

In cooperation with the
United States Air Force
Dover Air Force Base

Analytical Results From Ground-Water Sampling Using a Direct-Push Technique at the Dover National Test Site, Dover Air Force Base, Delaware, June–July 2001

Open-File Report 03-380

Analytical Results From Ground-Water Sampling Using a Direct-Push Technique at the Dover National Test Site, Dover Air Force Base, Delaware, June–July 2001

by

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United States Air Force
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U.S. Department of the Interior

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U.S. Geological Survey

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Conversion Factors and Vertical Datum

Multiply	By	To obtain
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
gallon	3.785	liter (L)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$^{\circ}\text{F} = (1.8 \times ^{\circ}\text{C}) + 32$$

Vertical datum: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929—a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C).

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L).

Acronyms and Abbreviations

°C	degrees Celsius	mg/L	milligram per liter
<i>cis</i> -1,2-DCE	<i>cis</i> -1,2-dichloroethene	mL	milliliter
DAFB	Dover Air Force Base	msl	mean sea level
DI	de-ionized	MTBE	methyl <i>tert</i> -butyl ether
DNAPL	dense non-aqueous phase liquids	ND	not detected
DNTS	Dover National Test Site	PCE	tetrachloroethene
DO	dissolved oxygen	QC	quality control
ft	feet	SERDP	Strategic Environmental Research and Development Program
ft bls	feet below land surface	TCE	trichloroethene
ft msl	feet mean sea level	USEPA	U.S. Environmental Protection Agency
GRFL	Groundwater Remediation Field Laboratory	USGS	U.S. Geological Survey
MCL	maximum contaminant level	VOC	volatile organic compound
MDL	method detection limit	µg/L	microgram per liter
MRL	method reporting limit	µS/cm	microsiemens per centimeter at 25 °Celsius

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Abstract

A joint study by the Dover National Test Site and the U.S. Geological Survey was conducted from June 27 through July 18, 2001 to determine the spatial distribution of the gasoline oxygenate additive methyl *tert*-butyl ether and selected water-quality constituents in the surficial aquifer underlying the Dover National Test Site at Dover Air Force Base, Delaware. The study was conducted to support a planned enhanced bio-remediation demonstration and to assist the Dover National Test Site in identifying possible locations for future methyl *tert*-butyl ether remediation demonstrations.

This report presents the analytical results from ground-water samples collected during the direct-push ground-water sampling study. A direct-push drill rig was used to quickly collect 115 ground-water samples over a large area at varying depths. The ground-water samples and associated quality-control samples were analyzed for volatile organic compounds and methyl *tert*-butyl ether by the Dover National Test Site analytical laboratory.

Volatile organic compounds were above the method reporting limits in 59 of the 115 ground-water samples. The concentrations ranged from below detection limits to maximum values of 12.4 micrograms per liter of *cis*-1,2-dichloroethene, 1.14 micrograms per liter of trichloroethene, 2.65 micrograms per liter of tetrachloroethene, 1,070 micrograms per liter of methyl *tert*-butyl ether, 4.36 micrograms per liter of benzene, and 1.8 micrograms per liter of toluene. Vinyl chloride, ethylbenzene, *p,m*-xylene, and *o*-xylene were not detected in any of the samples collected during this investigation. Methyl *tert*-butyl ether was detected in 47 of the 115 ground-water samples. The highest methyl *tert*-butyl ether

concentrations were found in the surficial aquifer from -4.6 to 6.4 feet mean sea level, however, methyl *tert*-butyl ether was detected as deep as -9.5 feet mean sea level. Increased methane concentrations and decreased dissolved oxygen concentrations were found in samples that contained methyl *tert*-butyl ether.

Introduction

Dover Air Force Base (DAFB) in Dover, Delaware was selected as the site for the Strategic Environmental Research and Development Program's (SERDP) Ground-Water Remediation Field Laboratory (GRFL). The GRFL is also known as the Dover National Test Site (DNTS), and is one of the National Environmental Technology Test Sites, which was established and funded by SERDP. The purpose of the DNTS is to investigate technologies for detecting and remediating chlorinated solvent source areas under controlled experimental conditions.

In 1999, a study was conducted by the Air Force Center for Environmental Excellence (AFCEE) to evaluate natural attenuation of ground water contaminated by petroleum hydrocarbons for the Installation Restoration Program Site SS27/XYZ, which is located near the DNTS (Air Force Center for Environmental Excellence, 1999). During that study, the gasoline oxygenate additive methyl *tert*-butyl ether (MTBE) was detected in the ground-water samples collected from monitoring wells located on and near the DNTS property. Concentrations ranged from 10.9 to 1,430 µg/L (micrograms per liter) of MTBE.

The U.S. Geological Survey (USGS) is providing continuing technical assistance on ground-water quality issues for DNTS. The USGS assesses ground-water flow in the surficial aquifer, and assists the DNTS in providing support to principal investigators who are developing and field-testing technologies for the characterization and cleanup of soil and ground water contaminated with solvents, fuels, and the fuel additive MTBE. As part of this support, the USGS conducted a plume-mapping study to better determine the distribution of MTBE at the site.

The objectives of this study were to determine the distribution of organic contaminants in the surficial aquifer, and to use this information to improve existing conceptual models and plan additional site-characterization work. Data collection was based on field-screening methodologies that are appropriate for plume mapping. The analytical data obtained during this investigation are consistent with U.S. Environmental Protection Agency (USEPA) analytical level III (U.S. Environmental Protection Agency, 1989). This level refers to laboratory analyses performed in accordance with standard USEPA procedures, and is appropriate for site characterization. In addition, the intended use of these data was to identify ground-water areas contaminated with MTBE near the DNTS to host potential demonstrations of MTBE remedial technologies.

Purpose and Scope

From June 27 through July 18, 2001, the USGS conducted a plume-mapping study to assist the DNTS in determining the distribution of MTBE and in identifying possible locations for a planned enhanced bioremediation demonstration and other future MTBE demonstrations. The purpose of this report is to present the analytical results from ground-water samples collected during this direct-push ground-water sampling study. The ground-water samples and associated quality-control (QC) samples were analyzed for volatile organic compounds (VOCs), MTBE, and selected field constituents by the DNTS analytical laboratory.

Description of Study Area

The DNTS is located in the northwestern corner of DAFB, Dover, Delaware (figs. 1a–1c). It is designed to support the needs of principal investigators developing and field-testing remediation technologies for the clean-up of soil and ground water contaminated with fuels and solvents. The primary focus of the DNTS is field-testing of technologies that remediate dense non-aqueous phase liquids (DNAPLs). The DNTS maintains the capability to conduct contained releases of DNAPLs into the surficial aquifer (Air Force Center for Environmental Excellence, 1999).

The DAFB is in the Coastal Plain Physiographic Province, and is underlain by unconsolidated clastic sedimentary deposits. These deposits are comprised of medium to fine sands that contain lenses of gravels, silts, and clays, and are collectively known as the Columbia Formation. Deposits in the area of the DNTS are between 36 and 47 ft (feet) thick (Dames and Moore, Inc., 2000). Underlying these deposits is an approximately 28-ft-thick unit of gray, firm, dense marine clay known as the Calvert Formation. This unit is an aquitard for the Columbia aquifer, which is an unconfined surficial aquifer (Dames and Moore, Inc., 2000).

Acknowledgments

The authors would like to thank Dale Williams of the Groundwater Remediation Field Laboratory, Dover National Test Site for the VOC analyses and project support. In addition, the authors thank the following U.S. Geological Survey personnel: Pat Mills for direct-push drilling support;



Figure 1a. Location of Dover Air Force Base and the Delaware Coastal Plain, Delaware.

William Stearns, Al Ruddy, and Pradumna Neupane for assisting in the collection of the water-quality samples; Kristen Alexander for field analyses for irons, nitrates, and sulfates; Jonathan Dillow for collection of water-level data and surveying; Lisa Olsen and Tracey Spencer for the methane analyses; Valerie Gaine for editorial review; and Timothy Auer for graphics. In addition, the authors would like to thank Cherie Miller and Michael Moran of the U.S. Geological Survey for their technical reviews.

