davis on Zoom; is that right?

21 A. In a meeting, yes, in meetings.

22 Q. Was that during the course of preparing
23 expert reports in the case?

24 A. I believe he and Dr. Jones had some
25 questions about the Tarawa Terrace model input

1 files, and so I think that's where we had
2 discussions over Zoom.

3 Q. And it was in the context of the -- the
4 litigation, correct?

5 A. Yes.

6 Q. Had you met either Jeffrey Davis or
7 Norman Jones prior to being retained by plaintiffs
8 as an expert?

9 A. I have met Dr. Jones previously.

10 Q. Okay. You had not met Mr. Davis prior
11 to working -- or that call with him in the context
12 of the litigation, correct?

13 A. That is correct.

14 Q. Had you worked with Mr. Davis prior to
15 that Zoom meeting with him?

16 A. No, I have not.

17 Q. And it sounds like you don't know him
18 personally or socially, correct?

19 A. That is correct.

20 Q. Now, you mentioned having met Dr. Jones
21 in the past?

22 A. Right.

23 Q. When have you met Dr. Jones in the
24 past?

25 A. I served with Dr. Jones on a review of

1 a National Science Foundation grant for the
2 University of Alabama. And so he was the chair of
3 the panel. And I think every year, every other
4 year, they have to have a review status report like
5 that, so that's -- that's where I met him in
6 person.

7 Q. Around what time frame would that
8 meeting have taken place?

9 A. 2021, 2022, someplace around there.

10 Q. Have you met him on any other
11 occasions?

12 A. Not in person, but I do know of him.

13 Q. How do you know of him?

14 A. Early on or as part of the Tarawa
15 Terrace analyses we found out that the -- I believe
16 it was the U.S. Army Corps of Engineers or U.S.
17 Army Corps of -- Hydrologic Center were developing
18 a software platform called GMS. And while they
19 were beta testing it, since we were a federal --
20 sister federal agency, they wanted people to test
21 it out. So they provided us with a license, and I
22 believe Dr. Jones was one of the original
23 developers of the GMS software and platform.

24 Q. Do you remember around what time frame
25 that would have been developed?

1 A. I don't know the start of GMS, but
2 there's probably some letters in my files or
3 e-mails. I'm going to say 2005, '6, somewhere --
4 maybe 2004, right when we were modeling or --
5 modeling Tarawa Terrace.

6 Q. Did Dr. Jones directly work on the
7 model -- ATSDR's Camp Lejeune model for Tarawa
8 Terrace?

9 A. No.

10 Q. Okay. You just had the conversation
11 with him in the context of the GMS software?

12 A. No, I've never had --

13 Q. Oh, you didn't. Okay.

14 A. It was just his -- his name as the
15 developer --

16 Q. Understood. Understood.

17 A. -- when we were provided the executable
18 code by -- I think it was U.S. Army Corps of
19 Engineers Hydrologic Engineering Center, and so I
20 just saw it -- saw it through there, okay?

21 Q. Outside of the work with the University
22 of Alabama and then the Zoom meeting that you
23 described for the purpose of this litigation, have
24 you worked with Dr. Jones in any other context?

25 A. No.

1 Q. Do you have any opinion about either
2 Mr. Davis or Dr. Jones?

3 A. Both very well qualified. Very good
4 analysts and they know their way around the GMS
5 modeling platform. And I believe Dr. Jones is the
6 chair of the Brigham Young University School of
7 Civil and Environmental Engineering.

8 Q. What about David Sabatini, who is
9 Dr. Sabatini?

10 A. I understand he's a professor -- and I
11 forget the university, whether it's Texas or
12 Oklahoma. Reading his report, he is -- appeared to
13 me to be an expert in volatilization issues, and I,
14 again, only met him over Zoom.

15 Q. And that was in the context of this
16 litigation, correct?

17 A. Yes.

18 Q. Had you met him prior to the Zoom
19 meeting in this litigation?

20 A. No, I have not.

21 Q. Do you have any opinion about Dr. -- or
22 David Sabatini?

23 A. The same as the others, very competent
24 and understands volatilization issues. Was able to
25 assess them both from a scientific engineering

1 standpoint as well as present them to a layperson
2 who is not as technically knowledgeable.

3 Q. Thank you.

4 A. Can I get a drink of water here?

5 Q. Sure.

6 (DFT. EXHIBIT 2, deposition of Morris
7 L. Maslia dated June 30, 2010 Bates-stamped
8 CLJA_Healtheffects-00000494487 through 0000049712,
9 was marked for identification.)

10 BY MR. ANWAR:

11 Q. I'm handing you what I'm marking as
12 Exhibit 2. Here you go. And I asked you these
13 questions last time around --

14 A. Okay.

15 Q. -- in September, but I just want to
16 confirm.

17 A. Okay. Can I take the rubber band off?

18 Q. Sure. Actually, that's all -- I
19 actually gave you all the copies.

20 A. Oh.

21 Q. Feel free to give one to Kevin.

22 A. Okay. Who else?

23 Q. And I can take that one. Exhibit 2 is
24 a transcript from a deposition you gave in 2010 in
25 Laura Jones versus the United States, correct?

1 A. That is correct.

2 Q. Okay. And at that time you were
3 employed still with the ATSDR, correct?

4 A. That is correct.

5 Q. And you were, I think, in the midst of
6 working on the Hadnot Point/Holcomb Boulevard
7 model, correct?

8 A. That is correct.

9 Q. And the Laura Jones versus United
10 States case, that was a prior Camp Lejeune case,
11 correct?

12 MR. DEAN: Object to the form of the
13 question.

14 THE WITNESS: It was never explained to
15 me, either by the Office of the General Counsel or
16 DOJ or the plaintiffs' attorney, what -- what
17 exactly the case was for.

18 BY MR. ANWAR:

19 Q. The focus of your deposition, was it on
20 your work on the ATSDR water modeling for Camp
21 Lejeune?

22 MR. DEAN: Object to the form of the
23 question.

24 THE WITNESS: It was for Tarawa
25 Terrace, my understanding was.

1 BY MR. ANWAR:

2 Q. Okay. So the focus of the deposition
3 was the Tarawa Terrace model, correct?

4 MR. DEAN: Object to the form of the
5 question.

6 THE WITNESS: That's my --

7 MR. DEAN: Give me time to -- you can
8 answer.

9 THE WITNESS: Okay. That -- that was
10 my understanding.

11 BY MR. ANWAR:

12 Q. Okay. And you testified under oath
13 during that deposition truthfully, correct?

14 A. Yes, I did.

15 Q. And you had an opportunity to -- to
16 review the transcript and make corrections on an
17 errata sheet, correct?

18 A. That is correct.

19 Q. And I believe the last page of the
20 transcript is your signed errata sheet. You can
21 take a look.

22 A. Yes, yes, it is.

23 Q. Okay. And as you sit here today, do
24 you stand by your prior deposition testimony?

25 A. I will say I generally do. If there's

1 a specific item in -- in here that there's a
2 question about, I would have to see what that
3 technical issue is and then I could specifically
4 tell you.

5 Q. Okay.

6 A. Okay.

7 Q. As you sit here today, you don't have
8 any changes that you want to make to that
9 testimony?

10 MR. DEAN: Object to the -- object to
11 the form.

12 BY MR. ANWAR:

13 Q. You didn't come with changes, correct?

14 A. No, I did not come with changes.

15 Q. Okay. So I am handing you now what I'm
16 marking as Exhibit 3.

17 (DFT. EXHIBIT 3, deposition of Morris
18 Maslia dated September 26, 2024, was marked for
19 identification.)

20 BY MR. ANWAR:

21 Q. Here you go.

22 MR. ANWAR: Kevin, here you go, if you
23 would like a copy.

24 MR. DEAN: All right. Thanks.

25 BY MR. ANWAR:

1 Q. I'll represent to you this is a copy of
2 the transcript from your September 26th, 2024
3 deposition in this case. Would you agree with
4 that?

5 A. It appears to be, yes.

6 Q. And this is deposition you gave in this
7 case in your sort of capacity as a fact witness,
8 correct?

9 A. That is my understanding, yes.

10 Q. And this deposition took place after
11 you had been retained by the plaintiffs, but before
12 you had disclosed your expert report in the case,
13 correct?

14 A. Yes, that is correct.

15 Q. And you gave that deposition testimony
16 under the oath to tell the truth and testify
17 truthfully, correct?

18 A. That is correct.

19 Q. And you had an opportunity to review
20 and make corrections on an errata sheet for that
21 deposition transcript as well, correct?

22 A. Yes, I did.

23 Q. And I say that deposition transcript.
24 I mean the September 2024 transcript; is that
25 correct?

1 A. Yes.

2 Q. Okay.

3 (DFT. EXHIBIT 4, Acknowledgement of
4 deponent and errata sheets, was marked for
5 identification.)

6 BY MR. ANWAR:

7 Q. I'm handing you what I'm marking as
8 Exhibit 4, which I'll represent to you is a copy of
9 your signed errata sheet for the September 2024
10 deposition transcript. Would you agree with that?

11 A. Yes, it is.

12 Q. Aside from the changes on that errata
13 sheet, do you have any changes to your prior
14 deposition testimony?

15 A. Not that I recall at this time.

16 Q. Okay. Nothing that you came with to
17 the deposition, correct?

18 A. Excuse me? I don't understand the
19 question.

20 Q. You didn't come prepared to make
21 changes or offer changes to your past deposition
22 testimony as you sit here right now, correct?

23 A. No, I do not.

24 Q. Okay. I am going to hand you now what
25 I'm marking as Exhibit 5.

1 (DFT. EXHIBIT 5, Expert Report of
2 Morris L. Maslia, P.E., D.WRE, DEE, Fellow EWRI,
3 was marked for identification.)

4 BY MR. ANWAR:

5 Q. Here you go.

6 MR. ANWAR: Here's a copy for you.

7 BY MR. ANWAR:

8 Q. Mr. Maslia, this is a copy of your
9 expert report in this case dated October 25th,
10 2024, correct?

11 A. That is -- I'm looking for the date on
12 here. There's no date on this copy.

13 Q. I think it's at the bottom there in the
14 middle.

15 A. Oh, there it is, yes. Okay. That is
16 correct.

17 Q. And to the -- you had an opportunity to
18 sort of look through that. True and accurate copy,
19 to the best of your review?

20 A. The copy is correct.

21 Q. And aside from the articles that you --
22 we discussed this morning already, is the
23 materials-considered list on there complete and
24 accurate?

25 A. Yes, as far as I know.

1 Q. Is there anything on -- in that report
2 that you believe needs to be added that's not
3 reflected in the report?

4 A. No.

5 Q. I am handing you now what I'm marking
6 as Exhibit 6.

7 (DFT. EXHIBIT 6, Rebuttal Response to
8 Reports of Alexandros Spiliotopoulos, Remy, J.-C.
9 Hennet & Jay Brigham, was marked for
10 identification.)

11 BY MR. ANWAR:

12 Q. Mr. Maslia, is Exhibit 6 a true and
13 accurate copy of your rebuttal expert report
14 submitted in this case?

15 A. Yes, it is.

16 Q. And it's dated January 14, 2024?

17 A. Yes, it is.

18 Q. And aside from the articles that you
19 mentioned this morning, is there anything missing
20 from the materials-considered list or the
21 references provided with this report?

22 A. No.

23 Q. And in this report, as the title
24 indicates, is in response to the reports of DOJ
25 experts Dr. Spiliotopoulos, Dr. Hennet and Brigham?

1 A. That is correct.

2 Q. Do you know Dr. Spiliotopoulos, Hennet
3 or Brigham?

4 A. I do not know any of them and have
5 never met any of them.

6 Q. Do you know of any of them?

7 A. I know of Dr. Spiliotopoulos. I
8 believe his name appeared in -- as an observer at
9 at least one of the ATSDR expert panel meetings.

10 Q. Okay.

11 A. But I could not tell you exactly which
12 one, okay?

13 Q. Have you ever met Dr. Spiliotopoulos?

14 A. No.

15 Q. Have you -- so fair to assume if you
16 haven't met him, you've never worked with him,
17 correct?

18 A. That is correct.

19 Q. And same with Dr. Hennet?

20 A. That is correct.

21 Q. And I assume same with Dr. Brigham?

22 A. That is correct.

23 Q. Do you have any opinion about
24 Dr. Spiliotopoulos, Hennet or Brigham?

25 A. Not other than they are the DOJ's

1 expert witnesses.

2 Q. Okay. In your -- either your primary
3 expert report or the rebuttal report, is there
4 anything that you believe is incorrect?

5 A. I would -- in my expert report there
6 was -- and there was discussion during my
7 deposition about model bias and geometric biases.
8 And I believe that we -- or I went back and --
9 because there were a number of duplicate samples.
10 And because our model was only on a monthly time
11 frame, it really is not correct to try to match
12 daily or even weekly samples within monthly model
13 output.

14 So if you take the average within the
15 month of the actual sample data, you get a much
16 closer geometric bias to 1 -- 1.5. So we
17 overstated both in the ATSDR report, and I'm
18 talking about Tarawa Terrace, as well as my expert
19 report, which came from -- had that overstated or
20 provided a higher geometric bias both for the
21 supply wells and the water treatment plant than I
22 believe should actually be there.

23 Q. Is that currently reflected in your
24 expert report?

25 A. No, it's not.

1 Q. And it's not reflected in the ATSDR
2 reports, correct?

3 A. No, no.

4 Q. When --

5 A. I'm sorry.

6 Q. No, go ahead.

7 A. My expert report reflects or copies
8 exactly the tables out of the ATSDR reports
9 specifically for Tarawa Terrace with that.

10 Q. When did you do this analysis about the
11 geometric bias? And this is specifically for
12 Tarawa Terrace?

13 A. Yes, I would say within -- as I was
14 preparing my rebuttal report to the DOJ experts and
15 within last month sometime, I started just reading
16 more about nondetection of sample data and multiple
17 samples within a month, which we had at Tarawa
18 Terrace, Hadnot Point, and then realizing that our
19 model results -- we only had one result per month
20 because they were monthly time steps. So the
21 implication was that the model could reproduce
22 those daily or multiple monthly sampling, and they
23 -- it really can't if you only have a one-month
24 time step.

25 Q. Does it follow, then, the -- the model

1 certainly -- because the model produced monthly
2 estimated concentrations, correct?

3 A. That is correct.

4 Q. And the model was not intended to
5 produce daily estimated concentrations, correct?

6 A. Not the groundwater flow and
7 contaminant transport. It was produced -- we had
8 monthly time steps, so that would be 31, 30, 28 or
9 29 days, depending on which month it was, and our
10 assumption was that represented the last day of
11 each month, like January 31st, February 28th, and
12 so on, but that it was equally likely to occur on
13 any day of the month.

14 Q. So is it your opinion because you used
15 daily samples, but the model was producing monthly
16 simulated contaminant concentration estimates, that
17 you overestimated the geometric bias?

18 A. Yes.

19 MR. DEAN: Object to the form.

20 THE WITNESS: We computed a geometric
21 bias that was higher than if you had a one-to-one
22 correspondence, one -- one sample and one model
23 result for each month.

24 BY MR. ANWAR:

25 Q. Have you actually done the calculations

1 on that?

2 A. Yes, I have.

3 Q. I guess, based on the opinion that
4 you're offering now, what is -- what is, in your
5 opinion, the geometric bias for the Tarawa Terrace
6 model?

7 A. For the supply wells, I believe it
8 comes down to somewhere below 1.5 and recalling a
9 value of 1.0 would be an exact match, okay? And at
10 the water treatment plant, I believe it comes down
11 to almost 1.0.

12 Q. Do you -- when you said you did the
13 calculations, is that reflected in writing
14 anywhere?

15 A. I've got notes, but not with me.

16 Q. Okay. If we requested those notes to
17 be produced, would you be agreeable?

18 MR. DEAN: Object -- object to the form
19 of the question. I'll let you finish. I'm not
20 sure if you were finished.

21 BY MR. ANWAR:

22 Q. Well, we will request the notes from
23 your lawyer and the lawyers will work it out, but
24 if your lawyers ask you for the notes, would you be
25 agreeable to giving it to them?

1 A. Yes.

2 MR. DEAN: Object to the form of the
3 question.

4 BY MR. ANWAR:

5 Q. And outside of those notes, this
6 opinion that you're offering now, it's not
7 reflected in either your current expert report or
8 rebuttal report or the ATSDR reports themselves?

9 A. That is correct.

10 Q. And sort of my general high-level
11 understanding of sort of the thrust of your main
12 expert report at least is, is that the -- the ATSDR
13 models for Tarawa Terrace and the model for Hadnot
14 Point and Holcomb Boulevard are sufficiently
15 reliable and accurate to -- in estimating
16 contaminant levels for purposes of using them to
17 make exposure determinations in this case; is that
18 right?

19 A. I would say that the models produce
20 reliable results on a monthly basis, the
21 groundwater flow and contaminant transport models
22 for both Tarawa Terrace and Hadnot Point, and that
23 we met one of the objectives that we were required
24 to meet by the study epidemiologists of providing
25 mean monthly concentrations.

1 Q. You're serving as an expert in this
2 case, correct?

3 A. That is correct.

4 Q. On behalf of the plaintiffs, correct?

5 A. That is correct.

6 Q. And do you understand that the
7 plaintiffs are offering the model for purposes of
8 estimating exposure in individual plaintiffs in the
9 litigation?

10 MR. DEAN: Object to the form of the
11 question.

12 THE WITNESS: When we did the model, I
13 was not aware of the end use of it. I was
14 concerned with and what I have presented to the
15 plaintiffs is that it's reliable to provide monthly
16 mean concentrations. I'm not involved in, nor have
17 I ever been involved in, any use post-modeling
18 results.

19 BY MR. ANWAR:

20 Q. You understand the -- and if not, I'm
21 telling you now, the plaintiffs' lawyers are
22 offering the model as a way to estimate exposure --
23 estimated exposures in individual plaintiffs. Do
24 you understand that?

25 MR. DEAN: Object to the form of the

1 question.

2 THE WITNESS: I understand what you
3 have just said, yes.

4 BY MR. ANWAR:

5 Q. Okay. And do you believe the model is
6 sufficiently reliable and accurate for that
7 purpose?

8 A. The model is sufficiently reliable and
9 accurate for the monthly mean concentrations in
10 groundwater and in drinking water. I don't know
11 what analyses they are conducting with those --
12 with those values, nor I have ever known, even when
13 I was at ATSDR, what the epidemiologists or how
14 they were planning on -- on using them other than
15 in a general framework. But the epidemiologists at
16 ATSDR believe the model results were reliable and
17 accurate for their use.

18 Q. Sort of at a high level I understood
19 the purpose of your report as -- to be supporting
20 the use of the model in the litigation. Would you
21 agree with that?

22 MR. DEAN: Object to the form of the
23 question.

24 THE WITNESS: Could you clarify which
25 report you're speaking of?

1 BY MR. ANWAR:

2 Q. Sure. I understood the purpose of your
3 expert report that you submitted as a litigation
4 expert in the case for which you're consulting with
5 the plaintiffs on as advocating for or supporting
6 the use of ATSDR's Tarawa Terrace and Hadnot
7 Point/Holcomb Boulevard models in the litigation.

8 MR. DEAN: I'm sorry.

9 BY MR. ANWAR:

10 Q. Do I understand -- am I -- would you
11 agree with that?

12 MR. DEAN: Object to the form of the
13 question. You're asking him if he understands the
14 same thing you understand? That's...

15 THE WITNESS: My understanding was --

16 MR. DEAN: For the record, I do not
17 know, nor has Mr. Anwar provided sufficient
18 information about what his understanding is to get
19 in his head in order to be able to have anyone
20 properly be able to respond to that question, so I
21 object to the form.

22 MR. ANWAR: And I appreciate your
23 objections, Kevin. I would appreciate if you also
24 limit your objections to form within the rules and
25 limit your speaking objections. Mr. Maslia is the

1 one here to testify. This isn't your deposition.

2 MR. DEAN: You're familiar with the
3 rules of the road and the rules of depositions, and
4 if you follow those rules, then I will certainly
5 follow them as well.

6 MR. ANWAR: And I am sort of raising
7 this now because if this continues to be a problem,
8 we intend to take that to the Court, so...

9 BY MR. ANWAR:

10 Q. Mr. Maslia, I will ask you the question
11 again. So you submitted an expert report in this
12 case?

13 A. Yes.

14 Q. And you submitted an expert report as a
15 paid litigation expert, correct?

16 A. That is correct.

17 Q. And you did so on behalf of the
18 plaintiffs, correct?

19 A. That is correct.

20 Q. Did you do so with the understanding
21 that the plaintiffs are offering the model or the
22 -- and when I say "the model", I mean ATSDR's
23 Tarawa Terrace model and ATSDR's Hadnot
24 Point/Holcomb Boulevard model -- for use in the
25 litigation?

1 MR. DEAN: Object to the form.

2 THE WITNESS: I did so as the expert
3 and the person who oversaw the development of the
4 ATSDR models to any technical or scientific
5 questions pertaining specifically to the model,
6 model assumptions, model results that the
7 plaintiffs' attorneys may have.

8 BY MR. ANWAR:

9 Q. Okay. I just want to make sure I'm
10 crystal clear on this because as of now the Court
11 intends to hold a hearing on -- or the -- there's
12 discussion of a potential hearing being held on
13 issues related to water contamination in the case.
14 And I imagine if the Court does hold a hearing,
15 you'll be called to testify. And if you're asked
16 by a lawyer or one of the judges that -- whether or
17 not the Court should use the model for making
18 exposure determinations for individual plaintiffs
19 in the case, what would your answer be?

20 MR. DEAN: Object to the form of the
21 question.

22 THE WITNESS: My response would be,
23 from my standpoint, my professional and expert
24 standpoint, that the model results are reliable
25 based on our assessment of model calibration, model

1 results, and that the -- as long as the models are
2 sufficiently calibrated, in my mind, anyone can use
3 them for whatever purpose they want to use them
4 for. In other words, we did not calibrate the
5 models with the end result of exposure assessment.
6 Again, we were, at ATSDR, blinded to anything with
7 the epidemiology in terms of cases, controls,
8 people, anything like that, other than the five
9 objectives that I believe I listed in my expert
10 report as to what the epidemiologists requested us
11 to meet.

12 BY MR. ANWAR:

13 Q. Okay. Now, Appendix A, which is page
14 120 of your initial expert report.

15 A. 2020. Yes, I'm there.

16 Q. Is that a true and accurate copy of
17 your curriculum vitae?

18 A. Yes, it is.

19 Q. To the best of your knowledge, as you
20 sit here today, is it complete?

21 A. Yes, it is.

22 Q. And there's not anything that needs to
23 be updated as far as you're aware on that
24 curriculum --

25 A. Not that I'm aware of.

1 MR. DEAN: So there's someone who has
2 just joined with an area code 202 number. You're
3 not muted. Would you mind muting your phone,
4 please. Thank you.

5 BY MR. ANWAR:

6 Q. And on page 17 of your report it states
7 that "I'm being compensated an hourly rate of 400
8 for my work for preparing this report. My rate for
9 depositions and trial testimony is 2,000 per day."
10 Did I read that correctly?

11 A. Yes, you read that correctly.

12 Q. And is that what you're being
13 compensated in the case?

14 A. Yes, as it states right here.

15 Q. I'm handing you what is being marked as
16 Exhibit 7.

17 (DFT. EXHIBIT 7, M.L. Maslia Consulting
18 Engineer invoices Bates-stamped
19 CL_PLG-Expert_Maslia_0000000609 through 0000000680,
20 was marked for identification.)

21 BY MR. ANWAR:

22 Q. These are invoices that were produced
23 to us in response to a document, subpoena,
24 accompanying your -- your deposition notice.

25 A. Okay.

1 Q. Are these the invoices for the -- for
2 your expert work performed on behalf of the
3 plaintiffs in the case?

4 A. I haven't gone through all of them, but
5 they appear to be with my signature and the
6 billable hours and expenses that I submitted, yes.

7 Q. Okay. Do you have an estimate on how
8 much you've billed to date in the case?

9 A. No, I just submit it on a monthly
10 basis.

11 Q. Sure.

12 A. And you would have to ask the --
13 whoever the accountant is for the plaintiffs or my
14 CPA who is filing my taxes.

15 Q. Well, so I went through the invoices.

16 A. Right.

17 Q. According to my calculation and
18 let's -- let's call this rough, it looks like
19 you've billed a little over 1100 hours in the
20 amount of about \$346,000, just under \$347,000, for
21 your work in this case and that's for professional
22 services. Does that sound about right to you?

23 MR. DEAN: Object to the form.

24 THE WITNESS: It sounds high to me,
25 but, again, you'll have to add these up. If you're

1 basing them on -- on these, that's all --

2 Q. Okay.

3 A. It does sound high. The 300 number
4 sounds high.

5 Q. Okay. But if it's -- if that's what
6 the invoices add up to, you wouldn't dispute it?

7 A. No, I would not.

8 Q. And I noticed your invoices were
9 separated out for professional services and then
10 you had travel and related expenses, correct?

11 A. That is correct.

12 Q. Okay. And so the hours and the numbers
13 I read to you just now were what I calculated for
14 professional services. For travel and related
15 expenses, again, roughly I calculated 82.5 hours in
16 the amount of about \$16,000. Does that sound about
17 right to you?

18 A. It would be hard for me to answer that
19 right at this instant of time without going through
20 them and adding them up.

21 Q. Okay. If that's what they add up to in
22 the invoices, do you have any reason to dispute
23 that?

24 A. No, I do not.

25 Q. We've been going for about an hour.

1 Would you like to take a break or --

2 A. Sure. That would be good.

3 Q. Okay. Let's do that.

4 THE VIDEOGRAPHER: Okay. We're going
5 off record. The time is 10:14 a.m.

6 (A recess transpired.)

7 THE VIDEOGRAPHER: Okay. We're going
8 back on the record. The time is 10:25 a.m.

9 BY MR. ANWAR:

10 Q. We are back on the record from a short
11 break, Mr. Maslia. Are you okay to continue?

12 A. Yes, I am.

13 Q. Did you speak with your lawyers during
14 the break?

15 A. No, I did not.

16 Q. Okay.

17 A. There is one thing I would like to
18 clarify.

19 Q. Sure.

20 A. If I could do that. When we were
21 speaking about the improved and reanalysis of the
22 geometric biases, I got the original thought
23 reading Dr. Konikow's expert report where he had
24 mentioned about duplicate values in his report.

25 Q. Okay.

1 A. So I just wanted to give credit for the
2 initial thought about that.

3 Q. No, I appreciate that. You actually
4 anticipated my question. I was going to ask you
5 sort of as a follow-up when you decided to do that
6 analysis and it sounds like it was in the last
7 month or two; is that right?

8 A. That is correct.

9 Q. Okay. And it was in the context of
10 reading Dr. Konikow's report?

11 A. Yes.

12 Q. Okay. Would that have been after he
13 had disclosed his report?

14 A. Yes, yes, it was the -- I mean, what
15 was submitted to DOJ.

16 Q. Okay. And was there any particular
17 reason you decided to do the analysis or it was
18 just the thought popped up in reading his report?

19 A. Well, he mentioned that -- specifically
20 I believe it was in reference to well TT26 at
21 Tarawa Terrace where there were, like, five samples
22 within a short time period, like within a day or
23 week.

24 Q. Yeah.

25 A. And that the models could not really

1 reproduce that, okay, on a monthly basis. And so
2 that's when I looked at our tables that we had
3 published in the Tarawa Terrace Chapter A report
4 where we computed the model biases and the
5 geometric biases, and I went back and took that
6 suggestion and did the analysis.

7 Q. Okay. And you indicated you have some
8 notes about that, right?

9 A. That is correct.

10 Q. Okay.

11 MR. ANWAR: We will -- we will formally
12 request those notes be produced. We will just
13 formally on the record request that those notes be
14 produced and reserve the right to reopen the
15 deposition depending on what's in the notes.

16 MR. DEAN: That's right. And we
17 reserve all of our objections and -- but we will
18 take a look at it and provide a response back to
19 you.

20 MR. ANWAR: Okay. Sounds good.
21 Thanks, Kevin.

22 MR. DEAN: I don't have what he's
23 referring to here either, so...

24 MR. ANWAR: Okay. Understood.

25 BY MR. ANWAR:

1 Q. And then I wanted to ask you,
2 Mr. Maslia, when we were talking about expert
3 reports that you had reviewed, did you review
4 Dr. Longley's report as well?

5 A. No, I did not.

6 Q. Okay. Did you review it at any point?

7 A. I don't know who Dr. Longley is.

8 Q. Okay. I wanted to ask you a few
9 questions about the invoices. There were a couple
10 of references to discussions with -- with Robert
11 Faye. And it looks like you spoke with Robert Faye
12 in August of 2024. I'll call him Bob Faye.
13 Everyone calls him Bob Faye, it appears. And one
14 of the notes is -- provide Robert Faye, Bob Faye,
15 with verbiage on the use of probabilistic analysis
16 for Tarawa Terrace models, compose table listing,
17 ATSDR data discovery activities, and then review so
18 -- review 2005 expert report panel. And I can
19 direct you to where in the invoices that is if you
20 would like to take a look at it, but --

21 A. Yeah, if you could, please.

22 Q. Sure. It's the page ending 626.

23 A. 626. Okay. Ah, okay. Sure. What
24 date in particular?

25 Q. It's August 24.

1 A. Okay.

2 Q. Why did you speak to Robert Faye there?
3 What was that about?

4 A. Well, Bob Faye and I have known each
5 other professionally probably for 40 years.

6 Q. Four or 40?

7 A. 40. 40. 40 years, more or less. And
8 he was the person responsible for developing the
9 Tarawa Terrace groundwater flow and contaminant
10 fate and transport models as well as analyzing all
11 the hydrogeologic data. And so I had found out,
12 maybe through Bob, that he had been retained by the
13 plaintiffs' attorneys and I think there was a
14 question on -- on his part as to how to properly --
15 or how to word something containing probabilistic
16 analyses, which is what I did at ATSDR. Not only
17 did that, but I was familiar with -- with that on
18 numerous occasions of doing that, and so I think
19 that's what the discussion was about.

20 Q. Do you know when Bob Faye was retained?

21 A. I don't know the date.

22 Q. But as of this day, August 24th, 2024,
23 you spoke with him and he was retained; is that
24 right?

25 A. That is my understanding.

1 Q. Okay. And on that same page there is
2 an entry phone call with R. Faye about review of
3 ABC One Cleaners site data 2007 to 2012. Do you
4 remember what that conversation was about?

5 A. I think the question came up in some of
6 the production that DOJ provided to the -- the
7 plaintiffs about what documents we may have had at
8 ATSDR and what documents either the Department of
9 Navy provided us --

10 Q. Sure.

11 A. -- in conducting the Tarawa Terrace
12 reports. And so that ABC Weston 2007 report came
13 up.

14 Q. Okay. And then if you turn the page to
15 the page ending 640.

16 A. Okay.

17 Q. There are a couple of entries for
18 December 28th and 29.

19 A. Right.

20 Q. The 29th entry is, review R. Faye
21 rebuttal report, call with R. Faye. Do you recall
22 that conversation?

23 A. On the 28th?

24 Q. 29th.

25 A. 29th. I'm sorry. I don't specifically

1 recall that -- that phone call. I mean, I don't
2 know what exactly I was reviewing in his report.
3 He may have asked me my opinion of something he was
4 writing and being that he was retained and I was
5 retained, I probably provided an opinion.

6 Q. Okay. We have not received a rebuttal
7 report from Bob Faye. One has not been disclosed.
8 I'm just wondering if you knew why that was?

9 MR. DEAN: Object to the form of the
10 question. It's confidential attorney work product
11 and I would instruct the witness not to answer the
12 question.

13 BY MR. ANWAR:

14 Q. Do you know if Bob Faye intends to
15 testify in this case?

16 A. I've -- I'm not involved in that part
17 of being retained as to who does and does not
18 testify, so I do not know.

19 Q. Okay. Other than sort of what's
20 reflected on these invoices, have you spoken with
21 Bob Faye about any other aspect of your work on
22 this case?

23 A. Well, just in reviewing the original
24 ATSDR reports where he was the primary author,
25 making sure I understood what he was writing about

1 or what his intent was.

2 Q. Sure.

3 A. For example, the Chapter F, fate and
4 transport model, I wanted to clarify, you know,
5 technically clarify something.

6 Q. When would that have taken --
7 conversation taken place?

8 A. Last week sometime.

9 Q. I also noticed from some of the entries
10 on your invoices that you exchanged some e-mails
11 with Jerry Ensminger; is that right?

12 A. If you could -- can you point me to
13 exactly where they -- they are?

14 Q. I don't -- I don't -- I can look during
15 one of the breaks --

16 A. Okay. Okay.

17 Q. -- and point you directly, but do you
18 recall exchanging e-mails with Jerry Ensminger or
19 talking with him during the course of your work on
20 this case?

21 A. He has called me a couple of times.

22 Q. Okay.

23 MR. DEAN: I think you might have
24 marked some of that in the first depo, if I
25 remember correctly, just for what it's worth to

1 help him remember. I think you might have marked a
2 couple that were produced.

3 BY MR. ANWAR:

4 Q. When is the last time you spoke with
5 Mr. Ensminger?

6 A. Sometime this past month he called me.

7 Q. What was that conversation about?

8 A. He wanted to know my opinion of the
9 ATSDR models. He did mention geometric bias
10 specifically, but whether the models were, you
11 know, accurate, did they overpredict, underpredict.

12 Q. Do you know why he called you in the
13 last month about that, about whether the models
14 were accurate?

15 A. No, he never provides a reason why he
16 calls. He just calls me. I mean, in that sense.

17 Q. You know, just in reviewing the
18 documents in the case, it seems like -- and you
19 should correct me if I'm wrong -- throughout the
20 years Mr. Ensminger has had a number of
21 conversations with you and others on the ATSDR side
22 about work that was being performed related to the
23 models and the epi studies. Is that consistent
24 with your recollection?

25 A. Well, Mr. Ensminger was a member of the

1 Camp Lejeune camp.

2 Q. Yeah.

3 A. And he probably called or talked to me
4 in that capacity because when I was at ATSDR -- and
5 I don't know what the situation is now -- they
6 would have quarterly CAP meetings, okay, and it's
7 mostly when -- if I was going to present some
8 information or whatever, I called in his capacity
9 as the -- as a CAP member. That's what I recall.

10 Q. Okay. I was just wondering if you had
11 any insight on why he called you now. Because it
12 seems like he probably has a pretty good
13 understanding of the models just from the years of
14 working with you-all. If you have any insight on
15 why he decided to call in the last month.

16 MR. DEAN: Object to the form of the
17 question.

18 THE WITNESS: No, I do not know why --
19 why he would call me, because I had not heard from
20 him in a while. I mean...

21 BY MR. ANWAR:

22 Q. Sure. And did you-all specifically
23 discuss geometric bias during that call?

24 A. Not -- not that specific verbiage, but
25 the concept and what it means.

1 Q. Okay. Now --

2 A. Those were the values -- I need to
3 clarify. Those were the values relating
4 specifically to the report, not anything additional
5 that I had done.

6 Q. Understood. Have you had any other
7 conversations with Mr. Ensminger during the course
8 of your work in this case?

9 A. I believe there's one e-mail where he
10 wanted to know if I had an award certificate where
11 we were awarded the grand prize in research from
12 the American Academy of Environmental Engineers and
13 Science in 2015, and I believe I did provide him
14 with a couple of images.

15 Q. Sure. And if my understanding -- if my
16 recollection from your prior deposition is correct,
17 Mr. Ensminger is a Camp Lejeune activist, right?

18 MR. DEAN: Object to the form.

19 THE WITNESS: I assume there's
20 different definitions for activist. I have always
21 known him as a member of the CAP and a -- I'll just
22 leave it at that. That's where I first met him and
23 that's -- even when he calls today, I still think
24 of him in terms of the Camp Lejeune CAP.

25 BY MR. ANWAR:

1 Q. And are you aware that he's a plaintiff
2 in the lawsuit as well?

3 A. No, I'm not aware of anyone who's a --
4 who's in the lawsuit.

5 Q. Is Mr. Ensminger a water modeler?

6 A. No, he is not.

7 Q. Is he an epidemiologist?

8 A. No, he's not. Let me qualify that, to
9 my knowledge, I guess.

10 Q. Sure. I also noticed in the invoices
11 at some point during the course of your work as a
12 retained expert, you spoke with Chris Portier. Do
13 you recall that?

14 A. I don't ever recall speaking with
15 Dr. Portier once I was retained here.

16 Q. Okay.

17 A. I spoke to him -- or he spoke to me
18 when I was at ATSDR. That's the last -- last time,
19 actually, I recall speaking to Dr. Portier.

20 Q. Who is Chris Portier?

21 A. Dr. Portier is a former director of the
22 Agency for Toxic Substances and Disease Registry.
23 I'm not sure when he started. Maybe 2010, perhaps,
24 and retired, my understanding is, in 2013.

25 Q. Okay. And then I noticed on the

1 invoices there were some e-mails or conversations
2 that took place with Walter Grayman; is that right?

3 A. That is correct.

4 Q. First off, let me ask you, who is
5 Walter Grayman?

6 A. Walter Grayman I would consider a
7 mentor in water distribution system modeling and
8 probably one of the godfathers of water
9 distribution system modeling using computational
10 methods.

11 Q. And why did you speak with Walter
12 Grayman?

13 A. In my capacity here or -- I don't
14 understand --

15 Q. Sure.

16 A. -- the question.

17 Q. During the course of your retention --

18 A. Right.

19 Q. -- as a -- for the plaintiffs in the
20 litigation as an expert. I noticed his name on
21 some of the invoices. Why did you speak with him
22 during the course of the litigation?

23 A. My understanding is that he was also
24 retained as an expert witness.

25 Q. Okay.

1 A. But he is no longer that. But that was
2 my initial understanding. So he had some questions
3 about the water distribution system modeling
4 because he had assisted us in conducting field
5 studies and using the -- the model, and so that's
6 probably why I spoke with him, about that.

7 Q. Do you recall any other conversations
8 that you've had with Walter Grayman during the
9 course of the litigation?

10 A. No, no.

11 Q. I wanted to -- we talked -- some of
12 this is going to overlap with our discussion during
13 the last deposition. I'm trying --

14 A. Okay.

15 Q. -- my best not to duplicate too much.
16 We talked about, in your prior deposition, sort of
17 when you started working on the Camp Lejeune water
18 modeling at ATSDR and when it concluded. And I
19 noticed in Dr. Aral's report submitted in this
20 case, he makes a statement that over the 15-year
21 period from 2000 to 2015, I had my team members
22 work with essentially EDRP at ATSDR -- and, for the
23 record, the EDRP is exposure dose reconstruction
24 program. The statement is "from 2000 to 2015, I
25 and my team members worked with other team members

1 at EDRP at ATSDR to perform analysis of Tarawa
2 Terrace, Holcomb Boulevard, Hadnot Point studies
3 related to Camp Lejeune."

4 Does that time period, 2000 to 2015, is
5 that right in terms of the work for the water
6 modeling?

7 A. For Camp Lejeune?

8 Q. Correct.

9 A. No, that is not correct. We had a --
10 as I indicated previously, we had the cooperative
11 agreement that ran every five years, and Georgia
12 Tech was the cooperative agreement university
13 partner. And so on other sites, for example, I
14 mentioned the journal article that was published in
15 2004, so we would work on other sites. We did not
16 begin working in earnest until 2003 on Camp -- Camp
17 Lejeune, at which point, if they were still part of
18 the cooperative agreement, which they were, that's
19 when they would have started or we would have
20 started to have discussions about Camp Lejeune and
21 the approaches we should be taking and things of
22 that nature.

23 Q. And that's helpful in terms of the
24 start date. And then the end date he had in his
25 report as 2015. I noted that the -- I think the

1 last Hadnot Point/Holcomb Boulevard report was
2 published in 2013. Is that consistent with your
3 understanding?

4 A. The last report series was released in
5 March 2013.

6 Q. Did -- did the work related to the
7 Hadnot Point/Holcomb Boulevard modeling at ATSDR,
8 did it conclude in March 2013 or did it go on
9 another year until 2015?

10 A. The actual modeling activities and data
11 analysis activities and report publishing concluded
12 March 2013. I may have been asked by the
13 epidemiologists to forward them the final modeling
14 results after March of 2013, but I don't recall the
15 exact date.

16 Q. Were you doing any work on the modeling
17 in the ATSDR, I guess, either Tarawa Terrace or
18 Hadnot Point/Holcomb Boulevard models, in 2015?

19 A. No, I was not.

20 Q. Okay. So the -- the time frame is just
21 slightly off a little bit in his report, it sounds
22 like?

23 A. That is correct.

24 Q. Okay. I just wanted to clarify that.

25 So you -- you worked on the ATSDR

1 models for Tarawa Terrace and Holcomb
2 Boulevard/Hadnot Point -- Hadnot Point/Holcomb
3 Boulevard for just over a decade; is that right?

4 A. Yes, that would be correct, although
5 the initial work plan development probably was in
6 early 2003 or maybe 2002, internal, internal work
7 plan.

8 Q. Understood. You said 2002, 2003?

9 A. Yes.

10 Q. Okay. 11, 12-year time frame?

11 A. That is correct.

12 Q. For the 11, 12-year time frame for the
13 work that you and your colleagues at ATSDR did
14 related to the Tarawa Terrace and the Hadnot
15 Point/Holcomb Boulevard models, correct?

16 A. That is correct.

17 Q. Okay. And during that period of time,
18 you were ATSDR's project officer for the exposure
19 dose reconstruction program, correct?

20 A. That is correct. I was the project
21 officer from the beginning of the exposure dose
22 reconstruction program, which was probably 2004 or
23 '5.

24 Q. Okay. And then you were also the --
25 the lead or the project manager for ATSDR's water

1 models on Camp Lejeune, correct?

2 A. That is correct.

3 Q. Okay. Now, when you were employed
4 during this period of time by ATSDR working on the
5 Camp Lejeune modeling, you were a federal
6 government employee, correct?

7 A. That is correct.

8 Q. Do you remember what grade you were
9 sort of in the GS system in terms of employed?

10 A. It changed over time because I was
11 classified under the Office of Personnel
12 Management's research grade evaluation system.

13 Q. Sure.

14 A. So I was promoted twice from a GS-13,
15 which is where I came into ATSDR, applied to be
16 reclassified as -- under the research grade, and
17 then was promoted to a GS-14 and a GS-15.

18 Q. When were you promoted to a GS-15?

19 A. I would have to look at my electronic
20 personnel file.

21 Q. Sure. Were you a GS-15 by the time you
22 were working on the Camp Lejeune water models at
23 ATSDR?

24 A. Somewhere in there. Not necessarily at
25 the beginning.

1 Q. Okay. I am going to hand you what I'm
2 marking as Exhibit 8.

3 (DFT. EXHIBIT 8, Federal employee
4 profile for Morris L. Maslia, was marked for
5 identification.)

6 BY MR. ANWAR:

7 Q. I -- I looked you up on the federal
8 government employee lookup tool, and you're welcome
9 to look me up, too, as a federal employee. But
10 does this document I hand you accurately reflect
11 your GS grade and your salary while employed at
12 ATSDR between 2004 and 2018?

13 A. Well, it's incorrect because I retired
14 on December 31st, 2017.

15 Q. Okay. Aside from the 2018 year, for
16 the other years, does that generally look correct?

17 A. I don't recall being a GS-15 all the
18 way down to 2004 because I do recall them -- under
19 the research grade evaluation program, what they do
20 is, depending on the grade, but at the 13 and above
21 they should review you every four to five years,
22 maximum. So they would -- you -- they call in a
23 panel and have experts and then they score you on a
24 point basis. And then if you make above a
25 certain -- a certain point level, then the agency

1 has to say yes, we've got a GS-15 position
2 available or not, okay?

3 So again, I just don't recall it being
4 in 2004, but I would have to look at my own -- I
5 know you pulled this off the -- I've got my own
6 electronic personnel folder at home, or it was on
7 my ATSDR LAN drive, because they wanted everybody
8 to keep a copy of their personnel -- electronic
9 personnel folder when they went to digital versions
10 of it. So I could tell by those. I'm familiar
11 with the -- whatever it is, SF-171 form that tells
12 each year or whatever when you get promoted.

13 Q. Sure. Would the salary amounts, do
14 they look roughly right?

15 A. They -- they -- they look, from my
16 recollection, correct, yes.

17 Q. Okay. And so for that 11- or 12-year
18 period, would it be fair sort of roughly to
19 estimate that your total salary, cumulative salary,
20 during that period exceeded a million dollars,
21 correct?

22 A. I've never -- I've never added it up,
23 to be quite honest about it, so I would need to add
24 that up before...

25 Q. Okay. But if we added that up and I

1 told you it's over a million dollars, do you have
2 any reason to dispute that?

3 A. No.

4 Q. Okay. Besides your salary as an ATSDR
5 employee and the compensations and billings we've
6 discussed related to your retention or your role as
7 an expert in the litigation, have you received any
8 other compensation related to Camp Lejeune?

9 A. No, I have not, nor have I ever.

10 Q. Now, if I remember correctly -- and
11 you're welcome to refer to your CV as we're going
12 through this. It's page 121 in your expert report.
13 You started at ATSDR in 1992?

14 A. Let me just get there, so --

15 Q. Sure.

16 A. -- I'm on the page that you're
17 referring to. I started at ATSDR in 1992, that's
18 correct.

19 Q. And you retired in 2017, right?

20 A. December 31st, 2017.

21 Q. And as we just discussed, you worked on
22 ATSDR's Camp -- the water modeling related to Camp
23 Lejeune for Tarawa Terrace and Hadnot Point/Holcomb
24 Boulevard from about 2003 to 2013, 2014?

25 A. Probably. I want to say through 2013.

1 I was being funded in part at that time by the
2 Department of Navy, and so whatever they put in the
3 budget for 2014, it would not have been funded
4 by -- to my knowledge, by Camp Lejeune because the
5 modeling was completed, okay.

6 Q. Okay. And give or take, for a little
7 over -- for roughly a little over a decade, I think
8 we said 11 or 12 years, you worked on Camp Lejeune
9 water modeling at ATSDR, right?

10 A. That is correct. We did have, though,
11 again, because I was not only project chief or
12 scientific technical project officer for Camp
13 Lejeune, but I was also over the exposure dose
14 reconstruction program. We had other EDRP
15 activities and a couple of sites that we worked in,
16 not using Camp Lejeune money, but using the
17 agency's other funds.

18 Q. Okay. You started at ATSDR in '92.
19 You left in 2017, and you worked -- so that's,
20 what, roughly 25 years?

21 A. Yes.

22 Q. Okay. And you worked on Camp Lejeune
23 water modeling for close to half of that, is that
24 right, at ATSDR?

25 A. Did we say 10 or 11 years, yes.

1 Q. Okay.

2 A. Maybe slightly less. Maybe slightly
3 less, but...

4 Q. Understood. Was the water modeling for
5 Camp Lejeune a significant portion of your work
6 portfolio at ATSDR?

7 A. It was a substantial, but there were
8 other sites, as I said, prior to Camp Lejeune and a
9 couple of sites -- or a couple of analyses that
10 were not Camp Lejeune related.

11 Q. Focusing on that period between 2002,
12 2003 to 2013, what percentage of your work would
13 you say was related to the ATSDR's Camp Lejeune
14 modeling?

15 A. I'll start after about mid-2003. I
16 think that's when the ATSDR, I assume, got approval
17 from either the Marine Corps or the Navy to expend
18 the budget money on Camp Lejeune. I would say it
19 was probably 95 percent on different aspects of
20 Camp Lejeune.

21 Q. As I was looking at your -- your CV,
22 and specifically I was looking at your list of
23 publications, without looking each and every one
24 up --

25 A. Right.

1 Q. -- it's on page 130.

2 A. Okay. Okay. I'm there.

3 Q. I counted about nine or ten articles
4 that you've published related to the modeling work
5 you did on Camp Lejeune at ATSDR; is that right?

6 A. That sounds about right. It would be
7 agency reports. It would be journal articles and
8 there were some symposia presentations.

9 Q. Do you have any -- well, let me ask it
10 this way. Just ballpark, not holding you to any
11 specific number, how many publications, symposiums,
12 presentations, have you given related to the Camp
13 Lejeune water modeling?

14 A. I would really have to go and count
15 them up. I just don't feel answering truthfully if
16 I just picked a number out.

17 Q. Would you -- I think I identified nine
18 publications. Would you agree over ten?

19 A. Yes.

20 Q. Do you think over 20?

21 A. If you count some symposia
22 presentations where we had to actually submit a
23 manuscript, sometimes we did, and others we just
24 did, like, PowerPoint presentations, okay?

25 Q. So potentially over 20?

1 A. Right, yes.

2 Q. What about over 30?

3 A. That may come under other activities.
4 Like I was adjunct professor at the Emory
5 University Rollins School of Public Health, and so
6 I would give some case studies to my students using
7 what was publicly released from Camp Lejeune. And
8 I may have been asked by other ATSDR professionals
9 who were teaching other courses on statistics or
10 risk assessment at Emory to be a guest speaker for
11 my -- and I would give, again, things we had
12 already published or publicly released by the
13 agency about Camp Lejeune.

14 Q. Would you agree that the work you did
15 on the water modeling for Camp Lejeune at ATSDR was
16 a significant part of your career at ATSDR?

17 A. I would say it was substantial. It
18 would not be the complete time.

19 Q. And I saw on your CV that you, in 2015,
20 received the 2015 Excellence and Environmental
21 Energy Award, the grand prize, from the American
22 Academy of Environmental Engineers and Scientists;
23 is that right?

24 A. That is correct, sir.

25 Q. And was that related to the water

1 modeling work that you did at ATSDR on Camp
2 Lejeune?

3 A. Yes, it was.

4 Q. What is AEEES?

5 A. It's a professional organization, as
6 the name implies, of environmental engineers and
7 other engineers and scientists, and they run a
8 competition each year with different categories,
9 for example, consulting small projects, government
10 projects, and research projects.

11 Q. Okay.

12 A. And I mean, they put on webinars and
13 things of that nature, continuing education
14 courses.

15 Q. I saw the picture that you produced
16 holding the award. You looked very happy. What
17 did that award mean to you?

18 A. It meant -- it was especially
19 meaningful not just to me, but for our entire team
20 because an outside organization recognized the
21 significance of our work and contribution about
22 Camp Lejeune to the profession.

23 Q. Are you proud of that award?

24 A. Yes, I am.

25 Q. Would you describe it as one of the

1 highlights of your career?

2 A. Yes.

3 Q. How would you describe the work you've
4 done on the Camp Lejeune water modeling at ATSDR in
5 the context of your career?

6 A. I would say it was one of the similar
7 works that I have done, just like prior to Camp
8 Lejeune, Dover Township. Toms River, New Jersey
9 was also a similar piece of work. It was at the
10 U.S. Geological Survey, the work on the Floridian
11 RASA was also a similar piece of work.

12 Q. Now, in your prior deposition we
13 briefly discussed some e-mail exchanges that you
14 had with the Bell Legal Group in a 2009/2010 time
15 frame. Do you recall that?

16 A. In the September deposition?

17 Q. Correct.

18 A. I don't specifically recall that, but
19 if it's in the verbatim transcript, then we
20 discussed it.

21 Q. Okay. I'll show you one of them later.

22 A. Okay.

23 Q. And then you were retained by the Bell
24 Legal Group in July 2022 to serve as an expert in
25 this litigation, right?

1 A. That is correct.

2 Q. I was wondering what -- what led you or
3 how did you decide to serve as an expert witness in
4 this case?

5 A. Well, after I retired, of course, I --
6 I did a few consulting jobs just to keep in the
7 profession, keep my mind fresh. And then I was
8 approached and I felt because I had probably the
9 most internal knowledge -- not internal ATSDR, but
10 about the modeling I'm talking about, about what --
11 what we did, what the results meant, our confidence
12 in them, and that I could advise them on those
13 aspects of it.

14 Q. Are you -- how do I ask this? Is one
15 of the factors you considered in serving as an
16 expert in a litigation helping plaintiffs pursue
17 their claims related to exposure to Camp Lejeune
18 water?

19 A. That never -- that was never discussed
20 with me and that was never my -- my understanding,
21 but rather that I was a technical expert on water
22 modeling.

23 Q. Do you want to help the plaintiffs in
24 this case pursue their claims related to exposure
25 to Camp Lejeune water?

1 MR. DEAN: Object to the form of the
2 question.

3 THE WITNESS: That really would be a
4 legal question. I'm not really involved in legal
5 aspects other than being retained to explain what
6 we did, what I did, and the meaning of the work at
7 -- the water modeling that came from Camp Lejeune.

8 BY MR. ANWAR:

9 Q. And I guess I'm not asking you sort of
10 in the legal sense of whether your work is being
11 used to support the plaintiffs. I'm just asking
12 you personally, do you want to help the plaintiffs
13 in the litigation?

14 MR. DEAN: Object to the form of the
15 question.

16 THE WITNESS: When we did work at ATSDR
17 and even when I was at the USGS, we did what I
18 would classify as science in the public's interest,
19 okay? And so it's important to me that the public
20 understands what we did and how we did it, and if
21 it can help them come to a better understanding of
22 what occurred at Camp Lejeune or Toms River, Dover
23 Township, New Jersey, then that's a good -- good
24 use of my time, expertise, and the taxpayer's
25 money.

1 BY MR. ANWAR:

2 Q. So does your desire to -- or your
3 involvement in the litigation, does that stem from
4 a desire to explain the work that you did related
5 to Camp Lejeune at ATSDR?

6 A. Yes, yes.

7 Q. Do you feel like your work is under
8 attack in the litigation?

9 A. Not personally under attack. I believe
10 there's been mischaracterization of the work and
11 perhaps at different points misunderstanding of
12 what we were tasked with or charged with doing and
13 the reliability of the work.

14 Q. Do you --- is one of the motivating
15 factors in serving as an expert for the plaintiffs,
16 is it to defend your work?

17 MR. DEAN: Object to the form.

18 THE WITNESS: Well, I think if I'm
19 asked a question about our work, I'm defending
20 the -- the work, okay? So -- so but my objective
21 is not necessarily to be hired so I can defend what
22 we did. I would like to think that more of
23 explaining what we did and explaining, you know,
24 assumptions, limitations, and data analyses and
25 things of that nature.

1 BY MR. ANWAR:

2 Q. Aside from sort of the scientific
3 explanation portion of it or defending or
4 explaining your work, is money a motivating factor
5 at all serving as an expert?

6 A. Not at all, not at all.

7 Q. If the Court were to say, hey, the work
8 that you did at ATSDR was very fine, but we don't
9 -- we, the Court, don't believe it's appropriate
10 for use in this -- this case, how would that make
11 you feel?

12 A. Well, I would have to understand or be
13 there when someone said -- said that. That's sort
14 of a hypothetical. And I've never looked at the
15 work as defending it because the Court is going to
16 say, we don't believe it, okay? That's the best I
17 can answer.

18 Q. Okay. We'll talk a little bit more
19 about some of these other subjects later in the
20 deposition. Did you feel like you were defending
21 your work from the National Research Council?

22 MR. DEAN: Object to the form.

23 THE WITNESS: You mean, the results of
24 -- of their report?

25 BY MR. ANWAR:

1 Q. I guess, did you perceive -- let me ask
2 it differently. Did you perceive the National
3 Research Council's comments on the ATSDR Camp
4 Lejeune water modeling to be an attack?

5 MR. DEAN: Object to the form.

6 THE WITNESS: I believe and I believe
7 we have explained, on a couple of occasions,
8 internal documents as well as the published article
9 in Groundwater, that it was a mischaracterization
10 and misunderstanding and there was what appeared to
11 be -- because I requested additional meetings and
12 they would not meet with us. And I believe they
13 made their -- part of their decision -- I didn't
14 review the entire report, so I'm not talking about
15 the toxicology or the epi or the rest or anything
16 like that.

17 Q. Sure.

18 A. But they are all in conclusion that
19 they -- there was a misunderstanding,
20 mischaracterization, of some of the key things. So
21 yes, I mean, it's...

22 Q. Yes, it was an attack, is what
23 you're --

24 A. I wouldn't call it an attack, no. I
25 would say it was a mischaracterization and

1 misunderstanding.

2 Q. Okay. What about the Navy's critique
3 of the ATSDR water modeling for Camp Lejeune? How
4 did you perceive that?

5 A. I perceived that as a very usual
6 professional discourse that you have some work,
7 whether it's a model, data analyses or whatever,
8 and you publish it, whether it's a peer-reviewed
9 journal or peer-reviewed report, and the Navy had
10 some technical comments on the report, and so we
11 addressed them, in other words. So -- and until
12 this day, I still perceived it as a professional
13 exchange.

14 Q. What about Prabhakar Clement's --
15 Dr. Clement's article?

16 A. Right.

17 Q. How did you perceive that?

18 A. At the time it was published, which I
19 believe is 2010, it came right after the
20 publication of the NRC report. And again, I
21 thought there were some misunderstandings and
22 mischaracterizations. I do understand now that
23 part of it was sort of philosophical. In fact, he
24 mentioned that in his rebuttal to us. He was
25 looking at more philosophical issues, but I felt

1 the need to respond editorially to Dr. Clement's
2 article.

3 Q. Sure. Now, in the instance of the NRC
4 and the Navy and Dr. Clement, you did respond to
5 each one of those, correct?

6 A. The -- to the NRC we wrote or I -- I
7 oversaw an internal document, okay, and advised my
8 management chain and leadership that we needed to
9 respond to the NRC, I guess, agency, and they and
10 CDC quickly invoked the 11th commandment, thou
11 shall not critique the NRC.

12 Q. Why do you think that is?

13 A. I have no idea, but we point -- and
14 that internal document was very -- I mean, it was
15 very technically oriented in going -- I wouldn't
16 say line by line, but topic by topic and explaining
17 where we saw some issues with the NRC report. And
18 I do know that -- I believe it was Dr. Portier,
19 when he -- Dr. Portier in 2009 was not director of
20 ATSDR, but when he became director, I provided him
21 with a copy of that internal -- it's called
22 document, okay, it wasn't a memo or anything like
23 that. And he had a couple of topics in his letter
24 to -- and I forget who he wrote exactly to, but
25 about -- about our work, about the NRC report.

1 Q. If I'm understanding you correctly, you
2 wanted to respond to NRC, correct?

3 A. Yes.

4 Q. Okay. And you had put together a
5 response?

6 A. That is correct.

7 Q. But the response was kept, for whatever
8 reason, by CDC and ATSDR, internal, correct?

9 A. I know by ATSDR. I don't know if it
10 ever made it up to CDC --

11 Q. Okay.

12 A. -- that's over ATSDR, but it did make
13 it up through my management chain, okay?

14 Q. And it was kept internal, correct?

15 A. That is my understanding.

16 Q. Okay. And you did respond to the
17 Navy's comments or critiques, correct?

18 A. That is public information on the ATSDR
19 website, yes.

20 Q. Okay. That -- there's this ATSDR
21 report that's -- we'll look at it later, but it's
22 sort of named response to the Navy's letter. Did
23 you draft that response?

24 A. Yes.

25 Q. Okay. And then --

1 A. With assistance of team members and
2 some epidemiologists.

3 Q. Understood. And the article that you
4 published along with, I believe, Dr. Aral and some
5 of the other ATSDR colleagues, Jason Sautner, maybe
6 Rene, a response to Dr. Clement's article as well,
7 correct?

8 A. That is correct, yes, the team. I
9 listed all of the team. When I say team, from an
10 agency standpoint, so that's why there are some
11 epidemiologists that's coauthors on it as well.

12 Q. And when I say -- because we were
13 talking -- just for purposes of the record, because
14 we were talking about the 2000 Clement article,
15 when I'm talking about Dr. Clement's article now,
16 it's the article, I think, in the mid-2000s, 2010,
17 2011, focused on hindcasting, correct?

18 A. That is correct.

19 Q. Okay. Did you introduce the
20 plaintiffs' lawyers to -- in this case to
21 Dr. Konikow?

22 A. Yes, I did. When I say introduced, let
23 me clarify. I think they were looking for a name
24 of somebody who was nationally renowned in fate and
25 transport modeling, and so from my days at USGS, I

1 knew Dr. Konikow.

2 Q. Okay. So you connected Dr. Konikow
3 with the Plaintiffs' Leadership, correct?

4 MR. DEAN: Object to the form.

5 THE WITNESS: I just provided contact
6 information.

7 BY MR. ANWAR:

8 Q. Okay. Did you introduce or provide
9 contact information to the plaintiffs' lawyers in
10 this case for Rob -- Bob Faye?

11 A. Yes.

12 Q. When did you do that?

13 A. I really don't remember.

14 Q. Was -- was it in the last 30 days?

15 A. It was prior to that.

16 Q. Last 60 days?

17 A. I've been, as you said, involved in
18 this case since July of 2022.

19 Q. I won't hold you to a precise date.
20 Was it in 2025?

21 A. No, it was -- must have been sometime
22 in 2024.

23 Q. Do you recall whether it was before or
24 after the September 26th deposition, 2024?

25 A. It would have been before.

1 Q. Did you -- do you have Bob Faye's
2 contact information?

3 A. Yes, I do.

4 Q. What is it?

5 A. I've got a phone number and an e-mail.

6 Q. Okay.

7 MR. DEAN: Hold on. I have his info as
8 well. I don't mind -- he's a retained consulting
9 expert. He's not been disclosed as an expert. So
10 if you were to get his contact information, I would
11 request that you not talk to him -- talk to
12 Mr. Faye without me being present or on the phone.

13 MR. ANWAR: Okay.

14 MR. DEAN: If at all because he is,
15 again, a confidential consulting expert for the
16 PLG.

17 MR. ANWAR: Okay. We can discuss that
18 separately.

19 MR. DEAN: Sure.

20 BY MR. ANWAR:

21 Q. Did you introduce or provide contact
22 information for any of the other experts for the
23 plaintiffs?

24 A. Just the two that you have mentioned,
25 Dr. Konikow and Mr. Faye.

1 Q. In documents that we received from
2 Dr. Konikow, there was an e-mail in there between
3 you and Dr. Konikow. I think you were e-mailing
4 him, and it included a line, it said "don't know if
5 Kevin explained the politics of the case now, but
6 it's quite eye opening to me." Do you recall that?

7 A. I may have said that in the e-mail. I
8 mean, if I saw the e-mail, then we could see.

9 Q. Sure. What did you mean by the
10 politics of the case?

11 A. Well, Camp Lejeune has always been
12 surrounded, you know, from a political standpoint,
13 okay, because you have different parties, meaning
14 the Navy, the CAP, ATSDR, and so on, having
15 different points of view, so that makes it -- and
16 you're in public health, which is -- always has
17 politics associated with public health. And so
18 that's what -- and then they passed or perhaps I
19 was aware -- I was aware of the Janey Ensminger
20 Act, okay. That would have been political to get
21 that passed. And I believe at the time they had
22 already passed the PACT Act, which contained the
23 section -- I forget the exact number for Camp --
24 Camp Lejeune.

25 So that's what I was referring --

1 referring to, is most of the time I know the work
2 that -- I can't speak for Dr. Konikow, but the work
3 that I did at, say, USGS, okay, and even most of
4 the work that I did at ATSDR, with the exception of
5 Dover Township, Toms River, and Camp Lejeune, were
6 not -- did not have necessarily political aspects
7 to them in terms of legislation being passed.

8 Q. Understood.

9 A. Things like that.

10 Q. I -- and we talked about this in your
11 last deposition, and I know that you were part of a
12 group from ATSDR that testified to Congress,
13 correct?

14 A. That would have been in, like,
15 June 12th, 2007.

16 Q. Okay. And that was about Camp Lejeune,
17 correct?

18 A. Right.

19 Q. Was it a House Committee Hearing, if I
20 remember correctly?

21 A. It was a Senate Subcommittee Hearing.

22 Q. Oh, I'm sorry.

23 A. And I actually was -- did not provide
24 the testimony. I believe it was Dr. Tom Sinks. I
25 was just there, I guess, as a -- again, a technical

1 expert, but I was seated at the table.

2 Q. Okay. Have you had any direct
3 conversations -- have you directly had any
4 conversations with any Congress members about Camp
5 Lejeune?

6 A. No, I have not.

7 Q. You have a quote in your -- your e-mail
8 signature block currently from Nobel prize
9 physicist Richard P. Feynman. Do you know what I'm
10 talking about?

11 A. Dr. Feynman, yes, yes, I do.

12 Q. And I believe the quote is "I would
13 rather have questions that can't be answered than
14 answers that can't be questioned"; is that right?

15 A. That is correct.

16 Q. Okay. Who is Richard P. Feynman?

17 A. He's a Nobel -- he's since deceased,
18 but he was a very young Nobel prize winning
19 physicist. And the laypeople probably know him for
20 his participation on and his famous experiment on
21 the Challenger explosion.

22 Q. Okay.

23 A. And I believe that's where he put that
24 quote in, but I wouldn't swear -- swear to it, and,
25 in fact, I just bought a copy of -- of a book about

1 -- about him.

2 Q. Okay. Why did you include that quote
3 in your signature block?

4 A. I thought it's appropriate to
5 everything in -- in life. It's very succinct.
6 Don't be afraid to say you don't know the answer,
7 but that's better than saying don't ask me the
8 question.

9 Q. Would you agree that that quote is
10 applicable to all of the work that you've done as
11 an engineer or an environmental scientist?

12 A. I would say it's a more philosophical
13 statement, okay?

14 Q. One that would apply to -- and you said
15 any aspect of life, right?

16 MR. DEAN: Object to the form.

17 THE WITNESS: Well, that's how I am
18 interpreting it, okay? I wasn't there when
19 Dr. Feynman stated it or published it, so I don't
20 know what was in his mind, but it seemed to me,
21 from a philosophical standpoint, it, you know, it
22 resonates with me just philosophically.

23 BY MR. ANWAR:

24 Q. Okay. We have been going for a little
25 over an hour. Do you want to -- should we take

1 another break?

2 A. Sure, yes.

3 THE VIDEOGRAPHER: Okay. We're going
4 off record. The time is 11:23 a.m.

5 (A recess transpired.)

6 THE VIDEOGRAPHER: Okay. We are going
7 back on the record. The time is 11:32 a.m.

8 BY MR. ANWAR:

9 Q. We are back on the record from a short
10 break. Mr. Maslia, are you okay to continue?

11 A. Yes, I am.

12 Q. Okay. And did you speak with your
13 lawyer during the break?

14 A. No, I did not.

15 Q. Could you turn to page 145 of your
16 expert report?

17 A. Yes. Okay.

18 Q. 145 is a -- includes on it a figure or
19 a chart laying out the team that worked on the
20 ATSDR water modeling for Tarawa Terrace and Hadnot
21 Point/Holcomb Boulevard, their titles and sort of
22 their roles; is that right?

23 A. That is correct.

24 Q. Okay. And you've included Xs. A dark
25 green X for senior author of a report chapter. A

1 light green X for a contributing author of a report
2 chapter, and then a light red O for project
3 management and coordination; is that right?

4 A. That's correct.

5 Q. Okay. As I -- as I look at this
6 figure, is it fair to say that you were a senior
7 author or a contributing author or project managed
8 and coordinated every single chapter of the Tarawa
9 Terrace model reports and the Hadnot Point/Holcomb
10 Boulevard model reports?

11 A. I was the technical or scientific
12 project officer over all of the Camp Lejeune water
13 modeling.

14 Q. Okay.

15 A. It's just not shown on here. You can't
16 print three different colors on the same box, okay?
17 So -- and then where the dark Xs are, obviously I
18 was the senior author on that and contributed to
19 most of the reports, but there were some individual
20 chapters or supplements that I did not have
21 authorship of.

22 Q. But you still oversaw and managed,
23 correct?

24 A. Yes, yes.

25 Q. Coordinated, managed?

1 A. Yes.

2 Q. Okay. In coordinating and managing
3 every chapter of the two models, Tarawa Terrace and
4 Hadnot Point, would you have reviewed and approved
5 every chapter on each of those reports?

6 A. I would have reviewed and then said
7 it's ready to go to -- through the agency peer
8 review and then to external -- or if any review
9 comes back and then go out to external peer review.
10 It's ultimately up to the agency, I guess, Office
11 of Science and CDC Office of Science to give the
12 final release.

13 Q. Understood. Would you be the one to
14 make the decision it's ready to go to the next step
15 of the process, the peer review process?

16 A. Yes.

17 Q. And in making that final decision,
18 would you -- for each chapter or each report, would
19 you have an opportunity to review and comment and
20 suggest edits to particular chapters of either of
21 the model reports?

22 A. Yes.

23 Q. Okay. We talked about, at the
24 beginning of the deposition, the -- sort of the
25 most recent calculations you've run --

1 A. Yes.

2 Q. -- with respect to geometric bias.

3 A. Right.

4 Q. As to the Tarawa Terrace model,
5 correct?

6 A. Yes, yes.

7 Q. That was in the last month or so,
8 correct?

9 A. That is correct, sir.

10 Q. Aside from that, do you stand by every
11 chapter of the Tarawa Terrace model?

12 A. Yes.

13 Q. And is that also true -- do you stand
14 by every chapter of ATSDR's Hadnot Point model?

15 A. Yes.

16 Q. Again, aside from that geometric bias
17 discussion that we had, is there anything that
18 you're aware of that should be changed or corrected
19 in either the Tarawa Terrace set of model reports
20 or the Hadnot Point/Holcomb Boulevard set of model
21 reports?

22 A. There's issues brought up by the DOJ's
23 experts that I've responded to.

24 Q. Okay.

25 A. Okay. Absorption parameters, for

1 example, the results, and they do not impact at all
2 the results of the Tarawa Terrace analyses.

3 Q. Understood. In preparing your expert
4 report, either the primary -- the main one or the
5 rebuttal report, did you rerun either of the Tarawa
6 Terrace or the Hadnot Point and Holcomb Boulevard
7 model?

8 A. No.

9 Q. Were your reports, the main report and
10 the rebuttal report, were they based on the ATSDR
11 reports that are publicly available now?

12 A. You're talking about my expert report?

13 Q. Correct.

14 A. Yes, they were all -- whatever was
15 publicly available on the ATSDR website, which
16 would be all the Tarawa Terrace expert panel
17 reports, response to the Navy, and the Hadnot
18 Point/Holcomb Boulevard series of reports.

19 Q. Okay.

20 A. And that's what my expert report would
21 rely on.

22 Q. Okay. And I think you've clarified
23 that for me. Basically what I'm getting at is you
24 didn't, you know, go and put MODFLOW on your
25 computer and run the groundwater model again. You

1 didn't go and get MT3DMS and run the fate and
2 transport model again, correct?

3 A. Not at all, no, I do not have those on
4 my computer.

5 Q. And same with EPANET and the water
6 distribution model, you didn't --

7 A. I did not rerun it, although I do have
8 EPANET on my computer at home.

9 Q. Okay. Do you consider yourself an
10 expert in groundwater modeling generally?

11 A. Yes.

12 Q. Any particular aspects of groundwater
13 modeling that you consider yourself an expert or do
14 you consider yourself an expert in all of it?

15 A. I would consider myself an applied
16 researcher, so applying the available models that
17 have been developed by others to sites, okay, and
18 doing that as well as experience with
19 post-calibration analyses to assess the goodness of
20 fit of models.

21 Q. In terms of groundwater modeling, do
22 you consider yourself an expert in groundwater flow
23 modeling?

24 A. Yes.

25 Q. Do you consider yourself an expert in

1 contaminant fate and transport modeling?

2 A. I would consider myself very
3 knowledgeable.

4 Q. Okay. But not an expert?

5 MR. DEAN: Object to the form of the
6 question.

7 THE WITNESS: I mean, I'm an expert
8 from the standpoint that I've had courses in
9 contaminant fate and transport. I applied some and
10 -- but I don't do it -- I did not do it routinely,
11 but I have run contaminant fate and transport
12 models.

13 BY MR. ANWAR:

14 Q. Do you consider yourself an expert in
15 water distribution modeling?

16 A. Yes.

17 Q. Why do you consider yourself an expert
18 in water distribution modeling?

19 A. Well, we've applied -- when I say we,
20 at ATSDR, we applied water distribution system
21 modeling to a couple of sites: Dover Township,
22 Toms River, New Jersey as well as Camp Lejeune.
23 And we were -- for the Dover Township analysis, we
24 were actually awarded the best practice oriented
25 paper in 2000 by the Journal of Water Resources

1 Planning and Management based on the work in field
2 monitoring of the water distribution system in Toms
3 River, New Jersey. So yes, I would consider myself
4 an expert there.

5 Q. Okay. Let's turn to page 17 of your
6 report.

7 A. Of my expert?

8 Q. Your main report, yes.

9 A. Expert report?

10 Q. Correct.

11 A. Page 17. Okay.

12 Q. Page 17 contains a summary of your
13 opinions; is that right?

14 A. It has one item.

15 Q. Oh, I'm sorry. 17 and 18.

16 A. And 19.

17 Q. And 19. 17 through 19?

18 A. Yes.

19 Q. Starting on 17 is a section entitled
20 "summary of your opinions" and it concludes on page
21 19, right?

22 A. Yes.

23 Q. Okay. I wanted to focus on opinion
24 number three. It states, "the reconstructed
25 simulated monthly mean contaminant concentrations

1 of PCE, TCE, 1-2 DCE, vinyl chloride, benzene at
2 Tarawa Terrace, Hadnot Point and Holcomb Boulevard
3 are contained in ATSDR report appendices A-2 for
4 Tarawa Terrace, A-3 and A-7 for Hadnot Point, and
5 A-8 for Holcomb Boulevard." Did I read that
6 correctly?

7 A. Yes.

8 Q. Okay. And then opinion three goes on.
9 It says, "these reconstructed monthly mean
10 concentrations are also included in this report in
11 appendixes H, I, J and K" -- well, let me -- "these
12 reconstructed monthly mean concentrations are also
13 included in this report in appendixes H, I, J and
14 K, comma, are reliable and represent, within
15 reasonable scientific and engineering certainty,
16 the contaminant levels in selected water-supply
17 wells and in finished water at Camp Lejeune from
18 1953 to 1996." Did I read that correctly?

19 A. That is correct.

20 Q. Okay.

21 A. The ones for Hadnot Point probably go
22 to 2008. That's what the model runs did.

23 Q. Okay.

24 A. I'm not sure about the '96. That may
25 have been when the wells -- all the wells -- I --

1 but I do recall, because we had 2008 or 2006
2 through 2008, a remediation rate of Hadnot Point
3 that ran the model all the way out to 2008. So I
4 would...

5 Q. When you say there that the
6 reconstructed mean -- or reconstructed monthly mean
7 concentrations in the ATSDR reports are reliable
8 and represent, within reasonable scientific and
9 engineering certainty, what do you mean by
10 reasonable scientific and engineering certainty?

11 MR. DEAN: Object to the form.

12 THE WITNESS: When you conduct
13 scientific and engineering analysis application and
14 you come up with the value of -- that you believe
15 is the most likely value and -- then there's
16 always, you know, plus or minus a certain percent,
17 okay, and that's accepted. That's a pragmatic
18 engineering approximation to a modeling problem,
19 okay? You do the best you can and see if the level
20 of uncertainty is way beyond the information that
21 you have in terms of giving a reliable solution or
22 if it's within, then -- but there's always some --
23 some differences or errors in any of the solutions.

24 Q. When you say reliable there, what do
25 you mean? Is that --

1 A. Reliable, to me, means that -- and I'm
2 going to say for their ATSDR analyses, of course,
3 that are published -- somebody could pull that off
4 the shelf or off -- offline, I guess, now, and with
5 the model input files, duplicate what we did, okay?

6 Q. In this opinion, are you stating -- are
7 you opining that the reconstructed monthly mean
8 concentrations in the ATSDR reports are accurate
9 within a reasonable degree -- or reasonable
10 scientific and engineering certainty?

11 A. Yes.

12 Q. So it's your opinion that the simulated
13 monthly mean concentrations are accurate within
14 reasonable scientific and engineering certainty?

15 A. They are the most likely values to
16 occur.

17 Q. And --

18 A. Or to have occurred.

19 Q. When we're talking about reasonable
20 scientific and engineering certainty, help me
21 quantify that into a percentage. Are they
22 50 percent accurate, 75 percent accurate, 51
23 percent? Are they 90 percent likely to be
24 accurate?

25 MR. DEAN: Object to the form of the

1 question. Calls for legal conclusion.

2 THE WITNESS: Depending on the
3 application, not necessarily just on Camp Lejeune,
4 but in -- generally speaking, it depends on a lot
5 of factors. The quality of the field data. How
6 you constructed the model. What your calibration
7 targets may have been, or at least you try to
8 figure them out, and so each application will have
9 a different level of uncertainty, okay, and
10 reliability.

11 BY MR. ANWAR:

12 Q. What do you mean by depending on the
13 application?

14 A. Well, for example, we did water
15 distribution system modeling, okay? Water
16 distribution system modeling takes hour time steps,
17 not monthly, but hour time steps. And we measure
18 and we gather data because -- we personally
19 gathered them both in -- at Dover Township and at
20 Camp Lejeune. We had 15-minute readings per hour,
21 okay? So that's more data. So then you have to
22 assess that model based on the data that you have
23 and can you accept the difference between the
24 modeling results and the data that you -- that you
25 have and the way you interpret the data.

1 In other instances you may have monthly
2 data or sporadic data, and so the level of
3 reliability may change. And it also depends,
4 again, how you constructed the model. The size of
5 the grid, how you hydrogeologically conceptualized
6 the model. There's a lot of factors that go --go
7 into there, so you just can't -- I don't think it's
8 accurate to say on a blanket statement there's this
9 uncertainty in terms of percent or not percent, you
10 know.

11 Q. If the -- there is uncertainty to the
12 simulated monthly mean contaminant concentrations,
13 why were they -- those contaminant concentrations,
14 I'm just wondering, why were they produced in this
15 -- kind of this table format at the -- in multiple
16 places in the report, but do you know what I'm
17 referring to, at the end of Appendix A for Tarawa
18 Terrace, for instance?

19 MR. DEAN: Object to the form of the
20 question.

21 THE WITNESS: Can I just take a look at
22 Appendix A?

23 BY MR. ANWAR:

24 Q. Sure. Here, we'll go ahead and mark it
25 -- mark them both.

1 A. Okay. Oh, I've got a copy right here
2 that's unmarked. That's A. No, that's not A.
3 Here's Tarawa Terrace.

4 Q. Okay. I'll give you the one for the
5 court reporter.

6 MR. DEAN: Just use that.

7 THE WITNESS: Okay. Okay.

8 (DFT. EXHIBIT 9, Analyses of
9 Groundwater Flow, Contaminant Fate and Transport,
10 and Distribution of Drinking Water at Tarawa
11 Terrace and Vicinity, U.S. Marine Corps Base Camp
12 Lejeune, North Carolina: Historical Reconstruction
13 and Present-Day Conditions, Chapter A, Summary of
14 Findings, Bates-stamped
15 CLJA_Healtheffects-0000221172 through 0000221287,
16 was marked for identification.)

17 (DFT. EXHIBIT 10, Analyses and
18 Historical Reconstruction of Groundwater Flow,
19 Contaminant Fate and Transport, and Distribution of
20 Drinking Water Within the Service Areas of the
21 Hadnot Point and Holcomb Boulevard Water Treatment
22 Plants and Vicinities, U.S. Marine Corps Base Camp
23 Lejeune, North Carolina, Chapter A, Summary and
24 Findings Bates-stamped CLJA_Healtheffects-000022136
25 through 0000221535, was marked for identification.)

1 THE WITNESS: So based on the Appendix
2 2 in Tarawa Terrace?

3 BY MR. ANWAR:

4 Q. I am talking about Appendix A3 and A --
5 A3.

6 A. A -- in Tarawa Terrace it's Appendix
7 A3. It's questions and answers.

8 Q. Oh, I'm sorry. I have the wrong one.
9 You're probably right. A2, yeah.

10 A. Okay. A2. Okay. Could you repeat the
11 question?

12 Q. Sure. I guess given the uncertainty
13 and the -- the -- the application being important,
14 I was just wondering why were these concentrations
15 presented in the format that they were in A2?

16 A. By format, what do you mean?

17 Q. The summary -- I mean, you -- for
18 instance, can a person go on page A90 --

19 A. Okay. Hold on. A90. Okay.

20 Q. Stress period, 301, is for January of
21 1976 and the model simulated a PCE monthly mean
22 concentration of 73.96 micrograms per liter; is
23 that right?

24 A. That's directly, yes, from the model
25 output.

1 Q. Sure.

2 A. Okay.

3 Q. Do you know for sure that's what the
4 PCE concentration was in micrograms per liter in
5 January of 1976?

6 A. I would say the most likely value was
7 74 micrograms per liter, just rounding.

8 Q. Okay.

9 A. Most likely.

10 Q. Didn't a moment ago you say there are
11 sort of -- there's uncertainty associated with the
12 model outputs and there's a range --

13 A. Yes.

14 MR. DEAN: Let him finish the question
15 and then if I have an objection.

16 THE WITNESS: Okay. Okay. Oh, okay.
17 No problem.

18 MR. DEAN: Can you --

19 BY MR. ANWAR:

20 Q. Didn't you say that a moment ago?

21 MR. DEAN: Object to the form of the
22 question.

23 THE WITNESS: A moment ago I said
24 there's -- yes, I also said there's uncertainty
25 with the data; there's, you know, uncertainty

1 exists, okay?

2 BY MR. ANWAR:

3 Q. Why wasn't this numerical data
4 presented with the uncertainty, the range, and the
5 potential error bands for the data?

6 MR. DEAN: Object to the form of the
7 question.

8 THE WITNESS: I believe it was in
9 figure -- let me see if I can find the figure here.
10 Figure -- on page A60, figure -- the figure there,
11 A26, it's presented in terms of the 95 percent
12 confidence.

13 Q. Okay. Let's turn to page -- well, let
14 me -- let me ask some just for purposes of the
15 record questions. When we're talking about Camp
16 Lejeune water modeling, we're really talking about
17 two separate water models, correct? And what I
18 mean by that is there was a model that related to
19 Tarawa Terrace and then there was a separate model
20 that related to Hadnot Point and Holcomb Boulevard,
21 correct?

22 A. I'd say there was an analysis related
23 to Tarawa Terrace.

24 Q. Sure.

25 A. And then there were subsequent analyses

1 because of the complexity of Hadnot Point and
2 Holcomb Boulevard and the interconnection related
3 to those areas.

4 Q. Was the model for the analyses for
5 Tarawa Terrace, did that actually consist of two
6 separate models?

7 A. For Tarawa Terrace? Consisted of
8 MODFLOW and MT3DMS and then a mixing model. That
9 would be three models.

10 Q. Understood. And MODFLOW is a
11 groundwater flow model -- modeling software,
12 correct?

13 A. That is correct.

14 Q. And MT3DMS is a contaminant fate and
15 transport model, correct?

16 A. That is correct.

17 Q. For Tarawa Terrace, rather than running
18 a -- sort of a water distribution model, you used
19 the simple mixing model, correct?

20 A. No, that's -- that's mixing apples and
21 oranges, okay? Let's separate off water
22 distribution system modeling. For the groundwater
23 flow analyses we ran MODFLOW, which generated
24 groundwater flow velocities of different layers.
25 That's directly imported into MT3DMS. And then we

1 applied a flow-weighted mixing because you had
2 different wells turning on and off. And then we
3 used the mixing model, which was described on page
4 A40 in equations one and two, and that was because
5 all the wells mixed at the water treatment plant,
6 and that was the final output to which we compared
7 available samples that were collected at the water
8 treatment plant.

9 Q. Understood. So you assumed in the
10 Tarawa Terrace model that the -- the water from the
11 treatment plant was the same water that the end
12 user received, correct?

13 A. Yes.

14 Q. Now, I think that's what I was getting
15 at. The -- now, the Tarawa Terrace analysis was
16 completed in 2009, right?

17 A. The last chapter was published in 2009.

18 Q. Chapter A was published roughly 2007,
19 is that...

20 A. In -- because of the -- excuse me.
21 Because of the Senate Subcommittee Hearing, there
22 was an executive summary released June the 12th,
23 2007.

24 Q. Okay.

25 A. And then the full Chapter A, summary of

1 findings, was released in July of 2007. But other
2 work had been done. Again, it was a summary
3 document, so obviously it had results in here from
4 -- it was just a matter of finalizing the reports.

5 Q. And then the Hadnot Point/Holcomb
6 Boulevard analysis, that was completed in 2013,
7 right?

8 A. March 2013, the Chapter A, summary of
9 findings, and in that situation, rather than
10 individual additional chapters, the agency decided
11 to make supplements for the other contributing
12 analyses described in the summary of findings.

13 Q. You would agree that when running a
14 groundwater flow model using, for instance,
15 MODFLOW, there is some level of uncertainty,
16 correct?

17 A. Yes, yes.

18 Q. And when you run a fate and transport
19 model using, for instance, MT3DMS, there is also
20 some level of uncertainty associated with the fate
21 and transport aspect, correct?

22 A. Yes, but there are different types of
23 uncertainty, okay? In other words, there's what's
24 referred to as scenario uncertainty, and that is
25 your understanding or conceptualizing the system

1 that can be an error before you ever get to the
2 model. There's model uncertainty. For example,
3 someone were to try to apply an analytical model,
4 which assumes constant flow field in the
5 groundwater, constant velocities, then that would
6 be uncertain -- model uncertainty.

7 Q. And so when you're -- when you're using
8 a groundwater flow model, a MODFLOW, and then
9 taking the results and putting them into a fate and
10 transport model, an MT3DMS, doesn't that certainty
11 then accumulate because you're combining
12 uncertainty -- uncertain results with even more
13 uncertain results?

14 MR. DEAN: Object to the form of the
15 question.

16 THE WITNESS: That's -- actually, if
17 you read some papers published and all of that,
18 it's a common mistake is to linearly add up
19 uncertainty. It doesn't work that way, okay? It
20 may compound it. It may get reduced or whatever,
21 but you just can't add that you've got a 10 percent
22 uncertainty or a 95 percent confident band on the
23 flow model. You just can't say, okay, well, the --
24 the transport model has 90 percent, add the two
25 together and call it 92 and a half. It doesn't --

1 it doesn't work like that.

2 BY MR. ANWAR:

3 Q. And I think you just said it could
4 compound it, though, right?

5 A. You would have to look at the -- again,
6 the specific application, the specific site that
7 you're looking at, the specific model that
8 you're -- you're applying.

9 Q. And I'm just quoting back your words.
10 You would agree, though, it could compound it?

11 MR. DEAN: Object to the form of the
12 question.

13 THE WITNESS: I would not necessarily
14 say it would compound it. You would have
15 uncertainty associated with each of the models that
16 you applied as well as uncertainty in the data,
17 okay, that you're calibrating to. And so that's
18 why it's, I think, critical after you complete --
19 in our case it was a four-stage calibration, to try
20 to -- or even after a third-stage, try to assess
21 the goodness of fit of the model to data. To look
22 at sensitivity analyses, to look at uncertainty
23 analyses, and probabilistic uncertainty analyses to
24 quantify that, okay?

25 BY MR. ANWAR:

1 Q. Now, let's turn to page Roman numeral
2 three.

3 A. Chapter A?

4 Q. Chapter A, correct, of Tarawa Terrace,
5 which is, for the record, Exhibit 9.

6 A. Oh, okay. I'm sorry. Roman -- the
7 foreword?

8 Q. Correct. Okay. And you would agree
9 with me, there it says, in the foreword, "the
10 ATSDR, an agency of HHS, is conducting an
11 epidemiological study to evaluate whether in utero
12 and infant, up to one year of age, exposures to
13 volatile organic compounds in contaminated drinking
14 water at U.S. Marine Corps Base Camp Lejeune,
15 North Carolina, were associated with specific birth
16 defects and childhood cancers." Did I read that
17 correctly?

18 A. Yes, you did.

19 Q. Okay. And it goes on to say "the study
20 includes births occurring during the period 1968 to
21 1985 to women who were pregnant while they resided
22 in family housing at the base." Did I read that
23 correctly?

24 A. Yes, you did.

25 Q. Then if you go to the next paragraph,

1 "historical exposure data needed for the
2 epidemiological case-control study are limited. To
3 obtain estimates of historical exposure, ATSDR is
4 using water modeling techniques and the process of
5 historical reconstruction. These methods are used
6 to quantify concentrations of particular
7 contaminants in finished water and to compute the
8 level and duration of human exposure to
9 contaminated water." Did I read that correctly?

10 A. To contaminated drinking water.

11 Q. Contaminated drinking water. Thank
12 you.

13 A. Yes, yes.

14 Q. And so you would agree with me, and I
15 think you have before, that the Camp Lejeune water
16 modeling for Tarawa Terrace was performed to
17 provide data for this epidemiological study,
18 correct?

19 A. It was conducted to address five
20 questions, as I've put in my expert report. Number
21 one was which contaminants you needed to look at.
22 These are questions posed by the epidemiologist.
23 You know, whether it's volatile organics, I mean,
24 volatiles, pesticides. Another conclusion, it's a
25 military base, so there's a numerous one. Number

1 two, when the contaminants arrived at water-supply
2 wells, monthly mean. And then number three, what
3 was the concentration in the wells. Number four,
4 what was the concentration in the water distributed
5 throughout, in this case, Tarawa Terrace. And
6 number five was what were the range of the values.
7 And we interpret that, from a modeling stance, is
8 some type of sensitivity or uncertainty analyses.

9 Those were -- those -- those were
10 always from -- I guess when we first had our first
11 kickoff meeting with the Marine Corps and Navy and
12 all of that in October of 2003, that's what we
13 presented to them.

14 Q. And that was in support of this
15 epidemiological study that was --

16 A. Yes, it was in support of.

17 Q. Of the epi study, correct?

18 A. Yes.

19 Q. Okay. And if you turn to A98.

20 A. Okay. I'm there.

21 Q. There is a -- so A98 is a page of a
22 question and answer section of Chapter A, Tarawa
23 Terrace report, which is identified as Appendix A3.
24 The question is "ATSDR's historical reconstruction
25 analysis documents that Tarawa Terrace drinking

1 water was contaminated with PCE that exceeded the
2 MCL" --

3 A. I'm not -- I'm not following where you
4 are. You said you were on A96?

5 Q. A98.

6 A. A98. And the --

7 Q. The last question --

8 A. Oh, okay. Okay. Okay.

9 Q. -- is about the results of the model,
10 "what does this mean in terms of my family's
11 health?"

12 A. Right.

13 Q. The response is "ATSDR's exposure
14 assessment cannot be used to determine whether you
15 or your family suffer -- suffered any health
16 effects as a result of past exposure to PCE
17 contaminated drinking water at Camp Lejeune",
18 correct?

19 A. That's what it says there, yes.

20 Q. And you -- your -- in the chart that we
21 looked at earlier, you're the -- the primary author
22 of Chapter A, correct?

23 A. Yes.

24 Q. Okay. And so you wrote these words,
25 correct?

1 A. I wrote these -- this section -- let me
2 go back -- the questions and answers, okay. When I
3 was at ATSDR they required you, if you conducted a
4 technical analyses modeling or whether it was epi,
5 whatever, to provide the public with a layperson's
6 understanding, okay? So I drafted these. They
7 were reworded by the Office of Communications and
8 then sent back down to me to see if I agreed with
9 their edits, which there were many. And then they
10 were published as that appendix.

11 Q. Okay. And you're the primary author?
12 You're listed first?

13 A. Yes.

14 Q. And you would stand by what's in this
15 report today, correct?

16 A. Yes.

17 Q. Okay. Now, if you would take a look at
18 Exhibit 10, which is Chapter A for Hadnot Point.

19 A. Okay. I've got a copy here. Okay.
20 Here we go. Okay. Yes, it's unmarked.

21 Q. Okay. If we turn to page three again,
22 foreword, Roman numeral three.

23 A. Okay.

24 Q. And again. There it says "ATSDR is
25 conducting epidemiological studies to evaluate the

1 potential health effects from exposures to volatile
2 organic compounds such as PCE, TCE, and benzene in
3 drinking finished water at U.S. Marine Corps Base,
4 Camp Lejeune, North Carolina." Did I read that
5 correctly?

6 A. Yes.

7 Q. Okay. "Historical exposure data needed
8 for the epidemiological studies are limited. To
9 obtain estimates of historical exposures, ATSDR is
10 using water modeling techniques in the process of
11 historical reconstruction to quantify
12 concentrations of particular contaminants in
13 finished water and to compute the level of duration
14 of human exposure to contaminated water." Did I --
15 "drinking water." Did I read that correctly?

16 A. That is correct.

17 Q. Okay. And you're also the principal
18 author of Chapter A for Hadnot Point/Holcomb
19 Boulevard, correct?

20 A. That is correct.

21 Q. Okay. And these are your words,
22 correct?

23 A. Yes.

24 Q. Okay. And so again, the -- the -- the
25 model for Hadnot Point and Holcomb Boulevard were

1 -- was done in support of an epidemiological study,
2 correct?

3 MR. DEAN: Object to the form of the
4 question. Asked and answered, too.

5 THE WITNESS: It was done to address
6 the five objectives or questions that the
7 epidemiologists asked us to -- to address.

8 BY MR. ANWAR:

9 Q. Okay. In support of the
10 epidemiological studies, correct?

11 MR. DEAN: Object to the form of the
12 question. I'll let him answer it one more time.
13 The same thing happened recently in another depo.

14 MR. ANWAR: Please --

15 MR. DEAN: You keep asking the same
16 question.

17 MR. ANWAR: If we need to get Judge
18 Jones on -- I'm going to ask you to stop making
19 speaking objections and coaching the witness.

20 BY MR. ANWAR:

21 Q. Doctor, it's a yes-or-no question. The
22 question is --

23 A. Well, no, it's not because you're
24 asking me about what the epidemiologists did. And
25 what I can tell you is I'm not an epidemiologist.

1 I don't know how they used the information, but I
2 do know that they asked us to address five
3 objectives. And one of the objectives was to
4 provide monthly mean concentrations in drinking
5 water that was delivered to residents, in this case
6 it would be Hadnot Point/Holcomb Boulevard, and
7 also express some range of confidence.

8 Q. And it was for the epidemiological
9 studies? That's what it says here.

10 MR. DEAN: Object to the form of the
11 question. The document speaks for itself.

12 THE WITNESS: That's what it says in --
13 in the report, but I would like to be clear that I
14 am not an epidemiologist, so how it's being used
15 from once we provided -- we provided -- all we
16 provided were the monthly mean concentrations.

17 BY MR. ANWAR:

18 Q. You're not an epidemiologist, but you
19 felt comfortable serving as a primary author in
20 this report that says that, right?

21 A. I felt confident because these were
22 water modeling reports and water modeling analyses,
23 yes.

24 Q. Okay. Let's go to page A182.

25 A. Okay. Okay.

1 Q. And this is Appendix A-9, another Q and
2 A section --

3 A. Yes.

4 Q. -- for the Hadnot Point and Holcomb
5 Boulevard report, correct?

6 A. That is correct.

7 Q. And per the modeling results -- in
8 terms of the modeling results, "what does this mean
9 in terms of my family's health." It again states,
10 "ATSDR's exposure estimates cannot be used alone to
11 determine whether you or your family suffered any
12 health effects as a result of past exposure to TCE
13 contaminated drinking water at U.S. Marine Corps
14 Base Camp Lejeune." Did I read that correctly?

15 A. Yes, you did.

16 Q. You have both Chapter As in front of
17 you?

18 A. Yes.

19 Q. And for the Tarawa Terrace Chapter A
20 and the Hadnot Point/Holcomb Boulevard Chapter A --

21 A. Excuse me, the mike fell off.

22 Q. Oh, no problem.

23 A. Okay. Am I okay? Okay. Sorry.

24 Q. No, it's okay. In either of the two
25 Chapter A reports for the Tarawa Terrace analysis

1 or the Hadnot Point/Holcomb Boulevard analysis, can
2 you point me to any statement in, I guess, Chapter
3 A or any of the reports that the models were
4 intended to be used for exposure determinations in
5 specific individuals?

6 MR. DEAN: Object to the form of the
7 question.

8 THE WITNESS: The purpose of these
9 reports were to document model analyses, data,
10 calibrations, to provide epidemiologists with mean
11 monthly concentrations. How they intended to use
12 it, their epidemiological studies, or how anyone
13 else intended to use it is -- does not disqualify
14 the model and is not a model limitation. The text
15 that you have read both in Chapter -- Appendices
16 Chapter A and that, that is a statement of agency
17 policy because ATSDR's a public health agency and
18 they do not conduct, to my knowledge, at least when
19 I was there, individual analyses.

20 BY MR. ANWAR:

21 Q. And so --

22 A. Right? So that's a statement that --
23 but what people can do, what anyone else wants to
24 do with -- with these models -- we had the same
25 situation when we did Dover Township. In fact, we

1 had consultants call ATSDR and wanted to know,
2 well, can you estimate for us what our exposure was
3 at, you know, 123 Main Street -- I'm making that
4 up.

5 Q. So I think -- go ahead.

6 MR. DEAN: Let him finish his answer.

7 BY MR. ANWAR:

8 Q. I think the --

9 A. The answer -- so -- and the answer was
10 from an agency policy standpoint, no.

11 Q. No, none of the reports say that the
12 models were intended or should be used to determine
13 exposure to contaminated water in specific
14 individuals, correct?

15 MR. DEAN: Object to the form of the
16 question. Can we go off the record and have you
17 step out of the room, please, sir.

18 THE WITNESS: Sure.

19 MR. DEAN: Thank you.

20 THE VIDEOGRAPHER: Okay. Going off
21 record. The time is 12:14 p.m.

22 (Off the record.)

23 THE VIDEOGRAPHER: We're going back on
24 record. The time is 12:16 p.m.

25 BY MR. ANWAR:

1 Q. We are back on the record, Mr. Maslia.
2 In order to expedite things a little bit, I'm going
3 to ask you this question. It's going to be similar
4 to at least the prior question, but it is a
5 different question, for the record.

6 In any of the ATSDR modeling reports
7 for Tarawa Terrace, Hadnot Point or Holcomb
8 Boulevard, any of the expert panel summaries that
9 you put together, any of the transcripts from the
10 expert panels, 2005 and 2009, can you point me to a
11 single statement from any of those experts at the
12 time or in any of your reports, the numerous
13 voluminous reports, stating that the results of the
14 models are sufficiently reliable and accurate to be
15 used for exposure determinations in specific
16 individuals?

17 MR. DEAN: Object to the form of the
18 question.

19 THE WITNESS: We express in numerous
20 places that they are reliable, acceptable. Again,
21 we were not asked or -- nor were we ever asked to
22 apply them to individuals.

23 BY MR. ANWAR:

24 Q. Okay. Let's -- I'm going to show you
25 another exhibit.

1 (DFT. EXHIBIT 11, Appendix 15
2 Bates-stamped CLJA_Healtheffects-0000061127 through
3 0000061136, was marked for identification.)

4 THE WITNESS: Okay.

5 BY MR. ANWAR:

6 Q. I'm going to represent to you -- do you
7 recognize this document -- I've handed you what
8 I've marked as Exhibit 11 -- Mr. Maslia?

9 A. It says Appendix I-5. Let me just find
10 -- well, that's not it. Chapter I. Oh, okay.
11 Okay. Yes, that's the sensitivity -- that's the
12 Tarawa Terrace Chapter I report.

13 Q. Okay. This is an appendix to the
14 Tarawa Terrace Chapter I report, correct?

15 A. Yes.

16 Q. Okay. And there at the -- the second
17 paragraph in the appendix is a disclaimer, right?

18 A. I don't recall putting that there, but
19 -- can I look at my full chapter on it?

20 Q. Sure.

21 A. It's not on my Chapter I.

22 Q. Yeah. And that's one of my questions
23 to you. It's on ATSDR's website currently and it's
24 been produced in the litigation. It is attached as
25 part of a table to Chapter I, but not directly

1 included in the reports. And on the table we
2 discussed earlier, you're the primary author of
3 Chapter I, correct?