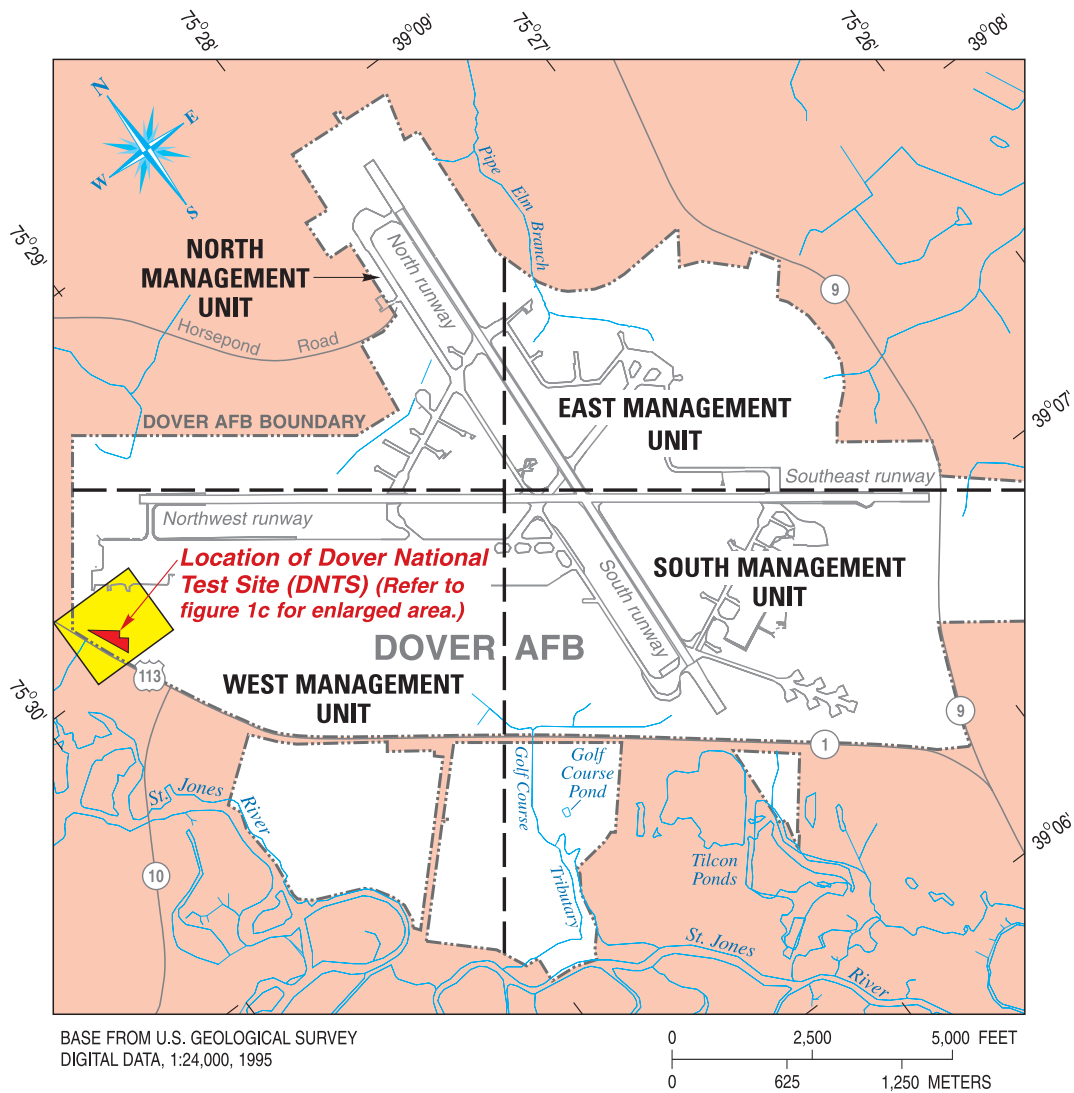


Figure 1b. Location of Dover National Test Site (DNTS) at Dover Air Force Base, Delaware.

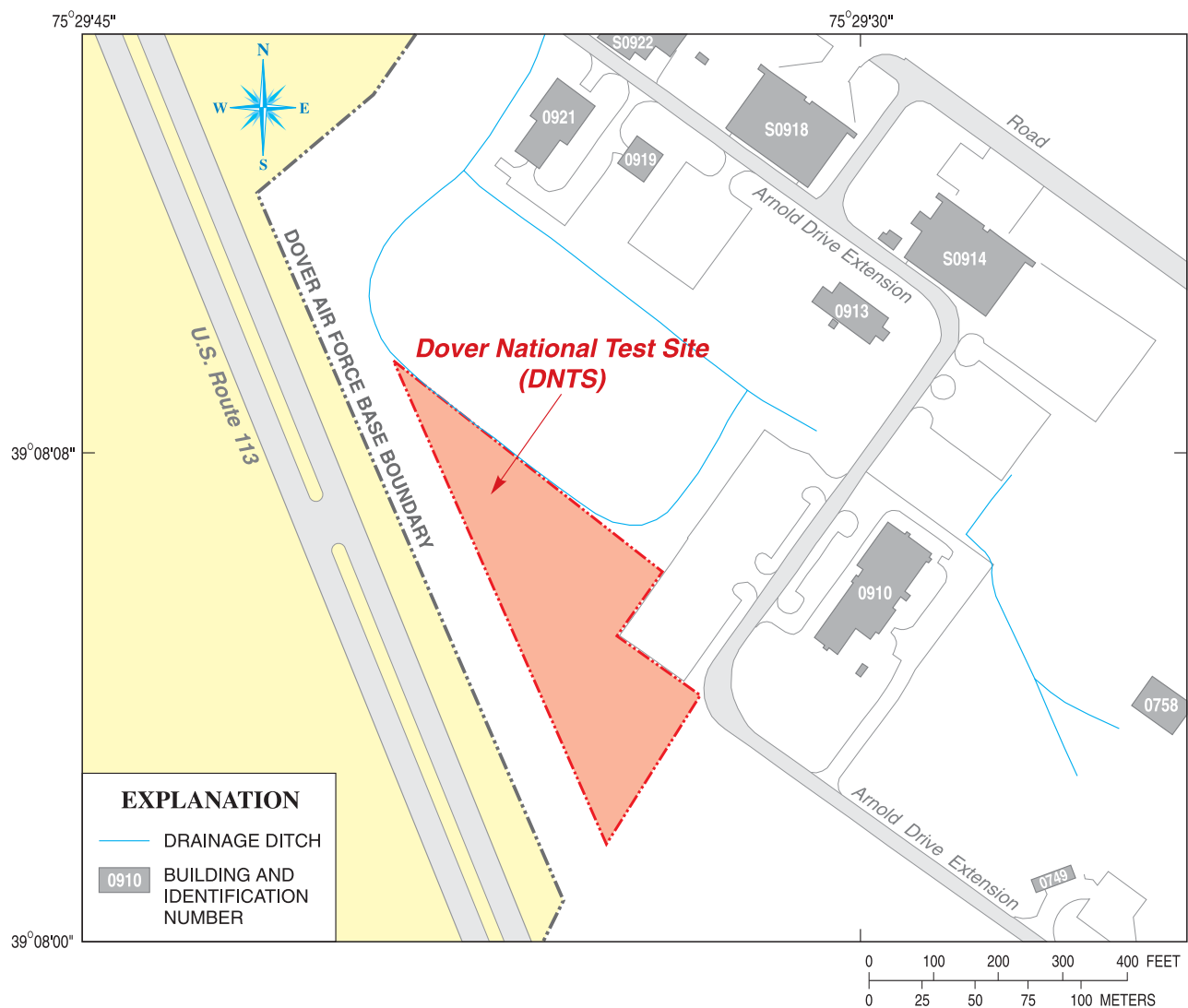


Figure 1c. Location of Dover National Test Site (DNTS) boundaries, Dover Air Force Base, Delaware.

Methods of Investigation

Data collection was based on field-screening methodologies commonly used for plume mapping. The study focused on the measurement of the geochemical conditions that could potentially affect the natural attenuation of MTBE at the DNTS. In addition, the degradation of VOCs can affect the geochemical conditions in the surficial aquifer. To determine geochemical conditions in the surficial aquifer, concentrations of dissolved oxygen (DO), ferrous and total iron, sulfate, and sulfide were measured in most ground-water samples. Methane was analyzed in selected ground-water samples.

Drilling

Drilling was performed with a direct-push Geoprobe drilling rig. The drilling rods (1.5-inch outer diameter by 0.625-inch inner diameter) were pushed into the ground with a hydraulically powered percussion machine until the deepest sample depth was reached. A 4-ft stainless steel well screen was then exposed for ground-water sample collection. After the sample was collected, the drilling rod with the exposed screen was pulled up to the next sample depth; as the exposed screen is pulled up, the hole below the screen collapses. At each drilling location, the deepest samples were typically collected from 36–40 ft below ground surface, then about every 8 ft moving upward. The final sample for each borehole was obtained near the water table. Each sample identification number includes the borehole number and an alphabetical suffix to indicate the depth of the sample, where “A” represents the deepest sample. The aquifer is predominantly sand and smearing of contamination is not an issue of concern. The screen, rod, and all drilling equipment that could potentially come in contact with the sample were thoroughly cleaned with soap and de-ionized (DI) water, then rinsed with DI water between each sample location.

The direct-push locations were used only to collect ground-water samples, and no permanent wells were installed. This drilling method did not generate any cuttings or fluids. Each borehole was backfilled to ground surface with bentonite grout. After the study was completed, all drilling locations were surveyed for spatial position and ground-surface altitude.

Ground-Water Sample Collection

A total of 147 ground-water samples (115 VOC samples and 32 quality-assurance samples) were collected from various depths at 48 locations at the DNTS (fig. 2). Field constituents were measured using a Hydrolab when there was sufficient ground-water yield. The Hydrolab is a multiprobe meter that was connected to a flow-through cell on the discharge line of a peristaltic pump. Purging was stopped when temperature, pH, DO, and specific conductance stabilized. At 11 of the 115 VOC sample intervals, there was insufficient yield for the collection of field constituents. In addition, selected samples were analyzed in the field for ferrous and total iron, sulfate, sulfite, and methane.

A peristaltic pump equipped with a short piece of silicone pump tubing was used for purging and sampling. Reusable 1/4-inch-diameter Teflon tubing in line with the pump was placed downhole to collect the ground-water samples. Three drops of concentrated hydrochloric acid were used as a sample preservative for all field blanks and ground-water samples, which were collected in 40-mL (milliliter) VOC septum vials with no headspace. The ground-water samples were analyzed for tetrachloroethene (PCE), trichloroethene (TCE), *cis*-1,2-dichloroethene (*cis*-1,2-DCE), vinyl chloride, MTBE, benzene, toluene, ethylbenzene, and the xylene isomers.

Because reusable sample tubing was used at each sampling location, it was decontaminated between samples to avoid cross-contamination. After samples were collected, the outside of the tubing was washed using soapy DI water. In addition, soapy DI water was pumped through the tubing for approximately 2–3 minutes using a peristaltic pump. A new piece of flexible tubing was used with the peristaltic pump for each sample.

Quality-Control Samples and Methods

The QC sample group consisted of 14 field blanks (DI water samples collected after the field sampling equipment is cleaned), 10 sequential duplicate samples (sequential aquifer water samples), 7 screen blanks (DI water samples collected after the drilling equipment is cleaned) and 1 equipment blank (a DI water sample collected from the equipment at the start of the study). Field blanks are clean samples that are collected after field equipment is cleaned to verify that the cleaning methods were performed correctly. Field blanks were collected to check the effectiveness of the sample tubing cleaning procedure. The flexible tubing on the peristaltic pump was replaced before each sample location and the Teflon tubing was cleaned. The field blank was collected using the peristaltic pump, the new piece of flexible tubing, and the clean Teflon tubing. The 10 duplicate samples were collected in a separate VOC vial in sequence after the environmental sample was collected. Screen blanks were collected to ensure that the well screen was clean after decontamination. After all drilling equipment was thoroughly cleaned, the screen was placed in the drill rod. DI water was poured into the screen and rod. The screen blank sample was then dispensed directly into the VOC vial. All of the field blanks were collected with DI water from the USGS Delaware Subdistrict Laboratory in Dover, Delaware. All blanks were analyzed at the DNTS laboratory for VOCs. To minimize cross-contamination, the Hydrolab, flow-through cell, and glassware were rinsed with DI water between samples.

Sample Handling Procedures and Analytical Methods

The laboratory and field analytical methods and preservatives for ground-water samples collected from direct-push ground-water sampling at the DNTS are listed in table 1. VOC samples were placed on ice in a cooler and delivered to the DNTS laboratory on the day of sample collection. All samples and blanks were analyzed using method SW-846

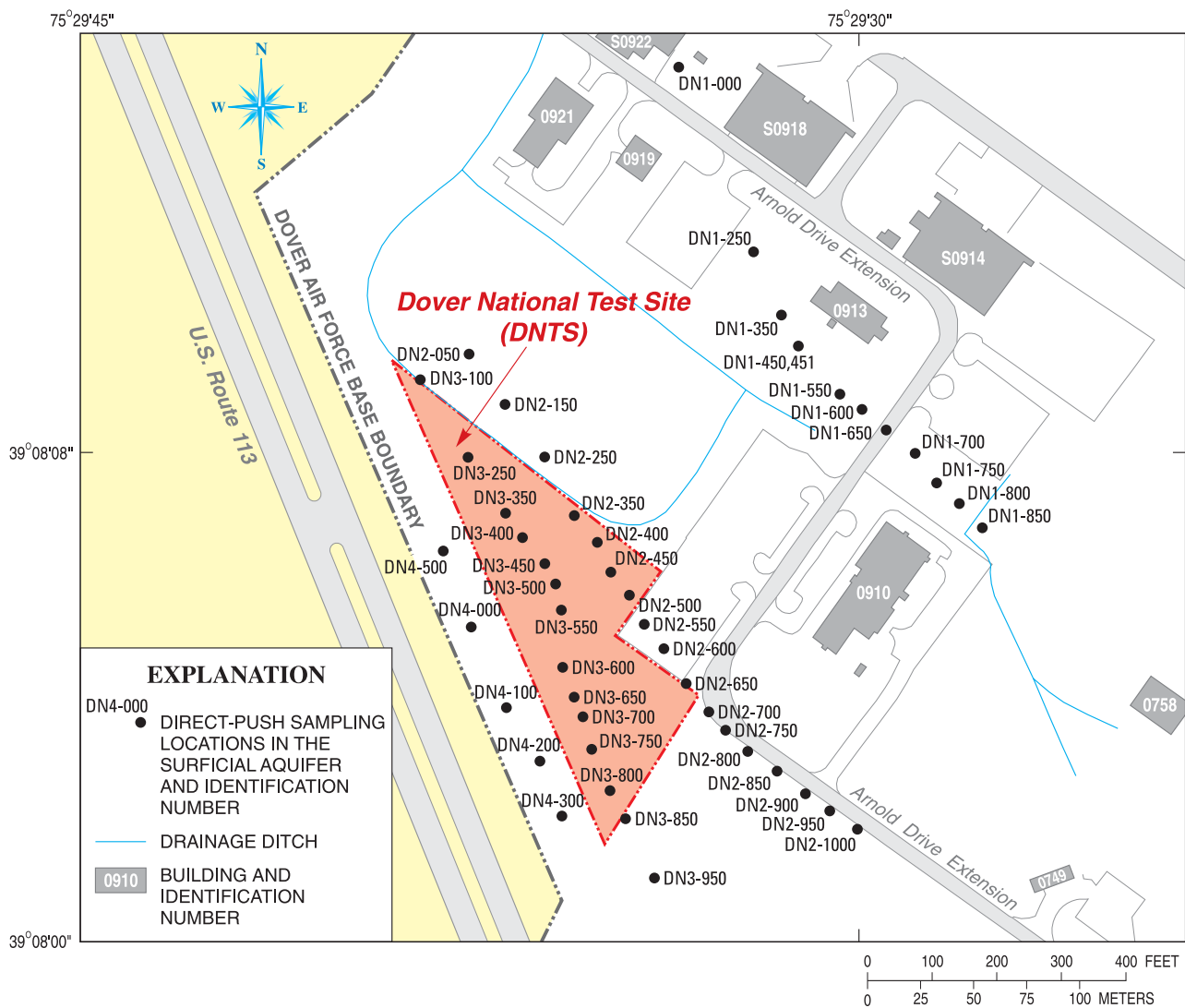


Figure 2. Locations of direct-push sampling sites at the Dover National Test Site, Dover Air Force Base, Delaware.

Table 1. *Field and laboratory methods for direct-push ground-water samples collected at the Dover National Test Site, Dover Air Force Base, Delaware, June–July 2001*

[HCl, hydrochloric acid; HgCl₂, mercuric chloride]

Constituent	Analytical Method	Preservative
Laboratory		
Volatile organic compounds	¹ SW-846 8021B	HCl
Methane	² U.S. Geological Survey	Hg Cl ₂
Field		
pH, specific conductance, temperature	Hydrolab/Direct Measurement	None
Dissolved oxygen	Hydrolab/Winkler Titration	None
Total iron	HACH DR2000/Colorimetric	None
Ferrous iron	HACH DR2000/Colorimetric	None
Sulfide	HACH DR2000/Colorimetric	None
Sulfate	HACH DR2000/Colorimetric	None

¹ SW-846, U.S. Environmental Protection Agency, 1996.

² Baedecker and Cozzarelli, 1992.

8021B (U.S. Environmental Protection Agency, 1996). Method reporting limits (MRLs) for the VOCs of interest are shown in table 2.

Temperature, pH, specific conductance, and DO were analyzed in the field with a Hydrolab multiprobe connected to a flow-through cell on the discharge line of the pump. The pH and specific conductance probes of the Hydrolab were calibrated daily with standard solutions prepared at the USGS laboratory in Ocala, Florida. When the DO level reached 2 mg/L (milligrams per liter) or less with the multiprobe, a modified Winkler titration was used to determine the DO concentration. This method is more accurate and reproducible at low DO concentrations (Baedecker and Cozzarelli, 1992). The MRL for DO is 0.2 mg/L.