4 A. Yes.

5 Q. Okay.

6 MR. DEAN: Let me object to the form of
7 the question because I think the witness just said
8 it was not attached to his -- or you may have said,
9 I misunderstood, that this document Appendix I-15
10 is not a part of the report that was released, but
11 is now on the website; is that what you said?

12 MR. ANWAR: It's available on the
13 website.

14 THE WITNESS: I don't know anything
15 about that. When I left ATSDR, the only things on
16 the website were the published reports in 2017. So
17 no, I have never seen that disclaimer.

18 BY MR. ANWAR:

19 Q. Right. Let's -- let's read through the
20 disclaimer together.

21 A. Okay.

22 Q. It starts "the water modeling analysis
23 results presented herein are provided as a service
24 to the public for informational purposes. All
25 analyses and computer simulation results have been

1 reviewed for accuracy and completeness based on
2 available information and current modeling
3 assumptions."

4 A. It says "all data, analyses, and
5 computer-simulations."

6 Q. Okay. "All data, analyses and
7 computer-simulation results have been reviewed for
8 accuracy and completeness based on available
9 information and current modeling assumptions." Did
10 I read that correctly?

11 A. Yes.

12 Q. Then it goes on to say "the results,
13 however, may not reflect the actual exposure of
14 specific individuals to contaminants in the water
15 system." Did I read that correctly?

16 A. Yes.

17 Q. "In addition, more updated information,
18 if and when obtained, may change interpretations
19 presented herein. For details pertaining to
20 assumptions and limitations, the public should
21 refer to the aforementioned reference list above."
22 Did I read all of that correctly?

23 A. Yes.

24 Q. I most wanted -- most importantly I
25 wanted to focus on -- it states, "the results,

1 however, may not reflect the actual exposure of
2 specific individuals to contaminants in the water
3 system." Did I read that correctly?

4 MR. DEAN: Well, you can answer that.
5 I don't have an objection to that question.

6 THE WITNESS: Okay. Yes, you read that
7 correctly.

8 BY MR. ANWAR:

9 Q. And is it your testimony that you've
10 never seen this before?

11 A. No, it is my testimony I have never
12 seen this before.

13 Q. Were you involved in any way in
14 drafting it?

15 A. Not that I recall.

16 MR. DEAN: Object to the form of the
17 question. He just told you he didn't know anything
18 about it.

19 THE WITNESS: I don't know when it went
20 on the website. The last time I checked, which was
21 not recently, maybe two years ago or whatever, I
22 don't recall seeing it.

23 BY MR. ANWAR:

24 Q. Do you know why this disclaimer is
25 included as part of an appendix in Chapter I and

1 not in Chapter A?

2 MR. DEAN: Object to the form of the
3 question. Asked and answered.

4 THE WITNESS: It's not in -- in the
5 published report, okay? It's -- so I don't know
6 why or who put the disclaimer there or when it went
7 on there. As I said, to my best knowledge, when I
8 left in -- or retired in December of 2017, the only
9 thing on the website were these complete reports.
10 And I would not -- I don't understand why they
11 would pull just this out and put it like that on
12 the website. That may -- again, somebody at ATSDR
13 must have made a decision, but I was not involved
14 in that, nor was this ever -- the reference
15 citation is correct, but the disclaimer I've never
16 seen.

17 BY MR. ANWAR:

18 Q. Okay.

19 MR. BELL: At a good stop -- good point
20 for a break or not?

21 MR. ANWAR: I have a little bit more
22 questioning and then we can take a lunch break.

23 MR. BELL: Yeah, the chef out there
24 won't ring the bell for the employees until we go
25 get our food because y'all are the guests of the

1 day. I'll leave it up to you.

2 MR. DEAN: Well, give him five more
3 minutes if that's okay.

4 MR. BELL: No problem.

5 (DFT. EXHIBIT 12, Analyses of
6 Groundwater Flow, Contaminant Fate and Transport,
7 and Distribution of Drinking Water at Tarawa
8 Terrace and Vicinity, U.S. Marine Corps Base Camp
9 Lejeune, North Carolina: Historical Reconstruction
10 and Present-Day Conditions Disclaimer Bates-stamped
11 CLJA_Watermodeling_01-0000938451, was marked for
12 identification.)

13 BY MR. ANWAR:

14 Q. Okay. I am handing you what I'm
15 marking as Exhibit 12.

16 A. Okay.

17 Q. Exhibit 12 is a redline of the
18 disclaimer that we just looked at.

19 A. Okay.

20 Q. Would you agree with that?

21 MR. DEAN: Object to the form of the
22 question.

23 THE WITNESS: It looks like a big
24 difference to me, redlined.

25 BY MR. ANWAR:

1 Q. It's been redlined, correct?

2 A. Well, I know. I'm -- it's...

3 Q. And so this is a redlined version
4 reflecting changes that were made to, I guess, the
5 original disclaimer -- well, let me -- let me reask
6 that question.

7 This is -- so the redlined language in
8 here is what made it into the final disclaimer that
9 we just looked at in Exhibit 11, correct?

10 MR. DEAN: Object to the form of the
11 question.

12 THE WITNESS: No, that's the wrong
13 sign. There's differences here. For example --
14 I'll just give a quick -- it says "the documents,
15 graphs, and water modeling analyses." It says the
16 water modeling analyses.

17 BY MR. ANWAR:

18 Q. I've got you. Okay.

19 A. Okay.

20 Q. Have you seen this before?

21 A. I don't recall seeing it.

22 Q. Okay. I will represent to you that the
23 meta analysis indicates that ATSDR is a custodian
24 and you're the author.

25 A. Okay.

1 Q. And it's dated May 23rd, 2007. Do you
2 recall this document?

3 MR. DEAN: I -- object to the form of
4 the question, not that we don't accept your
5 representation, and asked and answered.

6 THE WITNESS: This seems to me to be
7 two different documents because this, the one that
8 you handed me, Exhibit 11, okay, the appendix stuff
9 is from the Chapter I, not -- not the cover, not
10 the cover page. The reference is correct, but not
11 that. If you're saying -- and Chapter I probably
12 came out in 2009. I can take a look at the date.
13 February 2009. Okay.

14 BY MR. ANWAR:

15 Q. Do you remember --

16 A. The fact that it may have been in under
17 my ATSDR land or wherever you obtained it from, I
18 don't know how -- how these documents are obtained
19 by DOJ. It could have been sent as an e-mail
20 attachment or Office of Communication or even an
21 epidemiologist, Office of the Director, anybody
22 saying this is what we want to use, but, whatever,
23 I -- you know, honestly do not remember these
24 disclaimers.

25 Q. Okay. It is attached to an e-mail and

1 I will pull that e-mail during the break. We can
2 talk through that e-mail.

3 A. Okay.

4 Q. The one that you're -- you're included
5 on.

6 A. Thank you.

7 MR. ANWAR: Let's take a break for
8 lunch and --

9 MR. DEAN: 45?

10 MR. ANWAR: That's fine.

11 THE VIDEOGRAPHER: Okay. We're going
12 off record. The time is 12:29 p.m.

13 (A luncheon recess transpired.)

14 THE VIDEOGRAPHER: We're going back on
15 record. The time is 1:24 p.m.

16 BY MR. ANWAR:

17 Q. Good afternoon, Mr. Maslia. We are
18 back on the record from a lunch break. Are you
19 okay to continue?

20 A. Yes, I am.

21 Q. Okay. Did you speak with your -- with
22 the counsel about your testimony during the break?

23 A. No, I did not.

24 Q. Okay. Thank you. Before we went on
25 the lunch break, we were discussing what I had

1 marked as Exhibit 12, which is a redlined version
2 of Exhibit 11, Exhibit 11 being a disclaimer and
3 Exhibit 12 being the redline of that disclaimer.

4 A. Okay.

5 Q. I'm going to show you another document
6 that I'm marking as Exhibit 13.

7 (DFT. EXHIBIT 13, e-mail correspondence
8 Bates-stamped CLJA_ATSDR_BOVE-0000157167 through
9 0000157170, was marked for identification.)

10 BY MR. ANWAR:

11 Q. I will represent to you Exhibit 13 is
12 an e-mail exchange from 2007 with you and Deb Tress
13 from ATSDR and Frank Bove from ATSDR. And the
14 e-mail includes an attachment with -- which is a
15 redline of the disclaimer that we were discussing
16 before the break. Take -- take a minute to look at
17 it, but would you agree with that?

18 A. Agree that this is an e-mail about
19 this -- yes.

20 Q. Okay. And so if we start at the
21 beginning of the chain, it looks like you sent an
22 e-mail on May 23rd, 2007 to Deborah Tress and the
23 subject is disclaimer for website. And in it you
24 write, "Deborah, I need a disclaimer that will come
25 up when a person enters the Camp Lejeune water

1 modeling website. Here's my attempt. Can you
2 please review and provide correct legal verbiage?
3 Thanks, Morris." Did I read that correctly?

4 A. Yes, yes.

5 Q. What -- what water modeling website are
6 you referring to?

7 A. Thinking back to 2007, 15 years ago or
8 whatever, I'm looking at the date. It's May 23rd.
9 The -- neither the executive summary or the Chapter
10 A report had come out yet because they were
11 June 2007, is when they came out. And the only
12 thing I can think of is someone above me, my
13 supervisor or the division, were thinking that just
14 like with other ATSDR documents, they wanted to put
15 results on the website, but they wanted a
16 disclaimer, an agency policy-type -- type
17 disclaimer. That's the only thing I can, I mean,
18 recall this many years back, okay?

19 Q. Okay. And I think this came up in your
20 2010 deposition. I realize that's now 15 years
21 ago.

22 A. Okay.

23 Q. But at one point, did the ATSDR website
24 contain a page or have a page that allowed an
25 individual to go in and enter sort of when they

1 were at Camp Lejeune and it produced numbers from
2 the model?

3 A. Yes.

4 Q. Okay. Can you tell me about that?

5 A. Well, as part of our Tarawa Terrace
6 analyses -- at that time it was just Tarawa
7 Terrace. And, of course, ATSDR is focused on
8 providing information to the public on their
9 health, so we requested -- we were working with the
10 U.S. Geological Survey. They had some web
11 developer guys, so we requested an app that someone
12 who resided at Lejeune or someone who didn't reside
13 at Lejeune could put in dates, dates of service,
14 and get an estimate, a quantitative estimate of
15 exposure -- when I say exposures, concentrations of
16 PCE.

17 Q. Okay.

18 A. Okay. And so the web application did
19 go on the website. I'm trying to figure out how --
20 I think you showed me -- it was with this table,
21 because that was Chapter I. That was the last
22 chapter being -- I'm not saying we didn't have the
23 numbers, but anyway, and at some point after it
24 went on the website, I know I got a call and I'm
25 sure my supervisor or the agency got a call from

1 the Department of Navy that they were not pleased
2 with it at all.

3 Q. The website itself?

4 A. You have to pull it down, yes.

5 Q. Okay.

6 A. Pull the application down off your
7 website.

8 Q. What do you recall about the
9 conversation -- about the call with the Department
10 of the Navy?

11 A. Only that it gave quantitative
12 estimates of mean concentrations, and my point --
13 it's the team's point -- was that it's contained in
14 the report and it was just an easier way to present
15 if someone didn't want to read the entire report to
16 do it, and that's all I remember, is that there was
17 some conversations with the Department of Navy.
18 And then our web guys said there was something
19 about security or whatever and the web -- that
20 application never got put back on -- on the web.
21 So my assumption is the agency just wanted to go
22 with tabular values right out of the reports.

23 Q. Okay. We'll get back to the website.

24 A. Okay.

25 Q. I wanted to focus on the e-mail

1 exchange and the -- the redline disclaimer --

2 A. Okay.

3 Q. -- that was attached. So it's -- based
4 on this first -- the first thread on the chain, it
5 sounds like you attempted to draft the disclaimer
6 and you sent it to Deborah Tress, correct?

7 MR. DEAN: Object to the form of the
8 question. Mischaracterizes the document.

9 THE WITNESS: I don't know. If I
10 recall, I was probably asked to produce the table,
11 okay, here because someone wanted it up on the
12 website, okay? And then someone probably said,
13 well, we need to have a disclaimer, okay? I don't
14 know who. I don't know who, but -- and so I
15 attempted to draft a disclaimer not being an
16 attorney, okay --

17 Q. Okay.

18 A. -- or agency policy person.

19 Q. Okay. And so the next exchange is an
20 e-mail from Deb Tress responding to you saying, "so
21 does the website help them estimate their own
22 exposure to the contaminated water?" Did I read
23 that correctly?

24 A. Yes.

25 Q. And then you respond to that further up

1 in the chain. You say, "yes, but they cannot
2 modify our numbers. It just provides results of
3 modeling based on the dates they enter to a website
4 and they can also download a graph and table as a
5 PDF." Did I read that correctly?

6 A. Yes, that's what I just said about
7 getting the tables from the report, okay?

8 Q. And now going further up on the chain
9 to the first page of the exhibit, Deb Tress's
10 response to you on May 23, 2007 says, "how about
11 this? I'm not totally clear how this is being
12 presented, so please edit as needed. I'm not that"
13 -- it says considered, but I think I might be
14 concerned "with liability by ATSDR for the use of
15 the tool, so I took out that type of language."

16 A. Okay.

17 Q. "Thanks". Did I read that correctly?

18 A. Yes.

19 Q. Okay. And then you forward that on to
20 Frank Bove, correct?

21 A. That is correct.

22 Q. And that's the first e-mail on the
23 page, the top of the chain. It says, "Frank,
24 attached is a disclaimer that will appear on the
25 water modeling website. It's been edited by Deb

1 Tress. Let me know if you agree to it and then I
2 will send to our web gurus." Did I read that
3 correctly?

4 A. That is correct.

5 Q. Okay. So earlier you indicated you --
6 you at least couldn't recall having seen this
7 disclaimer before?

8 A. That is correct, yes.

9 Q. But based on this e-mail -- this is
10 your e-mail address and you would have received the
11 disclaimer, correct?

12 A. Yes, yes.

13 Q. Okay.

14 A. That's -- I mean, as I said, it was a
15 lot of things going on around May 2007 with the
16 prep for the subcommittee hearing and trying to get
17 reports approved by the Office of Science and the
18 Office of Director and stuff and...

19 MR. DEAN: So for the record, so we
20 just clarify that Bates stamp numbers ends in one
21 -- Bove 167 and goes through 170. I haven't gone
22 to look, but I presume the document attached is
23 what you're saying is the document that is attached
24 that -- that he sent to Frank Bove?

25 MR. ANWAR: The last document on this

1 chain --

2 MR. DEAN: 170.

3 MR. ANWAR: -- 170 is the attachment to
4 that e-mail thread.

5 MR. DEAN: Okay. Thank you.

6 BY MR. ANWAR:

7 Q. You didn't recall it earlier, but you
8 would have received it and you were involved in the
9 drafting process, correct?

10 A. It's got my e-mail address on it and,
11 again, it looks like Office of General Counsel,
12 Deborah Tress, edited it, okay?

13 Q. Okay.

14 A. And probably -- and sent it back to me
15 and then I -- I didn't accept or reject the
16 redline. It's blue on here, but that's fine. I
17 just sent it on, as you can see by the title of the
18 attachment, is disclaimer underscore MLMOGC
19 reviewed.

20 Q. Okay.

21 A. Okay. So that's -- I forwarded it on
22 to Dr. Bove.

23 Q. Okay. And Exhibit 11, which we
24 discussed before the break, was the Chapter I,
25 Appendix I-5 document. Do you recall that?

1 A. It's the table from Appendix I-5.

2 Q. Yes.

3 A. Again, the final version of the report
4 -- the numbers are the same, but the final version
5 of the complete report was not published until
6 February of 2009, so this must have been -- I
7 can -- I can only surmise that once this was
8 published in 2009, they went back and replaced the
9 original tables. Same numbers, but original
10 tables, okay? We had completed the Monte Carlo
11 simulation, but we had not had the Chapter I report
12 approved, okay? So it's, you know, I guess I'm
13 confused as to -- because the e-mail is dated 2007.

14 Q. Yeah.

15 A. The report is not -- typically we would
16 get a report approved and then if we wanted to pull
17 a table or a PDF or a figure or whatever from it,
18 we would do it that way. So it's the same table.
19 I've checked the numbers, or spot-checked the
20 numbers, and it's the same -- same table. So maybe
21 it was -- the report wasn't drafted when we went
22 ahead and put that, you know, forwarded that to
23 Dr. Bove.

24 Q. Do you have any idea why the disclaimer
25 didn't make it into Chapter I itself, the full

1 report?

2 A. No, that's -- that's a mystery to me.
3 I will say to give credit to ATSDR leadership and
4 management, they did believe in the peer review and
5 expert review panels that we put together, and
6 every report went through at least two peer
7 reviews, one internal and one external, and so I
8 think that's why none of the reports really -- with
9 the -- we'll get to Hadnot Point in a minute, but
10 none of the reports contained any disclaimers like
11 -- like you're showing here. So I don't know what
12 prompted the disclaimer, but...

13 Q. Well, I will -- I will represent to you
14 that -- and you're, obviously, welcome to go look
15 for it yourself. The Appendix I disclaimer is
16 still included on the website as part --

17 A. On the website.

18 Q. -- of the table -- as part of a table
19 document. In the disclaimer where it says "the
20 results, however, may not reflect the actual
21 exposure of specific individuals to contaminants in
22 the water system" --

23 A. Are you referring to the redline or
24 blue line -- I mean, blue line or redline?

25 Q. On Exhibit 11.

1 A. Okay. I'm sorry. Okay. Okay. Go
2 ahead.

3 Q. The final version that's on the website
4 now.

5 A. Okay.

6 Q. In the middle of the disclaimer, it
7 says, "the results, however, may not reflect the
8 actual exposure of specific individuals to
9 contaminants in the water system." Do you agree
10 with that statement?

11 MR. DEAN: Object to the form of the
12 question.

13 THE WITNESS: I would say it has to say
14 that because what we're presenting is a Monte Carlo
15 simulation result, so you've got the calibrated
16 value, the probability at 2.5 percent, the
17 probability at 50 percent, and the probability at
18 97.5 percent. So your exposure may be someplace in
19 the middle there in between those ranges. So from
20 that standpoint, that's a correct statement
21 because, you know, a person's individual exposure
22 could be within that range anywhere.

23 Q. Okay.

24 A. And can I just qualify something?

25 Q. Go ahead.

1 A. When I use the words from my standpoint
2 of exposure, I'm talking about the estimated value
3 of the contaminated drinking water. I'm not
4 referring to exposure like ingestion, inhalation,
5 thermal exposure, okay? I'm just -- so I'm using
6 the word exposure in that sense.

7 Q. You're using exposure in -- in the
8 sense of drinking water?

9 A. Drinking water. Drinking water. But
10 the definition of exposure -- exposure assessment
11 is you have to really look at which pathway or
12 multiple pathways, okay, someone may -- may have
13 been or may be exposed.

14 Q. Understood. Let's turn back to your
15 rebuttal report, which is Exhibit 6.

16 A. This is 5.

17 Q. I know, a lot of documents.

18 A. Four. I've got a copy here, if that's
19 okay.

20 MR. DEAN: Yeah.

21 THE WITNESS: The tabs are just
22 typographical edits. Not technical, typographical.

23 BY MR. ANWAR:

24 Q. That's your version of --

25 A. Yeah, that's my version of my response

1 report.

2 Q. Okay. Your rebuttal report?

3 A. Yes.

4 Q. Which is -- I've marked as Exhibit 6.

5 A. Yeah, it's here someplace.

6 Q. Do you have any, like, markings or
7 writing in that?

8 A. I only corrected -- due to the
9 Maslia-genetic OCD, you know, like, I referenced
10 date is incorrect, but nothing technical. No
11 technical changes or technical reinterpretations on
12 here.

13 Q. Okay. Just like a typo?

14 A. Yes, yes, yes.

15 Q. Okay. Let's -- let's turn to page 27.

16 A. Okay. Okay.

17 Q. Page 27, at the bottom of it, contains
18 a section in your rebuttal report, Section 4.3,
19 excuse me, volatilization of VOCs during water
20 treatment process, correct?

21 A. Yes.

22 Q. And this is a response to the opinions
23 of DOJ's expert Remy Hennet about VOC losses that
24 would have occurred during the water treatment and
25 distribution process at Tarawa Terrace and Hadnot

1 Point, correct?

2 A. It would have occurred only during the
3 water treatment process. It's not possible for it
4 to occur during the distribution because you're
5 dealing with closed pressurized pipes.

6 Q. Okay. You would agree during the water
7 treatment process, correct?

8 A. Well, that's -- yeah, that's -- yes.

9 Q. So I don't want to necessarily read
10 this line by line.

11 A. Okay.

12 Q. Unless you want to direct me to a
13 specific portion, but I'll start more generally.

14 A. Okay.

15 Q. For much of this it appears that you
16 are restating Dr. David Sabatini's opinion on how
17 VOC losses are calculated and the extent of the VOC
18 losses that would have occurred; is that right?

19 A. That is correct.

20 Q. Okay. And do you defer to Mr. --
21 Dr. Sabatini on those opinions?

22 A. Yes, the calculations that he did, the
23 interpretations that he did, I defer to him.
24 That's his area of expertise.

25 Q. Okay. You're not doing any independent

1 calculations on VOC losses, correct?

2 A. No, I'm not.

3 Q. And you're not doing any independent
4 interpretation of those calculations of VOC losses,
5 correct?

6 A. I'm doing comparisons.

7 Q. You're comparing Dr. Hennet's opinion
8 with Dr. Sabatini's opinion, correct?

9 A. And -- and the Marine Corps'
10 consultant, AH Environmental.

11 Q. Okay.

12 A. And our experts who served on the
13 expert panels.

14 Q. Determining VOC losses or calculating
15 them, that's not your expertise, correct?

16 A. That is correct.

17 Q. Okay. So turning to page 30 in your
18 report.

19 A. Okay.

20 Q. Actually, it might be 29. Sorry about
21 that.

22 A. Okay.

23 Q. Okay. I misspoke again. I'm sorry.
24 It's page 31.

25 A. 31?

1 Q. Yeah.

2 A. Okay. I'm there.

3 Q. Okay. So in the -- in the second
4 paragraph there, the first large paragraph, you go
5 on to discuss -- it says, "additionally, in
6 contrast to Remy Hennet's contention that ATSDR
7 ignored or did not account for VOC losses during
8 storage treatment and distribution"...

9 A. I'm there. I'm following.

10 Q. "This issue, including the results of
11 the AH Environmental Consultants report, was
12 discussed in detail with the expert panels convened
13 by ATSDR in 2005 and 2009." Did I read that
14 correctly?

15 A. Yes, yes, you did.

16 Q. Okay. And a little further down it
17 says, "excerpts from the verbatim transcript are
18 provided in Appendix A", and you're talking about
19 the expert panel. "The consensus was there was
20 negligible volatilization, at most 10 percent, from
21 the spiractors." And -- so -- and then you quote,
22 "so although we said it's probably negligible and I
23 agree with Tom's number here, at 90 percent what's
24 going in is coming out on the other end." Did I
25 read that correctly?

1 A. Yes, and then it references Appendix A
2 at the end of the sentence.

3 Q. Correct.

4 A. Okay. To be clear, that's not my
5 quotation.

6 Q. Correct. That's from the expert panel,
7 correct?

8 A. Yes.

9 Q. And that's Dr. Pommerenk?

10 A. Yes.

11 Q. Okay. And the last sentence there is,
12 "in light of the conclusions of AH Environmental
13 Consultants, 2004, and the recommendations of its
14 expert panels, ATSDR made the decision to consider
15 any potential VOC losses from storage, treatment
16 and distribution as negligible." Did I read that
17 correctly?

18 A. Yes.

19 Q. And I believe you reference in it in
20 your report, but I'll pull out the actual document
21 as well.

22 A. In which report? The expert report?

23 Q. It's in your expert report, but let me
24 -- I'm going to pull out the -- the AHE report for
25 you. Hang on a second.

1 (DFT. EXHIBIT 14, ATSDR Support
2 Estimation of VOC Removal report from AH
3 Environmental Consultants Inc., Bates-stamped
4 CLJA_Watermodeling_010000071446 through 0000071512,
5 was marked for identification.)

6 BY MR. ANWAR:

7 Q. I'm handing you what I'm marking as
8 Exhibit 14. Exhibit 14 is the 2004 environmental
9 -- or AH Environmental Consultants report, correct?

10 A. That is correct.

11 Q. It's the one that you reference in your
12 rebuttal report, correct?

13 A. Yes.

14 Q. If you turn to page 4-4.

15 A. Which page? Oh, report page four?

16 Q. Report page 4-4. Thank you.

17 A. Okay.

18 Q. At the top of the page there it states,
19 "based on these observations, there is some
20 uncertainty in removal estimates from the effluent
21 pipes. Additional uncertainties are introduced by
22 varying head losses in the pipes caused by calcium
23 carbonate scale built-up and manual clearing --
24 cleaning. However, it is estimated that PCE and
25 TCE removals due to aeration at the spiractor

1 effluent pipes are likely to be no larger than
2 15 percent." Did I -- Did I read that correctly?

3 A. Yes, yes.

4 Q. So AHE's report determined up to or no
5 larger than 15 percent, correct?

6 MR. DEAN: Object to the form of the
7 question.

8 BY MR. ANWAR:

9 Q. And let me -- let me repeat the
10 question. This AHE report determined that PCE and
11 TCE losses or VOC loss due to aeration at the
12 spiractor effluent pipes are likely to be no larger
13 than -- no, to be -- than 15 percent?

14 A. That's what it states.

15 Q. Okay.

16 A. That's what the report states.

17 Q. And looking back at page 31 of your
18 rebuttal report, that last -- that paragraph we
19 were just looking at, the last sentence is, "so in
20 light of the conclusions of the AHE consultants,
21 2004, and the recommendations of the expert panels,
22 ATSDR made the decision to consider any potential
23 VOC losses from storage, treatment, and
24 distribution as negligible." Did I read that
25 correctly?

1 A. Yes.

2 Q. Whether it's 10 percent VOC losses or
3 up to 15 percent VOC losses, is it your opinion
4 that 10 or 15 percent is negligible -- a negligible
5 percent of losses?

6 A. Yes, compared with the differences, for
7 example, in water sampling or the quality sampling,
8 the uncertainties associated with well scheduling
9 operations. And you've got to look at, you know,
10 everything, not just isolate on -- on the water
11 treatment plant, but considering everything 10
12 percent -- percent, we assumed and we were, I
13 believe, justified in assuming it was negligible,
14 okay? That is an -- the approach we took was a
15 pragmatic engineering approximation through a
16 modeling issue.

17 Q. For purposes of determining exposure in
18 an individual, is a 10 or 15 percent VOC loss --
19 would you consider that to be negligible?

20 A. You would have to speak with the
21 epidemiologist or toxicologist, okay? I couldn't
22 say on an individual level, okay?

23 (DFT. EXHIBIT 15, Analyses of
24 Groundwater Flow, Contaminant Fate and Transport,
25 and Distribution of Drinking Water at Tarawa

1 Terrace and Vicinity, U.S. Marine Corps Base Camp
2 Lejeune, North Carolina: Historical Reconstruction
3 and Present-Day Conditions Response to the
4 Department of the Navy's Letter on: Assessment of
5 ATSDR Water Modeling for Tarawa Terrace,
6 Bates-stamped CLJA_Watermodeling_01_09_0000033263
7 through 0000033326, was marked for identification.)

8 BY MR. ANWAR:

9 Q. I'm handing you what I'm marking as
10 Exhibit 15.

11 A. Okay. Response. Okay.

12 Q. And I wanted to direct your attention
13 to page six, I believe, of the report.

14 A. Okay. The pages, I don't believe, are
15 numbered.

16 Q. I think they're on the top left. Well,
17 and let me --

18 A. Can you give me a Bates number because
19 this doesn't have a report page number.

20 Q. Before I begin, let me -- let me start
21 by asking you a few questions.

22 A. Sure.

23 Q. This is the ATSDR response to the
24 Department of Navy's letter or their critiques on
25 the Tarawa Terrace modeling, correct?

1 A. That's -- yes, this is --

2 Q. And it's entitled, on the first page
3 there, response to the Department of Navy -- to the
4 Department of the Navy's letter on quote -- colon,
5 assessment of ATSDR water modeling for Tarawa
6 Terrace, correct?

7 A. That's correct.

8 Q. Okay. Did you write this response?

9 A. Again, other reports, I wrote parts of
10 it and I coordinated other people's response. I
11 may have asked them for input and if they could
12 respond to a certain section or not, but I
13 coordinated the overall report.

14 Q. Okay. So in coordinating it, similar
15 to the other reports that you oversaw and
16 coordinated, would you have reviewed and had an
17 opportunity to review the -- to comment on the
18 report?

19 A. Yes.

20 Q. And ultimately, what was decided, would
21 you have had an opportunity to sign off on the
22 report?

23 A. It would have come from me in going up
24 through the clearance process, report clearance
25 process of the agency, okay? And so I would have

1 been the one that put it into the clearance process
2 at the first stage once I was satisfied with the
3 report.

4 Q. So you would have -- you would have
5 approved it and then pushed it up the chain,
6 correct?

7 A. Yes.

8 Q. Okay.

9 A. Well, technically a report is only
10 approved by either the Office of the Director or
11 the Office of Science at CDC, okay? An author
12 cannot approve an agency report. They can submit
13 it, they can comment on it and all of that, but
14 it's only those two, Office of Director and Office
15 of Science at CDC, when I was there.

16 Q. And perhaps "approve" is a bad term
17 because it may be a term of art --

18 A. Right.

19 Q. -- within an agency, but you would have
20 had an opportunity to review, comment and sign up
21 -- sign off on it and then send it up the chain to
22 be approved, correct?

23 A. Yes, that is correct.

24 Q. Okay. So on the page with the Bates
25 ending in 33272, if you could turn there.

1 A. Yeah, yeah. 272?

2 Q. Correct.

3 A. Okay. I'm there, 33272.

4 Q. Okay. And then the page before, 33271,
5 it's a Department of Navy comment statement 7.1 and
6 it's an excerpt from their letter. It says,
7 "however, all comparisons did not fall within the
8 calibration range. At the water treatment plant,
9 12 percent of the simulated PCE concentrations
10 failed the calibration standard at the water supply
11 wells, a majority, 53 percent, of the simulated
12 concentrations fell outside the calibration
13 standard."

14 A. Correct.

15 Q. Did I read that correctly?

16 A. Yes.

17 Q. Okay. And so then ATSDR responds. And
18 if you turn the page, as part of the response on
19 the last page there it states, "to address the
20 issue of the intended use of the water modeling
21 results by the current ATSDR epidemiological study,
22 the DON, Department of Navy, should be advised that
23 a successful epidemiological study places little
24 emphasis on the actual or absolute estimate of
25 concentration and, rather, emphasizes the relative

1 level of exposure. That is, exposed individuals
2 are, in effect, ranked by exposure level and
3 maintain their rank order of exposure level
4 regardless of how far off the estimated
5 concentration is to the, quote, true measured PCE
6 concentration." Did I read that correctly?

7 A. Yes.

8 Q. Were you involved in -- did you -- did
9 you write that section?

10 A. No, I did not.

11 Q. Okay. But you reviewed it and you
12 signed off on the response before you sent it off
13 to the appropriate --

14 A. I did not. It seems to me, looking at
15 the language or the verbiage in that last
16 paragraph, that that was written by an
17 epidemiologist, and what I would have done as we
18 were preparing this report -- as I said, we had a
19 team. I may have forwarded it to the
20 epidemiologists of the study and asked them
21 specifically would they review it and care to add
22 anything to it.

23 Q. But you oversaw the response and you
24 reviewed it?

25 A. Yes.

1 Q. And you signed off and sent it up the
2 chain to be approved, correct?

3 A. That is -- that is correct.

4 Q. Okay. And so as I understand it, as
5 I'm reading this, it's -- and this is coming as
6 part of a response to a concern, so maybe you wrote
7 about -- raised about the accuracy of the model
8 based on the calibration. As far as -- it sounds
9 like for purposes of the epidemiological study that
10 was being conducted in which the modeling was
11 supporting, the absolute concentration values
12 produced by the model didn't matter; would you
13 agree with that?

14 MR. DEAN: Object to the form.

15 THE WITNESS: Well, it doesn't say
16 didn't matter. It says little emphasis is placed
17 on it.

18 BY MR. ANWAR:

19 Q. Okay.

20 A. And again, it's from -- I would
21 interpret this, because I know I did not write this
22 section, that that's -- you really need to ask an
23 epidemiologist on the epidemiological
24 interpretation of that.

25 Q. What it says is that that is

1 successful -- that the -- the intended use of the
2 water modeling results by the current
3 epidemiological study places little emphasis on the
4 actual absolute estimate of concentration and
5 rather emphasizes the relative level of exposure,
6 right?

7 A. That's what it says.

8 Q. All right. And then it says, "that is,
9 exposed individuals, in effect -- are, in effect,
10 ranked by exposure level and maintain their rank
11 order of exposure level regardless of how far off
12 the estimated concentration is to the true measured
13 PCE concentration", correct?

14 A. That's what that -- that sentence that
15 you just read says.

16 Q. Okay. So if in that context for the --
17 of the water modeling and what was happening at the
18 time, when you-all were -- so let's turn back to
19 the discussion in your rebuttal report about the
20 VOC losses --

21 A. Okay.

22 Q. -- and ATSDR's characterization of 10
23 or 15 percent of VOC losses as negligible. If
24 ATSDR was performing an epidemiological study that
25 was ranking exposure level and maintaining the rank

1 order of individuals, does it matter -- it doesn't
2 matter whether the VOC losses are 10 percent,
3 15 percent, 25 percent, does it?

4 A. It's an epidemiology question or
5 toxicology or a combination of both, okay? Again,
6 in the response, again, I can tell that's not the
7 way I write. It was written by an epidemiologist
8 in there and I just -- I'm not comfortable
9 answering an interpretation from one or the other,
10 okay?

11 Q. The point I'm getting at is that
12 whatever the concentration level, you know, we're
13 talking about is produced by the model, let's say
14 100, across the board for individuals, the same
15 amount is coming off the top for the VOC losses, so
16 10 percent, 15 percent, it doesn't change the rank
17 of the order -- the rank of individuals for
18 purposes of the epi study, right?

19 MR. DEAN: Object to the form of the
20 question.

21 THE WITNESS: Again, that's an
22 epidemiological analysis. I've never done one of
23 those. I've never ranked, okay, so I don't know
24 what assumptions they are using to put into there.
25 I know they are using the mean monthly

1 concentrations that we reconstructed, but that's as
2 far as I can go.

3 BY MR. ANWAR:

4 Q. ATSDR made the decision -- treated VOC
5 losses as negligible because the water modeling was
6 supporting an epi study, right?

7 A. No.

8 MR. DEAN: Object to the form of the
9 question.

10 THE WITNESS: One has nothing to do
11 with the other. I think we're comparing apples and
12 oranges here. The VOC potential volatilization was
13 geared towards our water modeling and taking the
14 results of the simple mixing model and then putting
15 it through the water treatment process. We did not
16 model the water treatment process and, you know,
17 distributing the -- the water to wherever,
18 locations within Camp -- Camp Lejeune.

19 If -- back up. Based on -- again, I'm
20 referring to the AH report, our experts. We had
21 one of our distribution system experts, and it was
22 our conclusion that 10 percent, 15 percent, was
23 well within engineering applications. That is
24 typically done in -- in engineering applications.
25 You go from theory -- from contaminant fate and

1 transport equation, groundwater flow, and then you
2 have to make some assumptions, okay, some
3 simplifying assumptions or pragmatic --

4 SIRI: I'm sorry. I didn't quite catch
5 that. Can you please say that again?

6 BY MR. ANWAR:

7 Q. Siri wants you to repeat it.

8 A. Okay. I didn't know someone was
9 listening, but -- and so that -- that's what our
10 focus is. Our focus was never on how the
11 epidemiology were going to interpret or use the
12 results other than that the most likely estimates
13 were mean monthly concentrations.

14 Q. When you're building a model and you're
15 -- you're starting with the conceptual model, isn't
16 part of the -- developing the conceptual model
17 understanding what the purpose and the model will
18 be used for?

19 A. No, the purpose is to get -- in terms
20 of, if we can get specific, a groundwater flow
21 model, for example, your conceptual model would be
22 how does water move through the different aquifers
23 or different layers. And contaminant transport, if
24 there's a contaminant source or sources, how do
25 those contaminants then mix or move with

1 groundwater, and then how are they mixed with the
2 different wells that may or may not intercept
3 contaminated water, and then how they're
4 distributed, okay?

5 And so your groundwater flow has
6 specific equations with some parameters that you
7 have to make assumptions on. The contaminant fate
8 and transport has equations that we have to make
9 some engineering approximations or simplifications,
10 and the treatment process we -- we said after
11 looking also at the data, the data, the sampling
12 data that was provided by whoever did the lab
13 analyses that came -- provided to us by our points
14 of contact at Camp Lejeune, but somebody did the
15 analyses, that there was very little negligible
16 indication of any kind of VOC loss from the
17 untreated, where all the raw water went in, to the
18 treated. And that's -- I put that in -- is this
19 the rebuttal report? I put that in the rebuttal
20 report. We had some sampling data that showed
21 that.

22 Q. I guess one of the things I -- and this
23 is just me, like, leveling --

24 A. Right.

25 Q. -- and not, you know, taking off the

1 lawyer hat. One of the things I sort of struggle
2 with is this idea that when the modeling was being
3 performed, that the purpose for which the model was
4 being used is somehow divorced from the decisions
5 that were made with respect to building the actual
6 model. And I'm saying candidly, like, reading the
7 e-mails, the documents --

8 A. Right.

9 Q. -- it's all over the paperwork and the
10 documents at the time that the modeling was built
11 to support the epi study. And I think -- it sounds
12 like, to me, you're saying that when you're
13 building the model, you just had no idea what they
14 were doing with the -- the model results.

15 MR. DEAN: Object to the form of the
16 question. You can answer.

17 THE WITNESS: As I said before, if you
18 look at the start of the project, the start, they
19 asked us -- they saw what we did with Toms River,
20 New Jersey and came to us and said, well, can you
21 do the same thing with Camp Lejeune, meaning
22 monthly concentrations or monthly -- yeah, monthly
23 water concentrations. And so that's where we
24 started and there were, again, the five objectives
25 that I've stated previously, and that's how we

1 designed the model, is to be able to reconstruct
2 concentrations to meet those five objectives and
3 to, you know, express some reliability, uncertainty
4 associated with them.

5 How the epidemiology side or toxicology
6 side of -- of the agency would then take those and
7 what analyses they would do, as I said, we were
8 blinded to that, okay? I could never tell you --
9 to this day, I do not know who was classified as a
10 case, who was a controlled, where they lived, what
11 -- how they served, when they served or anything
12 like that. Because in developing these -- the
13 models for historical reconstruction, they should
14 be, as I termed it, robust, meaning anyone, not
15 just the epidemiologists, anyone should be able to
16 take the results of your model and apply them as
17 they see fit given the uncertainties, the
18 limitations of modeling.

19 BY MR. ANWAR:

20 Q. Frank Bove was the epidemiologist
21 performing the studies, correct?

22 A. He was the senior epidemiologist.
23 There was also -- now it's Dr. Perri Ruckart.

24 Q. Okay.

25 A. Those are the two people I interacted

1 with.

2 Q. Dr. Bove and Dr. Ruckart, correct?

3 A. Yes.

4 Q. And if you were developing the model,
5 you were certainly communicating with Dr. Bove,
6 correct?

7 A. There were e-mails, but not -- he was
8 not questioning us and what assumptions we were
9 making. They would more communicate with us on two
10 aspects. One, there's a CAP meeting and we need an
11 update on the modeling and, two, when are we going
12 to have some final results that we can use for the
13 epi study, okay?

14 Q. Okay. You were communicating with
15 Dr. Bove when building the model, though, correct?

16 MR. DEAN: Object to the form of the
17 question.

18 THE WITNESS: When you say building,
19 are you talking about calibrating the model or
20 doing the conceptual groundwater flow model and
21 what type of code we were going to use?

22 BY MR. ANWAR:

23 Q. Any aspect of developing either of the
24 Tarawa Terrace model or the Hadnot Point/Holcomb
25 Boulevard model. During the course of it, you were

1 discussing what Dr. Bove's needs were, correct?

2 MR. DEAN: Object to the form of the
3 question. Mischaracterizes his prior testimony.

4 THE WITNESS: We communicated about
5 what results they would need, the epidemiologists
6 would need, and could we provide them. They
7 indicated that they would need, at one point,
8 trimester information. So if we could give them
9 monthly, that would -- they would be comfortable
10 with -- with monthly values.

11 BY MR. ANWAR:

12 Q. Was Dr. Bove permitted the opportunity
13 to weigh in on modeling decisions? So, for
14 instance, parameter inputs that you decided on and
15 assumptions that were made?

16 A. I may have copied him if I sent out a
17 group e-mail, if we were discussing modeling
18 things, but he would not come back and say, no, you
19 should use, you know, 100 or 30 or whatever
20 parameter. We never had those kinds of
21 discussions. He left that strictly to the water
22 modeling team.

23 Q. So turning back to your rebuttal
24 report.

25 A. Okay.

1 Q. I think it's page 31.

2 A. Okay.

3 Q. There -- actually, I may have told you
4 the wrong page again. Give me one second. Okay.
5 It's page 30, actually. I'm sorry.

6 A. Okay.

7 Q. At the top of that page it starts, "in
8 addition, Remy Hennet's assertion that" --

9 A. Wait. Page 30.

10 Q. 30 of your rebuttal.

11 A. This says rebuttal.

12 Q. It's the first full sentence.

13 A. Oh, okay. I see it. Okay.

14 Q. It states, "in addition Remy Hennet's
15 assertion that ATSDR did not account for such VOC
16 losses is incorrect." And then it goes on, "first
17 ATSDR analyzed sampling data of water from both
18 pretreatment and posttreatment." And then you list
19 in a table sampling data for the Hadnot Point water
20 treatment system?

21 A. Correct.

22 Q. And the rest of that is a discussion
23 about the sampling data from the Hadnot Point water
24 treatment system. I don't see anywhere in that
25 paragraph any discussion about Tarawa Terrace. And

1 it's true that the Tarawa Terrace model didn't
2 account for VOC losses at all, right?

3 A. No, we said they were negligible at
4 each treatment facility. It's just that at Hadnot
5 Point we actually had sampling data, okay? A pair
6 and a triplet, okay? And, for example, for
7 July 27th, 1982 for TCE, we have -- the untreated
8 water is 19 micrograms per liter and that same day
9 -- I can't say what time it was taken at, but we've
10 got treated water at 21 micrograms per liter,
11 allowing for measurement error. It appears to me
12 that there is no VOC loss and that is in sampling
13 data that -- and so, again, you can calculate using
14 equations, but the sampling data showed no VOC
15 loss.

16 Again, on here there is -- at the top
17 of page 31 it says "at the Tarawa Terrace water
18 treatment plant there's triplet measured data taken
19 on July 28th, 1982." And in this -- in this one
20 it's classified as finished, untreated, and treated
21 water. So 104 micrograms per liter finished water,
22 76 untreated, and 82 treated water, okay?

23 Q. Those --

24 A. Now, again, you have variations like
25 this in water -- water samples, but it does not

1 seem to me that there are any VOC losses.

2 Q. So we'll turn to the sampling data as
3 it relates to Hadnot Point --

4 A. Okay.

5 Q. -- because that discussion is all about
6 Hadnot Point, correct?

7 A. No, no, I just said this is Tarawa
8 Terrace. I just -- the triplet is data from Tarawa
9 Terrace. The TTWTP is our acronym for that.

10 Q. What page are you looking?

11 A. Page 31 at the top.

12 Q. Now, when you were comparing the
13 sampling data to determine no VOC losses, so for
14 both Hadnot Point and Holcomb Boulevard, did you
15 take into account whether or not the -- the wells,
16 the contaminated wells, for those two treatment
17 systems had been pumping?

18 A. We do not have information on sampling
19 data, I believe, on any of the sampling data,
20 whether the wells were pumping or not -- not
21 pumping. We may be able to make some judgments
22 based on before and after if it's at the same --
23 same -- same well, whether the well was pumping or
24 not, but we had no information on the pumping
25 status of the well, but that would not have -- you

1 would not have lost any VOCs in the well because
2 it's not that you have air space in there. The
3 well is screened down through the aquifer, okay?
4 It's completely filled with water.

5 Q. Well, you're -- you're basing the
6 conclusion at the top of page 31 as it relates to
7 Tarawa Terrace, and I think for Hadnot Point as
8 well, you're comparing finished water samples
9 versus untreated water samples, and you're reaching
10 the conclusion, it seems to me, that in comparing
11 those, just the -- the sampling results, there were
12 no VOC losses, right?

13 A. Well, the data indicate that and then
14 taking that in addition to what our expert panel
15 said, maybe 10 percent or so, that leans you
16 towards the minimum for the negligible losses
17 because I would expect if there were VOC losses,
18 and let's say 10 percent, I would expect to see
19 that in the sampling data to be reduced for the
20 sampling data from the untreated water, which is
21 probably the raw water tank where all the wells mix
22 in together, go through the treatment process, and
23 then they put it into a treated water tank either
24 elevated or underground. I would have expected to
25 see some losses.

1 Furthermore, I might add, in the period
2 January 28th through February 8th, 1984, there was
3 an eight-day period when they had to shut down the
4 Holcomb Boulevard water treatment plant. Holcomb
5 Boulevard was never served with -- did not -- the
6 treatment plant was -- never had contaminated
7 water, but when they shut down during that
8 eight-day period, the distribution system going
9 into Holcomb Boulevard received contaminated Hadnot
10 Point water. And if you just look at some of the
11 values, and I put the ranges in there. I believe
12 there's a CLW document that lists them all the way
13 from 24.1 to over 1100. So again, I'm going to ask
14 again, where are the losses?

15 Q. So for instance, for Tarawa Terrace,
16 the -- the source or the primary contaminated well
17 was TT26, right?

18 A. That -- that was the main well, yes.

19 Q. And there's statements in the reports,
20 and we'll look at them, that -- but would you agree
21 that when TT26 was pumping, the -- the contaminant
22 concentration levels were higher?

23 A. Yes.

24 Q. And when TT26 was not pumping, the
25 contaminant concentration levels decreased, and I

1 think you stated in your expert panel that -- in
2 one of the expert panels that the concentration
3 levels went down to almost zero?

4 A. Well, that's shown in our Chapter A
5 report, too. When they shut the well down for
6 maintenance, okay, so it was not pumping, the
7 concentrations at the water treatment plant went
8 down to near -- near zero, and that also is what
9 proved to us that TT26 was the driving force or the
10 driving well in that whole -- whole system.

11 Q. So the only point I'm trying to make
12 with respect to comparing finished samples from
13 finished water versus untreated water at Tarawa
14 Terrace and at Hadnot Point, I mean, simply --
15 context matters. Simply comparing samples from
16 untreated water and finished water doesn't tell you
17 whether the well was pumping, whether the
18 contaminants were increasing, whether the well --
19 whether the well had stopped pumping and the
20 contaminants were decreasing, you can't make a
21 determination on VOC losses solely by comparing a
22 finished water sample and an untreated water
23 sample?

24 MR. DEAN: Object to the form of the
25 question. Compound. Complex.

1 BY MR. ANWAR:

2 Q. You can answer.

3 A. Okay. I think you are confusing -- and
4 I don't mean that as a personal attack.

5 Q. Sure. No offense taken.

6 A. Confusing different mechanisms and
7 different aspects of the entire process of
8 delivering, obtaining water from the aquifer to the
9 delivery point, okay? The samples -- there's some
10 samples at TT26, okay, that's at the well, and that
11 -- that says nothing about -- and honestly, that
12 says nothing about the treatment process. The
13 treatment process occurs after all the wells mix in
14 in the entry to the water treatment plant, okay?

15 So if I take a sample, and let's say
16 untreated water, which will be the raw water tank,
17 okay, and I get a -- a value, a concentration, and
18 then I take a similar sample and I'm assuming they
19 are using the same testing methodology at the
20 treated end, which would be on the other side of
21 the spiractors, the other side, and I don't see
22 any -- any losses, any changes, decreases in
23 concentration, excuse me, can I -- then what I am
24 saying is it's a good assumption, a good
25 engineering assumption, that even -- whatever

1 losses there are are so negligible that we're not
2 able to measure them. Or the people that measured
3 them, the same -- the ATSDR did not actually
4 measure those -- those samples, okay? And that's,
5 again -- and everything that we do in modeling and
6 interpretations and all of that, it's sort of a
7 weight of evidence approach.

8 Q. Sure.

9 A. Okay? So we've got the AH report.
10 We've got our expert panel. We've got -- these
11 members actually did water distribution system
12 testing at various -- not at Camp Lejeune, but at
13 various locations, and we've got sampling data. So
14 you've got to take it all -- all together, okay?

15 Q. I just have a few more questions on
16 this topic --

17 A. Sure.

18 Q. -- and then we'll take a break.

19 A. Okay.

20 Q. Now, using Tarawa Terrace again as the
21 example, TT26 was the main well that was
22 contaminated, correct?

23 A. That is -- that is correct. There was
24 some contamination at TT23, which is referred to as
25 the TT new well. It only ran for about nine months

1 maybe. When it was put in, it was put in to a
2 contaminated aquifer, okay, so that's why its
3 concentrations are high immediately. But again,
4 TT26 was the major contributor.

5 Q. TT26 and TT23 weren't the only wells
6 providing water in Tarawa Terrace, right?

7 A. That is correct.

8 Q. And the wells at Camp Lejeune,
9 including Tarawa Terrace, were cycled, right, in
10 terms of the usage?

11 A. They recycled, yes, yes.

12 Q. And so simply comparing a finished
13 water sample versus an untreated water sample
14 doesn't tell you anything about which well the
15 water was coming from, right?

16 A. Well, we knew that based --

17 MR. DEAN: Object to the form.

18 THE WITNESS: We knew that based on the
19 modeling, okay, the contaminant fate and transport
20 model. The output of the contaminant fate and
21 transport model were the concentrations at specific
22 wells, okay? And you have to look in the model
23 output and you can see which wells were turned on
24 or off during which month. And then we had, again,
25 a simple mixing model.

1 BY MR. ANWAR:

2 Q. And --

3 A. And the key is the simple mixing model
4 mixed all -- all the wells together, okay, for
5 conservation of mass and continuity. And so when
6 we get a monthly concentration out of the mixing
7 model, okay, that's what we said went into the
8 water treatment plant.

9 Q. In -- in comparing finished water
10 samples and untreated water samples for purposes of
11 your rebuttal report in offering opinions about VOC
12 losses --

13 A. Right.

14 Q. -- at Hadnot Point and Tarawa Terrace,
15 did you go back and look to see what time frame the
16 samples came from, whether the wells -- which wells
17 were turned on and off, what information was
18 available?

19 A. Let's see what this is. I looked at
20 the treatment process, okay, because that's -- that
21 was the focal point of those claiming there were
22 major VOC losses versus negligible. And so I
23 looked -- you have to look at the treatment
24 process, okay? The treatment process starts at the
25 mixing of all the wells into the raw water tank.

1 And the assumption, engineering assumption, is that
2 there's instantaneous mixing, and we prove that in
3 the Chapter I report because we run parallel
4 models. We run the full-blown EPANET model, which
5 is water distribution, and we run the mixing model.
6 And after a week or ten days, they are equivalent
7 to the -- out to the four decimal places. So that
8 means you have -- the mixing model in addition to
9 what our expert panel told us, all the wells were
10 mixing at the water treatment plant in the raw
11 water tank and there was instantaneous mixing
12 compared to our monthly concentration needs.

13 Q. Okay. I think my last question on
14 this, so just taking the Tarawa Terrace example
15 here in your report at the top of page 31 where
16 you're comparing the 104 microgram per liter
17 unfinished water versus the 76 microgram per liter
18 in untreated water and the 82 microgram per liter
19 in treated water --

20 A. Right.

21 Q. -- I don't see it anywhere in your
22 report, but -- and so I think you would agree that
23 you don't know what percentage of water in the
24 untreated, treated, and finished water samples at
25 Tarawa Terrace came from TT26, right?

1 MR. DEAN: Object to the form.

2 THE WITNESS: You -- you could -- you
3 could actually compute that because the process to
4 get the mixing model results would be is you take
5 the well's capacity for a given month, how much
6 it's pumping, what the concentration is -- let me
7 back up. Hold on. Get the chapter right. It's
8 easier for me to explain the Chapter A here. Here.
9 Okay. It's -- it's a model here. Okay. Page A40
10 in Chapter A, equations one and two. Concentration
11 of PCE in finished water, okay? So we have all of
12 the information. You see it's summing over however
13 many wells were pumping versus whether they are
14 contaminated or not. So, yes, we do know, but the
15 assumption was -- in agreement with what our expert
16 panel recommended -- is that you could assume
17 instantaneous was a CSTR, continuously stirred tank
18 reactor model, for the mixing model. And so the
19 minute the wells hit the raw water tank, they all
20 mixed. And to us instantly was anything less -- a
21 good portion less than a month. And that's shown
22 in the Chapter I report. I can tell you exactly
23 where in a minute.

24 Q. Why don't we go ahead and take a break
25 if you're --

1 A. Okay.

2 THE VIDEOGRAPHER: Okay. We're going
3 off. Record the time is 2:33 p.m.

4 (A recess transpired.)

5 THE VIDEOGRAPHER: Okay. We are going
6 back on record. The time is 2:43 p.m.

7 THE WITNESS: Is it possible to qualify
8 or continue with where we left off?

9 BY MR. ANWAR:

10 Q. Sure. Did you have something you
11 wanted to --

12 A. Yes.

13 Q. -- correct or --

14 A. I would like you to turn to the Hadnot
15 Point/Holcomb Boulevard Chapter A report.

16 Q. Sure. What page are you --

17 A. Page A38, Figure A15.

18 Q. A38, A15.

19 A. Yes.

20 Q. Okay.

21 A. Okay. This is the same mixing model
22 that we talked about at the Tarawa Terrace. You'll
23 notice the equations on page -- the next, page A1
24 and A2 are the same equations one and two in Tarawa
25 Terrace report in Chapter A.

1 Q. Okay.

2 A. What I want to point out to is -- and
3 this is a conceptual or a schematic. If you look
4 at the distribution network of pipes on the
5 left-hand part of the Figure A -- mixing model
6 approach is the title of that section.

7 Q. Okay.

8 A. You'll see that there are little --
9 towards the right there's HPWTP, that tank
10 represents HP, and you've got contaminated, meaning
11 red, or uncontaminated, blue, symbols there mixing
12 into the -- into the HPWTP. Now, we did not do
13 step-by-step treatment process. What the
14 assumption is, and a correct assumption, an
15 approximation, is that they all instantaneously
16 mixed in the raw water tank. Once they mixed in
17 the raw water tank, if, in fact, there's this
18 massive VOC loss, you would see it in the samples,
19 and we didn't. And so our assumption was that
20 there was negligible losses within the treatment
21 process, and so what -- the concentration in the
22 tank through the mixing model is the same as the
23 contamination anywhere throughout the distribution
24 system.

25 Q. Okay. But you're talking sort of --

1 you're talking in the context of model -- still the
2 model, right?

3 A. That's exactly correct, yes.

4 Q. And at the end of the day, a model is
5 an approximation of reality, right?

6 A. Yes.

7 Q. There is no way to perfectly replicate
8 reality, right?

9 A. No, a model is an approximation. Some
10 are closer approximations and some are -- are not
11 as close, but it is an approximation. But at the
12 end of the day, if we are going to test the model
13 out, I'm speaking generically now of the model,
14 then that's where we go and gather some field
15 information or sampling information and see if it,
16 in fact, proves or supports -- that's probably a
17 better word -- supports the assumptions that we
18 made using this model.

19 Q. The pumping data for Tarawa Terrace and
20 TT26, the wells in Tarawa Terrace and TT26 in
21 particular, that was limited, right?

22 A. The pumping data? We had -- we had
23 monthly data. We had some early on in the --
24 early, early '50s or '40s. We had some annual
25 pumpage data. And then in -- I believe from about

1 -- for Hadnot Point from about 1998 through 2008,
2 we had daily pumping values.

3 Q. You said from 1998 to 2008?

4 A. That's my recollection, yes, we had
5 daily -- daily values.

6 Q. Well -- and those values are sort of
7 outside the time period we're -- we're interested
8 in, right?

9 A. No. Again, you've got the
10 epidemiological study, which goes from '68 to '85,
11 but we're using -- and I'm going to limit this
12 right now to groundwater flow and contaminant fate
13 and transport models; those are boundary-valued
14 problems. So you've got to take them out or start
15 them from a period of known water level, a period
16 of known concentration, and run them out until you
17 get back to a period of known information.

18 We -- at Hadnot Point we had some known
19 information because they were doing remediation
20 pumping so that the models there went out all the
21 way to 2008 because it was another set of data in
22 addition to the 1980s data that could get -- build
23 confidence, substantial confidence, in the modeling
24 results. So the models went out or started based
25 on hydrogeologic and modeling concepts and

1 frametimed where -- and part of the model went
2 through the epidemiologic study period, the two --
3 in other words, the epidemiology did not control
4 when we started or ended the model.

5 Q. 1998 is after 1987, right?

6 A. Yes.

7 Q. And --

8 A. If you're interested in building
9 confidence in your model and testing out the
10 goodness of fit of your calibration, if you've got
11 another set of information past the epidemiology --
12 again, the epidemiology doesn't impact how we're
13 calibrating or developing the model -- then you
14 want to use that.

15 Q. I guess more broadly speaking, you
16 know, we can debate the points of the actual
17 modeling, which, you know, you're an expert on it
18 and I'm not. But if ATSDR's modeling accounted for
19 VOC losses, why was it necessary to make a
20 statement that the VOC losses were -- were
21 negligible and, you know, why was it necessary to
22 make that -- that determination?

23 A. Okay. Because you needed to somehow
24 quantify, I felt, what he meant by negligible. He
25 does not say zero. He said negligible, okay? And

1 I'm speaking again in terms of pragmatic
2 engineering applications doing modeling; you make
3 these kinds of assumptions, okay? He also had
4 wanted to make sure someone -- when we say
5 negligible, if they read the expert panel and saw
6 Dr. Pommerenk, who is, I believe, AH consultant for
7 the Marine Corps who sat on our expert panel
8 saying, well, less than 10 percent, then someone
9 reading our reports would say, okay, negligible 10
10 percent -- even if there's VOC losses, there's
11 somewhere less in that -- in that range, and now
12 I'm looking at sampling data and it doesn't appear
13 to be from the sampling data any -- even 10 percent
14 loss anywhere, so negligible is a good
15 approximation.

16 Q. You -- and coming out of the expert
17 panel, you-all landed on 10 percent, right?

18 A. That's what the expert panel said,
19 okay? And that's when we got together either in a
20 team meeting, not part of the expert panel, but,
21 you know, subsequent, because the expert panel made
22 many recommendations, which we typically either
23 generally followed, and we, you know, we would just
24 say, oh, well, it's 10 percent, that's negligible
25 compared to the variation and all the other

1 parameters. Sampling data, aquifer properties, and
2 things of that -- well operations, things of that
3 nature. So we were confident with the -- had
4 confidence in assuming negligible VOC losses.

5 Q. And the AEE report said up to
6 15 percent, right?

7 A. Yes.

8 Q. And so when -- when we're talking about
9 negligible in terms of the decision ATSDR made in
10 determining VOC losses were negligible, we're
11 talking about between 10 and 15 percent, right?

12 MR. DEAN: Object to the form of the
13 question. Mischaracterizes the prior testimony.

14 THE WITNESS: I would say it was 10
15 percent because the representative of AH Consulting
16 Dr. Pommernek, who was also representing the
17 Department of Navy, U.S. Marine Corps on the expert
18 panel then -- then said, well, you know, I'll give
19 you that 90 -- there's a 90 percent passthrough, so
20 that's 10 percent. And then we also had other
21 water distribution system experts on there and --
22 like Dr. Walski, Dr. Grayman, Dr. Clark, and they
23 indicated in their experience that there would be
24 even less than 10 percent negligible.

25 Q. Okay.

1 A. And they have done analyses with other
2 water distribution systems like Tucson, Arizona,
3 Redlands, California and so on.

4 Q. Let's turn to Exhibit 10, which is
5 Chapter A for Hadnot Point and Holcomb Boulevard.

6 A. Okay. Oh, I've got it open right here.
7 Okay.

8 Q. And let's turn to page A1.

9 A. Okay.

10 Q. So just -- just so the record is clear,
11 we're now discussing the analysis for Hadnot
12 Point/Holcomb Boulevard, right?

13 A. That is correct, summary of findings.

14 Q. And footnote number seven on the first
15 page states, "for this study, finished water is
16 defined as groundwater that has undergone treatment
17 at a water treatment plant and was subsequently
18 delivered to a family housing unit or other
19 facility. Throughout this report and the Hadnot
20 Point/Holcomb Boulevard report series, the term
21 finished water is used in place of terms such as
22 finished drinking water, drinking water, treated
23 water or tap water." Did I read that correctly?

24 A. Yes.

25 Q. So ATSDR modeled -- ATSDR said it

1 modeled water that had undergone treatment at a --
2 at a water treatment plant at Hadnot Point,
3 correct?

4 A. That's not what that says, or that's
5 not what I interpret that to say. What that is is
6 trying to define what finished water is, okay?
7 There are different names. Some people would say
8 potable water, okay? It's not the same as potable
9 water. It's not the same as groundwater. It's
10 treated water, but that statement does not say we
11 modeled the treatment process. And I've -- I've
12 never maintained that we modeled the treatment
13 process.

14 Q. Okay.

15 A. And our expert panel in 2005 also said
16 that the treatment process did not have to be
17 modeled.

18 Q. Let's turn to page A33.

19 A. Okay. Okay. I'm there.

20 Q. Looking at number nine.

21 A. Okay.

22 Q. It states, "reconstructed simulated
23 monthly mean concentrations of PCE, TCE, 1-2-DCE,
24 and vinyl chloride and benzene for finished water
25 at the Hadnot Point water treatment plant were

1 determined by using a materials balance model
2 simple" --

3 A. Materials mass balance.

4 Q. Excuse me. "Materials mass balance
5 model, simple mixing, to compute the flow-weighted
6 average concentration of the aforementioned
7 contaminants. This computational method is based
8 on the principals of continuity and conservation of
9 mass, Masters 1998. The use of the materials mass
10 balance method is justified because all raw water
11 from water supply wells within the Hadnot Point
12 water treatment plant service area was mixed at the
13 Hadnot Point water treatment plant prior to
14 treatment and distribution." And then it says,
15 "details of this method are described in a
16 subsequent section of the report." Did I -- did I
17 read all that correctly?

18 A. Yes.

19 Q. Would you agree that what ATSDR called
20 finished water at the Hadnot Point water treatment
21 plant was based on a material mass balance model,
22 simple mixing, to compute flow-weighted average
23 concentrations of contaminants?

24 A. Yes.

25 Q. And agree that mass -- a mass balance

1 -- agree it was a mass balance model based on
2 continuity and conservation of mass?

3 A. Yeah, that's what equations A1 and A2
4 in this report and equations one and two in the
5 Tarawa Terrace Chapter A report -- the first
6 equation is continuity. The second one is
7 conservation of mass.

8 Q. Agree that continuity and conservation
9 of mass means the simple mixing model assumed that
10 mass of all contaminants entering the water
11 treatment plant were conserved through the water
12 treatment plant?

13 A. Yes.

14 Q. Okay. And they continued, correct?

15 A. What do you mean?

16 MR. DEAN: Objection to form.

17 BY MR. ANWAR:

18 Q. It assumed that they continued the --

19 A. You mean the flow continued?

20 Q. The mass of the contaminants.

21 A. I'm not following you. Are you asking
22 did the concentration from one -- once it's mixed
23 at the raw water tank is the same as the
24 concentration in the finished water tank?

25 Q. I think you answered my question.

1 Let's -- would you agree ATSDR modeled influent to
2 the water treatment plant as having the same
3 contaminant concentrations as the effluent from the
4 water treatment plant?

5 A. No, we modeled -- the influent, to me,
6 by definition, would be the different wells coming
7 into the raw water treatment tank. If you look at
8 the water distribution system utility maps, you'll
9 -- you'll see that the raw water from wells were
10 typically piped over to the raw water tank through
11 concrete pipes, okay, underground pipes. So once
12 all the wells fed into there, in the raw water
13 tank, I assumed there was instantaneous mixing, as
14 the mixing model does, okay, and then that -- that
15 would equal the finished water concentration.

16 Q. Okay. Let's look at A62.

17 A. What? I'm sorry?

18 Q. A62.

19 A. On HP report?

20 Q. Yes.

21 A. Page 62. Okay. Okay.

22 Q. Looking -- focusing on Table A18, you
23 would agree that Table 18 shows, among other
24 things, measured TCE concentrations at the Hadnot
25 Point water treatment plant?

1 A. Yes.

2 Q. Looking at TCE, you would agree there
3 are only a few measurements each of treated and
4 untreated water?

5 A. Yes.

6 Q. Agree the data is insufficient to
7 conclude no treatment losses, right?

8 MR. DEAN: Object to form.

9 BY MR. ANWAR:

10 Q. You can answer.

11 A. Okay. Using the data that we have, you
12 always want more data as a modeler, okay, always.
13 That's -- okay. So if you're asking me as a
14 modeler would I want more data than this, yes, but
15 we were working with the data that we had and that
16 was presented to us. And given this data, I see,
17 again, July 27th, treated -- or let me see the
18 exact wording, untreated and treated, footnote five
19 and six, they are approximately the same value.
20 That's the data I referenced in my rebuttal report.
21 So you use that data because that's what we have.

22 Q. Direct me to that again.

23 A. On page A62, if you go to 7/27/82, the
24 first listing has a footnote five which says
25 untreated. The second listing, 7/27/1982, under

1 TCE, it says 21.

2 Q. You said 7/27/1982?

3 A. Yes.

4 Q. TCE. And then the listing underneath
5 it, you're saying is --

6 A. It gives the treatment status.

7 Q. And your -- your opinion is that the
8 model indirectly accounted for treatment losses
9 based on those two points of data?

10 A. Based on those two points. Based on,
11 also, the January 28th through February 4th, 1985
12 shutdown of the Holcomb Boulevard treatment plant
13 where we just saw huge slugs of TCE within the
14 Holcomb Boulevard treatment system -- not
15 treatment, but distribution system. So again, we
16 used a weight of evidence approach. And then,
17 again, referring back to the expert panel report
18 that said, well, we did 10 percent, we -- we said
19 that justified the assumption of negligible.

20 Q. For the samples that you're -- that
21 we're discussing, the 7/27/1928 for TCE.

22 A. Yes, uh-huh.

23 Q. ATSDR didn't know if HP651 was pumping
24 on that day, right?

25 A. We could go back to the reconstructed

1 -- reconstructed pumping schedule and -- and figure
2 out if it was pumping or not. I would have to look
3 -- I would have to look at our pumping schedule.

4 Q. Okay. But that's a reconstructed
5 pumping schedule, correct?

6 A. It's still the only thing close to
7 reality that we have.

8 Q. But it's not reality, right?

9 MR. DEAN: Object to form.

10 THE WITNESS: It's what we used to
11 reconstruct and then compare these values to -- to
12 that. So it was -- it was pumping in the model.

13 BY MR. ANWAR:

14 Q. For -- in the absence of pumping data
15 for Tarawa Terrace, at least --

16 A. Right.

17 Q. -- ATSDR assumed that a well was
18 pumping unless you had evidence affirmatively
19 disproving that it was pumping, correct?

20 A. That is correct. And we then tested
21 that out through an uncertainty analysis by varying
22 the pumping through a Monte Carlo-type uncertainty
23 analysis, but the calibrated model assumed
24 continuous pumping unless it was shut down for
25 maintenance purposes.

1 Q. And with respect to the samples that
2 we've been discussing, the July 27, 1982, ATSDR
3 didn't know if HP651 was pumping the day before
4 either, right?

5 A. No, there's no indication as to the
6 status of the water supply wells feeding the raw
7 water tank. These are taken at the treatment
8 plant, not at the wells, if I'm -- yes, these are
9 taken at the treatment plant. So the wells have
10 already mixed, on, off, whatever.

11 Q. When you say no indication, what do you
12 mean?

13 A. There's no -- this table here is from
14 the water treatment plant, okay?

15 Q. Yeah.

16 A. So it does not contain an indication as
17 to which wells were on, which wells were
18 contaminated, which wells were on and not
19 contaminated, and which wells were off, okay?
20 This -- this particular table, okay? This is a
21 result of applying the -- a mixing model, a
22 flow-weighted mixing model.

23 Q. When you say this is the result, what
24 do you mean "this?"

25 A. Well, if you look under the

1 reconstructed column, the middle column there.

2 Q. Yeah.

3 A. Okay. That's what -- once we got the
4 concentrations out of the model for each of the
5 Hadnot Point wells --

6 Q. Yeah.

7 A. -- and we can tell which ones were
8 operating, which ones were not and have a zero
9 there, and then we knew what the reconstructed
10 concentration is, so then we would tabulate those
11 into an Excel spreadsheet, do the flow-weighted
12 mixing in the Excel spreadsheet.

13 Q. And, you know, I'm talking about not
14 the reconstructed schedule, but about real-world
15 data?

16 A. I understand that, but, again, as I
17 think we've discussed real early on, if my
18 recollection is correct, these are one point in
19 time samples, okay? And we are -- we are doing
20 monthly simulations, monthly results. So that's,
21 you know, just -- you need to keep that in mind
22 when you're looking at data versus modeling
23 results.

24 Q. Agree -- you would agree that you don't
25 know the percentage of water in those samples that

1 came from HP651?

2 A. Not in the -- not in the samples, but I
3 would know -- I would have to tabulate it, but I
4 would know in the reconstructed column.

5 Q. But the reconstructed column is a
6 simulation, right?

7 A. That's our best estimate, most likely
8 estimate.

9 Q. Okay. And that's because you don't
10 know the real-world data on whether -- what
11 percentage of water in those samples came from
12 HP651?

13 A. Not from the sampling data. However,
14 you do have the previous table, I think, or
15 somewhere in here, it's early on, there is a table
16 -- let's see. Here you go. Page A48.

17 Q. So I wanted to actually change topics a
18 little bit.

19 A. Oh, sure. Okay.

20 Q. Shift gears a little bit. You would
21 agree that it takes time for water to get through
22 the -- the water treatment plant, right?

23 A. Compared to the groundwater system,
24 it's instantaneous. I'm talking about hours or
25 maybe even minutes compared to days or months or

1 longer than that, you know. That's -- I think, as
2 I said previously, water distribution system models
3 use an hour time step, and you typically would
4 measure pressures. If you had any concentrations,
5 you would measure those at, say, at 15-minute
6 intervals, so you're talking about a much more
7 rapid process.

8 Q. Similar to our discussion on TT26 for
9 Hadnot Point, you would agree that whether --
10 whether HP651 was pumping had a significant impact
11 on the concentration of TCE entering the Hadnot
12 Point water treatment plant, right?

13 A. Yes.

14 Q. And you would agree that when HP651
15 stops pumping or stopped pumping, concentration of
16 TCE entering the Hadnot Point water treatment plant
17 would go down very quickly?

18 MR. DEAN: Object to the form.

19 THE WITNESS: Well, we could look at
20 the graph on page A63 in Chapter A here, Figure
21 A27. And you do see up and down with -- of TCE at
22 the water treatment plant, which is indicative of
23 cycling on and off of HP651. But unlike TT26, the
24 only time it goes to zero or close to zero is after
25 they completely turned the well -- the well off.

1 Q. But when HP651 stops pumping,
2 concentration of TCE entering the HP -- the Hadnot
3 Point water treatment plant goes down, right?

4 A. It -- it gets reduced, but because
5 there were so many -- there were other wells
6 pumping and contributing to the water treatment
7 plant and supplied -- supplied water, some of those
8 other wells, if they were contaminated, would --
9 would, you know, add to the concentration at the
10 water treatment plant.

11 Q. You would agree that when HP651 stops
12 pumping, at that very moment water coming out of
13 the Hadnot Point water treatment plant entered into
14 it with TCE concentrations from when HP651 was
15 pumping, correct?

16 A. Could you repeat the question again?
17 I'm sorry. I didn't follow.

18 Q. Sure. So when -- when HP651 stops
19 pumping, the water that was pumping into the Hadnot
20 Point water treatment plant doesn't immediately go
21 away, right?

22 A. That is correct.

23 Q. That water that had been pumping from
24 HP651 continues through the water treatment plant,
25 correct?

1 A. Yes. Again, the pipes are pressurized
2 and water is flowing full, okay? A storage tank is
3 not pressurized like the distribution pipeline, but
4 it's full, and so it's not that you have no water
5 stopped at 651 and then the raw water tank has no
6 more water in it. It's still filled with the
7 previous day's concentration, and if 651 was not
8 pumping on a particular day, you would still have
9 contaminated water in that raw water tank.

10 Q. And so carrying that through to
11 conclusion, if 651 stopped pumping and that water
12 -- but the water that had been pumping from 651
13 into the Hadnot Point water treatment plant entered
14 into it and then continued to be distributed, the
15 finished water sample from -- from that water that
16 pumped through 651 -- or excuse me, from the 651
17 water that had pumped through the Hadnot Point
18 water treatment plant would reflect that
19 contaminated water, right?

20 MR. DEAN: Object to form.

21 THE WITNESS: Okay. Could you clarify
22 that?

23 BY MR. ANWAR:

24 Q. Sure. So a moment ago you agreed with
25 me that when HP651 stops pumping, at that precise

1 moment the water that had been pumping into the
2 water treatment plant at Hadnot Point doesn't go
3 away, right?

4 A. That is correct.

5 Q. It -- that water that had been pumping
6 from 651 remains in the water treatment plant,
7 correct?

8 A. Yes, the water that's there the
9 previous day when HP651 was pumping, let's say --
10 for argument's sake let's say it's still there,
11 okay, but over a day's period it probably moved
12 through the treatment process.

13 Q. And a moment ago we -- we discussed
14 that ATSDR treated or used a mixing model for
15 purposes of finished water, correct?

16 A. That is correct.

17 Q. And so -- well, let's -- let's --
18 stepping away from the model, that water in the
19 Hadnot Point treatment plant from 651, that doesn't
20 immediately disappear, that still ends up in the
21 finished water, correct?

22 A. That is correct.

23 Q. Okay. And then 651 is now stopped and
24 other wells are pumping water to it, correct?

25 A. They are compensating for the loss of

1 the volume of the well, okay? Because at the end
2 of the day, when we were there in 2004 and
3 historically, having spoken with past operators,
4 they had to keep their tanks, finished water tanks
5 nearly filled for fire protection, okay, so they --
6 you would have had to compensate for HP651 with
7 other -- other wells.

8 Q. And those other wells pumping into the
9 HP treatment plant could include wells that weren't
10 contaminated, right?

11 A. That is correct.

12 Q. So in that case, if you were to take an
13 untreated sample and compare it to the treated
14 sample from the -- the HP651 water that went
15 through the system, the treated water would be
16 higher, likely, than the -- the untreated water
17 sample taken at the water treatment plant?

18 A. Again, I think we need to view this in
19 terms of the historical reconstruction that we did
20 on a monthly basis. Even though -- even though the
21 distribution system does the EPANET model, you can
22 do hourly calculations, meaning you can do daily
23 calculations. The output from the contaminant fate
24 and transport model and the mixing model are valid
25 on a monthly basis. So over a month, you would

1 have seen 651 come back on.

2 Q. But again, we're talking about the
3 model simulation world and not the real world?

4 A. But that's what we did at ATSDR. I
5 mean, that's -- that's the whole concept of
6 historical reconstruction or modeling in general,
7 is that we used models and applied models where we
8 may not have information, real data, and you build
9 confidence by the calibration process to use -- use
10 those models. We took, at ATSDR, the sampling data
11 that was provided to us by the Marine Corps,
12 Department of Navy or other -- other water quality
13 labs and that's the data that -- that we had.

14 Q. I'm going to hand you what I'm marking
15 as --

16 MR. ANWAR: I'm sorry. Can you remind
17 me, is this 15? I forgot to write one down. 16.

18 (DFT. EXHIBIT 16, Analyses and
19 Historical Reconstruction of Groundwater Flow,
20 Contaminant Fate and Transport, and Distribution of
21 Drinking Water Within the Service Areas of the
22 Hadnot Point and Holcomb Boulevard Water Treatment
23 Plants and Vicinities, U.S. Marine Corps Base Camp
24 Lejeune, North Carolina, Chapter A-Supplement 2,
25 Development and Application of a Methodology to

1 Characterize Present-Day and Historical Water
2 Supply Well Operations, was marked for
3 identification.)

4 BY MR. ANWAR:

5 Q. Did I actually hand you the exhibit?

6 A. No.

7 Q. Sir, do you have the exhibit?

8 A. No, you didn't tell me what 16 was.

9 Q. Sorry. I just put the sticker on it
10 and I lost my train of thought. I'll just put
11 another sticker on it.

12 Okay. I'm handing you what I've marked
13 as Exhibit 16.

14 A. Supplement 2. Okay.

15 Q. Can you turn to page -- so for
16 starters, this is part of the Hadnot Point/Holcomb
17 Boulevard analysis, correct?

18 A. Yes, it's Supplement 2 of Chapter A.

19 Q. Okay. And the title is "development
20 and application of a methodology to characterize
21 present-day and historical water-supply well
22 operations", correct?

23 A. That is correct.

24 Q. Okay. If you could turn to page S2.2.

25 A. 2.2. Okay. 2.2. Okay. Background?

1 Q. Yeah.

2 A. Okay.

3 Q. And so at the top of that page on the
4 right-hand side --

5 A. Right.

6 Q. -- paragraph starting "detailed daily
7 data."

8 A. Let me just take a look. Okay. I'm
9 there.

10 Q. Okay. So it starts by stating,
11 "detailed daily data pertaining to the pumping
12 schedule of the wells are available subsequent to
13 January 1998", correct?

14 A. That's -- yes, that's what we
15 previously discussed.

16 Q. Sure. And then "prior to 1998, data
17 pertaining to wells operation are limited or
18 unavailable", correct?

19 A. That is correct.

20 Q. And then it goes on to state,
21 "similarly, daily water treatment plant raw water
22 samples are available" --

23 A. Raw water volumes.

24 Q. Volumes. Excuse me, are -- let me
25 reread that.

1 A. Okay.

2 Q. "Prior to, similarly, daily water
3 treatment plant raw water volumes are available
4 after December 1994", correct?

5 A. That is correct.

6 Q. "And then between 1980 and 1994,
7 monthly raw water volumes are available. Yearly
8 volumes are available for some times -- for some
9 years prior to 1980. A trendline was used to
10 estimate raw water flows for years prior to 1980
11 when no data exist. Monthly raw water flow
12 percentages were then calculated using known
13 monthly data for the period 1980 to 2004. These
14 values are used to estimate monthly raw water flows
15 prior to 1980. This methodology is based on two
16 assumptions: Similar characteristics of the
17 operational patterns of the wells and water
18 treatment plants for the periods of time before and
19 after January 1998 and, two, the quality between
20 total water volume delivered to the water treatment
21 plant from the operating wells and the water
22 treatment plant raw water volume data at all
23 times." Did I read that correctly?

24 A. Yes, you did.

25 Q. Okay. Agree -- you'd agree that prior

1 -- based on this, prior to 1998, data pertaining to
2 well operations was limited or unavailable?

3 A. Yes, that's what that says.

4 Q. Agree that according to this, that
5 there were daily water treatment plant raw water
6 volumes available after 19 -- after December 1994,
7 correct?

8 A. Yes.

9 Q. Agree there were monthly raw water
10 volumes available for 1980 to 1994, right?

11 A. Yes.

12 Q. And then there were some yearly volumes
13 prior to 1980, right?

14 A. That is correct.

15 Q. ATSDR had to estimate pumping schedules
16 due to the lack of this data, right?

17 A. We had to estimate pumping schedules to
18 get the operational -- I'm equating operational and
19 pumping schedules to be able to code them in -- on
20 a monthly basis to the -- to the model, to the
21 groundwater flow and contaminant fate and
22 transport.

23 Q. And so if we go on to the next
24 paragraph, data availability.

25 A. Okay.

1 Q. "Four types of data sources pertinent
2 to water supply well operation -- operational
3 records and water treatment plant raw water records
4 are used in this supplement." It says "these are
5 daily operational records, January 1998 to
6 June 2008. Number two, Camp Lejeune historic
7 drinking water consolidated document repository
8 records. Number three, Camp Lejeune water
9 documents. Number four, U.S. Geological Survey.
10 Using these data sources, operational chronologies
11 for 1996" -- excuse me.

12 A. Wait.

13 Q. "Using these data sources operational
14 chronologies for 96 wells supplying groundwater, in
15 parentheses, raw water, to the Hadnot Point water
16 treatment plant and Holcomb Boulevard water
17 treatment plant were developed." Did I read that
18 correctly?

19 A. Yes, yes.

20 Q. You would agree that ATSDR didn't use
21 pumping data from the '80s, but used data from
22 pumping schedules after 1998 to estimate pumping
23 schedules during 1953 to 1987?

24 A. The way the methodology that's
25 described in Supplement 2, there was a training

1 period and then a predictive period. So the
2 training period typically went from 1998 to 2008
3 because that was known information on a daily
4 basis. And once we obtained the characteristics of
5 the operating wells based on that, then we could go
6 out and where we either had partial data or missing
7 data, use the prediction from there and apply the
8 prediction to the data gaps.

9 Q. So for Hadnot Point/Holcomb Boulevard
10 analysis and the model, you used predictions based
11 on pumping schedules after 1998, correct, to -- to
12 let me ask that again.

13 So based -- for Hadnot Point/Holcomb
14 Boulevard you used pumping schedules from after
15 1998 and predicted backwards the pumping schedules
16 during 1953 to 1987, right?

17 MR. DEAN: Object -- object to the
18 form.

19 THE WITNESS: Again, it says -- I think
20 it was up -- yeah, we also used -- for data we're
21 missing a trendline, which is an accepted
22 statistical approach in engineering. And the
23 algorithm developed by who is now Dr. Telci, the
24 first author on here. At the time he was with
25 Georgia Tech, used the training period for periods

1 of known water supply operations and then used the
2 predictive period for when we had to predict the
3 operations. So you have a combination of both
4 training and prediction.

5 BY MR. ANWAR:

6 Q. And that's training and prediction, but
7 that's -- that's both simulated pumping schedules,
8 correct?

9 A. No, well, the training was based on
10 daily data, okay, and all we're interested in is
11 monthly.

12 Q. The training was based on pumping
13 schedule data after 1998, correct?

14 A. Yes, yes.

15 Q. And then the simulated is the pumping
16 schedule from 1953 to 1987, right?

17 A. It would go through '98, actually. I
18 mean, for -- Hadnot Point/Holcomb Boulevard didn't
19 come online until '72, so you have different
20 periods there, but, yes, it would -- that's the
21 predictive period, is where you had either limited
22 -- because you might have a month information here
23 and there and stuff like that, but that's -- or
24 unknown information that you would use the
25 predictive values that came out for each well, each

1 certain well.

2 Q. Let's turn to page S12.

3 A. Okay. Okay.

4 MR. DEAN: S2.12 or just S12?

5 MR. ANWAR: I'm sorry. It's S2.12.

6 MR. DEAN: Okay.

7 MR. ANWAR: I've been staring at these
8 documents too long.

9 BY MR. ANWAR:

10 Q. And at the top of the left-hand --

11 A. Right.

12 Q. -- page it says, historical
13 reconstruction period, 1942 to 2007, prediction
14 process, correct?

15 A. Right.

16 Q. And this is the -- the training and the
17 -- this -- this paragraph in this section is
18 addressing the training and the prediction process
19 you were just describing, correct?

20 A. I believe it is. This shows the start
21 of prediction process. There should be another
22 flow chart somewhere, I seem to recall.

23 Q. I wanted to just ask you about some of
24 the language in the first paragraph.

25 A. Okay. Sure, sure. Go ahead.

1 Q. It says, "similar to the training
2 process, the prediction process, PP, is structured
3 as a series of calculations and checking steps.
4 The results of the steps were placed in separate
5 sheets of a Microsoft Excel workbook." And then
6 that last sentence, "because some wells did not
7 physically exist during the training period,
8 surrogate wells were selected to represent these
9 untrained wells." Did I read that correctly?

10 A. Yes, yes.

11 Q. And so you would agree in the training
12 process for reconstructing historical well pumping
13 schedules, ATSDR used surrogate wells for wells
14 that were untrained?

15 A. No, for wells that -- wells that did
16 not physically exist, okay? If you look at Figure
17 S2.2 on page S2.4.

18 Q. 2.4?

19 A. Yes. It's a full-page figure.

20 Q. Okay. Oh, I see. It's 2.4 --

21 A. S2.4, Figure S2.2.

22 Q. Okay. Yeah, I'm looking at 2.40. Go
23 ahead.

24 A. Okay. For example, you can take an
25 example here, let's just look at -- coming down,

1 HP604, okay? It stops operations at about 1960,
2 but then you've got HP637. So HP604 may be -- or
3 HP637 may be a surrogate well because HP604 no
4 longer exists. And I think we list the --
5 somewhere in here there's a table -- oh, there you
6 go. The surrogate wells, okay. Table S2.2 on page
7 S2.13, there's a list.

8 Q. Okay. So --

9 A. And looking at those wells and looking
10 at that figure, you can see which wells were
11 surrogate for wells that were no longer operating.

12 Q. On S2.13.

13 A. Yes.

14 Q. Table S2.2.

15 A. Right.

16 Q. Just looking at that, the surrogate
17 wells include -- let me double-check. Surrogate
18 wells were used for HP651, HP634, HP602, HP603 and
19 HP608, right?

20 A. 608, yes.

21 Q. You would agree that ATSDR modeled
22 reconstructed pumping schedules for these wells --
23 strike that.

24 Okay. You would agree that ATSDR
25 modeled reconstructed pumping schedules for these

1 wells based on 1998 to 2008 pumping schedules for
2 different wells, correct?

3 A. Say that -- say that again.

4 Q. Sure. So a moment ago we talked -- you
5 know, we -- we went through a list of the wells,
6 651, 634, 602, 603, 608, for which surrogate wells
7 were -- were used, right?

8 A. Yes.

9 Q. And to determine the pumping schedule
10 for these wells, 651, 634, 602, 603, 608, ATSDR
11 reconstructed the pumping schedule for surrogate --
12 based on surrogate wells from 1998 to 2008,
13 correct?

14 A. Yes.

15 Q. Okay.

16 A. That was the training period.

17 Q. Let's go back to Exhibit 10, which is
18 Chapter A for Hadnot Point/Holcomb Boulevard.

19 A. Okay. I'm right here. Yes.

20 Q. Give me a second and I will catch up
21 with you. Turn to page A84, please.

22 A. Okay. A84. Okay. Where it says
23 "trichloroethylene source release date sensitivity
24 analysis?"

25 Q. Correct.

1 A. Okay.

2 Q. So this is a discussion in Chapter A
3 for Hadnot Point/Holcomb Boulevard about TCE's
4 source release date and the sensitivity analysis
5 that was performed, correct?

6 A. Yes.

7 Q. Okay. So I wanted to start by reading
8 from that first paragraph on the left.

9 A. Okay.

10 Q. Which starts, "historical records
11 delineating the timing and volume of inadvertent
12 releases of solvents during routine -- routine
13 operations from leaking" -- it says "UST". Those
14 are underground storage tanks, right?

15 A. That's correct.

16 Q. Okay. "From leaking UST systems or
17 from disposal solvent waste, spent dry cleaning
18 filters or other materials, were not available for
19 the Hadnot Point/Holcomb Boulevard study area."
20 Did I read that correctly?

21 A. Yes.

22 Q. "For modeling purposes, a median source
23 release date of nine years from the date of the
24 underground storage tank system installation or
25 site development, in the case of the HPLF area",

1 which is a Hadnot Point landfill area, "was used in
2 the contaminant fate and transport models." Did I
3 read that correctly?

4 A. Yes.

5 Q. "This source release date formulation
6 is consistent with empirical data indicating that
7 the median time frame for leak development in
8 underground storage tank systems, typically in
9 piping and joint components, is nine years from
10 installation date." And there's a source to an EPA
11 document and another cite source. Did I read that
12 correctly?

13 A. That is correct.

14 Q. Okay. Then it goes on to state, "UST
15 systems were not the source of contaminants in the
16 Hadnot Point landfill area. However, given the
17 lack of historical information, a similar source
18 release time frame, in this case seven years from
19 site development, was applied to the Hadnot Point
20 landfill area sources within the model." Did I
21 read that correctly?

22 A. Yes.

23 Q. Would you -- you'd agree, based on this
24 paragraph, that historical records delineating or
25 providing information about the time and volume of

1 solvent contaminant releases from underground
2 storage tank systems, disposal of solvent waste,
3 spent dry cleaning filters or other materials
4 wasn't available for the Hadnot Point area?

5 A. That is correct. And that is why we
6 went to external references or other references
7 like the ones that we -- we cited, the EPA report
8 '6/'87 and the Gangadharan, et al., '87. I think
9 they discussed something like over 12,000 tanks
10 that they analyzed that -- and so we -- we felt
11 that was a good source of information to use.

12 Q. ATSDR -- still based on this paragraph,
13 you would agree ATSDR, the Hadnot Point/Holcomb
14 Boulevard model, assumed all underground storage
15 tank systems began releasing contaminants nine
16 years after the system was installed, right?

17 A. It's -- typically it was the piping
18 joints, okay? I think we say in there the actual
19 tank did not necessarily leak, but it was at the
20 pipe joints because of the construction methods
21 back then in the '40s and '50s and '60s, unlike
22 today where you have to have a concrete pad, solid,
23 and then you put the tank on. They just dug the
24 hole, put the tank on, then when they -- and
25 connected the pipes. And when the tank filled up,

1 then the pipes flexed, and that's where you got the
2 leakage.

3 Q. So it -- ATSDR, the Hadnot
4 Point/Holcomb Boulevard model assumed that the
5 piping joints for underground storage systems began
6 releasing contaminants nine years after
7 the systems --

8 A. Yes, based -- based --

9 Q. -- were installed?

10 A. -- on the references that we cited.

11 Q. Okay. And as you indicated, based on
12 references, that was based on an EPA study on
13 underground storage tank system leaks, that
14 following nine years was the median time frame for
15 leak development?

16 A. Yes.

17 Q. ATSDR assumed contaminant sources in
18 Hadnot -- in the Hadnot Point landfill started
19 seven years --

20 A. Yes.

21 Q. -- after site development, right?

22 A. Yes.

23 Q. Okay.

24 A. That's because the landfill, to our
25 knowledge, was unlined and it was not tanks. It

1 was just disposal of landfill material,
2 contaminated landfill material.

3 Q. And it was necessary to make these
4 assumptions about sort of the contaminant start
5 dates because the information of when the
6 underground storage tanks and the Hadnot Point
7 landfill began releasing contaminants, that's not
8 available, right?

9 A. You're talking about the Hadnot Point
10 industrial area or the landfill?

11 Q. Well, let's -- let's break them up.

12 A. Okay.

13 Q. So the assumption was made about
14 underground storage tanks systems beginning to
15 release contaminants nine years after the system
16 was installed, right?

17 A. Yes, that would be the Hadnot Point
18 industrial area.

19 Q. And -- but that's because -- and that
20 assumption was made because the data available
21 precisely identifying or pinning down when the
22 underground storage tanks began releasing
23 contaminants does not exist?

24 A. That is correct.

25 Q. Okay. And the same is true for the --

1 the Hadnot Point landfill assumption, correct?

2 A. Right. And we used a shorter time
3 period, again, because there were not underground
4 storage tanks, per se. It was a landfill, most
5 likely unlined, okay, and not individual tanks, but
6 just waste thrown or disposed of into the landfill.
7 So we assumed it would have a, you know, two-year,
8 short period until it started leaking for the
9 modeling purposes.

10 Q. But -- okay. Understood. But in terms
11 of real-world data, in terms of the actual data,
12 precisely pinning down when the Hadnot Point
13 landfill started releasing contaminants, that
14 doesn't exist, right?

15 A. Not to my knowledge, but that, again,
16 is part of the model -- model calibration process,
17 okay? That makes the source, then, a calibration
18 parameter both in terms of strength and in terms of
19 duration.

20 Q. Okay. And if -- turning to the next
21 page, A85.

22 A. Yes.

23 Q. That's the calibration you're -- you're
24 referencing, right?

25 A. That's a sensitivity -- you're in the

1 sensitivity analysis section, which is part of the
2 uncertainty analysis. We wanted to see the impact
3 of varying, again, the source release date.

4 Q. And that's what I meant. So this -- as
5 I read the sensitivity analysis, you varied the
6 release source -- the source release date from a
7 period of -- let's see -- minus nine years, meaning
8 nine years before the calibrated source release
9 date, to plus nine years, meaning nine years after
10 the calibrated release source date, correct?

11 A. That is correct.

12 Q. And in all of these scenarios, nine
13 years before the release -- calibrated source
14 release date, the model was still able to -- well,
15 strike that.

16 Well, can you remind me, what was the
17 calibrated source release date?

18 A. Hold on. Let me see. I have to go
19 back to off the top of my head. Well, the model
20 started in 1942 for Hadnot Point.

21 Q. Sure.

22 A. Hadnot Point landfill industrial, 1942,
23 I believe. So nine -- nine years after that would
24 be 1951, so that would be the calibrated.

25 Q. Okay. I've got you. Let's -- looking

1 -- returning back to the sensitivity analysis.

2 A. Okay.

3 Q. As -- you agree that this shows the
4 effect of the calibrated model of varying the start
5 date of contaminant sources, right?

6 A. Yes. What it does not show, as any
7 sensitivity analysis, it doesn't show whether
8 that's realistic or not. These are numerical,
9 okay? In other words, it just shows numerically
10 how the concentrations would shift forward or
11 backwards depending on the release date.

12 Q. In all of these scenarios, nine years
13 earlier than the calibrated source release date --

14 A. Right.

15 Q. -- five years earlier than the
16 calibrated source release date, the actual
17 calibrated source release date, which I see there,
18 it appears to be 1951, 1952?

19 A. Yeah, that's what we said, yeah.

20 Q. Yeah. Five years after the calibrated
21 release source date --

22 A. Right.

23 Q. -- nine years --

24 A. Right.

25 Q. -- after the calibrated release source

1 date, they all seem to converge during the period
2 of the epidemiological study. Do you see that?

3 A. Yes.

4 Q. And so based on the sensitivity
5 analysis, it's possible any one of these ranges
6 could have been the release source date?

7 A. No, because we assumed, as we did with
8 Tarawa Terrace, that we had a -- the calibrated
9 parameters would be your most likely to have
10 occurred, okay? And then these others are just
11 seeing the impact on -- on the model, I mean,
12 that's, you know, a five-year or nine-year change
13 is a pretty major, major change --

14 Q. Don't these --

15 A. -- of the release date, okay, so -- but
16 the most likely one is the calibrated one. I think
17 that's important to understand.

18 Q. I understand that the -- the most
19 likely is the -- you know, it's your opinion the
20 most likely --

21 A. Yes.

22 Q. -- is the calibrated?

23 A. Yes.

24 Q. But doesn't the sensitivity analysis
25 show that plus or minus nine years or five years

1 from the calibrated source release date, that it's
2 possible?

3 A. It's a possibility.

4 MR. DEAN: Object to the form.

5 THE WITNESS: It's a possibility, but,
6 again, that's -- typically, when you're conducting
7 sensitivity analyses and uncertainty analyses, you
8 want to get an understanding of how the system is
9 reacting to changes in -- in this case, it's a
10 single parameter.

11 Q. I'm going to mark another exhibit.

12 (DFT. EXHIBIT 17, Analyses and
13 Historical Reconstruction of Groundwater Flow,
14 Contaminant Fate and Transport, and Distribution of
15 Drinking Water Within the Service Areas of the
16 Hadnot Point and Holcomb Boulevard Water Treatment
17 Plants and Vicinities, U.S. Marine Corps Base Camp
18 Lejeune, North Carolina, Chapter C: Occurrence of
19 Selected Contaminants in Groundwater at
20 Installation Restoration Program Sites, was marked
21 for identification.)

22 BY MR. ANWAR:

23 Q. I'm handing you what I'm marking as
24 Exhibit 17.

25 A. Chapter C. Okay.

1 Q. This is Chapter C for the Hadnot
2 Point/Holcomb Boulevard analysis, correct?

3 A. That's correct.

4 Q. I would like you to turn to C98.

5 A. C98. Okay. Well, okay. Let's -- let
6 me rearrange the clip so I can...

7 Q. What's that?

8 A. Let me rearrange the clip.

9 Q. Sure.

10 A. Okay. C98. Okay. Table C8.

11 Q. Yes, Table C8. And Table C8 is
12 entitled -- or titled "summary of analysis for
13 benzene, toluene, ethylbenzene and total xylene and
14 water samples collected at Hadnot Point water
15 supply wells, Camp Lejeune", right?

16 A. Right.

17 Q. Okay. I wanted -- directing your
18 attention to HP602.

19 A. Okay.

20 Q. It has concentrations there for one,
21 two, three, four, five, six, seven, eight dates
22 there between 1984 to 1981, correct?

23 A. Yes, with two below detection limits.

24 Q. Correct, so two below detection limits
25 for HP602?

1 A. Yes.

2 Q. And then the other five above detection
3 limits with some value?

4 A. No, there's six.

5 Q. Oh, there's six. Excuse me.

6 The other six are above the detection
7 limit with some value and they are all ranging from
8 1984 to 1991, correct?

9 A. That is correct.

10 Q. And it appears five of the samples, the
11 -- for benzene there at HP602 are from '84?

12 A. Is that a question? I'm sorry.

13 Q. Yeah, is that right?

14 A. Okay. I've got one from '84, one, two,
15 three, four. Four above detection limits are from
16 1984.

17 Q. Okay. And then there's one from '85,
18 one from '86, then one from '91, correct?

19 A. Yes, that's correct.

20 Q. And then if we go down to HP608.

21 A. Okay.

22 Q. There are four samples between '84 and
23 '86, correct?

24 A. Yes.

25 Q. And one appears to be below the

1 detection limit?

2 A. Right.

3 Q. Okay. You would agree that this table,
4 it summarizes the measurements of benzene at the
5 Hadnot Point water supply -- water supply wells,
6 right?

7 A. Yes.

8 Q. And agree that benzene -- you would
9 agree that benzene at the Hadnot Point source wells
10 found only benzene above the detection limit at
11 HP602 and HP608, correct?

12 A. 608, yes. Let me -- 608, that's
13 correct, and then -- yes, above -- yeah, above the
14 detection levels, yes.

15 Q. And the samples at 602, the
16 concentration levels of benzene and the samples at
17 602 are much higher than the samples at 608, right?

18 A. Yes.

19 Q. For instance, the highest sample there,
20 at 602, is 720 micrograms per liter, right?

21 A. Yes.

22 Q. And the highest sample at 608 appears
23 to be four micrograms per liter?

24 A. Yeah, yes.

25 Q. Okay. So you would agree that the

1 driving source of benzene contamination at the
2 Hadnot Point water treatment plant was HP602,
3 right?