Ferrous and total iron, sulfide, and sulfate were measured colorimetrically in unfiltered samples immediately after collection in the DNTS laboratory. These analyses were performed with spectrophotometers that contain pre-programmed calibration curves. Iron was analyzed with a Hach DR2000 spectrophotometer. One total iron and one ferrous iron check standard were run daily along with ground-water samples. Sulfide was analyzed with a Chemetrics sulfide kit and sulfate was analyzed with a Hach sulfate kit. Spectrophotometers were zeroed with raw ground water before each sample was read in the instrument. The method detection limits (MDLs) for ferrous and total iron are 0.02 mg/L. The instrument detection limit for sulfide is 0.01 mg/L and the lowest calibration standard used for sulfate is 7 mg/L. Seven duplicate field analyses were run on ferrous and total iron, sulfate, and sulfide. In addition, check standards were run

daily on sulfate. Twenty-one field blank samples were run for ferrous and total iron, sulfate, and sulfide.

Methane samples were not collected at all sampling locations, although samples were generally collected from locations where the DO concentrations were less than 1.0 mg/L. Some samples were collected in locations where DO concentrations were greater than 1.0 mg/L to determine whether methane was present at these locations. The methane samples were injected by syringe into sealed serum vials, which had been preserved with mercuric chloride and purged with nitrogen gas prior to sample collection. All methane samples were collected in duplicate. Methane samples were analyzed using a gas chromatograph with a flame-ionization detector. This procedure is described in detail in Baedecker and Cozzarelli (1992). The USGS field laboratory at Aberdeen Proving Ground, Maryland analyzed the methane samples, and uses internal standards and surrogates on every sample and blank that is analyzed. In addition, the field laboratory participates in a blind sampling program (Spencer and others, 2000).

VOCs were analyzed at the DNTS at DAFB. Samples were analyzed using the U.S. Environmental Protection Agency (USEPA) Method 8021B procedure (U.S. Environmental Protection Agency, 1996), Headspace Method 5021 (U.S. Environmental Protection Agency, December 1996). Samples were analyzed on a Hewlett Packard 6890A gas chromatograph (GC) equipped with flame ionization and electron capture detectors, a Hewlett Packard 7694 automatic headspace sampler, and a Supelco SPB-624 capillary

Table 2. Method reporting limits and maximum contaminant levels for volatile organic compounds

[MTBE, methyl *tert*-butyl ether; PCE, tetrachloroethene; TCE, trichloroethene; *cis*-1,2-DCE, *cis*-1,2-dichloroethene; µg/L, micrograms per liter; DNTS, Dover National Test Site; --, no data]

Target Analyte	DNTS Modified 8021B Method Reporting Limit ¹ (µg/L)	Maximum Contaminant Levels (µg/L)
MTBE	0.5	--
PCE	1.3	5
TCE	0.8	5
<i>cis</i> -1,2-DCE	0.6	70
Benzene	0.6	5
Toluene	1.4	1,000
Ethylbenzene	1.3	700
<i>p,m</i> -xylene	2.6	10,000
<i>o</i> -xylene	1.2	10,000

¹ U.S. Environmental Protection Agency, 1996.

column. To prepare samples and standards for analyses, 5 mL of sample was transferred to 20-mL headspace vials and sealed. For quality control, check standards (Supelco custom VOC mixture and MTBE standards) were run approximately every 10 samples during each sample run, and laboratory blanks prepared with reagent grade DI water were run periodically, as needed. A five-point calibration curve was used to determine VOC concentrations (Barbaro and Neupane, 2002). Analytical MRLs are shown in table 2. According to USEPA Method 8021B, Method 5021 for headspace GC recoveries must be below a 20-percent difference, which means that standards must be monitored frequently and compared against the initial calibration curve. If the recoveries ever exceed a 20-percent difference, the standards need to be replaced, the initial calibration has to be recomputed, and then the samples are rerun. Standards are routinely replaced according to the manufacturers' specifications. A detailed explanation of the standard preparation can be found in the USEPA Method 8021B documentation (U.S. Environmental Protection Agency, December 1996).

Analytical Results of Ground-Water Samples

The analytical results from the direct-push sampling program are summarized in this section. Field measurements (pH, temperature, specific conductance, and DO) and sampling depths for each sample are presented in table 3. The lack of field parameters for some samples is due to low ground-water yield at those locations. pH values ranged

from 4.3 to 5.9. The DO concentrations ranged from below the MRL (0.2 mg/L) to 7.0 mg/L. Results below the MRL for DO are listed as less than (<) 0.2 mg/L.

Concentrations of VOCs from all wells are shown in table 4. Maximum contaminant levels (MCLs) were not exceeded for benzene, toluene, ethylbenzene, xylenes, *cis*-1,2-DCE, TCE, or PCE. The MCLs for selected VOCs are shown in table 2. Currently, there is no MCL for MTBE. However, the USEPA has a drinking-water advisory of 20–40 µg/L (micrograms per liter) for MTBE that is based on taste and odor (U.S. Environmental Protection Agency, 1997). Values for compounds that were detected but had concentrations below the MRL of a given compound are listed as less than (<) the detection limit. This means that the compound was identified but not quantifiable. Compounds that were not detected are listed as not detected (ND). In addition, vinyl chloride was not detected in any samples.

VOCs were above the MRLs in 59 ground-water samples. The concentrations ranged from below the MRLs to maximum values of 12.4 µg/L of *cis*-1,2-DCE, 1.14 µg/L of TCE, 2.65 µg/L of PCE, 1,070 µg/L of MTBE, 4.36 µg/L of benzene, and 1.8 µg/L of toluene. Vinyl chloride, ethylbenzene, *p,m*-xylene, and *o*-xylene were not detected in any of the samples collected during this study. MTBE was detected above the MRL in 47 of the 115 ground-water samples with a maximum concentration of 1,070 µg/L.

Concentrations of ferrous iron, total iron, sulfide, sulfate, and methane in ground-water samples from direct-push sampling are shown in table 5. All analyses were performed on unfiltered samples. Ferrous iron concentrations ranged from <0.02 to 6.0 mg/L. Total iron concentrations ranged from

<0.02 to 25.2 mg/L. When unfiltered samples are collected using a direct-push drilling method and analyzed using a colorimetric method in the field, turbidity can interfere with the analyses when low levels of total and ferrous iron are present. Therefore, for selected samples the ferrous iron value may exceed the total iron value for low-level detections. The exact extent to which the precision of the method was influenced was not determined, however, because the iron data are only being used as a screening tool. Sulfide concentrations were below the MDL for all samples, except for those from sites DN3-400A and DN3-450A. Sulfate concentrations ranged from <7 to 149 mg/L. Methane concentrations ranged from below the MDL to 741.1 µg/L.

Twenty-one sets of DI blank water samples were analyzed for total iron, ferrous iron, sulfate, and sulfide. Total iron, ferrous iron and sulfide were below the MDL for all DI blank water samples. Two DI blank water samples had sulfate concentrations of 8 mg/L; the other 19 were below the MDL. Check standards of 7, 20, 50, and 70 mg/L of sulfate were used daily. All check standards agreed consistently with the meter readings.

Water-Level Measurements

Water-level measurements were collected on July 1, 2001 from wells in and around the DNTS. The locations of ground-water level measurements in the upper and lower parts of the surficial aquifer are shown in figures 3a and 3b. Ground-water elevation data for the surficial aquifer are shown in table 6.

Quality-Control Results

QC samples collected from June 27 through July 18, 2001 consisted of 1 equipment blank, 14 field blanks, 10 duplicates, and 7 screen blanks (table 7). VOCs were not detected in most of the QC samples. TCE and PCE were detected in some QC samples, but the concentrations were below the laboratory reporting limits. The low VOC concentrations in the blanks may have been the result of internal laboratory contamination or the tubing-cleaning procedure. However, concentrations in the blanks were not high enough to bias the interpretation of environmental concentrations of VOCs. The median for TCE and *cis*-1,2-DCE in the QC samples was <8 µg/L and not detected, respectively, which means that the median for TCE was not detected and the median *cis*-1,2-DCE was not quantifiable. MTBE was detected in one of the screen blanks. It is unlikely that this contamination affected the next sample, because that location had the highest MTBE concentration in the study area (DN1-850B).

For detected compounds, the consistency between concentrations in duplicate samples is indicated by the relative percent difference (RPD) and is shown in table 8. The equation used to calculate the RPD is as follows:

$$\frac{|(x1 - x2)|}{ave(x1, x2)} * 100,$$

where *x1* is a sample value, *x2* is the duplicate sample value, and *ave* is average.

Estimates of measurement reproducibility for some analytes were limited because the concentration of one or both duplicates in the pair was frequently below the method reporting limit. RPDs were not calculated for these pairs. All RPD values were less than or equal to 22.1 percent, with the exception of one site (DN1-650A; the RPD for the concentrations of the duplicate pair for *cis*-1,2-DCE was 104 percent, and the concentrations were 0.9 µg/L and 2.84 µg/L).

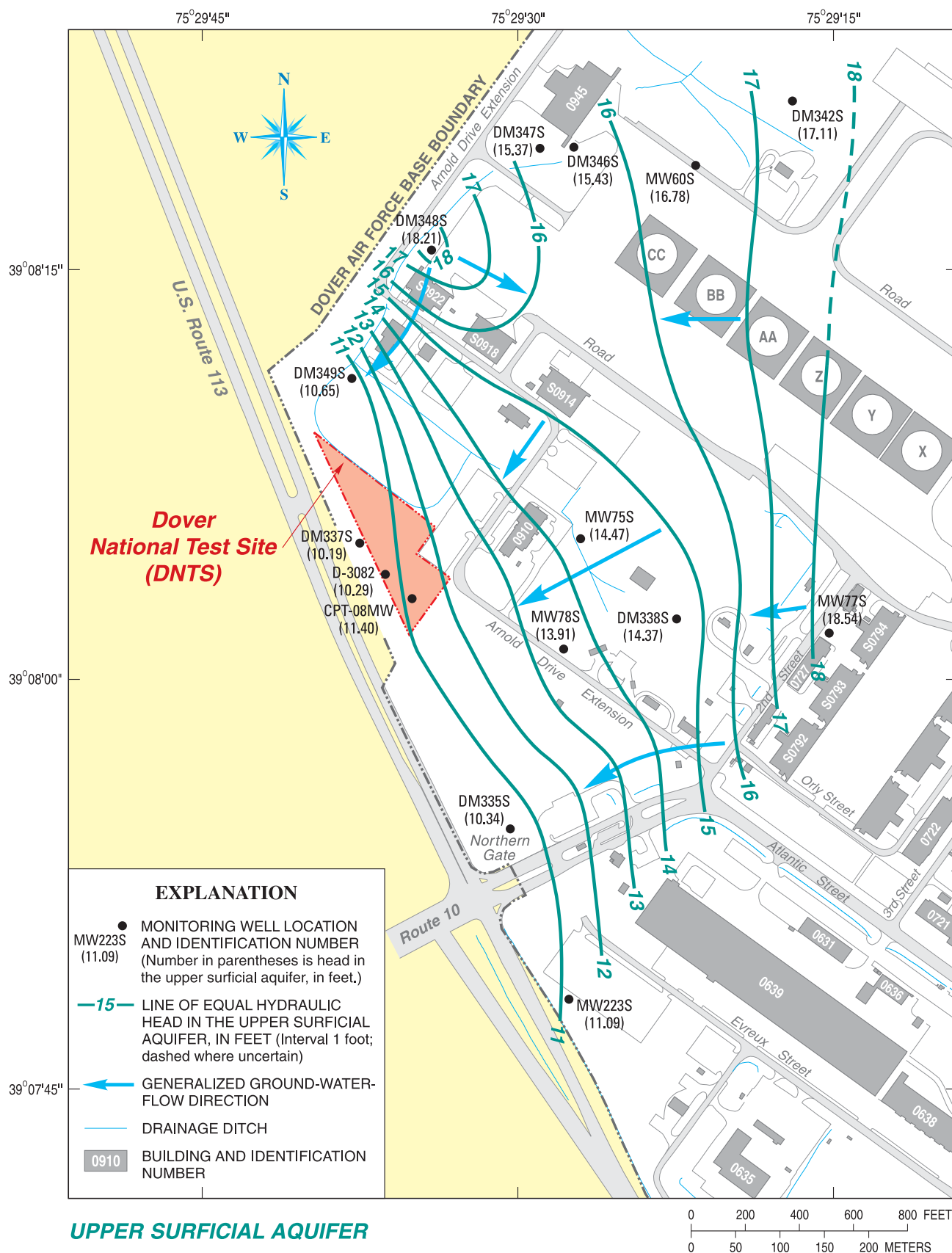


Figure 3a. Location of ground-water level measurements in the upper part of the surficial aquifer, Dover National Test Site, Dover Air Force Base, Delaware, July 1, 2001.

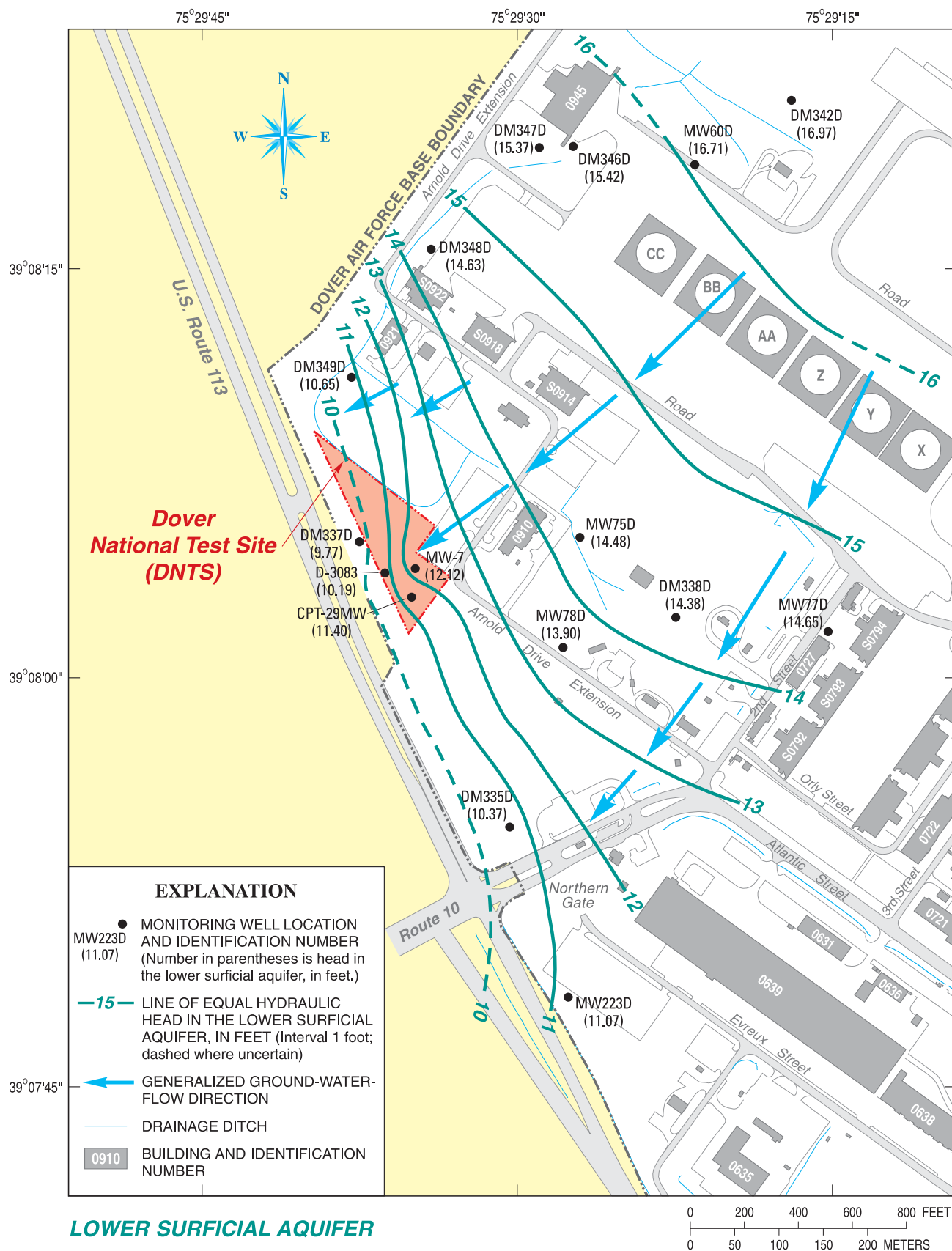


Figure 3b. Location of ground-water level measurements in the lower part of the surficial aquifer, Dover National Test Site, Dover Air Force Base, Delaware, July 1, 2001.