4 A. I would actually like to look at my
5 graphs here because we really need to look at --
6 okay. Benzene. HP602, yes.

7 Q. That was the --

8 A. Yes.

9 Q. -- driving source of benzene
10 contamination for that Hadnot Point water treatment
11 plant, right?

12 A. That's -- that's the measured data that
13 we have, so yes.

14 Q. Okay.

15 A. Based -- based on the measured data.

16 Q. Okay.

17 A. And the -- and the supply list.

18 Q. Let's turn back to -- I'm jumping
19 around a little bit -- Chapter A for Hadnot Point,
20 which is Exhibit 10.

21 A. For Hadnot Point? Yeah, I've got it
22 right here.

23 Q. Actually it's Supplement 1 for --

24 A. Okay. I don't have Supplement 1. I've
25 got Supplement 2 that you gave me.

1 Q. Okay. Let me mark it, then.

2 THE VIDEOGRAPHER: Sir, I'm going to
3 need to change the media when you get to a stopping
4 point.

5 MR. ANWAR: Sure. Let's stop right
6 now.

7 THE VIDEOGRAPHER: All right. Going of
8 record. The time is 3:59 p.m.

9 (A recess transpired.)

10 THE VIDEOGRAPHER: Okay. We are going
11 back on record. The time the 4:10 p.m.

12 BY MR. ANWAR:

13 Q. We are back on the record from a short
14 break, Mr. Maslia. Are you okay to continue?

15 A. Yes.

16 Q. Okay. Did you speak with your counsel
17 outside or during the break?

18 A. No, I did not.

19 Q. Okay. Thank you.

20 I'm handing you what I'm marking as
21 Exhibit 18.

22 (DFT. EXHIBIT 18, Analyses and
23 Historical Reconstruction of Groundwater Flow,
24 Contaminant Fate and Transport, and Distribution of
25 Drinking Water Within the Service Areas of the

1 Hadnot Point and Holcomb Boulevard Water Treatment
 2 Plants and Vicinities, U.S. Marine Corps Base Camp
 3 Lejeune, North Carolina, Chapter A-Supplement 1,
 4 Descriptions and Characterizations of Data
 5 Pertinent to Water-Supply Well Capacities,
 6 Histories, and Operations, was marked for
 7 identification.)

8 BY MR. ANWAR:

9 Q. Okay. This is Chapter A, Supplement 1
 10 for the Holcomb Boulevard/Hadnot Point analysis --
 11 or the Hadnot Point/Holcomb Boulevard analysis.

12 A. Right, that's correct.

13 Q. And it's titled "descriptions and
 14 characterizations of data pertinent to water-supply
 15 well capacities, histories and operations", right?

16 A. Yes.

17 Q. Okay. If you could turn to page S117.

18 A. Okay. I'm there.

19 Q. S117 is a figure for well HP602, right?

20 A. It's a table, yes.

21 Q. Table. You'd agree that this table
 22 shows what ATSDR concluded about HP602 operating
 23 history and capacity history, right?

24 A. Yes.

25 Q. Okay. You'd agree that well HP602 had

1 a relatively small capacity, right?

2 A. I would say -- I would say it'd
3 probably have an average capacity. I mean, there's
4 some -- like 69 goes down to 50 or 30, it looks
5 like. They then redeveloped the well. So I would
6 say it's average. It's average capacity.

7 Q. If you compare it to HP well 608 on
8 page S126.

9 A. HP608. Okay.

10 Q. Would you agree that the capacity for
11 well HP602 was less than, generally speaking, the
12 capacity for well HP608?

13 A. Yes.

14 Q. And focusing back on HR602 on S117.

15 A. Okay.

16 Q. Would you agree that the capacity
17 fluctuated significantly?

18 A. Yes, it fluctuated.

19 Q. Okay. And it fluctuated in a range
20 from 30 GPM on September 4th, 1969 --

21 A. Right.

22 Q. -- to 154 GPM on October 24, 1984,
23 right?

24 A. Yes.

25 Q. Looking at the table for HP602, you

1 would agree that HP602 was out of service multiple
2 times, correct?

3 MR. DEAN: Object to the form.

4 THE WITNESS: No, it's only out of
5 service one, two, three -- three times.

6 BY MR. ANWAR:

7 Q. I see -- it was out of service April of
8 1979?

9 A. Yes, that's one. Oh, out four times.
10 Out.

11 Q. It was out of service in October of
12 1981?

13 MR. DEAN: Which well? 60 --

14 THE WITNESS: 602.

15 MR. DEAN: Okay.

16 BY MR. ANWAR:

17 Q. You agree with that?

18 A. Yes, yes -- well, no, it says out.
19 Again, these records are directly from either the
20 water utility at Camp Lejeune or the well driller
21 or whatever. So it says out. It does not say out
22 of service. I don't know if that means -- if that
23 means it was just out on that date or whatever, but
24 the rest of them say out of service.

25 Q. Okay. It was -- it says out of service

1 on October 1981, correct?

2 A. Yes.

3 Q. So there's an October 1981 that says,
4 quote, out, and then the following entry on the
5 table is October 1981, out of service, right?

6 A. Yes, to me indicates we had, at least
7 on that one, a multiple record or two different
8 sources of records.

9 Q. And then November 30th, 1984, it was
10 out of service as well, right?

11 A. Yes.

12 Q. So it was out of service at least three
13 times, correct?

14 A. Yes.

15 Q. And then as of November 30th, 1984, it
16 was permanently closed or terminated, right?

17 A. Well, service was terminated and then
18 abandonment would be in '94, permanently closed.

19 Q. What -- what do you understand the
20 distinction to be between service terminated and
21 abandoned?

22 A. Service terminated would indicate they
23 just stopped using it, but it might still be
24 available for emergency purposes, whereas,
25 abandonment would mean that they would, I would

1 say, pull the well screen out, pull the pump out,
2 and maybe they seal it up with bentonite, concrete,
3 the hole up.

4 Q. Okay.

5 A. That's the difference. There's an
6 example for -- at Tarawa Terrace for TT23 that --
7 it says it was out of service, but, in fact, we
8 have records that show during April of '85 they
9 actually used it because they were short of water,
10 okay? So unless it's abandoned, the well casing
11 pulled and then concrete up -- that's what service
12 terminated means to me, is that it's not being
13 used.

14 Q. Okay. Based on the information in the
15 table, which I assume comes from the available
16 data, HP602 wasn't used after November 30th, 1984,
17 right?

18 A. That's what that indicates.

19 Q. Okay.

20 A. We have no -- no data between -- or
21 there's -- yeah, no data listed in the table
22 between -- after November 30th, 1984 and June 1994.
23 So just looking at those two pieces of data, it's
24 terminated in '84 and then abandoned in '94.
25 There's no indication on here as to whether it was

1 used for emergency purposes or other things like
2 that.

3 Q. Okay.

4 A. Which is always a possibility with a
5 well that's not abandoned.

6 Q. Turning the page back to S16 -- excuse
7 me, S126. Looking at the table on HP608.

8 A. Yes. Okay.

9 MR. DEAN: S?

10 THE WITNESS: 26. 1.26.

11 MR. DEAN: I guess I don't have that
12 one.

13 THE WITNESS: Is this Supplement 1?

14 BY MR. ANWAR:

15 Q. You'd agree that ATSDA -- ATSDR
16 determined capacity of HP608 ranged from 115 GPM to
17 230 GPM?

18 A. Yes.

19 Q. And as we discussed a few moments ago,
20 compared to 60 -- HP602 --

21 A. Wait. Hold on just a second. It
22 continues on page S127. It's got a capacity of 226
23 on 1983 -- March 21st, 1984.

24 Q. I see that. So my question was, do you
25 agree that the range for -- ATSDR determined the

1 capacity of HP608 to be in the range of 115 GPM on
2 the low end and 230 GPM on the high end?

3 A. Yes.

4 Q. And --

5 A. I just wanted to make sure we had the
6 full table in front of us.

7 Q. No, I appreciate that. Compared to --
8 and we discussed a moment ago, and you're welcome
9 to turn back to look if you would like, but for
10 HP602 the range was 30 GPM to 154 GPM?

11 A. Yeah, that's correct.

12 Q. Okay. You agree that the table on --
13 for HP608 on page S127 shows that service was
14 terminated for HP608 on December 6, 1984, correct?

15 A. Yes, that's what it states.

16 Q. Okay. I would like to turn back to
17 Chapter C.

18 A. Chapter C. Okay.

19 Q. For the Hadnot Point/Holcomb Boulevard
20 analysis.

21 A. Yes. Okay. Chapter C.

22 Q. If I could direct you to page 108.

23 A. 108. Okay.

24 Q. Page C108, there's a Table C12 on it,
25 right?

1 A. Yes.

2 Q. Okay. So there are three entries
3 there, November 19, 1985, where benzene was
4 detected at 2500 micrograms per liter, right?

5 A. Yes.

6 Q. And then there's an entry December 10,
7 1985 where benzene was detected, 38 micrograms per
8 liter, right?

9 A. Yes.

10 Q. And then there is an entry just below
11 it, December 18, 1985, where benzene was detected,
12 one microgram per liter, right?

13 A. That's correct.

14 Q. Okay. Outside of those three entries
15 in November 1985 and December 1985, according to
16 this table, benzene was never detected above the
17 detection limit at the Hadnot Point water treatment
18 plant, right?

19 MR. DEAN: Object to the form.

20 THE WITNESS: Based on the sample data?
21 We're talking about the data in this table?

22 BY MR. ANWAR:

23 Q. Yeah.

24 A. With the exception of those three
25 readings that you cited, everything else was below

1 the detection limit.

2 Q. And just for the record, the -- we're
3 looking at Table C12. It's entitled "summary of
4 analyses for benzene, toluene, ethylbenzene and
5 total xylene in water samples collected at the
6 Hadnot Point water treatment plant at Camp
7 Lejeune", right?

8 A. Yes.

9 Q. Okay. So these are samples collected
10 at the Hadnot Point water treatment plant?

11 A. Right.

12 Q. Okay. And so a moment ago -- so for --
13 still focusing on C12 on -- Table C12 on
14 November 19, 1985, December 10, 1985, and
15 December 1985. Do you see that?

16 A. Yes.

17 Q. A moment ago we looked at tables with
18 the operating and pumping histories for HP602 and
19 HP608. Do you recall that?

20 A. Yes.

21 Q. So at the time of these three
22 detections for benzene, HP602 and HP608 were shut
23 down, right?

24 MR. DEAN: Object to the form.

25 THE WITNESS: I need to -- let's see.

1 Supplement 1, I'm guessing, yeah.

2 BY MR. ANWAR:

3 Q. Yeah, and if you want to --

4 A. Share the dates.

5 Q. -- go look over it, it was -- the 608
6 is on S126 and 27.

7 A. Okay. November 19th, '85.
8 November 19th, '85.

9 Q. HP608 --

10 A. Yes, yes, it was not, according to this
11 table, not operating, not in service.

12 Q. Yeah. And according to the table, it
13 was terminated in December, December 6th, 1984,
14 right?

15 A. Right.

16 Q. So almost -- it had been shut down for
17 almost a year --

18 A. Right.

19 Q. -- by the time the benzene was
20 detected --

21 A. Uh-huh.

22 Q. -- at the Hadnot Point water treatment
23 plant, right?

24 A. That's correct.

25 Q. Okay. Then 602, which is page 17,

1 S117.

2 A. Okay. I'm there.

3 Q. And we discussed this service was
4 terminated November 30th, 1984?

5 A. Yes.

6 Q. And it, likewise, had been shut down
7 almost a year by the time benzene was detected at
8 -- above detection limits at the --

9 A. Right.

10 Q. Or strike that.

11 It too -- the HP602 was -- also had
12 been shut down in November 30th, 1984, which was
13 about a year after benzene was detected at the
14 Hadnot Point water treatment plant, correct?

15 A. No, we've got '85 at the water
16 treatment plant. Is that what you're speaking
17 with, the benzene detections at the water treatment
18 plant?

19 Q. Correct.

20 A. That was in November '85 and it says
21 service terminated November 30, 1984.

22 Q. So almost a year had passed, right?

23 A. Yes.

24 Q. Okay. Would you agree that -- well,
25 strike that. Let me ask it this way. Residual

1 benzene from HP602 or HP608 used -- before
2 December 1984 was not the source of benzene in the
3 November and December 1985 samples we just looked
4 at, right?

5 MR. DEAN: Object to the form.

6 THE WITNESS: Again, this well says
7 service terminated. There's always the possibility
8 that they were operated and not recorded as
9 operated. I'm saying we observed at that Tarawa
10 Terrace, but -- and for the 2500 part per billion,
11 if you go to the Chapter C report, it might be in
12 this report also, we noted that the base chemist,
13 Elizabeth Betz, noted on that one that it was not
14 representative, okay? She did not say -- the
15 samples don't say that that's not a valid sample.
16 It said it was just not representative.

17 And we actually had a phone interview
18 with her and there's some documentation, with
19 Elizabeth Betz, to ask her did that mean that
20 sample was, you know, not valid and all of that. I
21 asked the question and she answered to me that, no,
22 she just meant that benzene sample -- especially
23 benzene samples would go up and down, up and down
24 until there was no regularity to the
25 concentrations.

1 BY MR. ANWAR:

2 Q. Well, in that conversation, was she
3 referring to the 2500 micrograms per liter?

4 A. I specifically asked her about that,
5 yes.

6 Q. And your understanding is -- from her
7 is that that sample from Hadnot Point water
8 treatment plant was not representative?

9 A. Yes, but I asked her -- that's marked
10 on the JTC lab reports. It's not -- and it's also
11 marked in our Chapter C.

12 Q. Sure.

13 A. Just to be clear. And I asked her what
14 was meant or what was her understanding of not
15 representative, and she said that -- and it's
16 recorded in the notes or meeting notes that we had
17 with her, phone conference, that she meant that
18 there was just -- the benzene sampling data would
19 go up and down, up and down by a large amount, and
20 so that's why it was not representative. She did
21 not say -- I asked her and she said she -- because
22 I asked if she meant that she would consider that
23 sample or, you know, or it was an erroneous sample,
24 and she definitely said, no, she just -- her
25 meaning was that it was -- the sampling data went

1 high and low, high and low.

2 Q. As you sit here today, you don't have
3 any reason to believe that the residual -- residual
4 benzene from HP602 or HP608 used before December
5 1984 was the source of benzene samples in November,
6 December 1985?

7 A. We really did not do a residual
8 analysis and, as you know, benzene is a floater.
9 It floats on top of water, so like salad dressing
10 with oil and vinegar. When you shake it up, maybe
11 stir it up, and then it separates out. So we
12 really did not do a residual analysis to see you
13 know, that specificity.

14 Q. But you don't have any definitive data
15 demonstrating that it was residual benzene from
16 HP602 or HP608 used before December 1984 that was
17 the source of this November, December 1985 benzene
18 samples?

19 A. Well, we've got our reconstructed
20 values at the water treatment plant.

21 Q. Well, and we don't need to look at
22 those.

23 A. Okay.

24 Q. I'm just talking in terms of the
25 real-world data, not in terms of the model right

1 now.

2 A. Okay. So again, ask your question
3 again.

4 Q. Just some terms of real-world data, you
5 don't -- there isn't any real-world data available
6 or that exists demonstrating that HP602 -- residual
7 benzene from HP602 or HP 608 used before
8 December 1984, which is when those two wells
9 closed, was the source of the
10 November/December 1985 measurements in the Hadnot
11 Point water treatment plant?

12 A. I do not have data for those wells
13 after they went out of service.

14 Q. Now, Tarawa Terrace, if I remember
15 correctly, ATSDR didn't use nondetects in the
16 geometric bias; is that right?

17 A. What's published in the published
18 title, yes, that's correct, we did not ignore the
19 data. They're published in the table, but when we
20 went to compute the geometric bias, we did not
21 include the nondetects because there's a whole area
22 of analysis about nondetects value -- what value
23 should you include or what value should you assign
24 or not assign and things of that nature.

25 Q. And in the published data you didn't --

1 ATSDR didn't use nondetects in the geometric bias,
2 which was used to assess calibration, right?

3 A. That is correct.

4 Q. Okay.

5 A. But we did publish it in the tables
6 accompanying -- accompanying that, okay, for both
7 the wells and -- supply wells and the treatment
8 plant.

9 Q. And as I understand it, from the very
10 beginning of our conversation today, it sounds like
11 you've done some additional work with respect to
12 geometric mean -- or geometric bias?

13 A. Yes.

14 Q. Okay. And was that only for Tarawa
15 Terrace?

16 A. It was for Tarawa Terrace and I'd have
17 to look at my notes. I might have done it for the
18 Hadnot Point water treatment plant.

19 Q. That would be reflected in your notes?

20 A. Yes.

21 Q. And do you intend to offer that opinion
22 if called to testify at trial?

23 A. That we -- that I reassessed the
24 computation?

25 Q. Yes.

1 A. Yes. Well, I mean, I will defer to the
2 attorneys on that, but I have notes that I'll turn
3 over to the attorneys.

4 Q. Okay. How --

5 MR. DEAN: Well, I mean, you should
6 answer his question fully because you can update
7 and amend your opinions pursuant to the rules in
8 the deposition if he asked. So if you've completed
9 your answer, fine. If you didn't, finish answering
10 his question.

11 THE WITNESS: No. I mean, I looked
12 again, as we discussed earlier today, after reading
13 Dr. Konikow's report, and he discussed the issue of
14 using duplicate samples or triplicate samples
15 within the same day or same month when the model
16 results only provide you one value per month. So
17 then I went back and recomputed using that
18 approach. So if we had two samples in a month,
19 then I would take an average. If you had three, I
20 would take an average, so I would compare one to
21 one.

22 Q. Okay. I have to find my place again.
23 Okay. How did ATSDR assess calibration of the
24 Hadnot Point mixing model for benzene with only --
25 or primarily nondetect data points?

1 A. Let me get to Chapter C and in table --
2 on Table A18 on page A62, we've got supply well.

3 Q. Is this on Chapter A or Chapter --

4 A. Chapter A. I'm on Chapter A, yes.
5 Chapter A of Hadnot Point.

6 Q. Okay. What -- what page were you
7 looking at?

8 A. I was on page A62. Okay. I misspoke.
9 That was the water treatment plant, okay? We had
10 measured data and then we had reconstructed data.
11 So I may have computed a geometric mean just, like,
12 on scratch paper, but I did not publish it as part
13 of the Chapter A for Hadnot Point/Holcomb Boulevard
14 report.

15 Q. Why did you treat that differently than
16 for Tarawa Terrace?

17 A. I really don't -- don't know. I know
18 we were under a timeline crunch to get it out and
19 it just may have been that it was not -- that I
20 looked at -- I just looked at visually the values,
21 reconstructed versus measured, and said, you know,
22 that was, you know, provided a good fit. And also
23 looked at the wells on page -- well, they're graphs
24 and stuff like that, but also there's a table
25 earlier on. Somewhere there's a table. And just

1 said that I was satisfied with -- with the -- with
2 the fit or the goodness of fit of the calibrated
3 results with the available water treatment plant
4 data.

5 It was also -- with Tarawa Terrace we
6 had just PCE, okay, one constituent. Whereas here
7 we had multiple constituents and I may have -- I
8 said, well, maybe we need to look into each one
9 individually or something like that. It was a
10 little more complex computation, and so it did not
11 end up in -- in the published report.

12 Q. Would you agree that not assessing
13 geometric bias affects uncertainty and reliability
14 for the Hadnot Point model?

15 A. Not necessarily because, again,
16 geometric bias just gives me an estimate; is the
17 model way over or way under or it's in the
18 ballpark, okay? And again, I'm looking at the
19 plot. A graphic is just as good as a geometric
20 bias. A geometric bias is putting a quantitative
21 estimate on a graphic, okay? Had this graphic, and
22 so it was just a computation that was not done for
23 this -- this analysis. You can go back and -- and
24 do it. I mean, as I said, I've got my notes.

25 Q. Okay. If you could turn back to

1 Chapter C on page C106.

2 A. 106?

3 Q. Yeah.

4 A. 106. Okay. I've got it.

5 Q. On C106 there's a Table C11, right?

6 A. Yes.

7 Q. It states, "summary analyses for PCE,
8 TCE, 1-1-DCE, trans-1-2-DCE, 1-2-DCE" -- it says,
9 "1-2-DCE, total 1-2-DCE, and vinyl chloride in
10 water samples collected at the Hadnot Point water
11 treatment plant, Camp Lejeune", correct?

12 A. Yes.

13 Q. Okay. I just wanted to ask you a few
14 questions about this.

15 A. Sure.

16 Q. You'd agree that this table summarizes
17 measured PCE and degradation product observations
18 at the Hadnot Point water treatment plant?

19 A. Yes.

20 Q. You'd agree that vinyl chloride was
21 never detected above the reporting limit at Hadnot
22 Point water treatment plant?

23 A. There's -- on February '85 the value --
24 estimated value of 2.9.

25 Q. Where are you looking? February --

1 A. C11, February 5th, 1985 all the way
2 across the last column. It says 2.9J.

3 Q. Okay. Aside from that one time, would
4 you agree that vinyl chloride was not detected
5 above the detection limit?

6 A. Let me make sure this goes -- is this
7 the same -- Table C10, C11. You're just talking
8 about Table C11, right?

9 Q. Correct.

10 A. Yes, that would be --

11 Q. You would agree that aside from that --
12 that one time in -- on February 5th, 1985, that
13 vinyl chloride was never detected above the
14 detection limit?

15 A. Yes.

16 Q. And this is for that Hadnot Point water
17 treatment plant, right?

18 A. That's correct.

19 Q. Okay. And then you would agree that
20 DCE was rarely detected above the detection limit
21 at the Hadnot Point water treatment plant?

22 MR. DEAN: Object to the form.

23 THE WITNESS: No, where there's a
24 trans-DCE, 1-2-DCE on February 5th, again, 1985, of
25 150 micrograms per liter.

1 BY MR. ANWAR:

2 Q. So that's that one time?

3 A. Yes.

4 Q. Would you agree, aside from that one
5 time, that DCE was not detected above the reporting
6 limit at the Hadnot Point water treatment plant?

7 MR. DEAN: Object to the form.

8 THE WITNESS: Yes.

9 BY MR. ANWAR:

10 Q. Okay. Let -- jumping around. Let's
11 turn back to Chapter A for Hadnot Point/Holcomb
12 Boulevard.

13 A. Okay. Okay.

14 Q. I would like to direct your attention
15 to A46.

16 A. Page A46?

17 Q. Correct.

18 A. Okay.

19 Q. There are a series of graphs there
20 entitled Figure A18, correct?

21 A. A18, yes.

22 Q. And A18 is titled "reconstructed or
23 simulated and measured concentrations of TCE at
24 selected water supply wells within the Hadnot Point
25 industrial area." Did I read that correct?

1 A. Yes.

2 Q. Okay. And the wells reflected on these
3 graphs are HP602, HP608, HP634, and then there's
4 well HP601 and, slash, HP660, correct?

5 A. That is correct.

6 Q. Would you agree that these -- this
7 figure shows calibrated model values at HP well
8 601, 602, 608 and 634?

9 A. They show the -- yes, the red line is
10 the simulated values.

11 Q. Okay.

12 A. Or reconstructed values, and the black
13 dots are the measured.

14 Q. So the -- for instance, at HP602 there
15 are one, two, three, four, five, six measured
16 values reflected on the graph, right?

17 A. Yes.

18 Q. For HP601 it looks like there are three
19 measured values on the graph, right?

20 A. Yes, they are measured for HP660, which
21 was the replacement well.

22 Q. For 601, right?

23 A. Yes.

24 Q. For HP608, it looks like there are four
25 values reflected on the graph?

1 A. Yes.

2 Q. And for HP634 it looks like there is
3 one value reflected on the graph?

4 A. Yes.

5 Q. Those are the measured values we're
6 talking about, correct?

7 A. That is correct.

8 Q. And then the -- that red -- the red
9 line is what the model is simulating as estimated
10 concentrations?

11 A. Yes, that's correct.

12 Q. These graphs show some measured values,
13 but they show none of the nondetect values,
14 correct?

15 A. That's correct.

16 Q. And you would agree that if we turn to
17 -- you might keep this page open --

18 A. Okay.

19 Q. -- but also turn to Chapter C, C95.

20 A. Right. C95?

21 Q. Correct.

22 A. Okay. I'm there. Table C7.

23 Q. Yes.

24 A. Okay.

25 Q. C7, "summary of analyses, PCE, TCE, DCE

1 and vinyl chloride for water samples collected at
2 Hadnot Point water treatment plant", right?

3 A. Right.

4 Q. Okay. For HP634 there, there are four
5 values below the nondetect limit, right -- or
6 excuse me, there are four -- four nondetects?

7 A. In Table C9 -- I mean, on Table C7?

8 Q. Yes.

9 A. For 634 there's -- yes, that's correct.

10 Q. And if you go back and look at A46,
11 there's one measured value reflected there, right?

12 A. That's correct.

13 Q. But those -- those four nondetects are
14 not reflected?

15 A. That's correct. The issue with trying
16 to graphically represent nondetects gets back to
17 what value are you going to use. If we use the
18 detection limit, then someone can argue, well, you
19 don't know that definitively because it was
20 nondetect. If you want to use half the detection
21 limit, again, that's just an estimate. There are
22 some other complex methods where people -- Dennis
23 Helsel and others who have worked in the nondetect
24 area, that you can estimate and quantify the
25 nondetects, but for our purposes we used the

1 graphics in the reports as -- and companions to the
2 tables. So if someone wanted to see what all the
3 values were, they could go to the -- to the table
4 and see that we had nondetects and we also had
5 above detection limits.

6 Q. Okay. Let's -- let's look at -- and
7 let me mark it. Let's switch gears a little bit.

8 A. Okay.

9 Q. I'm going to hand you what I'm marking
10 as Exhibit 19.

11 (DFT. EXHIBIT 19, Analyses and
12 Historical Reconstruction of Groundwater Flow,
13 Contaminant Fate and Transport, and Distribution of
14 Drinking Water Within the Service Areas of the
15 Hadnot Point and Holcomb Boulevard Water Treatment
16 Plants and Vicinities, U.S. Marine Corps Base Camp
17 Lejeune, North Carolina Chapter A-Supplement 6,
18 Characterization and Simulation of Fate and
19 Transport of Selected Volatile Organic Compounds in
20 the vicinities of the Hadnot Point Industrial Area
21 and Landfill, was marked for identification.)

22 THE WITNESS: Okay.

23 BY MR. ANWAR:

24 Q. Here you go.

25 A. Supplement 6. Okay.

1 Q. Exhibit 19 is a Hadnot Point/Holcomb
2 Boulevard Chapter A-Supplement 6, right?

3 A. That is correct.

4 Q. Okay. And it's titled
5 "characterization and simulation of fate and
6 transport of selected volatile organic compounds in
7 the vicinities of the Hadnot Point industrial area
8 and landfill", right?

9 A. That is correct.

10 Q. Okay. Can I have you turn to page
11 S645?

12 A. Okay. 645. Okay.

13 Q. And S645 includes a discussion of --
14 it's entitled discussion and limitations, correct?

15 A. That is correct.

16 Q. And that's of the Hadnot Point/Holcomb
17 Boulevard analysis and model, correct?

18 A. Yes, yes.

19 Q. Okay. Looking over on the right-hand
20 side, second paragraph, it starts, "for contaminant
21 fate and transport modeling reported herein,
22 however, insufficient water quality data existed to
23 conduct a statistical analysis for assessment of
24 model calibration fit. In addition, specific data
25 pertinent to the timing of initial deposition of

1 contaminants to the ground or subsurface
2 chronologies of waste disposal operations such as
3 dates and times when contaminants were deposited in
4 the Hadnot Point landfill or descriptions of the
5 temporal variation of contaminant concentrations in
6 the subsurface generally are not available."

7 Did I read that all correctly?

8 A. Yes.

9 Q. Okay. And then it goes on,
10 "determining these types of source identification
11 and characterization data became part of the
12 historical reconstruction, whereby the contaminant
13 fate and transport model was used to test source
14 locations, varying concentrations, and beginning
15 and ending dates for leakage and migration of
16 source contaminants to the subsurface and the
17 underlying groundwater flow system." Did I read
18 that correctly?

19 A. That's correct.

20 Q. Okay. So then the next starts,
21 "conducting a robust uncertainty analysis using
22 Monte Carlo analysis requires simulating thousands
23 of realizations. When using available
24 computational equipment, the Hadnot Point
25 industrial area and the Hadnot Point landfill

1 models have a simulation time of about six to
2 eight hours for each simulation. The lengthy
3 simulation times and the substantial data
4 limitations therefore make a comprehensive
5 uncertainty analysis computationally prohibitive
6 based on available resources and time limitations.
7 Thus, the ranges of values presented in the
8 sensitivity analysis section of this report assess
9 a limited number of input and output model
10 parameters. The results, in other words, range of
11 concentration presented in the sensitivity analysis
12 reported herein, should not be considered or
13 interpreted as the results of a robust and
14 comprehensive uncertainty analysis, but do provide
15 insight into parameter sensitivity and uncertainty
16 in a qualitative sense."

17 Did I read that all correctly?

18 A. Yes.

19 Q. Based on the two paragraphs we just
20 read together, you would agree that ATSDR did not
21 conduct a statistical analysis to assess model
22 calibration and fit at Hadnot Point because there
23 wasn't sufficient water quality data, right?

24 MR. DEAN: Object to the form of the
25 question and misstates and mischaracterizes the

1 document.

2 THE WITNESS: I'm just seeing where we
3 said that on this -- I'm sure I'm --

4 MR. BELL: Are y'all allowed to have
5 candy bars?

6 MR. ANWAR: Sure.

7 MR. BELL: I know it's late in the day.
8 Someone said, well, don't give him anymore.

9 THE WITNESS: Yeah, it's -- as it
10 states in the report, insufficient water quality
11 data and the statistical analysis for assessment of
12 model calibration is not -- was not conducted,
13 okay? I believe they were referring to -- this was
14 the -- this was the groundwater flow -- the
15 contaminant fate and transport groundwater model,
16 not necessarily the mixing model and -- at the
17 Hadnot Point water treatment plant, okay? That may
18 have been able to have been computed.

19 BY MR. ANWAR:

20 Q. But you agree statistical analysis to
21 assess model calibration fit wasn't conducted
22 because -- because there was insufficient water
23 quality data, right?

24 A. Yes, that's what it says.

25 Q. Okay. And in this paragraph, when it's

1 referencing water quality data, you would agree
2 that means measurements of contaminant
3 concentrations, right?

4 MR. DEAN: Object to the form.

5 THE WITNESS: That's what I would
6 interpret it to mean.

7 BY MR. ANWAR:

8 Q. Okay. So earlier, just, I think, a few
9 minutes ago, we talked about geometric bias at the
10 Hadnot Point mixing model?

11 A. Right.

12 Q. Would you agree this says one wasn't
13 done?

14 A. Again, I'm looking at -- this is
15 strictly a groundwater contaminant fate and
16 transport. It would have been done or could have
17 been done in the summary chapter, Chapter A, but I
18 do not see it there, so it was not conducted.

19 Q. One was --

20 A. It was not computed. Let me just -- it
21 was not computed like it was computed for Tarawa
22 Terrace.

23 Q. One wasn't computed for the fate and
24 transport model for Hadnot Point, correct?

25 A. One was not computed for the water

1 supply wells at Tarawa Terrace -- let's go back.
2 We computed geometric bias for the water supply
3 wells and then we also computed a geometric bias
4 for the water treatment plant, okay? So Supplement
5 6 is strictly the groundwater flow model, so there
6 was not one conducted -- computed for the supply
7 wells at Hadnot Point and Holcomb Boulevard.

8 Q. Okay. I just want to make sure. There
9 was not one computed for the supply wells, correct?

10 A. That is correct.

11 Q. And would you agree there was not one
12 conducted for fate and transport?

13 MR. DEAN: Object to the form.

14 THE WITNESS: That would -- that would
15 be the supply wells.

16 BY MR. ANWAR:

17 Q. Okay. I've got you.

18 A. Okay. The fate and transport model,
19 you would pull out the concentrations at the well
20 locations.

21 Q. Okay. That's what I wanted to make
22 sure I understood. Thank you.

23 And so now kind of looking back at the
24 paragraphs we just read.

25 A. Okay. Hold on. Go back there.

1 MR. DEAN: Page 45, 645. I think
2 that's where...

3 THE WITNESS: Yeah, I'm there.

4 BY MR. ANWAR:

5 Q. It says, you'd agree, "that specific
6 data pertinent to the timing of initial deposition
7 of contaminants to the ground or subsurface
8 chronologies of waste disposal operations such as
9 dates and times when contaminants were deposited in
10 the Hadnot Point landfill or descriptions of the
11 temporal variation of contaminant concentrations in
12 the subsurface generally were not available at
13 Hadnot Point", right?

14 A. That's what it says, yes.

15 Q. Okay. And you agree that historical --
16 quote, historical reconstruction, as used in the
17 paragraphs, had to include testing source
18 locations, varying concentrations, and beginning
19 and ending dates for leakage and migration of
20 source contaminants to the subsurface and the
21 underlying groundwater flow system?

22 A. That would be the calibration process.

23 Q. You'd agree that a comprehensive
24 uncertainty analysis wasn't done at Hadnot Point
25 because, as it states in the paragraph, "lengthy

1 simulation times and substantial data limitations
2 were computationally prohibited" --

3 A. Yes.

4 Q. "Prohibitive."

5 A. Yes, that's what it says.

6 Q. ATSDR did a sensitivity analysis, but
7 it said, results should not be considered or
8 interpreted as results of a robust and
9 comprehensive uncertainty analysis, correct?

10 A. Yes.

11 MR. DEAN: Object to the form.

12 BY MR. ANWAR:

13 Q. And your answer was yes, right?

14 A. Yes, I'm confirming what -- you read it
15 from the report.

16 Q. It's the last sentence of the last
17 paragraph. So ATSDR did a sensitivity analysis,
18 but said its results should not be considered or
19 interpreted as the results of a robust and
20 comprehensive uncertainty analysis, right?

21 MR. DEAN: We can stipulate you read
22 that sentence correctly.

23 BY MR. ANWAR:

24 Q. And you agree with that, right?

25 MR. DEAN: Object to the form.

1 THE WITNESS: It can be considered
2 qualitative. That's what we say in here, okay? We
3 did conduct sensitivity analyses.

4 BY MR. ANWAR:

5 Q. Let's jump ahead -- or let's jump to --
6 back to Supplement 6 -- or we are on Supplement 6.

7 A. Yes.

8 Q. So let's turn to page 44, S6.44.

9 A. 44, okay.

10 Q. So the page before.

11 A. Okay.

12 Q. On page S6 there is a Figure S6.23,
13 correct?

14 A. Yes.

15 Q. And the figure is titled "variations in
16 reconstructed simulated finished water
17 concentrations of TCE derived using a Latin
18 hypercube sampling methodology on water-supply well
19 monthly operational schedules for Hadnot
20 Point/Holcomb Boulevard study area", correct?

21 A. Yes.

22 Q. Okay. This is the -- the -- the figure
23 for the uncertainty analysis on the Hadnot
24 Point/Holcomb Boulevard model, right?

25 A. Yes, at the water treatment plant.

1 Q. Okay. At the water treatment plant.

2 And agree that the results of this
3 uncertainty analysis at the Hadnot Point water
4 treatment plant where reconstructed monthly well
5 operations -- okay. Let me ask that again.

6 You agree that the results of the
7 uncertainty analysis here were -- for reconstructed
8 monthly well operations schedules were varied?

9 A. Yes.

10 Q. And this -- this reflects the -- the
11 water-supply well monthly operational schedules,
12 correct?

13 A. Yes.

14 Q. It's an uncertainty analysis about the
15 water-supply well monthly operational schedules,
16 correct?

17 A. That is correct.

18 Q. Okay. And the uncertainty analysis
19 shows -- the uncertainty analysis was varied,
20 right?

21 MR. DEAN: Object to the form.

22 THE WITNESS: I'm not sure I understand
23 what you mean by the uncertainty analyses was
24 varied.

25 BY MR. ANWAR:

1 Q. The results of the uncertainty analysis
2 were varied, correct?

3 MR. DEAN: Object to the form.

4 THE WITNESS: The results were not
5 varied.

6 BY MR. ANWAR:

7 Q. I thought a moment ago you agreed they
8 were varied.

9 MR. DEAN: Object to the form.

10 THE WITNESS: You asked me about the
11 water-supply wells.

12 BY MR. ANWAR:

13 Q. Okay.

14 A. That's the parameter that was varied.

15 Q. Okay. Understood. Ah, yeah. And
16 you'd agree -- so let me -- just so the record is
17 clean, agree this -- the -- this uncertainty
18 analysis at Hadnot Point is where reconstructed
19 monthly well operations schedules were varied,
20 correct?

21 A. Yes.

22 Q. Okay. Thank you. And you agree that
23 the results of this uncertainty analysis suggests
24 that changes in pumping schedules produce very
25 different modeled monthly mean contaminant

1 concentrations, right?

2 MR. DEAN: Object to the form.

3 THE WITNESS: There's variation from
4 the mean to the high or low.

5 BY MR. ANWAR:

6 Q. There's significant variation, right?

7 MR. DEAN: Object to the form.

8 THE WITNESS: I don't know if I would
9 call it significant. If you compare it to the data
10 spread, it's not -- it's greater than at Tarawa
11 Terrace.

12 BY MR. ANWAR:

13 Q. You agree it is greater than Tarawa
14 Terrace, right?

15 A. Yes, but we still considered it to meet
16 our modeling objectives.

17 Q. You'd agree this was a Monte Carlo
18 simulation like in Tarawa Terrace, but unlike
19 Tarawa Terrace, only the one input parameter, well
20 pumping schedule, was varied, correct?

21 A. It was a Latin hypercube sampling,
22 which is a variant of Monte Carlo simulation when
23 Monte Carlo simulation becomes computationally
24 prohibitive. So it is a Monte Carlo, but it's
25 Latin hypercube sampling.

1 Q. A moment ago we were talking about the
2 degree of variation. Would you agree that the
3 variation is hundreds of micrograms per liter?

4 A. Once -- you're talking about the
5 reconstructed results or the sampling data?

6 Q. The -- the reconstructed results.

7 A. Once HP651 kicks in, yes, after July --
8 I think June or July of '72.

9 Q. That's where you see the -- on the
10 figure, Figure S623, dot 23, it spike up, correct?

11 A. Yes.

12 Q. Now, looking at this Figure S6.23, you
13 would agree the gray line show all of the Monte
14 Carlo simulations drawn on the same chart?

15 MR. DEAN: Object to the form of the
16 question.

17 THE WITNESS: They -- they show all the
18 Latin hypercube sampling results on -- on this
19 graph.

20 BY MR. ANWAR:

21 Q. Why not show the 95 percent realization
22 balance like ATSDR did for Tarawa Terrace?

23 A. It was not -- with Latin hypercube you
24 -- you had -- in this case we used ten equal
25 subdivision or sampling points, okay? That's the

1 definition of Latin hypercube, is you have an equal
2 probability within each sampling domain, which we
3 had ten. And so it was just not possible to
4 compute a confidence limit, but -- using -- using
5 that approach.

6 Q. Okay.

7 A. But it did give us both a quantitative,
8 in terms of high/low, and qualitative feeling of
9 the model results at the water treatment plant.

10 Q. Got it. I think we are in the home
11 stretch, about 40 minutes left, probably 40, 45.
12 Why don't we take a quick five or five or ten. I
13 would like to take a look at my notes and --

14 A. Okay. Sure.

15 MR. ANWAR: Thank you.

16 THE VIDEOGRAPHER: Going off record.
17 The time is 5:10 p.m.

18 (A recess transpired.)

19 THE VIDEOGRAPHER: Okay. We are going
20 back on record. The time is 5:23 p.m.

21 BY MR. ANWAR:

22 Q. We are back on the record from a short
23 break. Mr. Maslia, are you okay to continue?

24 A. Yes, I am.

25 Q. Did you speak to your lawyers during

1 the break?

2 A. No, I did not.

3 Q. Okay. I may bounce around a little
4 bit. I wanted to ask you a few questions about
5 your rebuttal report, your opinions in your
6 rebuttal report. Dr. Spiliotopoulos pointed out,
7 for the Tarawa Terrace model, that the KD values
8 and the bulk density values for the calculation of
9 the retardation factor contained errors. Do you
10 recall that?

11 A. He pointed out that the bulk density
12 did.

13 Q. Okay. And my -- my understanding of
14 your opinions about that are essentially that you
15 don't dispute the error, but it doesn't, in your
16 opinion, change the analysis much; is that right?

17 A. It's not so much of an error. What was
18 used originally was the wet bulk density, and it
19 was pointed out to us in 2009, by one of the
20 experts on the Hadnot Point/Holcomb Boulevard panel
21 when we had sent the Tarawa Terrace report, that we
22 had a wet bulk density. So we went back and
23 changed that value and, of course, you've got to
24 understand is that in the contaminant fate and
25 transport equations, bulk density and distribution

1 coefficient are not included. What's included is
2 retardation factor, okay? And we originally had a
3 retardation factor of 2.93. So if we adjusted the
4 bulk density to drop down, that means we could
5 adjust KD up. They are compensating, okay, because
6 they are calibration -- KD is a calibration
7 parameter.

8 Q. Sure.

9 A. And that resulted in the exact same
10 retardation factor of 2.93, and it resulted in
11 identical to the decimal place concentrations that
12 we had published in the Chapter A report.

13 Q. Okay. And thank you for -- for
14 explaining that. The -- if I'm understanding your
15 testimony correctly, it's not so much that the --
16 the difference of opinion about bulk density or the
17 error, as Dr. Spiliotopoulos has described it,
18 doesn't exist; it's that it's offsetting such that
19 it doesn't impact the retardation factor?

20 A. That is correct.

21 Q. Okay.

22 A. Our retardation factor was consistent
23 -- it was identical to what it was in the published
24 report, okay, but it was also very consistent with
25 existing literature values as well for PCE in this

1 type of terrain.

2 Q. Now, the retardation factors -- excuse
3 me, the bulk density and the KD value used for
4 Hadnot Point and Holcomb Boulevard model or
5 analysis is different than the one for the Tarawa
6 Terrace model, is that --

7 A. I would like to just compare the two so
8 we're --

9 Q. Sure.

10 A. -- comparing apples to apples here. So
11 let get me to Hadnot Point. Okay. There's -- I'm
12 looking at page A41 for the Hadnot Point report.
13 Ah, here you go. So you asked about bulk density.

14 Q. Yeah, the -- let's start with bulk
15 density.

16 A. Well, yes, but, again, as I said, we
17 corrected the one that was in Chapter A once we
18 realized that was a wet bulk density. The
19 corrected value came very close to 46,700 grams per
20 cubic foot.

21 Q. Okay.

22 A. Which is what we used in the Hadnot
23 Point.

24 Q. But the values for the actual
25 calculation -- for the actual -- how you calculated

1 the retardation factor between Tarawa Terrace and
2 for Hadnot Point, can you direct me to the page
3 that you're looking?

4 A. Okay. I'm on page A41 of the Hadnot
5 Point/Holcomb Boulevard report.

6 Q. Sure.

7 A. And then also page A29 of the Tarawa
8 Terrace report.

9 Q. Okay. Okay. Let's come back to that.

10 A. Okay.

11 Q. I'm going to mark what is, I think,
12 Exhibit 20 now.

13 (DFT. EXHIBIT 20, letter dated February
14 21, 2007 from Morris Maslia to Dr. Leonard F.
15 Konikow Bates-stamped
16 CL_PLG-Expert_Konikow_0000000006 through
17 0000000021, was marked for identification.)
18 BY MR. ANWAR:

19 Q. Here you go. This -- the first page of
20 Exhibit 20 is dated February 21, 2007, correct?

21 A. Yes.

22 Q. And it is a letter from you to
23 Dr. Leonard Konikow enclosing feedback to comments
24 that Dr. Konikow had raised about the Tarawa
25 Terrace analysis, correct?

1 A. Yes, he was a peer-reviewer, external
2 peer-reviewer --

3 Q. Okay.

4 A. -- on that particular chapter for
5 Tarawa Terrace.

6 Q. Now, these -- these responses to
7 Dr. Konikow's concerns or what are identified as
8 major concerns were drafted by Bob Faye, correct?

9 A. Yes.

10 Q. Did you have a chance to review these
11 before they were sent out?

12 A. I -- I reviewed it. It's been a while
13 since I've seen these, but I did -- did review it.

14 Q. Would you have discussed the responses
15 with Bob Faye before they were sent back to
16 Dr. Konikow?

17 A. Not necessarily discussed it. If I had
18 an issue with the response, I may have talked to
19 him.

20 Q. Okay.

21 A. And asked him, but I typically -- my
22 approach was not to micromanage the modelers,
23 right? So since Bob Faye was the primary author on
24 Chapter F, I assume that's what this chapter is --
25 yes, then I would allow him to develop the

1 responses. And, of course, he was a subcontractor
2 to ATSDR through Eastern Research Group, so that's
3 -- that's who he would send the responses to and
4 they would provide me with a copy.

5 Q. Okay. So on -- let's call it the page
6 ending in Bates label 08.

7 A. Okay. Okay.

8 Q. Actually, let's go to 09.

9 A. Okay.

10 THE WITNESS: Do you need a copy? Do
11 you need a copy?

12 MR. DEAN: I have one.

13 THE WITNESS: Oh, okay. Okay.

14 BY MR. ANWAR:

15 Q. Number three, Dr. Konikow raised as a
16 major concern, "the reliability of the estimate of
17 the biodegradation rate constant based on the
18 assumption that concentration declines" -- excuse
19 me. Let me read that again.

20 Number three of Dr. Konikow's major
21 concerns reads, "the reliability of the estimate of
22 the biodegradation rate constant based on the
23 assumption that concentration declines observed at
24 one location over a period of several -- several
25 years can be explained solely by biodegradation."

1 Did I read that correctly?

2 A. Yes, you read that correctly.

3 Q. Okay. And it looks like Bob Faye's
4 response there was "the author never claimed that
5 the biodegradation rate computer using field data
6 was reliable or the sole reason for the observed
7 decline in PCE concentration." Did I read that
8 correctly?

9 A. Yes.

10 Q. Okay. Do -- do you agree with that
11 statement?

12 A. That's Mr. Faye's opinion as the person
13 who did the -- the model in response to
14 Dr. Konikow's question or comment, but, you know,
15 what is generally being said is that some of these
16 transport parameters, like biodegradation rate,
17 that's very limited field -- field data, and so,
18 you know, there could be any possibilities for the
19 decline in the concentration. And I think that's
20 what Dr. Konikow was raising as well.

21 Q. And the next sentence says, "rather,
22 the computed rate was presented as an approximate
23 value useful to begin model calibration." Did I
24 read that correctly?

25 A. Yes. And I would agree with that.

1 Q. So if you go on, the rest of it reads,
2 "well TT26 is located on a direct migration, slash,
3 advective pathway from the PCE source at ABC
4 One-Hour Cleaners." Did I read that correctly?

5 A. Yes.

6 Q. Do you agree with that?

7 A. Yes.

8 Q. Okay. And then it says, "to the extent
9 that migration of PCE mass towards and away from
10 supply well TT26 occurred at about equal rates
11 during 1985 to 1991, the computed degradation rate
12 of 0.00053 per day approximates a long-term average
13 degradation rate." Did I read that correctly?

14 A. Yes.

15 Q. It goes on to say, "on the other hand,
16 if a significant quantity of the PCE degraded in
17 the vicinity of supply well TT26 was replaced by
18 advection, then the degradation rate computed using
19 equation three is probably a minimum rate,"
20 correct?

21 A. Yes, that's what you read.

22 Q. Okay. And do you agree with that?

23 A. I agree with that concept, yes. He's
24 basically saying we had two data points at TT26 in
25 '85 and '91, and so that's what was used to compute

1 the initial -- to start model calibration.

2 Q. And then it goes on to say, "the report
3 does not state or indicate that the decline in PCE
4 mass at supply well TT23 is due entirely to
5 biodegradation rate -- biodegradation. Rather, the
6 report indicates that the computed first-order
7 degradation rate is an estimate used as a basis to
8 begin model calibration," correct?

9 A. Yes. It's important to understand that
10 the value that we ended up for the calibrated rate,
11 which is five times ten to the minus four per day,
12 0.0005, compares extremely favorably with the
13 values that Dr. Clement came up with in his model
14 for his paper.

15 Q. That who came up with?

16 A. Dr. Clement.

17 Q. Okay. And you're talking about the
18 Dover Air Force Base model?

19 A. Yes, yes, very similar lithology. We
20 did have a gravel zone in there, but, again, he
21 came up with -- I think it was somewhere around one
22 to four times ten to the minus four. I would have
23 to look at the paper and see.

24 Q. That's okay.

25 A. But that's, you know...

1 Q. I wanted to turn your attention to the
2 Bates page ending now in 15.

3 A. Yeah, could I just make sure I gave you
4 the right numbers?

5 Q. Sure.

6 A. Here we go. Okay. Here you go. The
7 estimated -- the field estimated apparent reaction
8 rates range from 3.5 to seven times ten to the
9 minus four per day for PCE, and we're smack dab in
10 the middle with five times ten to the minus four.

11 Q. Let's turn to the page ending in 15.

12 A. Okay.

13 Q. There is a comment about -- towards the
14 bottom of -- about mass loading. Starting page 59,
15 it says, "mass loading, disagree, see my comments
16 under major concerns item five. The reviewer seems
17 to assign a high degree of accuracy and credibility
18 to the PCE mass computation that is unwarranted."
19 Did I read that correctly?

20 A. Yes.

21 Q. And then it says, "as explained
22 previously, the computation of PCE mass was highly
23 interpretive and somewhat subjective process
24 frequently based on questionable data." Did I read
25 that correctly?

1 A. Yes.

2 Q. Do you agree with that?

3 A. Not necessarily. We had data from ABC
4 Dry Cleaners, PCE data, and we used a technique
5 that was published in Groundwater journal that's
6 documented in the Chapter E and the Chapter F -- F
7 report in -- the key fact takeaway, and I mentioned
8 this in -- I believe it was my expert report, is
9 that the mass computed using the field data and the
10 mass determined from the MT3DMS model were the same
11 order of magnitude, which gave us -- it's almost
12 another calibration check, okay?

13 Q. The comment goes on to say, "field data
14 applied to the PCE mass computation were limited
15 both spatially and vertically," right?

16 A. Right.

17 Q. And that's a true statement, right?

18 A. That is. They were limited, but they
19 were still field data available.

20 Q. And then, "the computation was
21 accomplished regardless of data limitations to
22 provide an estimate of a minimum mass loading rate
23 to begin model calibration." Did I read that
24 correctly?

25 A. Yes.

1 Q. Okay. Now, for the Tarawa Terrace
2 model, ATSDR assumed mass loading on January 1,
3 1953, correct?

4 A. That is correct.

5 Q. And I think, was it -- without pulling
6 up the report, was it 1300 -- or no, 1200?

7 A. That was the calibrated value, is 1200.
8 We started at 200. And again, that is a
9 calibration parameter that you're free to adjust
10 during the model calibration process. We're
11 adjusting, you know, conductivity. You're
12 adjusting reaction rate. You're adjusting a number
13 of parameters. And so it was adjusted and the best
14 fit value came up to, I believe, 1200 grams per
15 day.

16 Q. Okay. And I understand that DOJ's
17 expert has offered a -- well, let me -- let me ask
18 you this: You reviewed Dr. Spiliotopoulos's
19 report, correct?

20 A. Yes.

21 Q. Okay. And you saw that his opinion
22 that the -- the later start date for ABC Cleaners,
23 correct?

24 A. Right, correct.

25 Q. Of July 1954, correct?

1 A. That is correct.

2 Q. Okay. And in the ATSDR Tarawa Terrace
3 model, the start date was assumed to be January 1,
4 1953, correct?

5 A. That is correct.

6 Q. And on day one, the calibrated mass
7 loading rate is 1200 micrograms per liter, correct?

8 A. No, grams per day.

9 Q. Per day. I'm sorry.

10 A. Yeah, grams. The way it was input to
11 the model as a source loading rate, so it would be
12 grams per day.

13 Q. Thank you for that. It was assumed to
14 be a constant 1200 micrograms per day, correct?

15 A. The calibrated value.

16 Q. For Tarawa Terrace?

17 A. Yes.

18 Q. Okay. In the real world, if
19 contaminants on the surface were to start leaking,
20 would they immediately reach the aquifer?

21 A. They would within, in this case,
22 probably a couple of years.

23 Q. So in -- in -- for Tarawa Terrace it's
24 your opinion that whenever ABC Cleaners released
25 PCE into the -- onto the ground, it would have

1 taken a couple of years for it to reach the
2 aquifer?

3 A. To reach any of the supply wells
4 pumping. In other words, it would have gone
5 vertically horizontal and, of course, the -- say
6 TT26 is pumping, is putting tremendous gradient,
7 vertical gradient, down right near to the well, so
8 it would have fallen horizontal and then vertically
9 down into the well -- a well casing or a well
10 screen and been pulled -- pulled up. And the
11 assumption was, again, the engineering assumption,
12 that it started on January 1st, 1953 when ABC
13 Cleaners started operations.

14 Q. Okay. So you assumed the constant --
15 the calibrated constant mass loading rate on day
16 one, but you agree in the real world it may have
17 taken a couple of years for contaminants from ABC
18 Cleaner to actually get to the supply wells,
19 correct?

20 A. It may have, but we did not do -- you
21 would have to do an unsaturated zone modeling or
22 analysis to actually quantify that.

23 Q. Why did you-all decide to assume a
24 constant mass loading rate on day one?

25 A. Because if we did not assume a constant

1 value, that would be, to me, indicative that we
2 must have had some additional data to say that, you
3 know, it was a certain rate this day, a different
4 rate in another day, and so on. So we did not have
5 that information, so in keeping with accepted model
6 calibration practice, we assumed the constant rate
7 that we computed -- we computed initial, which was
8 a minimum value, and then through the calibration
9 process increased it using calibration to check
10 results for the available contaminant concentration
11 data at the wells.

12 (DFT. EXHIBIT 21, e-mail correspondence
13 Bates-stamped CLJA_Watermodeling_05-0000021184
14 through 0000021188, was marked for identification.)
15 BY MR. ANWAR:

16 Q. I'm handing you what I'm marking as
17 Exhibit 21.

18 A. Okay.

19 Q. I hope that's right, 21. We were just
20 talking about mass loading with respect to Tarawa
21 Terrace. I would like to shift gears to -- to sort
22 of mass loading with respect to Hadnot
23 Point/Holcomb Boulevard.

24 A. Okay.

25 Q. And this is an e-mail from Barbara

1 Anderson to you dated -- the first e-mail -- well,
2 I guess the chain, both of them, are dated
3 September 26th, 2011, correct?

4 A. It's September 26, 2011, yes.

5 Q. Okay. And this e-mail is discussing
6 mass loading of benzene, correct, or, I guess,
7 LNAPL, light non-aqueous phase liquid?

8 A. I believe this is discussing the LNAPL
9 that's dissolved because -- it says LNAPL on it, so
10 I'll leave it at that right now.

11 Q. The third paragraph states, "the first
12 scenario is a simple step function. The second
13 scenario incorporates some information we have
14 about the Hadnot Point fuel farm area and
15 conceptualizes the source strength LNAPL area as
16 increasing over time. In reality, the LNAPL
17 footprint grew and spread as the UST system leaks
18 and releases progressed. At some point in time the
19 LNAPL footprint grew to be the size that -- that GT
20 calculated from the free product data, 1988 to
21 1999, but it was not that size from the beginning
22 start date. This is shown in scenario two."

23 Did I read that correctly?

24 A. Yes.

25 Q. And do you agree with Barbara Anderson

1 that in reality the LNAPL footprint grew and spread
2 as the underground storage tank system leaks and
3 releases progressed?

4 A. Conceptually, yes, I would agree with
5 that.

6 Q. And scenario two shows a -- the leaks
7 and releases progressing over time, correct?

8 A. That is correct.

9 Q. Whereas, the scenario one is a step
10 function that shows immediate mass loading or
11 release right away, correct?

12 A. That is correct.

13 Q. And for the Hadnot Point/Holcomb
14 Boulevard model as it relates to LNAPL, ATSDR used
15 scenario one, correct?

16 A. I would have to go back and read -- the
17 LNAPL was rather complicated because we had the
18 folks at the multi-environmental simulations lab at
19 Georgia Tech looking at the volume and then the
20 movement within the saturated zone to the water
21 table. And then we had the other people, like
22 Barbara and Mr. Elliott Jones, who did the fate and
23 transport part, looking at it moving the water
24 table.

25 So I would have to go back and -- and

1 look at how each one characterized the mass loading
2 rate or the source -- source rate and -- but I know
3 Barbara was our data analyst, and I think the task
4 here was to look at two different
5 conceptualizations for how mass loading at the
6 Hadnot Point industrial area and fuel farm could
7 have occurred.

8 Q. Okay. And scenario two is more
9 realistic, right, in the real world?

10 MR. DEAN: Object to the form.

11 THE WITNESS: Again, that's -- I think
12 that's an data analysis engineering call as to what
13 it could be.

14 BY MR. ANWAR:

15 Q. Okay.

16 A. You know, where it's almost -- you'd
17 have to run a sensitivity analyses on here and see
18 which one provided you closer agreement.

19 Q. Okay. As you, Mr. Maslia, sit here
20 today, are you planning to amend or supplement your
21 expert report in the case?

22 A. Well, we mentioned about the geometric
23 bias. I don't know if that amends my report or --
24 and we included that extra paper reference --

25 Q. Okay.

1 A. -- from Clement, so that definitely, I
2 think, should be in there. And, you know, I don't
3 have any intentions of any major changes based on
4 additional modeling that I'm -- I'm doing. I'm not
5 planning on doing any.

6 Q. When you say no intent on major
7 changes --

8 A. Right.

9 Q. -- are you planning to -- and when I
10 say supplemental disclosure, are you planning to
11 provide, like, another written document with
12 additional or updated opinions --

13 MR. DEAN: So --

14 BY MR. ANWAR:

15 Q. -- major or minor?

16 MR. DEAN: Let me -- let me take over
17 here and answer for the witness, if it's okay. And
18 that is, as you know, DOJ recently belatedly
19 produced a bunch of photos from Dr. Hennet without
20 any sort of a disclosure of what it is. So we
21 can't respond to our experts until we sort of know
22 some explanation as to what that is. So that could
23 potentially, depending on Mr. Hennet's deposition,
24 trigger something from him, but he nor any of our
25 experts at this time can answer your question about

1 additional thoughts or opinions or whatever. And,
2 of course, there's been some correspondence about
3 this. Mr. Bain has sent a letter and we've
4 responded. So we just -- he's reserving that right
5 as to that stuff.

6 MR. ANWAR: Okay. Well, we will wait
7 to see -- we'll wait to receive the documents
8 related to the geometric bias and we will reserve
9 our right to keep the deposition open or to reopen
10 it. And I think I only have a few minutes left, so
11 thank you for your time. I'll reserve those final
12 minutes. Thank you for your time today.

13 THE WITNESS: Okay. Thank you.

14 MR. DEAN: Okay. Let's go off the
15 record, if it's okay, for maybe about ten minutes.
16 Take a break. Let me get my thoughts together.
17 I've got some questions. They won't be long, but
18 I've got a few questions.

19 THE VIDEOGRAPHER: Okay. Going off
20 record. The time is 5:56.

21 (A recess transpired.)

22 THE VIDEOGRAPHER: Okay. We are going
23 back on record. The time is 6:15 p.m.

24 EXAMINATION

25 BY MR. DEAN:

1 Q. All right. Mr. Maslia, I just have a
2 few questions, so I don't think we'll be long,
3 okay?

4 A. Okay.

5 Q. Oh, there we go. So earlier you were
6 shown Exhibit 9, which is the Chapter A Tarawa
7 Terrace report, and I want to ask you if you can
8 look at your version and turn to page -- I believe
9 it's A -- excuse me. You were shown Chapter C.

10 A. Hadnot Point?

11 Q. Hadnot Point, page C98. So it looks
12 like it's Chapter C.

13 A. Yeah, I'm trying to find...

14 Q. Can you tell me what that exhibit
15 number was?

16 MS. SILVERSTEIN: 17.

17 THE WITNESS: I've got Exhibit 17.

18 BY MR. DEAN:

19 Q. Okay. So take a look at Exhibit 17;
20 put it in front of you.

21 MR. ANWAR: What page are you on?

22 MR. DEAN: Page C98.

23 THE WITNESS: Okay. C98. Okay. I'm
24 at C98.

25 BY MR. DEAN:

1 Q. Do you remember Mr. Anwar asking you
2 quite a few questions about the sampling for
3 benzene at Hadnot -- or HP602?

4 A. Yes, I do.

5 Q. Okay. And y'all went over -- spent
6 quite a while on reviewing those different sampling
7 results. Do you remember that?

8 A. Yes.

9 Q. Now, can I have exhibit number --
10 MR. DEAN: Do we just want to continue
11 the same number sequence?

12 MR. ANWAR: Whatever you want, yes.

13 (DFT. EXHIBIT 22, Appendix A5
14 Bates-stamped CLJA_Watermodeling_010000942748
15 through 0000942750, was marked for identification.)
16 BY MR. DEAN:

17 Q. I'm just going to use this just to
18 shortcut it. I believe it's the end of -- this is
19 Appendix I-5, Exhibit 22.

20 A. Okay. That's from the Chapter A report
21 for Hadnot Point/Holcomb Boulevard.

22 Q. Correct. Now, you -- you were also
23 asked some questions about the same time -- y'all
24 were having a discussion about when the well was on
25 and when was well was off. Do you remember that?

1 A. Yes.

2 Q. Okay. Can you explain to me as it
3 concerns those sampling that was done post-turning
4 off of the well, what the significance would be for
5 those test results as it concerns the existence of
6 the continuing contamination?

7 MR. DEAN: Object to the form.

8 THE WITNESS: Well, what these plots
9 show, show early time, '51, the contamination in
10 '68, the wells are pumping. November '84, the
11 wells are pumping and shut off. And then it shows
12 the plume -- this is the benzene plume, I believe,
13 yes, benzene. It still shows it migrating under
14 the hydraulic gradient, which is heading east to
15 northwest, okay?

16 Q. Okay. And what is the significance of
17 that with regard to the validity of any of the
18 either calibration or contaminant testing
19 concentrations after the well was shut off?

20 MR. DEAN: Object to the form.

21 THE WITNESS: What that indicates to
22 me, and I think we had this discussion, is even
23 though the tables that we have based on information
24 provided by the Marine Corps for the Navy shows a
25 well shut off, if you're still observing benzene

1 concentrations in the water treatment plant, there
2 had to be some wells pumping, okay? Maybe not
3 continuously, but the plume is still moving past
4 the well. I'm looking at well -- well 602 there,
5 and even in 2008 there's still a plume over there.
6 So if that well was ever turned on again, even
7 though it says out of service, you would -- it
8 would -- you would get benzene.

9 Q. Sorry.

10 A. This is similar to what we observed at
11 Tarawa Terrace with TT26, and even though they shut
12 down TT26, the plume kept moving.

13 Q. Okay. And were samples taken for
14 concentrations in the area of the wells after those
15 wells were shut down?

16 A. Were they?

17 Q. Yes.

18 A. I would have to look and see on the
19 Chapter C report.

20 Q. Now, the Prabhakar Clement article that
21 was previously -- I believe it was marked as an
22 exhibit, the 2000 paper.

23 A. Yes, that one.

24 Q. Okay. Exhibit 1.

25 A. Okay.

1 Q. When did you locate that paper?

2 A. I would say within the last six months.

3 Q. When you were giving your 2010
4 deposition and responding to a question from the
5 plaintiff's lawyer in that case -- well, strike
6 that.

7 Before I go there, who was defending
8 you during that 2010 deposition?

9 A. Mr. Adam Bain from the Department of
10 Justice.

11 Q. Okay. And did you meet with him and
12 prepare for that deposition in -- in -- either by
13 phone or in person?

14 A. I met with him in the afternoon along
15 with attorneys for CDC's Office of General Counsel
16 on the 29th, the day before, for a few hours in the
17 afternoon.

18 Q. Okay.

19 A. And since I had never been deposed
20 before, he went over the ground rules and --

21 Q. And during that meeting or any other
22 conversations y'all had, did Mr. Bain ever question
23 the validity of your work at -- for which you were
24 about to testify to?

25 A. No, he did not.

1 Q. Now, you -- he asked -- excuse me, not
2 he. The plaintiff's lawyer in that case asked a
3 question to which you responded something -- I'm
4 using the word mob, do you remember that?

5 A. Yes.

6 Q. Referring to the work or some of the
7 work that was done here. Were you aware at -- in
8 2010, or had you seen Dr. Clement's paper at that
9 time?

10 A. I had not seen this particular journal
11 article.

12 Q. All right. I'm going to show you
13 Exhibit 23.

14 (DFT. EXHIBIT 23, Author's reply by T.
15 Prabhakar Clement from Ground Water,
16 January-February 2012 Bates-stamped
17 CLJA_Watermodeling_010000092109 through 0000092111,
18 was marked for identification.)

19 MR. ANWAR: And I'm just going to note
20 for the record that conversations that took place
21 when you were an employee of ATSDR and the
22 Department of Justice are privileged.

23 THE WITNESS: Okay.

24 MR. DEAN: And I'm not sure I agree,
25 but I don't think it matters, just for the record.

1 You know what, I don't think I have an extra copy
2 of this. I'll show it to you. I don't have an
3 extra copy of it.

4 MR. ANWAR: I have a copy.

5 MR. DEAN: It's the response to...

6 BY MR. DEAN:

7 Q. So I'm going to show you Exhibit No.
8 23. And can you tell me what that document is?

9 A. This looks like Dr. Clement's response
10 to our editorial review or editorial comment on his
11 2010 paper about hindcasting.

12 Q. And can you read the first -- let me
13 see. I think it's just the first full sentence.

14 A. I believe I've got a copy if you want
15 me to just use my copy and then...

16 Q. Yes, it's -- it's actually the first
17 full sentence. It's a rather long sentence, but...

18 A. Yeah, I got --

19 Q. You can just use this one.

20 A. Oh, okay. Okay. Okay.

21 Q. Can you read into the record --

22 A. The first full sentence?

23 Q. Yes, sir. Now, let's give it a little
24 context. What is Dr. Clement responding to?

25 A. Dr. Clement published an article in

1 Groundwater, in the same journal, I believe it was
2 in 2010, about basically hindcasting, historical
3 reconstruction to us, when is enough enough, and
4 used the Camp Lejeune project as a case study or an
5 example.

6 Q. Okay. And who is Dr. Clement as it
7 concerns his relationship with any of the Camp
8 Lejeune work? What -- what role, if any, did he
9 play at any point in time with regard to Camp
10 Lejeune work?

11 A. Dr. Clement was the hydrogeologist and
12 modeler expert on the National Research Council
13 that assessed ATSDR's Camp Lejeune work.

14 Q. So when people refer to the 2009 NRC
15 report, he was the water modeler that was -- served
16 as one of those panel members?

17 A. He was the only water modeler.

18 Q. Okay. So later on he must have written
19 an article in 2010 about additional information
20 about Camp Lejeune?

21 A. Yes.

22 Q. Okay. And can you read into the record
23 what he said in his response to ATSDR's response?

24 A. Okay. In the response to our
25 editorial.

1 Q. Yes.

2 A. Okay. "The goal of my article was not
3 to review the Camp Lejeune, in parentheses, CLJ,
4 modeling studies." Do you want me to continue?

5 Q. You can -- you can read the next line.

6 A. Okay. "Rather it was to use the CLJ
7 problem as an example to highlight issues related
8 to model complexities and to speak -- and to spark
9 an open debate on when, where, and why we should
10 limit model complexity."

11 Q. Okay. Now, you spent a lot of time,
12 both you and Mr. Anwar, using a word,
13 "uncertainty?"

14 A. Yes.

15 Q. Okay. And of course, lawyers and the
16 general public may use the word "uncertainty"
17 differently than water modelers; is that correct?

18 A. Yes.

19 Q. So what -- when you were referring --
20 using the word with -- uncertainty in responding to
21 questions that used the word "uncertainty", can you
22 explain to the Court and jury what is an
23 uncertainty -- what is uncertainty definition or an
24 uncertainty analysis as you're using it in this
25 deposition?

1 A. I'm using it in this deposition and the
2 modeling analyses.

3 Q. Is uncertainty unusual in water
4 modeling work?

5 A. Not at all.

6 Q. And explain that to the Court, sir.

7 A. Again, that -- that was -- I'll say
8 that was one of our primary concerns and
9 disagreement with the NRC report because it -- it
10 described the uncertainty about data about
11 modeling. We never disagreed that there was
12 uncertainty. An example being you have a sample
13 measurement and, you know, you can have a lower
14 value or a higher value. And so the uncertainty
15 would be that range in there in terms of numerical
16 analysis, like Monte Carlo gives you upper band, a
17 mean, and a lower band. And so that band is the
18 uncertainty or the confidence, okay? So when we're
19 talking about uncertainty, we're also talking about
20 the confidence that we have in the results.

21 Q. Okay. And you expect to see the word
22 "uncertainty" in any -- everyday garden variety of
23 water modeling project?

24 MR. DEAN: Object to form.

25 THE WITNESS: They should. If you look

1 at some of the earlier modeling procedures or
2 protocols of models -- when I say earlier, prior to
3 1980, prior to 19 -- you might see sensitivity
4 analysis and that's part of uncertainty analysis,
5 but good modeling practice would include both
6 sensitivity analysis and an uncertainty analysis.

7 BY MR. DEAN:

8 Q. All right. Let's go to one other area
9 real quick. I don't know the exhibit number. It's
10 the e-mail related to the disclaimer.

11 A. Oh, okay. Here, 11.

12 Q. Okay.

13 MS. SILVERSTEIN: The e-mail is
14 Exhibit 13.

15 THE WITNESS: Here you go. 13.

16 BY MR. DEAN:

17 Q. 13, yes.

18 A. The exhibit is 12.

19 Q. Yeah, the disclaimer. So with regard
20 to Exhibits 12 and 13 having to do with this issue
21 that arose, it appears, in May of 2007, do you
22 remember having a conversation of questions back
23 and forth with Mr. Anwar?

24 A. Yes, I do.

25 Q. Okay. And -- but I didn't hear him

1 ask, nor did I -- or maybe I missed it, but did you
2 -- did someone reach out to you and complain or did
3 some -- something come to you from another
4 department or agency upset about what was being
5 posted on the website that generated the need for a
6 disclaimer on the website?

7 MR. DEAN: Object to form.

8 THE WITNESS: I recall that it was
9 conveyed to me in the source sent to me, the
10 Department of Navy, where or who -- I'm not sure,
11 it could have been a representative at Camp Lejeune
12 that -- my point of contact, but the message was
13 that the Navy was upset about anyone being able to
14 access values on the ATSDR website.

15 Q. And calculate for their own benefit
16 specific numbers?

17 A. Yes, yes, yes.

18 Q. Okay. So up until the time, based on
19 your information from a source that it's the Navy
20 that made this complaint, there was not any
21 consideration for the need for a waiver; is that
22 fair?

23 MR. DEAN: Object to form.

24 THE WITNESS: We -- we did not have
25 that in our protocol so to speak --

1 BY MR. DEAN:

2 Q. Sure.

3 A. -- that we needed to put up a
4 disclaimer.

5 Q. It still today doesn't show up in the
6 written published reports, bound, produced reports,
7 other than on the website?

8 A. No, no, it does not appear in the
9 reports.

10 Q. And when you were communicating with
11 the lawyer about a form of a disclaimer,
12 Ms. Deborah Tress in May 2007, do you know whether
13 or not she was communicating with Adam Bain and the
14 Department of Justice at the same time with regard
15 to this disclaimer?

16 MR. DEAN: Object to form.

17 THE WITNESS: I do not know. We were
18 just told --

19 BY MR. DEAN:

20 Q. And for the record, Ms. Deborah,
21 Debbie, Tress, she's a lawyer, in-house lawyer,
22 employed by the federal government working for the
23 ATSDR CDC in-house counsel?

24 A. At the time of that e-mail, she was the
25 CDC in the CC Office of the General Counsel and we

1 were told she would be the one handling any Camp
2 Lejeune-type issues.

3 Q. Okay.

4 A. From a legal standpoint.

5 Q. So late this afternoon, probably in the
6 last hour or so, you answered some questions with
7 regard to timing of contaminants to Tarawa Terrace
8 TT26. Do you remember that?

9 A. Yes.

10 Q. And I believe it is Alex
11 Spiliotopoulos's report where he has some
12 suggestions and a graph where he has the
13 contaminants going -- instead of going through the
14 water column, dropping into the ground -- are you
15 familiar with what I'm referring to?

16 A. Yes, I am.

17 Q. Okay. How is the most reasonable way
18 in which you expect contaminants that get into the
19 water column -- are they going to continue in the
20 water table or are they going to drop in the
21 ground, is my first question?

22 A. Well, they're going to go along a
23 pathway, a horizontal pathway. And as I put in my
24 rebuttal report and Dr. Konikow explained, they'll
25 -- they'll go horizontally almost until they reach

1 the well, and that's because you've got a cone of
2 depression around the well as the well is pumping,
3 and then go very rapidly vertically into the --
4 into the well.

5 Q. And scientifically, why does -- why --
6 why is that? Why does that occur, in your opinion?

7 A. Because the groundwater is -- velocity
8 is flowing with the gradient. So the gradient is
9 decreasing or the water level is decreasing as you
10 approach the well.

11 Q. Okay. And is the contaminants -- is
12 the -- traveling in the water table versus reaching
13 the well itself, is one faster than the other?

14 A. Yes, the -- the last, let's call it,
15 the few -- few feet or where the cone of depression
16 of the well is going to much more rapidly pull in
17 any contaminants, and the time is going to be much
18 more shortened because of the high velocities at
19 the well and within the cone of depression.

20 Q. I'm sorry. My dog is -- they can't
21 find my -- my wife can't find my dog, so I told her
22 where he was at.

23 Okay. Let's give this back.

24 A. Okay.

25 Q. Between the time -- when did you --

1 remind me when you retired?

2 A. December 31st, 2017.

3 Q. Okay. When you retired on January the
4 -- January of 2018 until the unfortunate time when
5 I gave you a call in '22, did you do any work on
6 Camp Lejeune during that time frame?

7 A. No, I did not.

8 Q. Okay.

9 A. Nor did I speak to anyone.

10 Q. Okay. Let me ask a -- the timing
11 question, let me ask one last different way. For
12 purposes of the timing of contaminants to reach the
13 aquifer, is that different from the time for it to
14 reach the water table?

15 A. Well, conceptually, the aquifer in
16 Tarawa Terrace that we modeled starts at the water
17 table, okay? And we didn't look at -- we didn't on
18 MODFLOW, MT3DMS, did not look above the water
19 table. It was maybe about 10 feet, 15 feet of
20 saturated zone. And so we looked at everything --
21 all our models assume it's at the water table, and
22 that the timed travel through the unsaturated zone,
23 so typically down vertically, would be minimal.

24 MR. DEAN: All right. I believe that's
25 all the questions I have. Thank you.

1 MR. ANWAR: I just have a couple of
2 follow-up questions in my --

3 THE WITNESS: Sure.

4 MR. ANWAR: -- few remaining minutes.

5 EXAMINATION

6 BY MR. ANWAR:

7 Q. Mr. Dean showed you, I think, what was
8 marked as Exhibit 22.

9 A. Yes.

10 Q. If you would like to take a look. My
11 only question about this is Exhibit 22 is the
12 depiction of plumes at Hadnot Point -- the
13 contaminant plume at Hadnot Point, correct?

14 A. Yes, yes, yes. It's the -- you're
15 talking about benzene?

16 Q. For the benzene plume, correct?

17 A. Yes, yes. Let's see, what -- what page
18 you're on?

19 Q. It's A146.

20 A. A146. Okay. Okay. I'm there.

21 Q. My only question about it is that what
22 we're seeing here is a visual depiction of the
23 reconstructed plume based on the model, right?

24 A. That is correct.

25 Q. Okay. I'm going to mark one exhibit.

1 (DFT. EXHIBIT 24, e-mail correspondence
2 Bates-stamped CLJA_ATSDR_BOVE-0000108607 and
3 0000108608, was marked for identification.)

4 BY MR. ANWAR:

5 Q. I'll hand it to you, Exhibit 23. 24.
6 I'm sorry. Let me fix that. I can't count. I
7 will represent to you this is an e-mail exchange
8 that starts between you and Dr. Clement and then
9 that you forward on to the ATSDR team in February
10 of 2008. Would you agree with that?

11 A. Yes.

12 Q. Okay. And in the -- the e-mail
13 exchange -- the e-mail from Clement, Dr. Clement,
14 to you at the bottom of the chain, he's offering
15 some -- some -- his sort of feedback and some
16 compliments about the work that you-all did with
17 respect to the Tarawa Terrace analysis, correct?

18 A. It does not specifically say Tarawa
19 Terrace. However, given the date of that, it would
20 have been Tarawa Terrace because we would not have
21 probably even started on Hadnot Point.

22 Q. Sure. And the subject says sensitivity
23 analysis on well --

24 A. Oh, okay. Okay.

25 Q. -- TT26, right?

1 A. Okay. Yes.

2 Q. Okay. And he says, "yesterday I read
3 most of your report and I found them to be very
4 thoughtfully organized. It is a complex problem,
5 but you guys did the best possible job a modeler
6 can. They are lucky to have you guys as a modeling
7 team. Thanks for your support." Did I read that
8 right?

9 A. Yes.

10 Q. Okay. And then you forward it to your
11 team and you say, "look at the second paragraph
12 from Dr. Clement, a member of the National Research
13 Council committee on contamination of drinking
14 water at Camp Lejeune. It's nice to get words of
15 praise from unbiased and technically competent
16 colleagues about our abilities and work." Did I
17 read that correctly?

18 A. Yes.

19 Q. Okay. And I understand that
20 subsequently the NRC report was published, correct,
21 in 2009?

22 A. That's correct, that's correct.

23 Q. And after the NRC report, Dr. Clement
24 published his -- his article on hindcasting, and
25 then you-all -- you and Dr. Aral and the ATSDR team

1 had a response, and then he published sort of a
2 response to your response, correct?

3 A. Right, that's correct.

4 Q. Okay.

5 A. That's typically what's done in the
6 journal article type.

7 Q. Sure. Do you -- in your view, as you
8 sit here today, is Dr. Clement still an unbiased
9 and technically competent colleague?

10 MR. DEAN: Object to the form.

11 THE WITNESS: Yes, I never -- I never
12 said he was biased. We always said it was the NRC
13 report, the final -- the final report. Again, I
14 think we discussed this in my previous deposition,
15 that that is what really caught the entire team by
16 surprise because we were providing information and
17 data to Dr. Clement. I think we also provided it
18 to Dr. Knuckles and some other people.

19 Q. Sure.

20 A. And the feedback was this is, you know,
21 great -- great stuff, great job and all of that.
22 And the report -- and especially the -- I guess,
23 what is it, the public summary or whatever, really
24 just took a 180-degree opposite turn.

25 Q. Okay.

1 A. Okay.

2 MR. ANWAR: Those are all the questions
3 I have. Thank you.

4 EXAMINATION

5 BY MR. DEAN:

6 Q. Mr. Maslia, he's -- I'm just focusing
7 on Exhibit 24, and Mr. Anwar is pointing out the --
8 your use of the word "unbiased" --

9 A. Right.

10 Q. -- with respect to the reference to
11 Dr. Clement on February 21st, 2008. Do you see
12 that?

13 A. Yes, I do.

14 Q. At the time that e-mail was sent and
15 words that you're issuing, the NRC report had not
16 been issued yet, right?

17 A. Yes, you're correct.

18 Q. And it had not been issued until July
19 -- I think it's July 2009.

20 A. June 2009.

21 Q. June 2009. Have you now read Susan
22 Martel's deposition and all of the exhibits that
23 are attached to it?

24 A. Yes.

25 Q. And do you have an opinion as to

1 whether or not the NRC was, in fact, biased or
2 unbiased in the issuance of that final report?

3 A. The NRC report, I believe, contained
4 numerous -- numerous -- it contained -- it
5 contained mistakes, mischaracterizations, and it
6 appeared to us to be -- and I'm talking about the
7 project team, including the epidemiologists and
8 whatever toxicologist, that it was a biased report.

9 MR. DEAN: Thank you. I have no
10 further questions.

11 MR. ANWAR: Nothing from me. Thank
12 you.

13 THE WITNESS: Thank you.

14 THE VIDEOGRAPHER: Okay. Then we're
15 going off record the time is 6:49 p.m. This
16 concludes today's deposition.

17 (The witness, after having been advised
18 of his right to read and sign this transcript, does
19 not waive that right.)
20
21
22
23
24
25

CERTIFICATE OF REPORTER

I, Lauren A. Balogh, Registered Professional Reporter and Notary Public for the State of South Carolina at Large, do hereby certify that the foregoing transcript is a true, accurate, and complete record.

I further certify that I am neither related to nor counsel for any party to the cause pending or interested in the events thereof.

Witness my hand, I have hereunto affixed my official seal this 18th day of March, 2025 at Myrtle Beach, Horry County, South Carolina.



Lauren A. Balogh
My Commission expires
March 19, 2030

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EXHIBIT 15

Rebuttal to Reports of Dr. Alex Spiliotopoulos and Dr. Remy J.-C. Hennet

Leonard F. Konikow

January 13, 2025

Qualifications:

I received a PhD in Geosciences from Penn State University in 1973, specializing in hydrogeology and groundwater modeling. I worked as a research hydrologist for the U.S. Geological Survey for about 42 years, and was the Editor-in-Chief of *Groundwater* journal for four years (2020-2023). At the USGS, I was mostly involved in the development, documentation, and application of groundwater flow models and groundwater solute-transport models. I was elected to the National Academy of Engineering in 2015. I am a Fellow of the American Geophysical Union and the Geological Society of America, which also presented me with their Meinzer Award for publications that have significantly advanced the science of hydrogeology. I have served on several Expert Peer Review Panels during my career, including those for ATSDR's Camp Lejeune groundwater modeling studies in 2005 and in 2009.

My curriculum vitae is included with this report as **Attachment A**, and a list of the publications I authored in the previous 10 years is included as **Attachment B**. I am being compensated at an hourly rate of \$400 for my work on this litigation. I have not testified at a deposition or trial in the last 4 years.

Introduction:

ATSDR prepared reports describing models developed to simulate groundwater flow and contaminant transport at two areas of Camp Lejeune, North Carolina: Tarawa Terrace (TT) and Hadnot Point/Holcomb Boulevard (HPHB). Their use of the models was innovative in the sense that instead of a typical use of a groundwater model to predict future behavior, they used the model to "predict" how the system evolved in the past (before concentration observations were made) from a known state (an initial condition), in which no contaminants were present, to a contaminated aquifer with a mapped distribution in the early to mid-1980s when contamination was observed at a number of locations (wells, soil samples, and water treatment plants). ATSDR's use of groundwater models to reconstruct trends during a historical gap in concentration measurements is a legitimate and not unprecedented application of groundwater models. In fact, there are other publications in which doing this is documented and considered to be a normal and necessary part of the model calibration process, as discussed in more detail below. Modeling is the best and most logical approach for providing this information.

The ATSDR modeling work was reviewed and commented on by Dr. Alex Spiliotopoulos and Dr. Remy J.C. Hennet. In turn, I was asked to review the reports prepared by Dr. Spiliotopoulos and Dr. Hennet. This report presents my response, comments, and concerns about the technical content of Dr. Spiliotopoulos' and Dr. Hennet's reports. A list of the materials I have considered in rendering my opinions will be provided within seven days.

My opinions expressed in this rebuttal report are based on my review of the reports of Dr. Spiliotopoulos, Dr. Hennet, Mr. Maslia (Oct. 2024), Dr. Aral (Oct. 2024) and Jones & Davis (Oct. 2024), the ATSDR published reports, published literature, documents produced in this litigation, my work on the Camp Lejeune Expert Peer Review Panels, and my experience and expertise in the fields of hydrogeology

and groundwater modeling. I hold these opinions to a reasonable degree of scientific certainty. I reserve the right to supplement and/or amend my opinions in this matter as necessary if additional documents or information are made available for my review.

Background comments about groundwater modeling related to DOJ Expert Reports

This section responds to the opinions of Drs. Spiliotopoulos and Hennes regarding the methodology used by ATSDR to reconstruct groundwater contamination, including their assertions that this methodology is novel, speculative and unfounded, and their repeated claims that this methodology cannot be used where there is limited to no historical data. (*E.g.*, Spiliotopoulos Report, pages 25-30).

A numerical computer model of groundwater flow and/or transport is a simplified representation of a complex reality. A model uses averages, approximations, and assumptions to simulate groundwater behavior and to reproduce its properties and characteristics. Because of uncertainty in defining aquifer properties and boundary conditions, groundwater models must be calibrated. Field observations of aquifer responses (such as changes in water levels for flow models and changes in concentration for transport models) are compared to corresponding model-calculated values. The objective of this calibration procedure is to minimize differences between the observed data and calculated values. The minimization is accomplished by adjusting parameter values within their ranges of uncertainty until a best fit is achieved.

Anderson and Woessner (1992) present a dichotomy of prevailing opinions about mathematical models:

1. "Models are worthless because they require too many data and therefore are too expensive to assemble and run. Furthermore, they can never be proved to be correct and suffer from a lack of scientific certainty."

2. "Models are essential in performing complex analyses and in making informed predictions."

They go on to conclude that "Although groundwater models are time-consuming to design and therefore expensive in terms of labor time, it is also true that use of a groundwater model is the best way to make an informed analysis or prediction about the consequences of a proposed action. ... For these reasons, the bias of this book is, of course, toward opinion #2."

Groundwater contamination became widely recognized as a serious and pervasive problem in the 1980s. It is common that the existence of a groundwater contamination problem in a particular area would not be recognized until that contamination has migrated far enough and long enough that it affected a water-supply well or a surface water source. Then a monitoring program might be initiated. But this might not happen for several years to a few decades after the contaminant had entered the aquifer. Therefore, it is common that early-time data on concentrations are simply not available, as is the case at Camp Lejeune. Groundwater modeling is a widely recognized and accepted approach to understanding and managing these contamination problems. Models must be (and have been) calibrated in the absence of early time concentration data, as ATSDR has done. Other representative published examples where this has been successfully accomplished include the Rocky Mountain Arsenal, CO (Konikow, 1977) and Lawrence Livermore National Laboratory, CA (Rogers, 1992). In both of these cases, the early time history was reconstructed as part of the model calibration process (it just wasn't called "hindcasting").

In comparing hindcasting to forecasting, there are some similarities and some differences. In both cases, the analyst is using the model to estimate conditions during a time period outside of the calibration

period, and both types of “predictions” have uncertainty associated with them. One difference is that for predictions of future conditions (forecasting), you can come back later and assess the accuracy of those model predictions. With hindcasting, that is not directly possible. Another difference is that with forecasting (predicting), future conditions are somewhat unbounded, so that uncertainty will tend to increase with time beyond the calibration period. With hindcasting, there is often a way to estimate initial or early time conditions, thereby putting a constraint or bound on uncertainty going back in time. While predictive uncertainty exists and must be recognized, hindcasting is an acceptable and reasonable way to use a calibrated model to assess groundwater conditions during a historical period when there were no observations.

“Hindcasting” was accomplished as part of a study of the Rocky Mountain Arsenal (CO) contamination problem, in which I developed and calibrated a groundwater flow and transport model (Konikow, 1977). The RMA began operations in or about 1943. A groundwater contamination problem was recognized in 1954 & 1955. No observations of concentration (chloride in this early case) were made until late 1955 to 1956. The model was developed to simulate the entire history of operation and contamination at RMA, starting in 1943, but no concentration data were available for the first 13 years of operation. Konikow (1977) made and described reasonable assumptions about the initial conditions, source locations, and source loading—but of course there was uncertainty associated with those estimates (as described by Konikow and Thompson, [1984]). The RMA model was calibrated using measurements made at four distinct times including 1956, 1961, 1969 and 1972. Work was documented and published in a 1977 USGS Water-Supply Paper (<https://pubs.usgs.gov/wsp/2044/report.pdf>), which received wide distribution. The RMA site became one of the first sites to fall under the Installation Restoration Program. Another example of reconstructing the early history of contamination migration was published by Rogers (1992) in *Groundwater* journal about their model calibration at the Lawrence Livermore National Laboratory site in California. In both of these earlier studies, the historical reconstruction wasn’t called “hindcasting,” but was considered a scientifically valid component of the model development and application.

Numerical simulation models of groundwater flow and transport processes in porous media are probably the most valuable single tool available to help analysts understand subsurface systems, integrate available data, evaluate conceptual models, and predict responses of groundwater systems to various stresses (such as pumping from wells and leakage or loading of contaminants into the subsurface environment). Groundwater flow models typically estimate the head distribution (equivalent to water levels, water table elevation, or potentiometric surface) in an aquifer system and how the head may change over time in response to changes in well locations or pumping rates. Groundwater transport models (solute transport or contaminant transport for dissolved chemicals) calculate how the concentration of a particular dissolved chemical will vary from place to place and over time. Groundwater systems are three-dimensional in nature, and their properties vary both horizontally and with depth. Therefore, groundwater models must typically be three-dimensional in nature. There is a large record in the published peer-reviewed literature of cases describing the development and application of models for complex real groundwater problems.

Contaminant transport in the subsurface is strongly influenced by the groundwater flow field. Thus, contaminant-transport modeling for a specific site requires a reasonably reliable groundwater flow model. If the contaminant is nonreactive or mildly reactive, the groundwater velocity (based on hydraulic

gradients and effective porosity) is the primary control on advective and dispersive contaminant migration.

Comments about the distribution coefficient (K_d) and the retardation coefficient (R_f)

This section provides background information in support of my responses later in this report to Opinion 3 of Dr. Spiliotopoulos and Opinion 11 of Dr. Hennet regarding the methodology ATSDR used to calculate the retardation factor.

If a contaminant undergoes chemical reactions during the transport process, its net movement relative to the flow of groundwater may be slowed down. Such effects can be (and often are) represented in a simplified manner as a retardation process. Two parameters that are used to simulate retardation are discussed frequently in the comments by Dr. Spiliotopoulos. The contaminant transport conceptual model is that the migration of a contaminant may be slower than the average velocity of the groundwater in which it is dissolved because of adsorption to material in the aquifer. The net effect of this process is described by a so-called “retardation factor” (R_f), which is calculated as:

$$R_f = 1 + (\rho_b K_d) / \theta$$

where R_f = retardation factor; ρ_b = bulk density; K_d = distribution coefficient; and θ = porosity.

The model calculates R_f on the basis of the three parameter values on the right side of the above equation, all of which can vary in space and will include uncertainty in their estimated values. If ρ_b is estimated too high by 25% and K_d is too low by 25%, then the errors in those two estimates cancel each other out (i.e., they are compensating errors), and the net estimated value of R_f used in the model will be the same as if those two parameters were estimated precisely to their “true” values.

In general, the use of a distribution coefficient (K_d) as a component of a retardation factor in contaminant transport modeling in groundwater systems is a common modeling approach in simulating contaminant transport in aquifers, but one whose rigorous scientific basis is debatable. The K_d approach assumes that sorption of the PCE is instantaneous, reversible, and follows a linear equilibrium isotherm, and that “the solid matrix has an infinite sorption capacity” (Zhang & Bennett, 2002, p. 81). But in transport through complex heterogeneous porous media, the actual behavior of PCE would not match these idealized assumptions. Nevertheless, it is a simplifying assumption that can be useful in light of the uncertainties about the contaminant’s distribution and reactive behavior. In effect, it represents an engineering approximation, which is why using a model calibration process to arrive at an approximate average value is an acceptable, reasonable, and common approach. Thus, Drs. Spiliotopoulos and Hennet’s concern about precisely and accurately defining a value for K_d is misplaced because the theoretical underpinnings for this parameter are not rigorous. That is, conceptual uncertainty in its application must always be recognized, and this conceptual uncertainty carries forward to the use of a conceptually simple retardation factor in the transport equation. This theoretical uncertainty, however, does not preclude the use of these two parameters (K_d and R_f) for characterizing the average transport behavior of a contaminant such as PCE in flowing groundwater.

Zheng & Bennett (2002) describe some limitations in modeling sorption processes. They note that there are significant computational difficulties inherent in coupling advective-dispersive transport with

chemical reactions (p. 79). They further note (p. 79-80) that "... field problems always involve uncertainty as to the nature of the controlling reactions, and as to the quantities and properties of the reacting substances. As a result, the biogeochemical processes represented in field-scale transport models at the present time are largely limited to reactions of the simplest kind, based on highly idealized representations of the effects of more complex reactions."

Kret et al. (2015) studied a Quaternary sandy aquifer to estimate sorption coefficients for PCE fate and transport modeling. They estimated K_d from both batch and column experiments and concluded that reasonable values for R_f for PCE are typically between 1.1 and 3.6.

Rogers (1992) developed a groundwater transport model for the Lawrence Livermore National Laboratory (LLNL) site in California, which includes "several hundred feet of complexly interbedded, unconsolidated alluvial sediments" with an upper boundary represented by an unconfined water table condition. Their calibration and history matching resulted in reasonable matches for R_f values between 1.0 and 3.0, with their conclusion that "a spatially averaged retardation factor of approximately 3 is recommended..."

Model Documentation:

To facilitate assessment of the scientific credibility and scientific defensibility of a groundwater model, the model study should be well documented. Reilly and Harbaugh (2004) state: "Because models are embodiments of scientific hypotheses, a clear and complete documentation of the model development is required for individuals to understand the hypotheses, to understand the methods used to represent the actual system with a mathematical counterpart, and to determine if the model is sufficiently accurate for the objectives of the investigation. ... The appropriate level of documentation will vary depending on the study objectives and the complexity of the simulations."

Reilly and Harbaugh (2004) list ten topics that should be addressed in reports documenting model studies. These are:

1. Describe the purpose of the study and the role that simulation plays in addressing that purpose.
2. Describe the hydrologic system under investigation.
3. Describe the mathematical methods used and their appropriateness to the problem being solved.
4. Describe the hydrogeologic character of the boundary conditions used in the simulation of the system.
5. If the method of simulation involves discretizing the system (finite-difference and finite-element methods for example), describe and justify the discretized network used.
6. Describe the aquifer system properties that are modeled.
7. Describe all the stresses modeled such as pumpage, evapotranspiration from groundwater, recharge from infiltration, river stage changes, leakage from other aquifers, and source concentrations in transport models.
8. For transient models, describe the initial conditions that are used in the simulations.
9. If a model is calibrated, present the calibration criteria, procedure, and results.
10. Discuss the limitations of the model's representation of the actual system and the impact those limitations have on the results and conclusions presented in the report.

The documentation for the ATSDR model studies at Tarawa Terrace and HPHB study areas are detailed, comprehensive, and clear, and meet or exceed these guidelines, as evidenced by the series of model documentation reports that include 11 separate book chapters for Tarawa Terrace and 4 separate book chapters and 8 supplemental volumes for HPHB. Careful review of this comprehensive documentation indicates that ATSDR used scientifically acceptable tools and followed correct scientific methodology in performing its historical reconstruction, in contrast to the assertions of Dr. Spiliotopoulos and Dr. Hennes.

Review Comments on Dr. Spiliotopoulos' Opinions:

Opinion 1: Dr. Spiliotopoulos states "Due to the absence of sufficient historically observed data and site-specific parameters, the results of these calculations [in the ATSDR models] are highly uncertain and cannot be used for determining dose reconstructions at the level of detail that ATSDR presented in their analyses." I would counter that although early time data are lacking, there are still a lot of data and historical observations available, as documented in the several ATSDR reports on the investigations. Dr. Spiliotopoulos fails to specify how much data would be "sufficient". In any groundwater modeling study, there are never "enough" data and there is always uncertainty in the final model results. This is normal and expected. In this case, there were enough data to calibrate groundwater flow and transport models, and the data deficiencies were not so great as to prevent a historical reconstruction. In fact, a reasonable historical reconstruction was indeed accomplished, so it was possible. The historical reconstruction recognized the existence of uncertainty and assessed its impact on the results.

Dr. Spiliotopoulos refers to Section 4 of his report as his support for this opinion. Following are comments about his discussion in Section 4 of his report.

In the introduction to Section 4 (p. 27, para. 2), Dr. Spiliotopoulos overstates the lack of data for the Camp Lejeune groundwater system. He says that without site-specific data and a lack of observations, a model "can even be considered speculative and unfounded." That might be true if there were no site-specific data and no observations. But that is simply not true for these models. There are certainly site-specific data available on subsurface properties, as well as observations of heads, boundary conditions, and chemical concentrations for some time periods. These are all described in detail in the numerous reports published by ATSDR. There is no basis for applying the characterization of "speculative and unfounded" to the ATSDR models of TT and HPHB. Even for predictive periods, the system behavior simulated in the model still obeys the laws of physics and hydraulic principles, and contaminants will move in directions predictable by the hydraulic gradient, as calculated with the flow model.

In para. 3 (p. 27), he states that "'predictions' refer to model output, regardless of whether its results are used for hindcasting or forecasting ..." I agree with this statement. However, in the next paragraph he discusses "When historical data are not available..." But whether the model predictions are used for forecasting or hindcasting, if it's truly a prediction, then there will be no measurements available (except later for a forecasting prediction). But at the time of model development, observation data for heads and concentrations will only be available during the calibration period. Implying that the lack of data during a predictive period is a problem is misleading. (If data were available during a historical period of interest,

hindcasting would not be needed—it would just be used as part of the observed data set for the calibration period.)

In para. 2 (p. 29), Dr. Spiliotopoulos states that Dr. Clement (in Clement's 2011 publication) "indicated that ATSDR's analysis implied almost exact knowledge of past conditions." I disagree. I find that ATSDR is clear that uncertainty exists about the conditions during the historical reconstruction period, as well as during the calibration period, and the results include assessments of uncertainty. If Dr. Clement inferred that ATSDR believed they had an exact knowledge of past conditions, then that is Dr. Clement's mistake. In the same paragraph on p. 29, Dr. Spiliotopoulos quotes Dr. Clement's comments about the uncertainty analysis. Although the quote starts with Dr. Clement saying that "the results appear to be reasonable ...", he ends the quote with an apparent criticism by saying: "The figure also shows that closer to the initial starting point the confidence band is almost 100%, implying that our knowledge of initial conditions, initial source loadings, and initial stresses is almost exact." Although it may be counterintuitive, as I discuss in my Introduction, I actually do have high confidence in the assumption that there were no (or negligible) contaminants in the groundwater from ABC Cleaners prior to Jan. 1953, and probably very little for at least several months after that. Thus, at some point the confidence band should get narrower going backwards in time towards the starting date of the simulation.

In his Summary of Opinion 1 (p. 30), Dr. Spiliotopoulos says "these models were largely not constructed using site-specific data ..." I strongly disagree. The geometry and boundary conditions of the model and its hydrogeologic framework are derived from hydrogeologic and geophysical studies of the subsurface aquifer system at the Camp Lejeune and adjacent areas, as documented in USGS reports and in several of the ATSDR reports. This type of information provides a critical and necessary foundation for the models. The potentiometric and water table maps also provide important information for the construction and calibration of the models. Dr. Spiliotopoulos also states in this summary that the models were not "calibrated to observed data for the first 30 years of simulation." Of course, because those concentration data did not exist. That is the reason these models were built—to estimate those concentrations in a state-of-the-art way that is consistent with principles of groundwater flow and transport processes. The models did not generate arbitrary or random numbers. The results are based on the physics of groundwater flow and contaminant transport, and the results appear reasonable and realistic, and the existence of error bands or uncertainty ranges around the estimates is expected and openly acknowledged.