Table 3. *Sample-collection information and field measurements from direct-push ground-water samples collected at the Dover National Test Site, Dover Air Force Base, Delaware, June–July 2001*

[ft, feet; bls, below land surface; msl, mean sea level; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25°C; mg/L, milligrams per liter; --, no data; <, less than]

Sample identification number	Sampling date	Ground surface (ft msl)	Total depth (ft bls)	Altitude of top of sample interval (ft msl)	Altitude of bottom of sample interval (ft msl)	pH	Temperature (°C)	Specific conductance (µS/cm)	Dissolved oxygen (mg/L)
DN1-000C	06/29/2001	27.6	20	11.6	7.6	4.9	17.0	188	3.3
DN1-000B	06/29/2001	27.6	28	3.6	-0.4	5.7	17.3	153	0.27
DN1-000A	06/29/2001	27.6	36	-4.4	-8.4	4.9	18.6	71	0.30
DN1-250C	06/29/2001	29.3	20	13.3	9.3	5.4	17.6	335	1.1
DN1-250B	06/29/2001	29.3	28	5.3	1.3	4.9	18.7	170	0.50
DN1-250A	06/29/2001	29.3	36	-2.7	-6.7	4.8	20.0	91	0.40
DN1-350C	06/29/2001	28.4	20	12.4	8.4	5.2	17.4	248	0.39
DN1-350B	06/29/2001	28.4	28	4.4	0.4	4.8	19.1	165	0.74
DN1-350A	06/29/2001	28.4	36	-3.6	-7.6	4.9	18.4	105	0.31
DN1-450C	06/27/2001	27.9	16	12.9	11.9	--	--	--	--
DN1-450B	06/27/2001	27.9	24	4.9	3.9	--	--	--	--
DN1-450A	06/27/2001	27.9	32	-3.1	-4.1	5.0	20.6	146	0.26
DN1-451B	06/27/2001	27.9	24	7.9	3.9	5.1	19.4	245	0.57
DN1-451A	06/27/2001	27.9	32	-0.1	-4.1	4.9	18.2	169	0.32
DN1-550C	06/28/2001	28.2	19	13.2	9.2	4.6	18.1	156	2.0
DN1-550B	06/28/2001	28.2	27	5.2	1.2	5.0	19.4	172	0.34
DN1-550A	06/28/2001	28.2	36	-3.8	-7.8	4.9	18.3	115	0.33
DN1-600C	07/16/2001	27.3	20	11.3	7.3	4.9	18.9	299	0.25
DN1-600B	07/16/2001	27.3	28	3.3	-0.7	5.1	19.6	210	0.24
DN1-600A	07/16/2001	27.3	36	-4.7	-8.7	5.2	19.4	124	0.30

Table 3. Sample-collection information and field measurements from direct-push ground-water samples collected at the Dover National Test Site, Dover Air Force Base, Delaware, June–July 2001—Continued

Sample identification number	Sampling date	Ground surface (ft msl)	Total depth (ft bls)	Altitude of top of sample interval (ft msl)	Altitude of bottom of sample interval (ft msl)	pH	Temperature (°C)	Specific conductance (µS/cm)	Dissolved oxygen (mg/L)
DN1-650C	06/28/2001	27.1	19	12.1	8.1	4.9	19.0	2	0.45
DN1-650B	06/28/2001	27.1	27	4.1	0.1	5.3	19.8	713	2.8
DN1-650A	06/28/2001	27.1	36	-4.9	-8.9	4.8	20.6	215	0.21
DN1-700C	07/16/2001	26.2	20	10.2	6.2	5.1	18.3	155	0.28
DN1-700B	07/16/2001	26.2	28	2.2	-1.8	5.2	18.6	142	0.28
DN1-700A	07/16/2001	26.2	36	-5.8	-9.8	5.2	18.9	220	0.26
DN1-750C	06/28/2001	25.6	20	9.6	5.6	4.9	17.7	134	0.41
DN1-750B	06/28/2001	25.6	28	1.6	-2.4	4.9	18.3	158	0.24
DN1-750A	06/28/2001	25.6	36	-6.4	-10.4	5.3	19.5	595	3.5
DN1-800C	07/16/2001	25.5	20	9.5	5.5	4.9	16.8	127	0.28
DN1-800B	07/16/2001	25.5	28	1.5	-2.5	5.2	17.3	151	0.14
DN1-800A	07/16/2001	25.5	36	-6.5	-10.5	5.3	18.0	140	0.52
DN1-850C	06/28/2001	24.5	20	8.5	4.5	5.1	15.5	156	0.26
DN1-850B	06/28/2001	24.5	28	0.5	-3.5	5.1	16.6	20	<0.20
DN1-850A	06/28/2001	24.5	36	-7.5	-11.5	4.8	17.7	108	0.54
DN2-050B	07/03/2001	31.0	24	11.0	7.0	5.2	20.6	227	1.2
DN2-050A	07/03/2001	31.0	32	3.0	-1.0	5.2	19.9	182	0.21
DN2-150B	07/03/2001	30.6	20	14.6	10.6	5.0	22.6	178	1.9
DN2-150A	07/03/2001	30.6	32	2.6	-1.4	4.9	--	189	1.2
DN2-250B	07/03/2001	30.0	24	10.0	6.0	4.6	17.6	173	3.2
DN2-250A	07/03/2001	30.0	32	2.0	-2.0	4.9	20.1	174	2.0

Table 3. Sample-collection information and field measurements from direct-push ground-water samples collected at the Dover National Test Site, Dover Air Force Base, Delaware, June–July 2001—Continued

Sample identification number	Sampling date	Ground surface (ft msl)	Total depth (ft bls)	Altitude of top of sample interval (ft msl)	Altitude of bottom of sample interval (ft msl)	pH	Temperature (°C)	Specific conductance (µS/cm)	Dissolved oxygen (mg/L)
DN2-350B	07/03/2001	30.9	24	10.9	6.9	4.8	17.5	244	3.0
DN2-350A	07/03/2001	30.9	32	2.9	-1.1	4.8	16.6	235	1.0
DN2-400B	07/13/2001	30.6	28	6.6	2.6	5.1	17.9	246	1.7
DN2-400A	07/13/2001	30.6	36	-1.4	-5.4	5.0	17.6	171	0.44
DN2-450B	07/02/2001	31.0	24	11.0	7.0	5.3	17.9	177	2.6
DN2-450A	07/02/2001	31.0	32	3.0	-1.0	5.3	17.7	175	0.55
DN2-500C	07/14/2001	29.9	22	11.9	7.9	--	--	--	--
DN2-500B	07/14/2001	29.9	27	6.9	2.9	5.7	20.5	167	0.79
DN2-500A	07/14/2001	29.9	36	-2.1	-6.1	5.6	19.4	143	0.40
DN2-550C	07/14/2001	30.3	22	12.3	8.3	5.5	19.2	174	6.1
DN2-550B	07/14/2001	30.3	28	6.3	2.3	5.7	17.7	176	0.75
DN2-550A	07/14/2001	30.3	36	-1.7	-5.7	5.6	17.7	151	0.49
DN2-600B	07/13/2001	31.0	24	11.3	7.3	4.8	18.0	173	6.4
DN2-600A	07/13/2001	31.0	31.3	3.7	-0.7	4.9	17.9	157	0.48
DN2-650B	07/13/2001	31.3	24	11.3	7.3	4.8	18.1	173	6.4
DN2-650A	07/13/2001	31.3	32	3.3	-0.7	5.0	18.0	157	0.48
DN2-700C	07/16/2001	31.3	22	13.3	9.3	5.3	18.5	415	5.4
DN2-700B	07/16/2001	31.3	28	7.3	3.3	5.3	16.0	291	2.9
DN2-700A	07/16/2001	31.3	36	-0.7	-4.7	5.2	16.1	165	0.33
DN2-750B	07/02/2001	31.2	24	11.2	7.2	5.0	16.5	421	5.8
DN2-750A	07/02/2001	31.2	32	3.2	-0.8	5.1	--	188	1.3

Table 3. Sample-collection information and field measurements from direct-push ground-water samples collected at the Dover National Test Site, Dover Air Force Base, Delaware, June–July 2001—Continued

Sample identification number	Sampling date	Ground surface (ft msl)	Total depth (ft bls)	Altitude of top of sample interval (ft msl)	Altitude of bottom of sample interval (ft msl)	pH	Temperature (°C)	Specific conductance (µS/cm)	Dissolved oxygen (mg/L)
DN2-800C	07/12/2001	31.0	22	13.0	9.0	4.4	--	548	--
DN2-800B	07/12/2001	31.0	28	7.0	3.0	4.4	17.7	262	4.4
DN2-800A	07/12/2001	31.0	36	-1.0	-5.0	4.7	18.9	1	0.50
DN2-850C	07/18/2001	30.6	20	14.6	10.6	--	--	--	--
DN2-850B	07/18/2001	30.6	28	6.6	2.6	4.8	17.4	148	0.83
DN2-850A	07/18/2001	30.6	36	-1.4	-5.4	4.8	16.9	136	0.54
DN2-900C	07/12/2001	30.2	20	14.2	10.2	4.5	17.3	346	5.5
DN2-900B	07/12/2001	30.2	28	6.2	2.2	4.7	17.4	142	1.7
DN2-900A	07/12/2001	30.2	36	-1.8	-5.8	4.7	17.8	93	0.51
DN2-950C	07/18/2001	29.9	20	13.9	9.9	--	--	--	--
DN2-950B	07/18/2001	29.9	28	5.9	1.9	4.8	17.2	154	2.4
DN2-950A	07/18/2001	29.9	36	-2.1	-6.1	4.7	17.7	120	0.68
DN2-1000C	07/12/2001	29.5	20	13.5	9.5	5.4	16.8	598	3.8
DN2-1000B	07/12/2001	29.5	28	5.5	1.5	4.7	17.8	133	0.48
DN2-1000A	07/12/2001	29.5	36	-2.5	-6.5	4.6	16.7	117	0.28
DN3-100B	07/05/2001	28.7	24	8.7	4.7	4.9	17.8	177	2.7
DN3-100A	07/05/2001	28.7	32	0.7	-3.3	4.9	17.9	134	0.80
DN3-250B	07/05/2001	32.4	28	8.4	4.4	4.9	20.7	204	2.6
DN3-250A	07/05/2001	32.4	36	0.4	-3.6	4.9	17.2	191	2.3
DN3-350B	07/05/2001	32.8	24	12.8	8.8	4.6	19.3	174	3.3
DN3-350A	07/05/2001	32.8	32	4.8	0.8	4.7	17.6	171	1.6

Table 3. Sample-collection information and field measurements from direct-push ground-water samples collected at the Dover National Test Site, Dover Air Force Base, Delaware, June–July 2001—Continued

Sample identification number	Sampling date	Ground surface (ft msl)	Total depth (ft bls)	Altitude of top of sample interval (ft msl)	Altitude of bottom of sample interval (ft msl)	pH	Temperature (°C)	Specific conductance (µS/cm)	Dissolved oxygen (mg/L)
DN3-400B	07/10/2001	33.5	28	9.5	5.5	4.3	21.1	2	3.3
DN3-400A	07/10/2001	33.5	32	5.5	1.5	4.7	23.7	240	2.8
DN3-450B	07/05/2001	33.5	28	9.5	5.5	5.0	22.4	190	1.7
DN3-450A	07/05/2001	33.5	36	1.5	-2.5	5.0	--	199	1.2
DN3-500B	07/13/2001	33.5	26	11.5	7.5	--	--	--	2.6
DN3-500A	07/13/2001	33.5	32	5.5	1.5	4.9	21.2	161	0.91
DN3-550B	07/05/2001	33.6	28	9.6	5.6	5.2	19.1	146	3.8
DN3-550A	07/05/2001	33.6	36	1.6	-2.4	5.0	20.8	152	0.50
DN3-600B	07/13/2001	35.4	28	11.4	7.4	5.1	20.4	165	4.1
DN3-600A	07/13/2001	35.4	36	3.4	-0.6	5.2	19.5	167	0.51
DN3-650B	07/06/2001	35.6	28	11.6	7.6	--	--	--	--
DN3-650A	07/06/2001	35.6	36	3.6	-0.4	4.9	20.0	139	0.40
DN3-700B	07/13/2001	35.4	28	11.4	7.4	5.0	21.2	753	7.0
DN3-700A	07/13/2001	35.4	36	3.4	-0.6	4.9	19.4	259	0.59
DN3-750B	07/06/2001	34.8	28	10.8	6.8	4.3	23.4	188	4.8
DN3-750A	07/06/2001	34.8	36	2.8	-1.2	4.8	21.4	113	0.85
DN3-800B	07/12/2001	35.2	28	11.2	7.2	4.9	20.5	190	5.5
DN3-800A	07/12/2001	35.2	36	3.2	-0.8	4.5	17.7	100	0.62
DN3-850B	07/10/2001	34.8	28	10.8	6.8	4.9	20.1	147	4.6
DN3-850A	07/10/2001	34.8	36	2.8	-1.2	--	--	--	--

Table 3. *Sample-collection information and field measurements from direct-push ground-water samples collected at the Dover National Test Site, Dover Air Force Base, Delaware, June–July 2001—Continued*

Sample identification number	Sampling date	Ground surface (ft msl)	Total depth (ft bls)	Altitude of top of sample interval (ft msl)	Altitude of bottom of sample interval (ft msl)	pH	Temperature (°C)	Specific conductance (µS/cm)	Dissolved oxygen (mg/L)
DN3-950B	07/10/2001	34.2	28	10.2	6.2	4.7	21.5	156	3.2
DN3-950A	07/10/2001	34.2	36	2.2	-1.8	4.8	18.8	106	0.37
DN4-000A	07/10/2001	36.8	36	4.8	0.8	--	--	--	--
DN4-100C*	07/11/2001	36.5	--	--	--	--	--	--	--
DN4-100B	07/11/2001	36.5	28	12.5	8.5	--	--	--	--
DN4-100A	07/11/2001	36.5	32	8.5	4.5	5.4	21.0	232	4.7
DN4-200B	07/11/2001	37.4	32	9.4	5.4	5.4	21.8	347	0.65
DN4-200A	07/11/2001	37.4	40	1.4	-2.6	--	--	--	--
DN4-300B	07/11/2001	36.8	32	8.8	4.8	5.9	20.5	254	0.2
DN4-300A	07/11/2001	36.8	40	0.8	-3.2	5.2	19.9	119	1.2
DN4-500B	07/17/2001	36.0	36	4.0	0.0	5.6	22.0	192	<0.20
DN4-500A	07/17/2001	36.0	40	0.0	-4.0	5.1	22.0	213	<0.20

* Field parameters were not collected due to insufficient sample volume.

Table 4. Concentrations of volatile organic compounds in ground water from direct-push samples collected at the Dover National Test Site, Dover Air Force Base, Delaware, June–July 2001

[*cis*-1,2-DCE, *cis*-1,2-dichloroethene; TCE, trichloroethene; PCE, tetrachloroethene; MTBE, methyl *tert*-butyl ether; µg/L, micrograms per liter; ND, not detected; <, less than; detections of MTBE in **bold**]

Sample identification number	<i>cis</i> -1,2-DCE (µg/L)	TCE (µg/L)	PCE (µg/L)	Vinyl chloride (µg/L)			Benzene (µg/L)	Toluene (µg/L)	Ethylbenzene (µg/L)		
DN1-000C	ND	<0.8	<1.3	ND	ND	ND	ND	ND	ND	ND	ND
DN1-000B	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
DN1-000A	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
DN1-250C	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
DN1-250B	ND	<0.8	ND	ND	ND	ND	ND	ND	ND	ND	ND
DN1-250A	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
DN1-350C	ND	<0.8	ND	ND	ND	ND	ND	ND	ND	ND	ND
DN1-350B	ND	<0.8	ND	ND	ND	ND	ND	ND	ND	ND	ND
DN1-350A	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
DN1-450C	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
DN1-450B	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
DN1-450A	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
DN1-451B	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
DN1-451A	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
DN1-550C	4.63	<0.8	ND	ND	ND	ND	ND	ND	ND	ND	ND
DN1-550B	3.86	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
DN1-550A	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
DN1-600C	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
DN1-600B	ND	<0.8	ND	ND	ND	ND	ND	ND	ND	ND	ND
DN1-600A	ND	ND	ND	ND	1.54	ND	ND	ND	ND	ND	ND

Table 4. Concentrations of volatile organic compounds in ground water from direct-push samples collected at the Dover National Test Site, Dover Air Force Base, Delaware, June–July 2001—Continued

Sample identification number	cis-1,2-DCE (µg/L)	TCE (µg/L)	PCE (µg/L)	Vinyl chloride (µg/L)	MTBE (µg/L)	Benzene (µg/L)	Toluene (µg/L)	Ethylbenzene (µg/L)	p,m-xylene (µg/L)	o-xylene (µg/L)
DN1-650C	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
DN1-650B	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
DN1-650A	0.9	ND	ND	ND	6.27	ND	ND	ND	ND	ND
DN1-700C	ND	ND	<1.3	ND	ND	ND	ND	ND	ND	ND
DN1-700B	ND	ND	ND	ND	22.5	ND	ND	ND	ND	ND
DN1-700A	ND	ND	ND	ND	4.64	ND	1.8	ND	ND	ND
DN1-750C	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
DN1-750B	ND	ND	ND	ND	ND	3.24	ND	ND	ND	ND
DN1-750A	ND	<0.8	<1.3	ND	ND	ND	ND	ND	ND	ND
DN1-800C	ND	ND	<1.3	ND	248	ND	ND	ND	ND	ND
DN1-800B	ND	ND	ND	ND	74.1	3.06	1.7	ND	ND	ND
DN1-800A	ND	ND	ND	ND	87.3	4.13	<1.4	ND	ND	ND
DN1-850C	ND	ND	ND	ND	551	1.02	<1.4	ND	ND	ND
DN1-850B	ND	<0.8	ND	ND	1,070	3.81	<1.4	ND	ND	ND
DN1-850A	ND	ND	ND	ND	290	4.36	1.67	ND	ND	ND
DN2-050B	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
DN2-050A	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
DN2-150B	ND	<0.8	ND	ND	ND	ND	ND	ND	ND	ND
DN2-150A	ND	<0.8	ND	ND	ND	ND	ND	ND	ND	ND
DN2-250B	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
DN2-250A	ND	<0.8	ND	ND	ND	ND	ND	ND	ND	ND