Opinion 2: Dr. Spiliotopoulos says that ATSDR used "parameters and assumptions that are incorrect or not representative of site conditions ..." Parameter values for groundwater models are never known precisely and accurately. That is an unfortunate fact of life in groundwater modeling. The parameter estimation process (essentially, the model calibration exercise) is conducted to adjust parameter values within a range of reasonable values to yield a best fit between model simulation results and the limited observation data available. This naturally allows and/or creates compensating errors in the input data for the model. Dr. Spiliotopoulos says this results in conservative estimates of estimated monthly contaminant concentrations. It is not clear what is meant by "conservative" or why that is not a good trait. He also says the results are biased high. His main argument for that opinion seems to be that early (in time) results often lie above the mid-point of the uncertainty bands. The uncertainty bands reflect a zone within which results are expected 95% of the time; if results mostly fall within the uncertainty

bounds, they should be considered acceptable. He cites sections 4.1.1 and 4.1.2 of his report for support of this Opinion.

On p. 31 (Section 4.1, 4th para.) Dr. Spiliotopoulos states “ATSDR’s calibrated model sits at the top of the uncertainty range, ... This demonstrates that the calibrated model was biased high.” But it does not prove ATSDR’s model is wrong. The results are within the uncertainty bounds and true values are expected to lie somewhere within the uncertainty bands. Furthermore, best estimates of concentrations do not have to lie at the center of the error band. A model may become insensitive to certain parameters used to create the error bounds at their upper or lower limits, and the response of the model to some parameter variations is not linear.

In para. 7 on p. 31, Dr. Spiliotopoulos quotes the NRC (2009) report where it says “Reporting precise values based on model predictions gives the misleading impression that the exposure of the former residents and workers at Tarawa Terrace during specific periods can be accurately defined.” Would he prefer imprecise values? NRC gives no examples of where the ATSDR-reported values are too precise or are prone to misinterpretation in light of the pervasive discussions of model uncertainty provided by ATSDR in its reports. Furthermore, Dr. Spiliotopoulos fails to cite the first sentence of that same paragraph, where the NRC report states “The committee concluded that ATSDR applied scientifically rigorous approaches to address the complex groundwater-contamination scenario at Tarawa Terrace.” [emphasis added.]

For Section 4.1.1 (p. 32), Dr. Spiliotopoulos uses the heading “Available data are limited to non-existent”, but the first statement after that notes that there were 36 aquifer tests at TT to estimate aquifer properties. This is actually a lot of data, especially considering that aquifer tests are time-consuming and expensive to run. Data for TT are certainly *not* non-existent. I am sure many groundwater models have been developed for areas where there were less than 36 aquifer tests available.

In his summary of Opinion 2 (p. 33), Dr. Spiliotopoulos references his Fig. 5, which includes a reproduction of ATSDR’s Fig. F16 about TT results, and goes on to say that ATSDR’s work resulted in “biased high estimates.” I reproduce that part of Dr. Spiliotopoulos’ Fig. 5 (Fig. F16) here because it actually illustrates the opposite. It shows 5 measured PCE concentrations in samples from well TT-26 collected within weeks of each other in early 1985. Over this relatively short time span, the concentrations varied greatly (bracketed between a high of 1,580 ug/L on 01/16/1985 to a low of 3.8 ug/L on 02/12/1985)—a rate of change that cannot be replicated in a model using monthly time steps. Most importantly, the plot shows that the model results fell almost exactly at the midpoint of the range of observed values (about 800 ug/L)—countering the claim of the model being biased high.

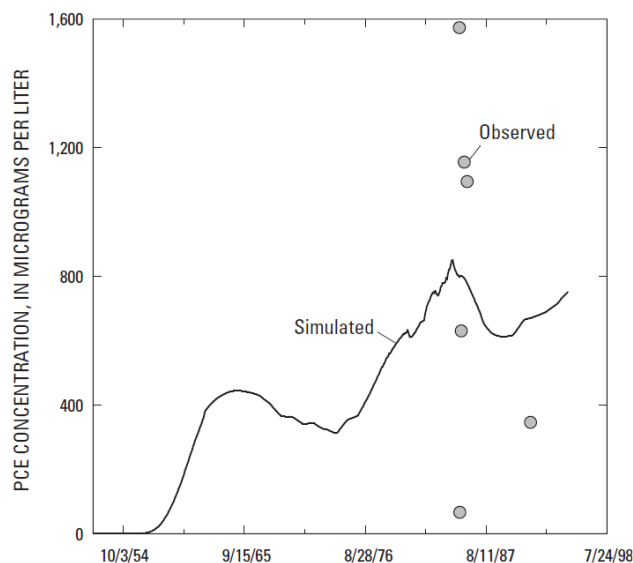


Figure F16. Simulated and observed tetrachloroethylene (PCE) concentrations at water-supply well TT-26, Tarawa Terrace, U.S. Marine Corps Base Camp Lejeune, North Carolina, January 1952–December 1994 (see Figure F6 for location).

Section 4.1.2, p.34, 1st para.: Dr. Spiliotopoulos quotes TT Chapter C (p. C38) saying that “... simulation results are unqualified for the years 1951-1977, ...” This is a statement of recognition by ATSDR that there is a paucity of water-level measurements during that early time period. This is also part of ATSDR’s consistent messaging that uncertainty exists, and is greater for some time periods than for other time periods. However, it does not disqualify or “unqualify” the model itself, as even during that same time period, other calibration controls and constraints exist in terms of boundary conditions and stresses. Specifically, the adjacent surface water systems represent hydrologic boundaries with known average elevations that change very little over periods of decades. Average monthly recharge can also be estimated based on precipitation and other climatic data that are available. Given such constraints, there is a limited range over which the simulated heads can vary, and that range is not unqualified or unconstrained.

In Section 4.1.2, p.34-36, Dr. Spiliotopoulos cites ATSDR (TT, Chapter F) as noting that 53% of comparisons of simulated to observed concentrations violated ATSDR’s calibration target. But many of these samples were collected on the same day or within a short time of other samples (Figure 6 (Table F13), p. 35), so giving equal weight to each comparison is not statistically reasonable. These temporally closely spaced samples are not truly independent samples. Alternatively, I would say a fair comparison should be made on the basis of the quality of the agreement between simulated and observed concentrations at the 11 separate sampling (well) locations. This gives equal weight to every sampling location. Of these, 8 can be deemed “accurate” (including two that have some low and some high samples, so accurate on average), one is high but within the target range, one is slightly high, and one is consistently high (TT-23). On this basis, 73% of the sampling wells show reasonably and acceptably accurate simulation results. Also see my related discussion of calibration targets below (for Section 3.3).

On p. 36, para. 4, in his summary of Opinion 2, Dr. Spiliotopoulos states that the “model calibration did not rely on observed data prior to 1984.” Yes, no contaminant concentration data were available then, and that is why ATSDR needed a deterministic groundwater simulation model to estimate how the contaminants were distributed in the aquifer during that time period.

Opinion 3: This Opinion notes that the calibrated model for TT was built using different parameter values and assumptions than the HPHB model. Dr. Spiliotopoulos cites sections 4.1.2.2, 4.1.2.3, and 4.2.3.2 of his report for support. In general, I note that these two study areas do not overlap. Although they are adjacent, and one would expect similar characteristics, having differences is not surprising and certainly the two independent calibrations can yield different values for the various parameters in the models. The models were also developed and calibrated at different times (TT being the earlier model) and improved calibration (parameter estimation) software was applied in developing the latter (HPHB) model.

Dr. Spiliotopoulos (Section 4.1.2.2.1, p. 37) indicates that an error was made in calculating the bulk density (ρ_b) for the TT system. Using an average value for total porosity of about 35%, he calculated that ρ_b should be lower, stating that “In the Hadnot Point model, this error was not repeated.” That value was 1.65 g/cm³. He states that “This has a significant impact on the calculation of the retardation factor, resulting in faster (sooner) arrival of PCE at the water-supply wells, ...” However, as Dr. Spiliotopoulos himself admits, this significant impact on R_f does not actually occur because the calibration process compensates for an overestimate of ρ_b by estimating a value for K_d that appears to be too low. Recall that neither of these two parameters are used directly in the transport model. Rather, the retardation factor is used to calculate the migration velocity of the contaminant, and this retardation factor depends on the product of ρ_b and K_d . The calibration process yields a very reasonable value for R_f for PCE—a value (about 2.9) that is very consistent with values in other field studies reported in the literature (e.g., Rogers, 1992; Kret et al., 2015). In Section 4.1.2.3, Dr. Spiliotopoulos has a whole paragraph describing the erroneous consequences “if ATSDR had used a retardation factor of 6.44.” But ATSDR did *not* use a R_f = 6.44, so this argument is irrelevant. In summary, the two specific possible errors cited by Dr. Spiliotopoulos for ρ_b and K_d largely offset each other, and have a minimal or negligible impact on the final results, as documented by ATSDR (CLJA_WATERMODELING_01-0000075468; ATSDR_WATERMODELING_01-0000887324).

Dr. Spiliotopoulos (Section 4.1.2.4, p. 39 and elsewhere) and Dr. Hennet (Opinion 11) raise concerns that site-specific data were not used to estimate total organic carbon (TOC) or to calculate K_d . TOC is used to estimate f_{oc} , which in turn is used together with an estimate of K_{oc} to estimate K_d , which in turn is but one factor in the equation used to estimate R_f . That is a long string of dependencies. Appendix A of Dr. Spiliotopoulos’ report shows that reported values of TOC vary over a range of about four orders of magnitude. That is a huge variation and uncertainty, which is not accounted for. You cannot simply assume that the mean of that distribution of TOC values is the true and correct one to use to estimate K_d . Overall, there would be much less uncertainty, greater value, and more clarity in just estimating an average value for R_f as part of the calibration process, which is the methodology ATSDR employed. I believe that this is not optional and that R_f must be estimated during and in accordance with the calibration process. In light of this, it simply would not have mattered if K_d had been preliminarily

estimated by ATSDR using highly variable site-specific measurements of f_{oc}/TOC . In the end, the value of $R_f = 2.9$ calibrated by the ATSDR modeling work is very close to other values reported in the literature for aquifers having similar geologic materials.

Dr. Hennet also criticizes ATSDR for failing to consider available site-specific data for f_{oc} (fraction of organic carbon) to estimate values of K_d (his Opinion 11). Rogers (1992, p. 51) in discussing the K_d parameter says "Numerous researchers have used theoretical methods correlating the organic carbon content (OCC) of the subsurface material and the K_d (Karickhoff, 1984). Others have used the partitioning between octanol and water to predict the K_d (Kenega, 1980). **These methods are not considered appropriate where the OCC is less than approximately 0.1%.**" OCC is equivalent to TOC, and 0.1% is equivalent to a fraction of 0.001. Hennet's Expert report lists (Exhibit 3-2, and p. D-11 to D-12) 21 Camp Lejeune samples where f_{oc} is given. The median value is 0.0013, barely above the indicated limit, and 9 samples (43% of the samples) have values <0.001 , indicating that the use of f_{oc} to estimate K_d is not appropriate. If ATSDR had used this approach, it would have introduced additional errors and sources of uncertainty.

In his summary of his Opinion 2&3 (p. 38-39), Dr. Spiliotopoulos states (in reference to ρ_b and K_d) that "parameter values in the Tarawa Terrace model were different than those used in the Hadnot Point model, even though both models simulated similar hydrogeologic conditions." This is not a problem, and it would be more surprising if they had applied identical values. The areas have similar conditions, not exactly the same conditions. Hydraulic conductivity measurements show notable differences between the two areas, reflecting local differences in aquifer material properties. These differences also cause differences in the factors contributing to the R_f . There is nothing wrong or unexpected about this. R_f was estimated in the calibration process, and the HPHB calibration used a different (and supposedly better) automated parameter estimation software package, which was not used in the TT calibration. So of course some differences will result. If they had applied the same parameter estimation software to both sites, it still would most likely result in different values for the average R_f in the two different areas. But the differences are small and inconsequential.

In a summary of his Opinion 3 (p. 39), Dr. Spiliotopoulos states that "these incorrect assumptions resulted in faster plume migration in the aquifer and estimated monthly concentrations that were conservative and biased-high." However, this would only be the case if the errors in the two parameters were considered separately and alone. But the model does not respond to these values separately. It responds to their net effect on the retardation factor, which was calibrated to a very reasonable value consistent with other peer-reviewed studies. The errors were compensatory and that compensation was built into the critical R_f value by the calibration process, as would be expected from a calibration process for a groundwater model.

Opinion 4: Dr. Spiliotopoulos says that use of "parameter values based on site-specific data ... in Tarawa Terrace would result in substantially lower estimated monthly concentrations. Furthermore, the model uncertainty range would also be lower." Dr. Spiliotopoulos cites his Section 4.1.2.5 as support.

On p. 39, Dr. Spiliotopoulos argues that site-specific data for calculating K_d would result in a higher K_d value. Again, the model calibration process adjusted values of K_d , one component of the retardation

factor, so that the value of R_f was as reasonable and accurate as possible for maintaining consistency with the available observed concentrations. Furthermore, in calculating K_d , Dr. Spiliotopoulos used a porosity value of 20%, which was the effective porosity used in the transport model. However, in calculating ρ_b , the other component of R_f , Dr. Spiliotopoulos used a porosity value of about 35%—a value representing the total porosity measured in two soil samples (p. 37). Using two different values for porosity in the same equation is inherently wrong, creating an inconsistency of 75%, and is done with no explanation.

In section 4.1.2.5, Dr. Spiliotopoulos develops a “revised” model using a late start date and a different K_d value. He presents his results in comparison to the ATSDR model results in his Figs. 7 and 8. He accentuates the early time differences by plotting results arithmetically rather than logarithmically. But that’s a minor point. The proper start date is outside the scope of my opinions. But adjusting the K_d without also adjusting p_b is one-sided. In any case, Dr. Spiliotopoulos’ value for R_f in the revised model is 3.48. The value of 2.93 used by ATSDR is only 16% lower than this new value used in Dr. Spiliotopoulos’ revised model. This difference is relatively small. Furthermore, as seen in those two figures, the difference between the ATSDR results and Dr. Spiliotopoulos’ revised model results are very small after approximately 1970. More importantly, both models are consistent in showing that PCE concentrations are above the MCL for most of the study period—and since Jan. 1, 1960 in both models, at both Well TT-26 and in influent to the TT WTP.

Also noteworthy in Dr. Spiliotopoulos’ Fig. 7 is that for both models, there is a peak concentration shortly before 12/84. When K_d is higher and R_f is consequently higher, then one would expect that a peak moving through the groundwater system would be somewhat delayed, yet there is no indication in the results for Dr. Spiliotopoulos’ revised model that this peak concentration was delayed at all. Instead, it appears to have arrived at TT-26 at the same time as in the ATSDR model. This demonstrates a lack of sensitivity to the value of K_d in this particular system. It simply did not make a significant difference.

Dr. Spiliotopoulos’ only support for his opinion that the uncertainty range would be lower is a concluding statement in his Summary on p. 41, which states, “The uncertainty range for such historical reconstruction would also be lower, as it would be based on slower plume migration and lower concentrations for many years after the start of contaminant releases from the source.” However, this is an inference that itself is not supported by analytics. Dr. Spiliotopoulos has not demonstrated that the uncertainty range would be lower. Dr. Spiliotopoulos’ results also do not demonstrate significantly slower plume migration (peaks are coincident) or significantly lower concentrations (after 1970 they are almost identical—differing at TT-26 by an average of about 30 or 40 ug/L out of an average concentration of roughly about 500 ug/L—less than 10%).

Opinion 5: This opinion states that the ATSDR groundwater model for TT “resulted in biased-high estimates of monthly contaminant concentrations at one of the water-supply wells.” The well in question is TT-23. Dr. Spiliotopoulos cites Section 4.1.2.6 of his report in support of this opinion.

Section 4.1.2.6 (p. 42) offers no clear evidence that the discrepancy at this one well (out of many) has a substantial impact on the overall results. Based on ATSDR Table E2, of the nine unique sampling dates for this well, six had an observed level of PCE or TCE above the MCL. Furthermore, with respect to the overall effect on concentrations estimated at the WTPs, it is important to note that TT-23 was

operational for only about 9 months or less, starting in 1984, and had the shortest operational (pumping) period of any of the 16 pumping wells operating in the TT area (see Table H3 in Chapter H of the TT series of reports). When it was pumping, the contribution from this well provided only a small fraction of the total groundwater inflow to the WTP with concentrations far less than well TT-26 (with its modeled concentrations likely being underestimated). Thus, if indeed the estimates for this well were too high (by less than two times), the effect on calculated concentrations in the WTP would be minimal both in magnitude and in duration.

Opinion 6: Dr. Spiliotopoulos says that the ATSDR model did not reflect “observed data that indicated absence of contamination in the aquifer.” Does he doubt that there was contamination in the aquifer? The presence of contamination in the aquifer is well documented; the absence of contamination in some locations means little overall—only that the contamination was not everywhere. That is normal. The statement and implication that there is no contamination in the aquifer is simply incorrect. The ATSDR reports clearly document observations where the contaminants were not detected (e.g., Table F13), and their analyses reflect that. Support for this opinion is stated to lie in Section 4.1.2.7.

In Section 4.1.2.7, Dr. Spiliotopoulos makes a major point about plotting non-detects, and he criticizes ATSDR for not plotting nondetects. He cites the reason as being that “non-detections listed as zeros are not visible in a logarithmic-scale scatterplot. This is because a logarithmic scale can only show numbers greater than zero.” However, nondetects do not mean that the value is zero—only that it is less than the detection limit. In aiming to support his point, Dr. Spiliotopoulos relies on an analysis that is arbitrary, incorrect, and biased. He selects a value of 0.1 ug/L to represent all nondetects. For these samples, the detection limits were between 2 and 10 for most analyses. Helsel and Lee (2006) say: “The most common procedure within environmental chemistry to deal with nondetects continues to be substitution of some fraction of the detection limit. This method is better labeled as “fabrication”, as it reports and uses a single value for concentration data where a single value is unknown. Within the field of water chemistry, one-half is the most commonly used fraction, so that 0.5 is used as if it had been measured whenever a <1 (detection limit of 1) occurs.” If representing nondetects in a plot is to be done, a reasonable value and common way to represent a nondetect would be halfway between the detection limit and zero. For the Camp Lejeune data with detection limits of 2.0 and 10.0, the plotted position should be either 1.0 or 5.0 respectively (the latter being 50 times greater than the arbitrary value Dr. Spiliotopoulos used—so plotting 0.1 instead of 5.0 is a significantly misleading/biased-low way to present the data). This will make a big difference on his plot (such as his Fig. 18). Note: On this topic, Helsel and Lee (2006) also state: “All such plots [scatterplots using halfway points] are misleading, because unique censored values are unknown. Instead, left-censored data can be plotted as intervals between zero and the detection limit for each observation. In this way, no false statements about where an individual value is located, or that all such observations are at the same value, are made.” There may also be other alternatives for plotting nondetects (newer and better, but more complicated). Regardless, Dr. Spiliotopoulos’ selection of 0.1 to represent all nondetects is arbitrary, misleading, and wrong. ATSDR’s approach of not plotting nondetects avoids the possible perception of “fabrication” and is more defensible than Dr. Spiliotopoulos’ approach of assuming all nondetects can be fairly represented by an arbitrary value of 0.1, as shown in his Fig. 9 (p. 43). The discussions of Helsel and Lee (2006) justify the ATSDR’s approach for not including nondetects on the data plots because of the risk of appearing to

fabricate data or presenting misleading plots. ATSDR does show nondetects in all tables of measured concentrations.

In para. 1 (p. 45), Dr. Spiliotopoulos notes that the model results indicate a low value of 5.8 ug/L in well TT-54, but the observed value was a nondetect. He states that the calibration “is not supported by the non-detection in the sample collected in February 1985.” I would argue that it is indeed supported by that data. The detection limit for that analysis was 10 ug/L (TT Table F2). The halfway point between zero and the detection limit is 5.0, a value that is very close to ATSDR’s simulated value, and that close agreement is certainly supportive of the quality of the calibration.

Dr. Spiliotopoulos notes (p. 45) that “Well TT-54 had a reported non-detection in July 1991. However, the ATSDR model indicated an increasing concentration trend at well TT-54, suggesting that the PCE plume continued arriving at that well until that time. This is unlikely to be accurate.” However, if one examines the predevelopment and transient potentiometric surfaces (TT Chapters C and F), it is clear that TT-54 is downgradient from the ABC Cleaners, and that a plume evolving from that source while several water-supply wells are operational will likely contribute some contaminants to well TT-54.

Dr. Spiliotopoulos’ Summary of Opinion 6 (p. 45) picks two of the wells to generalize that “ATSDR’s model overestimated the plume migration extent and rate of migration, which were both conservative and biased-high.” This is an overgeneralization that ignores other wells and locations where estimates were very close or were underestimated. The nature of model calibration is that there will be compensating errors and that some simulated values will be too high and others too low. Certainly, the results for the flow model (e.g., Fig. C9) do not support a generalization that the flow model is inaccurate or biased-high.

Opinion 7: Dr. Spiliotopoulos states that “the presentation of results of the uncertainty analysis conducted by ATSDR for the Tarawa Terrace model was misleading by showing a narrow uncertainty range around the calibrated model.” Support is given in Section 4.1.3.1.

In 4.1.3.1, Dr. Spiliotopoulos’ characterization changes from “misleading” to “visually misleading.” The stated reason is that “they used a logarithmic scale, which visually compresses the uncertainty range around their calibrated model [results].” However, the use of a logarithmic scale is a valid and common approach in engineering and scientific studies, and is not characterized as being misleading by scientists and engineers. He observes that the plot ranges over six orders of magnitude on the axis for PCE concentration, but the width of the uncertainty bands do not. When values span such a large range, it is normal and standard to use a log plot. Using just an arithmetic scale would effectively hide all the changes in the lower part of the scale.

Dr. Spiliotopoulos states (p. 46, para. 4) that “the difference between the high and low values in Figure 11 [ATSDR’s Fig. I29] is not significant enough to justify the use of a logarithmic scale.” I disagree because the observed values span more than two orders of magnitude (excluding nondetects) and the simulated values span more than five orders of magnitude. Plotting these using a log scale is reasonable and informative, and is the only way to portray the early time results of the simulation in the same graphic. It is fine to also present these results plotted on an arithmetic scale (Fig. 12), but not sufficient to do so solely. Dr. Spiliotopoulos’ concern over the concentration plots is mostly cosmetic.

On p. 48 (para. 1), Dr. Spiliotopoulos criticizes the uncertainty analysis, saying "... the concentrations calculated by the model should be generally in the middle of the uncertainty range ... However, the calibrated model-simulated concentrations are almost identical to the upper bound of the uncertainty range in the early years of operation (1957-1963)." However, if one examines his Fig. 12 (p. 48 of his report), it clearly shows that the results are indeed generally in the middle of the uncertainty range. In the few early years it is above the middle, but consistently below the upper bound, as desired. Such a result is within a probabilistic expectation. In those early years the concentrations are the smallest. For example, in 1960 the difference between the upper bound and the middle of the range is only about 10 ug/L, which is a small value on the full scale of PCE values considered. Being "generally near the middle" is not an objective or quantitative rule.

Opinion 8: Dr. Spiliotopoulos states that "ATSDR's uncertainty analysis was not bound by historical concentration data, and as a result, focused only on model precision and not accuracy in predicting COC concentrations. ATSDR's uncertainty analysis was presented as though it evaluated the model's accuracy. It did not." Support is stated as being in Section 4.1.3.2.

The criticism is based on the lack of historical data on concentrations prior to 1982 (Section 4.1.3.2, p. 49), and would mean that "the uncertainty analysis would result in precise but not necessarily accurate solutions ..." However, once again, the lack of concentration data prior to 1982 is the reason that the model was developed. Data are available afterwards, and initial conditions for the contaminant distribution can be stated with reasonable reliability that the concentrations in the TT area were zero prior to the start of operations at ABC Cleaners. That is an important known concentration condition for the early 1950s. What the model does is estimate how the concentration changed spatially between the time of the start of ABC operations and the time when observations of PCE became available, and it does so in a manner that is consistent with the principles of groundwater flow field and solute transport, with the further recognition that the groundwater flow field has been simulated with acceptable accuracy.

The ATSDR assessed uncertainty using a sophisticated but standard and acceptable statistical approach—using a Monte Carlo simulation method. They carefully documented their approach, which generated 840 realizations. In a Monte Carlo simulation approach, no single realization is expected to be "accurate." Rather, the ensemble of realizations is intended (and expected) to bracket a range of feasible but realistic outcomes. The range of results (generally considering 95% of the outcomes) is a measure of the model's predictive accuracy. The Monte Carlo uncertainty analysis would not be expected to yield a different calibrated model.

In the last paragraph on p. 49, Dr. Spiliotopoulos states that "one of the most critical parameters for determining how fast contaminants will migrate in the aquifer is the retardation factor." I would argue that both the speed and direction of migration is more critically determined by the head distribution (hydraulic gradients, as determined by the groundwater flow model) and the effective porosity. The retardation factor will have no effect on the direction of transport of a contaminant for a given flow field. Furthermore, the results presented by Dr. Spiliotopoulos in his Fig. 7 show that the model results, at least at Well TT-26, are relatively insensitive to a range of uncertainty in the assumed value of K_d and R_f .

On p. 50 (para. 3), the Monte Carlo approach used by ATSDR is criticized by Dr. Spiliotopoulos "... because ATSDR implemented a 'probability distribution function' ... to describe how values closer to the mean

value of the range are more probable than those away from the mean.” I do not see a problem here as this is an option within standard practice for random sampling of parameter values for a MC analysis when information or theory indicates that a parameter has a statistically normal or log-normal distribution. Zheng & Bennett (2002, p. 353) say “The Monte Carlo method is by far the most commonly used method for analysis of uncertainty associated with complex numerical methods.” They further state (p. 356) “The heart of the Monte Carlo method is the generation of multiple realizations (or samples) of input parameters that are considered to be random variables. Each random variable is assumed to follow a certain probabilistic model characterized by its probability density function (PDF). The probability distributions commonly used in hydrogeologic studies include *normal*, *lognormal*, *exponential*, *uniform*, *triangular*, *Poisson*, and *beta* distributions.” It is worth noting that when this book was published, co-author Bennett was an employee of SSP&A and first author Zheng was a former employee and affiliate of SSP&A.

The plots shown in Fig. 13 are discussed in para. 8 (p. 50, Section 4.1.3.2). Dr. Spiliotopoulos notes that the results of the calibrated model “sits at the upper bound of the retardation-factor uncertainty range.” However, that is not true for the majority of the simulation period. It is close to the middle of the range during the period of 1962 through the end (around Dec. 1987). And prior to 1962, it still lies within the uncertainty bounds, which is acceptable and not indicative of bias. As stated earlier, error bounds need not be evenly distributed around the mean because a model can be sensitive to a parameter at either high or low values, but not both.

In the 3rd paragraph on p. 51, Dr. Spiliotopoulos presents the values for the retardation factor with four significant figures. Whether R_f is estimated by adjustments during model calibration or estimated from highly variable and uncertain site-specific data, presenting it with 4 significant figures is an unjustified and meaningless precision.

Opinion 9: This continues the previous discussion of the uncertainty analysis and cites the same section (4.1.3.2) as support. Dr. Spiliotopoulos says that the uncertainty analysis for TT “... did not encompass uncertainty bounds representative of site-specific conditions, resulting in biased-high uncertainty range.”

It is not clear exactly what is meant by a “biased-high uncertainty range.” If it means that the uncertainty range is incorrectly too high, that implies that the model is even more accurate than indicated.

On p. 52 and in Fig. 14, Dr. Spiliotopoulos discusses the results if R_f were 4.3 instead of 2.9. But this value of 4.3 is higher than those presented in published peer-reviewed articles of PCE transport in similar types of aquifer materials (Rogers, 1992, and Kret et al., 2015). Even with Dr. Spiliotopoulos’ high value of R_f , Fig. 14 shows that after about 1970, the differences at Well TT-26 are small—less than 100 ug/L difference during the final 20 years of the simulation, with Dr. Spiliotopoulos’ revised model showing lower concentrations because it includes a larger sorption rate. Again, it is relevant to note that the observed data shown in this figure range from about 3 ug/L to almost 1600 ug/L for samples collected over a relatively short time period in early 1985. The ATSDR model results fall very close to the midpoint at that time—at about 800 ug/L—not indicative of any bias. However, Dr. Spiliotopoulos’ revised model with the higher R_f value calculated a PCE concentration of about 700 ug/L at the time when the data are available—lower than the mid-point, which does not provide evidence that the higher value of R_f is more

accurate (actually, it's an indication that it is less accurate). Either way, the computed PCE concentration values are higher than the MCL for all times after 1960, which is a critical point.

The three highest observed values of PCE in well TT-23 were underestimated by the ATSDR model, which counters the claim that the ATSDR model is biased high.

On p. 55, Dr. Spiliotopoulos says that "ATSDR's selection of the retardation factor parameters forced the calibrated model to simulate fastest arrival of PCE at well TT-26 ...". This use of the word "forced" appears to unfairly attribute an unscientific and biased motive to the way the model calibration was conducted. First of all, this was not the fastest possible arrival. If they had used a value of $R_f = 2$, the arrival would have been faster than the value they calibrated to. I think a fairer way to characterize the calibration relative to R_f is that they varied the values of R_f and of other parameters and selected parameter values that yielded the best overall fit to the available data. This happened to be a value of 2.9 for R_f , which was very consistent with other values reported in the literature for PCE transport in similar types of geologic material.

Opinion 12: This opinion focuses on the model post-audit performed by Jones and Davis. The opinion says that the post-audit showed that "ATSDR's dose reconstruction groundwater model for drinking water in Tarawa Terrace used parameters and assumptions that resulted in conservative and biased-high estimates of monthly contaminant concentrations." Support is said to be given in Section 4.1.5.

It is my understanding that Jones and Davis, as well as Maslia, will respond to this opinion in their rebuttal reports. A few general comments about the content of section 4.1.5 follow.

In Section 4.1.5.1 (p. 60, para. 2) Dr. Spiliotopoulos states that "Observed concentrations of zero correspond to non-detections." As mentioned previously, this statement is not accurate in the sense that nondetect values do not necessarily have a value of zero, but their value may be anywhere below the detection limit for that particular analysis. Also, in para. 3 and Fig. 18 (p. 60), Dr. Spiliotopoulos repeats the same error in assuming that a nondetect can be substituted by a value of 0.1 ug/L. This is arbitrary and biasing.

Dr. Spiliotopoulos calculates a mean error for partitioned segments of the data set—separately for points where the observed value is higher and separately for points where the simulated value is higher. This is not a common or standard way to compute a mean error. Based on my experience and expertise, the standard methodology is to compute the mean error for all data.

Opinion 13: This opinion also focuses on the model post-audit performed by Jones and Davis, and is closely related to Opinion 12. It suggests what Maslia and Aral should have done with the data of Jones and Davis. Support is again said to be given in Section 4.1.5. It is my understanding that Maslia will respond to this opinion in his rebuttal report, but I have a general comment regarding the absence of data.

On p. 63, Dr. Spiliotopoulos expresses concern that "no data are available to evaluate whether the overall extents of the simulated plume are real." Some data are certainly available. It would be nice if

more data were available. If extensive data were available to map the plume in detail over time, there would be little need for a simulation model. The ATSDR models reliably simulate the groundwater flow field and head distributions so that the transport models can simulate advective and dispersive processes, as modified by chemical reactions and adsorption (as simplified using the retardation factor), to fill in the gaps in the observational database in a way consistent with widely accepted governing principles of groundwater hydraulics and transport phenomena. This is a reasonable and appropriate approach to addressing this issue.

Opinion 14: This opinion restates previous ones, but for Hadnot Point, and says that the ATSDR model “was constructed and calibrated using parameters and assumptions that are uncertain or incorrect.” Support is said to be given in Sections 4.2.1, 4.2.2, 4.2.3, and 4.2.4.

In general, groundwater systems occur within subsurface geologic frameworks that are complex, heterogeneous, and hidden from view. There are and always will be uncertainty associated with even the best efforts to define the properties and relevant characteristics of these systems. This does not preclude the development of reliably sound numerical models to simulate groundwater flow and transport processes. But model developers must always be aware of, and assess, the existence of uncertainty and the sensitivity of the model results to this uncertainty. ATSDR has indeed accomplished this. For TT, they have produced a 187-page chapter (Chapter I) solely about this task (in addition to many discussions of it throughout the other chapters). For HPHB, there are two sections in Chapter A of their reports focused on these topics.

Dr. Spiliotopoulos states (p. 68, para. 4) that “Unlike the Tarawa Terrace model, ATSDR did not know the precise location of all contamination sources and the magnitude of contamination each source contributed.” This is true—there is uncertainty in the source terms (as with all model parameters). But that can be handled and does not preclude the development of a reasonable flow and contaminant transport model. Assumptions had to be made, but they were not “arbitrary” and were clearly and comprehensively documented. He cites the NRC (2009) report, which said “There were multiple sources of pollutants, including an industrial area, ... [etc.]” What is certain is that all of these are likely sources of groundwater contamination. Industrial operations in the 1950s, 60s, and 70s were typically not concerned with protecting groundwater quality.

In footnote 235 (p. 68-69), Dr. Spiliotopoulos says, “ATSDR used simulated contaminant concentrations in the influent to the WTP to calculate concentrations in the water delivered to a family housing or other facility, without considering any contaminant losses during treatment.” However, unless the treatment process was designed to treat these contaminants, it would have been “arbitrary” and highly uncertain to simply assume that the treatment reduced contaminant concentrations or removed contaminant mass.

p. 69: Dr. Spiliotopoulos cites “evaporative” losses in a treatment plant. However, evaporation is rarely significant in a water treatment plant and direct evidence would be needed to support this hypothetical claim. Contaminant loss due to volatilization during the treatment and distribution process was discussed at the March 28, 2005 expert panel meeting where panelists—including Dr. Pommerenk of AH Environmental—opined that any loss would be minimal (See March 28, 2005 Expert Panel Meeting Transcript at 55:2-57:14, 56:2-57:14).

In para. 3, Dr. Spiliotopoulos says “Based on [his] professional judgment, there was insufficient data to conduct groundwater flow and contaminant transport model calibration and uncertainty analysis.” But in fact, ATSDR did “conduct” it, and clearly documented their calibration and uncertainty analyses. In my professional judgment, they did a good job with the limited data available.

In para. 4 (p. 69), Dr. Spiliotopoulos repeats that “prior to 1982, no water quality data were available ...” However, groundwater flow directions can be deduced with typically small uncertainties, and flow rates (velocities) and advective-dispersive transport can be simulated with some additional uncertainty, but these key processes are reasonably well defined. Also, it is highly certain that prior to the start of these industrial and landfill operations, the contaminant concentrations were zero—an important early-time data point.

In para. 7, Dr. Spiliotopoulos quotes NRC (2009) as saying “simpler modeling approaches should be used to assess exposures from the Hadnot Point water system.” While this is easy to say and sounds appealing, they don’t say how to do that or what simple modeling approach would work. How does one know if a model is too simple? What processes should be eliminated in the simpler model? In fact, the way to produce a simpler model is to first develop and calibrate a maximally realistic “complex”, detailed, and comprehensive model that can be then used to assess which processes or factors have little effect on the results and so can be safely eliminated to produce a simpler model. The benefit cited by NRC is faster and more efficient modeling, but that potential benefit is not a major need here, and the use of models that might be too simple is offset by their reduced realism and risk of oversimplification.

On p. 70 (section 4.2.1), Dr. Spiliotopoulos says “available data are limited or non-existent” but in the first bullet point states that “more than 200 aquifer and slug test analyses” exist. This is a lot of data! There are many groundwater models that have been developed and calibrated on the basis of much fewer hydraulic testing at the specific site of interest.

On p. 70, Dr. Spiliotopoulos is also concerned that pumpage data for individual wells were estimated on the basis of “ancillary data.” This is common standard practice in groundwater modeling, as pumpage measurements for wells are often not available or are of questionable quality.

In the last para. (p. 70) Dr. Spiliotopoulos notes that the HP WTP was built in 1942 and during its first 40 years of operation, there were no water quality data for the contaminants of concern. This is unfortunate, but not unexpected; it is rather common for groundwater contamination problems that a chemical that turns out to be problematic at a later date is not monitored prior to that awareness. This is why ATSDR had to use modeling to help reconstruct the historical record as well as possible, using documented quantitative methods. Of course, there will be uncertainty in the results, but they seem reasonable given the information that is available.

p. 71, Fig. 25 (ATSDR Fig. A18): Dr. Spiliotopoulos presents four plots of simulated and observed TCE concentrations at four wells in the HPHB study area. All four plots show that the simulated values were either close to the middle point between observations (HP-602 and HP-608) or below the observed values (HP-634 and HP-601/660). There is no indication here that the model overestimated concentrations (or was biased-high).

In summarizing Opinion 14 (p. 71), Dr. Spiliotopoulos says “Selection of model parameters was based, primarily, on professional judgment.” This is always the case. Data are always limited, and professional

judgment is required to assess how to deal with that paucity of data and how much weight to give the limited number of measurements. A groundwater modeler always wishes they had more data, but the reality is that there are never so much data available so as to avoid using professional judgment.

In Section 4.2.2 (p. 72) the claim is made that ATSDR “made arbitrary assumptions to reconstruct pumping history ...” In my opinion, the assumptions were not arbitrary, but rather were well-informed, well-reasoned, and carefully documented. Assumptions had to be made about the pumping history, and they were made, but they were not arbitrary. For example, Dr. Spiliotopoulos notes that “Yearly volumes are available for some years prior to 1980. A trendline was used to estimate raw-water flows for years prior to 1980 when no data exist.” This appears to be a sound statistical approach, and the use of a trend line is certainly not arbitrary.

In Section 4.2.2 (p. 72-73) Dr. Spiliotopoulos offers a further criticism that “it was assumed that a well would be operated in the historical period based on a pattern similar to the more recent ‘training period,’ with further adjustments to account for information on the varying capacity of wells, where available.” Dr. Spiliotopoulos’ statement actually contradicts his assertion that estimates were arbitrary. Here he describes a reasoned and reasonable approach to estimating a pattern of past water use (well pumpage)—an approach that is not “arbitrary.”

In several additional paragraphs on p. 73 (as well as elsewhere), he repeats the claim that pumping rates were based on arbitrary assumptions. ATSDR uses sound statistical methods (such as regression and correlation) to estimate pumpage. This is neither arbitrary nor unreasonable. Similar wells managed by the same operating authority are likely to have been operated in a similar manner. If not, that would be arbitrary. It is unlikely that Dept. of Navy engineers operating the well fields did so in an arbitrary manner. In the early years they just weren’t required to maintain as detailed records as would be expected today. Again, ATSDR made reasonable assumptions with the data that they had available.

Near the top of p. 77, Dr. Spiliotopoulos states that model calibration was “improperly influenced” by “erroneous concentrations reported for well HP-634 ... while non-detections were ignored.” It has not been established nor agreed that erroneous concentrations (actually, one single value) were reported for well HP-634. This is discussed in more detail below in reference to Section 4.2.3.3. Non-detections were not ignored. They are clearly listed and labeled in many tables presented in the ATSDR reports (such as Table A4 in Chapter A of the HPHB report series, and in many other places too).

In Section 4.2.3.1 (p. 77) Dr. Spiliotopoulos claims that “The groundwater flow model has significant limitations in the absence of data for calibration.” Although the model has limitations, there is no evidence that the limitations are significant for the purposes that the model was developed. Furthermore, there is not an “absence of data for calibration.” In the very next paragraph, Dr. Spiliotopoulos notes that more than 700 water-level measurements were used in calibrating the predevelopment model, which is also the initial conditions for the transient groundwater flow model. Also, there are a lot of data available on the boundary conditions and hydrogeologic framework for the model.

In the 6th paragraph (p. 77), Dr. Spiliotopoulos indicates that the simulation of contaminant transport in the aquifer is inherently uncertain. This is true for all groundwater models. But the uncertainty does not mean that the model is not useful.

In Section 4.2.3.2, p. 78, Dr. Spiliotopoulos notes that ATSDR recognizes that explicit data defining source locations and mass loadings are not available, but then he criticizes ATSDR by saying “these quantities were arbitrarily assigned to the model in order to fit the limited water-quality data available starting in 1982.” However, by criticizing ATSDR’s methodology, Dr. Spiliotopoulos in effect is criticizing the essence of the model calibration, history matching, and parameter estimation process practiced in groundwater modeling, in which parameter values are adjusted (either manually or automatically) in order to improve the fit (e.g., see Hill and Tiedeman, 2007). Furthermore, the source locations and mass loadings were not “arbitrarily assigned.” The general locations of the sources are well-documented, and sources were placed in the vicinity of these documented locations. Consistent with principles of model calibration, the exact placement and strength of these sources were varied within limits until the observed concentrations were reasonably matched by the model. The variation in the exact location, timing, and strength of sources is rarely known, and adjustment of source properties is a commonly-accepted part of calibrating a flow and transport model.

p. 79: Dr. Spiliotopoulos discusses the lack of data to define the source loading terms for the model in the HPHB area. However, there is no doubt that these chemical contaminants (including TCE and PCE) were present in the groundwater at toxic concentrations (above the MCLs) in the HPHB area, and that they were pumped out of the aquifer by several operating water-supply wells.

p. 79: In the summary for Opinion 14, Dr. Spiliotopoulos criticizes the ATSDR for having “assumed constant mass loading of the same magnitude at all sources for more than 40 years”, which he characterizes as “highly uncertain, if not impossible.” Viewed from a different perspective, what ATSDR did was apply an average rate over the critical time period because there was no basis for differentiating how the loading might have varied over time. In my opinion, this was a reasonable approach. Furthermore, the constant source resulted in a reasonable model calibration, and so there was no reason to incorporate a variable source in the absence of data on transient source characteristics.

Opinion 15: In this opinion, Dr. Spiliotopoulos repeats the claim that ATSDR included an erroneous value in its analysis and model calibration (presumably for the 1,300 ug/L value measured in a sample from HP-634). Section 4.2.3.3 is cited for support.

In Section 4.2.3.3, Dr. Spiliotopoulos argues that concentration data for well HP-634 was incorrectly interpreted and that the reported value of 1,300 ug/L on Jan. 16, 1985 “should be considered erroneous” (although he considers other samples from that well that showed non-detects to be valid). I believe that his basis for this conclusion is speculative and unsupported by facts, as discussed below.

On p. 80, Dr. Spiliotopoulos says “it is unlikely that this well [HP-634] was ever contaminated with elevated TCE concentrations,” and he and Dr. Remy Hennes argue that the analysis showing a concentration of 1,300 ug/L should be thrown out. Although Dr. Spiliotopoulos and Dr. Hennes claim the well was shut down permanently, documentation suggests that HP-634 was online in January 1985 (see CLJA_CLW00000004559, CLW4546, and CLW1818). However, even if the well was shut down permanently shortly before the date this sample was collected, I strongly disagree with Dr. Spiliotopoulos’ argument that “contamination could not have reached that well when it was non-operational.” It is plausible and possible that TCE could have reached the well sometime after the previous sample had been collected. As Dr. Spiliotopoulos surely knows, after a pumping well is shut off,

water levels do not instantly recover and the head distribution does not instantly return to a nonpumping configuration and nonpumping hydraulic gradients. During predevelopment (nonpumping steady-state) conditions, flow near HP-634 is predominantly to the west and southwest (see HPHB reports Fig. A19 for 1951, reproduced below). While this well was operational, a cone of depression (a drawdown of water levels) formed around it, lowering the heads and reversing local hydraulic gradients, and enabling the movement of contaminants from nearby areas containing contaminants west of HP-634 to move eastwards towards HP-634 (as also shown for later times in Fig. A19 below). When a well is shut down, the heads take time to recover (recovery is not instantaneous). During the slow recovery period, water and contaminants will continue to move towards the well while the cone of depression is slowly filled in and recovers. This simple normal response of groundwater systems to the cessation of pumping easily explains the presence of contaminants in a sample collected after the pumping was stopped. Note that concentrations of DCE and VC were also unusually high in this same sample, so the TCE value is not an isolated “outlier” (see table C7 in report Chapter C). This progression is seen in the maps for all three layers for the November 1984 maps shown in Fig. A19 below, where the contaminant is shown to have moved very close to HP-634 from its previous location in the industrial area just to the west. If Dr. Spiliotopoulos argues that it is not possible for contaminants to reach HP-634 once its pump ceases operation, then it is contingent on him to provide some evidence that (a) the recovery is so fast that it is irrelevant (i.e., how long would it take for the hydraulic gradients to reverse again and return to a predevelopment condition?), and (b) that the contaminants were so far from HP-634 when it was shut off that it could not have migrated that distance during the recovery time. Without such calculations or evidence, one can conclude that it is indeed possible for contamination to reach that well shortly after it became non-operational. The primary evidence that it did become contaminated is the measurement of 1,300 ug/L in the January 1985 well sample, and I do not see conclusive evidence that that sample analysis should be discarded.

Dr. Hennet argues that this well was not contaminated by TCE because some vials in the shipment were broken (he does not say the samples for this analysis were in broken vials, so the relevancy of other vials being broken is not apparent). I doubt that the lab would or could perform an analysis or report a value on a sample taken from a broken vial. Dr. Hennet says a CCLJ report shows the value as 10 ug/L. However, the lab that did the analysis reported 1,300 ug/L. Hennet and Spiliotopoulos also say that the value of 1,300 is an outlier, so should be discarded. But there are many high-valued “outliers” in the record, and the record shows other instances where the value can change over similar large magnitudes in a very short time (e.g., TT-26 shown in Fig. F16, where the PCE concentration changed from 1,580 to 3.8 ug/L in successive samples collected just 4 weeks apart, mirroring the change in HP-634 from ND to 1,300 ug/L in a similar 4 week timeframe). The reasoning by Dr. Spiliotopoulos and Dr. Hennet to discard this reported value seems entirely speculative. They offer no actual evidence that the analysis or its reporting was erroneous.

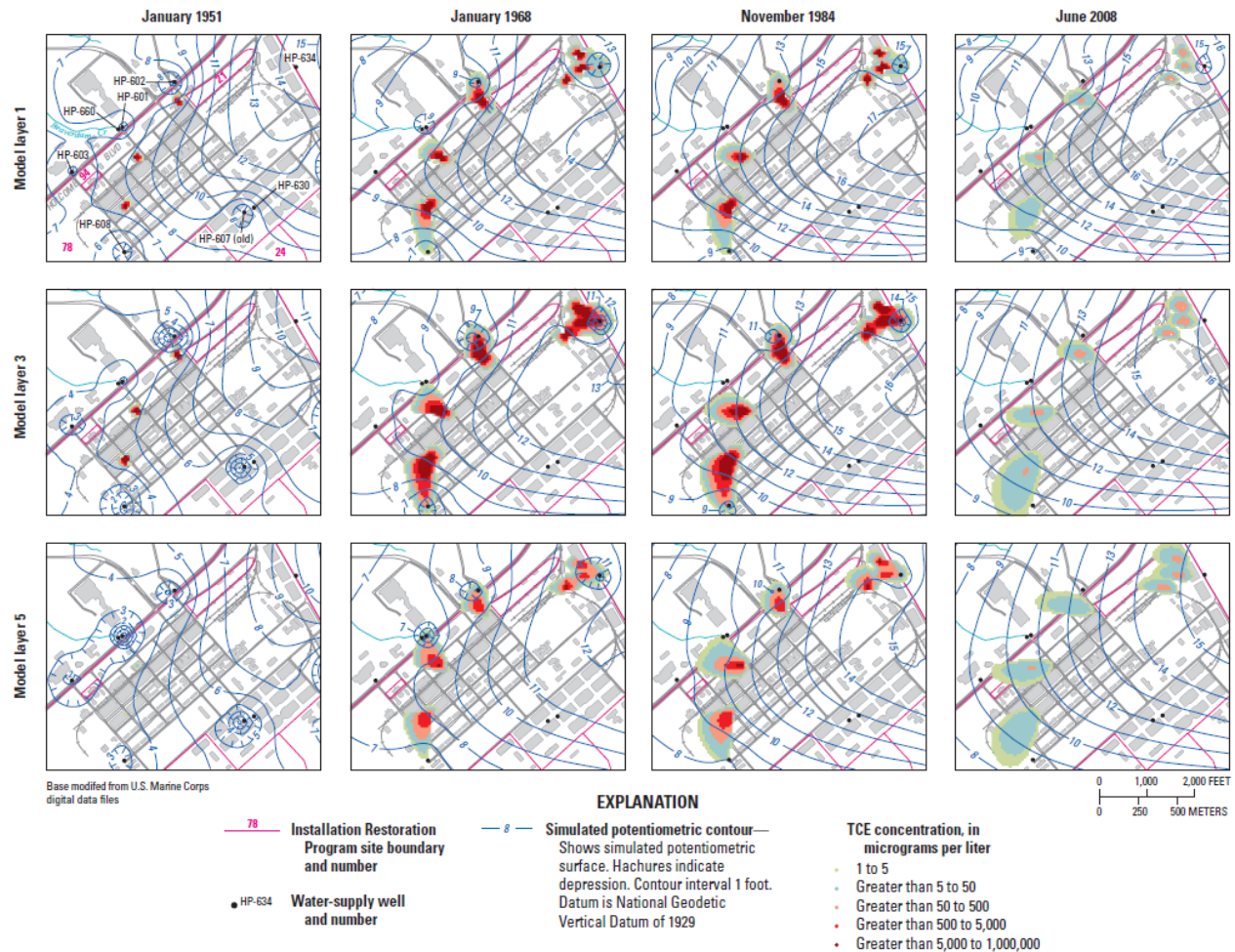
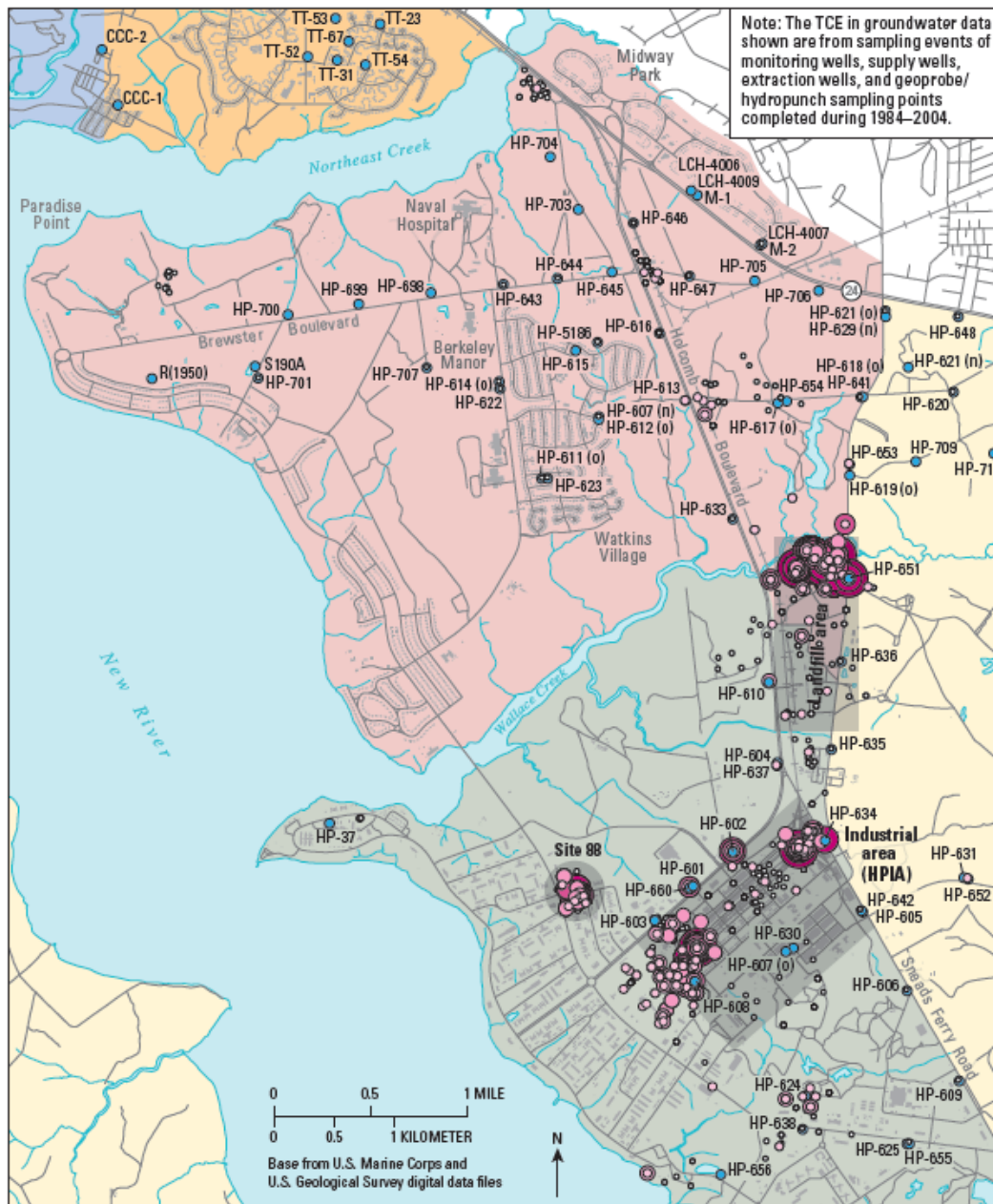


Figure A19. Reconstructed (simulated) water levels and distribution of trichloroethylene (TCE) within the Hadnot Point Industrial Area fate and transport model subdomain, model layers 1, 3, and 5, Hadnot Point–Holcomb Boulevard study area, U.S. Marine Corps Base Camp Lejeune, North Carolina, January 1951, January 1968, November 1984, and June 2008. (See Figure A13 for location and building numbers; see Appendix A4 for more detailed maps and results.)

On p. 81, Dr. Spiliotopoulos presents his Fig. 31 plotting of TCE concentrations in HP-634. However, he purposely does not include the data point with the value of 1,300 in his plot; including it would yield a very different picture, and show a much better match between simulated and observed TCE at the well location. TCE is found to be present in many locations immediately adjacent to HP-634, as seen in Fig. C33 (reproduced below). HP-634 is within the industrial area HPIA in that map (close to its northeastern boundary).



EXPLANATION

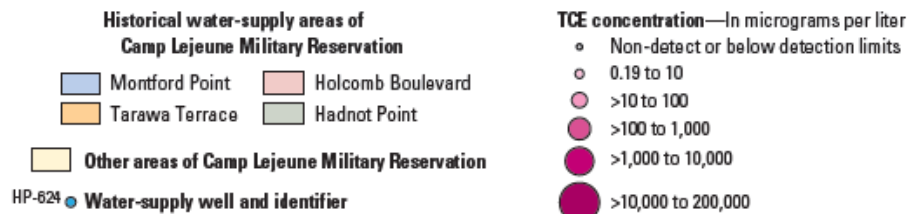


Figure C33. Groundwater sample locations for trichloroethylene (TCE) and ranges of TCE concentration in monitor and supply wells within the Hadnot Point–Holcomb Boulevard study area, U.S. Marine Corps Base Camp Lejeune, North Carolina.

Opinion 16: Dr. Spiliotopoulos argues here that the model for VOC degradation products was based on limited data, and “ATSDR’s historical reconstruction prior to December 1984 cannot be verified.” He cites section 4.2.4 as support.

In section 4.2.4 (p. 82-83), Dr. Spiliotopoulos states that “As illustrated in Figure 33 [ATSDR Fig. A25], the historical reconstruction prior to 1985 cannot be verified, due to lack of observed data for the period.” This is true, and it is the reason why a simulation model was needed and was developed. For the four contaminants shown in Fig. 33, the agreement between simulated values and observed data is excellent in all four plots. This close agreement when observations are available builds confidence in the reliability of the model and its predictions, including for the hindcasting results for times prior to 1985.

In the summary for Opinion 16 (p. 83), Dr. Spiliotopoulos repeats that “... such data were not available prior to December 1984. Therefore, the estimated monthly contaminant concentrations cannot be verified.” Again, the whole point was to use a technically sound model, which would be calibrated to available data in and after 1985, to estimate the values during the 15 or so years prior to that calibration period to inform the epidemiological studies. For PCE and TCE, the fit with the LCM model was actually slightly better than with the MT3DMS model, which was not designed to simulate degradation products. The quality of that fit is illustrated in Figure A25.

Opinion 17: Dr. Spiliotopoulos says that “the sensitivity analysis for the various contaminant sources in Hadnot Point indicated that the timing of source-release start date is uncertain and, therefore, it is impossible to determine the historical period that contamination was present in groundwater.” The conclusion of this sentence does not follow from the precedent. Of course there is uncertainty in the timing of the release. That is well known. But the uncertainty does not make analyses impossible. Also, the uncertainty is not unconstrained. The model helps constrain the reconstructed history as it incorporates the physics of groundwater flow and solute (contaminant) transport. It is *not* impossible “to determine the historical period that contamination was present in groundwater.” It can be (and was) estimated, but with the recognition of uncertainty in the model and in the predictions. There are a fair amount of data on the groundwater flow field, which provide the calibration basis for the flow model, and the calibrated flow model has sufficient accuracy and reliability to estimate groundwater velocities and directions. The model basically shows that to simulate the observed increases in concentration at observation points, the timing of the source release becomes more narrowly constrained and its uncertainty is reduced (but not eliminated). The key is that the flow model simulates groundwater flowpaths and velocities with reasonable and acceptable accuracy.

On p. 84, referring to underground storage tanks, Dr. Spiliotopoulos says “The empirical data for UST releases may or may not be applicable to the USTs installed at Camp Lejeune and, therefore, assignment of timing and magnitude for these sources is arbitrary and uncertain.” Although uncertainty is clearly recognized, the assignment is not arbitrary. The basis is the EPA data on more than 12,000 leak incidents. Without direct observation to the contrary, why would one think that these USTs would behave much differently than the average failure time for such a large representative sample of documented cases? The approach used is not arbitrary, nor “highly” uncertain, nor an unreasonable assumption.

On p. 85, Dr. Spiliotopoulos goes on to discuss the range of years used in the sensitivity analysis, which spanned ± 9 years. The point is not that the starting release date could have been anytime in that 18-year span, but rather to examine how sensitive the results are to such uncertainty. The results shown in Fig. 34 (ATSDR Fig. A37) indicate that at the later times—i.e., during the 18 years of the epidemiological studies—uncertainty in the starting release dates has little effect on estimated TCE concentrations. For the period between about 1950 and 1970, results from each of the various starting dates tend to converge on the same solution after only 3 or 4 years of simulation time.

In the summary for opinion 17 (p. 86), Dr. Spiliotopoulos says “it is not possible to confidently determine the actual period of groundwater contamination ...” I would counter that it is possible to do so with some reasonable level of confidence, and ATSDR has done so. Of course there is uncertainty.

Opinion 18: Dr. Spiliotopoulos states that “the sensitivity analysis of the dose reconstruction model for HP was based on parameter variability unsupported by data.” And that “the results of the sensitivity analysis were incorrectly presented as an uncertainty analysis range.” Support is said to be in Section 4.2.5.1.2.

First, I note that there is some overlap and linkage between sensitivity analysis and uncertainty analysis. Anderson & Woessner (in their 1992 book on “Applied Groundwater Modeling”) in discussing sensitivity analysis state: “The purpose of a sensitivity analysis is to quantify the uncertainty in the calibrated model caused by uncertainty in the estimates of aquifer parameters, stresses, and boundary conditions.”

On p. 87 (Section 4.2.5.1.2) Dr. Spiliotopoulos argues that the sensitivity analysis used extreme values for parameters. But these “extreme” values were not used for the hindcasting (historical reconstruction), which was done using the calibrated model and calibrated parameter values. The wide range in parameter values was only used to assess model sensitivity and uncertainty, and thereby gain some further understanding of how and why the model is behaving as it does. This is not unusual. It has minimal or negligible effect on the calibrated model.

On p. 89, Dr. Spiliotopoulos argues that the range of parameter values in the sensitivity analysis was too wide. The inference then seems to be that the range of results (shaded areas) shown in Fig. 35 (ATSDR’s Fig. A34, shown on p. 90) is too wide and should be narrower (closer to the results for the calibrated model). This doesn’t seem like a major problem, as it would imply that the model results may be better defined than indicated otherwise. In looking at sensitivity, ATSDR did not imply that these “extreme” values were realistic or expected. They only illustrated a possible maximum bracketing of results.

In the Summary comments for Opinion 18, Dr. Spiliotopoulos concludes that “ATSDR presented the results of this analysis as indicative of the expected range of reconstructed monthly contaminant concentrations.” I don’t see where they said or implied this.

Opinion 19: Dr. Spiliotopoulos expresses a concern that the Hadnot Point analysis “only partially addressed model uncertainty.” Support is included in Section 4.2.5.2.

In Section 4.2.5.2 (p. 91): In the first paragraph Dr. Spiliotopoulos seems to imply that ATSDR’s use of Latin Hypercube Sampling was somehow an oversimplified approach. This is a valid and appropriate

method to use in these circumstances. For example, in conducting the Performance Assessment for the radioactive waste repository at the WIPP site in New Mexico, DOE and Sandia National Labs used the LHS approach with their groundwater flow and transport models for the WIPP site, as part of their application for approval to begin operations. This work was carefully reviewed by a National Academy Committee (NRC, 1996) and WIPP was granted approval to begin operations by the U.S. Environmental Protection Agency in the mid-1990s. There is nothing wrong (and a lot right) with the use of this method. EPA approval was granted even though there were no observations at all of concentrations in the aquifer of concern, yet predictions were made for 10,000 years into the future.

Section 4.2.5.2 (p. 91): In indicating that the uncertainty analysis was incomplete, Dr. Spiliotopoulos says (para. 2, p. 91) "ATSDR considered a small number of only 10 uncertainty scenarios." While it is debatable as to whether ten is a "small" number of scenarios to evaluate, it is a reasonable number to consider, and the 10 scenarios encompass a lot of the uncertainty in parameters and boundary conditions. ATSDR accomplished the goal of completing and documenting an uncertainty analysis, although it would have been possible to add additional scenarios to consider. It is highly unlikely, however, that adding more scenarios would lead to a modification of the calibrated model or to a different historical reconstruction.

In the first paragraph on p. 92, Dr. Spiliotopoulos quotes Doherty: "ideally, the value of the prediction should lie somewhere near the center of the uncertainty band." He then states that the ATSDR calibrated model "fails to conform with this rule ..." However, this is not anyone's "rule." It is an idealization. Where the calibrated model lies off the center of the uncertainty range of estimates, it may simply be because additional parameters and scenarios need to be incorporated into the Monte Carlo simulations. In statistical testing, it is generally acceptable for a point or sample to fall within a range of two standard deviations of the mean.

In his summary for Opinion 19 (p. 92), Dr. Spiliotopoulos states that "the analysis only partially addressed the model uncertainty." But if more scenarios were considered or if more than 95% of the results were shown, the increased number of scenarios would widen the range and place the calibration results more consistently towards the middle of the range. Most of the time, the calibration is within the range of uncertainty brackets; when not, it is only very slightly above them. Overall, this does not seem to be a major issue. If additional factors were considered, the range would likely be wider and encompass all of the calibrated results. I also see no reason why this would have led to a different set of calibrated parameters.

Section 4.2.5.3, Concluding Remarks (p. 92): Dr. Spiliotopoulos reiterates his concern that there is lack of historical data to constrain the calibration. He quotes an article that says the "model should replicate observed system behavior." This must be taken in a general way because a model is by definition a simplified approximation of a complex real system, and no model can literally replicate a real system and its behavior. He argues that "The ATSDR model results did not meet this requirement." I disagree, and believe that there was a satisfactory representation of observed behavior for both head distributions and concentration distributions. Could it have been better? Sure, if more data had been available. Is it good enough to produce a reasonable hindcast historical reconstruction? I believe the answer is yes. Dr. Spiliotopoulos says "that there is 'no observed system behavior.'" This is simply wrong. There are some water-level data available, and very good agreement between observed and simulated heads (water

levels). This agreement provides confidence in the computed directions and velocities of contaminant migration. There are some observed concentrations. It would be nice if more concentration observations had been made in the past, but they weren't. Where such data are available, the model often provides a very good match to those data. With the goal and implementation of computing monthly averages, there is no way that the model could have replicated the large concentration changes sometimes observed over short time periods and between successive samples. He also states that "ATSDR failed to quantify the uncertainty range reliably." But they did quantify it and document it. They did so reliably. Perhaps it could have been more comprehensive and considered more factors, but that doesn't mean that they didn't "quantify it reliably." Although comprehensive uncertainty analysis is desirable, doing so is not a necessary condition for calibrating a groundwater model.

Section 4.2.5.3, Concluding Remarks (p. 93): Dr. Spiliotopoulos says "If parameter sensitivity and uncertainty can only be evaluated in a qualitative way, ..." then the results and conclusions are not "scientifically defensible." The sensitivity and uncertainty analyses were definitely quantitative, and the quote from ATSDR (bottom p. 92) did not say these analyses were ONLY "qualitative". I believe that the model development by ATSDR for both TT and HPHB are scientifically defensible.

Review Comments on Chapter 3:

p. 10, Section 3.1.8 (Concluding Remarks): Dr. Spiliotopoulos says "Model calibration is not possible when there are no historical data to match." However, there are historical data available for Camp Lejeune. The ATSDR models were calibrated using comparisons to historical data—both groundwater level observations and some data on solute concentrations in water samples. There are many direct measurements of hydraulic conductivity—a key parameter in simulating groundwater flow and velocity. So the concluding statement above is simply not applicable to the ATSDR model development and calibration.

p. 12, Section 3.2: In this paragraph, Dr. Spiliotopoulos concludes by stating "However, the timing and quantification of contaminant releases from that source [ABC Cleaners] are uncertain, due to a lack of historical data." Of course, the timing and quantification of contaminant releases from ABC Cleaners has some associated uncertainty. However, there is knowledge of when they operated, precise information on its location, and there is little doubt that it was a source of contamination. The modeling exercises help reduce the uncertainty about the timing and strength of the contaminant source. It is rare (if ever) that the precise release dates and strengths of a historical contamination source are known. This is a type of uncertainty that is commonly dealt with in model development, and this type of uncertainty does not preclude the development, calibration, and usefulness of a groundwater model.

A related issue of contaminant travel times from ABC Cleaners to well TT-26: (Hennet's report, p. 5-15 – 5-16 and his Attachment D): Dr. Hennet estimates a range of values for travel times of PCE between ABC Cleaners and TT-26 that are stated to be "in the 15 to 25 years range", based on three assumed "representative" flow paths, indicating the arrival didn't occur until the 1970s. He presents supporting material and calculations in his Attachment D. Dr. Hennet assumes the horizontal travel distance in the shallow aquifer is either (1) 200 ft in the shallow aquifer and 800 ft in the pumped aquifer, (2) 500 ft in the shallow aquifer and 500 ft in the pumped aquifer, or (3) 800 ft in the shallow aquifer and 200 ft in the pumped aquifer. He further assumes that the hydraulic gradient in the layer 2 confining unit is the same

in all cases (i.e., at three different distances from the pumping well). This is not a reasonable assumption (for example, see TT Figs. C19 & C21). In the pumped aquifer, a cone of depression will form with lowest heads adjacent to the well and higher heads further from the well. In the shallow aquifer, the heads will not change much due to pumping in the deeper aquifer. This drawdown effect is strongest near the well, and results in a greater hydraulic gradient (and faster velocity) across the confining layer closer to the well.

Pumping also results in a steeper horizontal gradient (and faster velocity) closer to the well in model layer 3, and a shallower gradient further from the well. Dr. Hennet's calculations assume the same horizontal velocity in the pumped aquifer regardless of the distance from the pumped well, which is not a valid assumption.

Examining the heads for model layers 1 and 3 as shown in TT Figs. C18 and C19, and looking at a point about halfway between ABC Cleaners and TT-26 and at a point very close to TT-26, the head difference between the two layers (across the confining bed) is about $10' - 9' = 1$ ft at the halfway location and about $5' - 2' = 3$ ft at a location close to TT-26. Therefore, the hydraulic gradient potentially driving downward flow is about 3 times greater close to the well than it is halfway between the well and the contaminant source. So this large spatial change in vertical hydraulic gradient must be accounted for, and the assumption that it is the same at all locations cannot be supported. Dr. Hennet does not account for the steeper vertical gradient in layer 2 for the path closer to the pumped well, nor does he account for the faster velocity in layer 3 when the travel distance is only 200 ft.

It is more likely that the travel distance in the shallower aquifer for much of the contaminated shallow groundwater would be more than 800 ft and the corresponding travel distance in the pumped aquifer would be less than 200 ft because (1) the vertically downward transport is more likely to occur where the vertical gradient is the strongest in the confining layer, which is closest to the pumping well, (2) the downward velocity would be fastest where the gradient is steeper close to TT-26, and (3) according to Dr. Hennet's calculations, the downward flux is only about 5% of the horizontal flux in the shallow aquifer, so that even if some contaminant leaked downward at further upgradient distances from TT-26, much would remain in the shallow aquifer to migrate to locations closer to, or even adjacent to, TT-26, where downward leakage would be the fastest. Thus, Dr. Hennet's three "representative" flow paths did not include a more critical flow path in which travel in the shallower aquifer is close to 1,000 ft. For this critical flow path, the travel time would be much less than 15 years—on the order of 3.5 to 5 years. For these several reasons, Dr. Hennet's estimates of travel times from ABC to TT-26 are erroneous, misleading, biased-high, and based on unreliable assumptions.

Well TT-26 pumpage (Hennet's report p. 5-36): Dr. Hennet continues in criticizing the pumpage assumptions about well TT-26. He says, "ATSDR assumed that supply well TT-26 was constantly pumping prior to 1980. This is unlikely as supply wells cannot remain in service for decades without shut down periods for repairs and maintenance." Dr. Hennet implies it is unreasonable to assume this, yet offers absolutely no evidence to support his contention. This can be contrasted with ATSDR's study, which (p. 18) states that they have documented pumping records for TT-26 (and other wells) for some time periods and those estimates "are based on documented information detailing periods of maintenance for specific wells." For earlier periods in which there are no explicit pumping records, TT Chapter C (p. C22-C23) describes their estimation approach in detail (and Dr. Hennet does not offer a better way that this could have been done). Furthermore, in general, well maintenance frequently only requires a day to

a few days to complete. If TT-26 had been shut down for only a few days during a few months of every year for servicing, the monthly simulation model would still have to assume it operated for a full month each time, though at a proportionately reduced monthly pumping rate to reflect the actual total monthly withdrawal. It is hard to accept Dr. Hennet's speculative and hypothetical criticism or expect that it would make any difference.

p. 21-22 (Section 3.3) & p. 29: Dr. Spiliotopoulos cites Clement's 2011 issue paper (published in Ground Water journal); but these comments don't cite the Author's Reply (by Clement) to the published Comment by Maslia et al. in response to the original article. In his Reply to the Comment, Clement states "The goal of my article was not to review the Camp Lejeune (CLJ) modeling studies. Rather it was to use the CLJ problem as an example to highlight issues related to model complexities and to spark an open debate on when, where, and why we should limit model complexity." Therefore, Clement admits the article did not constitute a detailed technical review of the Camp Lejeune model study, so his 2011 Issue Paper that appeared to criticize it should not be taken as an expert analysis of the model or of its reliability or of the site. The Comment by Maslia et al. provided detailed rebuttals to Clement's concerns.

p. 21 (Section 3.3): Also, on p. 21 Dr. Spiliotopoulos states that "Dr. Clement's article echoed the NRC's concerns about the uncertainty in ATSDR's water model related to Tarawa Terrace and recommended a simpler approach for the water model related to Hadnot Point and Holcomb Boulevard to meet policy-oriented goals." Dr. Spiliotopoulos implies that the NRC report is a second independent review of the work. With regards to the groundwater modeling, it is not. Dr. Clement, a civil engineer, was the only groundwater expert on that committee (there were no geologists or hydrogeologists on that NRC Committee), so his concerns don't simply echo those of the NRC committee. Instead, it was likely that he was the source of those comments in the NRC Committee. While the use of "simpler models" might be okay for assessing policy-oriented goals, the simpler models would be subject to even greater uncertainty and lack of physical realism. Furthermore, the goals of historical reconstruction require a detailed and fairly complex modeling approach because the system being modeled is complex, and the use of simple models to meet such technical goals would be neither acceptable nor sufficiently accurate.

Regarding the 2009 NRC report and committee, Dr. Spiliotopoulos states that its primary charge was "to assess the strength of evidence in establishing a link or association between exposure to TCE, PCE, and other drinking-water contaminants and each adverse health effect suspected to be associated with such exposure." Consequently, almost all of the NRC Committee members were experts in medical and health fields. Only one was an expert in groundwater. The Committee had neither the focus, goal, intent, nor multiple experts to assess in depth the ATSDR's groundwater models. They were expected to focus on health effects.

Section 3.3 and scientific validity of ATSDR's models: In this section, Dr. Spiliotopoulos refers to statements by Dr. Dan Waddill. Dr. Waddill testified (Aug. 26, 2024, p. 234-235) regarding the ATSDR water modeling that "I do not think their results ... were scientifically valid because, you know, science needs to be based on real-world observations and analysis. ... and there were just not enough real-world measurements for this to count as a scientifically valid approach." He continues and concludes that the work was not scientifically valid because no concentration data were available in the 1950s-70s, and such observations can no longer be made (obviously). He argues that because of this, the hypothesis cannot be tested, so therefore it is not scientifically valid. I disagree.

I first note that Copi (1961) in discussing science and hypotheses states that “Few propositions in science are *directly* verifiable as true.” He later states, “They can, however, be tested *indirectly*.” Therefore, I would counter Dr. Waddill’s statements by noting that in developing and applying the ATSDR groundwater models, that scientifically valid methods were used, and the models were based on sound hydraulic and physical principles that themselves have been tested and shown to be accurate and reliable approaches to describing and predicting groundwater flow and contaminant transport. The models were also based on many available hydraulic tests measuring hydraulic properties of the subsurface that do not change over time, and hence were data applicable to the site during the 1950s through 1970s. The models are indirectly tested during the calibration process in that available observations are compared to simulated values. This is an indirect type of model testing (or hypothesis testing) in which observations are compared to simulated values. The underlying theories and models have been tested in numerous field studies and are widely recognized as being scientifically valid.

The question should be whether this model for this site was sufficiently well calibrated and representative to perform a hindcasting prediction. I believe it was. I think there are many questions in our universe that are addressed using principles and models of physics that cannot (for all practical purposes) be directly tested in the foreseeable future. That does not render that work to be unscientific or lacking scientific validity. Predictive uses of models, whether forward in time or backwards in time, are widely accepted uses of scientifically valid models, while allowing for the existence and recognition of uncertainty in those predictions. The fact that there is uncertainty does not mean that they are not scientifically valid or scientifically defensible. The fact that one type or time period of observations are not available does not mean that the model is not scientifically valid.

Section 3.3 and Calibration Targets: At several places in this section, the issue of “calibration targets” is mentioned along with criticism that some simulated values did not fall within the calibration target. Relevant to this discussion are my comments in the 2009 Expert Panel Report (p. 101), with which I still agree and which I therefore repeat verbatim here:

“a. Are there established standards for establishing specific calibration targets? If so, what are they? Overall, there are no standards and probably should not be any. Such targets are inevitably arbitrary and to some extent meaningless. They tend to distract from the quality of the calibration process and shift focus to the arbitrary goal. It is a “red herring.” Not achieving a predetermined calibration target should not disqualify a model, nor does that prove a model is not valuable or useful. Conversely, meeting such a predetermined calibration target does not prove that the model is a good one or that it meets the needs of the particular study or that its calculations and predictions are accurate and/or reliable.

“b. Should ATSDR establish different calibration targets than for the Tarawa Terrace model? In my opinion, the use of specific calibration targets should be abandoned. They have no real value in the context of hydrogeology, and can only serve to provide a false or meaningless image of the quality of the developed model. ATSDR only has a limited time to complete the study, and you will do the best job possible within that limited time and budget. Applying a calibration target will not lead to a better model, but it will cause some time to be spent on comparing the results to the target, and perhaps forcing the results to

fall within the target. It would be better to include on-going independent expert peer review during the model development process, as this will have a much higher payoff than calibration targets in terms of improving the quality of the final product.”

Conclusions:

Groundwater models must be (and have been) calibrated in the absence of early time concentration data, as ATSDR has done. Other representative published examples where this has been successfully accomplished include the Rocky Mountain Arsenal, CO (Konikow, 1977) and Lawrence Livermore National Laboratory, CA (Rogers, 1992). In both of these cases, the early time history was reconstructed as part of the model calibration process (it just wasn’t called “hindcasting”). This is a widely accepted procedure among groundwater modelers.

Although Dr. Spiliotopoulos repeatedly questions the accuracy of the ATSDR model and its calibration, I don’t see any evidence that it is unacceptably inaccurate. In my opinion, ATSDR followed generally accepted methods that yielded reasonably accurate results for the mean monthly concentration of contaminants. ATSDR’s TT Table F13 shows comparisons between observed and simulated concentration values, and most (but not all) are within the calibration target range. The presence of differences is not unexpected and does not indicate the model is unreasonably inaccurate or unscientific. Concentrations for many chemical constituents in groundwater typically show a high variation at local spatial scales and small time scales—much greater variability than presented by hydraulic heads. This is normal, and no groundwater transport model would be expected to reproduce or explain such small-scale variability in concentration.

Dr. Hennes presents a summary opinion on p. 5-36 of his report stating “ATSDR’s assumptions are deficient, not verifiable, and at times demonstratively incorrect.” I believe, to the contrary, that ATSDR’s assumptions are reasonable and clearly documented with their supporting basis clearly described in detail and with recognition of uncertainty. I would argue that his counter examples, such as for bulk density and K_d , make little to no difference. Dr. Hennes’s own estimates of travel times are clearly deficient and incorrect. Of course, the early time reconstructed concentrations cannot be directly verified. Those data don’t exist. That is why the state-of-the-art simulation models were needed. He further states that “ATSDR estimates are not quantitatively reliable as different plausible assumptions would lead to different results.” Nonuniqueness of calibrated groundwater models is a well-recognized issue. Different assumptions can lead to different results and different assumptions can also lead to identical results. This is true of every groundwater model ever developed. It does not negate the value or reliability of the model. This is why sensitivity and uncertainty analyses are helpful. Furthermore, it is why we put strong reliance on the expert judgment of those who have studied the particular aquifer system the longest and most in-depth, such as the ATSDR’s authors of the modeling reports. Finally, Dr. Hennes says “ATSDR COC concentration estimates are for raw water which is not equivalent to COC concentrations in the distributed water.” As I previously stated above, the opinion of experts on the 2005 Expert Review panel was that possible COC losses during water treatment at the Camp Lejeune WTPs would be small to minimal.

In my opinion, ATSDR has done an admirable job in completing a challenging task of using hindcasting with a calibrated model to reconstruct credible concentration distributions in time and space prior to the

availability of data from chemical analyses of groundwater samples in the mid-1980s. In the face of missing historical data, the ATSDR models provide useful input to epidemiological studies. ATSDR clearly and comprehensively documented the model development—providing transparency to their work. There is uncertainty in the calibrated models (as there always is in such models) and in the hindcasted results, and that is clearly recognized and evaluated. The uncertainty is not so large or unexpected as to preclude the use of the model results in the epidemiological studies or for providing monthly mean concentrations for use by health professionals to estimate past exposure of residents on an “as likely as not” or “more likely than not” basis. The methods used were rigorous and scientifically sound.

A handwritten signature in blue ink that reads "Leonard F. Konikow". The signature is written in a cursive style with a long horizontal flourish extending to the right.

Dr. Leonard F. Konikow, PhD, NAE

January 13, 2025

References

- Anderson, M.P. and Woessner, W.W., 1992, Applied Groundwater Modeling: Simulation of Flow and Advective Transport. Academic Press, San Diego. 381 pp.
- Copi, I.M., 1961, Introduction to Logic. [2nd Ed.] Macmillan, New York. 512 pp.
- Helsel, D. and Lee, L., 2006, Analysis of Environmental Data with Nondetects: Statistical Methods for Censored Environmental Data. Continuing Education Workshop at the Joint Statistical Meetings, American Statistical Association, Seattle, Washington (Aug. 2006). [Based on the textbook "Nondetects and Data Analysis: Statistics for censored environmental data" By Dennis Helsel, Wiley, 2005.]
- Hill, M.C. and Tiedeman, C., 2007, Effective Groundwater Model Calibration, with Analysis of Data, Sensitivities, Predictions, and Uncertainty. Wiley-Interscience, Hoboken, NJ, 455 pp.
- Konikow, L.F., 1977, Modeling chloride movement in the alluvial aquifer at the Rocky Mountain Arsenal, Colorado: U.S. Geol. Survey Water-Supply Paper 2044, 43 p.
- Konikow, L. F., and Thompson, D.W., 1984, Groundwater contamination and aquifer reclamation at the Rocky Mountain Arsenal, Colorado: *in* Groundwater Contamination, National Academy Press, Washington, D.C., p. 93-103.
- Kret, E., Kiecak, A., Malina, G., Nijenhuis, I., and Postawa, A., 2015. Identification of TCE and PCE sorption and biodegradation parameters in a sandy aquifer for fate and transport modelling: batch and column studies. Environ. Sci. Pollut. Res. 22. p. 9877–9888. DOI 10.1007/s11356-015-4156-9.
- National Research Council. 1996. *The Waste Isolation Pilot Plant--A Potential Solution for the Disposal of Transuranic Waste*. National Academy Press, Washington, D.C., 169 p.
- National Research Council. 2009. *Contaminated Water Supplies at Camp Lejeune: Assessing Potential Health Effects*. Washington, DC: The National Academies Press. <https://doi.org/10.17226/12618>.
- Reilly, T.E., and Harbaugh, A.W., 2004, Guidelines for evaluating ground-water flow models: U.S. Geological Survey Scientific Investigations Report 2004-5038, 30 p.
- Rogers, L. 1992. History matching to determine the retardation of PCE in ground water. *Groundwater* **30**, no. 1: p. 50–60.
- Zheng, C., and Bennett, G.D. 2002, Applied Contaminant Transport Modeling. [2nd Edition] Wiley-Interscience, New York. 621 pp.

EXHIBIT 16

Tarawa Terrace Flow and Transport Model Post-Audit

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The logo for Integral Consulting Inc. features the word "integral" in a lowercase, sans-serif font. A stylized, curved line starts from the bottom of the letter 'i' and sweeps upwards and to the right, ending under the letter 'l'.

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October 25, 2024

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ACRONYMS AND ABBREVIATIONS

ATSDR	Agency for Toxic Substances and Disease Registry
PCE	tetrachloroethylene
GMS	Groundwater Modeling System
MAE	mean absolute error
ME	mean error
NGWA	National Groundwater Association

EXECUTIVE SUMMARY

This post-audit report evaluates the performance of groundwater flow and transport models developed for the Tarawa Terrace region of Camp Lejeune by the Agency for Toxic Substances and Disease Registry (ATSDR). The models were originally designed to simulate the migration of tetrachloroethylene (PCE) contamination from the ABC Cleaners site, located adjacent to the northern boundary of Tarawa Terrace. The audit extends the original model's simulation period from 1995 to 2008 and assesses the accuracy of its predictions by comparing simulated PCE concentrations to actual concentrations measured at monitoring wells during this extended period.

The first step of the audit involved updating the original models, which were created using MODFLOW 96 and MT3DMS software. Both models covered a period between 1951 and 1994. These were successfully updated to MODFLOW 2000 and MT3DMS v5.3, ensuring compatibility with current software versions. Importantly, no significant discrepancies were detected between the original and updated models, confirming that the update process did not alter the results.

The simulation period was then extended to cover the years from 1995 through 2008. During this update, new rainfall and recharge data were incorporated in the MODFLOW model based on nearby weather stations, as the original station's data was incomplete. Additionally, the pumping rates for a set of remediation wells were included, as these wells played a role in altering groundwater flow during this period. The PCE source, which originated from ABC Cleaners and was terminated in the original model at the end of 1983, was left unchanged.

The extended MT3DMS model was found to perform well in simulating PCE concentrations at monitoring wells across the study area. The errors are remarkably well balanced, indicating a good overall fit between simulated and observed concentrations. There were localized discrepancies in error magnitude, particularly in areas where monitoring wells showed significant temporal and spatial variability. Some wells exhibited large fluctuations in measured concentrations over time, which likely resulted from natural subsurface variability, sampling errors, or differences in analytical methods. In other cases, wells showed significant differences in the magnitude of measured concentrations despite being adjacent to one another.

Despite these localized anomalies, the extended MT3DMS model captured the broader patterns of PCE plume migration with reasonable accuracy, particularly during the later years of the simulation. The largest errors were concentrated in a few monitoring wells that were already noted for irregularities in the observed data, but the model's predictions were generally consistent with observed concentrations at most well locations.

In summary, this post-audit found that the original Tarawa Terrace groundwater flow and transport models were developed using sound methodology and continue to provide reliable

insights into the migration of PCE contamination. Despite the inherent challenges in simulating complex subsurface conditions and dealing with incomplete data, the model effectively simulates long-term trends in contaminant migration. Based on this post-audit, we can find no significant evidence that would invalidate the analyses performed by ATSDR with the original model.

1 INTRODUCTION

Our names are Norman L. Jones and R. Jeffrey Davis, and we have been asked to provide a post-audit of groundwater flow and transport models originally developed by the Agency for Toxic Substances and Disease Registry (ATSDR). This post-audit included extending both models from 1995 through 2008. Based on this review, effort, and analysis, as more fully described herein, we have reached the conclusions and opinions set forth below. A complete list of all materials relied upon to form the opinions in the report will be produced within seven days of the report's submittal. Our conclusions are subject to any new materials, data, or other information provided to us prior to depositions or trial at which time our opinions and conclusions may be updated.

In July 2007, the ATSDR, U.S. Department of Health and Human Services, published a report on a groundwater flow and transport model of the Tarawa Terrace region of the Camp Lejeune military base (Maslia et al. 2007; Faye and Valenzuela 2008; Faye 2008). The model was developed to simulate groundwater flow in the aquifers beneath Tarawa Terrace and to simulate the migration of tetrachloroethylene (PCE)¹ in the aquifers resulting from the release of PCE by ABC Cleaners, which is directly adjacent to the northern boundary of the Tarawa Terrace property. The original model was developed using the MODFLOW 96 software (USGS 1996) to simulate groundwater flow and the MT3DMS software (Zheng and Wang 1999) to simulate contaminant transport. MODFLOW and MT3DMS are companion programs where the groundwater flow field computed by MODFLOW is used by MT3DMS to simulate the fate and transport of PCE.

The original Tarawa Terrace flow model was designed to simulate flow conditions over a period from 1951 to 1994. The computation grid used by the model consisted of 270 rows and 200 columns, resulting in a uniform grid cell size of 50 ft x 50 ft. In the vertical direction, the model contained seven layers corresponding to a series of hydrogeologic units, including the Tarawa Terrace aquifer and the underlying Castle Hayne aquifer system. Model features include recharge resulting from vertical percolation of water from rainfall, general head boundary conditions on the north simulating exchange (primarily inflow) of water with the aquifer north of Tarawa Terrace, no-flow boundary conditions on the west representing a no-flow boundary along a topographic divide, and specified head boundary conditions on the south and east representing Northeast Creek. The model also included the withdrawal of groundwater via pumping wells and a drain representing potential discharge of groundwater to the channel of Frenchmans Creek on the west side of the model.

For the transport model, PCE was introduced through a single cell corresponding to the ABC Cleaners spill location at a mass loading rate of 1,200 g/day for a period from January 1953 to December 1983, and the resulting plume migration was simulated through the end of the flow

¹ PCE is also known by other names, including tetrachloroethene. In this report we refer to it as tetrachloroethylene.

and transport simulation period in December of 1994. Transport processes simulated include advection, dispersion, sorption, and biodegradation.

The original flow and transport models were calibrated using a multi-stage process. In the first stage, the flow model was calibrated to steady state flow conditions representing a pre-development state prior to the introduction of groundwater extraction wells. It was then converted to a transient model with pumping wells and time-varying recharge over the period of 1951 to 1994. The transient model was calibrated to transient water levels measured at monitoring wells in the region. In the final stage, the MT3DMS transport model was included, and the parameters of both the flow and transport model were adjusted until both the heads simulated by MODFLOW and the concentrations simulated by MT3DMS matched the field-observed heads, flows, and PCE concentrations within a reasonable range.

The objective of the post-audit is to extend the range of the groundwater flow and transport models from 1995 to 2008 and compare the output of the transport model with concentrations sampled at monitoring wells in Tarawa Terrace during the 1995–2008 period to assess the performance of the model as an interpretive and predictive tool. This comparison involved both a quantitative analysis of simulated versus observed concentrations and a qualitative analysis of the shape and migration of the simulated PCE plume over that period.

In the following sections, we described the steps we took to a) import the original model and update it to work with recent versions of MODFLOW and MT3DMS, b) extend the flow model to 1995–2008 conditions, c) extend the transport model to 1995–2008 conditions, and d) compare the simulated PCE concentrations to field-observed PCE concentrations over the extended simulation period.

2 IMPORTING AND RUNNING THE ORIGINAL MODEL

To begin the post-audit, we were provided with a copy of the MODFLOW96 and MT3DMS input files used in the original model. We elected to use the Groundwater Modeling System (GMS) software, version 10.8 (Aquaveo LLC 2024) to perform the model updates. The GMS software is developed and distributed by Aquaveo LLC in Provo, Utah. GMS is a graphical user interface for the MODFLOW and MT3DMS codes and works as a pre- and post-processor (Owens et al. 1996). GMS can be used to build new models from scratch, or to import and modify existing models. The model data are then saved by GMS to input files that can be read by MODFLOW/MT3DMS. The model results output by MODFLOW/MT3DMS are then read by GMS where they can be displayed graphically and analyzed numerically.

We began by attempting to import the MODFLOW 96 files. MODFLOW has been continuously updated and improved since it was initially launched in 1984 (McDonald and Harbaugh 1984), resulting in numerous versions. MODFLOW 96 was released in 1996 and was widely used but was updated to MODFLOW 2000 (Harbaugh et al. 2000) and MODFLOW 2005 (Harbaugh 2005) in 2000 and 2005, respectively. More recent versions include MODFLOW-USG (Panday et al. 2013) and MODFLOW 6 (Langevin et al. 2017). While newer versions provide some new capabilities, both MODFLOW 2000 and MODFLOW 2005 are widely used and provide access to all of the model features used in the original Tarawa Terrace model. However, MODFLOW 96 has been mostly discontinued and is not supported by the GMS software. GMS does provide the capability to import MODFLOW 96 files and convert them to newer versions. When we attempted to import the original MODFLOW 96 files to GMS, we discovered that the files would not import properly, and GMS displayed an error message. After some exploration, we determined that we had to make a minor edit to the original WEL (wel.dat). Lines 4 through 13 were changed from a “-1” value to a value of “0.” Once the model was imported, we saved a copy of the model in MODFLOW 2000 format. To import the MT3DMS files, we had to manually update the mass loading of 1,200 g/day in GMS from January 1953 through December 1983. This was due to an outdated version of the Source Sink Mixing (SSM) package used in the original simulation. The MT3DMS files were saved in an updated format compatible with the current version of MT3DMS (v5.3) used by GMS.

After importing and converting the MODFLOW and MT3DMS files and saving them to the newer formats, we re-ran the flow and transport simulations and imported the solutions to GMS. At this point, we performed a qualitative analysis to ensure that the process of converting the files and updating to the newer versions did not change the model outputs. First, the simulated head contours from the updated flow model were compared to the head contours described in the ATSDR modeling report (Faye and Valenzuela 2008) as shown in Figure 1. The results of the updated model seem to match the results of the original model. Next, we compared PCE concentrations simulated by the updated MT3DMS model and to the concentrations simulated by the original MT3DMS model (Figure 2). Once again, the results seem to match well, indicating that no errors were introduced to the model in the conversion process.

3 EXTENDING THE FLOW MODEL

After confirming that the flow and transport simulations were properly imported and updated, we proceeded to modify both the flow and transport simulations for the post-audit. The changes made to the MODFLOW model are described in this section. The only changes made to the MODFLOW model were to extend the simulation period, update recharge values over the new period, and modify the pumping rates at remediation wells. No other changes were made to simulation settings or boundary conditions and sources/sinks.

3.1 SIMULATION PERIOD

The original simulation was from January 1951 through December 1994. We extended the simulation period through December 2008 so that the simulation included the period from 1995 to 2008. For the new simulation, no changes were made to the inputs for the original 1951–1994 period and thus the model solution for that period remained unchanged in the new model. For 1995–2008, we used the same stress period interval used in the original model, with monthly stress periods and one time step per stress period.

3.2 RAINFALL-RECHARGE

For the original flow model, the primary source of water to the aquifer was input from precipitation that infiltrated to the water table, which is simulated in MODFLOW as recharge where the units are length/time (feet/day). In the original model, a single annual recharge rate was used for each year of the simulation as illustrated in Table C7 of Faye and Valenzuela (2008). The recharge rate was found by applying a recharge coefficient of 0.235 to the annual precipitation to find an effective recharge rate representing the fraction of rainfall that percolates to the water table. This recharge rate is then entered into the Recharge Package in MODFLOW, and the package applies water to the top active cell during each stress period.

The precipitation values used in the original simulation were obtained from the Maysville-Hofman Forest station, which is north of Tarawa Terrace. For the post-audit, we attempted to obtain precipitation data from the same station. We found three different precipitation data sets that were purported to be from the Hofman Forest station, but each of these data sets was determined to be unusable. None of the data sets had a complete set of precipitation data for the 1995 to 2008 period. Furthermore, for the partial data during the period of interest, one of the data sets contained some extreme anomalies in monthly precipitation that did not appear in neighboring rain gauge stations. As a result, we elected to use rain gauge data from other stations in the vicinity of Tarawa Terrace. Using the National Oceanic and Atmospheric Administration National Weather Service website (National Weather Service 2024), we located three rain gauges near Tarawa Terrace that had a complete set of rainfall measurements during the period 1995 to 2008. The locations of these gauges relative to Tarawa Terrace are shown in

Figure 3. The mean rainfall for each of these gauges over the 1951 to 1994 period is similar to the mean rainfall for the Hofman Forest station over the same period, and the annual variations were in a consistent range. Thus, we took a simple average of each of the three stations over the 1995 to 2008 period to estimate the average annual rainfall at Tarawa Terrace and multiplied these averages by 0.235 to get the effective recharge rate and converted it to units of feet/day for use in the extended MODFLOW simulation. The rainfall values, averages, and effective recharge rates are summarized in Table 1.

3.3 PUMPING AT WELLS

Another change to the MODFLOW model over the extended simulation period was related to pumping associated with a set of remediation wells. These wells withdraw water from the aquifer, thus impacting both the flow field and the subsequent movement of contaminants simulated by the MT3DMS simulation. We were provided with a list of remediation wells and their pumping history for a period beginning in 1999 and continuing through the end of 2008. The well names, coordinates, model layers, and pumping histories over the period of interest are shown in Table 2. In each case, the pumping rates were turned on for each well at the rates shown on the corresponding dates and held constant at that rate until the next rate change or until the wells were turned off. All the other pumping wells in the model had zero pumping rates during the extended simulation period. The locations of the remediation wells are shown in Figure 4.

4 EXTENDING THE TRANSPORT MODEL

For the transport model, no changes were required to the MT3DMS inputs for the extended simulation period, except for enabling the Transport Observation package. The same dynamic transport step options used in the original model were applied to the new stress periods from 1995 to 2008. The PCE source at the location of the ABC Cleaners facility was turned off at the end of 1983, matching the original model.

4.1 OBSERVED CONCENTRATIONS

The main objective of extending the flow and transport simulation was to assess the performance of the model in simulating the migration of the PCE plume over the extended period and to compare the simulated PCE concentrations to PCE concentrations observed at monitoring wells during the 1995–2008 period. A list of the monitoring wells is shown in Table 3, the PCE concentrations observed at the wells in Table 4, and the locations of the wells in Figure 5. As presented in Table 4, the samples were all taken at 12 distinct dates beginning in 1997 and ending in 2008. The model layers associated with each well were determined by comparing the well screen depths with the grid cell top and bottom elevations for the grid cells containing the monitoring well locations and confirmed by documents provided by counsel (Weston ABC One-Hour Cleaners Dataset).

The monitoring well locations and the observed concentrations were imported as observation points in an “observation” coverage (spatial features layer) in the Map Module of the GMS software. This information was then linked by GMS to the MT3DMS Transport Observation package, which was turned on and used in the simulation. This allows MT3DMS to calculate the simulated PCE concentrations at the cells containing the observation wells and output the results in a format that we could easily access and use in our analysis.

4.2 TEMPORAL AND SPATIAL ANOMALIES

While the observed concentrations at each monitoring well listed in Table 4 are generally consistent over time, there are some exceptions that should be noted. For Well C13 in Model Layer 3, the observed concentration of 5,400 µg/L in 2002 is an order of magnitude higher than any subsequent concentrations observed at the same well and is substantially higher than all other concentrations but one. The highest concentration of 6,900 µg/L was measured at Well RWS-4A in Layer 1. The observed concentrations at this well showed extreme fluctuations over time. The observed concentration of 280 µg/L in January 2002 was followed only 3 months later by an observed concentration of 6,900 µg/L—the highest value measured. Then for the sequence of observations from 2003 to 2007, the concentrations oscillated from 1,100 → 0 → 1,000 → 92 → 1,600. This high degree of fluctuation could be due to sampling errors,

differences in analytical techniques, and/or extreme heterogeneity in aquifer properties near the well.

In addition to variations over time, there are spatial variations in the observed concentrations. Well FWS-13 has zero or low ($<5 \mu\text{g/L}$) observed concentrations over the entire range of sampling dates. However, as shown in Figure 5, it is immediately adjacent to FWS-12, RWS-3A, and RWS-4A, all of which show high concentrations over the entire range of sampling dates. Likewise, in Model Layer 3, monitoring well C12 has low observed concentrations despite being adjacent to RWC-2, which has high concentrations. Furthermore, Wells FWC-11 and C5 have zero or low ($<5 \mu\text{g/L}$) observed concentrations over all sampling dates and are relatively close to C3, which has high concentrations over most dates. C14 has high concentrations over the four dates sampled despite being directly adjacent to C13, C15-S, C15-D, and C16, all of which have low concentrations on those dates.

This temporal and spatial variability in concentrations at selected wells illustrates the extreme variability often seen when dealing with concentration data from monitoring wells. It highlights why focusing on absolute concentrations at specific dates and locations when analyzing the performance of a flow and transport model is less important than assessing the overall distribution of simulated concentrations and comparing the shape of the simulated plume with the general spatial distribution of observed concentrations. Each of these sites with high variability is generally correlated with higher model error, as shown below in the Results section.

5 RESULTS

The main objective of this post-audit is to assess the performance of the flow and transport model over the extended period of 1995 to 2008 using PCE concentrations observed in monitoring wells over that period. Before presenting the results, it is helpful to remember that when simulating the migration of a PCE contaminant plume using MODFLOW and MT3DMS, achieving a close match between simulated and observed concentrations can be challenging for several reasons:

1. **Complex Subsurface Conditions:** The subsurface environment is inherently complex, with variations in soil heterogeneity, permeability, porosity, and hydraulic conductivity. These properties vary spatially in ways that are not fully captured in the model, affecting how the contaminant plume moves through the groundwater system.
2. **Temporal Variability:** The concentration of contaminants can change over time due to factors like seasonal variations in groundwater flow, biodegradation, and chemical reactions. Simulating these dynamic processes accurately over the entire simulation period is challenging.
3. **Limitations in Model Resolution:** MODFLOW and MT3DMS rely on discretizing the subsurface into numerical grids consisting of cells that represent a subset of the aquifer. The resolution of these grids can limit the model's ability to capture fine-scale variations in plume behavior, particularly in areas with sharp concentration gradients, small-scale heterogeneities, or preferential pathways.
4. **Measurement Variability:** The observed concentrations at observation wells may contain some degree of measurement error or uncertainty. Field data collection is subject to variability, which adds another layer of complexity when trying to match it closely with model outputs. As outlined above in Section 4.2, extreme variations were observed in some of the measured concentrations used in this post-audit.

Each of these challenges was highlighted in the Faye (2008) report on pp. F44–45. It was reported that at several sites, measured concentrations varied by several orders of magnitude over a few feet of depth.

Given these challenges, it is important to qualitatively assess the overall behavior of the simulated plume in addition to quantitatively analyzing the differences in simulated and observed concentrations at specific times and locations. A qualitative evaluation helps ensure that the model captures the key processes governing plume migration, such as its general direction, spread, and interaction with sources, sinks, and aquifer boundaries. This broader perspective can offer valuable insights into the overall value of the model as an interpretive or predictive tool.

After running both the extended MODFLOW and MT3DMS simulations, we analyzed the resulting PCE concentrations at a set of monitoring well locations and compared them to the

observed concentrations. In the MT3DMS simulation, the spill at ABC Cleaners was simulated using a mass loading rate of 1,200 g/day at a single cell from January 1953 to December 1983 as described in Faye (2008). We did not alter this mass loading rate for the extended simulation. The resulting concentrations computed by the MT3DMS model are in units of grams/cubic foot. We converted these concentrations to units of micrograms/liter by multiplying the MT3DMS concentrations by a conversion factor of 35,314.7. We chose to present the simulated concentrations in micrograms/liter to match the units used in the original Faye (2008) report. This was applied to both the simulated concentrations at monitoring well locations and to the gridded data used to display the migration of the PCE plume.

5.1 MONITORING WELLS

A complete list of the observed and simulated concentrations at the monitoring well locations is shown in Table 5. The “Error” column represents the difference between the simulated and observed concentrations, and the “Abs(Error)” column is the absolute value of the error. These observations were sampled at a unique set of time periods as shown in Table 4. Taking all values into consideration, the mean error (ME) = 21 µg/L, indicating that the positive and negative errors are well balanced. The mean absolute error (MAE) = 334 µg/L.

These concentration values are displayed on a scatter plot of simulated concentrations versus observed concentrations in Figure 6. Because this is a log-log plot, it does not show values where either the simulated or observed concentrations are zero. The results are similar to the results for the original model shown in Figure F12 on p. F33 of the Faye (2008) report; although in this case, there are far more samples to compare. The dashed line in Figure 6 indicates a perfect match between the simulated and observed values. The points on the plot are mostly centered on the line, but as was the case with the original model, the simulated values appear to be biased on the high side, with the simulated values greater than the observed values. However, when the sites with zero observed or simulated concentrations (not shown on Figure 6) are factored in, the errors are balanced, as indicated by the low ME (21 µg/L) reported above.

We calculated a scatter plot of simulated versus observed concentrations for each monitoring well location where both the simulated and observed concentrations are non-zero, and the plots are shown in Figure 7. While there is high variability at some sites, most of the sites show good agreement.

Next, we generated time series plots of simulated versus observed concentrations at monitoring well locations. The results are shown in Figure 8. For Sites C1, S8, and S11, both simulated and observed concentrations were zero for all measurement dates. In general, the simulated and observed curves become closer as the simulation progresses. It should be noted that the vertical scale on each plot is variable, and the magnitude of the differences between simulated and observed concentrations can vary greatly from one plot to the next.

5.2 MIGRATION OF PCE PLUME

To get a qualitative understanding of the of the spatial distribution of the simulated PCE plume versus time and how it correlates with the temporal and spatial distribution of the observed PCE concentrations, we next generated a series of maps showing the simulated PCE plume in Model Layers 1, 3, and 5 at selected sampling dates (Figures 9–13). For each date, we overlaid the monitoring wells that were sampled on that date in each layer. The intervals and colors for the simulated PCE plume contours were selected to match those used in Figures F18–F25 in the Faye (2008) report. The monitoring well symbols are colored based on the relative magnitude of the absolute error at that date.

The results for each of the sampling dates are generally consistent. The spatial distribution of green and yellow symbols at monitoring well locations shows good overall fit of the simulated plume relative to observed concentrations, especially at the later sampling dates. The larger errors tend to be concentrated in the center of the plume where the simulated concentrations are greater. This is somewhat expected because comparing larger numbers will organically result in larger differences. Furthermore, the high errors generally coincide with the monitoring wells exhibiting high temporal and spatial variation, as described in Section 4.2. The wells identified in that section with extreme variability include FWS-13, RWS-4A, RWC-2, FWC-11, C5, and C14, all of which exhibit high errors. Other wells, such as S3 and S5, have high errors in the earlier dates but are in better agreement at later dates when the high simulated concentrations in the center of the plume dissipate over time.

To further compare the spatial distribution of the PCE plume with the PCE concentrations observed at monitoring wells, we took the errors and absolute errors from Table 5 and calculated the ME and MAE at each monitoring well location. The results are tabulated in Table 6. These MAE values were then used to create the maps shown in Figures 14–16. There is a separate map for each of the Model Layers 1, 3, and 5. In each figure, the MAE magnitudes for each monitoring well are displayed at the monitoring well locations and are superimposed on contour plots of the simulated PCE plume. The MAE error norm represents errors from multiple sampling dates, and the footprint of the plume migrated over time as illustrated previously in Figures 9–13. However, the intent here is to illustrate the spatial distribution of the error relative to the overall plume footprint, and the plume footprint is at the largest state at this point in the simulation, so it represents a useful basis of comparison.

The PCE plume for December 2008 for Model Layer 1 and the MAE at monitoring wells located in Layer 1 are shown in Figure 14. The errors at the wells are color-coded for three ranges, as shown in the figure legend. The spatial distribution of the errors indicates that there is a good overall agreement between the shape of the plume and the observed PCE concentrations at the monitoring wells. The wells with the highest errors are Wells FWS-13 and RWS-4A, which were noted in Section 4.2 as having high temporal and spatial anomalies. The simulated PCE plume for Layer 3 for the same date and the errors for monitoring wells in Layer 3 are shown in Figure 15. Once again, most of the wells on the fringes of the plume are in good agreement.

The highest errors are at Wells FWC-11, C5, C13, C14, and RWC-2, which were identified in Section 4.2 as having high anomalies. The simulated PCE plume and errors for Layer 5 are shown in Figure 16. This layer contained only two monitoring wells, and the errors are low.

In summary, the 7 wells identified as having anomalies in the observed data have high errors while the remaining 30 wells exhibit low or moderate errors, indicating good overall agreement between the simulated PCE plume and the observed concentrations over the range of the extended simulation.

6 CONCLUSIONS

Our conclusions from the post-audit analysis are as follows:

1. **Model Import and Update:** The original MODFLOW and MT3DMS models were successfully imported and updated to modern versions (MODFLOW 2000 and MT3DMS v5.3), ensuring compatibility with current software. The updated models matched the original model outputs, validating the update process.
2. **Extended Simulation Period:** The flow and transport models were extended from the original period (1951–1994) to cover the period from 1995 to 2008. Modifications included updating the recharge data based on new precipitation data and incorporating pumping rates for the remediation wells. The PCE source at ABC Cleaners was left unchanged, consistent with the original simulation ending in 1983.
3. **Observed vs. Simulated Concentrations:** The post-audit revealed that the updated MT3DMS model adequately simulated PCE concentrations at monitoring wells over the extended period. While there was a high variability at some monitoring well locations, the errors are remarkably well balanced, indicating a good overall fit between simulated and observed concentrations.
4. **PCE Plume Migration:** The extended model captured the overall migration of the PCE plume between 1995 and 2008. Simulated plumes were consistent with observed concentrations at most monitoring wells, especially during the latter stages of the simulation. The largest discrepancies occurred at a relatively small subset of wells that exhibited high temporal and spatial variability in observed concentrations. This variability may be due to sampling errors, aquifer heterogeneity, or variations in analytical methods.
5. **Model Performance:** The model performance was evaluated using both qualitative and quantitative methods. Despite challenges inherent in simulating subsurface flow and transport, such as soil heterogeneity, data uncertainty, and model resolution limits, the model reasonably captured the key behaviors of the PCE plume. The high variability in certain well measurements introduced some error but did not significantly undermine the model's overall accuracy.

In summary, the extended model demonstrates that the original model was developed using sound methods, and the model remains a reliable tool for understanding the general trends of contaminant migration in the Tarawa Terrace region. Based on this post-audit, we can find no significant evidence that would invalidate the analyses performed by ATSDR with the original model.

7 REFERENCES

Aquaveo LLC. 2024. Groundwater Modeling System, Aquaveo LLC, Provo, UT.

Faye, R.E., and C. Valenzuela. 2008. Analyses of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Drinking Water at Tarawa Terrace and Vicinity, U.S. Marine Corps Base Camp Lejeune, North Carolina: Historical Reconstruction and Present-Day Conditions – Chapter C: Simulation of Groundwater Flow. Agency for Toxic Substances and Disease Registry U.S. Department of Health and Human Services, Atlanta, GA.

Faye, R.E. 2008, Analyses of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Drinking Water at Tarawa Terrace and Vicinity, U.S. Marine Corps Base Camp Lejeune, North Carolina: Historical Reconstruction and Present-Day Conditions – Chapter F: Simulation of the Fate and Transport of Tetrachloroethylene (PCE). Agency for Toxic Substances and Disease Registry, U.S. Department of Health and Human Services, Atlanta, GA.

Harbaugh, A.W. 2005. MODFLOW-2005: The U.S. Geological Survey Modular Ground-Water Model—the Ground-Water Flow Process; Techniques and Methods. U.S. Geological Survey.

Harbaugh, A.W., E.R. Banta, M.C. Hill, and M.G McDonald. 2000. MODFLOW-2000, the U.S. Geological Survey Modular Ground-Water Model—User Guide to Modularization Concepts and the Ground-Water Flow Process. U.S. Geological Survey Open-File Report 00-92 2000. U.S. Geological Survey.

Langevin, C.D., J.D. Hughes, E.R. Banta, R.G. Niswonger, S. Panday, and A.M. Provost. 2017. Documentation for the MODFLOW 6 Groundwater Flow Model. U.S. Geological Survey.

Maslia, M.L., J.B. Sautner, R.E. Faye, R.J. Saurez-Soto, M.M. Aral, et al. 2007. Analyses of Groundwater Flow, Contaminant Fate and Transport, and Distribution of Drinking Water at Tarawa Terrace and Vicinity, U.S. Marine Corps Base Camp Lejeune, North Carolina: Historical Reconstruction and Present-Day Conditions – Chapter A: Summary of Findings. Agency for Toxic Substances and Disease Registry U.S. Department of Health and Human Services, Atlanta, GA.

McDonald, M.G., and A.W. Harbaugh. 1984. A Modular Three-Dimensional Finite-Difference Ground-Water Flow Model. Open-File Report.

National Weather Service. 2024. Home page. <https://www.weather.gov/>. Accessed on October 19, 2024. U.S. Department of Commerce and National Weather Service.

Owen, S.J., N.L. Jones, and J.P. Holland. 1996. A Comprehensive Modeling Environment for the Simulation of Groundwater Flow and Transport. *Eng. Comput.* 12:235–242.

Panday, S., C.D. Langevin, R.G. Niswonger, M. Ibaraki, and J.D. Hughes. 2013. MODFLOW–USG Version 1: An Unstructured Grid Version of MODFLOW for Simulating Groundwater Flow and Tightly Coupled Processes Using a Control Volume Finite-Difference Formulation. U.S. Geological Survey.

USGS. 1996. USGS MODFLOW-96: MODular Three-Dimensional Finite-Difference Ground-Water FLOW Model with the Hydrograph Package.
<https://water.usgs.gov/nrp/gwsoftware/modflow/modflow-96h.htm> Accessed on October 13, 2024. Available online: <https://water.usgs.gov/nrp/gwsoftware/modflow/modflow-96h.htm>. (Accessed on October 13, 2024). U.S. Geologic Survey.

Weston ABC One-Hour Cleaners Dataset²

Zheng, C., and P.P. Wang. 1999. MT3DMS, A Modular Three-Dimensional Multi-Species Transport Model for Simulation of Advection, Dispersion and Chemical Reactions of Contaminants in Groundwater Systems; Documentation and User's Guide. U.S. Army Engineer Research and Development Center Contract Report SERDP-99-1. Vicksburg, MS. 202 pp.

² Reference will be updated.

8 QUALIFICATIONS

I, **R. Jeffrey Davis**, P.E., CGWP, have almost 30 years of experience with civil and environmental engineering, hydrogeology, groundwater fate and transport modeling, and software and model development. I have both undergraduate and graduate degrees from Brigham Young University in civil engineering. I currently serve on the board of directors for the National Ground Water Association (NGWA), as well as on NGWA's per- and polyfluoroalkyl substances and Managed Aquifer Recharge advisory groups. I was one of the leads for NGWA's Groundwater Modeling Advisory Panel. I have developed and used numerous groundwater models for the agricultural industry and the mining industry, including projects involving environmental impact statements, environmental assessments, water management, groundwater-surface water interaction and contamination, dewatering, and water treatment. I also have extensive experience with the oil and gas industry, including water supply, hydraulic fracturing, and groundwater protection for the upstream market, and worked on a variety of oil release projects. I have extensive knowledge of groundwater flow-and-transport principles and have led numerous workshops and classes in the United States and around the world. I have taught several classes and workshops in association with NGWA and other professional organizations and universities for the past 3 decades. I also share my research and project work regularly with the professional societies with which I am affiliated. I frequently use groundwater models to explain fate and transport of contaminants or groundwater supplies and availability. Recent such examples include groundwater impacts from agricultural activities in Minnesota; aqueous film-forming foam contamination impacts to groundwater in Martin County, Florida; a pipeline of produced water spill in North Dakota; and groundwater availability and surface water impacts in Ventura County, California. I am regularly asked to provide opinions or participate on panels to discuss groundwater, water supply, or contaminated groundwater issues.

I, **Norman L. Jones**, Ph.D., have 33 years of experience in civil and environmental engineering. I graduated with a B.S. degree in civil engineering from Brigham Young University and with M.S. and Ph.D. degrees in civil engineering from the University of Texas at Austin. I have been a faculty member in the Civil and Construction Engineering Department at Brigham Young University since January 1991 where I currently hold the rank of Professor. I have taught university courses in a variety of subjects, including computer programming, soil mechanics, seepage and slope stability analysis, and groundwater modeling. The primary focus of my research has been groundwater flow and transport modeling, software development, remote sensing, groundwater sustainability analysis, and hydroinformatics. I was the original developer of the GMS software, which is a graphical user interface for MODFLOW and MT3DMS and is used by thousands of organizations all over the world. GMS is now developed and maintained by Aquaveo, LLC in Provo, Utah, a company that I helped found in 2007. I have taught numerous short courses on groundwater flow and transport modeling over my career. I am a member of the Hydroinformatics Research Laboratory at Brigham Young University. I have been the principal or co-investigator on more than \$20M of externally funded research. I

have authored 179 technical publications, including 88 peer-reviewed journal articles, and 1 book. I am a recipient of the Walter L. Huber Civil Engineering Research Prize from the American Society of Civil Engineers and the John Hem Award for Science and Engineering from NGWA. I have been involved in a number of consulting projects, including work as a technical expert in litigation cases. I am an active member of the American Water Resources Association, the NGWA, the American Geophysical Union, and the American Society of Civil Engineers.

9 COMPENSATION

My, **R. Jeffrey Davis**, experience is summarized in my resume, which is included as Exhibit 1. I am being compensated at a rate of \$498 an hour for my time in preparation of this report and \$498 an hour for my deposition and trial testimony, if necessary. My compensation is not contingent upon the opinions I developed or the outcome of this litigation case.

My, **Norman L. Jones**, experience is summarized in my resume, which is included as Exhibit 2. I am being compensated at a rate of \$500 an hour for my time in preparation of this report and \$1,000 an hour for my deposition and trial testimony, if necessary. My compensation is not contingent upon the opinions I developed or the outcome of this litigation case.

10 PREVIOUS TESTIMONY

I, **R. Jeffrey Davis**, have not given any deposition or trial testimony in the last 4 years.

I, **Norman L. Jones**, gave deposition testimony on October 20, 2021, in MICHAEL YATES and NORMAN L. JONES vs TRAEGER PELLET GRILLS LLC, in the United States District Court for the District of Utah Central Division, Case No. 2:19-cv-00723-BSJ. With the exception of this case, I have not given any deposition or trial testimony in the last 4 years.

Figures

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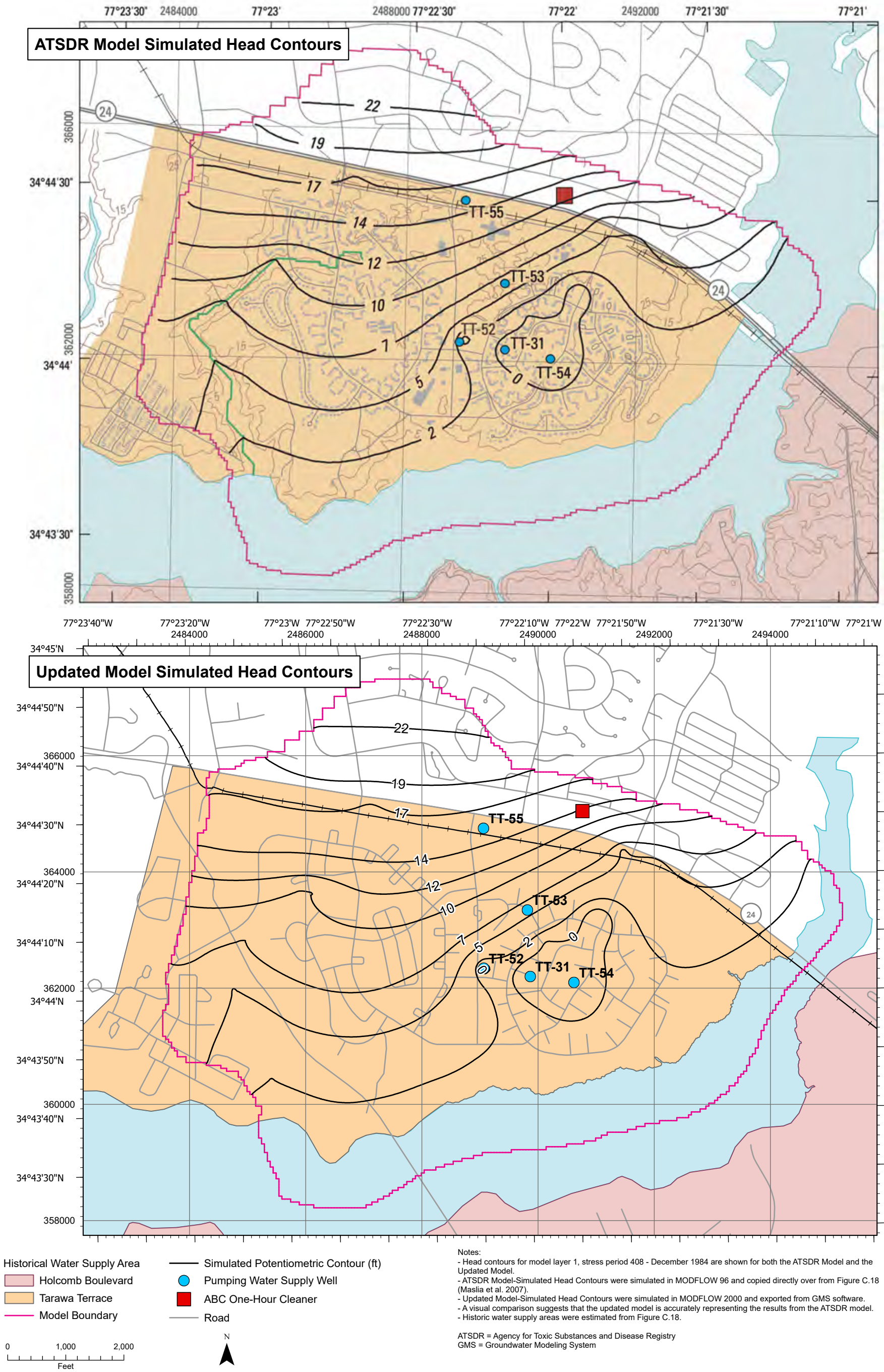
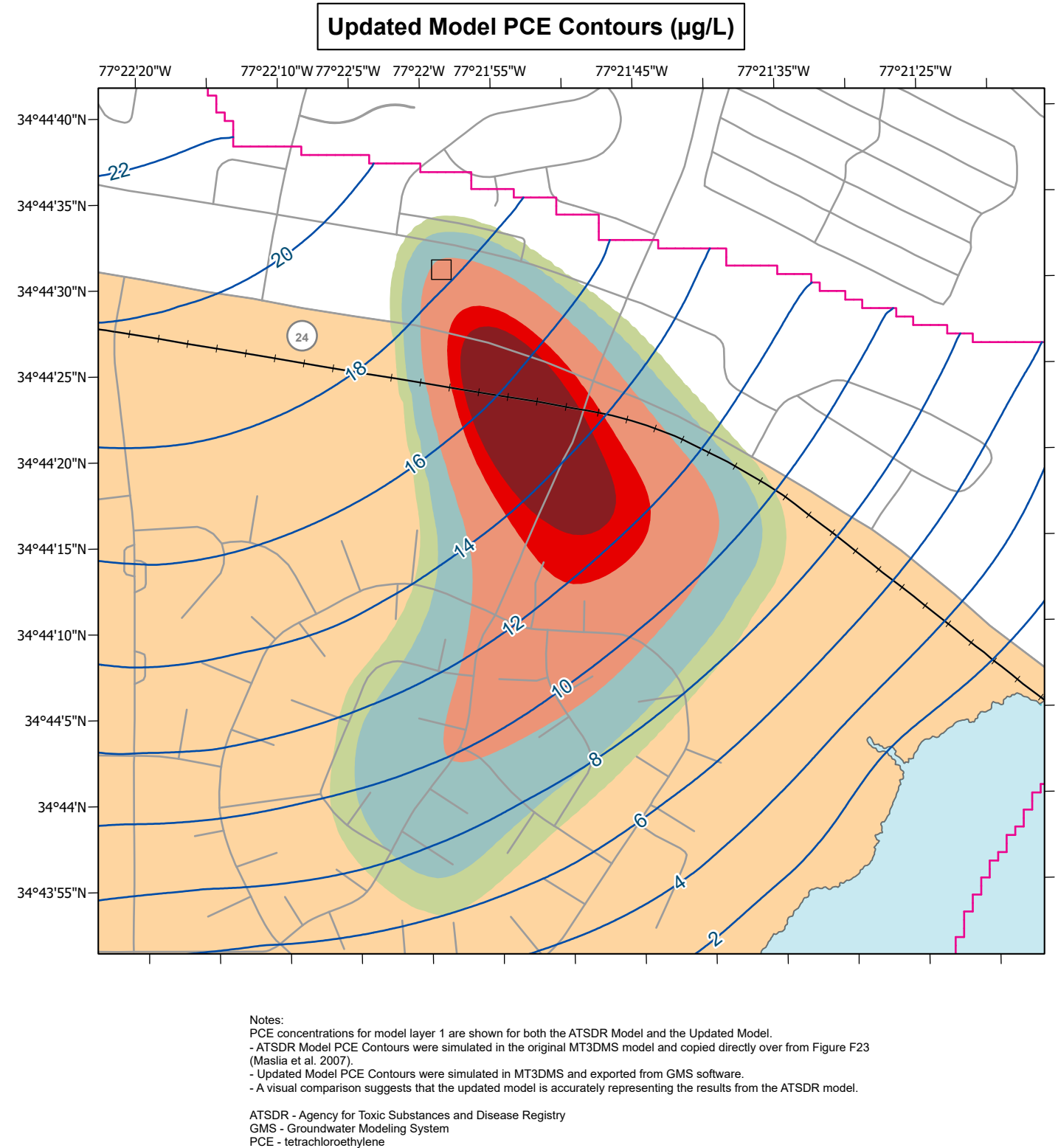
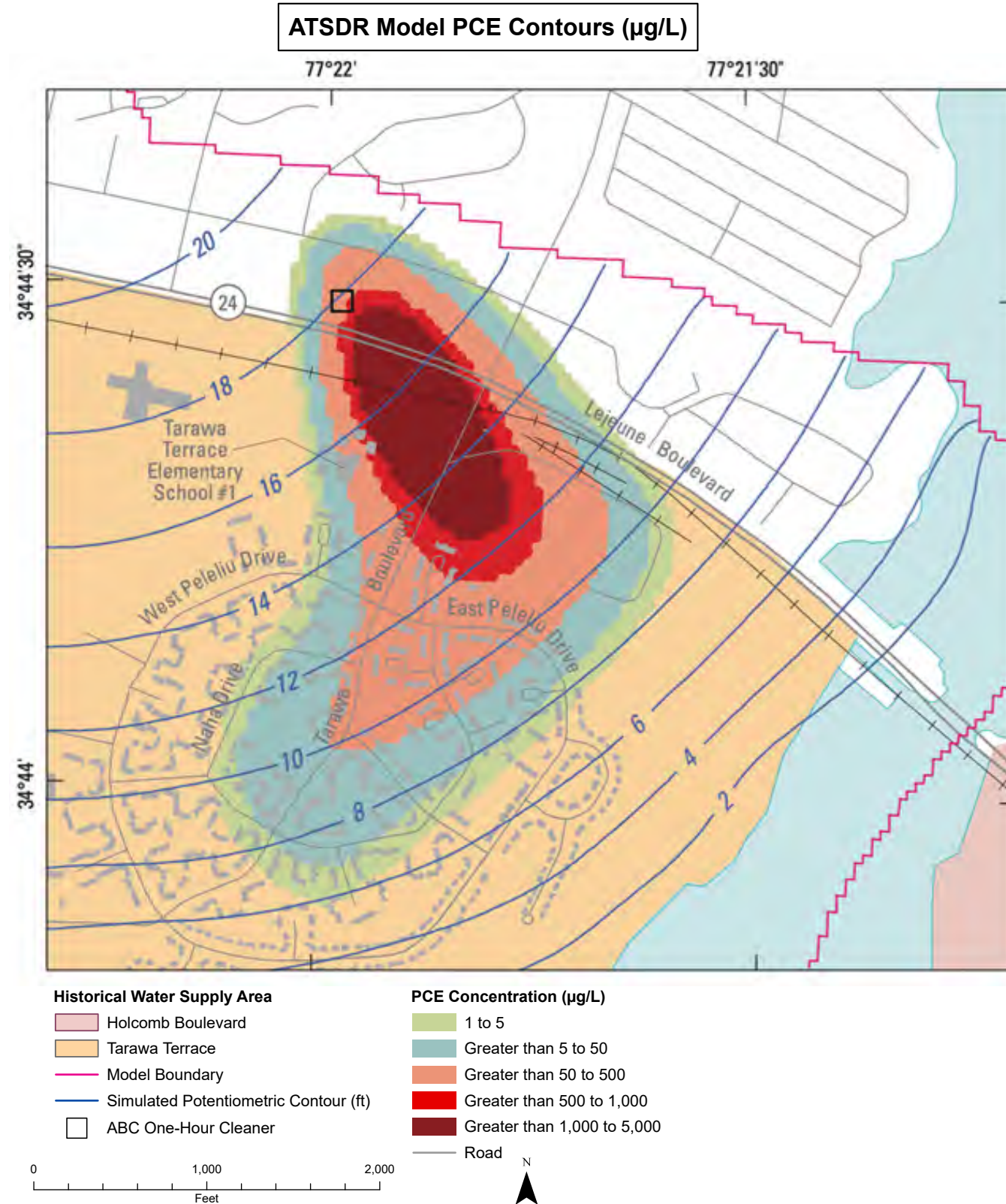


Figure 1.
Comparison of Original Model-Simulated Head Contours to
Updated Model-Simulated Head Contours
Tarawa Terrace Flow and Transport Model Post-Audit

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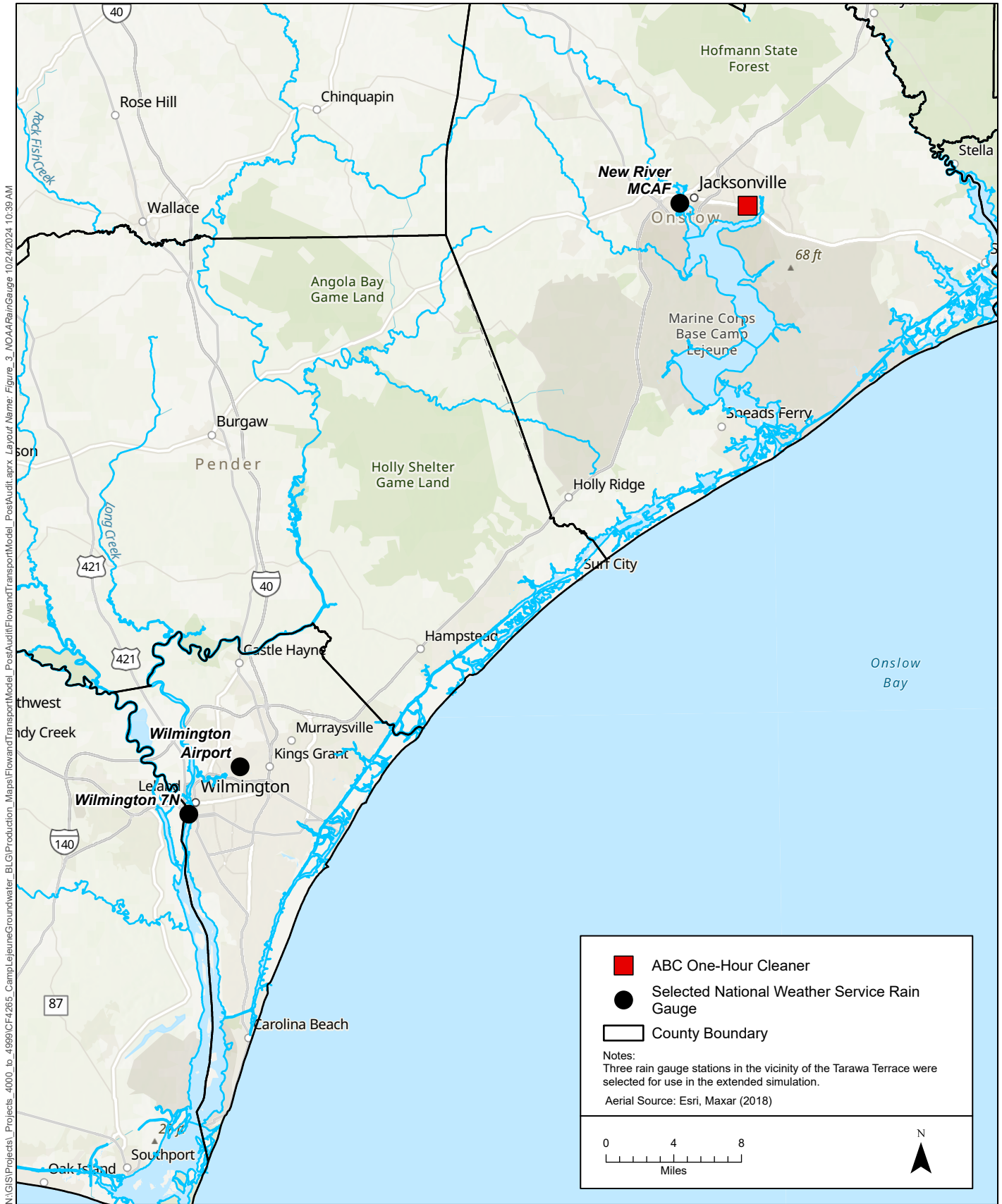


Figure 3.
National Weather Service Rain Gauge Locations Selected
for Extended Simulation
Tarawa Terrace Flow and Transport Model Post-Audit

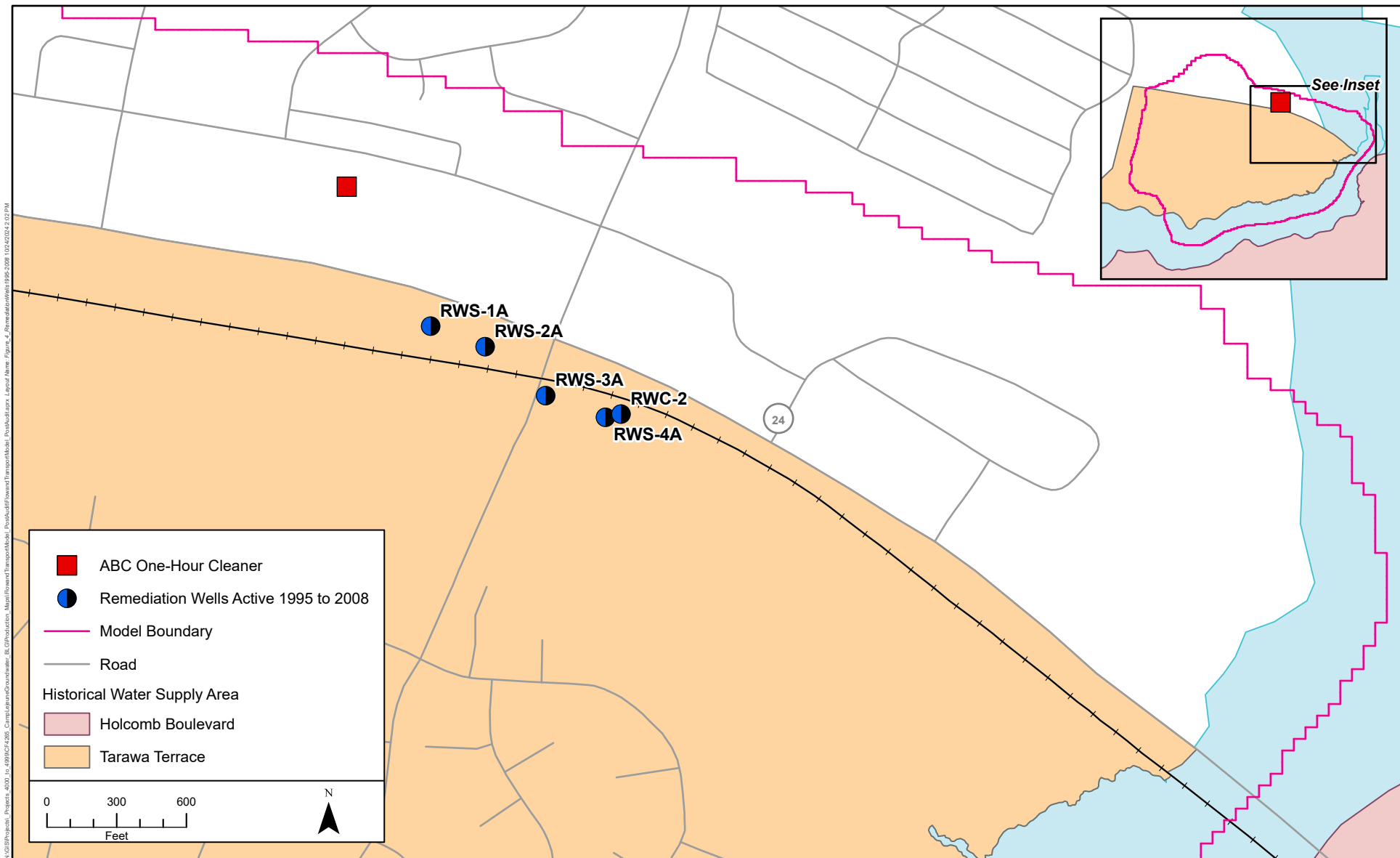


Figure 4.
 Location of Remediation Wells Active During the 1995 to 2008 Period
 Tarawa Terrace Flow and Transport Model Post-Audit

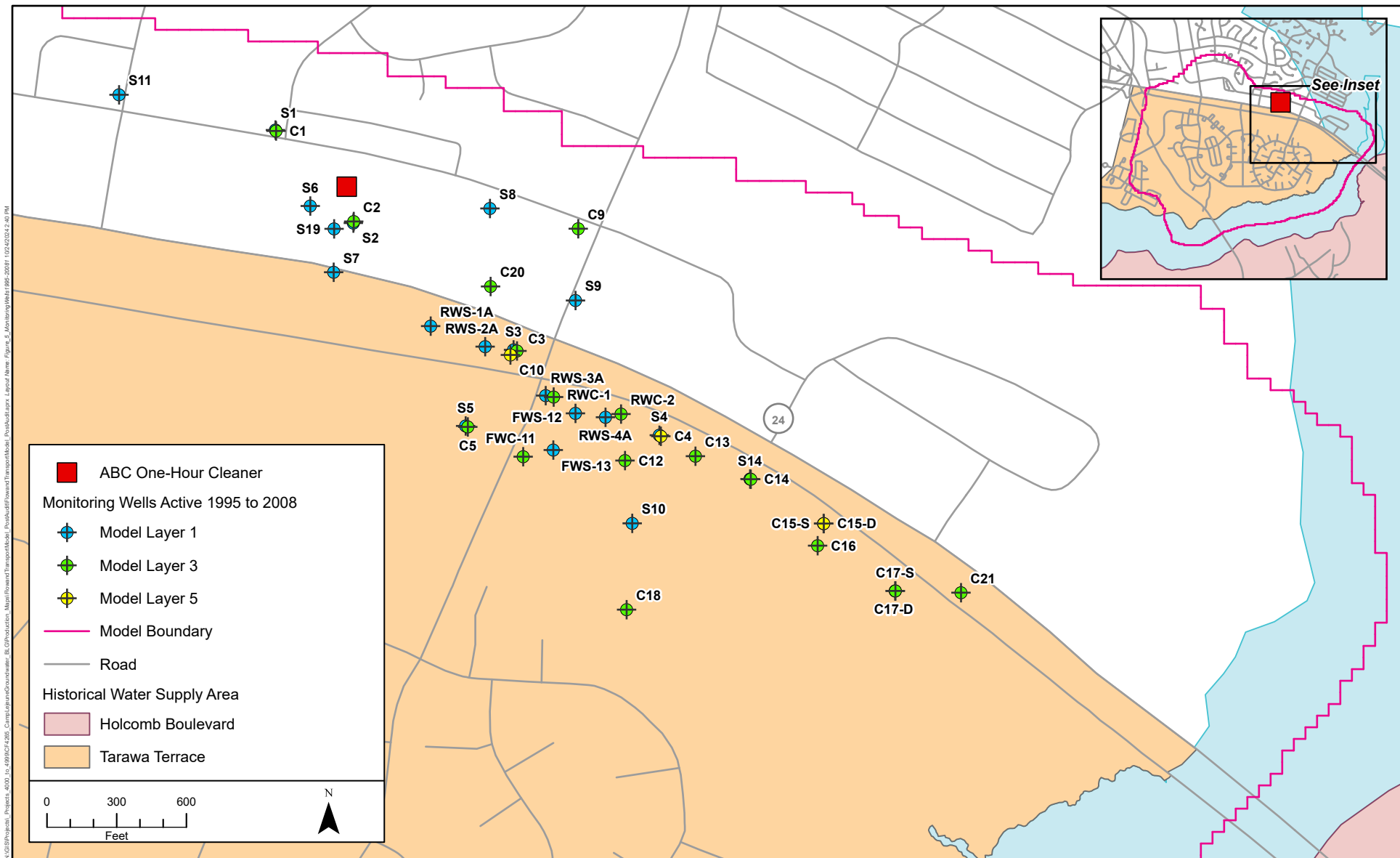


Figure 5.
Location of Monitoring Wells Active During the 1995 to 2008 Period
Tarawa Terrace Flow and Transport Model Post-Audit

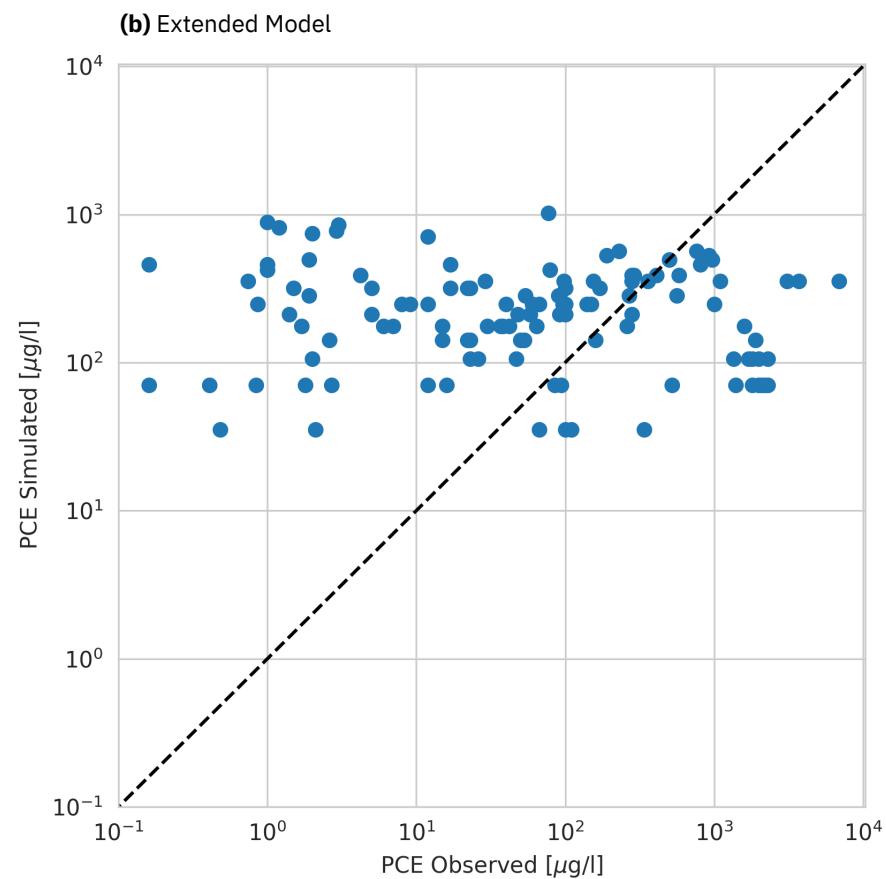
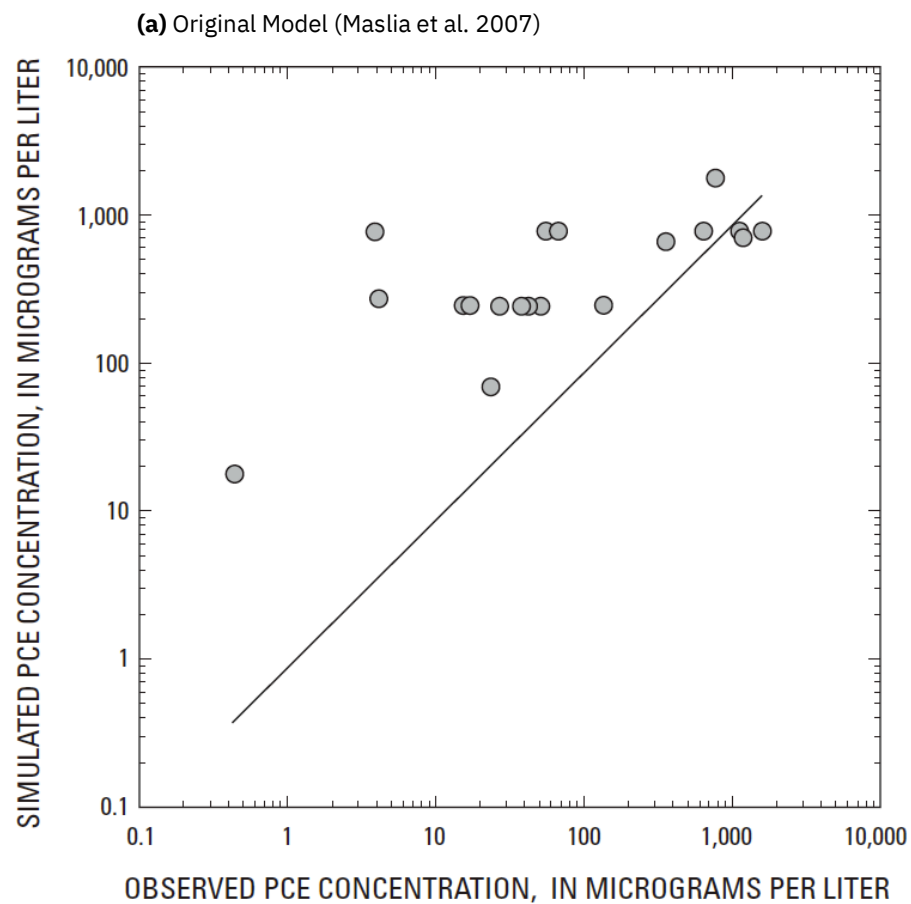
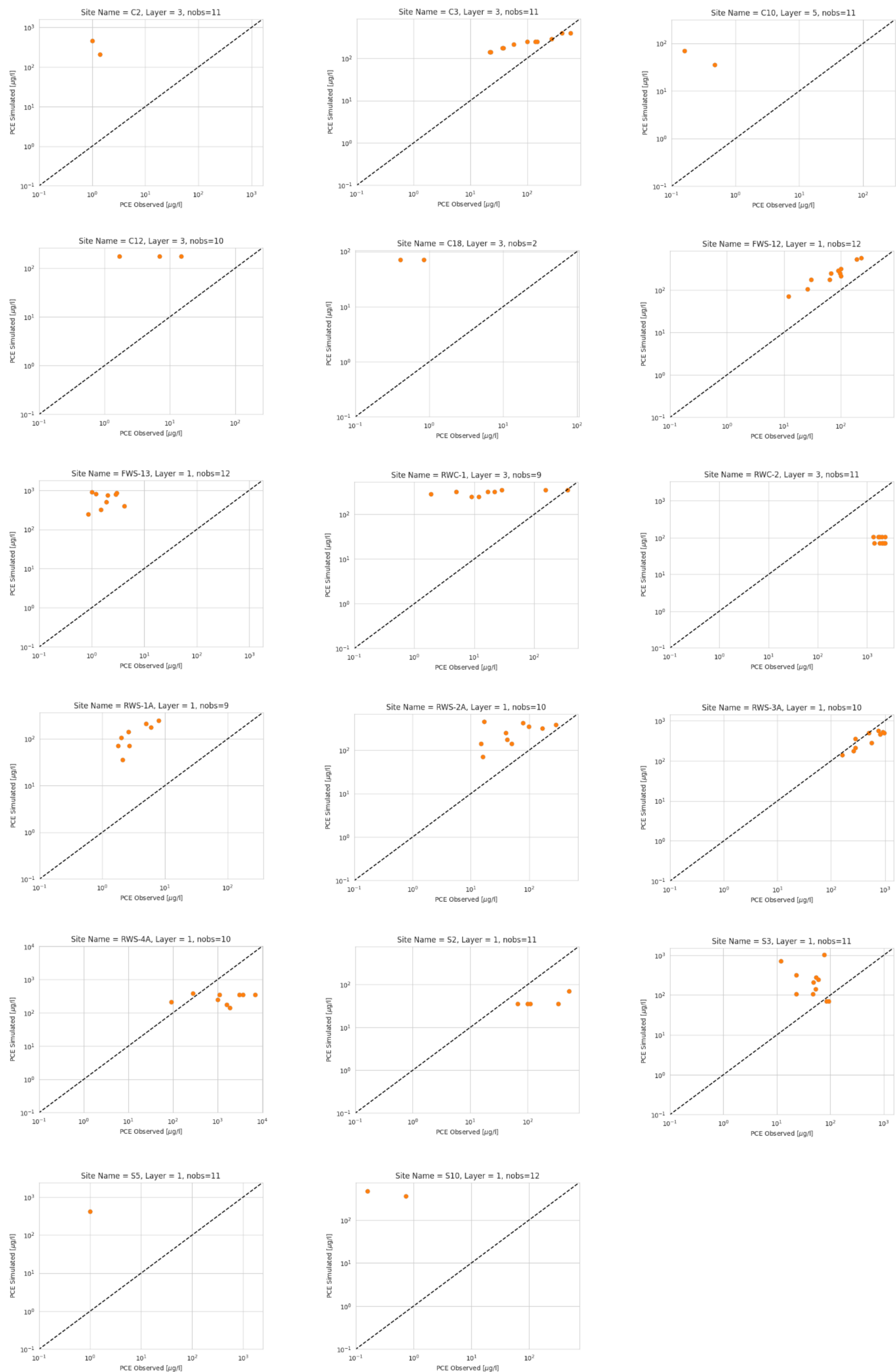


Figure 6.
 Simulated vs. Observed PCE Concentrations from (a)
 Original Model and (b) Extended Model
 Tarawa Terrace Flow and Transport Model Post-Audit



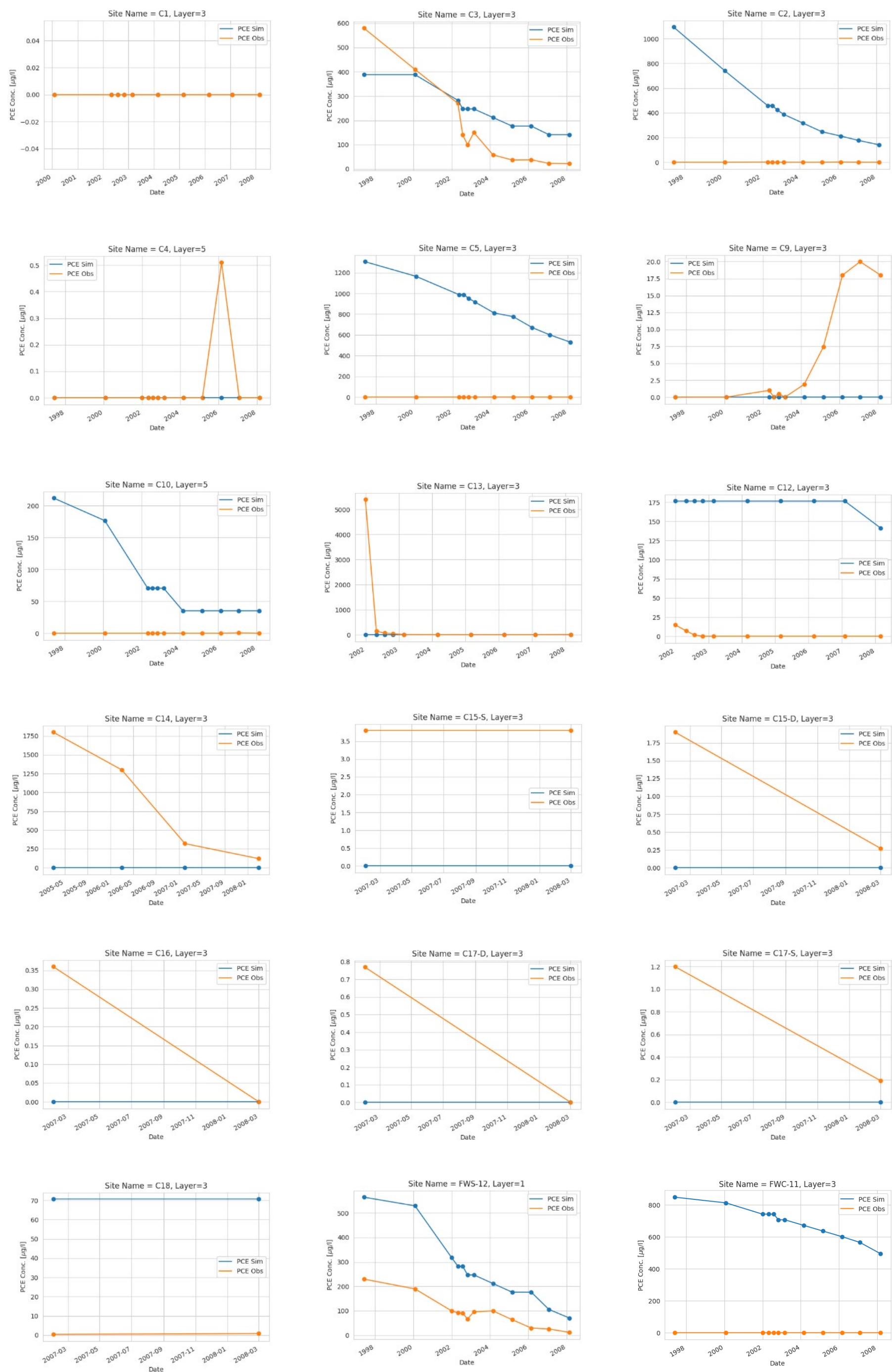


Figure 8a.

Time Series Plots of Simulated and Observed PCE Concentrations at Monitoring Well Locations
Tarawa Terrace Flow and Transport Model Post-Audit

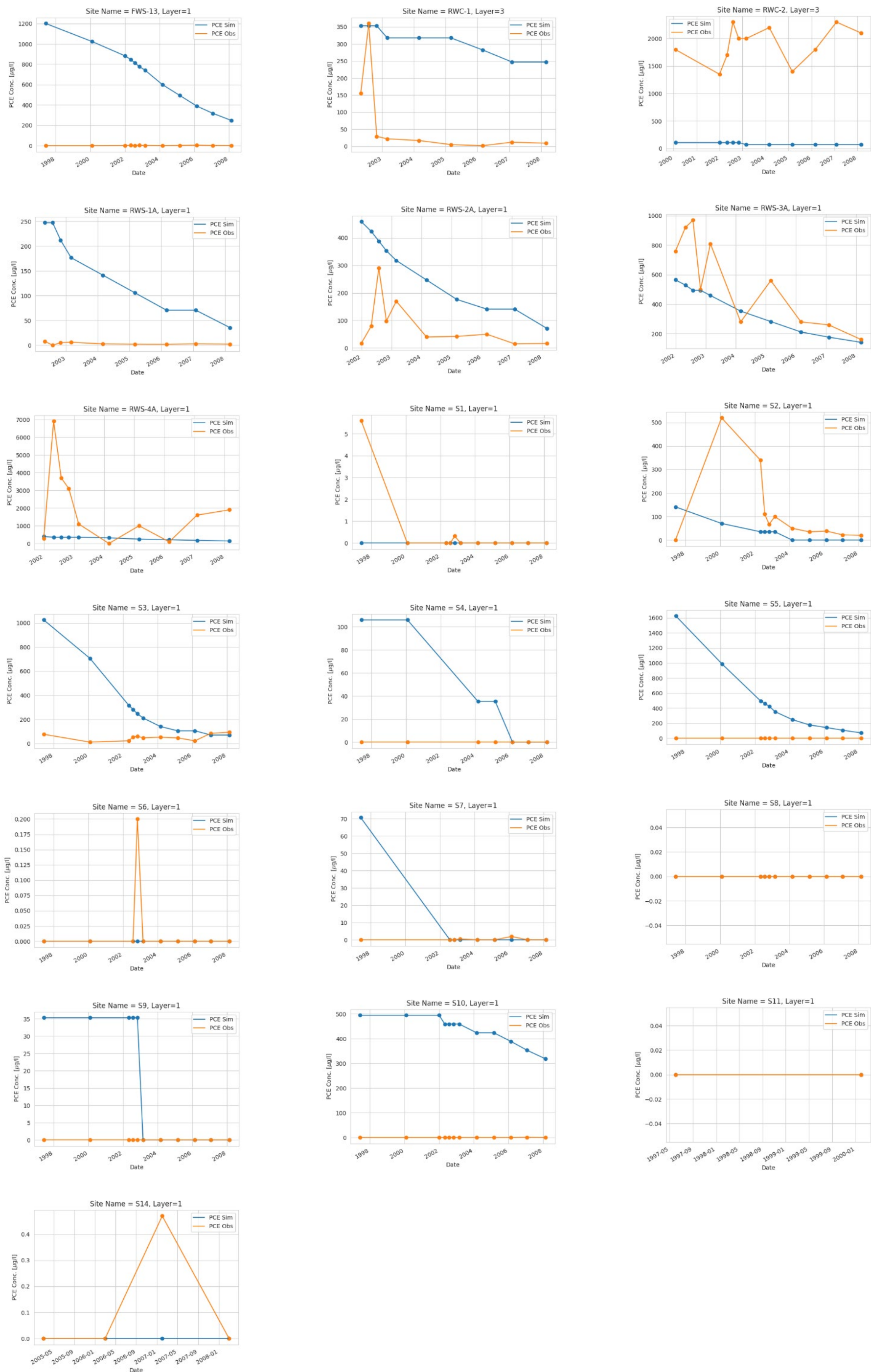


Figure 8b.
Time Series Plots of Simulated and Observed PCE Concentrations at Monitoring Well Locations
Tarawa Terrace Flow and Transport Model Post-Audit

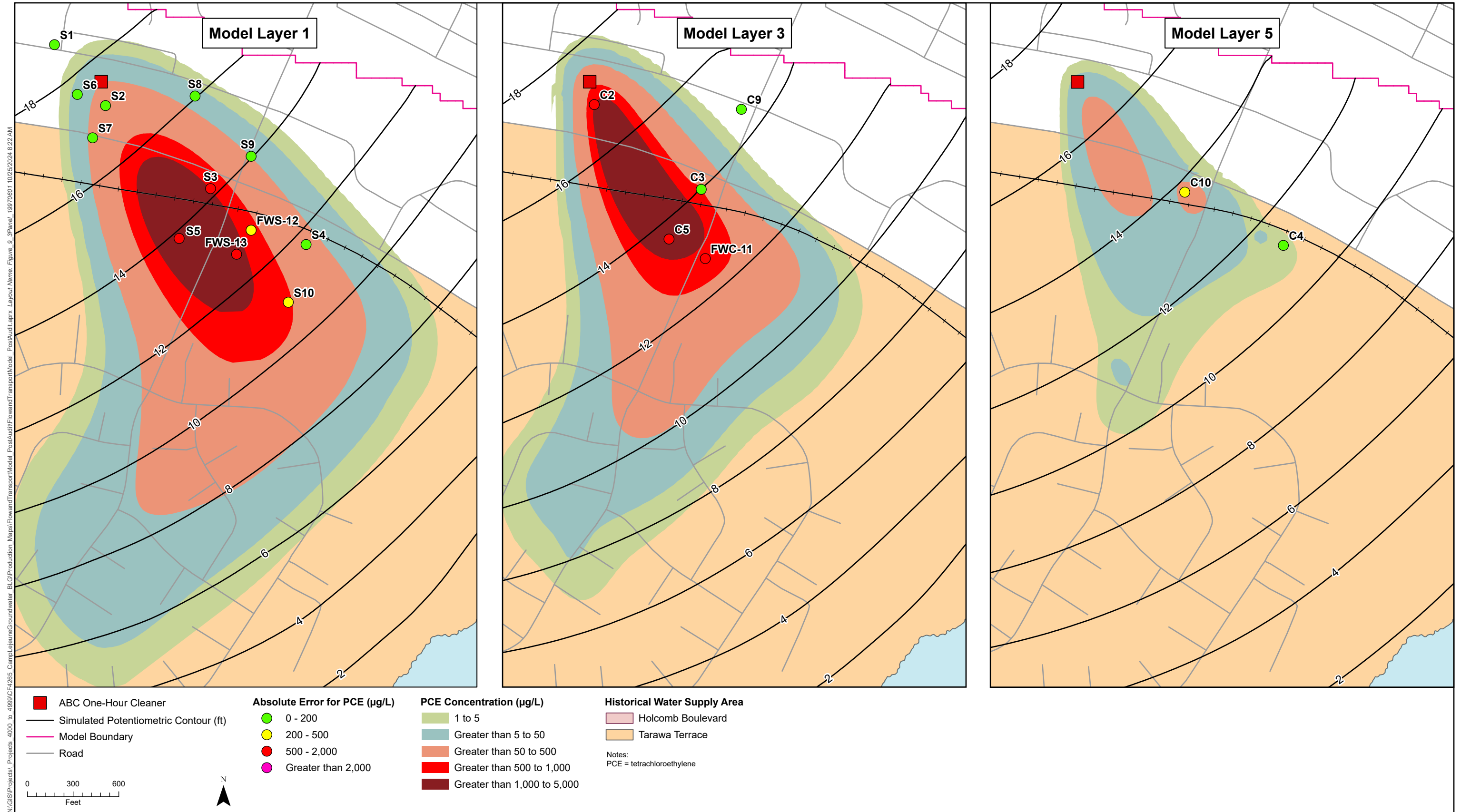


Figure 9.
 Simulated PCE Concentration for Three Model Layers
 Compared to Measured Values, June 1997
 Tarawa Terrace Flow and Transport Model Post-Audit

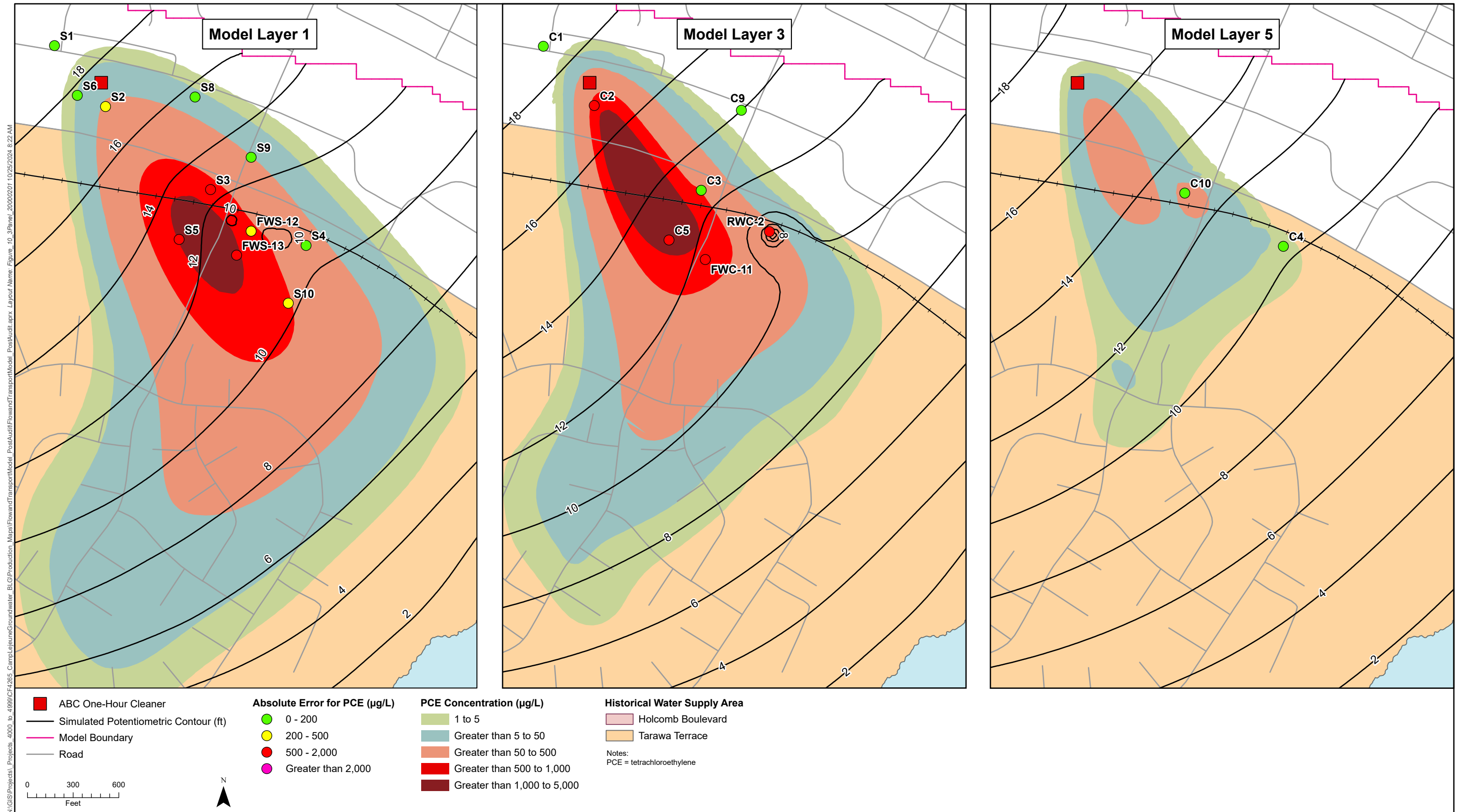
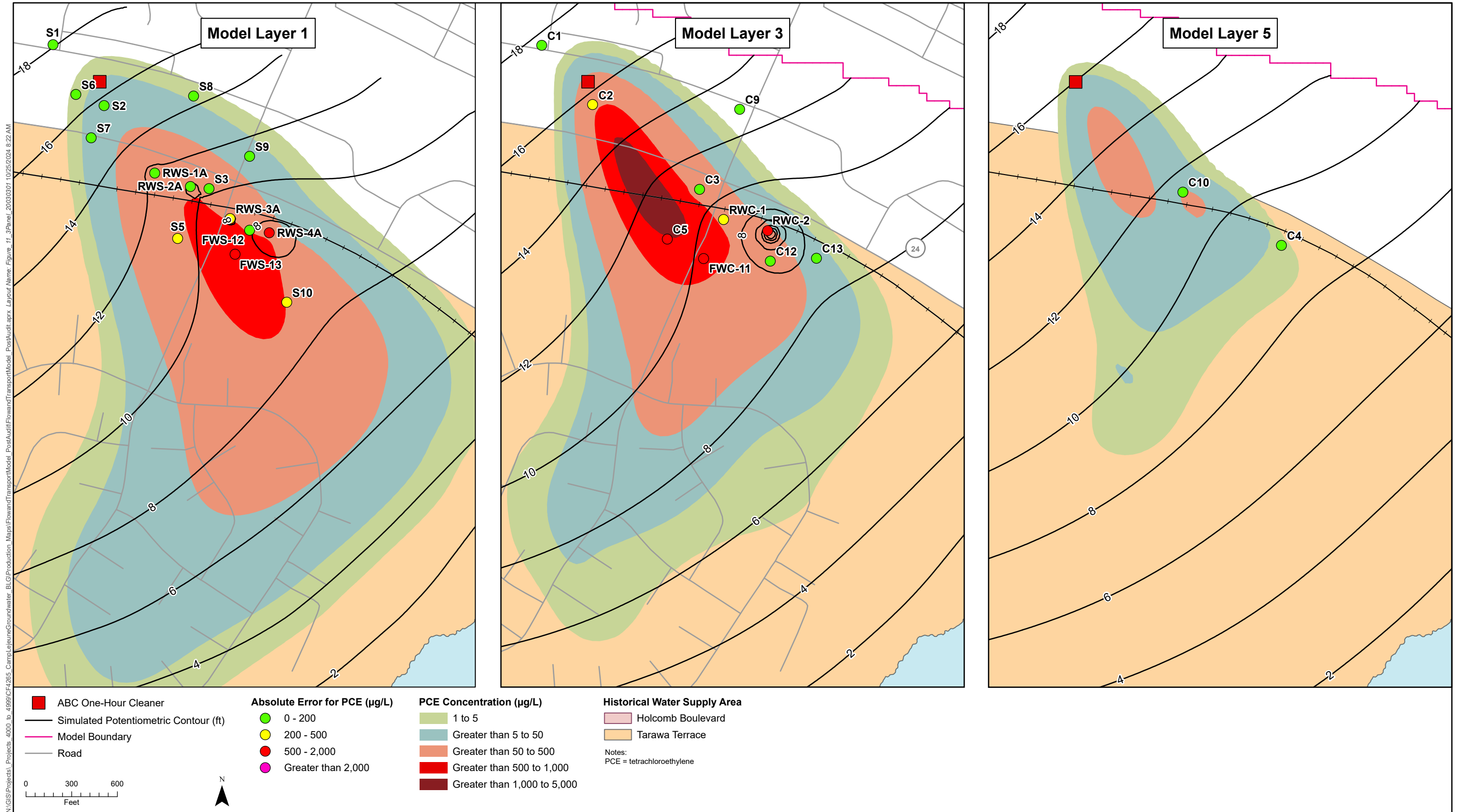


Figure 10.
 Simulated PCE Concentration for Three Model Layers
 Compared to Measured Values, February 2000
 Tarawa Terrace Flow and Transport Model Post-Audit



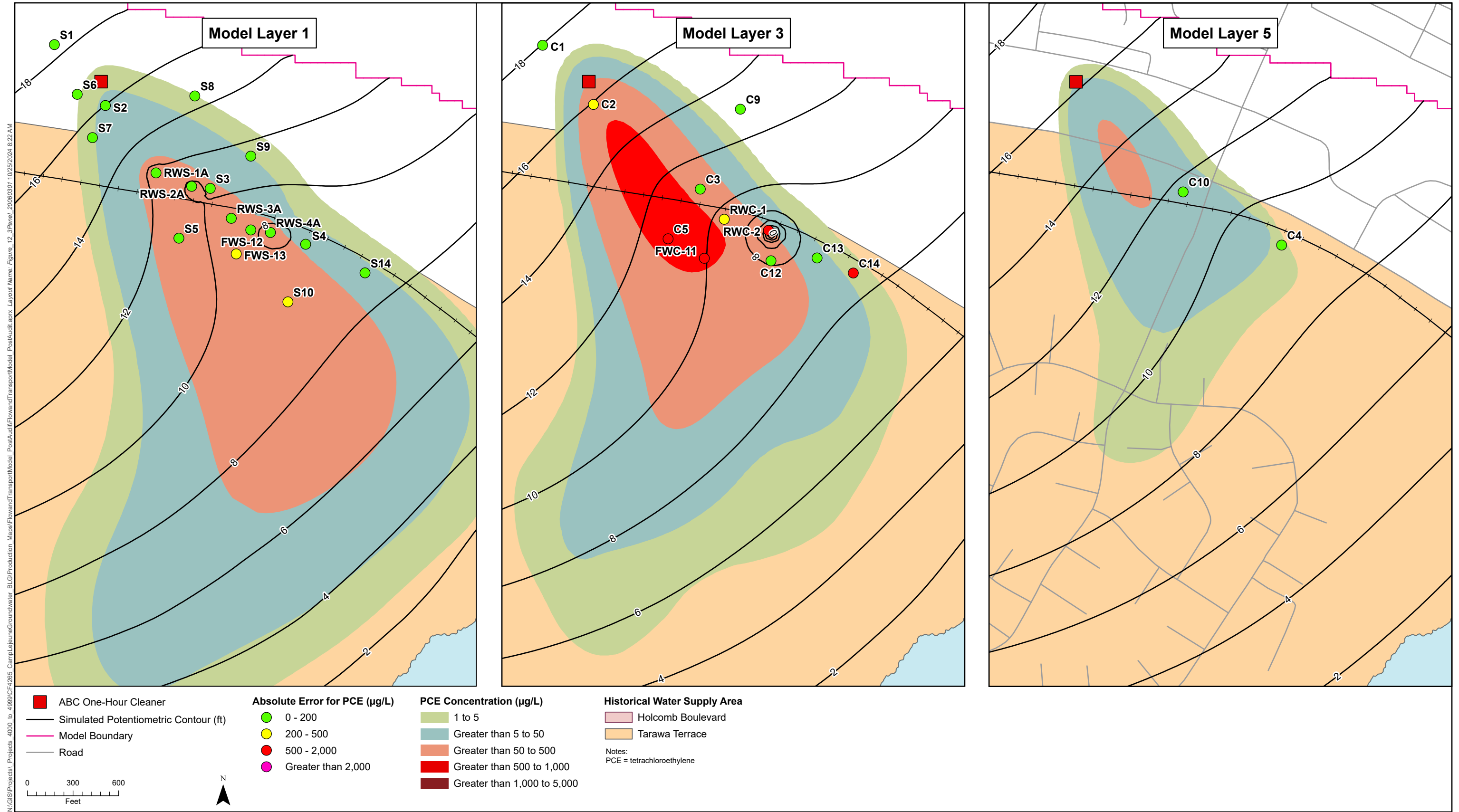


Figure 12.
Simulated PCE Concentration for Three Model Layers
Compared to Measured Values, March 2006
Tarawa Terrace Flow and Transport Model Post-Audit

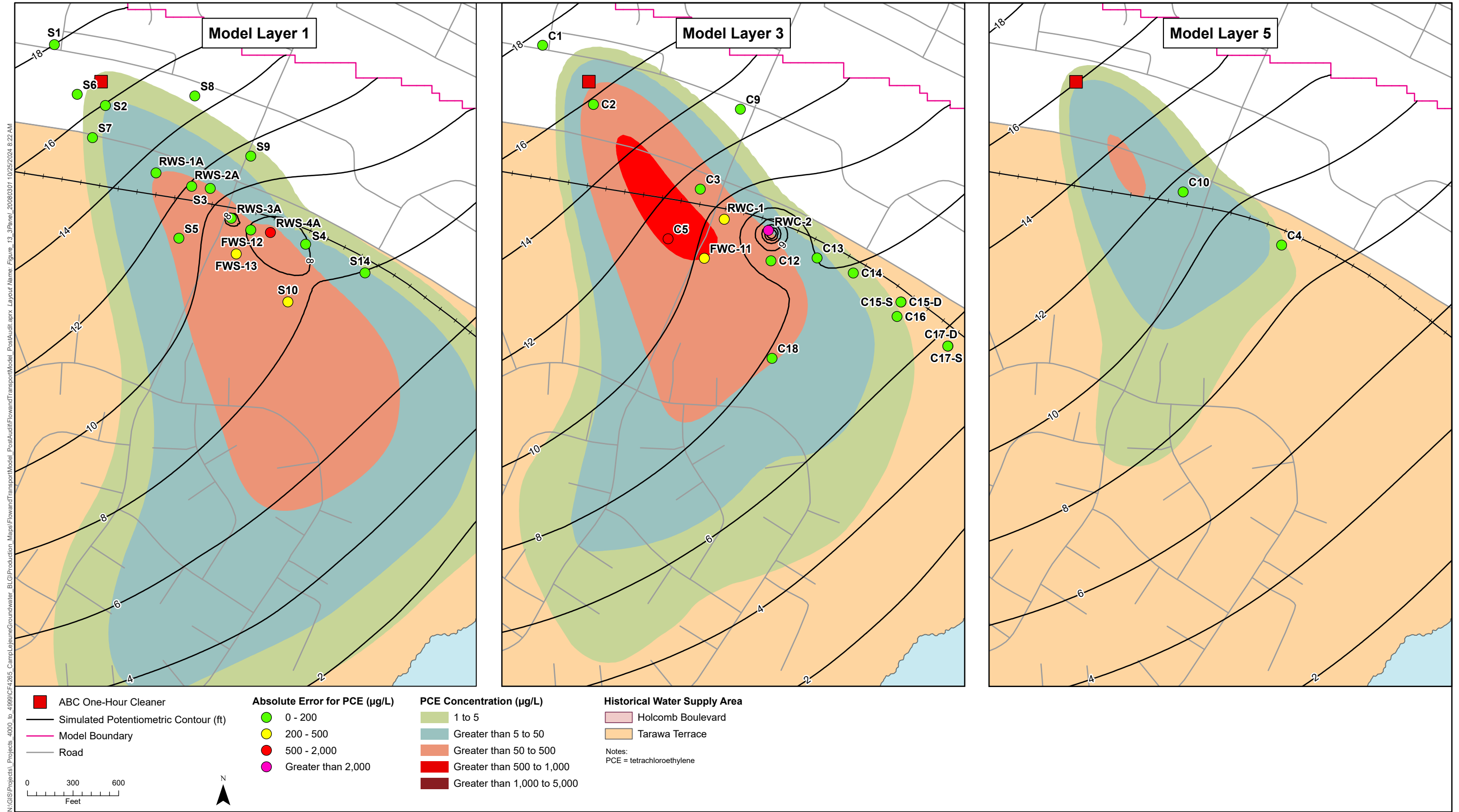


Figure 13.
 Simulated PCE Concentration for Three Model Layers
 Compared to Measured Values, March 2008
 Tarawa Terrace Flow and Transport Model Post-Audit

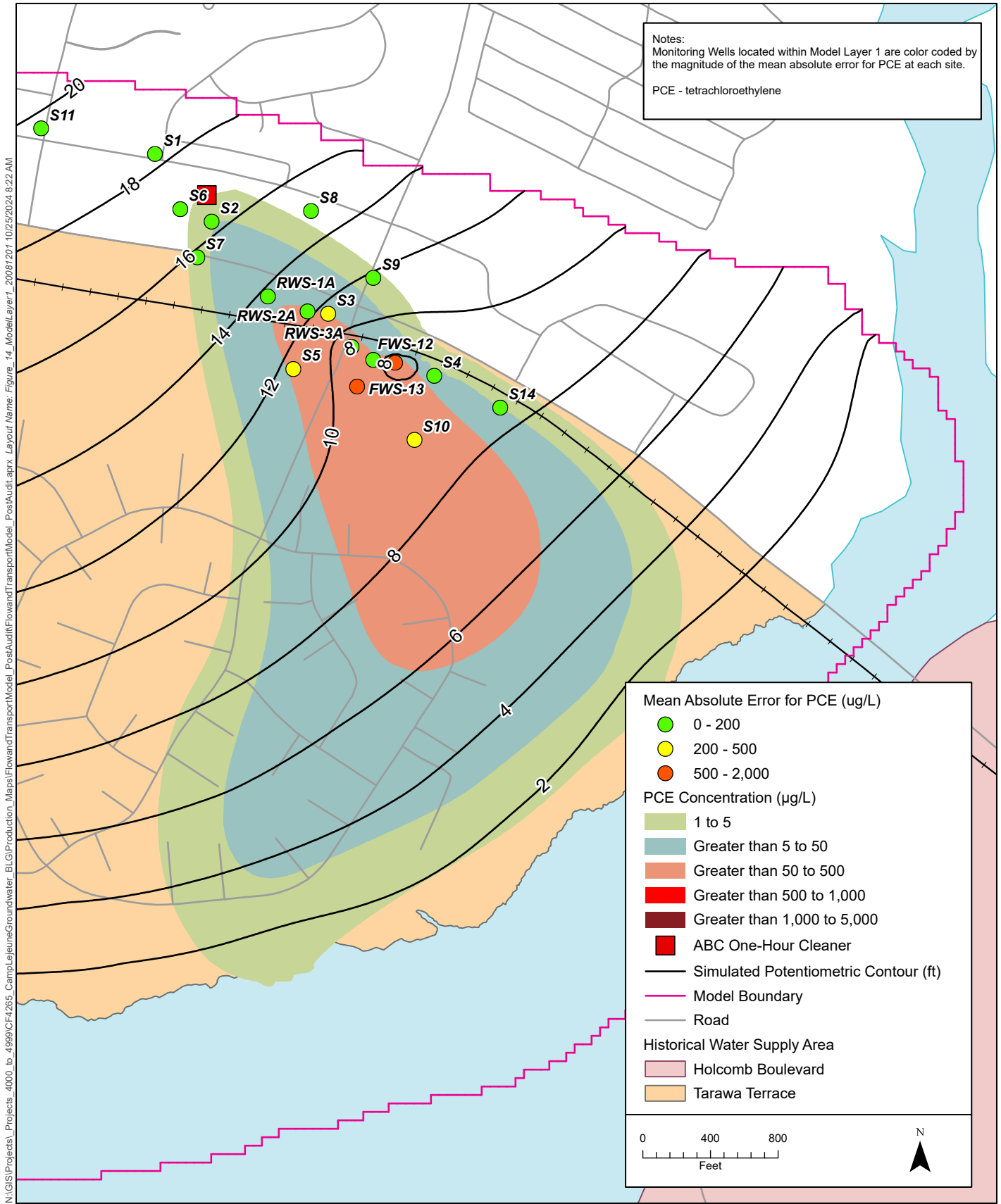
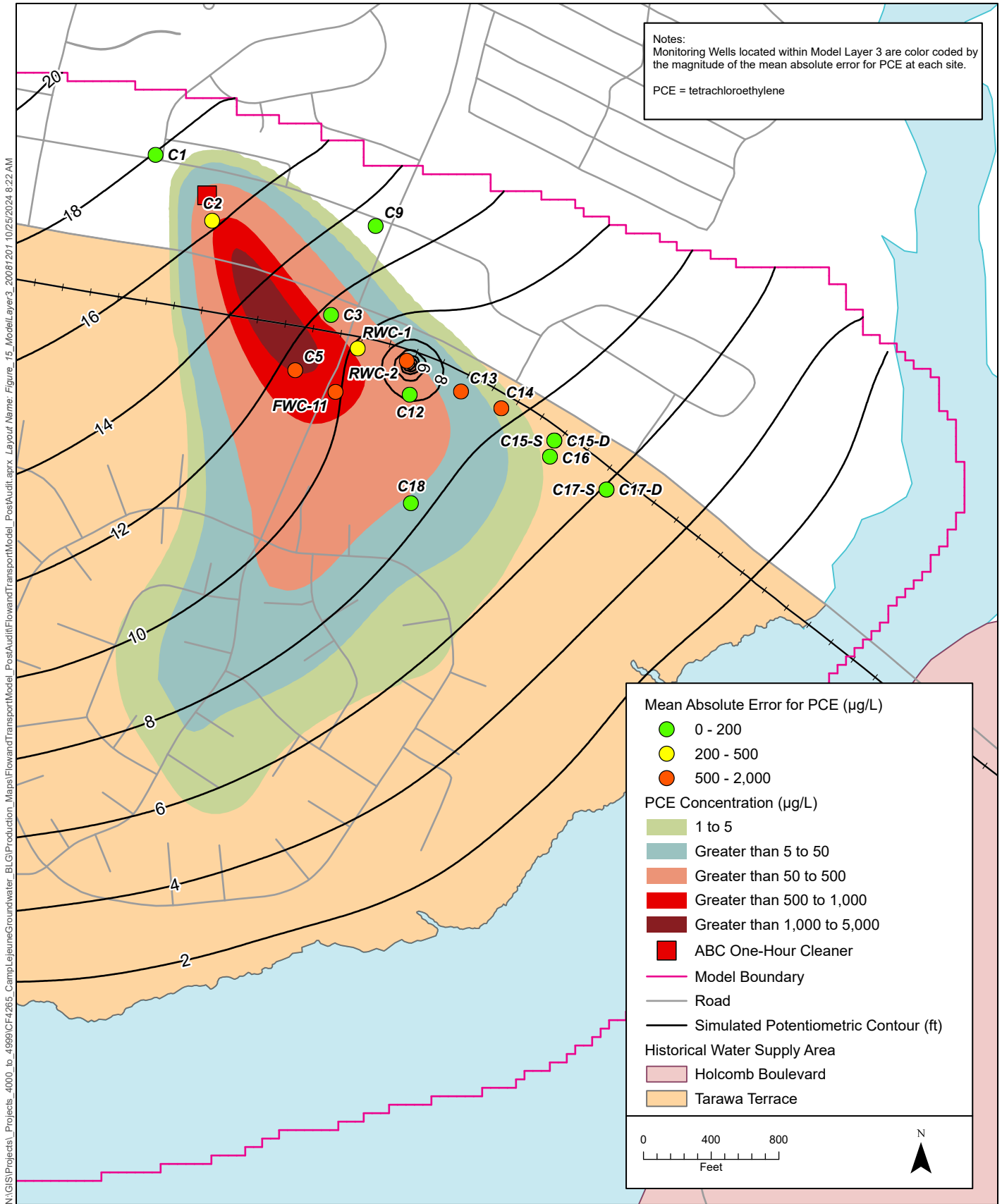


Figure 14.
Simulated PCE Plume for December 2008 for Model Layer 1
Tarawa Terrace Flow and Transport Model Post-Audit



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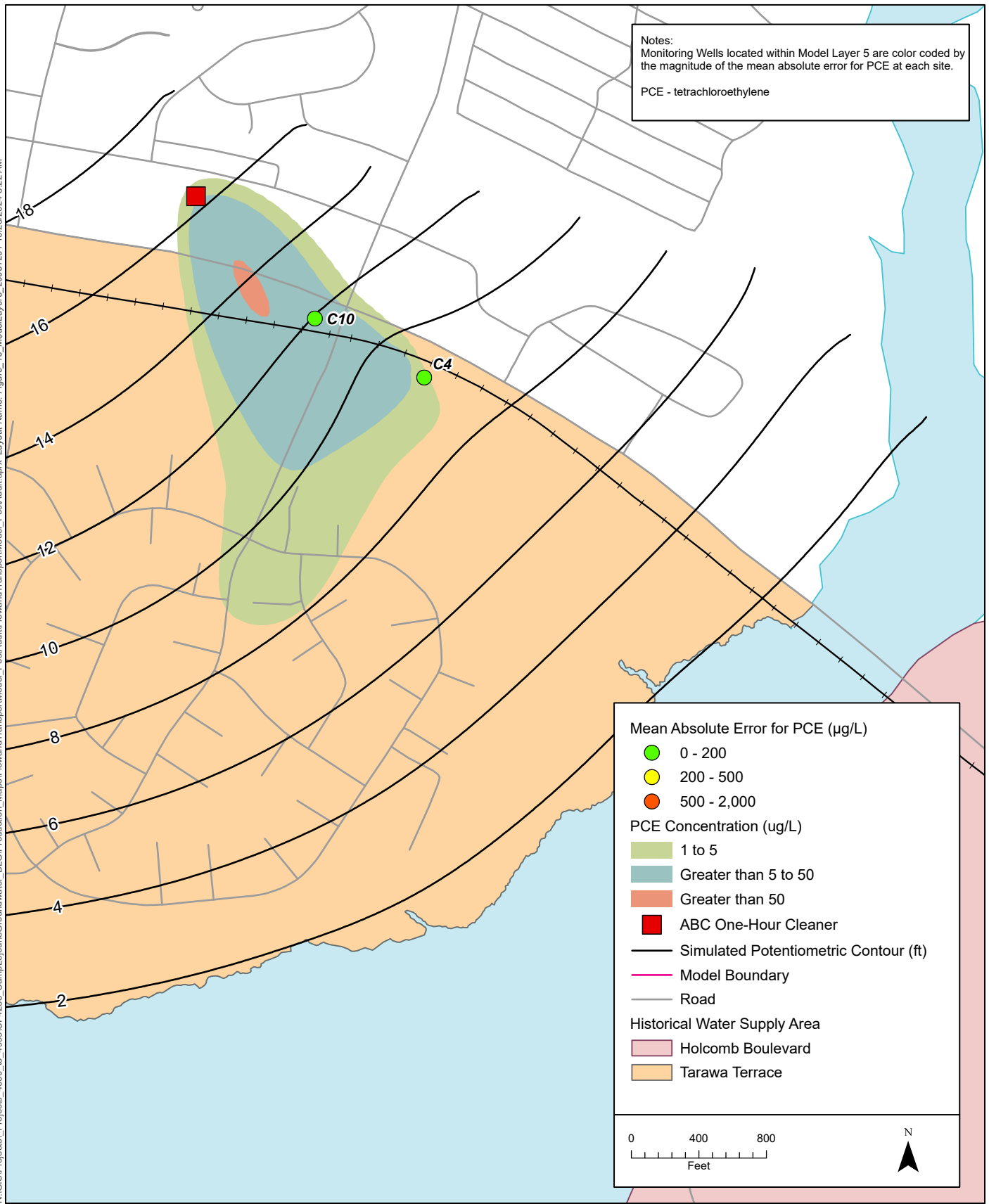


Figure 16.
Simulated PCE Plume for December 2008 for Model Layer 5
Tarawa Terrace Flow and Transport Model Post-Audit

Tables

Table 1. Annual Rainfall and Effective Recharge Rates

Year	Rainfall (in./yr)				Effective Recharge	
	Wilmington Airport	Wilmington 7N	New River MCAF	Average Rainfall	(in./yr)	(ft/day)
1995	65.1	64.4	48.6	59.3	13.94	0.00318
1996	64.4	52.7	75	64	15.04	0.00343
1997	49.6	51	53.6	51.4	12.07	0.00276
1998	64.2	77.2	70.1	70.5	16.55	0.00378
1999	72.1	82.1	63.2	72.5	17.02	0.00389
2000	53.8	59.2	50.4	54.5	12.79	0.00292
2001	38	57.4	43.5	46.3	10.87	0.00248
2002	49.3	56.9	49.4	51.9	12.18	0.00278
2003	63.6	72.8	50.5	62.3	14.64	0.00334
2004	50.7	71.7	51.7	58.1	13.63	0.00311
2005	69.3	68.4	59.2	65.6	15.41	0.00352
2006	63.8	62.7	62.5	63	14.8	0.00338
2007	33.4	37.3	60.4	43.7	10.26	0.00234
2008	60.8	48.4	56.4	55.2	12.96	0.00296
2009	59.7	59.4	53.6	57.6	13.53	0.00309

Notes:

Data publicly available at: <https://www.weather.gov/wrh/Climate?wfo=ilm>

Annual rainfall data were available for three locations proximal to the Tarawa Terrace: Wilmington Airport, Wilmington 7N, and New River MCAF.

Table 2. Pumping Rates for Remediation Wells Operating 1995 to 2008

Well	Northing	Easting	Model Layer	Pumping Rate (gpm)							
				11/1/1999	11/6/2001	3/7/2004	12/16/2004	3/31/2005	3/6/2006	2/20/2007	3/11/2008
RWS-1A	364445.7	2491125	1	5.5	18	20.8	12.1	20	20	0	0
RWS-2A	364351.5	2491359	1	3.8	18	3.5	2.34	28	24	0	0
RWS-3A	364146.8	2491620	1	29.2	24	18	1.07	15	30	30	30
RWS-4A	364053.7	2491878	1	13.3	24	24	22.5	28	25	30	25
RWC-2	364067.5	2491842	3	28.2	40	40	32.1	40	42	40	40

Notes:

Northing and easting values are given in NAD 1983 HARN North Carolina State Plane FIPS 3200 (US Feet)

gpm = gallons per minute

Table 3. Monitoring Wells Included in Extended Simulation

Monitoring Well	Northing	Easting	Model Layer	Well Completion Date	Borehole Depth (ft)	Finished Well Depth (ft)	Well Type
C1	365285.0	2490460.1	3	4/4/1992	104	100	Monitoring Well
C2	364895.7	2490794.3	3	4/8/1992	87	84.5	Monitoring Well
C3	364338.9	2491496.9	3	4/9/1992	90.5	89.4	Monitoring Well
C4	363971.9	2492116.1	5	4/3/1992	200	130	Monitoring Well
C5	364012.1	2491285.3	3	4/7/1992	92.5	90.5	Monitoring Well
C9	364864.6	2491760.5	3	9/10/1993	76.5	76	Monitoring Well
C10	364321.6	2491468.6	5	9/28/1993	80	0	Monitoring Well
C12	363867.4	2491961.7	3	11/6/2001	84	70	Monitoring Well
C13	363886.1	2492264.8	3	11/6/2001	83	76	Monitoring Well
C14	363787.1	2492503.0	3	5/12/2005	87	84.9	Monitoring Well
C15-D	363596.3	2492817.1	3	2/9/2007	110	110	Monitoring Well
C15-S	363596.3	2492816.1	3	2/9/2007	110	89	Monitoring Well
C16	363501.3	2492790.7	3	2/13/2007	95	94	Monitoring Well
C17-D	363306.6	2493125.4	3	2/13/2007	117	95	Monitoring Well
C17-S	363306.6	2493124.4	3	2/13/2007	117	85	Monitoring Well
C18	363226.0	2491968.6	3	2/15/2007	87	84	Monitoring Well
FWC-11	363884.0	2491523.5	3	--	89	88.6	--
FWS-12	364070.4	2491748.5	1	--	40	39.6	Monitoring Well
FWS-13	363912.7	2491653.1	1	--	38.5	38.2	Monitoring Well
RWC-1	364140.6	2491654.6	3	1/3-4/1998	91.5	--	Recovery Well
RWC-2	364067.5	2491944.6	3	1/5-6/1998	90	--	Recovery Well
RWS-1A	364445.7	2491125.4	1	--	55.5	55.5	Recovery Well
RWS-2A	364357.4	2491359.9	1	--	56	48.5	Recovery Well
RWS-3A	364146.8	2491620.4	1	--	60	55	Recovery Well
RWS-4A	364053.7	2491877.8	1	--	58.2	53	Recovery Well
S1	365289.2	2490457.3	1	3/22/1992	28	25.5	Monitor Well
S2	364889.0	2490792.7	1	3/26/1992	39.7	39.7	Monitor Well
S3	364343.6	2491482.1	1	4/2/1992	39.5	39.5	Monitor Well
S4	363976.4	2492109.4	1	4/3/1992	34	34	Monitor Well
S5	364016.2	2491275.9	1	4/1/1992	28	28	Monitor Well
S6	364962.4	2490607.3	1	3/26/1992	40.5	40.5	Monitor Well
S7	364677.4	2490707.9	1	4/5/1992	30.3	30.3	Monitor Well
S8	364951.7	2491380.5	1	4/4/1992	28	28	Monitor Well
S9	364555.9	2491748.8	1	3/21/1992	40	28.3	Monitor Well
S10	363597.3	2491992.8	1	3/20/1992	40	35	Monitor Well
S11	365440.7	2489784.3	1	9/11/1993	31	--	Monitor Well
S14	363788.1	2492499.8	1	5/10/2005	87	29	Monitor Well

Notes:

Northing and easting values are given in NAD 1983 HARN North Carolina State Plane FIPS 3200 (US Feet).

-- = information not available

^a Estimated value

Table 4. Observed PCE Concentrations at Monitoring Wells, 1995 to 2008

Monitoring Well	Model Layer	PCE Concentration (µg/L)											
		6/1/1997	2/1/2000	1/1/2002	5/1/2002	8/1/2002	11/1/2002	3/1/2003	3/1/2004	3/1/2005	3/1/2006	2/1/2007	3/1/2008
C1	3	--	<DL	--	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
C2	3	<DL	<DL	--	1	<DL	<DL	<DL	<DL	<DL	1.4	<DL	<DL
C3	3	580	410	--	270	140	100	150	58	37	38	23	22
C4	5	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	0.51	<DL	<DL
C5	3	<DL	<DL	--	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
C9	3	<DL	<DL	--	1	<DL	0.48	<DL	1.9	7.4	18	20	18
C10	5	<DL	<DL	--	<DL	<DL	0.16	<DL	<DL	<DL	<DL	0.48	<DL
C12	3	--	--	15	7	1.7	<DL	<DL	<DL	<DL	<DL	<DL	<DL
C13	3	--	--	5,400	140	68	44	6	3	2.8	2.5	2.7	7.8
C14	3	--	--	--	--	--	--	--	--	1,800	1,300	320	120
C15-D	3	--	--	--	--	--	--	--	--	--	--	1.9	0.27
C15-S	3	--	--	--	--	--	--	--	--	--	--	3.8	3.8
C16	3	--	--	--	--	--	--	--	--	--	--	0.36	<DL
C17-D	3	--	--	--	--	--	--	--	--	--	--	0.77	<DL
C17-S	3	--	--	--	--	--	--	--	--	--	--	1.2	0.19
C18	3	--	--	--	--	--	--	--	--	--	--	0.41	0.84
FWC-11	3	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
FWS-12	1	230	190	100	92	90	67	96	100	64	30	26	12
FWS-13	1	<DL	<DL	1	3	1.2	2.9	2	<DL	1.9	4.2	1.5	0.86
RWC-1	3	--	--	--	155	360	29	22	17	5	1.9	12	9.1
RWC-2	3	--	1,800	1,350	1,700	2,300	2,000	2,000	2,200	1,400	1,800	2,300	2,100
RWS-1A	1	--	--	--	8	<DL	5	6	2.6	2	1.8	2.7	2.1
RWS-2A	1	--	--	17	79	290	98	170	40	42	50	15	16
RWS-3A	1	--	--	760	920	970	500	810	280	560	280	260	160
RWS-4A	1	--	--	280	6,900	3,700	3,100	1,100	<DL	1,000	92	1,600	1,900
S1	1	5.6	<DL	--	<DL	<DL	0.32	<DL	<DL	<DL	<DL	<DL	<DL
S2	1	0	520	--	340	110	67	100	50	35	38	22	20
S3	1	77	12	--	23	54	60	48	53	47	23	85	94
S4	1	<DL	<DL	--	--	--	--	--	<DL	<DL	<DL	<DL	<DL
S5	1	<DL	<DL	--	<DL	<DL	1	<DL	<DL	<DL	<DL	<DL	<DL
S6	1	<DL	<DL	--	--	<DL	0.2	<DL	<DL	<DL	<DL	<DL	<DL
S7	1	<DL	--	--	--	<DL	<DL	0.5	<DL	<DL	1.9	<DL	<DL
S8	1	<DL	<DL	--	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL
S9	1	<DL	<DL	--	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL	<DL

Table 4. Observed PCE Concentrations at Monitoring Wells, 1995 to 2008

Monitoring Well	Model Layer	PCE Concentration (µg/L)											
		6/1/1997	2/1/2000	1/1/2002	5/1/2002	8/1/2002	11/1/2002	3/1/2003	3/1/2004	3/1/2005	3/1/2006	2/1/2007	3/1/2008
S10	1	<DL	<DL	<DL	<DL	<DL	0.16	<DL	<DL	<DL	<DL	0.74	<DL
S11	1	<DL	<DL	--	--	--	--	--	--	--	--	--	--
S14	1	--	--	--	--	--	--	--	--	<DL	<DL	0.47	<DL

Notes:

-- = no sample collected

<DL = sample result reported below the detection limit

PCE = tetrachloroethene

Table 5. Observed and Simulated PCE Concentrations at Monitoring Well Locations

Date	Monitoring Well	PCE Observed Concentration (µg/L)	PCE Simulated Concentration (µg/L)	Error	Abs(Error)
2/1/2000	C1	<DL	<DL	0	0
5/1/2002		<DL	<DL	0	0
8/1/2002		<DL	<DL	0	0
11/1/2002		<DL	<DL	0	0
3/1/2003		<DL	<DL	0	0
3/1/2004		<DL	<DL	0	0
3/1/2005		<DL	<DL	0	0
3/1/2006		<DL	<DL	0	0
2/1/2007		<DL	<DL	0	0
3/1/2008		<DL	<DL	0	0
6/1/1997	C2	<DL	1095	1095	1095
2/1/2000		<DL	742	742	742
5/1/2002		1	459	458	458
8/1/2002		<DL	459	459	459
11/1/2002		<DL	424	424	424
3/1/2003		<DL	388	388	388
3/1/2004		<DL	318	318	318
3/1/2005		<DL	247	247	247
3/1/2006		1.4	212	210	210
2/1/2007		<DL	177	177	177
3/1/2008		<DL	141	141	141
6/1/1997	C3	580	388	-192	192
2/1/2000		410	388	-22	22
5/1/2002		270	283	13	13
8/1/2002		140	247	107	107
11/1/2002		100	247	147	147
3/1/2003		150	247	97	97
3/1/2004		58	212	154	154
3/1/2005		37	177	140	140
3/1/2006		38	177	139	139
2/1/2007		23	141	118	118
3/1/2008		22	141	119	119
6/1/1997	C4	<DL	<DL	0	0
2/1/2000		<DL	<DL	0	0
1/1/2002		<DL	<DL	0	0
5/1/2002		<DL	<DL	0	0
8/1/2002		<DL	<DL	0	0
11/1/2002		<DL	<DL	0	0
3/1/2003		<DL	<DL	0	0
3/1/2004		<DL	<DL	0	0
3/1/2005		<DL	<DL	0	0
3/1/2006		0.51	<DL	-1	1
2/1/2007		<DL	<DL	0	0
3/1/2008		<DL	<DL	0	0

Table 5. Observed and Simulated PCE Concentrations at Monitoring Well Locations

Date	Monitoring Well	PCE Observed Concentration (µg/L)	PCE Simulated Concentration (µg/L)	Error	Abs(Error)
6/1/1997	C5	<DL	1307	1307	1307
2/1/2000		<DL	1165	1165	1165
5/1/2002		<DL	989	989	989
8/1/2002		<DL	989	989	989
11/1/2002		<DL	953	953	953
3/1/2003		<DL	918	918	918
3/1/2004		<DL	812	812	812
3/1/2005		<DL	777	777	777
3/1/2006		<DL	671	671	671
2/1/2007		<DL	600	600	600
3/1/2008		<DL	530	530	530
6/1/1997	C9	<DL	<DL	0	0
2/1/2000		<DL	<DL	0	0
5/1/2002		1	<DL	-1	1
8/1/2002		<DL	<DL	0	0
11/1/2002		0.48	<DL	0	0
3/1/2003		<DL	<DL	0	0
3/1/2004		1.9	<DL	-2	2
3/1/2005		7.4	<DL	-7	7
3/1/2006		18	<DL	-18	18
2/1/2007		20	<DL	-20	20
3/1/2008		18	<DL	-18	18
6/1/1997	C10	<DL	212	212	212
2/1/2000		<DL	177	177	177
5/1/2002		<DL	71	71	71
8/1/2002		<DL	71	71	71
11/1/2002		0.16	71	70	70
3/1/2003		<DL	71	71	71
3/1/2004		<DL	35	35	35
3/1/2005		<DL	35	35	35
3/1/2006		<DL	35	35	35
2/1/2007		0.48	35	35	35
3/1/2008		<DL	35	35	35
1/1/2002	C12	15	177	162	162
5/1/2002		7	177	170	170
8/1/2002		1.7	177	175	175
11/1/2002		<DL	177	177	177
3/1/2003		<DL	177	177	177
3/1/2004		<DL	177	177	177
3/1/2005		<DL	177	177	177
3/1/2006		<DL	177	177	177
2/1/2007		<DL	177	177	177
3/1/2008		<DL	141	141	141

Table 5. Observed and Simulated PCE Concentrations at Monitoring Well Locations

Date	Monitoring Well	PCE Observed Concentration (µg/L)	PCE Simulated Concentration (µg/L)	Error	Abs(Error)
1/1/2002	C13	5400	<DL	-5400	5400
5/1/2002		140	<DL	-140	140
8/1/2002		68	<DL	-68	68
11/1/2002		44	<DL	-44	44
3/1/2003		6	<DL	-6	6
3/1/2004		3	<DL	-3	3
3/1/2005		2.8	<DL	-3	3
3/1/2006		2.5	<DL	-3	3
2/1/2007		2.7	<DL	-3	3
3/1/2008		7.8	<DL	-8	8
3/1/2005	C14	1800	<DL	-1800	1800
3/1/2006		1300	<DL	-1300	1300
2/1/2007		320	<DL	-320	320
3/1/2008		120	<DL	-120	120
2/1/2007	C15-D	1.9	<DL	-2	2
3/1/2008		0.27	<DL	0	0
2/1/2007	C15-S	3.8	<DL	-4	4
3/1/2008		3.8	<DL	-4	4
2/1/2007	C16	0.36	<DL	0	0
3/1/2008		<DL	<DL	0	0
2/1/2007	C17-D	0.77	<DL	-1	1
3/1/2008		<DL	<DL	0	0
2/1/2007	C17-S	1.2	<DL	-1	1
3/1/2008		0.19	<DL	0	0
2/1/2007	C18	0.41	71	70	70
3/1/2008		0.84	71	70	70
6/1/1997	FWC-11	<DL	848	848	848
2/1/2000		<DL	812	812	812
1/1/2002		<DL	742	742	742
5/1/2002		<DL	742	742	742
8/1/2002		<DL	742	742	742
11/1/2002		<DL	706	706	706
3/1/2003		<DL	706	706	706
3/1/2004		<DL	671	671	671
3/1/2005		<DL	636	636	636
3/1/2006		<DL	600	600	600
2/1/2007		<DL	565	565	565
3/1/2008		<DL	494	494	494

Table 5. Observed and Simulated PCE Concentrations at Monitoring Well Locations

Date	Monitoring Well	PCE Observed Concentration (µg/L)	PCE Simulated Concentration (µg/L)	Error	Abs(Error)
6/1/1997	FWS-12	230	565	335	335
2/1/2000		190	530	340	340
1/1/2002		100	318	218	218
5/1/2002		92	283	191	191
8/1/2002		90	283	193	193
11/1/2002		67	247	180	180
3/1/2003		96	247	151	151
3/1/2004		100	212	112	112
3/1/2005		64	177	113	113
3/1/2006		30	177	147	147
2/1/2007		26	106	80	80
3/1/2008		12	71	59	59
6/1/1997	FWS-13	<DL	1201	1201	1201
2/1/2000		<DL	1024	1024	1024
1/1/2002		1	883	882	882
5/1/2002		3	848	845	845
8/1/2002		1.2	812	811	811
11/1/2002		2.9	777	774	774
3/1/2003		2	742	740	740
3/1/2004		<DL	600	600	600
3/1/2005		1.9	494	493	493
3/1/2006		4.2	388	384	384
2/1/2007		1.5	318	316	316
3/1/2008		0.86	247	246	246
5/1/2002	RWC-1	155	353	198	198
8/1/2002		360	353	-7	7
11/1/2002		29	353	324	324
3/1/2003		22	318	296	296
3/1/2004		17	318	301	301
3/1/2005		5	318	313	313
3/1/2006		1.9	283	281	281
2/1/2007		12	247	235	235
3/1/2008		9.1	247	238	238
2/1/2000	RWC-2	1800	106	-1694	1694
1/1/2002		1350	106	-1244	1244
5/1/2002		1700	106	-1594	1594
8/1/2002		2300	106	-2194	2194
11/1/2002		2000	106	-1894	1894
3/1/2003		2000	71	-1929	1929
3/1/2004		2200	71	-2129	2129
3/1/2005		1400	71	-1329	1329
3/1/2006		1800	71	-1729	1729
2/1/2007		2300	71	-2229	2229
3/1/2008		2100	71	-2029	2029

Table 5. Observed and Simulated PCE Concentrations at Monitoring Well Locations

Date	Monitoring Well	PCE Observed Concentration (µg/L)	PCE Simulated Concentration (µg/L)	Error	Abs(Error)
5/1/2002	RWS-1A	8	247	239	239
8/1/2002		<DL	247	247	247
11/1/2002		5	212	207	207
3/1/2003		6	177	171	171
3/1/2004		2.6	141	139	139
3/1/2005		2	106	104	104
3/1/2006		1.8	71	69	69
2/1/2007		2.7	71	68	68
3/1/2008		2.1	35	33	33
5/1/2002	RWS-2A	79	424	345	345
1/1/2002		17	459	442	442
8/1/2002		290	388	98	98
11/1/2002		98	353	255	255
3/1/2003		170	318	148	148
3/1/2004		40	247	207	207
3/1/2005		42	177	135	135
3/1/2006		50	141	91	91
2/1/2007		15	141	126	126
3/1/2008		16	71	55	55
1/1/2002	RWS-3A	760	565	-195	195
5/1/2002		920	530	-390	390
8/1/2002		970	494	-476	476
11/1/2002		500	494	-6	6
3/1/2003		810	459	-351	351
3/1/2004		280	353	73	73
3/1/2005		560	283	-277	277
3/1/2006		280	212	-68	68
2/1/2007		260	177	-83	83
3/1/2008		160	141	-19	19
1/1/2002	RWS-4A	280	388	108	108
5/1/2002		6900	353	-6547	6547
8/1/2002		3700	353	-3347	3347
11/1/2002		3100	353	-2747	2747
3/1/2003		1100	353	-747	747
3/1/2004		<DL	318	318	318
3/1/2005		1000	247	-753	753
3/1/2006		92	212	120	120
2/1/2007		1600	177	-1423	1423
3/1/2008		1900	141	-1759	1759

Table 5. Observed and Simulated PCE Concentrations at Monitoring Well Locations

Date	Monitoring Well	PCE Observed Concentration (µg/L)	PCE Simulated Concentration (µg/L)	Error	Abs(Error)
6/1/1997	S1	5.6	<DL	-6	6
2/1/2000		<DL	<DL	0	0
5/1/2002		<DL	<DL	0	0
8/1/2002		<DL	<DL	0	0
11/1/2002		0.32	<DL	0	0
3/1/2003		<DL	<DL	0	0
3/1/2004		<DL	<DL	0	0
3/1/2005		<DL	<DL	0	0
3/1/2006		<DL	<DL	0	0
2/1/2007		<DL	<DL	0	0
3/1/2008		<DL	<DL	0	0
6/1/1997	S2	<DL	141	141	141
2/1/2000		520	71	-449	449
5/1/2002		340	35	-305	305
8/1/2002		110	35	-75	75
11/1/2002		67	35	-32	32
3/1/2003		100	35	-65	65
3/1/2004		50	<DL	-50	50
3/1/2005		35	<DL	-35	35
3/1/2006		38	<DL	-38	38
2/1/2007		22	<DL	-22	22
3/1/2008		20	<DL	-20	20
6/1/1997	S3	77	1024	947	947
2/1/2000		12	706	694	694
5/1/2002		23	318	295	295
8/1/2002		54	283	229	229
11/1/2002		60	247	187	187
3/1/2003		48	212	164	164
3/1/2004		53	141	88	88
3/1/2005		47	106	59	59
3/1/2006		23	106	83	83
2/1/2007		85	71	-14	14
3/1/2008		94	71	-23	23
6/1/1997	S4	<DL	106	106	106
2/1/2000		<DL	106	106	106
3/1/2004		<DL	35	35	35
3/1/2005		<DL	35	35	35
3/1/2006		<DL	<DL	0	0
2/1/2007		<DL	<DL	0	0
3/1/2008		<DL	<DL	0	0

Table 5. Observed and Simulated PCE Concentrations at Monitoring Well Locations

Date	Monitoring Well	PCE Observed Concentration (µg/L)	PCE Simulated Concentration (µg/L)	Error	Abs(Error)
6/1/1997	S5	<DL	1624	1624	1624
2/1/2000		<DL	989	989	989
5/1/2002		<DL	494	494	494
8/1/2002		<DL	459	459	459
11/1/2002		1	424	423	423
3/1/2003		<DL	353	353	353
3/1/2004		<DL	247	247	247
3/1/2005		<DL	177	177	177
3/1/2006		<DL	141	141	141
2/1/2007		<DL	106	106	106
3/1/2008		<DL	71	71	71
6/1/1997	S6	<DL	<DL	0	0
2/1/2000		<DL	<DL	0	0
8/1/2002		<DL	<DL	0	0
11/1/2002		0.2	<DL	0	0
3/1/2003		<DL	<DL	0	0
3/1/2004		<DL	<DL	0	0
3/1/2005		<DL	<DL	0	0
3/1/2006		<DL	<DL	0	0
2/1/2007		<DL	<DL	0	0
3/1/2008		<DL	<DL	0	0
6/1/1997	S7	<DL	71	71	71
8/1/2002		<DL	<DL	0	0
11/1/2002		<DL	<DL	0	0
3/1/2003		0.5	<DL	-1	1
3/1/2004		<DL	<DL	0	0
3/1/2005		<DL	<DL	0	0
3/1/2006		1.9	<DL	-2	2
2/1/2007		<DL	<DL	0	0
3/1/2008		<DL	<DL	0	0
6/1/1997	S8	<DL	<DL	0	0
2/1/2000		<DL	<DL	0	0
5/1/2002		<DL	<DL	0	0
8/1/2002		<DL	<DL	0	0
11/1/2002		<DL	<DL	0	0
3/1/2003		<DL	<DL	0	0
3/1/2004		<DL	<DL	0	0
3/1/2005		<DL	<DL	0	0
3/1/2006		<DL	<DL	0	0
2/1/2007		<DL	<DL	0	0
3/1/2008		<DL	<DL	0	0

Table 5. Observed and Simulated PCE Concentrations at Monitoring Well Locations

Date	Monitoring Well	PCE Observed Concentration (µg/L)	PCE Simulated Concentration (µg/L)	Error	Abs(Error)
6/1/1997	S9	<DL	35	35	35
2/1/2000		<DL	35	35	35
5/1/2002		<DL	35	35	35
8/1/2002		<DL	35	35	35
11/1/2002		<DL	35	35	35
3/1/2003		<DL	<DL	0	0
3/1/2004		<DL	<DL	0	0
3/1/2005		<DL	<DL	0	0
3/1/2006		<DL	<DL	0	0
2/1/2007		<DL	<DL	0	0
3/1/2008		<DL	<DL	0	0
6/1/1997	S10	<DL	494	494	494
2/1/2000		<DL	494	494	494
1/1/2002		<DL	494	494	494
5/1/2002		<DL	459	459	459
8/1/2002		<DL	459	459	459
11/1/2002		0.16	459	459	459
3/1/2003		<DL	459	459	459
3/1/2004		<DL	424	424	424
3/1/2005		<DL	424	424	424
3/1/2006		<DL	388	388	388
2/1/2007		0.74	353	352	352
3/1/2008		<DL	318	318	318
6/1/1997	S11	<DL	<DL	0	0
2/1/2000		<DL	<DL	0	0
3/1/2005	S14	<DL	<DL	0	0
3/1/2006		<DL	<DL	0	0
2/1/2007		0.47	<DL	0	0
3/1/2008		<DL	<DL	0	0

Notes:

<DL = sample result reported below the detection limit

PCE = tetrachloroethene

Table 6. Mean Error and Mean Absolute Error for Monitoring Wells

Monitoring Well	Model Layer	Mean Error	Mean Absolute Error	Mean Absolute Error Category
C1	3	0	0	0-200
C2	3	423.6	423.6	200-500
C3	3	74.6	113.3	0-200
C4	5	0	0	0-200
C5	3	882.9	882.9	500-2,000
C9	3	-6.1	6.1	0-200
C10	5	77	77	0-200
C12	3	170.7	170.7	0-200
C13	3	-567.7	567.7	500-2,000
C14	3	-885	885	500-2,000
C15-D	3	-1.1	1.1	0-200
C15-S	3	-3.8	3.8	0-200
C16	3	-0.2	0.2	0-200
C17-D	3	-0.4	0.4	0-200
C17-S	3	-0.7	0.7	0-200
C18	3	70	70	0-200
FWC-11	3	688.6	688.6	500-2,000
FWS-12	1	176.4	176.4	0-200
FWS-13	1	693	693	500-2,000
RWC-1	3	242.1	243.6	200-500
RWC-2	3	-1817.9	1817.9	500-2,000
RWS-1A	1	141.8	141.8	0-200
RWS-2A	1	190.2	190.2	0-200
RWS-3A	1	-179.2	193.8	0-200
RWS-4A	1	-1677.6	1786.9	500-2,000
S1	1	-0.5	0.5	0-200
S2	1	-86.3	111.9	0-200
S3	1	246.2	253.1	200-500
S4	1	40.4	40.4	0-200
S5	1	462.2	462.2	200-500
S6	1	0	0	0-200
S7	1	7.6	8.1	0-200
S8	1	0	0	0-200
S9	1	16.1	16.1	0-200
S10	1	435.5	435.5	200-500
S11	1	0	0	0-200
S14	1	-0.1	0.1	0-200

Notes:

Northing and easting values are given in NAD 1983 HARN North Carolina State Plane FIPS 3200 (US Feet).

Exhibit 1

Resume for R. Jeffrey Davis



R. Jeffrey Davis, P.E., CGWP

Principal, Water Resources

(385) 955-5184

Salt Lake City, UT

jdavis@integral-corp.com

Education & Credentials

M.S., Civil & Environmental Engineering, Brigham Young University, Provo, Utah, 1998

B.S., Civil & Environmental Engineering, Brigham Young University, Provo, Utah, 1993

Professional Engineer, Utah (License No. 189690-2202), Texas (License No. 125406), Florida (License No. 74838), Colorado (License No. 0051575), Alabama (License No. PE52096), Idaho (License No. P-21839), Oregon (License No. 104270PE)

Certified Groundwater Professional, NGWA (2023)

Continuing Education

Certificate of Specialization in Leadership and Management, Harvard Business School Online (2023)

MSHA certified (2020)

First Aid and CPR certified (2020)

Professional Affiliations

National Ground Water Association

Utah Groundwater Association

Groundwater Resources Association of California

Mr. Jeff Davis is a licensed civil and environmental engineer, hydrogeologist, and certified groundwater professional with almost 30 years of global experience working on every continent except Antarctica. He currently serves on the Board of Directors for the National Ground Water Association. Mr. Davis has supported numerous litigation cases involving groundwater impacts and has experience as an expert witness. He has spent much of his career solving complicated water problems involving mining, oil and gas, and water resources. These projects include the clean water supply side as well as the remediation of contaminated sites. The contaminated sites include coal combustion residual (CCR) landfills and other waste impoundments, mining remediation sites, and industrial cleanup sites—both RCRA and CERCLA sites. In working with per- and polyfluoroalkyl substance (PFAS) compounds, MTBE, chlorinated solvents, hydrocarbons, nitrates, and road salt, he has developed and used numerous groundwater models for the mining, energy, chemical, and agricultural industries. Other projects have involved environmental impact statements, environmental assessments, water management, groundwater-surface water contamination, dewatering, and water supply and treatment. He has extensive knowledge of groundwater flow-and-transport principles and has taught numerous workshops and classes in the U.S. and around the world. His current focus is on water and groundwater sustainability and drought resiliency. Mr. Davis has extensive experience in the design and implementation of aquifer storage and recovery (ASR) projects across the country.

Relevant Experience

WATER MANAGEMENT

ASR Feasibility, Utah County, Utah — Served as principal investigator for a feasibility study for an ASR project. During the spring runoff of 2023, the team measured the runoff in several rivers, creeks, and ditches, and constructed a new infiltration basin, all in an effort to advance aquifer storage projects within the county.

ASR Feasibility, Utah County, Utah — Served as principal for a feasibility study for an ASR project. Former agricultural water rights were converted for industrial use and the effluent was being considered for aquifer replenishment. Both infiltration and direct injection of the treated water were considered as part of the feasibility study.

Provo ASR, Provo, Utah — Served as the project manager and engineer of record for the current Provo ASR project. Five sites (three infiltration and two direct injection) are currently permitted

for pilot studies that have been ongoing since 2020. Final engineering design and permitting have been completed for all five sites.

Water Reuse and Aquifer Sustainability, Eagle Mountain, Utah — Served as the client manager and engineer of record for the current Eagle Mountain City, Utah, water-reuse planning and aquifer sustainability project. Water rights for Eagle Mountain were evaluated along with the groundwater system to understand aquifer sustainability for the city, which is expecting tremendous future growth, including large industrial water demands.

ASR Evaluation, Weber County, Utah — Served as the project manager and engineer of record for the current evaluation of the Weber Basin Water Conservancy District, Utah, ASR project. This project has been actively operating for more than 10 years. Hired to evaluate the storage capacity of the program and obtain greater recovery volumes from the system, working with the Utah Division of Water Rights.

Drainage Reuse Initiative, Harris County, Texas — Served as part of a team for the development of the Drainage Reuse Initiative for Harris County Flood Control District in Harris County, Texas. The project investigated the feasibility of alternative methods of flood mitigation by conveying stormwater to the subsurface, including natural infiltration to groundwater, enhanced infiltration or injection into aquifers, and mechanical injection to deep aquifers.

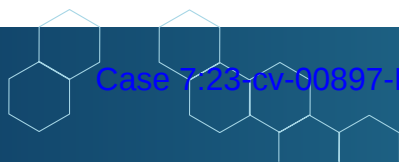
Roseville ASR, Roseville, California — Served as one of the groundwater leads for the development of an ASR program for the city of Roseville, California. Initial efforts involved developing a regional-scale conceptualization for the major portion of the Central Valley area. Developed a subsequent regional multilayer groundwater model, followed by a number of local-scale transport models to simulate pilot tests and understand the ASR process.

COAL COMBUSTION FACILITIES

Coal Combustion Residual Waste and Disposal, Bonanza, Utah — Served as the engineer of record for a coal power plant. Oversaw all efforts related to the monitoring and compliance of the facility's CCR waste and disposal. This included semiannual reporting, development of alternative source demonstrations, and annual groundwater monitoring reports.

Hexavalent Chromium Investigation, United States — Served as the principal investigator for a study to understand and evaluate the proposed EPA changes to hexavalent chromium (Cr(VI)) as it would apply to the monitoring and management of CCR landfill facilities. The work included examining potential regulatory levels from a human health perspective.

Alternate Water Sources Investigation, United States — Served as the principal investigator for a study to understand and evaluate differences at CCR facilities between upgradient and downgradient sources, and locate potential evidence of alternate sources using isotopes and microbial fingerprinting. After development of a sampling and analysis plan, advanced statistical and multivariate methods were used to document analyses that show potential for distinguishing source water from alternate sources.



OIL AND GAS WASTE MANAGEMENT

Oil and Gas Waste Facility, De Beque, Colorado — Served as the principal engineer for the permitting and operating of an 800-acre oil-and-gas waste-disposal facility southeast of De Beque, Colorado. Involved in several aspects of the permitting process, including the hydrogeological study and groundwater investigations; stormwater design; pond liner design and construction; closure certification; and submittal of the revised engineering design and operation plan.

Remedial Investigation, Billings, Montana — Served as the groundwater lead for the Yale Oil of South Dakota Facility in Billings, Montana. The Superfund site facility is in the remedial investigation phase; the risk-assessment work plan has been submitted to the Montana Department of Environmental Quality, and the client is waiting for comments before proceeding with the risk assessment.

EPA Study, Washington, DC — Served as participant and technical reviewer for EPA's "Study of Hydraulic Fracturing for Oil and Gas and Its Potential Impact on Drinking Water Resources." Participated in technical roundtables and technical workshops and completed a peer review of the EPA's five retrospective case studies.

Fate and Transport Modeling, Texas — Served as groundwater lead for fate-and-transport modeling and analysis of chloride contamination in southern Texas near the Gulf of Mexico. As part of the site mitigation phase, modeling was used to determine the potential migration of the chloride through the shallow aquifer system and nearby receptors.

Lockwood Solvent Groundwater Plume Site, Billings, Montana — Served as one of the groundwater leads performing groundwater modeling for the Lockwood Solvent Groundwater Plume site, an EPA Superfund site in Billings, Montana. The site spans 580 acres, and much of the groundwater there is contaminated with volatile organic compounds, including tetrachloroethene, trichloroethene, cis-1,2- dichloroethene, and vinyl chloride.

PLANNING AND PERMITTING

Beverage Can Manufacturing and Filling, Salt Lake City, Utah — Served as principal investigator for wastewater, stormwater, and Utah Pollutant Discharge Elimination System permitting, monitoring, and compliance for an aluminum can manufacturing and filling facility. Worked closely with the client, its operations team, and state and municipal regulators to regularly monitor and report all discharges from the facility.

Ely Energy Center EIS, White Pine County, Nevada — Served as principal lead for the development of a regional groundwater model for Steptoe Valley in White Pine County, Nevada. The investigation and model were part of the EIS for construction of the Ely Energy Center.

Haile Gold Mine EIS, Kershaw, South Carolina — Served as groundwater lead as the third-party contractor developing an EIS for the proposed Haile Gold Mine near Kershaw, South Carolina. The EIS analyzed the potential direct, indirect, and cumulative environmental effects of the proposed project and its alternatives. Work included project-team coordination for geology, groundwater, and surface water resources areas; review of applicant-supplied information; agency coordination; and public involvement.

Four Corners Power Plant EIS, Farmington, New Mexico — Served as groundwater lead as the third-party contractor in developing an EIS for the Four Corners Power Plant and Navajo coal mine in Farmington, New Mexico. The EIS analyzed the potential direct, indirect, and cumulative environmental effects of the proposed project and its alternatives. The groundwater portion included analyzing field investigations, pump tests, conceptual and numerical modeling of the project and surrounding area, and remediation and reclamation activities.

Iron Ore Operations Cumulative Impact Assessment, Pilbara, Western Australia — Served as one of the groundwater leads for a cumulative impact assessment for a proposed expansion of iron ore operations in the Pilbara in Western Australia. Work included identifying the methodology and developing the conceptual models to perform the assessment. The groundwater modeling included both quantitative and qualitative approaches.

LITIGATION SUPPORT

Expert Witness for PFAS Litigation, Martin County, Florida — Served as the groundwater expert witness for a litigation case in Martin County. The multidistrict litigation bellwether case involved PFAS contamination of groundwater affecting public drinking water. Opinions were given regarding PFAS sourcing, and fate and transport in groundwater, and regarding public water supply planning.

Water Resources Litigation, Grand County, Colorado — Served as principal investigator for a litigation case involving flooding damages caused by a canal breach. Surface water modeling was used to determine amount and extent of erosion and sedimentation from the flooding.

Water Resources Litigation, Northwest Minnesota — Served as principal investigator and expert witness for a litigation case involving agricultural water rights and pumping near tribal lands. Developed a conceptual model to understand the hydrogeological conditions and constructed a groundwater model to determine possible impacts due to the agriculture activities.

Groundwater Litigation, Ventura County, California — Served as the groundwater expert for a litigation case in Ventura County. The case includes the development of a basin-wide groundwater-surface water model, not only for purposes of litigation but also for compliance with Sustainable Groundwater Management Act requirements. The groundwater basin in question is currently listed as a priority basin by the State of California.

Pipeline Spill Litigation, Williston, North Dakota — Provided litigation services for groundwater and surface water contamination from a pipeline spill in North Dakota. A large spill of produced water (brine) impacted surface streams as well as the shallow aquifer system. Work included groundwater modeling, field investigations, and remedial strategies.

Road Salt Contamination Litigation, Vandalia, Ohio — Performed fate-and-transport modeling and analysis of sodium chloride contamination of an aquifer in Vandalia, Ohio. Stored road salt caused limited contamination of a shallow aquifer that supplied drinking water to nearby residential homes. The groundwater model included the local domestic pumping wells, which helped determine the possible extent of chloride impacts. Largely due to the conceptual site model and transport modeling results, litigation was settled out of court to the satisfaction of the client.

GROUNDWATER MODELING

Subsidence Monitoring/Modeling, Fort Bend and Harris Counties, Texas — Served as the groundwater lead and engineer on several groundwater development projects in Fort Bend and Harris counties. Groundwater withdrawals are strictly curtailed due to historical subsidence. The Subsidence Districts have installed GPS Port-A-Measure (PAM) units and used InSAR mapping. Using this data plus the output from the models PRESS and MODFLOW-SUB to measure subsidence impacts.

Groundwater Model Development, New Jersey — Led a team of hydrogeologists to construct a groundwater flow and fate and transport model of perfluorononanoic acid and other contaminants. The model will be used to design a pump and treat system and possible aquifer replenishment with the treated groundwater.

Hydrogeological Services, Montgomery County, Texas — Provided modeling and hydrogeological consulting services for the Lone Star Ground-water Conservation District's (Montgomery County, Texas) update of its desired future conditions and groundwater management plans. Also provided litigation services for the district.

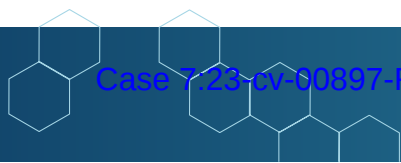
Groundwater Model Development, Havana, Florida — Provided consulting services for Northwest Florida Water Management District as it updated its regional groundwater model—an integrated groundwater-surface water model that provides regulatory control of the groundwater withdrawals and manages saltwater intrusion in the Floridan aquifer due to pumping.

Crop Production Services, Various Locations, U.S. — Served as the groundwater lead to provide modeling and hydrogeological consulting services for a number of crop production services legacy sites. The groundwater at the sites was contaminated with nitrates from long-term fertilizer use. Groundwater modeling was used to determine the fate and transport of the nitrates and to develop a remedial strategy for cleanup.

Legacy Way Tunnel Design, Brisbane, Australia — Provided senior oversight and technical review for all hydrogeologic assessments related to the Legacy Way tunnel design project, a 4.6 km underground tunnel in northern Brisbane, Australia. Work included evaluating field tests, preparing geotechnical and environmental reports, and modeling the entire project area.

Mercury Fate and Transport, Cincinnati, Ohio — Served as the groundwater lead for performing fate and-transport modeling and analysis of a mercury spill at a municipal landfill in Cincinnati, Ohio. As part of the project management phase, modeling was used to determine the potential migration of mercury through the landfill to the leachate collection system. Modeling efforts examined both the spatial distribution and the temporal component of the mercury transport.

Due Diligence Environmental Review, Pascagoula, Mississippi — Served as the environmental lead for performing an environmental assessment at a chemical plant in Pascagoula, Mississippi, as part of a due diligence effort. A number of groundwater and surface water contamination issues due to spills, leaks, and storage of hazardous materials were addressed. The location of the plant on the Gulf of Mexico makes possible environmental impacts from operation of the chemical plant a sensitive issue.



MINING

Bingham Canyon Mine Closure Planning, Copperton, Utah — Completed an independent third-party audit for a closure-plan pit-lake study for Bingham Canyon Mine. Reviewed the consultant scope of work for the pit-lake study and discussed the study, methodology, and pathway to completion with consultant staff. An independent audit report was compiled and submitted to the client.

Hooker Prairie Mine, Bartow, Florida — Served as the model expert to develop a contaminant and water budget and management model for the Hookers Prairie Mine in Florida using the GoldSim modeling software. The purpose of the model was to evaluate the probabilities of the mine meeting its current and future nutrient NPDES loading limits for certain contaminants. The project also included an evaluation of current monitoring data within the mine operations and at discharge locations, and the development of a complete monitoring plan integrated into a GIS as part of the model calibration and validation.

Bridger Coal Mine Investigation, Rock Springs, Wyoming — Served on a technical team to reevaluate groundwater conditions, and treatment and discharge alternatives at the Bridger coal mine in southwest Wyoming. Previous studies' predicted maximum flows into the mine had been exceeded. Reassessed the situation and provided solutions.

EMERGENCY RESPONSE

Emergency Response to Battery Fire, Confidential Location — Served as the principal in charge leading a team of multidisciplinary scientists, engineers, toxicologists, and risk assessors for an environmental emergency response at a large-scale battery power storage unit at a solar farm. A thermal incident where several cargo container boxes caught fire and burned required immediate action to assess the environmental and human health impacts.

ECOLOGICAL RESTORATION

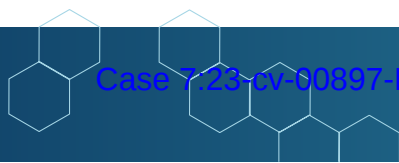
Ecological Restoration, Northeast Idaho — Serves as the principal in charge leading a team of scientists, engineers, and ecologists for an ecological restoration effort in northeast Idaho. The project has involved restoring flow to a creek and working with a number of state and federal agencies to develop and implement a conceptual restoration plan and a mitigation and monitoring plan. The project will also include obtaining the necessary permits and overseeing the restoration in an area of critical habitat.

PROJECT MANAGEMENT

GMS Software Development, Utah — Served as chief engineer for the original development of the software Groundwater Modeling System (GMS) at the Environmental Modeling Research Laboratory at Brigham Young University. A sophisticated graphical environment for groundwater model pre- and post-processing, 3-dimensional site characterization, and geostatistics, GMS is the official groundwater application of the U.S. Department of Defense and is also used by the U.S. Department of Energy, EPA, and thousands of users across the world.

NATURAL RESOURCE DAMAGE ASSESSMENT

Natural Resources Damage Assessment, Southeastern Idaho — Served as the groundwater expert determining groundwater damages in southeastern Idaho due to decades of phosphate



mining. Led a team of hydrogeologists evaluating the impacts of selenium and other contaminants and changes in natural groundwater flows across the entire region. The damage assessment included a number of mining areas as well as the facilities where the phosphate material was processed.

Presentations / Posters

Davis, R.J. 2023. Challenges limiting managed aquifer recharge (MAR) adoption in the West. National Ground Water Association Groundwater Summit. December 5–7. Las Vegas, NV.

Davis, R.J. 2023. Water, AI, and us: What does the future hold for solving Utah's water challenges. Hint: It can't be solved without you and me. Salt Lake County Watershed Symposium. November 15–16. Salt Lake City, UT.

Davis, R.J. 2023. Building climate resilience through sustainable remediation in the western region. Groundwater Resources Association of California Western Groundwater Congress. September 12–14. Burbank, CA.

Davis, R.J. 2023. Water in Utah: Navigating the present and shaping the future. American Groundwater Trust. August 14–15. Provo, Utah.

Davis, R.J. 2023. More managed aquifer recharge and saving the Great Salt Lake—A balancing act. Idaho Water Users Association. June 12–13. Sun Valley, ID.

Davis, R.J. 2023. More managed aquifer recharge: Deliberate resiliency to combat droughts and climate change in the West. Association for Environmental Health of Soils. March 20–23. San Diego, CA.

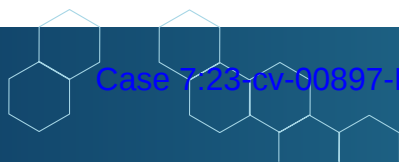
Davis, R.J. 2023. Resilient and sustainable remediation. ESG|Climate Resilient & Sustainable Remediation Symposium. Groundwater Resources Association of California Western Groundwater Congress. February 6–7. San Diego, CA.

Davis, R.J. 2022. More managed aquifer recharge: Solutions to combat droughts and climate change in the West. National Ground Water Association Groundwater Summit. December 6–8. Las Vegas, NV.

Davis, R.J. 2022. Saving our aquifers: Climate change and managed aquifer recharge. Salt Lake County Watershed Symposium. November 16–17. Salt Lake City, UT.

Davis, R.J. 2022. More managed aquifer recharge—A solution to combat droughts and climate change in the West. Groundwater Resources Association of California Western Groundwater Congress. September 21–23. Sacramento, CA.

Davis, R.J. 2022. Saving our aquifers—Climate change, sustainability, and managed aquifer recharge. International Water Holdings. August 24–25. Salt Lake City, UT.



Davis, R.J. 2022. More managed aquifer recharge (MMAR) a solution to combat droughts and climate change in the West. Groundwater Protection Council Annual Forum. June 21–23. Salt Lake City, UT.

Davis, R.J. 2022. Aquifer storage and recovery—Hydrogeologic considerations. American Water Resources Association. May 17. Salt Lake City, UT.

Davis, R.J. 2022. Utah hydrology—What you do and don't know about Utah hydrogeology. National Ground Water Association. May 4, 2022. Virtual.

Davis, R.J. and B. Lemon. 2022. Provo, Utah: From planning to pilot to a final aquifer storage and recovery (ASR) program. Utah Water Users Workshop. March 21–23. St. George, UT.

Davis, R.J. 2021. Provo, Utah, from planning to pilot to a final managed aquifer recharge (MAR) program. National Ground Water Association Groundwater Summit. December 7–8. Virtual.

Davis, R.J. 2021. Provo City aquifer storage and recovery project. Ground Water Protection Council Annual Forum, September 27–29. Virtual.

Davis, R.J. 2021. Provo, Utah, from planning to pilot to a final managed aquifer recharge (MAR) program. American Public Works Association Utah Section Annual Conference. September 21–22. Sandy, UT.

Davis, R.J. 2021. Provo City aquifer storage and recovery project. Utah Water Users Workshop. May 17–19. St. George, UT.

Davis, R.J. 2021. Provo, Utah: From planning to pilot to a final managed aquifer recharge (MAR) program. ASR for Texas, Virtual Webinar. May 4–5.

Davis, R.J. 2021. Provo aquifer storage and recovery—From planning to pilot. American Water Works Association Virtual Summit on Sustainable Water, PFAS, Waterborne Pathogens. February 10–11.

Davis, R.J. 2020. Update on Provo's aquifer storage and recovery program. American Water Works Association Virtual Intermountain Section Annual Conference. October 21–23. Sun Valley, ID.

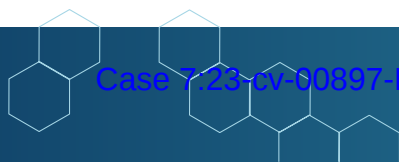
Davis, R.J. 2020. Are you prepared for the new federal permit process for CCR facilities? Second Annual Coal Ash and Combustion Residual Management Webinar, October 7–8. Virtual.

Invited Participant, Expert Panels, and Workshops

Bulk Water Innovation Partnership (BWIP): More managed aquifer recharge: Deliberate resiliency to combat droughts and climate change in the West. December 6, 2023. Virtual.

Rocky Mountain Association of Environmental Professionals (RMAEP): Great Salt Lake of Utah: watershed, legislative, and community issues surrounding it. September 20, 2023.

Salt Lake Chamber: Utah Water Outlook. April 13, 2022.



EDCUtah Webinar: Water: Constraints and Opportunities for Development in Utah panel. June 11, 2021.

ULI Utah: Trends Conference—Water: Constraints and Opportunities for Development in Utah panel. October 27, 2021.

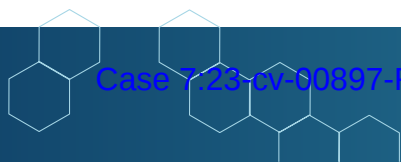


Exhibit 2

Resume for Norman L. Jones

Norman L. Jones, Ph.D.
Professor
Department of Civil & Construction Engineering
Brigham Young University

Education

Ph.D. Civil Engineering, University of Texas at Austin, 1990
M.S. Civil Engineering, University of Texas at Austin, 1988
B.S. Civil Engineering, Brigham Young University, 1986

Academic Experience

Department Chair, Civil & Construction Engineering, Brigham Young University (BYU), 2018-2024
Professor, Civil & Construction Engineering, BYU, 2002–present
Associate Professor, Civil & Environmental Engineering, BYU, 1997–2002
Assistant Professor, Civil & Environmental Engineering, BYU, 1991–1996

Current Membership in Professional Organizations

American Society of Civil Engineers (ASCE)
American Water Resources Association (AWRA)
National Ground Water Association (NGWA)
American Geophysical Union (AGU)

Professional Committees

AWRA 2014 GIS in Water Resources Technical Program Chair
NGWA Groundwater Modeling Interest Group Committee
American Society of Civil Engineers
EWRI Groundwater Management Committee
EWRI Emerging Technologies Committee
International Editorial Board for the Journal of HydroInformatics
Editor of AQUAmundi Journal
Great Salt Lake Basin Integrated Plan - Groundwater Technical Advisory Team
Tethys Geoscience Foundation - Board Member

Selected Honors and Awards

2001 Walter L. Huber Civil Engineering Research Prize
2002 College of Engineering & Technology Special Commendation Award
2003 Brigham Young University Technology Transfer Award
2007 Utah Engineering Educator of the Year – ACEC
2012 Brigham Young University Karl G. Maeser Research and Creative Arts Award
2016 AWRA Educator of the Year – Utah Section
2021 NGWA John Hem Award for Science and Engineering
2023 Brigham Young University Sponsored Research Award

University Courses Taught

CE En 101 - Introduction to Civil and Environmental Engineering
CE En 201 - Infrastructure
CE En 270 – Computer Methods in Civil Engineering
CE En 341 – Elementary Soil Mechanics
CE En 540 – Geo-Environmental Engineering
CE EN 544 - Seepage and Slope Stability Analysis
CCE 547 – Ground Water Modeling

Software

Led the development of the Groundwater Modeling System (GMS) software. GMS is a state-of-the-art three-dimensional environment for ground water model construction and visualization. It includes tools for site characterization including geostatistics and solid modeling of soil stratigraphy. GMS is the most comprehensive and sophisticated groundwater modeling software available and is used by over 10,000 organizations in over 100 countries. Currently managed and distributed by Aquaveo, LLC, a company I co-founded in 2007.

External Research Grants

1. Automated Mesh Generation For the TABS-2 System, \$19,000, 2/90 - 11/90, U.S. Army Engineer Waterways Experiment Station
2. A Geometry Pre-Processor for HEC-1 Employing Triangulated Irregular Networks, \$20,048, 3/91 - 10/91, U.S. Army Engineer Waterways Experiment Station
3. Real-Time Visualization for the TABS-2 Modelling System, \$14,123, 4/91 - 8/91, U.S. Army Engineer Waterways Experiment Station
4. An Investigation of X-Windows Interface Tools, \$49,556, 1/92 - 8/92, U.S. Army Engineer Waterways Experiment Station
5. Descriptive Geometry and Solid Rendering, \$24,000, 1/92 - 10/92, U.S. Army Engineer Waterways Experiment Station
6. An Investigation of Automated Pre-processing Schemes for TIN-Based Drainage Analysis, \$34,750, 4/92-10/92, U.S. Army Engineer Waterways Experiment Station
7. A Comprehensive Graphical User Environment for Groundwater Flow and Transport Modeling, \$246,526, 6/93-9/94, U.S. Army Engineer Waterways Experiment Station
8. An Integrated Surface Flow Modeling System, \$131,848, 1/94-1/95, U.S. Army Engineer Waterways Experiment Station
9. Productivity and Management Tools for Groundwater Flow and Transport Modeling, \$207,404, 5/94-4/95, U.S. Army Engineer Waterways Experiment Station
10. Enhanced Tools for Quality Control in Automated Groundwater Transport Modeling, \$246,553, 1/95-12/95, U.S. Army Engineer Waterways Experiment Station
11. Visualization for Two-Dimensional Surface Runoff Modeling, \$98,221, 1/95-10/95, U.S. Army Engineer Waterways Experiment Station
12. Visualization Tools for Two-Dimensional Finite Element Hydrologic Modeling, \$93,933, 11/95-10/96, U.S. Army Engineer Waterways Experiment Station
13. A Graphical Environment for Multi-Dimensional Surface Water Modeling, \$49,789, 3/96-9/96, U.S. Army Engineer Waterways Experiment Station
14. A Conceptual Modeling Approach to Pre-processing of Groundwater Models, \$475,743, 11/95-11/97, U.S. Army Engineer Waterways Experiment Station
15. Hydrosystems Modeling, \$2,458,083, 5/97-4/02, U.S. Army Engineer Waterways Experiment Station
16. Second Generation Hydroinformatics Research, \$4,958,127. U.S. Army Engineer Research and Development Center.
17. Flux Calculations and 3D Visualization for the SCAPS Piezocone and GeoViz System, \$34,931, U.S. Navy.
18. Development of modeling methods and tools for predicting coupled reactive transport processes in porous media under multiple scales. \$949,000. US Dept. of Energy. 1/07-12/09.
19. CI-WATER: Cyberinfrastructure to Advance High Performance Water Resource Modeling, \$3,435,873. National Science Foundation - EPSCoR. 9/11-8/14.

20. Comprehensive Streamflow Prediction and Visualization to Support Integrated Water Management, \$599,823. NASA SERVIR, 8/16-8/19.
21. Daniel P. Ames, E. James Nelson, Norman L. Jones, An AmeriGEOSS Cloud-based Platform for Rapid Deployment of GEOGLOWS Water and Food Security Decision Support Apps, \$540,658, NASA GEO, 1/2018-12/2020
22. Geospatial Information Tools That Use Machine-Learning to Enable Sustainable Groundwater Management in West Africa, \$657,232. NASA SERVIR, 11/19-11/22.
23. Advancing the NASA GEOGloWS Toolbox for Regional Water Resources Management and Decision Support. \$1.2M. NASA GEOGLOWS. 2022-2025. Dan Ames, Jim Nelson, Gus Williams, Norm Jones.
24. CIROH: National Cyberinfrastructure Framework for Engaging the Hydrologic Community (NCF). \$1,822,418. National Oceanographic and Atmospheric Administration. 2022-2025. Dan Ames, Jim Nelson, Gus Williams, Norm Jones.
25. CIROH: Advancing Science to Better Characterize Drought and Groundwater-Driven Low-Flow Conditions in NOAA and USGS National-Scale Models. \$801,221. 2023-2025. Norm Jones, Gus Williams, T. Prabhakar Clement, Donna Rizzo.
26. Improved Hydrologic Prediction Services for Resilience with GEOGLOWS, \$1,889,627, National Oceanic and Atmospheric Administration (NOAA), 4/1/2024-3/31/2027. Norm Jones, Jim Nelson, Andrew South.

Summary: PI or Co-PI on 26 projects totaling \$22,026,639.

Peer-Reviewed Publications in the Past 10 Years

1. Jones, N., Nelson, J., Swain, N., Christensen, S., Tarboton, D. Dash, P. Tethys: A Software Framework for Web-Based Modeling and Decision Support Applications. In: Ames, D.P., Quinn, N.W.T., Rizzoli, A.E. (Eds.), Proceedings of the 7th International Congress on Environmental Modelling and Software, June 15-19, San Diego, California, USA. ISBN: 978-88-9035-744-2
2. Jones, N., Griffiths, T., Lemon, A., Kudlas, S. Automated Well Permitting in Virginia's Coastal Plain Using SEAWAT and GIS Geoprocessing Tools. In: Ames, D.P., Quinn, N.W.T., Rizzoli, A.E. (Eds.), Proceedings of the 7th International Congress on Environmental Modelling and Software, June 15-19, San Diego, California, USA. ISBN: 978-88-9035-744-2
3. Y. Fan, S. Richard, R. S. Bristol, S. E. Peters, S. E. Ingebritsen, N. Moosdorf, A. Packman, T. Gleeson, I. Zaslavsky, S. Peckham, L. Murdoch, M. Fienen, M. Cardiff, D. Tarboton, N. Jones, R. Hooper, J. Arrigo, D. Gochis, J. Olson and D. Wolock (2014), DigitalCrust – a 4D data system of material properties for transforming research on crustal fluid flow, *GeoFluids*, Article first published online: 7 OCT 2014 | DOI: 10.1111/gfl.12114.
4. Swain, N.R., K. Latu, S.D. Christensen, N.L. Jones, E.J. Nelson, D.P. Ames, G.P. Williams (2015). "A review of open source software solutions for developing water resources web applications." *Environmental Modeling & Software* 67: 108-117.
5. Jones, David, Norm Jones, James Greer, and Jim Nelson, "A cloud-based MODFLOW service for aquifer management decision support," *Computers and GeoSciences*, Vol. 78, pp. 81-87, 2015.
6. Dolder, H., Jones, N., and Nelson, E. (2015). "Simple Method for Using Precomputed Hydrologic Models in Flood Forecasting with Uniform Rainfall and Soil Moisture Pattern." *J. Hydrol. Eng.*, [10.1061/\(ASCE\)HE.1943-5584.0001232](https://doi.org/10.1061/(ASCE)HE.1943-5584.0001232), 04015039.
7. Fatichi, S., Vivoni, E.R., Ogden, F.L., Ivanov, V.Y., Mirus, B., Gochis, D., Downer, C.W., Camporese, M., Davidson, J.H., Ebel, B., Jones, N., Kim, J., Mascaro, G., Niswonger, R., Restrepo, P., Rigon, R., Shen, C., Sulis, M., and Tarboton, D. (2016). *An Overview of Challenges, Current Applications and Future Trends of Distributed Process-based Models in Hydrology*.

- Journal of Hydrology. Vol 537, 45-60. DOI:10.1016/j.jhydrol.2016.03.026
8. Snow, Alan D., Scott D. Christensen, Nathan R. Swain, E. James Nelson, Daniel P. Ames, Norman L. Jones, Deng Ding, Nawajish S. Noman, Cédric H. David, Florian Pappenberger, and Ervin Zsoter, 2016. *A High-Resolution National-Scale Hydrologic Forecast System from a Global Ensemble Land Surface Model*. Journal of the American Water Resources Association (JAWRA) 52(4):950–964, DOI: 10.1111/1752-
 9. Perez, J. Fidel, Nathan R. Swain, Herman G. Dolder, Scott D. Christensen, Alan D. Snow, E. James Nelson, and Norman L. Jones, 2016. *From Global to Local: Providing Actionable Flood Forecast Information in a Cloud-Based Computing Environment*. Journal of the American Water Resources Association (JAWRA) 52(4):965–978. DOI: 10.1111/1752-1688.12392
 10. Swain, N. R., S. D. Christensen, A. D. Snow, H. Dolder, G. Espinoza-Dávalos, E. Goharian, N. L. Jones, E. J. Nelson, D. P. Ames and S. J. Burian (2016). "A new open source platform for lowering the barrier for environmental web app development." *Environmental Modelling & Software* 85: 11-26.
 11. Souffront Alcantara, Michael A.; Crawley, Shawn; Stealey, Michael J.; Nelson, E. James; Ames, Daniel P.; and Jones, Norm L. (2017) "Open Water Data Solutions for Accessing the National Water Model," *Open Water Journal*: Vol. 4 : Iss. 1 , Article 3.
 12. Souffront Alcantara, Michael, C Kesler, M Stealey, J Nelson, D Ames, N Jones, 2017. Cyberinfrastructure and Web Apps for Managing and Disseminating the National Water Model, *Journal of the American Water Resources Association, JAWRA Journal of the American Water Resources Association* 54, no. 4 (2018): 859-871.
 13. Christensen, Scott D., Nathan R. Swain, Norman L. Jones, E. James Nelson, Alan D. Snow, and Herman G. Dolder. "A Comprehensive Python Toolkit for Accessing High-Throughput Computing to Support Large Hydrologic Modeling Tasks." *JAWRA Journal of the American Water Resources Association* 53, no. 2 (2017): 333-343.
 14. Nelson, E. J., Pulla, S. T., Matin, M. A., Shakya, K., Jones, N., Ames, D. P., Ellenberg, W.L., Markert, K.N., Hales, R. (2019). Enabling Stakeholder Decision-Making With Earth Observation and Modeling Data Using Tethys Platform. *Frontiers in Environmental Science*, 7. <https://doi.org/10.3389/fenvs.2019.00148>
 15. Purdy, A. J., David, C. H., Sikder, M. S., Reager, J. T., Chandanpurkar, H. A., Jones, N. L., & Matin, M. A. (2019). An Open-Source Tool to Facilitate the Processing of GRACE Observations and GLDAS Outputs: An Evaluation in Bangladesh. *Frontiers in Environmental Science*, 7. <https://doi.org/10.3389/fenvs.2019.00155>
 16. Souffront Alcantara, M. A., Nelson, E. J., Shakya, K., Edwards, C., Roberts, W., Krewson, C., Ames, D. P., Jones, N. L., Gutierrez, A. (2019). Hydrologic Modeling as a Service (HMaaS): A New Approach to Address Hydroinformatic Challenges in Developing Countries. *Frontiers in Environmental Science*, 7. <https://doi.org/10.3389/fenvs.2019.00158>
 17. Evans, S.; Williams, G.P.; Jones, N.L.; Ames, D.P.; Nelson, E.J. Exploiting Earth Observation Data to Impute Groundwater Level Measurements with an Extreme Learning Machine. *Remote Sens.* 2020, 12, 2044. <https://doi.org/10.3390/rs12122044>
 18. Evans, S.W.; Jones, N.L.; Williams, G.P.; Ames, D.P.; Nelson, E.J. (2020). Groundwater Level Mapping Tool: An open source web application for assessing groundwater sustainability. *Environmental Modeling and Software*, Vol 131, September 2020. <https://doi.org/10.1016/j.envsoft.2020.104782>
 19. Nelson, S. T., Robinson, S., Rey, K., Brown, L., Jones, N., Dawrs, S. N., et al. (2021). Exposure Pathways of Nontuberculous Mycobacteria Through Soil, Streams, and Groundwater, Hawai'i, USA. *GeoHealth*, 5, e2020GH000350. <https://doi.org/10.1029/2020GH000350>
 20. Sanchez Lozano J, Romero Bustamante G, Hales R, Nelson EJ, Williams GP, Ames DP, Jones NL. A Streamflow Bias Correction and Performance Evaluation Web Application for GEOGloWS ECMWF Streamflow Services. *Hydrology*. 2021;

- 8(2):71. <https://doi.org/10.3390/hydrology8020071>
21. Dolder, Danisa; Williams, Gustavious P.; Miller, A. W.; Nelson, Everett J.; Jones, Norman L.; Ames, Daniel P. 2021. "Introducing an Open-Source Regional Water Quality Data Viewer Tool to Support Research Data Access" *Hydrology* 8, no. 2: 91. <https://doi.org/10.3390/hydrology8020091>
 22. Bustamante, G.R.; Nelson, E.J.; Ames, D.P.; Williams, G.P.; Jones, N.L.; Boldrini, E.; Chernov, I.; Sanchez Lozano, J.L. Water Data Explorer: An Open-Source Web Application and Python Library for Water Resources Data Discovery. *Water* 2021, 13, 1850. <https://doi.org/10.3390/w13131850>
 23. Hales, R.C.C.; Nelson, E.J.J.; Williams, G.P.P.; Jones, N.; Ames, D.P.P.; Jones, J.E.E. The Grids Python Tool for Querying Spatiotemporal Multidimensional Water Data. *Water* 2021, 13, 2066. <https://doi.org/10.3390/w13152066>
 24. Khattar, R., Hales, R., Ames, D. P., Nelson, E. J., Jones, N., & Williams, G. (2021). Tethys App Store: Simplifying deployment of web applications for the international GEOGloWS initiative. *Environmental Modelling & Software*, 105227. <https://doi.org/10.1016/j.envsoft.2021.105227>
 25. McStraw, T.C., Pulla, S.T., Jones, N.L., Williams, G.P., David, C.H., Nelson, J.E., and Ames, D.P.. 2021. "An Open-Source Web Application for Regional Analysis of GRACE Groundwater Data and Engaging Stakeholders in Groundwater Management." *Journal of the American Water Resources Association* 1– 15. <https://doi.org/10.1111/1752-1688.12968>.
 26. Barbosa, S.A.; Pulla, S.T.; Williams, G.P.; Jones, N.L.; Mamane, B.; Sanchez, J.L. Evaluating Groundwater Storage Change and Recharge Using GRACE Data: A Case Study of Aquifers in Niger, West Africa. *Remote Sens.* 2022, 14, 1532. <https://doi.org/10.3390/rs14071532>
 27. Nishimura, R.; Jones, N.L.; Williams, G.P.; Ames, D.P.; Mamane, B.; Begou, J. Methods for Characterizing Groundwater Resources with Sparse In Situ Data. *Hydrology* 2022, 9, 134. <https://doi.org/10.3390/hydrology9080134>
 28. Ramirez, S. G., Hales, R. C., Williams, G. P., & Jones, N. L. (2022). Extending SC-PDSI-PM with neural network regression using GLDAS data and Permutation Feature Importance. *Environmental Modelling & Software*, 105475. <https://doi.org/10.1016/j.envsoft.2022.105475>
 29. Hales, R. C., Nelson, E. J., Souffront, M., Gutierrez, A. L., Prudhomme, C., Kopp, S., Ames, D. P., Williams, G. P., & Jones, N. L. (2022) Advancing global hydrologic modeling with the GEOGloWS ECMWF streamflow service. *Journal of Flood Risk Management*, e12859. <https://doi.org/10.1111/jfr3.12859>
 30. Ramirez, S.G.; Williams, G.P.; Jones, N.L. (2022) Groundwater Level Data Imputation Using Machine Learning and Remote Earth Observations Using Inductive Bias. *Remote Sens.* 2022, 14, 5509. <https://doi.org/10.3390/rs14215509>
 31. Jones, J.E.; Hales, R.C.; Larco, K.; Nelson, E.J.; Ames, D.P.; Jones, N.L.; Iza, M. (2023) Building and Validating Multidimensional Datasets in Hydrology for Data and Mapping Web Service Compliance. *Water* 2023, 15, 411. <https://doi.org/10.3390/w15030411>
 32. Ramirez, S.G.; Williams, G.P.; Jones, N.L.; Ames, D.P.; Radebaugh, J. (2023) Improving Groundwater Imputation through Iterative Refinement Using Spatial and Temporal Correlations from In Situ Data with Machine Learning. *Water* 2023, 15, 1236. <https://doi.org/10.3390/w15061236>
 33. Jones, N.L. and Mayo, A.L. (2023), Urban Thirst and Rural Water – The Saga of the Southern Nevada Groundwater Development Project. *Groundwater*. <https://doi.org/10.1111/gwat.13364>
 34. Barbosa, S.A.; Jones, N.L.; Williams, G.P.; Mamane, B.; Begou, J.; Nelson, E.J.; Ames, D.P. (2023) Exploiting Earth Observations to Enable Groundwater Modeling in the Data-Sparse Region of Goulbi Maradi, Niger. *Remote Sens.* 2023, 15,

5199. <https://doi.org/10.3390/rs15215199>
35. Sanchez Lozano, J. L., Rojas Lesmes, D. J., Romero Bustamante, E. G., Hales, R. C., Nelson, E. J., Williams, G. P., Ames, D. P., Jones, N. L., Gutierrez, A. L., & Cardona Almeida, C. (2025). Historical simulation performance evaluation and monthly flow duration curve quantile-mapping (MFDC-QM) of the GEOGLOWS ECMWF streamflow hydrologic model. *Environmental Modelling & Software*, 183, 106235. <https://doi.org/10.1016/j.envsoft.2024.106235>

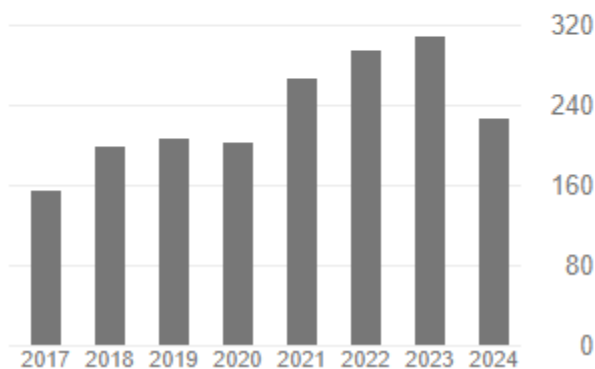
Summary: 88 total peer-reviewed publications.

Books

Strassberg, G., Jones, N., Maidment, D. (2011). Arc Hydro Groundwater: GIS for Hydrology. ESRI Press, Redlands, California, 250 pp.

Google Scholar Metrics

	All	Since 2019
Citations	3287	1507
h-index	27	19
i10-index	51	30



Complete CV: <https://www.et.byu.edu/~njones/vita/>

EXHIBIT 17

Rebuttal Report Regarding Tarawa Terrace Flow and Transport Model Post-Audit

Prepared for
Bell Legal Group
219 Ridge Street
Georgetown, SC 29440

Prepared by



Norman L. Jones
Norm Jones Consulting LLC
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January 14, 2025

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ACRONYMS AND ABBREVIATIONS

ATSDR	Agency for Toxic Substances and Disease Registry
PCE	tetrachloroethylene
GMS	Groundwater Modeling System
MAE	mean absolute error
ME	mean error
NGWA	National Groundwater Association

1 SUMMARY OF OPINIONS

The opinions presented in this report are in response to the portion of the Alexandros Spiliotopoulos report related to the post-audit we performed on the Agency for Toxic Substances and Disease Registry (ATSDR) flow and transport models for Tarawa Terrace. Our opinions are as follows:

Opinion 1: The Spiliotopoulos report exaggerated and distorted the model bias in the post-audit results.

Opinion 2: The calibration target of ± 0.5 order of magnitude used in the original ATSDR transport study was arbitrary and too narrow to use as a basis for evaluating the post-audit results.

Opinion 3: Spiliotopoulos did not effectively refute our qualitative assessment of the overall plume behavior.

Opinion 4: The numerical roundoff errors found by Spiliotopoulos were minor and did not significantly impact the model results.

Opinion 5: The pumping rate error and the mass loading termination date error found by Spiliotopoulos were both minor and did not significantly impact the model results.

Opinion 6: Nothing in the Spiliotopoulos report contradicts our overall conclusion about the post-audit results. The model effectively simulates long-term trends in contaminant migration, and we can find no significant evidence that would invalidate the analyses performed by ATSDR with the original model.

All of the opinions expressed in this rebuttal report are held by both of us. Our opinions are based on our review of the report of Dr. Spiliotopoulos, the ATSDR published reports, the references listed in this report and our Oct. 2024 report, our post-audit, and our experience and expertise in the fields of hydrogeology and groundwater modeling. We hold these opinions to a reasonable degree of scientific and engineering certainty.

2 INTRODUCTION

Our names are Norman L. Jones and R. Jeffrey Davis, and we have been asked to provide a rebuttal to a set of expert reports issued on December 9, 2024, related to the Camp Lejeune Water Litigation. Based on our review of these reports, we have reached the conclusions and opinions set forth below. A list of all materials considered to form the opinions in this rebuttal will be produced within seven days of the report's submittal. Our conclusions are subject to any new materials, data, or other information provided to us prior to depositions or trial, at which time our opinions and conclusions may be updated.

In July 2007, ATSDR, U.S. Department of Health and Human Services, published a report on a groundwater flow and transport model of the Tarawa Terrace region of the Camp Lejeune military base (Maslia et al. 2007; Faye and Valenzuela 2008; Faye 2008). The model was developed to simulate groundwater flow in the aquifers beneath Tarawa Terrace and to simulate the migration of tetrachloroethylene (PCE)¹ in the aquifers resulting from the release of PCE by ABC One-Hour Cleaners, which is directly adjacent to the northern boundary of the Tarawa Terrace property. The original Tarawa Terrace flow model was designed to simulate flow conditions over a period from 1951 to 1994. Output from the model was used to estimate the PCE concentration at the Tarawa Terrace Water Treatment Plant as part of an epidemiological study.

In 2024, we were tasked with performing a post-audit of the Tarawa Terrace flow and transport model.² The objective of the post-audit was to extend the range of the groundwater flow and transport model from 1995 to 2008 and compare the output of the transport model with concentrations sampled at monitoring wells in Tarawa Terrace during the 1995–2008 period to assess the performance of the model as an interpretive and predictive tool. This comparison involved both a quantitative analysis of simulated versus observed concentrations and a qualitative analysis of the shape and migration of the simulated PCE plume over that period. On October 25, 2024, we submitted a report of this effort titled *Tarawa Terrace Flow and Transport Model Post-Audit* (Jones and Davis, 2024). After performing the post-audit, we concluded:

In summary, this post-audit found that the original Tarawa Terrace groundwater flow and transport models were developed using sound methodology and continue to provide reliable insights into the migration of PCE contamination. Despite the inherent challenges in simulating complex subsurface conditions and dealing with incomplete data, the model effectively simulates long-term trends in contaminant migration. Based on this

¹ PCE is also known by other names, including tetrachloroethene. In this report we refer to it as PCE.

² The Tarawa Terrace groundwater model consists of a MODFLOW model to simulate flow and a coupled MT3DMS model to simulate PCE transport in the aquifer. Depending on context, in this report we will occasionally refer to the coupled MODFLOW/MT3DMS simulations as a singular “model” and in some cases we will refer to the two simulations as “models.”

post-audit, we can find no significant evidence that would invalidate the analyses performed by ATSDR with the original model.

On December 9, 2024, we were provided with the following three reports by experts hired by the U.S. Department of Justice:

1. Expert Report of **Alexandros Spiliotopoulos**, PhD. In the United States District Court for the Eastern District of North Carolina. No. 7:23-cv-897. In Re: Camp Lejeune Water Litigation. S.S. Papadopoulos & Associates, Inc. December 9, 2024.
2. Expert Report of **Remy J.-C. Hennet**. In the United States District Court for the Eastern District of North Carolina. No. 7:23-cv-897. In Re: Camp Lejeune Water Litigation. S.S. Papadopoulos & Associates, Inc. December 9, 2024.
3. Expert Report of **Jay L. Brigham**, PhD. In the United States District Court for the Eastern District of North Carolina Southern Division. Case No.: 7:23-CV-897. Camp Lejeune Water Litigation. Morgan, Angel, Brigham and Associates, LLC. December 9, 2024.

Of the three reports, the only one that directly referenced our 2024 post-audit was the Spiliotopoulos report. The objective of this document is to respond to issues raised in relation to our post-audit. Therefore, we will only reference the Spiliotopoulos report in the following sections.

3 RESPONSE TO SPECIFIC ITEMS IN THE ALEXANDROS SPILIOTOPOULOS REPORT

3.1 ASSESSING THE PERFORMANCE OF CONTAMINANT TRANSPORT MODELS

Before responding to specific issues raised in the Spiliotopoulos report, it would be useful to review some basic facts related to evaluating the performance of groundwater models in general, and more specifically to contaminant transport models.

3.1.1 Accuracy, Precision, and Model Fitting

In Section 3 of the Spiliotopoulos report, there is a discussion of general principles of model calibration, sensitivity, and uncertainty analysis. In the context of the discussion, the graphic shown in Figure 1 was presented (referenced as Figure 2 of the Spiliotopoulos report). This graphic was reproduced from a document produced by the National Oceanic and Atmospheric Administration to illustrate the concepts of “precision” and “accuracy” as they relate to natural sciences (NOAA 2024).

While this graphic may apply to some concepts of natural sciences, it presents a grossly unrealistic standard for the modeling of physical phenomena that exhibit a high degree of variance, as is the case with PCE concentrations at a contaminated site. For such cases, the graphics in our Figure 2 represent a more appropriate and realistic depiction of the modeling process. The red dots shown in Figure 2(a) represent a set of observations sampled in the field representing some physical phenomenon. The sample values are on the y-axis and the x-axis represents a variable such as distance or time. The red data points exhibit a high degree of scatter or variance. This could be the result of sampling error or variability, or some kind of local-scale heterogeneity that is a natural byproduct of the phenomenon in question. Despite the variance, the points show a general trend of decreasing y-values as the x-values increase. The blue line in Figure 2(a) represents a simple model that accurately captures the behavior of the phenomenon. The green dashed line in Figure 2(b) represents an alternative model that attempts to model the phenomenon represented by the red dots with a high degree of precision. This is a classic case of what is referred to as “model overfitting.” Even though it has less “precision,” the blue line in Figure 2(a) is a much more appropriate model. For example, if a second set of samples were obtained over the same x-domain, one would expect to see the same downward trend, but the data points would be different. The blue line in Figure 2(a) would still be a good fit to the second data set, but the green dashed line in Figure 2(b) would be a very poor fit.

The dangers of model overfitting and the importance of finding a balance between simple and complicated models in the field of groundwater modeling has been highlighted by a number of

respected groundwater researchers, including Carrera and Neuman (1986), Hill (2006), Hunt, et al. (2020), Yeh and Yoon (1981), Wali et al. (2024), and Zatlakovic et al. (2023). Hunt et al. (2020, p. 176) stated:

The highly parameterized approach often achieves an excellent fit but can also “overfit,” where the parameter estimation chases noise in the observations and yields unrealistic parameter values and distributions (e.g., parameter “bullseyes,” or hotspots).

Mary Hill’s research in particular underscores the importance of balancing model complexity with the risk of overfitting (Hill 1998, 2006, 2010). She advocates for starting with simpler models and gradually increasing complexity, allowing for a more accurate representation of the system without capturing extraneous noise. This approach not only aids in avoiding overfitting but also enhances the model’s predictive reliability.

3.1.2 Contaminant Concentrations Exhibit High Variance

The concepts illustrated in Figure 2 are important to understand in the context of a post-audit of the ATSDR Tarawa Terrace model. The PCE concentrations measured at the Tarawa Terrace site exhibit a high degree of variance. Figure 3 illustrates a histogram of the observed PCE values taken from observations wells at Tarawa Terrace used in the post-audit. The histogram is based on log-transformed values, indicating that data are log-normally distributed and vary over 5 orders of magnitude. Furthermore, as we explained in Section 4.2 of our post-audit report, a careful analysis of the observed concentrations from Tarawa Terrace shows high variance in the form of temporal and spatial anomalies. Some samples collected at similar times in wells separated by a short distance showed a high degree of variance. In other cases, samples taken at the same observation well but separated by a relatively short time also exhibited high variance.

High spatial and temporal variability in observed PCE concentrations results from a number of factors. Variations in sampling methods, equipment, and processing can lead to variation. Aquifer heterogeneity can also have a significant impact. Consider the conceptual diagram shown in Figure 4. At the local-scale, groundwater flow is not uniform. Groundwater preferentially flows through high permeability channels (shown in blue) and there is minimal flow in low permeability zones (shown in brown). Thus, a monitoring well screen that happens to coincide with a preferential flow channel (point B) may sample a substantially different concentration than a sample taken from a monitoring well that happens to be screened in a low permeability zone (point A).

The issue of high variability in PCE concentrations at Camp Lejeune was discussed at length by the Expert Panel convened by ATSDR to assess its methods and analyses for historical reconstruction. It noted that concentration measurements can vary greatly over short periods of time (ATSDR 2009c, p. 216). For example, wellhead concentrations can fluctuate significantly within a 2-week period. One well showed a high of 1,600, followed by 540, and

then 300 µg/L in subsequent samples (ATSDR 2009c, p. 121). There were concerns about the representativeness of individual samples due to the limitations of sampling procedures and laboratory analyses (ATSDR 2009b, p. 336; ATSDR 2009c, p. 217). It was noted that some of the observed PCE data may be biased low due to collection activities, and adjustments may be needed (ATSDR 2009c, p. 62). Because of this high variance, the panel suggested that instead of trying to match the model to every data point, it may be more useful to focus on capturing the general trends in the data and suggested using ranges of concentration to convey uncertainty rather than single values (ATSDR 2009d, p. 69).

3.1.3 Transport Models versus Flow Models

The diagram in Figure 2 is representative of the complexities inherent in simulating the transport of contaminants such as PCE in aquifers. By its nature, computer modeling of contaminant transport is substantially different from modeling groundwater flow, and calibrating transport models presents unique challenges (Zheng et al. 2012; Green et al. 2010). For a groundwater flow model, the primary variable simulated is the hydraulic (potentiometric) head. While there is some level of variance in hydraulic head, it is significantly less variable than contaminant concentrations. Heads are normally distributed, not log-normally distributed, and they do not vary by multiple orders of magnitude. The process of sampling heads at observation wells has a much lower possibility of error, and heads are much less sensitive to local-scale heterogeneity. For these reasons, when calibrating a flow model or assessing the performance of a flow model, one would expect lower variance in the observations and therefore lower residuals (difference between simulated and observed heads) at observation wells. Zheng et al. (2012, p. 1551) state:

To users of MT3DMS, the term “model calibration” generally describes a process in which the model structure and parameter values are adjusted, either manually or by using formal mathematical optimization procedures, until the model output satisfactorily matches a set of targets (Zheng and Bennett, 2002). The suggestion by Hill and Tiedeman (2007) that “satisfactory” needs to be considered in the context of data errors and model limitations is important to users of MT3DMS because of difficulties associated with simulating subsurface transport. Difficulties include the inaccessibility of subsurface systems and the many order of magnitude range of concentration values that can occur in the data set for a single site.

Another difference between flow models and transport models is that a flow model simulates the spatial and temporal distribution of hydraulic heads throughout the entire saturated zone of an aquifer. By contrast, a transport model simulates the migration of a contaminant plume that occupies a small fraction of the spatial extent of the aquifer. For the majority of the aquifer, the concentration is equal to zero. Simulated concentrations can vary from high concentrations inside the plume to zero concentrations outside the plume. Thus, if the spatial extent of the simulated plume differs from the spatial extent of the actual plume at certain locations due to

issues such as local-scale aquifer heterogeneity, the residuals can be large even though the general shape, trajectory, and timing of the plume is reasonably accurate.

3.1.4 Qualitative and Quantitative Assessment of Model Performance

For all of these reasons, when conducting an assessment of the performance of a transport model, one has to factor in the high variance of the concentration measurements and the unique nature of contaminant transport models. As we explained in our post-audit report, it is important to assess transport models using a qualitative analysis in addition to a quantitative analysis. A quantitative analysis may show high variance in the model residuals, but does the model do a reasonable job of simulating the overall shape, magnitude, and movement of the plume? This can be assessed by analyzing maps of plume migration versus time to see if the residuals are balanced spatially and temporally as we did in Section 5.2 of the post-audit report. Furthermore, examining the average error over the entire simulation can be a way of assessing the overall fit. If this error is low, the model has done a reasonable job of fitting the highly variable observation data, similar to the fit of the blue line in Figure 2(a).

3.2 OPINION 1—BIAS IN POST-AUDIT RESULTS

One of the primary claims made by Spiliotopoulos about the post-audit results is that the post-audit showed that the model has a high positive bias, indicating that the model-simulated concentrations are generally higher than those observed at the observation wells (see Section 4.1.5.1 of the Spiliotopoulos report). In our original post-audit report, we presented data relating to how well the extended simulation matched the larger set of PCE observations collected after the original ATSDR study. These data included tables of simulated and observed PCE concentrations at observation wells, the overall mean residual error (simulated – observed concentrations), scatter plots of simulated versus observed concentrations at individual wells, a scatter plot of all of the simulated versus observed data pairs, simulated versus observed time series at individual wells, and a series of plume maps showing the temporal and spatial distribution of residual error. However, in arguing for high bias, Spiliotopoulos seemed to focus primarily on a qualitative assessment of Figure 6 from the post-audit report, which is the simulated versus observed scatter plot. This figure is repeated in the left panel of Figure 5. The Spiliotopoulos report also noted some issues in the post-audit with model inputs and post-processing, which we respond to in detail below in Sections 3.5 and 3.6. Two of these issues relate to minor errors in the model inputs, which we corrected and then produced an updated simulation, as described in Section 3.7, below. The other issue was with the truncation of numerical precision in the simulated PCE results. This issue also had a relatively small impact on the overall model results. However, one artifact of the truncation error is that all simulated PCE concentrations lower than $\sim 17 \mu\text{g/L}$ were truncated to $0 \mu\text{g/L}$, which accounts for the lack of scatter points in the lower half of the original scatter plot shown in the left panel of Figure 5. Using the updated simulation results and ensuring that the results were processed at full precision, we recreated the scatter plot, and the results are shown in the right panel of

Figure 5. While the numbers indicate a high degree of variance, they are visually more balanced than the results we originally presented in the post-audit report.

In Section 4.1.5.1 of the Spiliotopoulos report, he generated a new plot of the post-audit results in an attempt to highlight model bias. This was presented in his report as Figure 19, and it was a ranked order plot where simulated and observed pairs were plotted using a sample ranking method where the pairs are ranked from high to low in terms of the observed value (reproduced here as Figure 6). The right side of this plot showed a large number of simulated values greater than the observed values, especially for a number of locations where the observed values are equal to zero. We have recreated this plot in the upper panel of Figure 7 using the same methodology used by Spiliotopoulos, but in this case, we used the updated simulation results with full precision. Once again, the plot shows more simulated values in the 0–17 $\mu\text{g/L}$ range, showing more balance. In addition, we created a second ranked order plot, but this time the ordering was performed in relation to the simulated values, rather than the observed values. The results are shown in Figure 7, lower panel. This plot is visually more balanced than the ranking based on observed values.

In Section 3.1.2, above, we discussed how and why the observed PCE concentrations exhibit a high degree of variance. When comparing model results to an observation data set that exhibits a high variance, one of the most important factors is the overall mean error (ME). The ME is found by calculating the average residual error (simulated PCE – observed PCE) for the entire data set. For the original post-audit results we calculated an ME value = 21 $\mu\text{g/L}$, indicating an extremely balanced fit with only a small high bias. For the updated post-audit results, the ME = 48 $\mu\text{g/L}$, indicating a small increase in the bias, but still relatively well balanced overall. This balance indicated by the ME value was largely ignored by Spiliotopoulos.

The objective of the original model was to simulate the aggregate concentration of PCE at the Tarawa Terrace Water Treatment Plant over a 30-year period. Matching highly-variable observed PCE concentrations at specific points in time and space will result in high residuals. However, if the overall model fit is balanced, the simulated concentrations, which are drawn from water pumped from a significant portion of the aquifer over a long period of time, should exhibit much lower variability.

Spiliotopoulos also noted that the simulated versus observed data set for the post-audit model includes many simulated-observed pairs where either a) the observed value is zero and the simulated value is non-zero, or b) the simulated value is zero and the observed value is non-zero. This result is not surprising for several reasons. First, as described in our post-audit report, there are several cases in the observed PCE concentration data set where two samples taken at the same time but only separated by a short spatial distance exhibited significantly different values, including a zero value for one sample and a large value for the other sample. In other cases, samples taken at the same observation well but separated by a few months in time, exhibited similar differences. These anomalies could be due to local-scale aquifer heterogeneity, sampling error, etc. Furthermore, a transport model generates a solution over a numerical grid consisting of cells with representative averaged parameter values. This

approach inherently smooths the simulated results. The actual contaminant plume might follow preferential flow paths, resulting in zones where the sample values are zero, whereas the simulated plume is more continuous due to the smoothing effect of the grid. This does not indicate that the model is inaccurate, but that the model is representing an aggregate condition of the aquifer using representative parameter values.

Opinion 1: The Spiliotopoulos report exaggerated and distorted the model bias in the post-audit results.

3.3 OPINION 2—CALIBRATION TARGETS AND VARIABILITY

In several of the simulated versus observed plots generated by Spiliotopoulos, he overlaid lines creating a narrow band around the line of equality corresponding to a calibration target of 0.5 order of magnitude (see Figure 6 for an example), and implied that the post-audit results indicate a poor fit because many of the simulated versus observed PCE values do not fall within this window. Before discussing that specific calibration target, it is helpful to review the concept of a calibration target in general.

When calibrating a groundwater model, it is customary to define a calibration target. For a flow model, this would be defined in terms of piezometric head (water table elevation). For example, a calibration target of 5 m would mean that the goal would be to have the simulated heads within ± 5 m of the observed heads. This could be evaluated both in terms of simulated versus observed heads for each observation or for global error norms (mean absolute error [MAE], root-mean squared error, etc.). For a transport simulation, it is more customary to define calibration targets in terms of orders of magnitude due to the high variance in both simulated and observed values. For example, a 1.5 order of magnitude calibration target would mean that residual errors are computed in terms of log-transformed concentrations and the interval is ± 1.5 orders of magnitude (log scales).

The concept of a calibration target is based on a recognition that it is impractical for a groundwater simulation to exactly match field observations for several reasons. First of all, the observations themselves are subject to variability resulting from measurement errors, differences in methods for processing lab samples, uncertainty in monitoring well elevations, errors in sampling methodology, etc. Furthermore, the interval also takes into account that constructing a computer model involves a large number of simplifying assumptions. It is impossible to fully characterize and incorporate all parameters and complexities of a real aquifer system in a discretized computer model. Given these considerations, the determination of an appropriate calibration target would theoretically require a) an accurate assessment of the uncertainty or variability of the sampling error, and b) an accurate characterization of the numerical impact of the simplifying assumptions and uncertainties of the model parameters used to build the model. One could then use these numbers to develop a calibration target perfectly tailored to the modeling exercise at hand. In practice, both of these numbers are impossible to obtain. Therefore, a calibration target is ultimately a subjective “goal” for the

calibration exercise derived as an educated guess by the modeling team. Ultimately, the calibration process continues until additional adjustments to the modeling parameters no longer improve the goodness of fit between the simulated and observed values (the overall error cannot be reduced further). Whether or not the calibration target was met is generally a secondary concern.

While the original ATSDR model was calibrated using a target of ± 0.5 order of magnitude, there was no indication of how this target was developed, and ultimately many of the PCE concentration residuals were outside the range of the calibration target (53%). For the transport model, the calibration process was continued until a good overall balance was achieved. The resulting simulated concentrations at the Tarawa Terrace Water Treatment Plant were compared with the measured concentrations, and a reasonable agreement was found. The National Research Council review of the ATSDR modeling studies noted that the calibration target was arbitrary:

The modeling studies did not include any formal analysis to account for the temporal or spatial data-averaging effects. Instead, in the analysis presented by Faye (2008), the point measurements were used to set a “calibration target range” for constraining the model predictions; the range was arbitrarily set at about half the order of magnitude of the detected point measurements (Faye 2008).
(NRC 2009, p. 46)

The basis used for setting the values of the “calibration target range” was unclear.
(NRC 2009, p. 49)

Furthermore, during the 2009 expert panel assessment of the ATSDR study there were comments provided by panel members regarding the approach of setting calibration targets (ATSDR 2009d). Panel member, Dr. Mary Hill said:

There is no one set of established guidelines, but there has been much effort internationally in pursuit of such guidelines.
(ATSDR 2009d, p. 96)

In the DON review it is noted that the ASTM guidelines mention a priori definition of a model fit criteria. To my knowledge it is not common in practice and is not a practice I would recommend. For the TT model, it seems to me that a priori definition of a model fit criteria lead to unrealistic expectations of model accuracy.”
(ATSDR 2009d, p. 96)

Panel member, Dr. Rao Govindaraju stated:

To the best of my knowledge, there are no accepted protocols for setting calibration targets. Typically, one sets calibration targets based on the available data and the goals of the study. Since the purpose of this modeling exercise is to reconstruct concentration

histories for use in an epidemiological study, the modeling study should provide an estimate of human exposure. Ideally, this goal should decide the calibration targets.” (ATSDR 2009d, p. 85)

Panel member, Dr. Konikow stated:

Overall, there are no standards and probably should not be any. Such targets are inevitably arbitrary and to some extent meaningless. They tend to distract from the quality of the calibration process and shift focus to the arbitrary goal. It is a “red herring.” Not achieving a predetermined calibration target should not disqualify a model, nor does that prove a model is not valuable or useful. Conversely, meeting such a predetermined calibration target does not prove that the model is a good one or that it meets the needs of the particular study or that its calculations and predictions are accurate and/or reliable.

In my opinion, the use of specific calibration targets should be abandoned. They have no real value in the context of hydrogeology, and can only serve to provide a false or meaningless image of the quality of the developed model.
(ATSDR 2009d, p. 101)

Ultimately, the ATSDR Expert Panel recommended against the use of a calibration target:

Overall, the panelists did not agree with the calibration criterion ATSDR planned to use. The panel suggested ATSDR not pre-specify numerical values of calibration targets. There was consensus among panel members that emphasis should be placed on more objectively estimating model parameters than on trying to closely match observed water-level or concentration data with model-simulated results for model calibration.”
(ATSDR 2009d, p. 2)

The U.S. Navy said the following in its review of the ATSDR study:

Navy recognizes the variability in the field data, and this kind of variability is expected. In our experience at many hundreds of sites across the country, measured concentrations of contaminants in groundwater vary significantly and somewhat unpredictably over time.”
(U.S. Navy 2009, p. 4)

In the ATSDR response to the U.S. Navy review, it noted a similar study on chlorinated organic compounds at U.S. Naval Air Station in Jacksonville, Florida (ATSDR 2009a). This study was peer-reviewed by the U.S. Geologic Survey (Davis 2003). In this case, even though the model was calibrated and later used as a predictive tool (Davis 2007), no calibration target was ever established or used to gauge the accuracy of the model, consistent with our point above that calibration targets are generally arbitrary.

Opinion 2: The calibration target of ± 0.5 order of magnitude used in the original ATSDR transport study was arbitrary and too narrow to use as a basis for evaluating the post-audit results.

3.4 OPINION 3—QUALITATIVE ASSESSMENT OF PLUME BEHAVIOR

One of the main conclusions of our original post-audit report was that given the high variability in observed PCE concentrations, it is important to assess the overall behavior of the simulated PCE plume relative to the observations. Specifically,

Given these challenges, it is important to qualitatively assess the overall behavior of the simulated plume in addition to quantitatively analyzing the differences in simulated and observed concentrations at specific times and locations. A qualitative evaluation helps ensure that the model captures the key processes governing plume migration, such as its general direction, spread, and interaction with sources, sinks, and aquifer boundaries. This broader perspective can offer valuable insights into the overall value of the model as an interpretive or predictive tool.

(Jones and Davis 2024, p. 5-1.)

One of the methods we used to achieve this was to overlay the residual errors for the observation points with plume maps at multiple model layers and at multiple points in time. With the exception of a few wells with known anomalies, this analysis indicated a good overall agreement between the simulated PCE plume and the observed concentrations over the range of the extended simulation.

This point was largely ignored by Spiliotopoulos. He addressed it only briefly and superficially at the bottom of p. 63 of his report. He critiqued our qualitative assessment of plume behavior, stating it is "unhelpful" due to significant discrepancies between observed and simulated concentrations, the small area of comparison, and the lack of data to evaluate the overall plume extents. This critique is limited and weak because it ignores the inherent challenges of contaminant transport modeling and dismisses a valuable approach to model evaluation.

The Spiliotopoulos report claims that comparisons are drawn within a very small area compared to the overall plume extents. However, the observation wells are concentrated in the area around the extraction wells used to feed the water treatment plant, which is also the area where the main part of the PCE plume is located. As our report states, this is the area where the concentrations ultimately impact the concentrations at the water treatment plant, making it the most important area from which to have observations. It is not necessary to have observations covering the entire modeling domain, which is impractical and cost prohibitive.

The Spiliotopoulos report notes that no data are available to evaluate whether the overall extents of the simulated plume are realistic. However, the lack of data outside the primary area of concern is a common challenge in contaminant transport modeling. It does not invalidate

the model's usefulness for assessing the plume behavior in the area of interest, which is where the impact on human health is most likely. Our post-audit used the available data to assess model performance, which is a valid approach and based on sound scientific methodology and accepted within the scientific community.

Opinion 3: Spiliotopoulos did not effectively refute our qualitative assessment of the overall plume behavior.

3.5 OPINION 4—ISSUES WITH POST-PROCESSED RESULTS

In Section 4.1.5.2 of his report, Spiliotopoulos also identified some anomalies with the post-processed results. Specifically, he noticed that for some wells we reported identical concentrations over a series of observation dates. He also recreated simulated concentrations at well RWC-2 and overlaid the simulated PCE concentrations for selected dates and showed that our simulated concentrations were of the right overall magnitude but exhibited a stair-step behavior. He also noted that in Figure 11 of our original report, we showed well S9 as being on the fringe but still inside the simulated PCE plume, yet we reported a zero concentration for well S9 at the date corresponding to the plume map (3/1/2003).

We investigated this issue and discovered the cause of the anomaly. In one of the steps we used to post-process the simulated PCE values, we inadvertently truncated the PCE values down to a low number of significant digits. This resulted in a “round-off” error where some of the simulated PCE values were too high and some were too low. This error only applied to the simulated PCE values at the observation well locations and not to the overall MT3DMS simulation results as shown in the PCE plume maps in Figures 9–16 in the post-audit report.

We reprocessed our original post-audit simulation results and the full precision numbers are shown in Table 1 along with the original truncated values. Fortunately, the magnitude of the roundoff error was relatively small and mostly balanced. The mean truncation error was $-1.47 \mu\text{g/L}$, the maximum absolute truncation error was $17.5 \mu\text{g/L}$, and the mean absolute truncation error was $7.2 \mu\text{g/L}$. The mean residual error from the original set of truncated values was $21 \mu\text{g/L}$, and for the full precision data set, the recalculated mean residual error was $22 \mu\text{g/L}$, indicating a minimal overall impact as the residual errors are still balanced.

One artifact of the truncation error is that it was most pronounced with the low magnitude concentrations. As a result, any simulated concentration lower than $\sim 17.5 \mu\text{g/L}$ was truncated to zero. This caused our simulated versus observed PCE concentration plot to show fewer simulated–observed points below the line of equality in Figure 6 of the post-audit report, as described above. This also explains the discrepancy noted by Spiliotopoulos for well S9 in the plume map shown in Figure 11 of our post-audit report. We reported a simulated PCE value of zero for 3/1/2003, but the full precision value = $15.7 \mu\text{g/L}$, which is why it plotted as inside the PCE plume in Figure 11 of the post-audit report.

Opinion 4: The numerical roundoff errors found by Spiliotopoulos were minor and did not significantly impact the model results.

3.6 OPINION 5—MODEL INPUT ERRORS

In Section 4.1.5.2 of his report, Spiliotopoulos identified an issue with two of the inputs to our post-audit model files.

3.6.1 Extended Model Timeframe

Spiliotopoulos noted that our report indicates that the source term in the extended model terminates in December 1983, and he checked the extended model input files to confirm that the source term in the input files indeed matched that date. He is correct that the original ATSDR report on the Tarawa Terrace MT3DMS simulation (Faye 2008) states that the source term was terminated in December 1984. This was an error in Source-Sink Mixing (SSM) package input file to the extended MT3DMS simulation used in the post-audit. We corrected the error and ran a new simulation. The updated simulation results are discussed in Section 3.6.3 below.

3.6.2 Pumping Rate for Well RWC-2

Spiliotopoulos also noted that Table 2 of our post-audit report stated a pumping rate of 40 gallons per minute (gpm) for well RWC-2 from 3/7/2004 through 12/16/2004. However, the input files for the extended simulation show a pumping rate of 20 gpm for this well for this time period. This was an error in the Well Package input file to the extended MODFLOW simulation used in the post-audit. We corrected the error and ran a new simulation. The updated simulation results are discussed in Section 3.6.3 below.

3.6.3 Updated Simulation Results

We have corrected both input errors and generated new MODFLOW and MT3DMS simulations. Table 2 shows the simulated PCE values at each monitoring well location from the original model, the simulated PCE concentrations from the updated model, and the difference between the two. The updated PCE concentrations are processed at the full numerical precision as discussed in Section 3.5, which accounts for a portion of the concentration differences.

The pumping rate error was small and only impacted a few months in 2004. Correcting the termination of the mass loading by changing it from the end of December 1983 to the end of December 1984 had a larger impact and increased the PCE concentration to some degree at most of the well locations. The average increase was 27 $\mu\text{g/L}$. Accordingly, the mean residual error increased from 21 to 48 $\mu\text{g/L}$. This indicates a small high bias, but the overall errors are still reasonably balanced.

To further illustrate the magnitude of the differences between the two simulations, we have generated a PCE time series for the grid cell containing well TT-26 using the original and updated post-audit results (Figure 8). The updated simulation has slightly higher concentrations from about 1990 onward.

We have also generated new versions of each of the tables and figures from our original post-audit report featuring simulated PCE values, using the updated post-audit simulation results, processed at full precision. These results are presented in Appendix A. The differences in the tables and figures relative to the original report are relatively minor overall. The differences are summarized as follows:

Appendix	Post-Audit	Differences
Table A1	Table 5	Mean increase of 27 mg/L as explained above.
Table A2	Table 6	Modest increase in ME and MAE. Of the 37 sites, 5 changed categories (see explanation below for Figures A10, A11, and A12).
Figure A1	Figure 2	No significant differences.
Figure A2	Figure 6	Differences noted previously in Section 3.2.
Figure A3	Figure 7	Various differences, mostly minor. See summary in Table 2.
Figure A4	Figure 8	Various differences, mostly minor. See summary in Table 2.
Figure A5	Figure 9	June 1997 plume map. Of 20 observations, 2 changed categories: S2 changed from green to yellow (141 µg/L → 208 µg/L), and S1 changed from yellow to red (494 µg/L → 505 µg/L).
Figure A6	Figure 10	February 2000 plume map. Of 21 observations, 1 changed category: S10 changed from yellow to red (494 µg/L → 503 µg/L).
Figure A7	Figure 11	March 2003. Of 27 observations, 3 changed categories: RWS-1A changed from green to yellow (171 µg/L → 265 µg/L), RWS-2A changed from green to yellow (148 µg/L → 280 µg/L), and S3 changed from green to yellow (164 µg/L → 256 µg/L).
Figure A8	Figure 12	March 2006. There were 30 observations. No changes.
Figure A9	Figure 13	March 2008. Of 26 observations, 1 changed category: FWC-11 changed from yellow to red (494 µg/L → 515 µg/L).

Appendix	Post-Audit	Differences
Figure A10	Figure 14	December 2008 (overall MAE) – layer 1. Of 18 sites, 4 changed categories: FWS-12 changed from green to yellow (176 µg/L → 218 µg/L), RWS-1A changed from green to yellow (142 µg/L → 207 µg/L), RWS-2A changed from green to yellow (190 µg/L → 301 µg/L), and S5 changed from yellow to red (462 µg/L → 528 µg/L).
Figure A11	Figure 15	December 2008 (overall MAE) – layer 3. Of 17 sites, 1 changed category: C2 changed from yellow to red (423 µg/L → 519 µg/L).
Figure A12	Figure 16	December 2008 (overall MAE) – layer 5. There were 2 sites. No changes.

Opinion 5: The pumping rate error and the mass loading termination date error found by Spiliotopoulos were both minor and did not significantly impact the model results.

3.7 OPINION 6—POST-AUDIT ROBUSTNESS

In summary, while Spiliotopoulos did correctly point out some issues with our post-processing and model inputs for the original post-audit results, the impact of these errors was relatively minor. Spiliotopoulos exaggerated the magnitude of the model bias and ignored the fact that the errors are mostly balanced. His use of the ± 0.5 order of magnitude calibration is arbitrary and overly restrictive.

This rebuttal underscores the robustness of the original post-audit findings for the Tarawa Terrace Flow and Transport Model. Despite critiques raised by Spiliotopoulos, the analyses validate that the extended model continues to reliably simulate the migration of PCE contamination over the extended period from 1995 to 2008. Our qualitative and quantitative assessments demonstrate that the model captures the key dynamics of PCE plume migration while accommodating the inherent complexities and high variances in observed concentrations. These findings support our original conclusion that the ATSDR model was developed using a methodology that is scientifically sound and accepted within the scientific community, and it remains a reliable tool for assessing the impacts of PCE contamination at Tarawa Terrace.

Opinion 6: Nothing in the Spiliotopoulos report contradicts our overall conclusion about the post-audit results. The model effectively simulates long-term trends in contaminant migration, and we can find no significant evidence that would invalidate the analyses performed by ATSDR with the original model.

4 REFERENCES

ATSDR. 2009a. Analyses of groundwater flow, contaminant fate and transport, and distribution of drinking water at Tarawa Terrace and vicinity, U.S. Marine Corps Base Camp Lejeune, North Carolina: Historical reconstruction and present-day conditions. Response to the Department of the Navy's Letter on: Assessment of ATSDR water modeling for Tarawa Terrace. Agency for Toxic Substances and Disease Registry Atlanta, GA. March.

ATSDR. 2009b. Expert Panel Meeting. Analyses and historical reconstruction of groundwater resources and distribution of drinking water at Hadnot Point, Holcomb Boulevard, and vicinity, U.S. Marine Corps Base Camp Lejeune, North Carolina. April 29, 2009. Verbatim Transcript. Agency for Toxic Substances and Disease Registry Atlanta, GA.

ATSDR. 2009c. Expert panel meeting. Analyses and historical reconstruction of groundwater resources and distribution of drinking water at Hadnot Point, Holcomb Boulevard, and vicinity, U.S. Marine Corps Base Camp Lejeune, North Carolina. April 30, 2009. Verbatim Transcript. Agency for Toxic Substances and Disease Registry Atlanta, GA.

ATSDR. 2009d. Expert panel assessing ATSDR's methods and analyses for historical reconstruction of groundwater resources and distribution of drinking water at Hadnot Point, Holcomb Boulevard, and vicinity, U.S. Marine Corps Base Camp Lejeune, North Carolina. M.L. Maslia (ed.). April 29–30, 2009. Agency for Toxic Substances and Disease Registry Atlanta, Georgia.

Carrera, J., and S.P. Neuman. 1986. Estimation of aquifer parameters under transient and steady state conditions: 1. Maximum likelihood method incorporating prior information. *Water Resources Research* 22(2): 199–210. <https://doi.org/10.1029/WR022i002p00199>

Davis, J.H. 2003. Fate and transport modeling of selected chlorinated organic compounds at Hangar 1000, U.S. Naval Air Station, Jacksonville, Florida. Tallahassee, FL: U.S. Geological Survey Water-Resources Investigations Report 03-4089.

Davis J.H. 2007. Fate and transport modeling of selected chlorinated organic compounds at Operable Unit 1, U.S. Naval Air Station, Jacksonville, Florida. Tallahassee, FL: U.S. Geological Survey Scientific Investigations Report 2007-5043.

Faye, R.E. 2008. Analyses of groundwater flow, contaminant fate and transport, and distribution of drinking water at Tarawa Terrace and vicinity, U.S. Marine Corps Base Camp Lejeune, North Carolina: Historical reconstruction and present-day conditions – Chapter F: Simulation of the fate and transport of tetrachloroethylene (PCE). Agency for Toxic Substances and Disease Registry, U.S. Department of Health and Human Services, Atlanta, GA.

Faye, R.E., and C. Valenzuela. 2008. Analyses of groundwater flow, contaminant fate and transport, and distribution of drinking water at Tarawa Terrace and vicinity, U.S. Marine Corps Base Camp Lejeune, North Carolina: Historical reconstruction and present-day conditions – Chapter C: Simulation of groundwater flow. Agency for Toxic Substances and Disease Registry U.S. Department of Health and Human Services, Atlanta, GA.

Green, C.T., J.K. Böhlke, B.A. Bekins, and S.P. Phillips. 2010. Mixing effects on apparent reaction rates and isotope fractionation during denitrification in a heterogeneous aquifer. *Water Resources Research* 46(8):1–19. <https://doi.org/10.1029/2009WR008903>

Hill, M.C. 1998. Methods and guidelines for effective model calibration; with application to UCODE, a computer code for universal inverse modeling, and MODFLOW, a computer code for inverse modeling with MODFLOW. In *Water-Resources Investigations Report* (98–4005). U.S. Geological Survey : Branch of Information Services [distributor]. <https://doi.org/10.3133/wri984005>

Hill, M.C. 2006. The *Practical Use of Simplicity in Developing Ground Water Models*. *Groundwater* 44(6):775–781. <https://doi.org/10.1111/j.1745-6584.2006.00227.x>

Hill, M.C. 2010. Comment on “Two statistics for evaluating parameter identifiability and error reduction” by John Doherty and Randall J. Hunt. *J. Hydrol.* 380(3-4): 481–488.

Hunt, R.J., M.N. Fienen, and J.T. White. 2020. Revisiting “An Exercise in Groundwater Model Calibration and Prediction” After 30 Years: Insights and New Directions. *Groundwater* 58(2): 168–182. <https://doi.org/10.1111/gwat.12907>

Maslia, M.L., J.B. Sautner, R.E. Faye, R.J. Saurez-Soto, M.M. Aral, et al. 2007. Analyses of groundwater flow, contaminant fate and transport, and distribution of drinking water at Tarawa Terrace and vicinity, U.S. Marine Corps Base Camp Lejeune, North Carolina: Historical reconstruction and present-day conditions – Chapter A: Summary of findings. Agency for Toxic Substances and Disease Registry U.S. Department of Health and Human Services, Atlanta, GA.

Jones, N.L., and R.J. Davis. 2024. Tarawa Terrace Flow and Transport Model Post-Audit. Integral Consulting Inc. Salt Lake City, Utah. October 25, 2024.

NOAA. 2024. Accuracy Versus Precision. National Oceanic and Atmospheric Administration. Revised March 19. Accessed January 16, 2024 at: https://celebrating200years.noaa.gov/magazine/tct/tct_side1.html

NRC. 2009. Contaminated water supplies at Camp Lejeune: Assessing potential health effects. National Research Council Board on Environmental Studies and Toxicology, 328. National Academies Press, Washington, DC.

U.S. Navy. 2009. *Navy Position on Tarawa Terrace Water Modeling*. U.S. Navy. April.

Wali, S.U., A.A. Usman, A.B. Usman, U. Abdullahi, I.U. Mohammed, and J.M. Hayatu. 2024. Resolving challenges of groundwater flow modelling for improved water resources management: A narrative review. *International Journal of Hydrology* Volume 8(Issue 5). <https://doi.org/10.15406/ijh.2024.08.00390>

Yeh, W.W.-G., and Y.S. Yoon. 1981. Aquifer parameter identification with optimum dimension in parameterization. *Water Resources Research* 17(3):664–672. <https://doi.org/10.1029/WR017i003p00664>.

Zatlakovič, M., D. Krčmář, K. Hodasová, O. Sracek, Š. Marenčák, Ľ. Durdiaková, and A. Bugár. 2023. The impact of groundwater model parametrization on calibration fit and prediction accuracy—Assessment in the form of a post-audit at the SLOVNAFT oil refinery site, in Slovakia. *Water* 15(5), Article 5. <https://doi.org/10.3390/w15050839>.

Zheng, C., M.C. Hill, G. Cao, and R. Ma. 2012. MT3DMS: Model use, calibration, and validation. *Transactions of the ASABE* 55(4):1549–1559. <https://doi.org/10.13031/2013.42263>

5 QUALIFICATIONS

I, **R. Jeffrey Davis**, P.E., CGWP, have almost 30 years of experience with civil and environmental engineering, hydrogeology, groundwater fate and transport modeling, and software and model development. I have both undergraduate and graduate degrees from Brigham Young University in civil engineering. I currently serve on the board of directors for the National Ground Water Association (NGWA), as well as on NGWA's per- and polyfluoroalkyl substances and Managed Aquifer Recharge advisory groups. I was one of the leads for NGWA's Groundwater Modeling Advisory Panel. I have developed and used numerous groundwater models for the agricultural industry and the mining industry, including projects involving environmental impact statements, environmental assessments, water management, groundwater-surface water interaction and contamination, dewatering, and water treatment. I also have extensive experience with the oil and gas industry, including water supply, hydraulic fracturing, and groundwater protection for the upstream market, and worked on a variety of oil release projects. I have extensive knowledge of groundwater flow-and-transport principles and have led numerous workshops and classes in the United States and around the world. I have taught several classes and workshops in association with NGWA and other professional organizations and universities for the past 3 decades. I also share my research and project work regularly with the professional societies with which I am affiliated. I frequently use groundwater models to explain fate and transport of contaminants or groundwater supplies and availability. Recent such examples include groundwater impacts from agricultural activities in Minnesota; aqueous film-forming foam contamination impacts to groundwater in Martin County, Florida; a pipeline of produced water spill in North Dakota; and groundwater availability and surface water impacts in Ventura County, California. I am regularly asked to provide opinions or participate on panels to discuss groundwater, water supply, or contaminated groundwater issues.

I, **Norman L. Jones**, Ph.D., have 33 years of experience in civil and environmental engineering. I graduated with a B.S. degree in civil engineering from Brigham Young University and with M.S. and Ph.D. degrees in civil engineering from the University of Texas at Austin. I have been a faculty member in the Civil and Construction Engineering Department at Brigham Young University since January 1991 where I currently hold the rank of Professor. I have taught university courses in a variety of subjects, including computer programming, soil mechanics, seepage and slope stability analysis, and groundwater modeling. The primary focus of my research has been groundwater flow and transport modeling, software development, remote sensing, groundwater sustainability analysis, and hydroinformatics. I was the original developer of the Groundwater Modeling System (GMS) software, which is a graphical user interface for MODFLOW and MT3DMS and is used by thousands of organizations all over the world. GMS is now developed and maintained by Aquaveo, LLC in Provo, Utah, a company that I helped found in 2007. I have taught numerous short courses on groundwater flow and transport modeling over my career. I am a member of the Hydroinformatics Research Laboratory at Brigham Young University. I have been the principal or co-investigator on more

than \$20M of externally funded research. I have authored 179 technical publications, including 88 peer-reviewed journal articles, and 1 book. I am a recipient of the Walter L. Huber Civil Engineering Research Prize from the American Society of Civil Engineers and the John Hem Award for Science and Engineering from NGWA. I have been involved in a number of consulting projects, including work as a technical expert in litigation cases. I am an active member of the American Water Resources Association, the NGWA, the American Geophysical Union, and the American Society of Civil Engineers.

6 COMPENSATION

My, **R. Jeffrey Davis**, experience is summarized in my resume, which is included as Exhibit 1. I am being compensated at a rate of \$498 an hour for my time in preparation of this report and \$498 an hour for my deposition and trial testimony, if necessary. My compensation is not contingent upon the opinions I developed or the outcome of this litigation case.

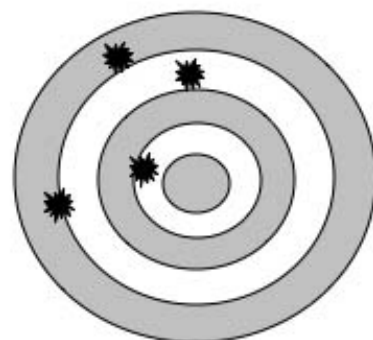
My, **Norman L. Jones**, experience is summarized in my resume, which is included as Exhibit 2. I am being compensated at a rate of \$500 an hour for my time in preparation of this report and \$1,000 an hour for my deposition and trial testimony, if necessary. My compensation is not contingent upon the opinions I developed or the outcome of this litigation case.

7 PREVIOUS TESTIMONY

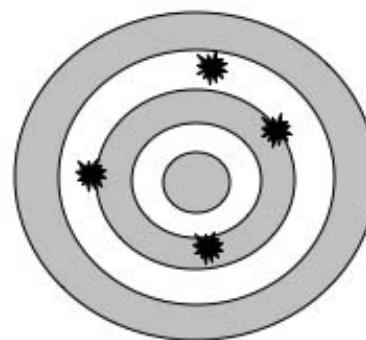
I, **R. Jeffrey Davis**, have not given any deposition or trial testimony in the last 4 years.

I, **Norman L. Jones**, gave deposition testimony on October 20, 2021, in MICHAEL YATES and NORMAN L. JONES vs TRAEGER PELLET GRILLS LLC, in the United States District Court for the District of Utah Central Division, Case No. 2:19-cv-00723-BSJ. With the exception of this case, I have not given any deposition or trial testimony in the last 4 years.

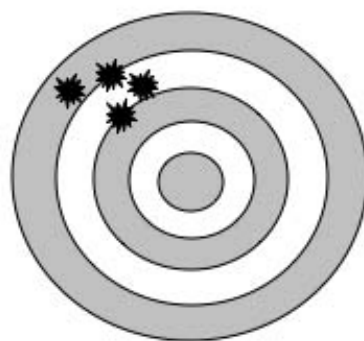
Figures



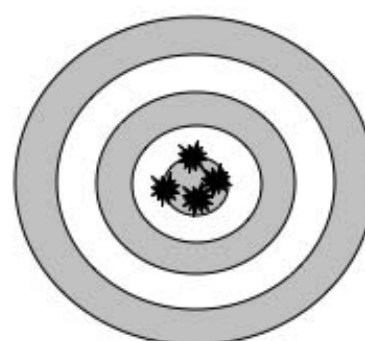
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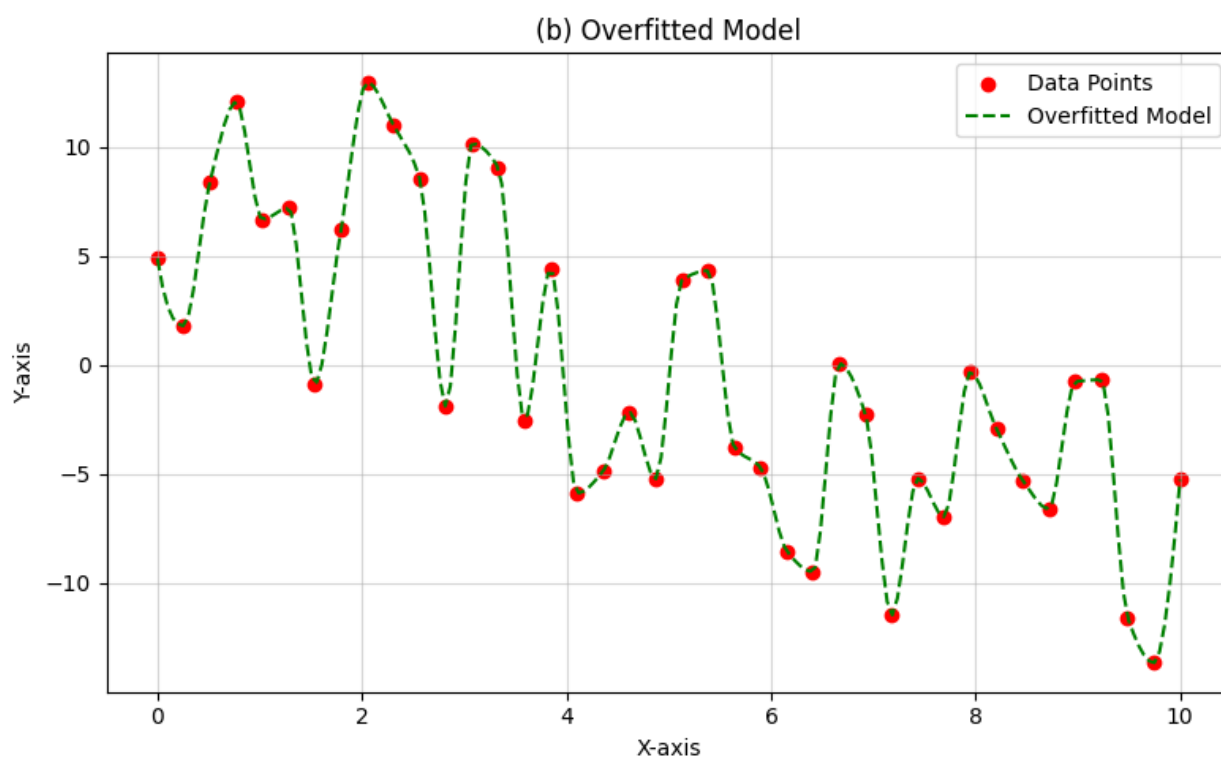
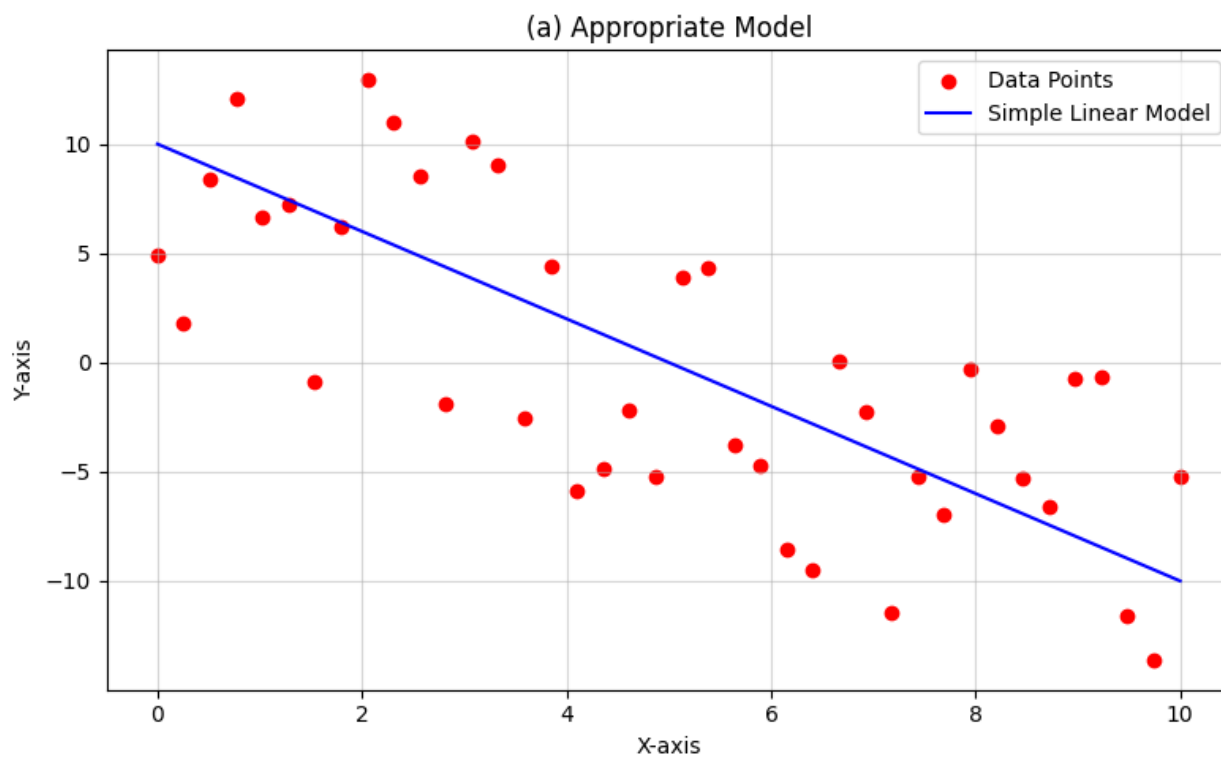


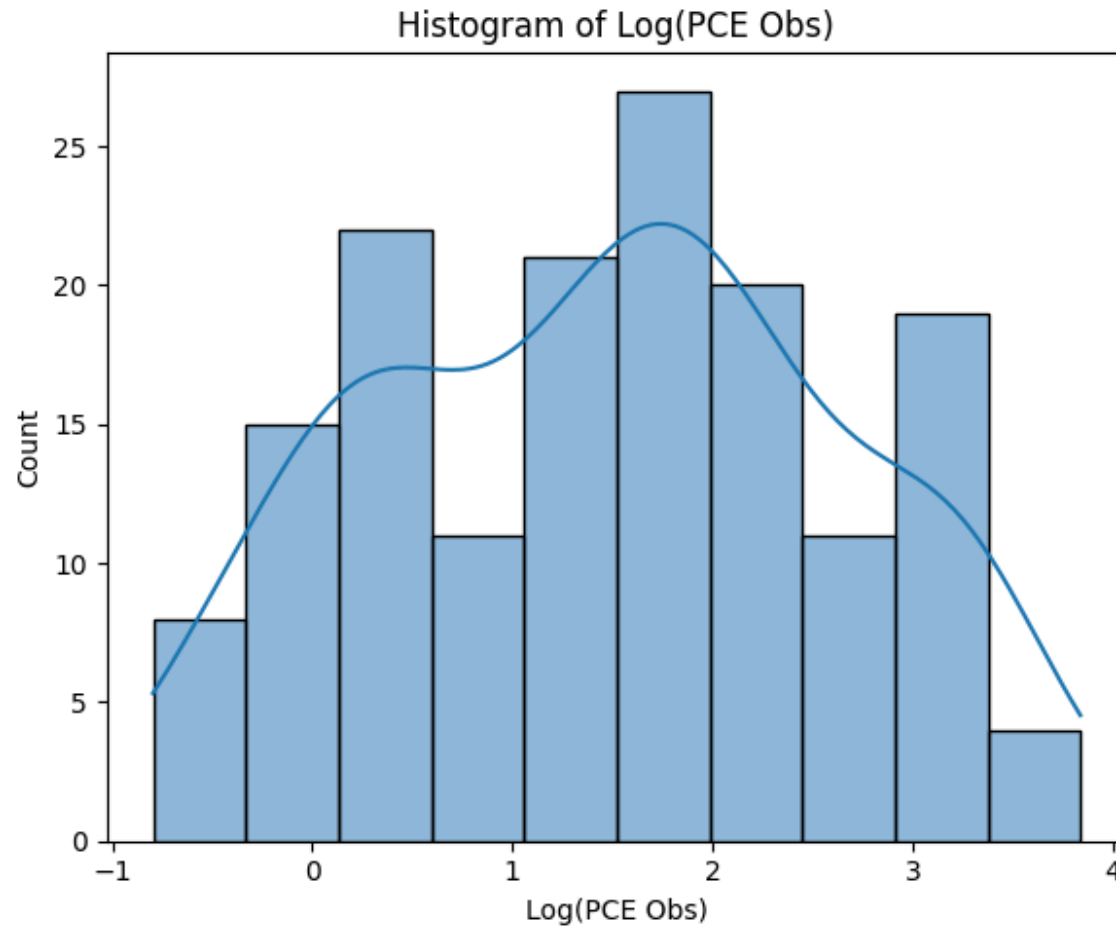
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Source: https://celebrating200years.noaa.gov/magazine/tct/tct_side1.html

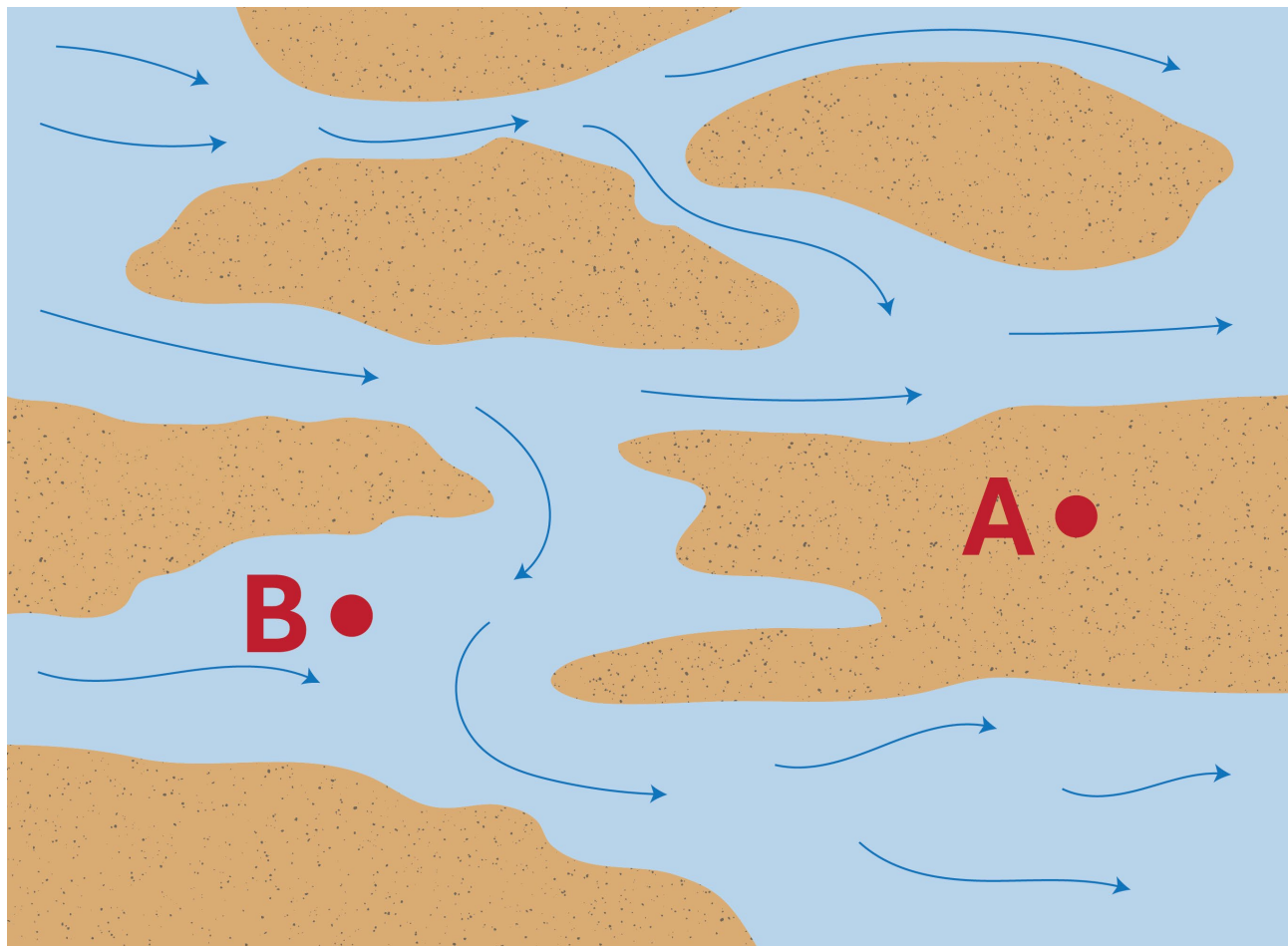




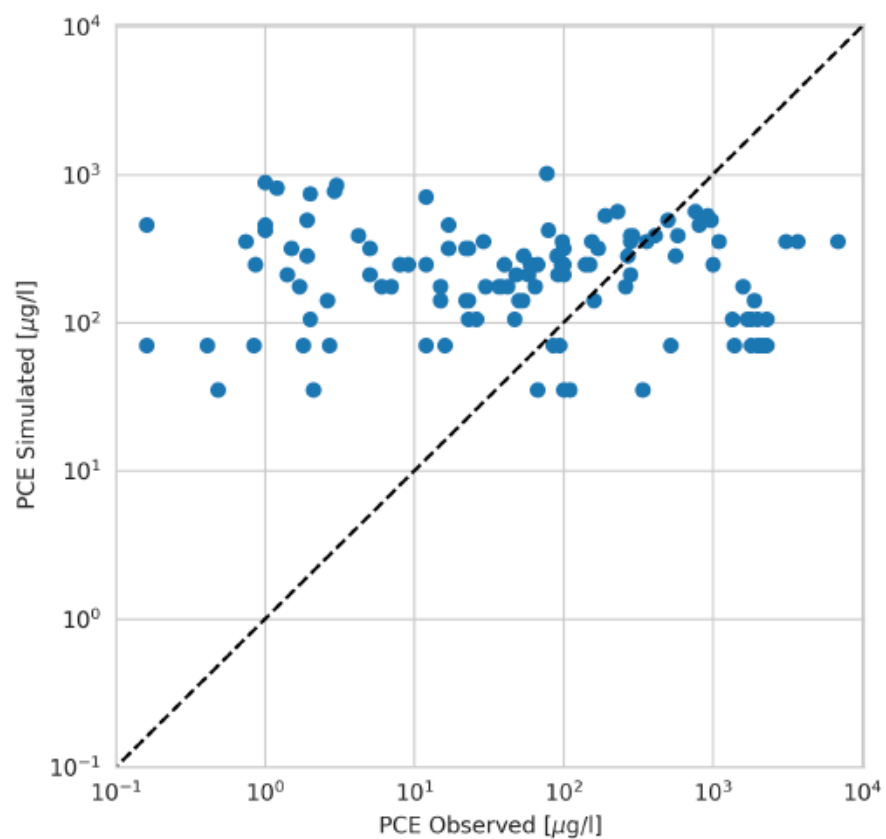
Note:
Log PCE observations are provided in $\mu\text{g/L}$.
PCE = tetrachloroethylene



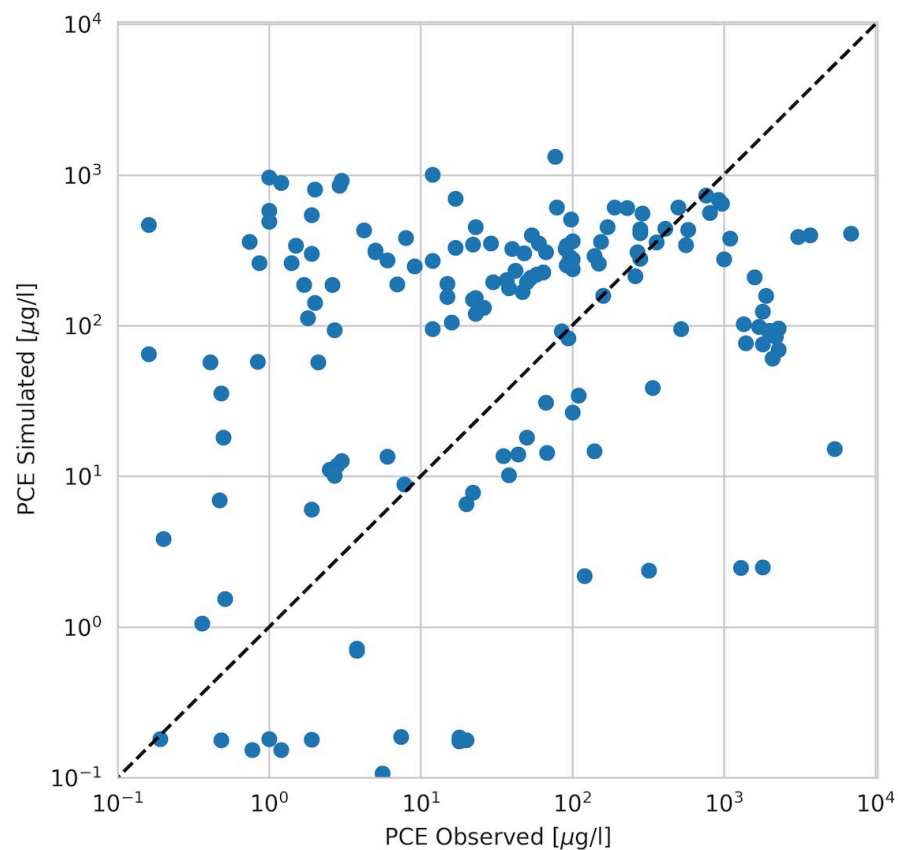
Figure 3.
Histogram of Log-Transformed PCE in Observation Wells at
Tarawa Terrace
Rebuttal Report Regarding Tarawa Terrace Flow and
Transport Model Post-Audit



Post-Audit Report



Updated Post-Audit Report

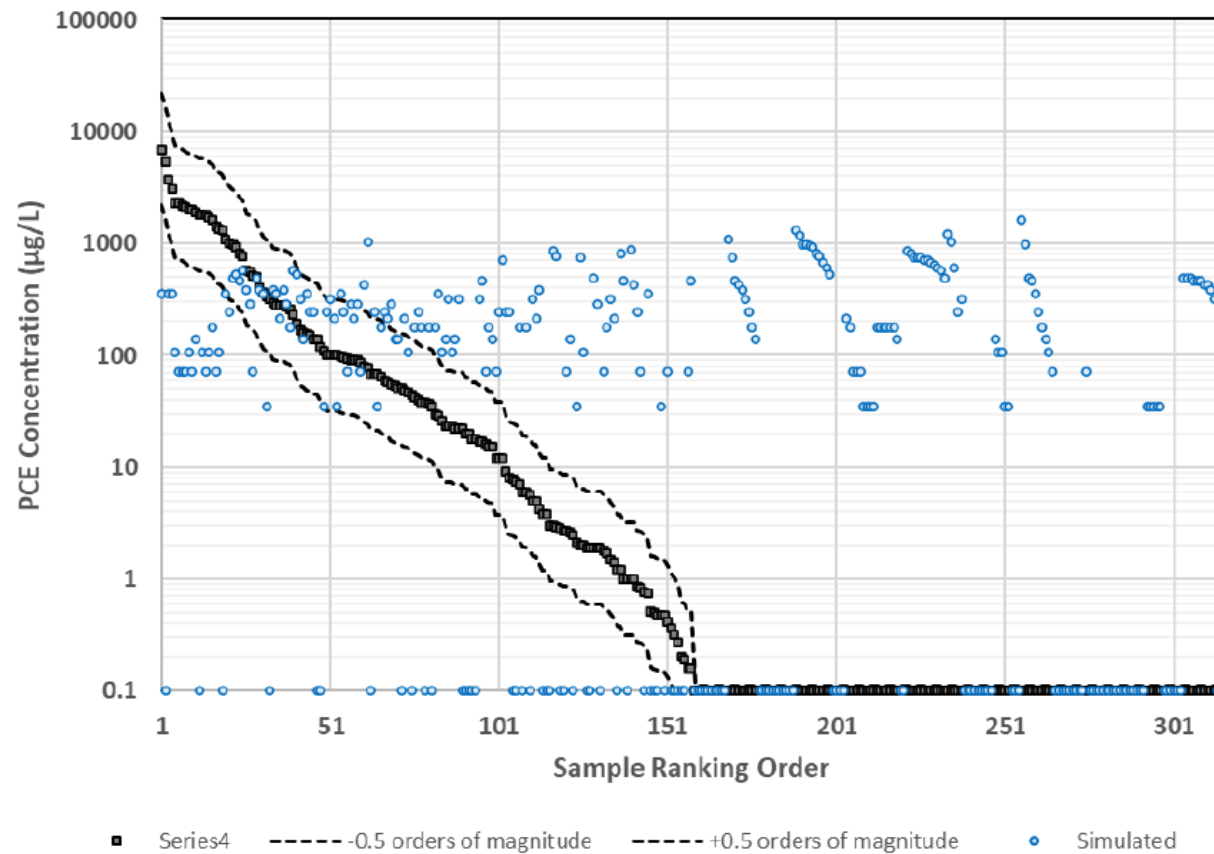


Note:
PCE = tetrachloroethylene



Figure 5.
Simulated vs. Observed PCE Concentrations
Rebuttal Report Regarding Tarawa Terrace Flow and
Transport Model Post-Audit

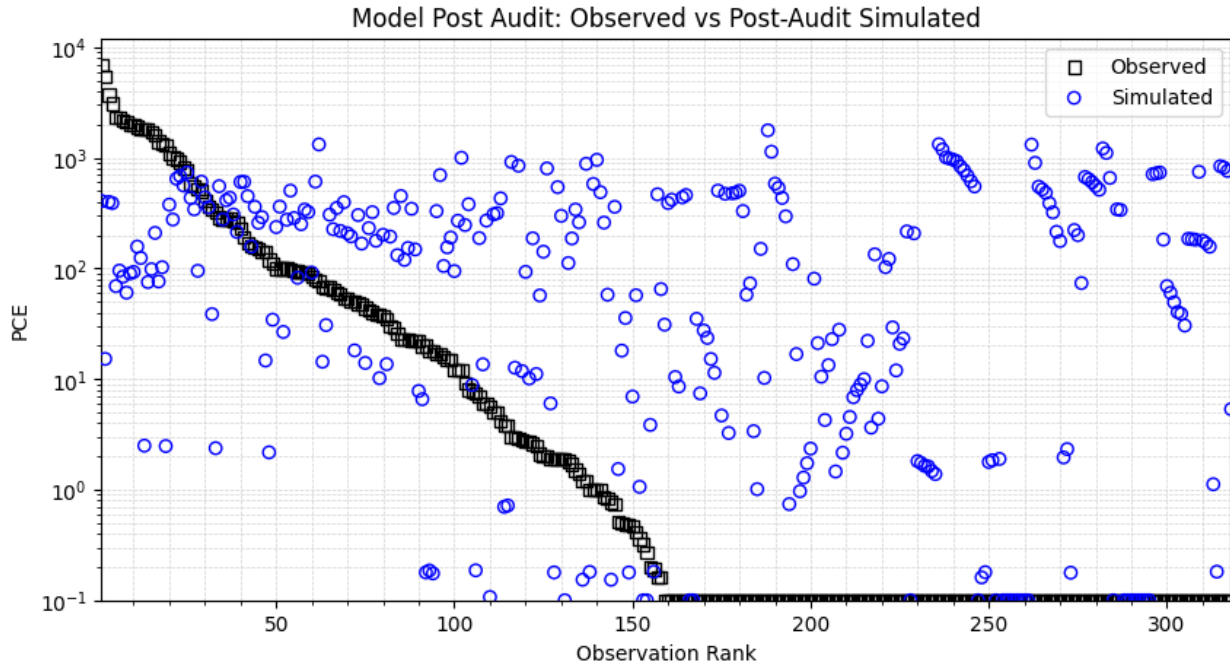
Model Post-Audit: Observed vs. ATSDR Simulated



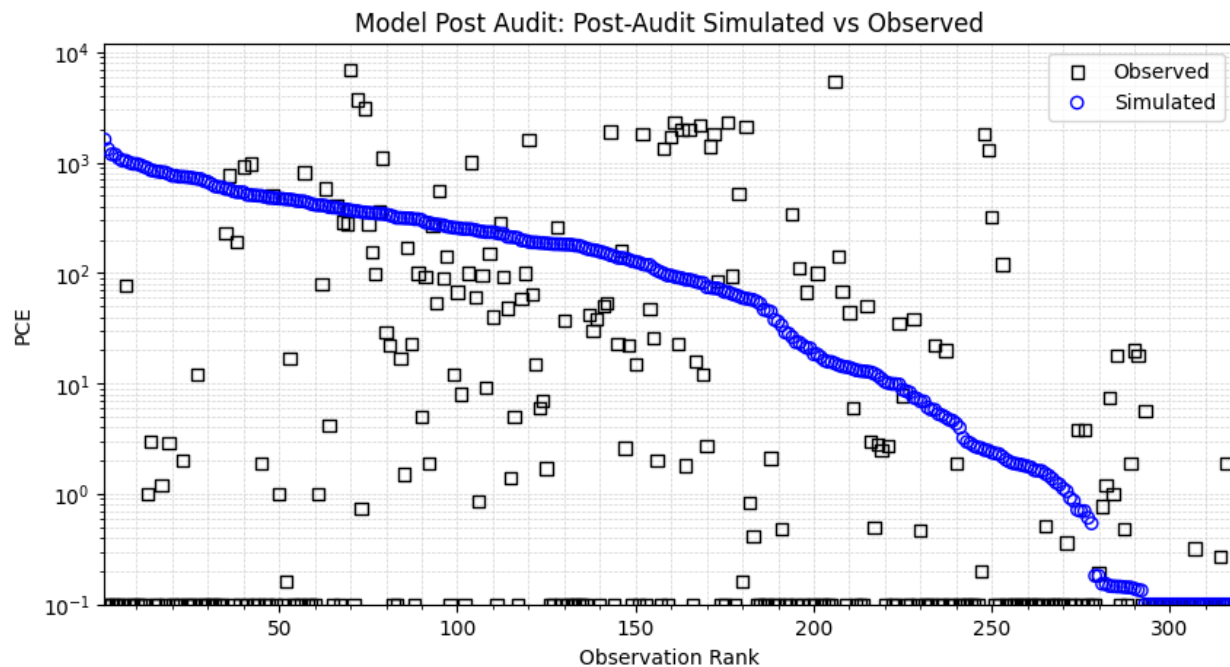
Notes:
PCE = tetrachloroethylene
Source: Spiliotopoulos Report, Figure 19

Figure 6.
Ranked Order Plot Produced by Spiliotopoulos Using the
Original Post-Audit Data
Rebuttal Report Regarding Tarawa Terrace Flow and
Transport Model Post-Audit

Decreasing Observed Value



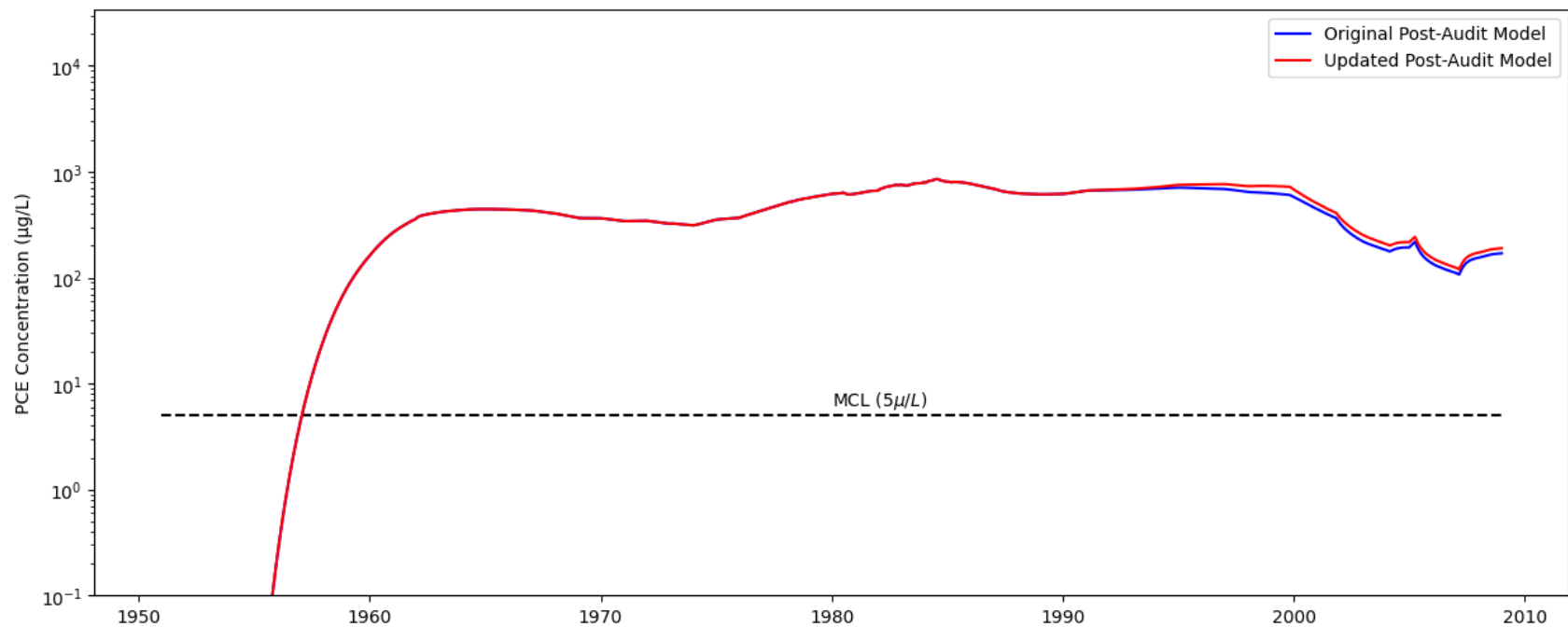
Decreasing Simulated Value



Notes:
 All PCE results are shown in $\mu\text{g/L}$.
 The upper panel shows ranked order plot using the updated post-audit results in order of decreasing observed value.
 The lower panel shows ranked order plot using the updated post-audit results in order of decreasing simulated value.
 PCE = tetrachloroethylene



Figure 7.
 Rank Order Plots Using Updated Post-Audit Results
 Rebuttal Report Regarding Tarawa Terrace Flow and
 Transport Model Post-Audit



Note:
PCE = tetrachloroethylene



Figure 8.
PCE Concentration in the Cell Containing Well TT-26 for
Original Post-Audit Model and Updated Post-Audit Model
Rebuttal Report Regarding Tarawa Terrace Flow and
Transport Model Post-Audit

Tables

Table 1. Comparison of Simulated PCE Values with Original Truncated Precision and Corrected Full Precision

Date	Well	Simulated PCE Concentration (µg/L) Original Truncated Precision	Simulated PCE Concentration (µg/L) Corrected Full Precision	Difference
2/1/2000	C1	0	0.03	0.03
5/1/2002	C1	0	0.03	0.03
8/1/2002	C1	0	0.03	0.03
11/1/2002	C1	0	0.03	0.03
3/1/2003	C1	0	0.03	0.03
3/1/2004	C1	0	0.02	0.02
3/1/2005	C1	0	0.02	0.02
3/1/2006	C1	0	0.02	0.02
2/1/2007	C1	0	0.02	0.02
3/1/2008	C1	0	0.02	0.02
6/1/1997	C2	1095	1091.49	-3.26
2/1/2000	C2	742	738.91	-2.7
5/1/2002	C2	459	472.77	13.68
8/1/2002	C2	459	446.65	-12.44
11/1/2002	C2	424	422.03	-1.74
3/1/2003	C2	388	392.26	3.8
3/1/2004	C2	318	315.82	-2.01
3/1/2005	C2	247	260.53	13.32
3/1/2006	C2	212	211.45	-0.44
2/1/2007	C2	177	173.13	-3.44
3/1/2008	C2	141	142.83	1.57
6/1/1997	C3	388	406.01	17.55
2/1/2000	C3	388	391.14	2.68
5/1/2002	C3	283	279.11	-3.41
8/1/2002	C3	247	264.07	16.86
11/1/2002	C3	247	250.33	3.12
3/1/2003	C3	247	234.33	-12.88
3/1/2004	C3	212	197.19	-14.7
3/1/2005	C3	177	181.38	4.81
3/1/2006	C3	177	160.07	-16.51
2/1/2007	C3	141	137.45	-3.81
3/1/2008	C3	141	132.76	-8.5
6/1/1997	C4	0	1.96	1.96
2/1/2000	C4	0	2.32	2.32
1/1/2002	C4	0	1.89	1.89
5/1/2002	C4	0	1.84	1.84
8/1/2002	C4	0	1.81	1.81
11/1/2002	C4	0	1.78	1.78
3/1/2003	C4	0	1.74	1.74
3/1/2004	C4	0	1.64	1.64
3/1/2005	C4	0	1.61	1.61
3/1/2006	C4	0	1.53	1.53
2/1/2007	C4	0	1.46	1.46

Table 1. Comparison of Simulated PCE Values with Original Truncated Precision and Corrected Full Precision

Date	Well	Simulated PCE Concentration (µg/L) Original Truncated Precision	Simulated PCE Concentration (µg/L) Corrected Full Precision	Difference
3/1/2008	C4	0	1.37	1.37
6/1/1997	C5	1307	1322.54	15.9
2/1/2000	C5	1165	1180.29	14.9
5/1/2002	C5	989	997.52	8.71
8/1/2002	C5	989	973.25	-15.57
11/1/2002	C5	953	949.25	-4.24
3/1/2003	C5	918	918.45	0.26
3/1/2004	C5	812	827.28	15.04
3/1/2005	C5	777	759.89	-17.03
3/1/2006	C5	671	678.12	7.14
2/1/2007	C5	600	601.5	1.15
3/1/2008	C5	530	539.05	9.33
6/1/1997	C9	0	0.05	0.05
2/1/2000	C9	0	0.13	0.13
5/1/2002	C9	0	0.15	0.15
8/1/2002	C9	0	0.14	0.14
11/1/2002	C9	0	0.14	0.14
3/1/2003	C9	0	0.14	0.14
3/1/2004	C9	0	0.14	0.14
3/1/2005	C9	0	0.15	0.15
3/1/2006	C9	0	0.15	0.15
2/1/2007	C9	0	0.14	0.14
3/1/2008	C9	0	0.14	0.14
6/1/1997	C10	212	207.67	-4.22
2/1/2000	C10	177	177.67	1.09
5/1/2002	C10	71	67.3	-3.33
8/1/2002	C10	71	63.27	-7.36
11/1/2002	C10	71	59.53	-11.1
3/1/2003	C10	71	55.21	-15.42
3/1/2004	C10	35	45.75	10.43
3/1/2005	C10	35	37.75	2.44
3/1/2006	C10	35	36.41	1.1
2/1/2007	C10	35	33.52	-1.8
3/1/2008	C10	35	28.97	-6.34
1/1/2002	C12	177	189.34	12.76
5/1/2002	C12	177	187.07	10.5
8/1/2002	C12	177	185.57	9
11/1/2002	C12	177	184.18	7.61
3/1/2003	C12	177	182.75	6.18
3/1/2004	C12	177	180.99	4.41
3/1/2005	C12	177	180.51	3.94
3/1/2006	C12	177	176.92	0.34
2/1/2007	C12	177	167.45	-9.13

Table 1. Comparison of Simulated PCE Values with Original Truncated Precision and Corrected Full Precision

Date	Well	Simulated PCE Concentration (µg/L) Original Truncated Precision	Simulated PCE Concentration (µg/L) Corrected Full Precision	Difference
3/1/2008	C12	141	155.69	14.43
1/1/2002	C13	0	15.18	15.18
5/1/2002	C13	0	14.67	14.67
8/1/2002	C13	0	14.3	14.3
11/1/2002	C13	0	13.95	13.95
3/1/2003	C13	0	13.54	13.54
3/1/2004	C13	0	12.61	12.61
3/1/2005	C13	0	11.76	11.76
3/1/2006	C13	0	11.04	11.04
2/1/2007	C13	0	10.06	10.06
3/1/2008	C13	0	8.77	8.77
3/1/2005	C14	0	2.5	2.5
3/1/2006	C14	0	2.47	2.47
2/1/2007	C14	0	2.37	2.37
3/1/2008	C14	0	2.17	2.17
2/1/2007	C15-D	0	0	0
3/1/2008	C15-D	0	0	0
2/1/2007	C15-S	0	0.7	0.7
3/1/2008	C15-S	0	0.72	0.72
2/1/2007	C16	0	1.06	1.06
3/1/2008	C16	0	1.12	1.12
2/1/2007	C17-D	0	0.15	0.15
3/1/2008	C17-D	0	0.18	0.18
2/1/2007	C17-S	0	0.15	0.15
3/1/2008	C17-S	0	0.18	0.18
2/1/2007	C18	71	57.2	-13.43
3/1/2008	C18	71	57.85	-12.78
6/1/1997	FWC-11	848	840.1	-7.45
2/1/2000	FWC-11	812	814.04	1.8
1/1/2002	FWC-11	742	758.42	16.81
5/1/2002	FWC-11	742	744.37	2.77
8/1/2002	FWC-11	742	733.6	-8.01
11/1/2002	FWC-11	706	722.82	16.53
3/1/2003	FWC-11	706	708.92	2.62
3/1/2004	FWC-11	671	667.79	-3.19
3/1/2005	FWC-11	636	638.38	2.72
3/1/2006	FWC-11	600	598.3	-2.05
2/1/2007	FWC-11	565	552.3	-12.74
3/1/2008	FWC-11	494	510.69	16.28
6/1/1997	FWS-12	565	577.02	11.99
2/1/2000	FWS-12	530	540.71	10.99
1/1/2002	FWS-12	318	307.21	-10.62
5/1/2002	FWS-12	283	286.97	4.45

Table 1. Comparison of Simulated PCE Values with Original Truncated Precision and Corrected Full Precision

Date	Well	Simulated PCE Concentration (µg/L) Original Truncated Precision	Simulated PCE Concentration (µg/L) Corrected Full Precision	Difference
8/1/2002	FWS-12	283	270.99	-11.52
11/1/2002	FWS-12	247	255.68	8.48
3/1/2003	FWS-12	247	237.34	-9.87
3/1/2004	FWS-12	212	196.5	-15.39
3/1/2005	FWS-12	177	189.46	12.88
3/1/2006	FWS-12	177	161.56	-15.01
2/1/2007	FWS-12	106	110.59	4.65
3/1/2008	FWS-12	71	81.32	10.69
6/1/1997	FWS-13	1201	1188.33	-12.37
2/1/2000	FWS-13	1024	1040.89	16.77
1/1/2002	FWS-13	883	892.95	10.08
5/1/2002	FWS-13	848	852.77	5.22
8/1/2002	FWS-13	812	820.69	8.46
11/1/2002	FWS-13	777	787.96	11.04
3/1/2003	FWS-13	742	743.93	2.33
3/1/2004	FWS-13	600	609.43	9.08
3/1/2005	FWS-13	494	499.76	5.36
3/1/2006	FWS-13	388	394.47	6.01
2/1/2007	FWS-13	318	314.12	-3.71
3/1/2008	FWS-13	247	239.71	-7.49
5/1/2002	RWC-1	353	349.08	-4.06
8/1/2002	RWC-1	353	344.46	-8.68
11/1/2002	RWC-1	353	339.59	-13.55
3/1/2003	RWC-1	318	333.25	15.42
3/1/2004	RWC-1	318	315.77	-2.06
3/1/2005	RWC-1	318	302.14	-15.69
3/1/2006	RWC-1	283	285.52	3
2/1/2007	RWC-1	247	257.03	9.83
3/1/2008	RWC-1	247	234.51	-12.7
2/1/2000	RWC-2	106	120.26	14.32
1/1/2002	RWC-2	106	98.78	-7.17
5/1/2002	RWC-2	106	94.91	-11.03
8/1/2002	RWC-2	106	92.26	-13.68
11/1/2002	RWC-2	106	89.8	-16.14
3/1/2003	RWC-2	71	87.15	16.52
3/1/2004	RWC-2	71	81.63	11
3/1/2005	RWC-2	71	73.83	3.2
3/1/2006	RWC-2	71	72.89	2.26
2/1/2007	RWC-2	71	67.26	-3.37
3/1/2008	RWC-2	71	58.75	-11.88
5/1/2002	RWS-1A	247	252.3	5.1
8/1/2002	RWS-1A	247	230.07	-17.13
11/1/2002	RWS-1A	212	210.56	-1.33

Table 1. Comparison of Simulated PCE Values with Original Truncated Precision and Corrected Full Precision

Date	Well	Simulated PCE Concentration (µg/L) Original Truncated Precision	Simulated PCE Concentration (µg/L) Corrected Full Precision	Difference
3/1/2003	RWS-1A	177	187.77	11.2
3/1/2004	RWS-1A	141	135.71	-5.54
3/1/2005	RWS-1A	106	105.51	-0.44
3/1/2006	RWS-1A	71	87.15	16.52
2/1/2007	RWS-1A	71	74.44	3.81
3/1/2008	RWS-1A	35	44.53	9.21
5/1/2002	RWS-2A	424	410.56	-13.22
1/1/2002	RWS-2A	459	463.7	4.61
8/1/2002	RWS-2A	388	376.75	-11.71
11/1/2002	RWS-2A	353	347.03	-6.12
3/1/2003	RWS-2A	318	313.2	-4.64
3/1/2004	RWS-2A	247	234.28	-12.92
3/1/2005	RWS-2A	177	163.89	-12.68
3/1/2006	RWS-2A	141	153.47	12.21
2/1/2007	RWS-2A	141	126.41	-14.85
3/1/2008	RWS-2A	71	83.48	12.85
1/1/2002	RWS-3A	565	576.44	11.4
5/1/2002	RWS-3A	530	537.69	7.97
8/1/2002	RWS-3A	494	508.57	14.17
11/1/2002	RWS-3A	494	480.11	-14.29
3/1/2003	RWS-3A	459	445.13	-13.96
3/1/2004	RWS-3A	353	351.52	-1.63
3/1/2005	RWS-3A	283	273.41	-9.11
3/1/2006	RWS-3A	212	226.94	15.06
2/1/2007	RWS-3A	177	182.61	6.04
3/1/2008	RWS-3A	141	136.94	-4.32
1/1/2002	RWS-4A	388	376.18	-12.28
5/1/2002	RWS-4A	353	370.51	17.36
8/1/2002	RWS-4A	353	363.18	10.03
11/1/2002	RWS-4A	353	354.54	1.39
3/1/2003	RWS-4A	353	343.27	-9.88
3/1/2004	RWS-4A	318	307.24	-10.59
3/1/2005	RWS-4A	247	249	1.79
3/1/2006	RWS-4A	212	226.94	15.05
2/1/2007	RWS-4A	177	191.67	15.1
3/1/2008	RWS-4A	141	144.9	3.64
6/1/1997	S1	0	0.07	0.07
2/1/2000	S1	0	0.04	0.04
5/1/2002	S1	0	0.02	0.02
8/1/2002	S1	0	0.02	0.02
11/1/2002	S1	0	0.02	0.02
3/1/2003	S1	0	0.02	0.02
3/1/2004	S1	0	0.01	0.01

Table 1. Comparison of Simulated PCE Values with Original Truncated Precision and Corrected Full Precision

Date	Well	Simulated PCE Concentration (µg/L) Original Truncated Precision	Simulated PCE Concentration (µg/L) Corrected Full Precision	Difference
3/1/2005	S1	0	0.01	0.01
3/1/2006	S1	0	0.01	0.01
2/1/2007	S1	0	0.01	0.01
3/1/2008	S1	0	0	0
6/1/1997	S2	141	124.51	-16.75
2/1/2000	S2	71	61.79	-8.84
5/1/2002	S2	35	26.24	-9.08
8/1/2002	S2	35	23.48	-11.83
11/1/2002	S2	35	21.07	-14.25
3/1/2003	S2	35	18.38	-16.93
3/1/2004	S2	0	12.8	12.8
3/1/2005	S2	0	9.8	9.8
3/1/2006	S2	0	7.46	7.46
2/1/2007	S2	0	5.77	5.77
3/1/2008	S2	0	4.94	4.94
6/1/1997	S3	1024	1037.81	13.68
2/1/2000	S3	706	713.61	7.31
5/1/2002	S3	318	312.68	-5.15
8/1/2002	S3	283	275.86	-6.66
11/1/2002	S3	247	245.39	-1.82
3/1/2003	S3	212	212.9	1.01
3/1/2004	S3	141	149.53	8.27
3/1/2005	S3	106	118.13	12.18
3/1/2006	S3	106	91.02	-14.93
2/1/2007	S3	71	72.79	2.16
3/1/2008	S3	71	64.85	-5.77
6/1/1997	S4	106	102.11	-3.84
2/1/2000	S4	106	118.47	12.53
3/1/2004	S4	35	28.26	-7.05
3/1/2005	S4	35	22.1	-13.22
3/1/2006	S4	0	16.19	16.19
2/1/2007	S4	0	12.9	12.9
3/1/2008	S4	0	9.89	9.89
6/1/1997	S5	1624	1614.87	-9.61
2/1/2000	S5	989	974.99	-13.82
5/1/2002	S5	494	489.5	-4.9
8/1/2002	S5	459	448.69	-10.4
11/1/2002	S5	424	411.03	-12.75
3/1/2003	S5	353	365.41	12.27
3/1/2004	S5	247	250.4	3.19
3/1/2005	S5	177	182.23	5.65
3/1/2006	S5	141	128.28	-12.98
2/1/2007	S5	106	95	-10.94

Table 1. Comparison of Simulated PCE Values with Original Truncated Precision and Corrected Full Precision

Date	Well	Simulated PCE Concentration (µg/L) Original Truncated Precision	Simulated PCE Concentration (µg/L) Corrected Full Precision	Difference
3/1/2008	S5	71	70.59	-0.04
6/1/1997	S6	0	13.15	13.15
2/1/2000	S6	0	6.87	6.87
8/1/2002	S6	0	2.87	2.87
11/1/2002	S6	0	2.6	2.6
3/1/2003	S6	0	2.3	2.3
3/1/2004	S6	0	1.62	1.62
3/1/2005	S6	0	1.22	1.22
3/1/2006	S6	0	0.92	0.92
2/1/2007	S6	0	0.7	0.7
3/1/2008	S6	0	0.54	0.54
6/1/1997	S7	71	85.53	14.91
8/1/2002	S7	0	15.71	15.71
11/1/2002	S7	0	14.1	14.1
3/1/2003	S7	0	12.29	12.29
3/1/2004	S7	0	8.28	8.28
3/1/2005	S7	0	6.06	6.06
3/1/2006	S7	0	4.33	4.33
2/1/2007	S7	0	3.21	3.21
3/1/2008	S7	0	2.72	2.72
6/1/1997	S8	0	17.28	17.28
2/1/2000	S8	0	13.01	13.01
5/1/2002	S8	0	5.78	5.78
8/1/2002	S8	0	5.15	5.15
11/1/2002	S8	0	4.6	4.6
3/1/2003	S8	0	3.97	3.97
3/1/2004	S8	0	2.64	2.64
3/1/2005	S8	0	1.87	1.87
3/1/2006	S8	0	1.27	1.27
2/1/2007	S8	0	0.87	0.87
3/1/2008	S8	0	0.61	0.61
6/1/1997	S9	35	46.58	11.27
2/1/2000	S9	35	52.71	17.39
5/1/2002	S9	35	23.64	-11.67
8/1/2002	S9	35	20.85	-14.47
11/1/2002	S9	35	18.39	-16.92
3/1/2003	S9	0	15.66	15.66
3/1/2004	S9	0	9.92	9.92
3/1/2005	S9	0	7.29	7.29
3/1/2006	S9	0	4.7	4.7
2/1/2007	S9	0	2.96	2.96
3/1/2008	S9	0	2.04	2.04
6/1/1997	S10	494	505.03	10.62

Table 1. Comparison of Simulated PCE Values with Original Truncated Precision and Corrected Full Precision

Date	Well	Simulated PCE Concentration (µg/L) Original Truncated Precision	Simulated PCE Concentration (µg/L) Corrected Full Precision	Difference
2/1/2000	S10	494	501.67	7.27
1/1/2002	S10	494	481.5	-12.91
5/1/2002	S10	459	475.01	15.92
8/1/2002	S10	459	470.05	10.96
11/1/2002	S10	459	465.03	5.94
3/1/2003	S10	459	457.9	-1.19
3/1/2004	S10	424	435.43	11.65
3/1/2005	S10	424	414.73	-9.04
3/1/2006	S10	388	386.07	-2.39
2/1/2007	S10	353	356.43	3.28
3/1/2008	S10	318	325.82	7.99
6/1/1997	S11	0	0	0
2/1/2000	S11	0	0	0
3/1/2005	S14	0	10.36	10.36
3/1/2006	S14	0	8.5	8.5
2/1/2007	S14	0	6.89	6.89
3/1/2008	S14	0	5.29	5.29

Note:

PCE = tetrachloroethylene

Table 2. Simulated PCE Concentrations for Original and Updated Post-Audit Models

Date	Well	Simulated PCE Concentration (µg/L)	Simulated PCE Concentration (µg/L)	Difference
		Original	Updated	
2/1/2000	C1	0	0.04	0.04
5/1/2002	C1	0	0.03	0.03
8/1/2002	C1	0	0.03	0.03
11/1/2002	C1	0	0.03	0.03
3/1/2003	C1	0	0.03	0.03
3/1/2004	C1	0	0.03	0.03
3/1/2005	C1	0	0.03	0.03
3/1/2006	C1	0	0.02	0.02
2/1/2007	C1	0	0.02	0.02
3/1/2008	C1	0	0.02	0.02
6/1/1997	C2	1095	1316.4	221.64
2/1/2000	C2	742	900.8	159.19
5/1/2002	C2	459	580.6	121.51
8/1/2002	C2	459	548.86	89.77
11/1/2002	C2	424	518.92	95.15
3/1/2003	C2	388	482.65	94.19
3/1/2004	C2	318	389.28	71.45
3/1/2005	C2	247	321.59	74.38
3/1/2006	C2	212	261.33	49.44
2/1/2007	C2	177	214.18	37.61
3/1/2008	C2	141	176.88	35.63
6/1/1997	C3	388	434.52	46.06
2/1/2000	C3	388	439.84	51.37
5/1/2002	C3	283	307.28	24.76
8/1/2002	C3	247	290.84	43.64
11/1/2002	C3	247	275.9	28.7
3/1/2003	C3	247	258.55	11.35
3/1/2004	C3	212	218.29	6.41
3/1/2005	C3	177	201.45	24.87
3/1/2006	C3	177	177.93	1.36
2/1/2007	C3	141	153.16	11.9
3/1/2008	C3	141	148.59	7.33
6/1/1997	C4	0	1.96	1.96
2/1/2000	C4	0	2.32	2.32
1/1/2002	C4	0	1.9	1.9
5/1/2002	C4	0	1.85	1.85
8/1/2002	C4	0	1.81	1.81
11/1/2002	C4	0	1.78	1.78
3/1/2003	C4	0	1.74	1.74
3/1/2004	C4	0	1.64	1.64
3/1/2005	C4	0	1.62	1.62
3/1/2006	C4	0	1.54	1.54
2/1/2007	C4	0	1.47	1.47
3/1/2008	C4	0	1.38	1.38
6/1/1997	C5	1307	1326.87	20.22
2/1/2000	C5	1165	1190.26	24.87
5/1/2002	C5	989	1009.86	21.05
8/1/2002	C5	989	985.68	-3.13

Table 2. Simulated PCE Concentrations for Original and Updated Post-Audit Models

Date	Well	Simulated PCE Concentration (µg/L)	Simulated PCE Concentration (µg/L)	Difference
		Original	Updated	
11/1/2002	C5	953	961.76	8.27
3/1/2003	C5	918	931.03	12.85
3/1/2004	C5	812	839.91	27.67
3/1/2005	C5	777	772.91	-4.02
3/1/2006	C5	671	690.68	19.7
2/1/2007	C5	600	613.37	13.02
3/1/2008	C5	530	551.21	21.48
6/1/1997	C9	0	0.06	0.06
2/1/2000	C9	0	0.16	0.16
5/1/2002	C9	0	0.18	0.18
8/1/2002	C9	0	0.18	0.18
11/1/2002	C9	0	0.18	0.18
3/1/2003	C9	0	0.18	0.18
3/1/2004	C9	0	0.18	0.18
3/1/2005	C9	0	0.19	0.19
3/1/2006	C9	0	0.19	0.19
2/1/2007	C9	0	0.18	0.18
3/1/2008	C9	0	0.17	0.17
6/1/1997	C10	212	222.31	10.42
2/1/2000	C10	177	199.93	23.36
5/1/2002	C10	71	73.7	3.07
8/1/2002	C10	71	69.19	-1.44
11/1/2002	C10	71	65.02	-5.61
3/1/2003	C10	71	60.18	-10.45
3/1/2004	C10	35	49.48	14.17
3/1/2005	C10	35	40.32	5
3/1/2006	C10	35	38.86	3.54
2/1/2007	C10	35	35.65	0.33
3/1/2008	C10	35	30.46	-4.85
1/1/2002	C12	177	190.3	13.73
5/1/2002	C12	177	188.12	11.55
8/1/2002	C12	177	186.68	10.1
11/1/2002	C12	177	185.33	8.76
3/1/2003	C12	177	183.96	7.39
3/1/2004	C12	177	182.37	5.8
3/1/2005	C12	177	181.97	5.4
3/1/2006	C12	177	178.52	1.94
2/1/2007	C12	177	169.07	-7.51
3/1/2008	C12	141	157.22	15.96
1/1/2002	C13	0	15.21	15.21
5/1/2002	C13	0	14.7	14.7
8/1/2002	C13	0	14.34	14.34
11/1/2002	C13	0	13.98	13.98
3/1/2003	C13	0	13.57	13.57
3/1/2004	C13	0	12.66	12.66
3/1/2005	C13	0	11.81	11.81
3/1/2006	C13	0	11.1	11.1
2/1/2007	C13	0	10.12	10.12

Table 2. Simulated PCE Concentrations for Original and Updated Post-Audit Models

Date	Well	Simulated PCE Concentration (µg/L)	Simulated PCE Concentration (µg/L)	Difference
		Original	Updated	
3/1/2008	C13	0	8.83	8.83
3/1/2005	C14	0	2.5	2.5
3/1/2006	C14	0	2.48	2.48
2/1/2007	C14	0	2.37	2.37
3/1/2008	C14	0	2.17	2.17
2/1/2007	C15-D	0	0	0
3/1/2008	C15-D	0	0	0
2/1/2007	C15-S	0	0.7	0.7
3/1/2008	C15-S	0	0.72	0.72
2/1/2007	C16	0	1.06	1.06
3/1/2008	C16	0	1.12	1.12
2/1/2007	C17-D	0	0.15	0.15
3/1/2008	C17-D	0	0.18	0.18
2/1/2007	C17-S	0	0.15	0.15
3/1/2008	C17-S	0	0.18	0.18
2/1/2007	C18	71	57.22	-13.41
3/1/2008	C18	71	57.87	-12.76
6/1/1997	FWC-11	848	840.57	-6.98
2/1/2000	FWC-11	812	815.82	3.58
1/1/2002	FWC-11	742	760.83	19.22
5/1/2002	FWC-11	742	746.89	5.28
8/1/2002	FWC-11	742	736.19	-5.41
11/1/2002	FWC-11	706	725.49	19.19
3/1/2003	FWC-11	706	711.68	5.39
3/1/2004	FWC-11	671	670.83	-0.15
3/1/2005	FWC-11	636	641.83	6.16
3/1/2006	FWC-11	600	601.95	1.6
2/1/2007	FWC-11	565	556.03	-9.01
3/1/2008	FWC-11	494	514.79	20.38
6/1/1997	FWS-12	565	605.2	40.17
2/1/2000	FWS-12	530	607.3	77.58
1/1/2002	FWS-12	318	362.09	44.26
5/1/2002	FWS-12	283	340.91	58.4
8/1/2002	FWS-12	283	323.49	40.97
11/1/2002	FWS-12	247	306.42	59.22
3/1/2003	FWS-12	247	285.52	38.31
3/1/2004	FWS-12	212	236.65	24.76
3/1/2005	FWS-12	177	226.34	49.76
3/1/2006	FWS-12	177	194.09	17.52
2/1/2007	FWS-12	106	131.8	25.86
3/1/2008	FWS-12	71	94.64	24.01
6/1/1997	FWS-13	1201	1215.23	14.53
2/1/2000	FWS-13	1024	1107.38	83.25
1/1/2002	FWS-13	883	959.83	76.97
5/1/2002	FWS-13	848	917.47	69.92
8/1/2002	FWS-13	812	883.55	71.31
11/1/2002	FWS-13	777	848.85	71.92
3/1/2003	FWS-13	742	802.06	60.45

Table 2. Simulated PCE Concentrations for Original and Updated Post-Audit Models

Date	Well	Simulated PCE Concentration (µg/L)	Simulated PCE Concentration (µg/L)	Difference
		Original	Updated	
3/1/2004	FWS-13	600	658.46	58.11
3/1/2005	FWS-13	494	543.52	49.12
3/1/2006	FWS-13	388	429.96	41.5
2/1/2007	FWS-13	318	341.03	23.2
3/1/2008	FWS-13	247	259.6	12.4
5/1/2002	RWC-1	353	360.92	7.77
8/1/2002	RWC-1	353	356.8	3.65
11/1/2002	RWC-1	353	352.36	-0.79
3/1/2003	RWC-1	318	346.48	28.64
3/1/2004	RWC-1	318	329.75	11.92
3/1/2005	RWC-1	318	316.15	-1.69
3/1/2006	RWC-1	283	298.96	16.44
2/1/2007	RWC-1	247	270	22.8
3/1/2008	RWC-1	247	246.9	-0.3
2/1/2000	RWC-2	106	124.38	18.44
1/1/2002	RWC-2	106	102.55	-3.39
5/1/2002	RWC-2	106	98.4	-7.54
8/1/2002	RWC-2	106	95.58	-10.36
11/1/2002	RWC-2	106	92.98	-12.97
3/1/2003	RWC-2	71	90.16	19.53
3/1/2004	RWC-2	71	84.29	13.66
3/1/2005	RWC-2	71	76.21	5.58
3/1/2006	RWC-2	71	75.2	4.57
2/1/2007	RWC-2	71	69.28	-1.35
3/1/2008	RWC-2	71	60.39	-10.24
5/1/2002	RWS-1A	247	380.65	133.45
8/1/2002	RWS-1A	247	342.01	94.81
11/1/2002	RWS-1A	212	308.75	96.86
3/1/2003	RWS-1A	177	270.86	94.29
3/1/2004	RWS-1A	141	187.28	46.02
3/1/2005	RWS-1A	106	141.68	35.73
3/1/2006	RWS-1A	71	111.86	41.23
2/1/2007	RWS-1A	71	93.16	22.53
3/1/2008	RWS-1A	35	56.99	21.68
5/1/2002	RWS-2A	424	609.72	185.95
1/1/2002	RWS-2A	459	697.9	238.81
8/1/2002	RWS-2A	388	554.12	165.66
11/1/2002	RWS-2A	353	505.35	152.2
3/1/2003	RWS-2A	318	450	132.17
3/1/2004	RWS-2A	247	322.81	75.61
3/1/2005	RWS-2A	177	231.7	55.12
3/1/2006	RWS-2A	141	195.03	53.78
2/1/2007	RWS-2A	141	155.12	13.87
3/1/2008	RWS-2A	71	105.2	34.57
1/1/2002	RWS-3A	565	734.63	169.59
5/1/2002	RWS-3A	530	685.63	155.91
8/1/2002	RWS-3A	494	647.45	153.04
11/1/2002	RWS-3A	494	609.53	115.12

Table 2. Simulated PCE Concentrations for Original and Updated Post-Audit Models

Date	Well	Simulated PCE Concentration (µg/L)	Simulated PCE Concentration (µg/L)	Difference
		Original	Updated	
3/1/2003	RWS-3A	459	562.36	103.27
3/1/2004	RWS-3A	353	435.76	82.61
3/1/2005	RWS-3A	283	342.42	59.9
3/1/2006	RWS-3A	212	277.36	65.47
2/1/2007	RWS-3A	177	213.69	37.12
3/1/2008	RWS-3A	141	157.95	16.7
1/1/2002	RWS-4A	388	413.29	24.83
5/1/2002	RWS-4A	353	406.97	53.83
8/1/2002	RWS-4A	353	399.1	45.95
11/1/2002	RWS-4A	353	389.75	36.6
3/1/2003	RWS-4A	353	377.41	24.26
3/1/2004	RWS-4A	318	337.47	19.64
3/1/2005	RWS-4A	247	276.72	29.52
3/1/2006	RWS-4A	212	251.29	39.41
2/1/2007	RWS-4A	177	209.57	33
3/1/2008	RWS-4A	141	157.5	16.24
6/1/1997	S1	0	0.11	0.11
2/1/2000	S1	0	0.06	0.06
5/1/2002	S1	0	0.03	0.03
8/1/2002	S1	0	0.03	0.03
11/1/2002	S1	0	0.03	0.03
3/1/2003	S1	0	0.02	0.02
3/1/2004	S1	0	0.02	0.02
3/1/2005	S1	0	0.01	0.01
3/1/2006	S1	0	0.01	0.01
2/1/2007	S1	0	0.01	0.01
3/1/2008	S1	0	0.01	0.01
6/1/1997	S2	141	207.79	66.53
2/1/2000	S2	71	95.18	24.55
5/1/2002	S2	35	38.63	3.31
8/1/2002	S2	35	34.41	-0.9
11/1/2002	S2	35	30.73	-4.58
3/1/2003	S2	35	26.65	-8.67
3/1/2004	S2	0	18.16	18.16
3/1/2005	S2	0	13.62	13.62
3/1/2006	S2	0	10.18	10.18
2/1/2007	S2	0	7.79	7.79
3/1/2008	S2	0	6.57	6.57
6/1/1997	S3	1024	1321.69	297.57
2/1/2000	S3	706	1001.42	295.12
5/1/2002	S3	318	451.57	133.73
8/1/2002	S3	283	397.13	114.62
11/1/2002	S3	247	352.03	104.83
3/1/2003	S3	212	303.81	91.92
3/1/2004	S3	141	207.92	66.66
3/1/2005	S3	106	167.82	61.88
3/1/2006	S3	106	119.56	13.62
2/1/2007	S3	71	91.67	21.04

Table 2. Simulated PCE Concentrations for Original and Updated Post-Audit Models

Date	Well	Simulated PCE Concentration (µg/L)	Simulated PCE Concentration (µg/L)	Difference
		Original	Updated	
3/1/2008	S3	71	82.39	11.76
6/1/1997	S4	106	102.72	-3.23
2/1/2000	S4	106	121.75	15.8
3/1/2004	S4	35	29.29	-6.02
3/1/2005	S4	35	22.94	-12.38
3/1/2006	S4	0	16.81	16.81
2/1/2007	S4	0	13.37	13.37
3/1/2008	S4	0	10.24	10.24
6/1/1997	S5	1624	1773.95	149.47
2/1/2000	S5	989	1136.51	147.7
5/1/2002	S5	494	584.04	89.63
8/1/2002	S5	459	534.73	75.64
11/1/2002	S5	424	489.23	65.46
3/1/2003	S5	353	434.22	81.08
3/1/2004	S5	247	295.95	48.74
3/1/2005	S5	177	216.07	39.5
3/1/2006	S5	141	150.33	9.08
2/1/2007	S5	106	109.32	3.37
3/1/2008	S5	71	80.8	10.17
6/1/1997	S6	0	21.11	21.11
2/1/2000	S6	0	10.5	10.5
8/1/2002	S6	0	4.26	4.26
11/1/2002	S6	0	3.85	3.85
3/1/2003	S6	0	3.38	3.38
3/1/2004	S6	0	2.35	2.35
3/1/2005	S6	0	1.73	1.73
3/1/2006	S6	0	1.28	1.28
2/1/2007	S6	0	0.97	0.97
3/1/2008	S6	0	0.74	0.74
6/1/1997	S7	71	134.14	63.51
8/1/2002	S7	0	23.27	23.27
11/1/2002	S7	0	20.84	20.84
3/1/2003	S7	0	18.07	18.07
3/1/2004	S7	0	11.97	11.97
3/1/2005	S7	0	8.59	8.59
3/1/2006	S7	0	6.02	6.02
2/1/2007	S7	0	4.38	4.38
3/1/2008	S7	0	3.64	3.64
6/1/1997	S8	0	27.91	27.91
2/1/2000	S8	0	22.16	22.16
5/1/2002	S8	0	9.98	9.98
8/1/2002	S8	0	8.89	8.89
11/1/2002	S8	0	7.93	7.93
3/1/2003	S8	0	6.85	6.85
3/1/2004	S8	0	4.54	4.54
3/1/2005	S8	0	3.2	3.2
3/1/2006	S8	0	2.16	2.16
2/1/2007	S8	0	1.46	1.46

Table 2. Simulated PCE Concentrations for Original and Updated Post-Audit Models

Date	Well	Simulated PCE Concentration (µg/L)	Simulated PCE Concentration (µg/L)	Difference
		Original	Updated	
3/1/2008	S8	0	1.01	1.01
6/1/1997	S9	35	57.92	22.6
2/1/2000	S9	35	73.25	37.93
5/1/2002	S9	35	35.02	-0.29
8/1/2002	S9	35	31.03	-4.29
11/1/2002	S9	35	27.5	-7.82
3/1/2003	S9	0	23.55	23.55
3/1/2004	S9	0	15.17	15.17
3/1/2005	S9	0	11.39	11.39
3/1/2006	S9	0	7.41	7.41
2/1/2007	S9	0	4.68	4.68
3/1/2008	S9	0	3.25	3.25
6/1/1997	S10	494	505.27	10.86
2/1/2000	S10	494	503.55	9.15
1/1/2002	S10	494	484.38	-10.02
5/1/2002	S10	459	477.98	18.89
8/1/2002	S10	459	473.09	14
11/1/2002	S10	459	468.13	9.03
3/1/2003	S10	459	461.09	2
3/1/2004	S10	424	438.9	15.12
3/1/2005	S10	424	418.76	-5.02
3/1/2006	S10	388	390.31	1.85
2/1/2007	S10	353	360.66	7.51
3/1/2008	S10	318	330.09	12.26
6/1/1997	S11	0	0	0
2/1/2000	S11	0	0	0
3/1/2005	S14	0	10.43	10.43
3/1/2006	S14	0	8.57	8.57
2/1/2007	S14	0	6.94	6.94
3/1/2008	S14	0	5.34	5.34

Note:

PCE = tetrachloroethylene

Exhibit 1

Resume for R. Jeffrey Davis



R. Jeffrey Davis, P.E., CGWP, CWRE

Principal, Water Resources

(385) 955-5184

Salt Lake City, UT

jdavis@integral-corp.com

Education & Credentials

M.S., Civil & Environmental Engineering, Brigham Young University, Provo, Utah, 1998

B.S., Civil & Environmental Engineering, Brigham Young University, Provo, Utah, 1993

Professional Engineer, Utah (License No. 189690-2202), Texas (License No. 125406), Florida (License No. 74838), Colorado (License No. 0051575), Alabama (License No. PE52096), Idaho (License No. P-21839), Oregon (License No. 104270PE)

Certified Groundwater Professional, NGWA (2023)

Certified Water Rights Examiner, Oregon (License No. 104270)

Continuing Education

Certificate of Specialization in Leadership and Management, Harvard Business School Online (2023)

MSHA certified (2020)

First Aid and CPR certified (2020)

Professional Affiliations

National Ground Water Association

Mr. Jeff Davis is a licensed civil and environmental engineer, hydrogeologist, and certified groundwater professional with almost 30 years of global experience working on every continent except Antarctica. He currently serves on the Board of Directors for the National Ground Water Association. Mr. Davis has supported numerous litigation cases involving groundwater impacts and has experience as an expert witness. He has spent much of his career solving complicated water problems involving mining, oil and gas, and water resources. These projects include the clean water supply side as well as the remediation of contaminated sites. The contaminated sites include coal combustion residual (CCR) landfills and other waste impoundments, mining remediation sites, and industrial cleanup sites—both RCRA and CERCLA sites. In working with per- and polyfluoroalkyl substance (PFAS) compounds, MTBE, chlorinated solvents, hydrocarbons, nitrates, and road salt, he has developed and used numerous groundwater models for the mining, energy, chemical, and agricultural industries. Other projects have involved environmental impact statements, environmental assessments, sea level rise and groundwater intrusion, water management, groundwater-surface water contamination, dewatering, natural resource damage assessment, and water supply and treatment. He has extensive knowledge of groundwater flow-and-transport principles and has taught numerous workshops and classes in the U.S. and around the world. His current focus is on water and groundwater sustainability and drought resiliency. Mr. Davis has extensive experience in the design and implementation of aquifer storage and recovery (ASR) projects across the country.

Relevant Experience

WATER MANAGEMENT

Water Supply and ASR Feasibility, Sacramento County, California — Served as principal investigator for a proposed land development project that evaluated the feasibility of developing a reliable water supply and implementing an ASR program. Key tasks included constructing a conceptual hydrogeologic model and conducting a geophysical survey to characterize the subsurface. The study provided critical insights into sustainable water management options to support the development while ensuring long-term resource stability.

Water Rights and Supply Analysis, Umatilla County, Oregon — Served as principal investigator for a project that involved a water rights and water supply study for an industrial client in eastern Oregon. The client was facing curtailment of groundwater withdrawals by the Oregon Water

Professional Affiliations (con't.)

Utah Groundwater Association

Groundwater Resources
Association of California

Resources Department. The department alleged that the client's pumping was impacting nearby stream flows, prompting a detailed analysis of hydrogeologic data and monitoring records. The study demonstrated minimal to no connection between the groundwater pumping and river flows, providing critical evidence to support the client's continued water use.

ASR Feasibility, Ada County, Idaho — Served as principal investigator for a feasibility study for an ASR project. Ada County owns and operates Hubbard Reservoir, which receives irrigation water from the New York Canal. The project included building a conceptual model of the site and refining an existing groundwater model to analyze the effects of recharge from the reservoir.

ASR Feasibility and Piloting, Utah County, Utah — Served as principal investigator for a feasibility study for an ASR project. During the spring runoff of 2023, the team measured the runoff in several rivers, creeks, and ditches, and constructed a new infiltration basin, all in an effort to advance aquifer storage projects within the county. The project has continued with permitting and the implementation of a pilot project for the constructed infiltration basin.

ASR Feasibility, Utah County, Utah — Served as principal for a feasibility study for an ASR project. Former agricultural water rights were converted for industrial use and the effluent was being considered for aquifer replenishment. Both infiltration and direct injection of the treated water were considered as part of the feasibility study.

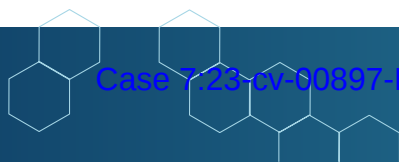
Provo ASR, Provo, Utah — Served as the project manager and engineer of record for the current Provo ASR project. Five sites (three infiltration and two direct injection) are currently permitted for pilot studies that have been ongoing since 2020. Final engineering design and permitting have been completed for all five sites.

Water Reuse and Aquifer Sustainability, Eagle Mountain, Utah — Served as the client manager and engineer of record for the current Eagle Mountain City, Utah, water-reuse planning and aquifer sustainability project. Water rights for Eagle Mountain were evaluated along with the groundwater system to understand aquifer sustainability for the city, which is expecting tremendous future growth, including large industrial water demands.

ASR Evaluation, Weber County, Utah — Served as the project manager and engineer of record for the current evaluation of the Weber Basin Water Conservancy District, Utah, ASR project. This project has been actively operating for more than 10 years. Hired to evaluate the storage capacity of the program and obtain greater recovery volumes from the system, working with the Utah Division of Water Rights.

Drainage Reuse Initiative, Harris County, Texas — Served as part of a team for the development of the Drainage Reuse Initiative for Harris County Flood Control District in Harris County, Texas. The project investigated the feasibility of alternative methods of flood mitigation by conveying stormwater to the subsurface, including natural infiltration to groundwater, enhanced infiltration or injection into aquifers, and mechanical injection to deep aquifers.

Roseville ASR, Roseville, California — Served as one of the groundwater leads for the development of an ASR program for the city of Roseville, California. Initial efforts involved developing a regional-scale conceptualization for the major portion of the Central Valley area.



Developed a subsequent regional multilayer groundwater model, followed by a number of local-scale transport models to simulate pilot tests and understand the ASR process.

COAL COMBUSTION FACILITIES

Coal Combustion Residual Waste and Disposal, Bonanza, Utah — Served as the engineer of record for a coal power plant. Oversaw all efforts related to the monitoring and compliance of the facility's CCR waste and disposal. This included semiannual reporting, development of alternative source demonstrations, and annual groundwater monitoring reports.

Hexavalent Chromium Investigation, United States — Served as the principal investigator for a study to understand and evaluate the proposed EPA changes to hexavalent chromium (Cr(VI)) as it would apply to the monitoring and management of CCR landfill facilities. The work included examining potential regulatory levels from a human health perspective.

Alternate Water Sources Investigation, United States — Served as the principal investigator for a study to understand and evaluate differences at CCR facilities between upgradient and downgradient sources, and locate potential evidence of alternate sources using isotopes and microbial fingerprinting. After development of a sampling and analysis plan, advanced statistical and multivariate methods were used to document analyses that show potential for distinguishing source water from alternate sources.

OIL AND GAS WASTE MANAGEMENT

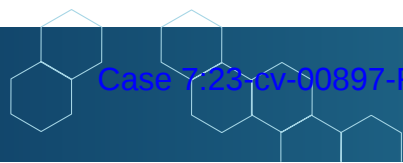
Oil and Gas Waste Facility, De Beque, Colorado — Served as the principal engineer for the permitting and operating of an 800-acre oil-and-gas waste-disposal facility southeast of De Beque, Colorado. Involved in several aspects of the permitting process, including the hydrogeological study and groundwater investigations; stormwater design; pond liner design and construction; closure certification; and submittal of the revised engineering design and operation plan.

Remedial Investigation, Billings, Montana — Served as the groundwater lead for the Yale Oil of South Dakota Facility in Billings, Montana. The Superfund site facility is in the remedial investigation phase; the risk-assessment work plan has been submitted to the Montana Department of Environmental Quality, and the client is waiting for comments before proceeding with the risk assessment.

EPA Study, Washington, DC — Served as participant and technical reviewer for EPA's "Study of Hydraulic Fracturing for Oil and Gas and Its Potential Impact on Drinking Water Resources." Participated in technical roundtables and technical workshops and completed a peer review of the EPA's five retrospective case studies.

Fate and Transport Modeling, Texas — Served as groundwater lead for fate-and-transport modeling and analysis of chloride contamination in southern Texas near the Gulf of Mexico. As part of the site mitigation phase, modeling was used to determine the potential migration of the chloride through the shallow aquifer system and nearby receptors.

Lockwood Solvent Groundwater Plume Site, Billings, Montana — Served as one of the groundwater leads performing groundwater modeling for the Lockwood Solvent Groundwater



Plume site, an EPA Superfund site in Billings, Montana. The site spans 580 acres, and much of the groundwater there is contaminated with volatile organic compounds, including tetrachloroethene, trichloroethene, *cis*-1,2- dichloroethene, and vinyl chloride.

PLANNING AND PERMITTING

Beverage Can Manufacturing and Filling, Salt Lake City, Utah — Served as principal investigator for wastewater, stormwater, and Utah Pollutant Discharge Elimination System permitting, monitoring, and compliance for an aluminum can manufacturing and filling facility. Worked closely with the client, its operations team, and state and municipal regulators to regularly monitor and report all discharges from the facility.

Ely Energy Center EIS, White Pine County, Nevada — Served as principal lead for the development of a regional groundwater model for Steptoe Valley in White Pine County, Nevada. The investigation and model were part of the EIS for construction of the Ely Energy Center.

Haile Gold Mine EIS, Kershaw, South Carolina — Served as groundwater lead as the third-party contractor developing an EIS for the proposed Haile Gold Mine near Kershaw, South Carolina. The EIS analyzed the potential direct, indirect, and cumulative environmental effects of the proposed project and its alternatives. Work included project-team coordination for geology, groundwater, and surface water resources areas; review of applicant-supplied information; agency coordination; and public involvement.

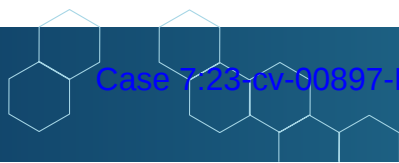
Four Corners Power Plant EIS, Farmington, New Mexico — Served as groundwater lead as the third-party contractor in developing an EIS for the Four Corners Power Plant and Navajo coal mine in Farmington, New Mexico. The EIS analyzed the potential direct, indirect, and cumulative environmental effects of the proposed project and its alternatives. The groundwater portion included analyzing field investigations, pump tests, conceptual and numerical modeling of the project and surrounding area, and remediation and reclamation activities.

Iron Ore Operations Cumulative Impact Assessment, Pilbara, Western Australia — Served as one of the groundwater leads for a cumulative impact assessment for a proposed expansion of iron ore operations in the Pilbara in Western Australia. Work included identifying the methodology and developing the conceptual models to perform the assessment. The groundwater modeling included both quantitative and qualitative approaches.

LITIGATION SUPPORT

Road Salt Contamination Litigation, Boise County, Idaho — Served as the principal lead to support litigation related to road salt contamination of a drinking water aquifer serving private wells in Lowman, Idaho. The contamination was traced to negligent storage practices by the Idaho Department of Transportation, with a conceptual model developed to demonstrate the source and migration of the salt into the aquifer. Provided recommendations to mitigate the contamination, restore groundwater quality, and prevent future impacts to the community's drinking water supply.

PCE Contamination Litigation, Onslow County, North Carolina — Served as a testifying expert for a project involving PCE-contaminated groundwater impacting a public water supply. Performed a post-audit of an existing groundwater fate and transport model to assess its



accuracy and reliability and extended the model's time domain to evaluate its performance against updated concentration data from multiple monitoring wells.

ASR Well Design and Construction Litigation, Washington County, Oregon — Served as a testifying expert in a litigation case involving allegations of design and construction failures in an ASR well. The client, accused of lacking standard of care in its engineering services, required a technical review of the well design, construction practices, and operational performance. The analysis provided an expert evaluation of the ASR well's deficiencies and clarified the extent of liability and adherence to professional standards.

Stormwater Pipeline Litigation, Sweetwater County, Wyoming — Served as the engineering expert for a litigation case involving the failure of a stormwater pipeline at a trona ore mining and processing facility, where the client, a construction company, faced accusations of negligence. The work included multiple site visits to assess pipeline conditions and a detailed review of engineering plans to evaluate construction practices and compliance with design specifications. The findings provided critical insights into potential causes of failure and helped clarify the client's responsibilities under standard construction practices.

Expert Witness for PFAS Litigation, Martin County, Florida — Served as the groundwater expert witness for a litigation case in Martin County. The multidistrict litigation bellwether case involved PFAS contamination of groundwater affecting public drinking water. Opinions were given regarding PFAS sourcing, and fate and transport in groundwater, and regarding public water supply planning.

Water Resources Litigation, Grand County, Colorado — Served as principal investigator for a litigation case involving flooding damages caused by a canal breach. Surface water modeling was used to determine amount and extent of erosion and sedimentation from the flooding.

Water Resources Litigation, Northwest Minnesota — Served as principal investigator and expert witness for a litigation case involving agricultural water rights and pumping near tribal lands. Developed a conceptual model to understand the hydrogeological conditions and constructed a groundwater model to determine possible impacts due to the agriculture activities.

Groundwater Litigation, Ventura County, California — Served as the groundwater expert for a litigation case in Ventura County. The case includes the development of a basin-wide groundwater-surface water model, not only for purposes of litigation but also for compliance with Sustainable Groundwater Management Act requirements. The groundwater basin in question is currently listed as a priority basin by the State of California.

Pipeline Spill Litigation, Williston, North Dakota — Provided litigation services for groundwater and surface water contamination from a pipeline spill in North Dakota. A large spill of produced water (brine) impacted surface streams as well as the shallow aquifer system. Work included groundwater modeling, field investigations, and remedial strategies.

Road Salt Contamination Litigation, Vandalia, Ohio — Performed fate-and-transport modeling and analysis of sodium chloride contamination of an aquifer in Vandalia, Ohio. Stored road salt caused limited contamination of a shallow aquifer that supplied drinking water to nearby residential homes. The groundwater model included the local domestic pumping wells, which

helped determine the possible extent of chloride impacts. Largely due to the conceptual site model and transport modeling results, litigation was settled out of court to the satisfaction of the client.

CLIMATE IMPACT ASSESSMENT

Sea Level Rise Groundwater Intrusion Modeling, Alameda County, California — Served as the principal groundwater lead and engineer for a project that supported a climate adaptation initiative for the Port of Oakland addressing the impacts of sea level rise on subsurface conditions. The work involved detailed subsurface characterization and groundwater intrusion modeling to assess the potential for rising seawater to affect infrastructure and operations. The analysis provided critical data to inform resilience strategies and adaptation measures for long-term sustainability.

Sea Level Rise Groundwater Intrusion Monitoring, Ventura County, California — Served as the principal groundwater lead and engineer for a project that supported a climate adaptation program for the naval facility at Point Mugu by evaluating groundwater intrusion risks associated with sea level rise. Analyzed groundwater monitoring data to identify trends and data gaps critical for assessing potential impacts on infrastructure and operations as well as habitat. The results informed targeted monitoring and adaptation strategies to enhance the facility's resilience to future climate-related challenges.

Sea Level Rise Groundwater Intrusion Assessment, Santa Barbara County, California — Served as the principal groundwater lead and engineer for a proposed coastal hotel expansion in Santa Barbara County. The project involved reviewing technical studies to assess potential environmental and resource challenges. Critically evaluated key reports, including a sea level rise hazard study, water resource reports, and stormwater and drainage studies, to identify gaps and raise concerns about the feasibility and sustainability of the development. The analysis provided valuable insights to guide decision-making and ensure compliance with long-term coastal resilience and resource management goals.

GROUNDWATER MODELING

Subsidence Monitoring/Modeling, Fort Bend and Harris Counties, Texas — Served as the groundwater lead and engineer on several groundwater development projects in Fort Bend and Harris counties. Groundwater withdrawals are strictly curtailed due to historical subsidence. The Subsidence Districts have installed GPS Port-A-Measure (PAM) units and used InSAR mapping. Using this data plus the output from the models PRESS and MODFLOW-SUB to measure subsidence impacts.

Groundwater Model Development, New Jersey — Led a team of hydrogeologists to construct a groundwater flow and fate and transport model of perfluorononanoic acid and other contaminants. The model will be used to design a pump and treat system and possible aquifer replenishment with the treated groundwater.

Hydrogeological Services, Montgomery County, Texas — Provided modeling and hydrogeological consulting services for the Lone Star Ground-water Conservation District's (Montgomery County, Texas) update of its desired future conditions and groundwater management plans. Also provided litigation services for the district.

Groundwater Model Development, Havana, Florida — Provided consulting services for Northwest Florida Water Management District as it updated its regional groundwater model—an integrated groundwater-surface water model that provides regulatory control of the groundwater withdrawals and manages saltwater intrusion in the Floridan aquifer due to pumping.

Crop Production Services, Various Locations, U.S. — Served as the groundwater lead to provide modeling and hydrogeological consulting services for a number of crop production services legacy sites. The groundwater at the sites was contaminated with nitrates from long-term fertilizer use. Groundwater modeling was used to determine the fate and transport of the nitrates and to develop a remedial strategy for cleanup.

Legacy Way Tunnel Design, Brisbane, Australia — Provided senior oversight and technical review for all hydrogeologic assessments related to the Legacy Way tunnel design project, a 4.6 km underground tunnel in northern Brisbane, Australia. Work included evaluating field tests, preparing geotechnical and environmental reports, and modeling the entire project area.

Mercury Fate and Transport, Cincinnati, Ohio — Served as the groundwater lead for performing fate and-transport modeling and analysis of a mercury spill at a municipal landfill in Cincinnati, Ohio. As part of the project management phase, modeling was used to determine the potential migration of mercury through the landfill to the leachate collection system. Modeling efforts examined both the spatial distribution and the temporal component of the mercury transport.

Due Diligence Environmental Review, Pascagoula, Mississippi — Served as the environmental lead for performing an environmental assessment at a chemical plant in Pascagoula, Mississippi, as part of a due diligence effort. A number of groundwater and surface water contamination issues due to spills, leaks, and storage of hazardous materials were addressed. The location of the plant on the Gulf of Mexico makes possible environmental impacts from operation of the chemical plant a sensitive issue.

MINING

Bingham Canyon Mine Closure Planning, Copperton, Utah — Completed an independent third-party audit for a closure-plan pit-lake study for Bingham Canyon Mine. Reviewed the consultant scope of work for the pit-lake study and discussed the study, methodology, and pathway to completion with consultant staff. An independent audit report was compiled and submitted to the client.

Hooker Prairie Mine, Bartow, Florida — Served as the model expert to develop a contaminant and water budget and management model for the Hookers Prairie Mine in Florida using the GoldSim modeling software. The purpose of the model was to evaluate the probabilities of the mine meeting its current and future nutrient NPDES loading limits for certain contaminants. The project also included an evaluation of current monitoring data within the mine operations and at discharge locations, and the development of a complete monitoring plan integrated into a GIS as part of the model calibration and validation.

Bridger Coal Mine Investigation, Rock Springs, Wyoming — Served on a technical team to reevaluate groundwater conditions, and treatment and discharge alternatives at the Bridger coal



mine in southwest Wyoming. Previous studies' predicted maximum flows into the mine had been exceeded. Reassessed the situation and provided solutions.

EMERGENCY RESPONSE

Emergency Response to Battery Fire, New York — Served as the principal in charge leading a team of multidisciplinary scientists, engineers, toxicologists, and risk assessors for an environmental emergency response at a large-scale battery power storage unit at a solar farm. A thermal incident where several cargo container boxes caught fire and burned required immediate action to assess the environmental and human health impacts.

Emergency Response to Battery Fire, California — Served as the principal in charge leading a team of multidisciplinary scientists, engineers, toxicologists, and risk assessors for an environmental emergency response at a large-scale battery power storage facility. A thermal incident where several cargo container boxes caught fire and burned required immediate action to assess the environmental and human health impacts.

ECOLOGICAL RESTORATION

Ecological Restoration, Northeast Idaho — Serves as the principal in charge leading a team of scientists, engineers, and ecologists for an ecological restoration effort in northeast Idaho. The project has involved restoring flow to a creek and working with a number of state and federal agencies to develop and implement a conceptual restoration plan and a mitigation and monitoring plan. The project will also include obtaining the necessary permits and overseeing the restoration in an area of critical habitat.

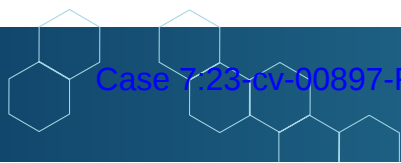
PROJECT MANAGEMENT

GMS Software Development, Utah — Served as chief engineer for the original development of the software Groundwater Modeling System (GMS) at the Environmental Modeling Research Laboratory at Brigham Young University. A sophisticated graphical environment for groundwater model pre- and post-processing, 3-dimensional site characterization, and geostatistics, GMS is the official groundwater application of the U.S. Department of Defense and is also used by the U.S. Department of Energy, EPA, and thousands of users across the world.

NATURAL RESOURCE DAMAGE ASSESSMENT

Natural Resource Damage Assessment, Southeastern Idaho — Served as the groundwater expert determining groundwater damages in southeastern Idaho due to decades of phosphate mining. Led a team of hydrogeologists evaluating the impacts of selenium and other contaminants and changes in natural groundwater flows across the entire region. The damage assessment included a number of mining areas as well as the facilities where the phosphate material was processed.

Natural Resource Damage Assessment, Eastern Washington — Served as the groundwater expert determining groundwater damages in eastern Washington due to decades of groundwater contamination. For future development on the site, an ASR program is being considered as part of the restoration and long-term sustainability of the groundwater resources.



Presentations / Posters

Davis, R.J. 2024. Assessing a social value of water in aquifer storage and recovery projects. National Ground Water Association Groundwater Week. December 9–12. Las Vegas, NV.

Davis, R.J. 2024. Assessing a social value of water in aquifer storage and recovery projects. Salt Lake County Watershed Symposium. November 20–21. Salt Lake City, UT.

Davis, R.J. 2024. Great Salt Lake of Utah: Watershed, legislative, and community issues surrounding it. Environmental Professional Industry Charities (EPIC). October 24. Salt Lake City, UT.

Davis, R.J. 2024. Assessing a social value of water in ASR projects. Groundwater Resources Association of California Western Groundwater Congress. October 7–9. Lake Tahoe, NV.

Davis, R.J. 2024. Assessing a social value of water in ASR projects. The Geological Society of America: Connects 2024. September 22–25. Anaheim, CA.

Davis, R.J. 2024. Water in Utah: Continuing to navigate the present and shaping our future water demands. American Groundwater Trust. August 6–7. Salt Lake City, UT.

Davis, R.J. 2024. Assessing a social value of water in ASR projects. Biennial Symposium on Managed Aquifer Recharge. April 4–5. Tucson, AZ.

Davis, R.J. 2023. Challenges limiting managed aquifer recharge (MAR) adoption in the West. National Ground Water Association Groundwater Summit. December 5–7. Las Vegas, NV.

Davis, R.J. 2023. Water, AI, and us: What does the future hold for solving Utah's water challenges. Hint: It can't be solved without you and me. Salt Lake County Watershed Symposium. November 15–16. Salt Lake City, UT.

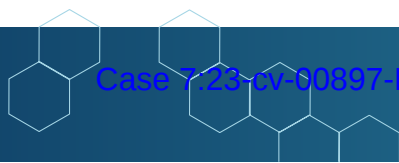
Davis, R.J. 2023. Building climate resilience through sustainable remediation in the western region. Groundwater Resources Association of California Western Groundwater Congress. September 12–14. Burbank, CA.

Davis, R.J. 2023. Water in Utah: Navigating the present and shaping the future. American Groundwater Trust. August 14–15. Provo, Utah.

Davis, R.J. 2023. More managed aquifer recharge and saving the Great Salt Lake—A balancing act. Idaho Water Users Association. June 12–13. Sun Valley, ID.

Davis, R.J. 2023. More managed aquifer recharge: Deliberate resiliency to combat droughts and climate change in the West. Association for Environmental Health of Soils. March 20–23. San Diego, CA.

Davis, R.J. 2023. Resilient and sustainable remediation. ESG|Climate Resilient & Sustainable Remediation Symposium. Groundwater Resources Association of California Western Groundwater Congress. February 6–7. San Diego, CA.



Davis, R.J. 2022. More managed aquifer recharge: Solutions to combat droughts and climate change in the West. National Ground Water Association Groundwater Summit. December 6–8. Las Vegas, NV.

Davis, R.J. 2022. Saving our aquifers: Climate change and managed aquifer recharge. Salt Lake County Watershed Symposium. November 16–17. Salt Lake City, UT.

Davis, R.J. 2022. More managed aquifer recharge—A solution to combat droughts and climate change in the West. Groundwater Resources Association of California Western Groundwater Congress. September 21–23. Sacramento, CA.

Davis, R.J. 2022. Saving our aquifers—Climate change, sustainability, and managed aquifer recharge. International Water Holdings. August 24–25. Salt Lake City, UT.

Davis, R.J. 2022. More managed aquifer recharge (MMAR) a solution to combat droughts and climate change in the West. Groundwater Protection Council Annual Forum. June 21–23. Salt Lake City, UT.

Davis, R.J. 2022. Aquifer storage and recovery—Hydrogeologic considerations. American Water Resources Association. May 17. Salt Lake City, UT.

Davis, R.J. 2022. Utah hydrology—What you do and don't know about Utah hydrogeology. National Ground Water Association. May 4, 2022. Virtual.

Davis, R.J. and B. Lemon. 2022. Provo, Utah: From planning to pilot to a final aquifer storage and recovery (ASR) program. Utah Water Users Workshop. March 21–23. St. George, UT.

Davis, R.J. 2021. Provo, Utah, from planning to pilot to a final managed aquifer recharge (MAR) program. National Ground Water Association Groundwater Summit. December 7–8. Virtual.

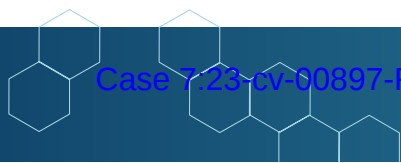
Davis, R.J. 2021. Provo City aquifer storage and recovery project. Ground Water Protection Council Annual Forum, September 27–29. Virtual.

Davis, R.J. 2021. Provo, Utah, from planning to pilot to a final managed aquifer recharge (MAR) program. American Public Works Association Utah Section Annual Conference. September 21–22. Sandy, UT.

Davis, R.J. 2021. Provo City aquifer storage and recovery project. Utah Water Users Workshop. May 17–19. St. George, UT.

Davis, R.J. 2021. Provo, Utah: From planning to pilot to a final managed aquifer recharge (MAR) program. ASR for Texas, Virtual Webinar. May 4–5.

Davis, R.J. 2021. Provo aquifer storage and recovery—From planning to pilot. American Water Works Association Virtual Summit on Sustainable Water, PFAS, Waterborne Pathogens. February 10–11.



Davis, R.J. 2020. Update on Provo's aquifer storage and recovery program. American Water Works Association Virtual Intermountain Section Annual Conference. October 21–23. Sun Valley, ID.

Davis, R.J. 2020. Are you prepared for the new federal permit process for CCR facilities? Second Annual Coal Ash and Combustion Residual Management Webinar, October 7–8. Virtual.

Invited Participant, Expert Panels, and Workshops

Avoiding the Pitfalls in Engaging Expert Consultants, Holland & Hart, March 18, 2024, Salt Lake City, UT.

Managed Aquifer Recharge Guidance, Interstate Technology & Regulatory Council, Managed Aquifer Recharge Team. December 2023.

Bulk Water Innovation Partnership (BWIP): More managed aquifer recharge: Deliberate resiliency to combat droughts and climate change in the West. December 6, 2023. Virtual.

Rocky Mountain Association of Environmental Professionals (RMAEP): Great Salt Lake of Utah: watershed, legislative, and community issues surrounding it. September 20, 2023.

Salt Lake Chamber: Utah Water Outlook. April 13, 2022.

EDCUtah Webinar: Water: Constraints and Opportunities for Development in Utah panel. June 11, 2021.

ULI Utah: Trends Conference—Water: Constraints and Opportunities for Development in Utah panel. October 27, 2021.

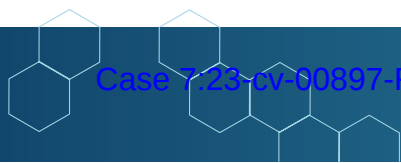


Exhibit 2

Resume for Norman L. Jones

Norman L. Jones, Ph.D.
Professor
Department of Civil & Construction Engineering
Brigham Young University

Education

Ph.D. Civil Engineering, University of Texas at Austin, 1990
M.S. Civil Engineering, University of Texas at Austin, 1988
B.S. Civil Engineering, Brigham Young University, 1986

Academic Experience

Department Chair, Civil & Construction Engineering, Brigham Young University (BYU), 2018-2024
Professor, Civil & Construction Engineering, BYU, 2002–present
Associate Professor, Civil & Environmental Engineering, BYU, 1997–2002
Assistant Professor, Civil & Environmental Engineering, BYU, 1991–1996

Current Membership in Professional Organizations

American Society of Civil Engineers (ASCE)
American Water Resources Association (AWRA)
National Ground Water Association (NGWA)
American Geophysical Union (AGU)

Professional Committees

AWRA 2014 GIS in Water Resources Technical Program Chair
NGWA Groundwater Modeling Interest Group Committee
American Society of Civil Engineers
EWRI Groundwater Management Committee
EWRI Emerging Technologies Committee
International Editorial Board for the Journal of HydroInformatics
Editor of AQUAmundi Journal
Great Salt Lake Basin Integrated Plan - Groundwater Technical Advisory Team
Tethys Geoscience Foundation - Board Member

Selected Honors and Awards

2001 Walter L. Huber Civil Engineering Research Prize
2002 College of Engineering & Technology Special Commendation Award
2003 Brigham Young University Technology Transfer Award
2007 Utah Engineering Educator of the Year – ACEC
2012 Brigham Young University Karl G. Maeser Research and Creative Arts Award
2016 AWRA Educator of the Year – Utah Section
2021 NGWA John Hem Award for Science and Engineering
2023 Brigham Young University Sponsored Research Award

University Courses Taught

CE En 101 - Introduction to Civil and Environmental Engineering
CE En 201 - Infrastructure
CE En 270 – Computer Methods in Civil Engineering
CE En 341 – Elementary Soil Mechanics
CE En 540 – Geo-Environmental Engineering
CE EN 544 - Seepage and Slope Stability Analysis
CCE 547 – Ground Water Modeling

Software

Led the development of the Groundwater Modeling System (GMS) software. GMS is a state-of-the-art three-dimensional environment for ground water model construction and visualization. It includes tools for site characterization including geostatistics and solid modeling of soil stratigraphy. GMS is the most comprehensive and sophisticated groundwater modeling software available and is used by over 10,000 organizations in over 100 countries. Currently managed and distributed by Aquaveo, LLC, a company I co-founded in 2007.

External Research Grants

1. Automated Mesh Generation For the TABS-2 System, \$19,000, 2/90 - 11/90, U.S. Army Engineer Waterways Experiment Station
2. A Geometry Pre-Processor for HEC-1 Employing Triangulated Irregular Networks, \$20,048, 3/91 - 10/91, U.S. Army Engineer Waterways Experiment Station
3. Real-Time Visualization for the TABS-2 Modelling System, \$14,123, 4/91 - 8/91, U.S. Army Engineer Waterways Experiment Station
4. An Investigation of X-Windows Interface Tools, \$49,556, 1/92 - 8/92, U.S. Army Engineer Waterways Experiment Station
5. Descriptive Geometry and Solid Rendering, \$24,000, 1/92 - 10/92, U.S. Army Engineer Waterways Experiment Station
6. An Investigation of Automated Pre-processing Schemes for TIN-Based Drainage Analysis, \$34,750, 4/92-10/92, U.S. Army Engineer Waterways Experiment Station
7. A Comprehensive Graphical User Environment for Groundwater Flow and Transport Modeling, \$246,526, 6/93-9/94, U.S. Army Engineer Waterways Experiment Station
8. An Integrated Surface Flow Modeling System, \$131,848, 1/94-1/95, U.S. Army Engineer Waterways Experiment Station
9. Productivity and Management Tools for Groundwater Flow and Transport Modeling, \$207,404, 5/94-4/95, U.S. Army Engineer Waterways Experiment Station
10. Enhanced Tools for Quality Control in Automated Groundwater Transport Modeling, \$246,553, 1/95-12/95, U.S. Army Engineer Waterways Experiment Station
11. Visualization for Two-Dimensional Surface Runoff Modeling, \$98,221, 1/95-10/95, U.S. Army Engineer Waterways Experiment Station
12. Visualization Tools for Two-Dimensional Finite Element Hydrologic Modeling, \$93,933, 11/95-10/96, U.S. Army Engineer Waterways Experiment Station
13. A Graphical Environment for Multi-Dimensional Surface Water Modeling, \$49,789, 3/96-9/96, U.S. Army Engineer Waterways Experiment Station
14. A Conceptual Modeling Approach to Pre-processing of Groundwater Models, \$475,743, 11/95-11/97, U.S. Army Engineer Waterways Experiment Station
15. Hydrosystems Modeling, \$2,458,083, 5/97-4/02, U.S. Army Engineer Waterways Experiment Station
16. Second Generation Hydroinformatics Research, \$4,958,127. U.S. Army Engineer Research and Development Center.
17. Flux Calculations and 3D Visualization for the SCAPS Piezocone and GeoViz System, \$34,931, U.S. Navy.
18. Development of modeling methods and tools for predicting coupled reactive transport processes in porous media under multiple scales. \$949,000. US Dept. of Energy. 1/07-12/09.
19. CI-WATER: Cyberinfrastructure to Advance High Performance Water Resource Modeling, \$3,435,873. National Science Foundation - EPSCoR. 9/11-8/14.

20. Comprehensive Streamflow Prediction and Visualization to Support Integrated Water Management, \$599,823. NASA SERVIR, 8/16-8/19.
21. Daniel P. Ames, E. James Nelson, Norman L. Jones, An AmeriGEOSS Cloud-based Platform for Rapid Deployment of GEOGLOWS Water and Food Security Decision Support Apps, \$540,658, NASA GEO, 1/2018-12/2020
22. Geospatial Information Tools That Use Machine-Learning to Enable Sustainable Groundwater Management in West Africa, \$657,232. NASA SERVIR, 11/19-11/22.
23. Advancing the NASA GEOGloWS Toolbox for Regional Water Resources Management and Decision Support. \$1.2M. NASA GEOGLOWS. 2022-2025. Dan Ames, Jim Nelson, Gus Williams, Norm Jones.
24. CIROH: National Cyberinfrastructure Framework for Engaging the Hydrologic Community (NCF). \$1,822,418. National Oceanographic and Atmospheric Administration. 2022-2025. Dan Ames, Jim Nelson, Gus Williams, Norm Jones.
25. CIROH: Advancing Science to Better Characterize Drought and Groundwater-Driven Low-Flow Conditions in NOAA and USGS National-Scale Models. \$801,221. 2023-2025. Norm Jones, Gus Williams, T. Prabhakar Clement, Donna Rizzo.
26. Improved Hydrologic Prediction Services for Resilience with GEOGLOWS, \$1,889,627, National Oceanic and Atmospheric Administration (NOAA), 4/1/2024-3/31/2027. Norm Jones, Jim Nelson, Andrew South.

Summary: PI or Co-PI on 26 projects totaling \$22,026,639.

Peer-Reviewed Publications in the Past 10 Years

1. Jones, N., Nelson, J., Swain, N., Christensen, S., Tarboton, D. Dash, P. Tethys: A Software Framework for Web-Based Modeling and Decision Support Applications. In: Ames, D.P., Quinn, N.W.T., Rizzoli, A.E. (Eds.), Proceedings of the 7th International Congress on Environmental Modelling and Software, June 15-19, San Diego, California, USA. ISBN: 978-88-9035-744-2
2. Jones, N., Griffiths, T., Lemon, A., Kudlas, S. Automated Well Permitting in Virginia's Coastal Plain Using SEAWAT and GIS Geoprocessing Tools. In: Ames, D.P., Quinn, N.W.T., Rizzoli, A.E. (Eds.), Proceedings of the 7th International Congress on Environmental Modelling and Software, June 15-19, San Diego, California, USA. ISBN: 978-88-9035-744-2
3. Y. Fan, S. Richard, R. S. Bristol, S. E. Peters, S. E. Ingebritsen, N. Moosdorf, A. Packman, T. Gleeson, I. Zaslavsky, S. Peckham, L. Murdoch, M. Fienen, M. Cardiff, D. Tarboton, N. Jones, R. Hooper, J. Arrigo, D. Gochis, J. Olson and D. Wolock (2014), DigitalCrust – a 4D data system of material properties for transforming research on crustal fluid flow, *GeoFluids*, Article first published online: 7 OCT 2014 | DOI: 10.1111/gfl.12114.
4. Swain, N.R., K. Latu, S.D. Christensen, N.L. Jones, E.J. Nelson, D.P. Ames, G.P. Williams (2015). "A review of open source software solutions for developing water resources web applications." *Environmental Modeling & Software* 67: 108-117.
5. Jones, David, Norm Jones, James Greer, and Jim Nelson, "A cloud-based MODFLOW service for aquifer management decision support," *Computers and GeoSciences*, Vol. 78, pp. 81-87, 2015.
6. Dolder, H., Jones, N., and Nelson, E. (2015). "Simple Method for Using Precomputed Hydrologic Models in Flood Forecasting with Uniform Rainfall and Soil Moisture Pattern." *J. Hydrol. Eng.*, [10.1061/\(ASCE\)HE.1943-5584.0001232](https://doi.org/10.1061/(ASCE)HE.1943-5584.0001232), 04015039.
7. Fatichi, S., Vivoni, E.R., Ogden, F.L., Ivanov, V.Y., Mirus, B., Gochis, D., Downer, C.W., Camporese, M., Davidson, J.H., Ebel, B., Jones, N., Kim, J., Mascaro, G., Niswonger, R., Restrepo, P., Rigon, R., Shen, C., Sulis, M., and Tarboton, D. (2016). *An Overview of Challenges, Current Applications and Future Trends of Distributed Process-based Models in Hydrology*.

- Journal of Hydrology. Vol 537, 45-60. DOI:10.1016/j.jhydrol.2016.03.026
8. Snow, Alan D., Scott D. Christensen, Nathan R. Swain, E. James Nelson, Daniel P. Ames, Norman L. Jones, Deng Ding, Nawajish S. Noman, Cédric H. David, Florian Pappenberger, and Ervin Zsoter, 2016. *A High-Resolution National-Scale Hydrologic Forecast System from a Global Ensemble Land Surface Model*. Journal of the American Water Resources Association (JAWRA) 52(4):950–964, DOI: 10.1111/1752-
 9. Perez, J. Fidel, Nathan R. Swain, Herman G. Dolder, Scott D. Christensen, Alan D. Snow, E. James Nelson, and Norman L. Jones, 2016. *From Global to Local: Providing Actionable Flood Forecast Information in a Cloud-Based Computing Environment*. Journal of the American Water Resources Association (JAWRA) 52(4):965–978. DOI: 10.1111/1752-1688.12392
 10. Swain, N. R., S. D. Christensen, A. D. Snow, H. Dolder, G. Espinoza-Dávalos, E. Goharian, N. L. Jones, E. J. Nelson, D. P. Ames and S. J. Burian (2016). "A new open source platform for lowering the barrier for environmental web app development." *Environmental Modelling & Software* 85: 11-26.
 11. Souffront Alcantara, Michael A.; Crawley, Shawn; Stealey, Michael J.; Nelson, E. James; Ames, Daniel P.; and Jones, Norm L. (2017) "Open Water Data Solutions for Accessing the National Water Model," *Open Water Journal*: Vol. 4 : Iss. 1 , Article 3.
 12. Souffront Alcantara, Michael, C Kesler, M Stealey, J Nelson, D Ames, N Jones, 2017. Cyberinfrastructure and Web Apps for Managing and Disseminating the National Water Model, *Journal of the American Water Resources Association, JAWRA Journal of the American Water Resources Association* 54, no. 4 (2018): 859-871.
 13. Christensen, Scott D., Nathan R. Swain, Norman L. Jones, E. James Nelson, Alan D. Snow, and Herman G. Dolder. "A Comprehensive Python Toolkit for Accessing High-Throughput Computing to Support Large Hydrologic Modeling Tasks." *JAWRA Journal of the American Water Resources Association* 53, no. 2 (2017): 333-343.
 14. Nelson, E. J., Pulla, S. T., Matin, M. A., Shakya, K., Jones, N., Ames, D. P., Ellenberg, W.L., Markert, K.N., Hales, R. (2019). Enabling Stakeholder Decision-Making With Earth Observation and Modeling Data Using Tethys Platform. *Frontiers in Environmental Science*, 7. <https://doi.org/10.3389/fenvs.2019.00148>
 15. Purdy, A. J., David, C. H., Sikder, M. S., Reager, J. T., Chandanpurkar, H. A., Jones, N. L., & Matin, M. A. (2019). An Open-Source Tool to Facilitate the Processing of GRACE Observations and GLDAS Outputs: An Evaluation in Bangladesh. *Frontiers in Environmental Science*, 7. <https://doi.org/10.3389/fenvs.2019.00155>
 16. Souffront Alcantara, M. A., Nelson, E. J., Shakya, K., Edwards, C., Roberts, W., Krewson, C., Ames, D. P., Jones, N. L., Gutierrez, A. (2019). Hydrologic Modeling as a Service (HMaaS): A New Approach to Address Hydroinformatic Challenges in Developing Countries. *Frontiers in Environmental Science*, 7. <https://doi.org/10.3389/fenvs.2019.00158>
 17. Evans, S.; Williams, G.P.; Jones, N.L.; Ames, D.P.; Nelson, E.J. Exploiting Earth Observation Data to Impute Groundwater Level Measurements with an Extreme Learning Machine. *Remote Sens.* 2020, 12, 2044. <https://doi.org/10.3390/rs12122044>
 18. Evans, S.W.; Jones, N.L.; Williams, G.P.; Ames, D.P.; Nelson, E.J. (2020). Groundwater Level Mapping Tool: An open source web application for assessing groundwater sustainability. *Environmental Modeling and Software*, Vol 131, September 2020. <https://doi.org/10.1016/j.envsoft.2020.104782>
 19. Nelson, S. T., Robinson, S., Rey, K., Brown, L., Jones, N., Dawrs, S. N., et al. (2021). Exposure Pathways of Nontuberculous Mycobacteria Through Soil, Streams, and Groundwater, Hawai'i, USA. *GeoHealth*, 5, e2020GH000350. <https://doi.org/10.1029/2020GH000350>
 20. Sanchez Lozano J, Romero Bustamante G, Hales R, Nelson EJ, Williams GP, Ames DP, Jones NL. A Streamflow Bias Correction and Performance Evaluation Web Application for GEOGloWS ECMWF Streamflow Services. *Hydrology*. 2021;

- 8(2):71. <https://doi.org/10.3390/hydrology8020071>
21. Dolder, Danisa; Williams, Gustavious P.; Miller, A. W.; Nelson, Everett J.; Jones, Norman L.; Ames, Daniel P. 2021. "Introducing an Open-Source Regional Water Quality Data Viewer Tool to Support Research Data Access" *Hydrology* 8, no. 2: 91. <https://doi.org/10.3390/hydrology8020091>
 22. Bustamante, G.R.; Nelson, E.J.; Ames, D.P.; Williams, G.P.; Jones, N.L.; Boldrini, E.; Chernov, I.; Sanchez Lozano, J.L. Water Data Explorer: An Open-Source Web Application and Python Library for Water Resources Data Discovery. *Water* 2021, 13, 1850. <https://doi.org/10.3390/w13131850>
 23. Hales, R.C.C.; Nelson, E.J.J.; Williams, G.P.P.; Jones, N.; Ames, D.P.P.; Jones, J.E.E. The Grids Python Tool for Querying Spatiotemporal Multidimensional Water Data. *Water* 2021, 13, 2066. <https://doi.org/10.3390/w13152066>
 24. Khattar, R., Hales, R., Ames, D. P., Nelson, E. J., Jones, N., & Williams, G. (2021). Tethys App Store: Simplifying deployment of web applications for the international GEOGloWS initiative. *Environmental Modelling & Software*, 105227. <https://doi.org/10.1016/j.envsoft.2021.105227>
 25. McStraw, T.C., Pulla, S.T., Jones, N.L., Williams, G.P., David, C.H., Nelson, J.E., and Ames, D.P.. 2021. "An Open-Source Web Application for Regional Analysis of GRACE Groundwater Data and Engaging Stakeholders in Groundwater Management." *Journal of the American Water Resources Association* 1– 15. <https://doi.org/10.1111/1752-1688.12968>.
 26. Barbosa, S.A.; Pulla, S.T.; Williams, G.P.; Jones, N.L.; Mamane, B.; Sanchez, J.L. Evaluating Groundwater Storage Change and Recharge Using GRACE Data: A Case Study of Aquifers in Niger, West Africa. *Remote Sens.* 2022, 14, 1532. <https://doi.org/10.3390/rs14071532>
 27. Nishimura, R.; Jones, N.L.; Williams, G.P.; Ames, D.P.; Mamane, B.; Begou, J. Methods for Characterizing Groundwater Resources with Sparse In Situ Data. *Hydrology* 2022, 9, 134. <https://doi.org/10.3390/hydrology9080134>
 28. Ramirez, S. G., Hales, R. C., Williams, G. P., & Jones, N. L. (2022). Extending SC-PDSI-PM with neural network regression using GLDAS data and Permutation Feature Importance. *Environmental Modelling & Software*, 105475. <https://doi.org/10.1016/j.envsoft.2022.105475>
 29. Hales, R. C., Nelson, E. J., Souffront, M., Gutierrez, A. L., Prudhomme, C., Kopp, S., Ames, D. P., Williams, G. P., & Jones, N. L. (2022) Advancing global hydrologic modeling with the GEOGloWS ECMWF streamflow service. *Journal of Flood Risk Management*, e12859. <https://doi.org/10.1111/jfr3.12859>
 30. Ramirez, S.G.; Williams, G.P.; Jones, N.L. (2022) Groundwater Level Data Imputation Using Machine Learning and Remote Earth Observations Using Inductive Bias. *Remote Sens.* 2022, 14, 5509. <https://doi.org/10.3390/rs14215509>
 31. Jones, J.E.; Hales, R.C.; Larco, K.; Nelson, E.J.; Ames, D.P.; Jones, N.L.; Iza, M. (2023) Building and Validating Multidimensional Datasets in Hydrology for Data and Mapping Web Service Compliance. *Water* 2023, 15, 411. <https://doi.org/10.3390/w15030411>
 32. Ramirez, S.G.; Williams, G.P.; Jones, N.L.; Ames, D.P.; Radebaugh, J. (2023) Improving Groundwater Imputation through Iterative Refinement Using Spatial and Temporal Correlations from In Situ Data with Machine Learning. *Water* 2023, 15, 1236. <https://doi.org/10.3390/w15061236>
 33. Jones, N.L. and Mayo, A.L. (2023), Urban Thirst and Rural Water – The Saga of the Southern Nevada Groundwater Development Project. *Groundwater*. <https://doi.org/10.1111/gwat.13364>
 34. Barbosa, S.A.; Jones, N.L.; Williams, G.P.; Mamane, B.; Begou, J.; Nelson, E.J.; Ames, D.P. (2023) Exploiting Earth Observations to Enable Groundwater Modeling in the Data-Sparse Region of Goulbi Maradi, Niger. *Remote Sens.* 2023, 15,

5199. <https://doi.org/10.3390/rs15215199>
35. Sanchez Lozano, J. L., Rojas Lesmes, D. J., Romero Bustamante, E. G., Hales, R. C., Nelson, E. J., Williams, G. P., Ames, D. P., Jones, N. L., Gutierrez, A. L., & Cardona Almeida, C. (2025). Historical simulation performance evaluation and monthly flow duration curve quantile-mapping (MFDC-QM) of the GEOGLOWS ECMWF streamflow hydrologic model. *Environmental Modelling & Software*, 183, 106235. <https://doi.org/10.1016/j.envsoft.2024.106235>

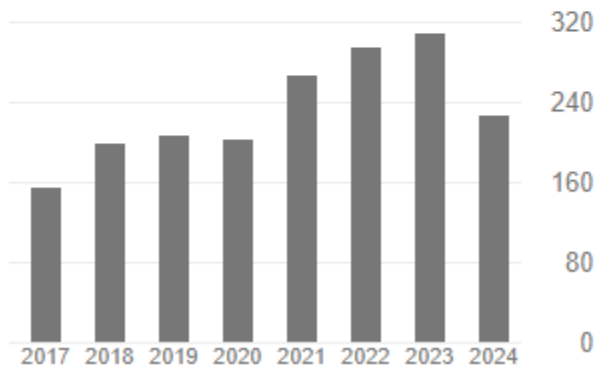
Summary: 88 total peer-reviewed publications.

Books

Strassberg, G., Jones, N., Maidment, D. (2011). Arc Hydro Groundwater: GIS for Hydrology. ESRI Press, Redlands, California, 250 pp.

Google Scholar Metrics

	All	Since 2019
Citations	3287	1507
h-index	27	19
i10-index	51	30



Complete CV: <https://www.et.byu.edu/~njones/vita/>

Appendix A

Updated Tables and Figures

Table A1. Observed and Simulated PCE Concentrations at Monitoring Well Locations (Compare to Table 5 in Post-Audit Report)

Date	Monitoring Well	PCE Observed Concentration (µg/L)	PCE Simulated Concentration (µg/L)	Error	Absolute Error
2/1/2000	C1	<DL	0.04	0.04	0.04
5/1/2002	C1	<DL	0.03	0.03	0.03
8/1/2002	C1	<DL	0.03	0.03	0.03
11/1/2002	C1	<DL	0.03	0.03	0.03
3/1/2003	C1	<DL	0.03	0.03	0.03
3/1/2004	C1	<DL	0.03	0.03	0.03
3/1/2005	C1	<DL	0.03	0.03	0.03
3/1/2006	C1	<DL	0.02	0.02	0.02
2/1/2007	C1	<DL	0.02	0.02	0.02
3/1/2008	C1	<DL	0.02	0.02	0.02
6/1/1997	C2	<DL	1316.4	1316.4	1316.4
2/1/2000	C2	<DL	900.8	900.8	900.8
5/1/2002	C2	1	580.6	579.6	579.6
8/1/2002	C2	<DL	548.86	548.86	548.86
11/1/2002	C2	<DL	518.92	518.92	518.92
3/1/2003	C2	<DL	482.65	482.65	482.65
3/1/2004	C2	<DL	389.28	389.28	389.28
3/1/2005	C2	<DL	321.59	321.59	321.59
3/1/2006	C2	1.4	261.33	259.93	259.93
2/1/2007	C2	<DL	214.18	214.18	214.18
3/1/2008	C2	<DL	176.88	176.88	176.88
6/1/1997	C3	580	434.52	-145.48	145.48
2/1/2000	C3	410	439.84	29.84	29.84
5/1/2002	C3	270	307.28	37.28	37.28
8/1/2002	C3	140	290.84	150.84	150.84
11/1/2002	C3	100	275.9	175.9	175.9
3/1/2003	C3	150	258.55	108.55	108.55
3/1/2004	C3	58	218.29	160.29	160.29
3/1/2005	C3	37	201.45	164.45	164.45
3/1/2006	C3	38	177.93	139.93	139.93
2/1/2007	C3	23	153.16	130.16	130.16
3/1/2008	C3	22	148.59	126.59	126.59
6/1/1997	C4	<DL	1.96	1.96	1.96
2/1/2000	C4	<DL	2.32	2.32	2.32
1/1/2002	C4	<DL	1.9	1.9	1.9
5/1/2002	C4	<DL	1.85	1.85	1.85
8/1/2002	C4	<DL	1.81	1.81	1.81
11/1/2002	C4	<DL	1.78	1.78	1.78
3/1/2003	C4	<DL	1.74	1.74	1.74
3/1/2004	C4	<DL	1.64	1.64	1.64
3/1/2005	C4	<DL	1.62	1.62	1.62
3/1/2006	C4	0.51	1.54	1.03	1.03
2/1/2007	C4	<DL	1.47	1.47	1.47
3/1/2008	C4	<DL	1.38	1.38	1.38
6/1/1997	C5	<DL	1326.87	1326.87	1326.87
2/1/2000	C5	<DL	1190.26	1190.26	1190.26
5/1/2002	C5	<DL	1009.86	1009.86	1009.86
8/1/2002	C5	<DL	985.68	985.68	985.68

Table A1. Observed and Simulated PCE Concentrations at Monitoring Well Locations (Compare to Table 5 in Post-Audit Report)

Date	Monitoring Well	PCE Observed Concentration (µg/L)	PCE Simulated Concentration (µg/L)	Error	Absolute Error
11/1/2002	C5	<DL	961.76	961.76	961.76
3/1/2003	C5	<DL	931.03	931.03	931.03
3/1/2004	C5	<DL	839.91	839.91	839.91
3/1/2005	C5	<DL	772.91	772.91	772.91
3/1/2006	C5	<DL	690.68	690.68	690.68
2/1/2007	C5	<DL	613.37	613.37	613.37
3/1/2008	C5	<DL	551.21	551.21	551.21
6/1/1997	C9	<DL	0.06	0.06	0.06
2/1/2000	C9	<DL	0.16	0.16	0.16
5/1/2002	C9	1	0.18	-0.82	0.82
8/1/2002	C9	<DL	0.18	0.18	0.18
11/1/2002	C9	0.48	0.18	-0.3	0.3
3/1/2003	C9	<DL	0.18	0.18	0.18
3/1/2004	C9	1.9	0.18	-1.72	1.72
3/1/2005	C9	7.4	0.19	-7.21	7.21
3/1/2006	C9	18	0.19	-17.81	17.81
2/1/2007	C9	20	0.18	-19.82	19.82
3/1/2008	C9	18	0.17	-17.83	17.83
6/1/1997	C10	<DL	222.31	222.31	222.31
2/1/2000	C10	<DL	199.93	199.93	199.93
5/1/2002	C10	<DL	73.7	73.7	73.7
8/1/2002	C10	<DL	69.19	69.19	69.19
11/1/2002	C10	0.16	65.02	64.86	64.86
3/1/2003	C10	<DL	60.18	60.18	60.18
3/1/2004	C10	<DL	49.48	49.48	49.48
3/1/2005	C10	<DL	40.32	40.32	40.32
3/1/2006	C10	<DL	38.86	38.86	38.86
2/1/2007	C10	0.48	35.65	35.17	35.17
3/1/2008	C10	<DL	30.46	30.46	30.46
1/1/2002	C12	15	190.3	175.3	175.3
5/1/2002	C12	7	188.12	181.12	181.12
8/1/2002	C12	1.7	186.68	184.98	184.98
11/1/2002	C12	<DL	185.33	185.33	185.33
3/1/2003	C12	<DL	183.96	183.96	183.96
3/1/2004	C12	<DL	182.37	182.37	182.37
3/1/2005	C12	<DL	181.97	181.97	181.97
3/1/2006	C12	<DL	178.52	178.52	178.52
2/1/2007	C12	<DL	169.07	169.07	169.07
3/1/2008	C12	<DL	157.22	157.22	157.22
1/1/2002	C13	5400	15.21	-5384.79	5384.79
5/1/2002	C13	140	14.7	-125.3	125.3
8/1/2002	C13	68	14.34	-53.66	53.66
11/1/2002	C13	44	13.98	-30.02	30.02
3/1/2003	C13	6	13.57	7.57	7.57
3/1/2004	C13	3	12.66	9.66	9.66
3/1/2005	C13	2.8	11.81	9.01	9.01
3/1/2006	C13	2.5	11.1	8.6	8.6

Table A1. Observed and Simulated PCE Concentrations at Monitoring Well Locations (Compare to Table 5 in Post-Audit Report)

Date	Monitoring Well	PCE Observed Concentration (µg/L)	PCE Simulated Concentration (µg/L)	Error	Absolute Error
2/1/2007	C13	2.7	10.12	7.42	7.42
3/1/2008	C13	7.8	8.83	1.03	1.03
3/1/2005	C14	1800	2.5	-1797.5	1797.5
3/1/2006	C14	1300	2.48	-1297.52	1297.52
2/1/2007	C14	320	2.37	-317.63	317.63
3/1/2008	C14	120	2.17	-117.83	117.83
2/1/2007	C15-D	1.9	0	-1.9	1.9
3/1/2008	C15-D	0.27	0	-0.27	0.27
2/1/2007	C15-S	3.8	0.7	-3.1	3.1
3/1/2008	C15-S	3.8	0.72	-3.08	3.08
2/1/2007	C16	0.36	1.06	0.7	0.7
3/1/2008	C16	<DL	1.12	1.12	1.12
2/1/2007	C17-D	0.77	0.15	-0.62	0.62
3/1/2008	C17-D	<DL	0.18	0.18	0.18
2/1/2007	C17-S	1.2	0.15	-1.05	1.05
3/1/2008	C17-S	0.19	0.18	-0.01	0.01
2/1/2007	C18	0.41	57.22	56.81	56.81
3/1/2008	C18	0.84	57.87	57.03	57.03
6/1/1997	FWC-11	<DL	840.57	840.57	840.57
2/1/2000	FWC-11	<DL	815.82	815.82	815.82
1/1/2002	FWC-11	<DL	760.83	760.83	760.83
5/1/2002	FWC-11	<DL	746.89	746.89	746.89
8/1/2002	FWC-11	<DL	736.19	736.19	736.19
11/1/2002	FWC-11	<DL	725.49	725.49	725.49
3/1/2003	FWC-11	<DL	711.68	711.68	711.68
3/1/2004	FWC-11	<DL	670.83	670.83	670.83
3/1/2005	FWC-11	<DL	641.83	641.83	641.83
3/1/2006	FWC-11	<DL	601.95	601.95	601.95
2/1/2007	FWC-11	<DL	556.03	556.03	556.03
3/1/2008	FWC-11	<DL	514.79	514.79	514.79
6/1/1997	FWS-12	230	605.2	375.2	375.2
2/1/2000	FWS-12	190	607.3	417.3	417.3
1/1/2002	FWS-12	100	362.09	262.09	262.09
5/1/2002	FWS-12	92	340.91	248.91	248.91
8/1/2002	FWS-12	90	323.49	233.49	233.49
11/1/2002	FWS-12	67	306.42	239.42	239.42
3/1/2003	FWS-12	96	285.52	189.52	189.52
3/1/2004	FWS-12	100	236.65	136.65	136.65
3/1/2005	FWS-12	64	226.34	162.34	162.34
3/1/2006	FWS-12	30	194.09	164.09	164.09
2/1/2007	FWS-12	26	131.8	105.8	105.8
3/1/2008	FWS-12	12	94.64	82.64	82.64
6/1/1997	FWS-13	<DL	1215.23	1215.23	1215.23
2/1/2000	FWS-13	<DL	1107.38	1107.38	1107.38
1/1/2002	FWS-13	1	959.83	958.83	958.83
5/1/2002	FWS-13	3	917.47	914.47	914.47
8/1/2002	FWS-13	1.2	883.55	882.35	882.35

Table A1. Observed and Simulated PCE Concentrations at Monitoring Well Locations (Compare to Table 5 in Post-Audit Report)

Date	Monitoring Well	PCE Observed Concentration (µg/L)	PCE Simulated Concentration (µg/L)	Error	Absolute Error
11/1/2002	FWS-13	2.9	848.85	845.95	845.95
3/1/2003	FWS-13	2	802.06	800.06	800.06
3/1/2004	FWS-13	<DL	658.46	658.46	658.46
3/1/2005	FWS-13	1.9	543.52	541.62	541.62
3/1/2006	FWS-13	4.2	429.96	425.76	425.76
2/1/2007	FWS-13	1.5	341.03	339.53	339.53
3/1/2008	FWS-13	0.86	259.6	258.74	258.74
5/1/2002	RWC-1	155	360.92	205.92	205.92
8/1/2002	RWC-1	360	356.8	-3.2	3.2
11/1/2002	RWC-1	29	352.36	323.36	323.36
3/1/2003	RWC-1	22	346.48	324.48	324.48
3/1/2004	RWC-1	17	329.75	312.75	312.75
3/1/2005	RWC-1	5	316.15	311.15	311.15
3/1/2006	RWC-1	1.9	298.96	297.06	297.06
2/1/2007	RWC-1	12	270	258	258
3/1/2008	RWC-1	9.1	246.9	237.8	237.8
2/1/2000	RWC-2	1800	124.38	-1675.62	1675.62
1/1/2002	RWC-2	1350	102.55	-1247.45	1247.45
5/1/2002	RWC-2	1700	98.4	-1601.6	1601.6
8/1/2002	RWC-2	2300	95.58	-2204.42	2204.42
11/1/2002	RWC-2	2000	92.98	-1907.02	1907.02
3/1/2003	RWC-2	2000	90.16	-1909.84	1909.84
3/1/2004	RWC-2	2200	84.29	-2115.71	2115.71
3/1/2005	RWC-2	1400	76.21	-1323.79	1323.79
3/1/2006	RWC-2	1800	75.2	-1724.8	1724.8
2/1/2007	RWC-2	2300	69.28	-2230.72	2230.72
3/1/2008	RWC-2	2100	60.39	-2039.61	2039.61
5/1/2002	RWS-1A	8	380.65	372.65	372.65
8/1/2002	RWS-1A	<DL	342.01	342.01	342.01
11/1/2002	RWS-1A	5	308.75	303.75	303.75
3/1/2003	RWS-1A	6	270.86	264.86	264.86
3/1/2004	RWS-1A	2.6	187.28	184.68	184.68
3/1/2005	RWS-1A	2	141.68	139.68	139.68
3/1/2006	RWS-1A	1.8	111.86	110.06	110.06
2/1/2007	RWS-1A	2.7	93.16	90.46	90.46
3/1/2008	RWS-1A	2.1	56.99	54.89	54.89
5/1/2002	RWS-2A	79	609.72	530.72	530.72
1/1/2002	RWS-2A	17	697.9	680.9	680.9
8/1/2002	RWS-2A	290	554.12	264.12	264.12
11/1/2002	RWS-2A	98	505.35	407.35	407.35
3/1/2003	RWS-2A	170	450	280	280
3/1/2004	RWS-2A	40	322.81	282.81	282.81
3/1/2005	RWS-2A	42	231.7	189.7	189.7
3/1/2006	RWS-2A	50	195.03	145.03	145.03
2/1/2007	RWS-2A	15	155.12	140.12	140.12
3/1/2008	RWS-2A	16	105.2	89.2	89.2
1/1/2002	RWS-3A	760	734.63	-25.37	25.37

Table A1. Observed and Simulated PCE Concentrations at Monitoring Well Locations (Compare to Table 5 in Post-Audit Report)

Date	Monitoring Well	PCE Observed Concentration (µg/L)	PCE Simulated Concentration (µg/L)	Error	Absolute Error
5/1/2002	RWS-3A	920	685.63	-234.37	234.37
8/1/2002	RWS-3A	970	647.45	-322.55	322.55
11/1/2002	RWS-3A	500	609.53	109.53	109.53
3/1/2003	RWS-3A	810	562.36	-247.64	247.64
3/1/2004	RWS-3A	280	435.76	155.76	155.76
3/1/2005	RWS-3A	560	342.42	-217.58	217.58
3/1/2006	RWS-3A	280	277.36	-2.64	2.64
2/1/2007	RWS-3A	260	213.69	-46.31	46.31
3/1/2008	RWS-3A	160	157.95	-2.05	2.05
1/1/2002	RWS-4A	280	413.29	133.29	133.29
5/1/2002	RWS-4A	6900	406.97	-6493.03	6493.03
8/1/2002	RWS-4A	3700	399.1	-3300.9	3300.9
11/1/2002	RWS-4A	3100	389.75	-2710.25	2710.25
3/1/2003	RWS-4A	1100	377.41	-722.59	722.59
3/1/2004	RWS-4A	<DL	337.47	337.47	337.47
3/1/2005	RWS-4A	1000	276.72	-723.28	723.28
3/1/2006	RWS-4A	92	251.29	159.29	159.29
2/1/2007	RWS-4A	1600	209.57	-1390.43	1390.43
3/1/2008	RWS-4A	1900	157.5	-1742.5	1742.5
6/1/1997	S1	5.6	0.11	-5.49	5.49
2/1/2000	S1	<DL	0.06	0.06	0.06
5/1/2002	S1	<DL	0.03	0.03	0.03
8/1/2002	S1	<DL	0.03	0.03	0.03
11/1/2002	S1	0.32	0.03	-0.29	0.29
3/1/2003	S1	<DL	0.02	0.02	0.02
3/1/2004	S1	<DL	0.02	0.02	0.02
3/1/2005	S1	<DL	0.01	0.01	0.01
3/1/2006	S1	<DL	0.01	0.01	0.01
2/1/2007	S1	<DL	0.01	0.01	0.01
3/1/2008	S1	<DL	0.01	0.01	0.01
6/1/1997	S2	<DL	207.79	207.79	207.79
2/1/2000	S2	520	95.18	-424.82	424.82
5/1/2002	S2	340	38.63	-301.37	301.37
8/1/2002	S2	110	34.41	-75.59	75.59
11/1/2002	S2	67	30.73	-36.27	36.27
3/1/2003	S2	100	26.65	-73.35	73.35
3/1/2004	S2	50	18.16	-31.84	31.84
3/1/2005	S2	35	13.62	-21.38	21.38
3/1/2006	S2	38	10.18	-27.82	27.82
2/1/2007	S2	22	7.79	-14.21	14.21
3/1/2008	S2	20	6.57	-13.43	13.43
6/1/1997	S3	77	1321.69	1244.69	1244.69
2/1/2000	S3	12	1001.42	989.42	989.42
5/1/2002	S3	23	451.57	428.57	428.57
8/1/2002	S3	54	397.13	343.13	343.13
11/1/2002	S3	60	352.03	292.03	292.03
3/1/2003	S3	48	303.81	255.81	255.81

Table A1. Observed and Simulated PCE Concentrations at Monitoring Well Locations (Compare to Table 5 in Post-Audit Report)

Date	Monitoring Well	PCE Observed Concentration (µg/L)	PCE Simulated Concentration (µg/L)	Error	Absolute Error
3/1/2004	S3	53	207.92	154.92	154.92
3/1/2005	S3	47	167.82	120.82	120.82
3/1/2006	S3	23	119.56	96.56	96.56
2/1/2007	S3	85	91.67	6.67	6.67
3/1/2008	S3	94	82.39	-11.61	11.61
6/1/1997	S4	<DL	102.72	102.72	102.72
2/1/2000	S4	<DL	121.75	121.75	121.75
3/1/2004	S4	<DL	29.29	29.29	29.29
3/1/2005	S4	<DL	22.94	22.94	22.94
3/1/2006	S4	<DL	16.81	16.81	16.81
2/1/2007	S4	<DL	13.37	13.37	13.37
3/1/2008	S4	<DL	10.24	10.24	10.24
6/1/1997	S5	<DL	1773.95	1773.95	1773.95
2/1/2000	S5	<DL	1136.51	1136.51	1136.51
5/1/2002	S5	<DL	584.04	584.04	584.04
8/1/2002	S5	<DL	534.73	534.73	534.73
11/1/2002	S5	1	489.23	488.23	488.23
3/1/2003	S5	<DL	434.22	434.22	434.22
3/1/2004	S5	<DL	295.95	295.95	295.95
3/1/2005	S5	<DL	216.07	216.07	216.07
3/1/2006	S5	<DL	150.33	150.33	150.33
2/1/2007	S5	<DL	109.32	109.32	109.32
3/1/2008	S5	<DL	80.8	80.8	80.8
6/1/1997	S6	<DL	21.11	21.11	21.11
2/1/2000	S6	<DL	10.5	10.5	10.5
8/1/2002	S6	<DL	4.26	4.26	4.26
11/1/2002	S6	0.2	3.85	3.65	3.65
3/1/2003	S6	<DL	3.38	3.38	3.38
3/1/2004	S6	<DL	2.35	2.35	2.35
3/1/2005	S6	<DL	1.73	1.73	1.73
3/1/2006	S6	<DL	1.28	1.28	1.28
2/1/2007	S6	<DL	0.97	0.97	0.97
3/1/2008	S6	<DL	0.74	0.74	0.74
6/1/1997	S7	<DL	134.14	134.14	134.14
8/1/2002	S7	<DL	23.27	23.27	23.27
11/1/2002	S7	<DL	20.84	20.84	20.84
3/1/2003	S7	0.5	18.07	17.57	17.57
3/1/2004	S7	<DL	11.97	11.97	11.97
3/1/2005	S7	<DL	8.59	8.59	8.59
3/1/2006	S7	1.9	6.02	4.12	4.12
2/1/2007	S7	<DL	4.38	4.38	4.38
3/1/2008	S7	<DL	3.64	3.64	3.64
6/1/1997	S8	<DL	27.91	27.91	27.91
2/1/2000	S8	<DL	22.16	22.16	22.16
5/1/2002	S8	<DL	9.98	9.98	9.98
8/1/2002	S8	<DL	8.89	8.89	8.89
11/1/2002	S8	<DL	7.93	7.93	7.93

Table A1. Observed and Simulated PCE Concentrations at Monitoring Well Locations (Compare to Table 5 in Post-Audit Report)

Date	Monitoring Well	PCE Observed Concentration (µg/L)	PCE Simulated Concentration (µg/L)	Error	Absolute Error
3/1/2003	S8	<DL	6.85	6.85	6.85
3/1/2004	S8	<DL	4.54	4.54	4.54
3/1/2005	S8	<DL	3.2	3.2	3.2
3/1/2006	S8	<DL	2.16	2.16	2.16
2/1/2007	S8	<DL	1.46	1.46	1.46
3/1/2008	S8	<DL	1.01	1.01	1.01
6/1/1997	S9	<DL	57.92	57.92	57.92
2/1/2000	S9	<DL	73.25	73.25	73.25
5/1/2002	S9	<DL	35.02	35.02	35.02
8/1/2002	S9	<DL	31.03	31.03	31.03
11/1/2002	S9	<DL	27.5	27.5	27.5
3/1/2003	S9	<DL	23.55	23.55	23.55
3/1/2004	S9	<DL	15.17	15.17	15.17
3/1/2005	S9	<DL	11.39	11.39	11.39
3/1/2006	S9	<DL	7.41	7.41	7.41
2/1/2007	S9	<DL	4.68	4.68	4.68
3/1/2008	S9	<DL	3.25	3.25	3.25
6/1/1997	S10	<DL	505.27	505.27	505.27
2/1/2000	S10	<DL	503.55	503.55	503.55
1/1/2002	S10	<DL	484.38	484.38	484.38
5/1/2002	S10	<DL	477.98	477.98	477.98
8/1/2002	S10	<DL	473.09	473.09	473.09
11/1/2002	S10	0.16	468.13	467.97	467.97
3/1/2003	S10	<DL	461.09	461.09	461.09
3/1/2004	S10	<DL	438.9	438.9	438.9
3/1/2005	S10	<DL	418.76	418.76	418.76
3/1/2006	S10	<DL	390.31	390.31	390.31
2/1/2007	S10	0.74	360.66	359.92	359.92
3/1/2008	S10	<DL	330.09	330.09	330.09
6/1/1997	S11	<DL	<DL	0	0
2/1/2000	S11	<DL	<DL	0	0
3/1/2005	S14	<DL	10.43	10.43	10.43
3/1/2006	S14	<DL	8.57	8.57	8.57
2/1/2007	S14	0.47	6.94	6.47	6.47
3/1/2008	S14	<DL	5.34	5.34	5.34

Notes:

<DL = sample result reported below the detection limit
PCE = tetrachloroethylene

Table A2. Mean Error and Mean Absolute Error for Monitoring Wells (Compare to Table 6 in Post-Audit Report)

Monitoring Well	Model Layer	Mean Error	Mean Absolute Error	Mean Absolute Error Category
C1	3	0	0	0-200
C2	3	519	519	500-2000
C3	3	98	124.5	0-200
C4	5	1.7	1.7	0-200
C5	3	897.6	897.6	500-2000
C9	3	-5.9	6	0-200
C10	5	80.4	80.4	0-200
C12	3	178	178	0-200
C13	3	-555	563.7	500-2000
C14	3	-882.6	882.6	500-2000
C15-D	3	-1.1	1.1	0-200
C15-S	3	-3.1	3.1	0-200
C16	3	0.9	0.9	0-200
C17-D	3	-0.2	0.4	0-200
C17-S	3	-0.5	0.5	0-200
C18	3	56.9	56.9	0-200
FWC-11	3	693.6	693.6	500-2000
FWS-12	1	218.1	218.1	200-500
FWS-13	1	745.7	745.7	500-2000
RWC-1	3	251.9	252.6	200-500
RWC-2	3	-1816.4	1816.4	500-2000
RWS-1A	1	207	207	200-500
RWS-2A	1	301	301	200-500
RWS-3A	1	-83.3	136.4	0-200
RWS-4A	1	-1645.3	1771.3	500-2000
S1	1	-0.5	0.5	0-200
S2	1	-73.8	111.6	0-200
S3	1	356.5	358.6	200-500
S4	1	45.3	45.3	0-200
S5	1	527.7	527.7	500-2000
S6	1	5	5	0-200
S7	1	25.4	25.4	0-200
S8	1	8.7	8.7	0-200
S9	1	26.4	26.4	0-200
S10	1	442.6	442.6	200-500
S11	1	0	0	0-200
S14	1	7.7	7.7	0-200

N:\GIS\Projects\4000 to 4999\CFR265 CompleteGroundwater BLG\Production Maps\US Phase1 Rebuttal\US Phase1 Rebuttal.aprx Layout Name: Figure A1 PCE 1994 Contour 1/10/2025 11:54 AM

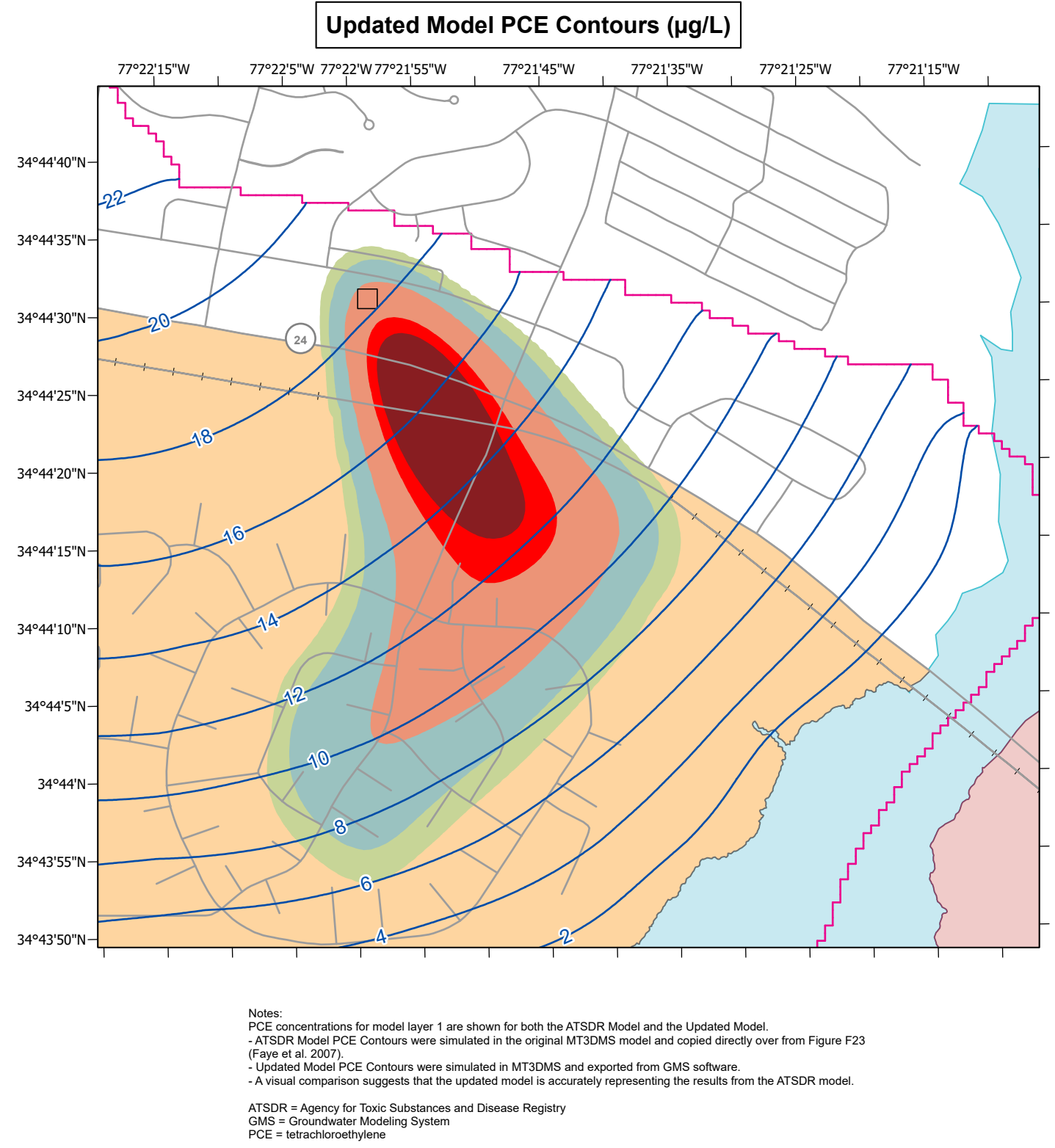
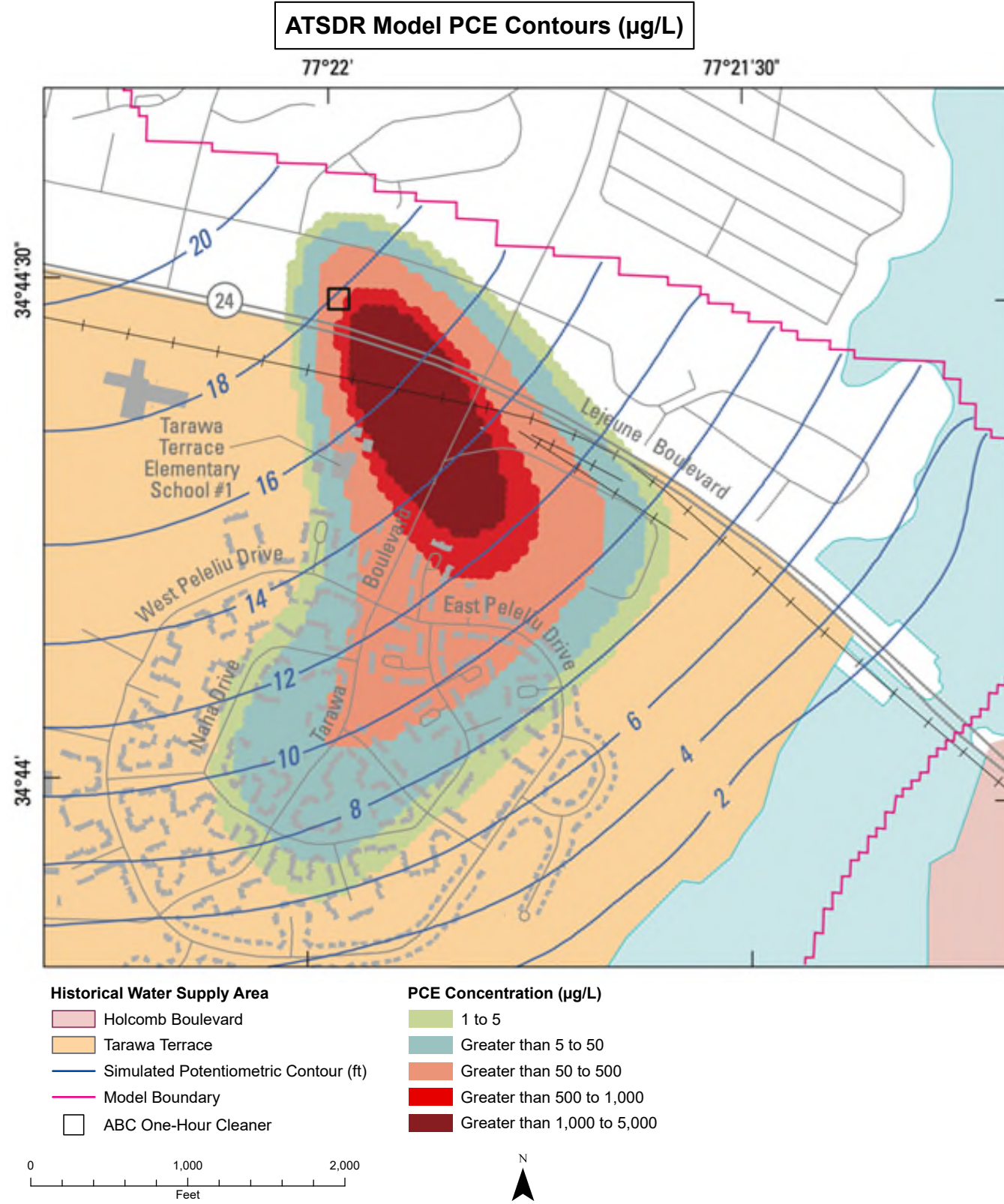
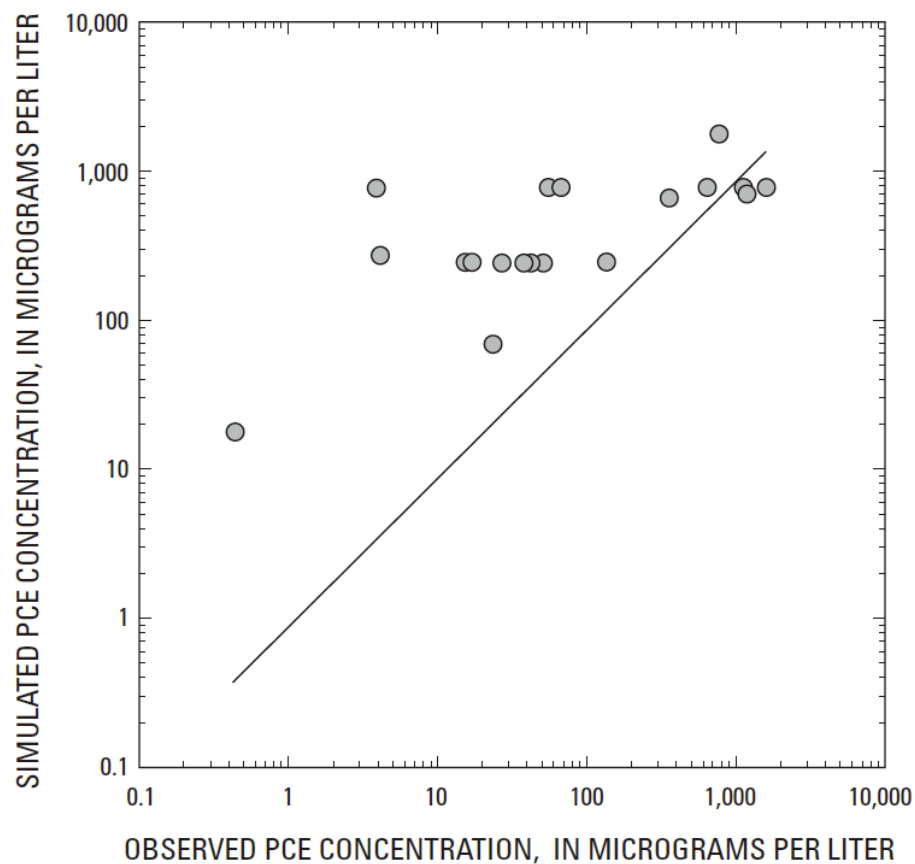
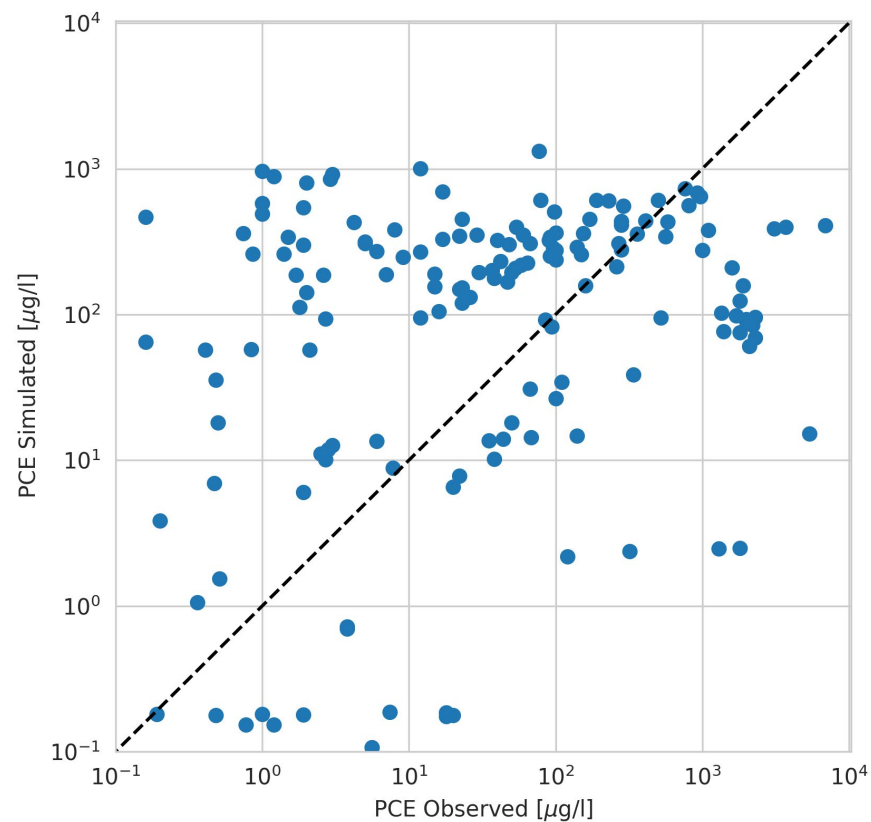


Figure A1.
Comparison of Original Model-Simulated PCE Concentrations (Compare to Figure 2 in Post-Audit Report) to Updated Model-Simulated PCE Concentrations
Rebuttal Report Regarding Tarawa Terrace Flow and Transport Model Post-Audit
Appendix A

Original Model



Updated Post-Audit Report



Notes:
 The Original Model results are from (Maslia et al. 2007).
 The Post-Audit results were shown in Figure 5 of Jones and Davis (2024).
 PCE = tetrachloroethylene



Figure A2.
 Simulated vs. Observed PCE Concentrations
 (Compare to Figure 6 in Post-Audit Report)
 Rebuttal Report Regarding Tarawa Terrace Flow and
 Transport Model Post-Audit
 Appendix A

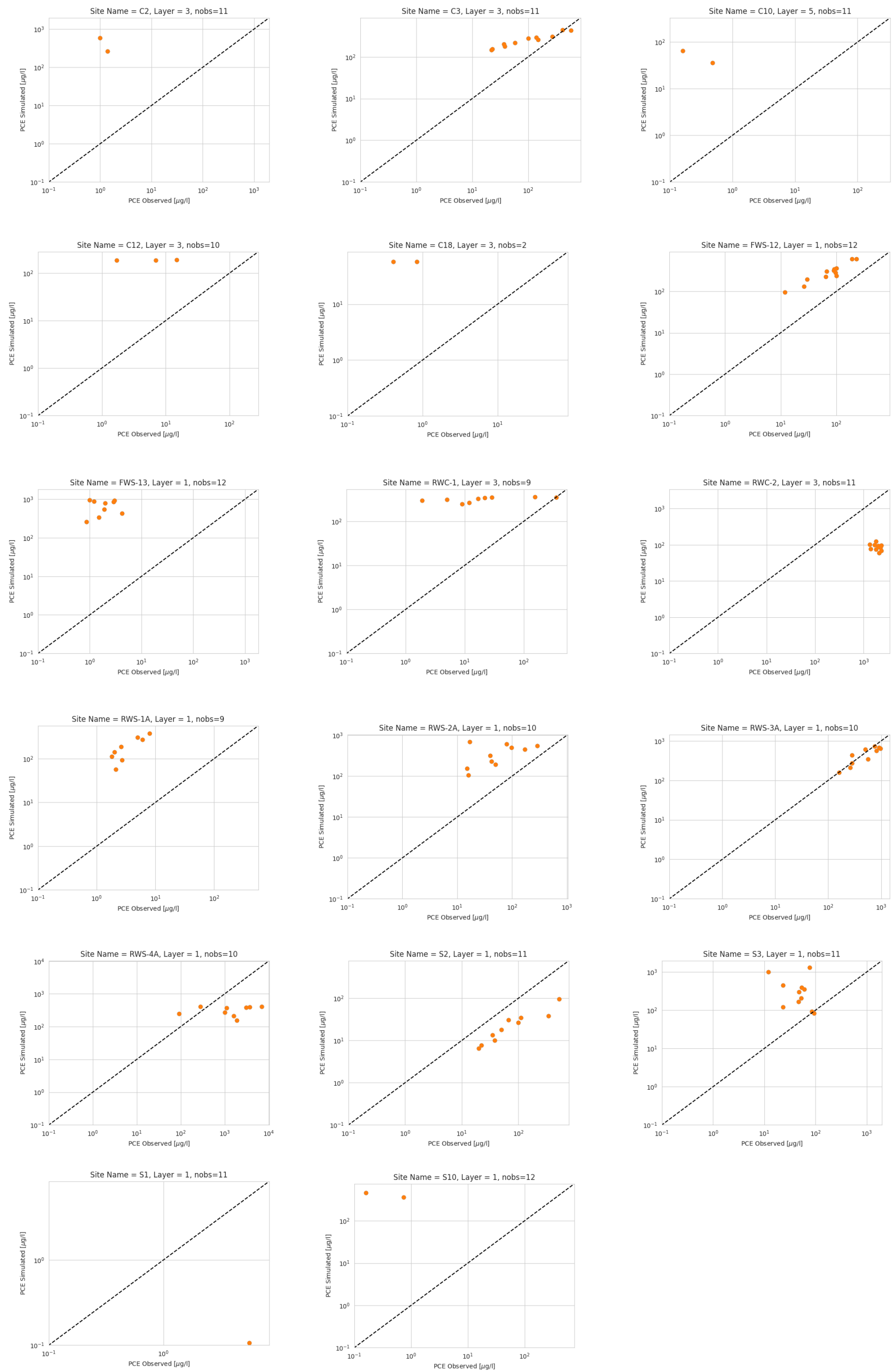


Figure A3.
Simulated vs. Observed PCE Concentrations
(Compare to Figure 7 in Post-Audit Report)
Rebuttal Report Regarding Tarawa Terrace Flow and
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Appendix A



Figure A4.
Time Series Plots of Simulated and Observed PCE Concentrations
(Compare to Figure 8 in Post-Audit Report)
Rebuttal Report Regarding Tarawa Terrace Flow and Transport
Model Post-Audit
Appendix A

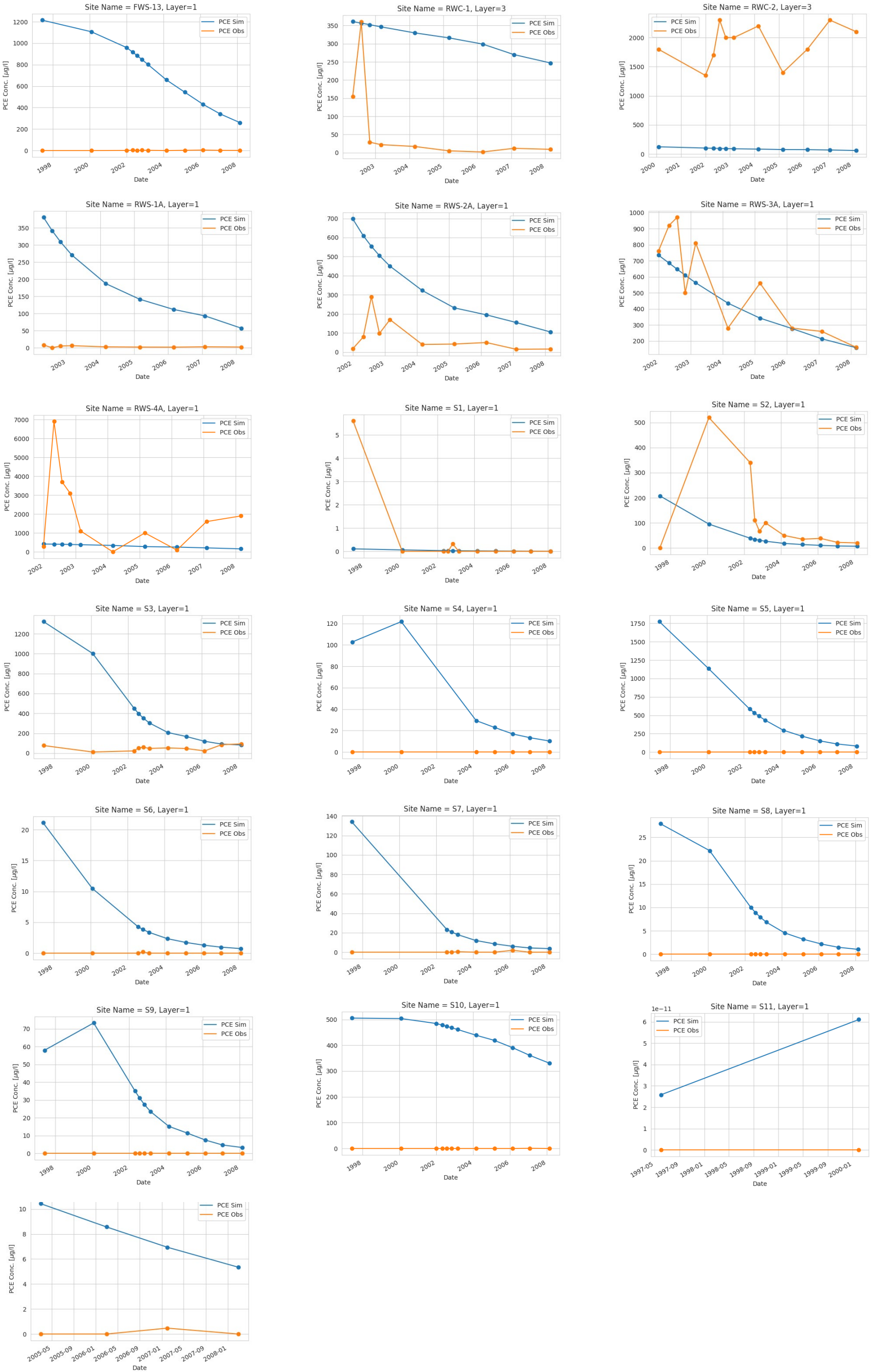


Figure A4.
Time Series Plots of Simulated and Observed PCE Concentrations
(Compare to Figure 8 in Post-Audit Report)
Rebuttal Report Regarding Tarawa Terrace Flow and Transport
Model Post-Audit
Appendix A

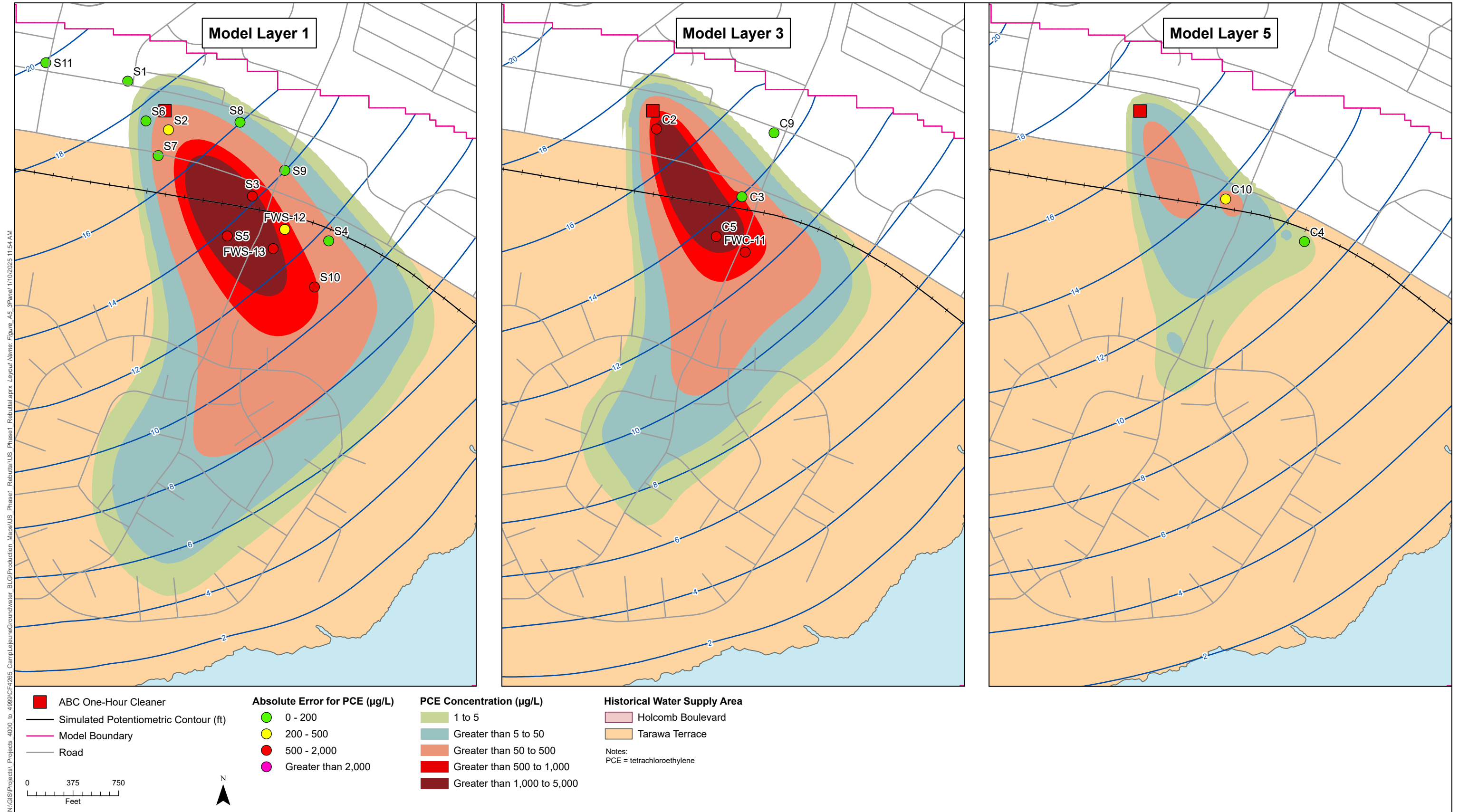


Figure A5.
Simulated PCE Concentration for Three Model Layers Compared to Measured Values, June 1997 (Compare to Figure 9 in Post-Audit Report) Rebuttal Report Regarding Tarawa Terrace Flow and Transport Model Post-Audit Appendix A

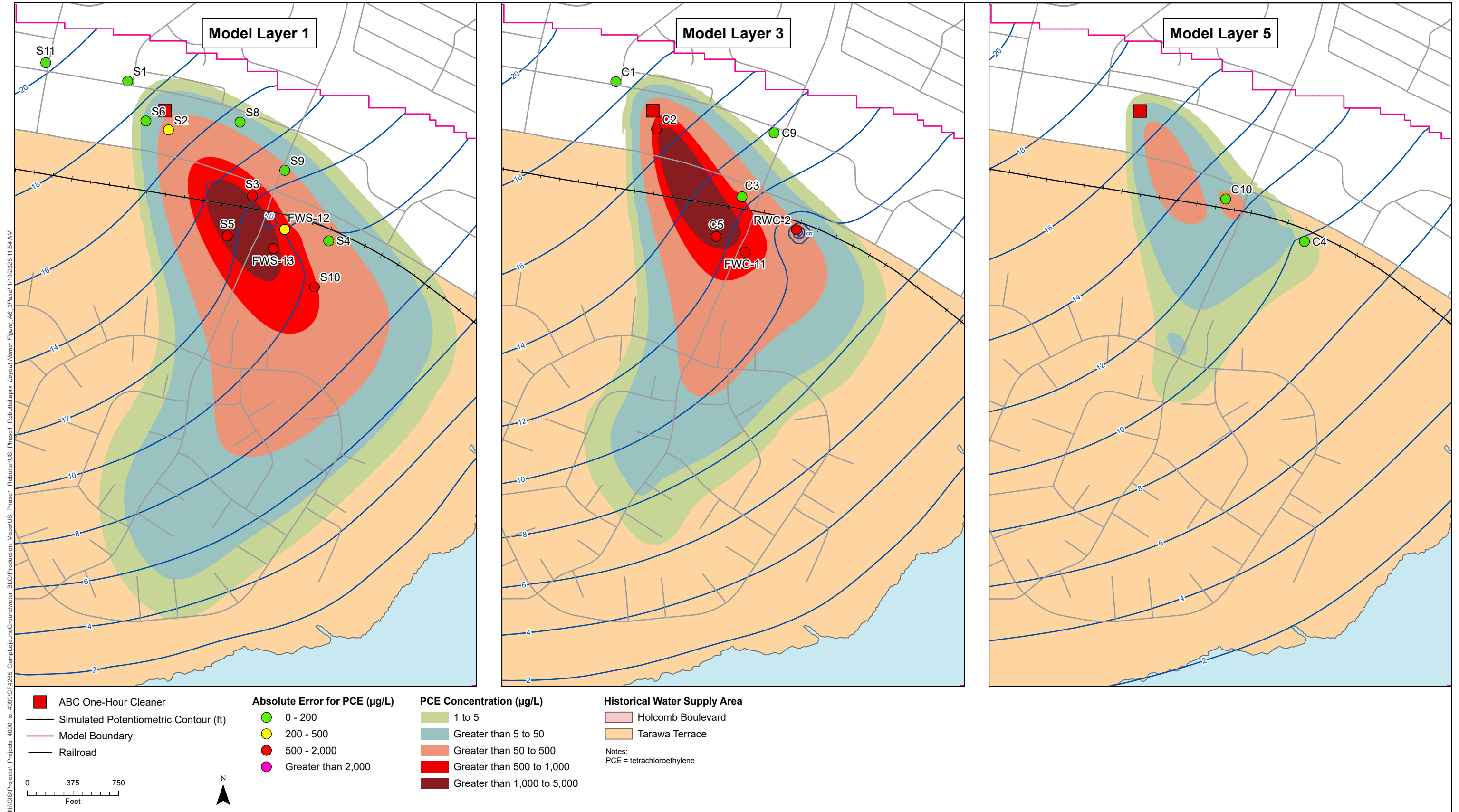


Figure A6.
Simulated PCE Concentration for Three Model Layers Compared to Measured Values, February 2000 (Compare to Figure 10 in Post-Audit Report) Rebuttal Report Regarding Tarawa Terrace Flow and Transport Model Post-Audit Appendix A

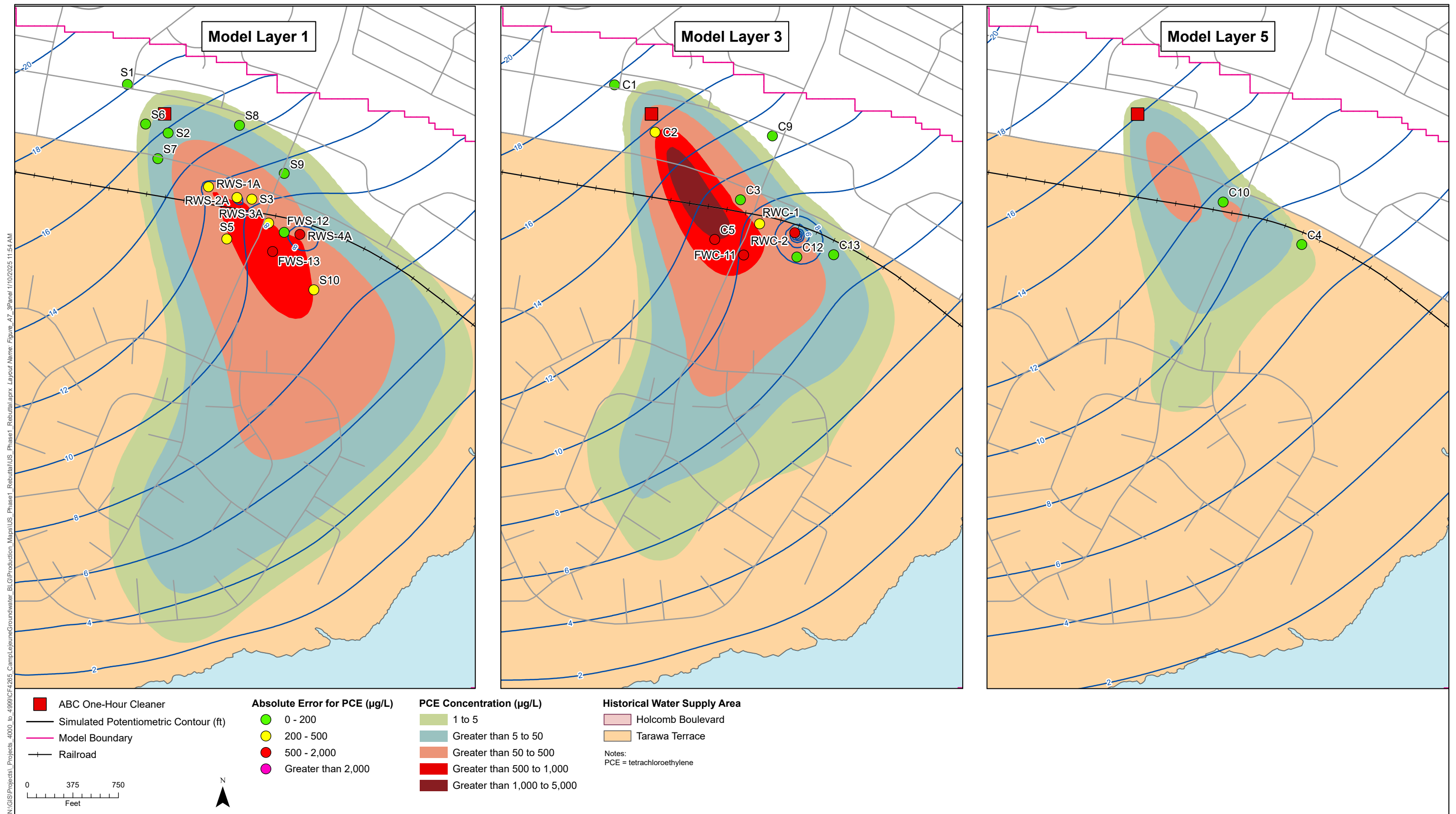


Figure A7.
 Simulated PCE Concentration for Three Model Layers
 Compared to Measured Values, March 2003
 (Compare to Figure 11 in Post-Audit Report)
 Rebuttal Report Regarding Tarawa Terrace Flow and
 Transport Model Post-Audit
 Appendix A

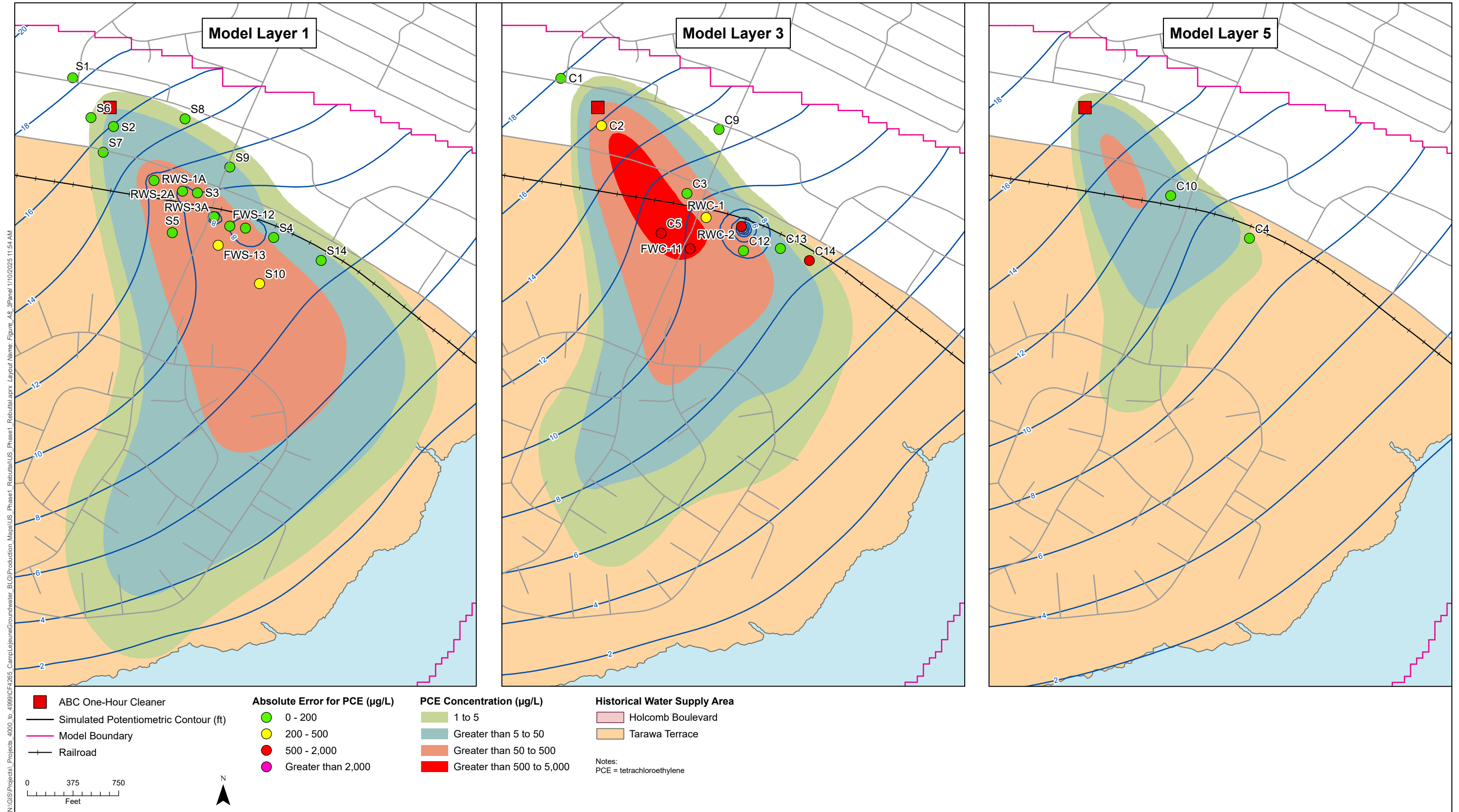


Figure A8.
 Simulated PCE Concentration for Three Model Layers
 Compared to Measured Values, March 2006
 (Compare to Figure 12 in Post-Audit Report)
 Rebuttal Report Regarding Tarawa Terrace Flow and
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 Appendix A

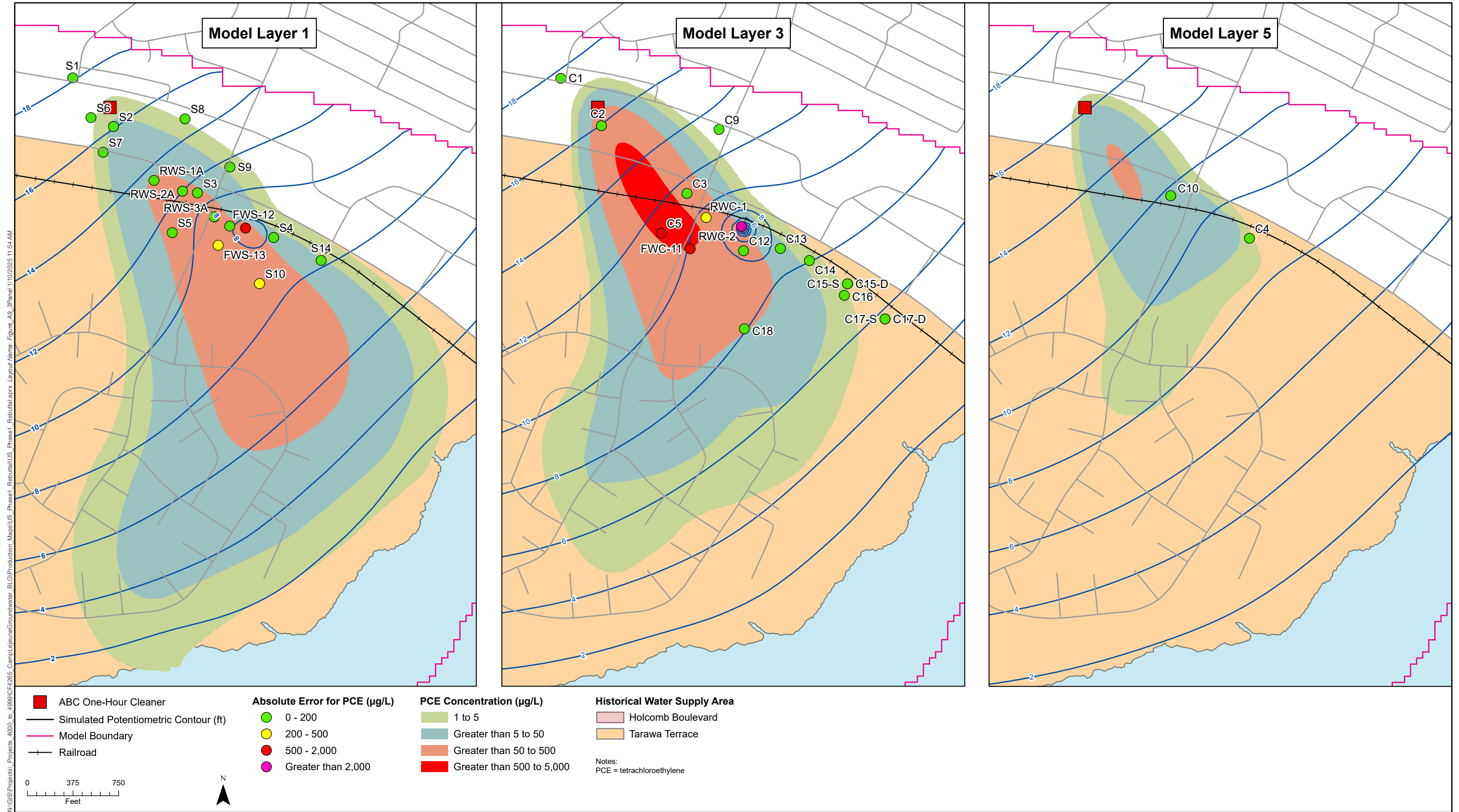
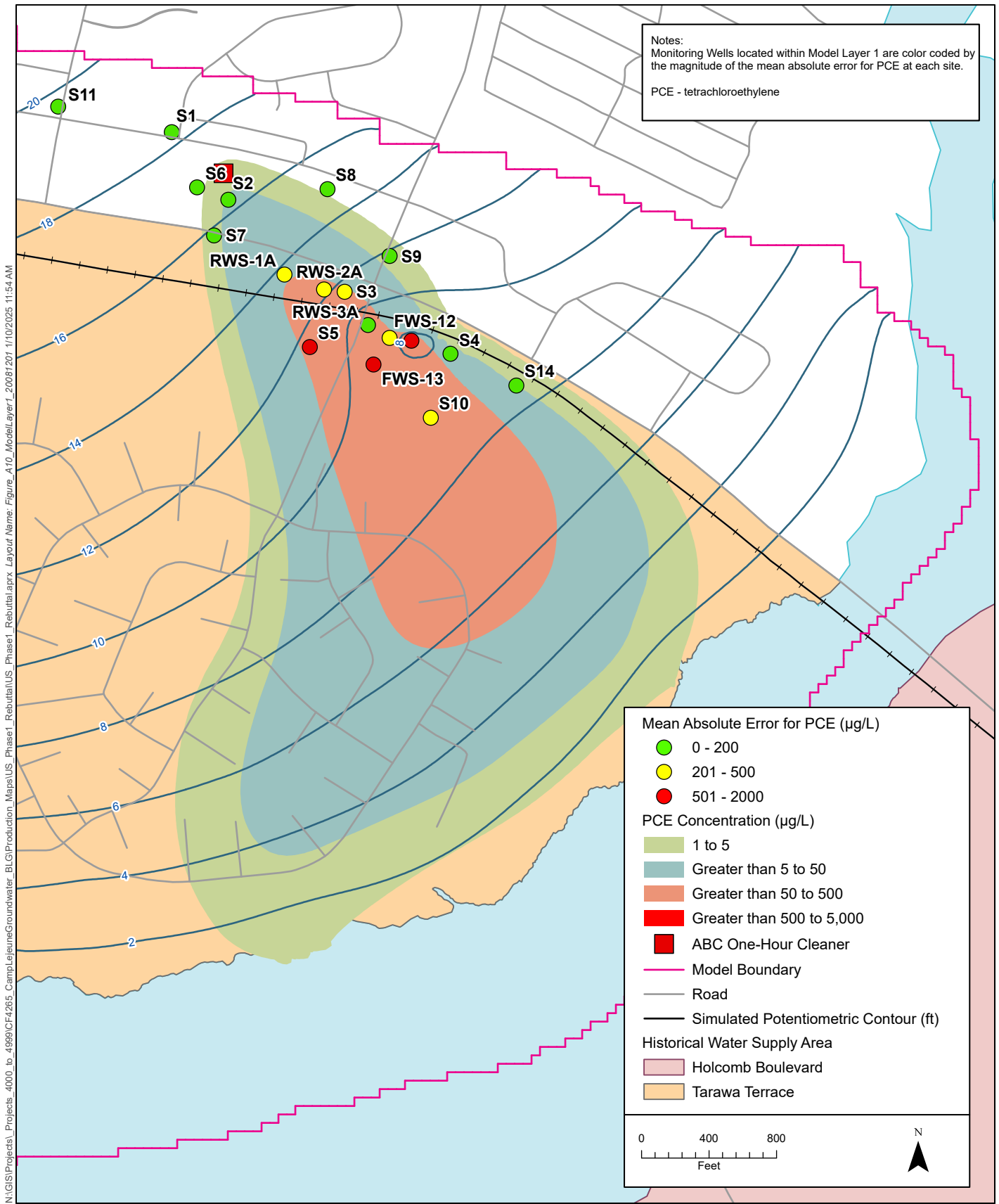
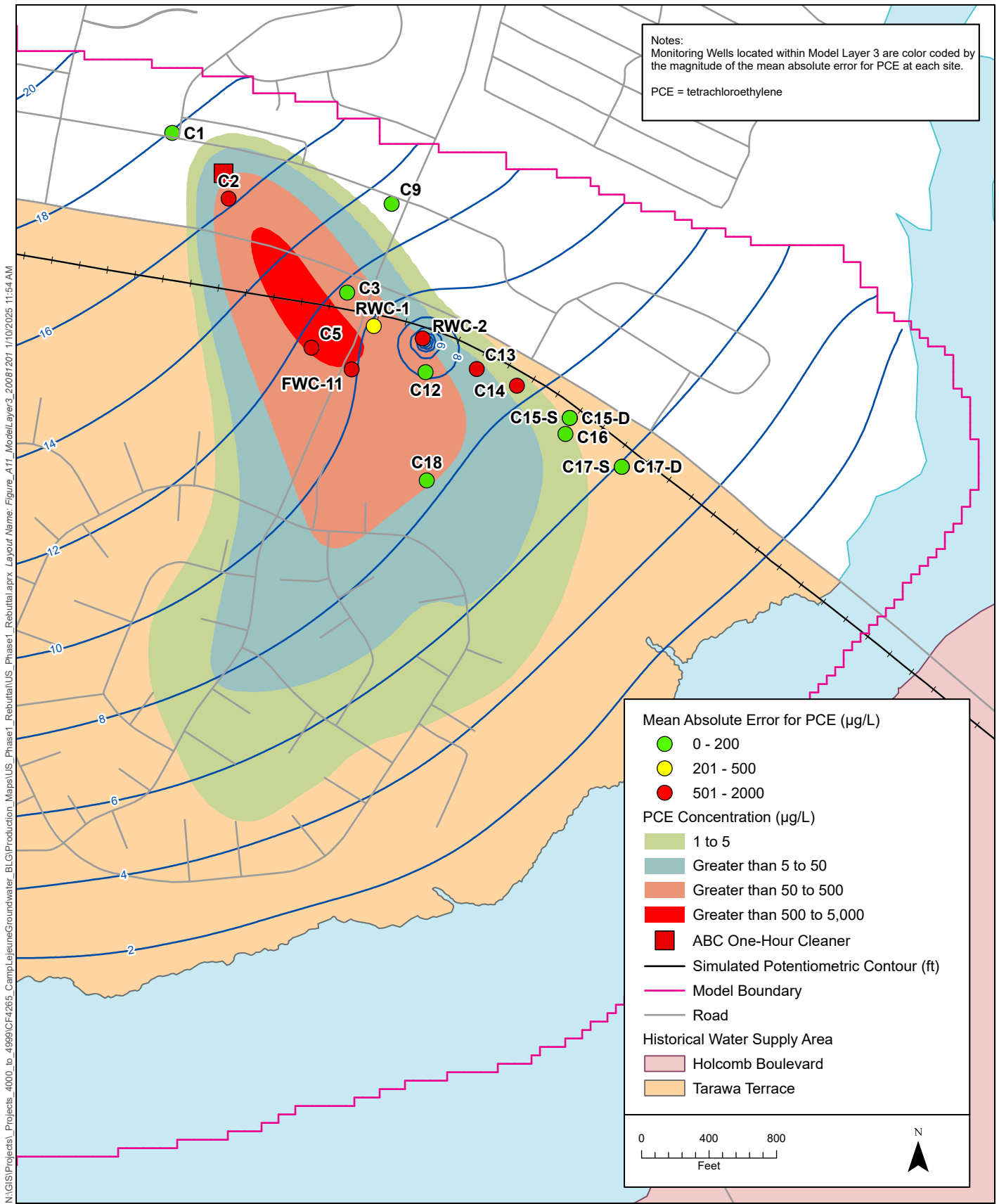


Figure A9.
Simulated PCE Concentration for Three Model Layers Compared to Measured Values, March 2008
(Compare to Figure 13 in Post-Audit Report)
Rebuttal Report Regarding Tarawa Terrace Flow and Transport Model Post-Audit
Appendix A





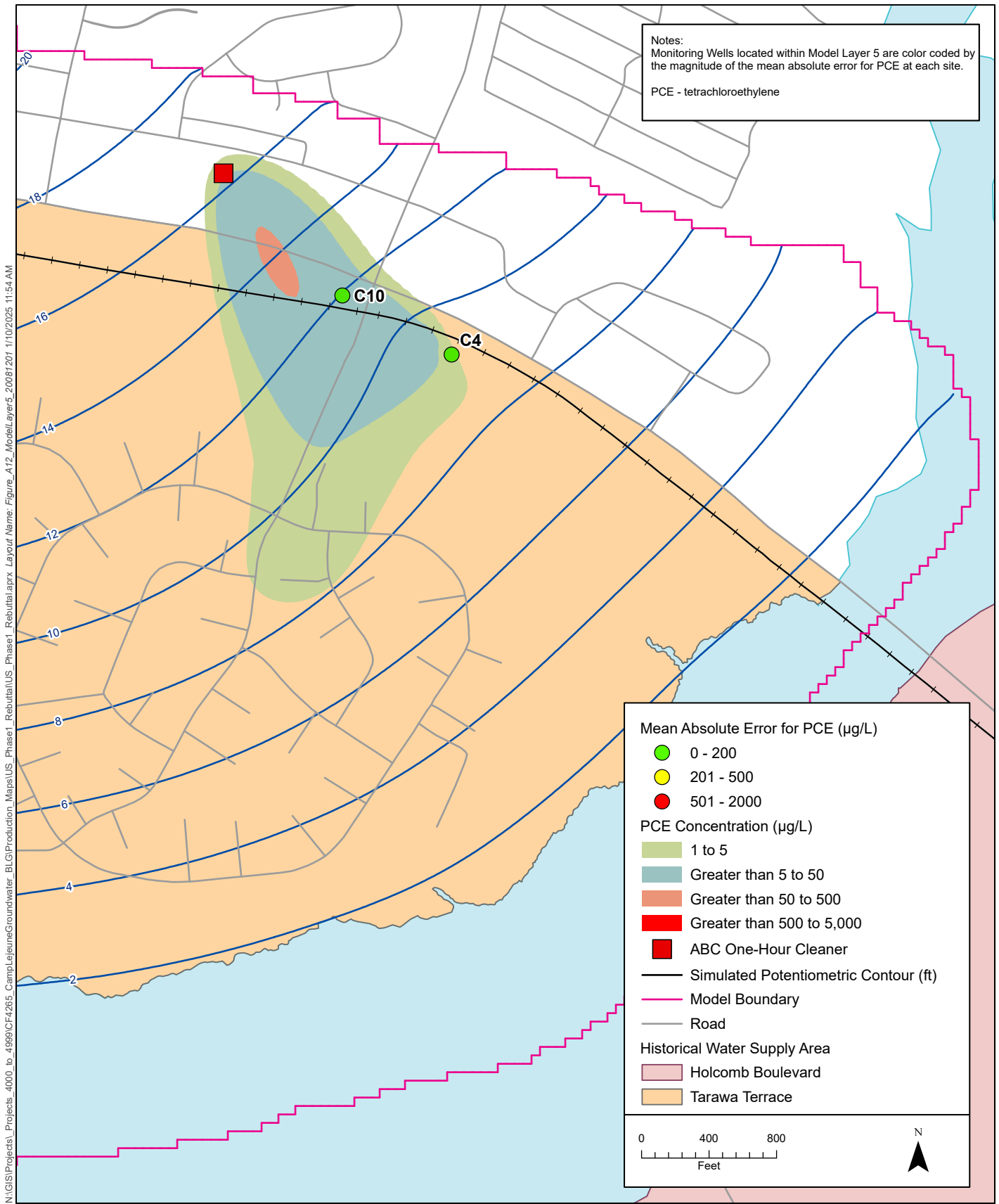


Figure A12.
Simulated PCE Plume for December 2008 for Model Layer 5
(Compare to Figure 16 in Post-Audit Report)
Rebuttal Report Regarding Tarawa Terrace Flow and
Transport Model Post-Audit
Appendix A