Table 4. Concentrations of volatile organic compounds in ground water from direct-push samples collected at the Dover National Test Site, Dover Air Force Base, Delaware, June–July 2001—Continued

Sample identification number	<i>cis</i> -1,2-DCE (µg/L)	TCE (µg/L)	PCE (µg/L)	Vinyl chloride (µg/L)	MTBE (µg/L)	Benzene (µg/L)	Toluene (µg/L)	Ethylbenzene (µg/L)	<i>p,m</i> -xylene (µg/L)	<i>o</i> -xylene (µg/L)
DN2-350B	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
DN2-350A	ND	ND	ND	ND	3.45	ND	ND	ND	ND	ND
DN2-400B	ND	ND	ND	ND	7.75	ND	ND	ND	ND	ND
DN2-400A	ND	<0.8	ND	ND	25.6	1.41	ND	ND	ND	ND
DN2-450B	ND	ND	ND	ND	37.2	ND	ND	ND	ND	ND
DN2-450A	ND	ND	ND	ND	127	<0.6	<1.4	ND	ND	ND
DN2-500C	ND	ND	ND	ND	29.2	ND	ND	ND	ND	ND
DN2-500B	ND	ND	ND	ND	200	ND	ND	ND	ND	ND
DN2-500A	ND	ND	ND	ND	213	0.63	ND	ND	ND	ND
DN2-550C	ND	ND	ND	ND	2.87	ND	ND	ND	ND	ND
DN2-550B	ND	ND	ND	ND	111	ND	ND	ND	ND	ND
DN2-550A	ND	<0.8	<1.3	ND	84.7	0.79	<1.4	ND	ND	ND
DN2-600B	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
DN2-600A	ND	ND	ND	ND	4.19	<0.6	ND	ND	ND	ND
DN2-650B	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
DN2-650A	ND	ND	ND	ND	5.69	ND	ND	ND	ND	ND
DN2-700C	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
DN2-700B	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
DN2-700A	ND	ND	ND	ND	8.18	0.81	ND	ND	ND	ND
DN2-750B	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
DN2-750A	3.19	ND	ND	ND	4.49	ND	ND	ND	ND	ND

Table 4. Concentrations of volatile organic compounds in ground water from direct-push samples collected at the Dover National Test Site, Dover Air Force Base, Delaware, June–July 2001—Continued

Sample identification number	cis-1,2-DCE (µg/L)	TCE (µg/L)	PCE (µg/L)	Vinyl chloride (µg/L)	MTBE (µg/L)	Benzene (µg/L)	Toluene (µg/L)	Ethylbenzene (µg/L)	p,m-xylene (µg/L)	o-xylene (µg/L)
DN2-800C	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
DN2-800B	ND	<0.8	<1.3	ND	ND	ND	ND	ND	ND	ND
DN2-800A	ND	ND	ND	ND	14.7	ND	ND	ND	ND	ND
DN2-850C	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
DN2-850B	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
DN2-850A	ND	ND	ND	ND	16.5	ND	ND	ND	ND	ND
DN2-900C	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
DN2-900B	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
DN2-900A	ND	ND	ND	ND	7.23	ND	ND	ND	ND	ND
DN2-950C	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
DN2-950B	ND	ND	ND	ND	2.15	ND	ND	ND	ND	ND
DN2-950A	ND	ND	ND	ND	6.88	ND	ND	ND	ND	ND
DN2-1000C	ND	ND	<1.3	ND	ND	ND	ND	ND	ND	ND
DN2-1000B	ND	<0.8	<1.3	ND	19.1	ND	ND	ND	ND	ND
DN2-1000A	ND	<0.8	<1.3	ND	20.4	ND	ND	ND	ND	ND
DN3-100B	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
DN3-100A	ND	<0.8	ND	ND	ND	ND	ND	ND	ND	ND
DN3-250B	ND	<0.8	ND	ND	ND	ND	ND	ND	ND	ND
DN3-250A	ND	<0.8	ND	ND	ND	ND	ND	ND	ND	ND
DN3-350B	ND	<0.8	ND	ND	ND	ND	ND	ND	ND	ND
DN3-350A	ND	<0.8	ND	ND	ND	ND	ND	ND	ND	ND

Table 4. Concentrations of volatile organic compounds in ground water from direct-push samples collected at the Dover National Test Site, Dover Air Force Base, Delaware, June–July 2001—Continued

Sample identification number	cis-1,2-DCE (µg/L)	TCE (µg/L)	PCE (µg/L)	Vinyl chloride (µg/L)	MTBE (µg/L)	Benzene (µg/L)	Toluene (µg/L)	Ethylbenzene (µg/L)	p,m-xylene (µg/L)	o-xylene (µg/L)
DN3-400B	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
DN3-400A	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
DN3-450B	ND	ND	ND	ND	17.4	ND	ND	ND	ND	ND
DN3-450A	ND	ND	ND	ND	42.7	ND	ND	ND	ND	ND
DN3-500B	ND	ND	ND	ND	104	ND	ND	ND	ND	ND
DN3-500A	ND	ND	ND	ND	139	ND	ND	ND	ND	ND
DN3-550B	ND	ND	ND	ND	26.1	ND	ND	ND	ND	ND
DN3-550A	ND	ND	ND	ND	230	0.79	ND	ND	ND	ND
DN3-600B	ND	ND	ND	ND	3.08	ND	ND	ND	ND	ND
DN3-600A	ND	ND	<1.3	ND	17.2	ND	ND	ND	ND	ND
DN3-650B	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
DN3-650A	ND	<0.8	<1.3	ND	11.3	ND	ND	ND	ND	ND
DN3-700B	ND	ND	<1.3	ND	ND	ND	ND	ND	ND	ND
DN3-700A	ND	ND	<1.3	ND	7.91	ND	ND	ND	ND	ND
DN3-750B	2.1	ND	ND	ND	ND	ND	ND	ND	ND	ND
DN3-750A	1.76	ND	ND	ND	11.3	ND	ND	ND	ND	ND
DN3-800B	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
DN3-800A	0.93	ND	ND	ND	8.21	ND	ND	ND	ND	ND
DN3-850B	1.77	<0.8	<1.3	ND	ND	ND	ND	ND	ND	ND
DN3-850A	6.33	<0.8	<1.3	ND	ND	ND	ND	ND	ND	ND

Table 4. Concentrations of volatile organic compounds in ground water from direct-push samples collected at the Dover National Test Site, Dover Air Force Base, Delaware, June–July 2001—Continued

Sample identification number	<i>cis</i> -1,2-DCE (µg/L)	TCE (µg/L)	PCE (µg/L)	Vinyl chloride (µg/L)	MTBE (µg/L)	Benzene (µg/L)	Toluene (µg/L)	Ethylbenzene (µg/L)	<i>p,m</i> -xylene (µg/L)	<i>o</i> -xylene (µg/L)
DN3-950B	1.12	<0.8	<1.3	ND	ND	ND	ND	ND	ND	ND
DN3-950A	1.81	1.14	2.65	ND	ND	ND	ND	ND	ND	ND
DN4-000A	ND	ND	ND	ND	63.0	ND	ND	ND	ND	ND
DN4-100C	1.45	ND	<1.3	ND	ND	ND	ND	ND	ND	ND
DN4-100B	1.42	ND	ND	ND	ND	ND	ND	ND	ND	ND
DN4-100A	12.4	ND	<1.3	ND	ND	ND	ND	ND	ND	ND
DN4-200B	4.01	<0.8	ND	ND	ND	ND	ND	ND	ND	ND
DN4-200A	3.42	ND	ND	ND	7.01	ND	ND	ND	ND	ND
DN4-300B	4.79	ND	ND	ND	ND	ND	ND	ND	ND	ND
DN4-300A	1.46	<0.8	ND	ND	1.4	ND	ND	ND	ND	ND
DN4-500B	ND	ND	ND	ND	ND	ND	<1.4	ND	ND	ND
DN4-500A	ND	<0.8	ND	ND	ND	ND	ND	ND	ND	ND

Table 5. *Concentrations of field constituents in direct-push ground-water samples collected at the Dover National Test Site, Dover Air Force Base, Delaware, June–July 2001*

[Samples for ferrous iron were unfiltered and turbidity may have interfered with sample analysis; mg/L, milligrams per liter; µg/L, micrograms per liter; --, no data available; <, less than]

Sample identification number	Ferrous iron (mg/L)	Total iron (mg/L)	Sulfide (mg/L)	Sulfate (mg/L)	Methane (µg/L)
DN1-000C	1.85	3.26	--	9	<25.4
DN1-000B	1.11	0.60	--	11	534.8
DN1-000A	1.03	7.50	--	8	<27.1
DN1-250C	3.90	4.80	--	11	--
DN1-250B	1.10	0.78	--	17	<26.4
DN1-250A	0.40	1.00	--	15	--
DN1-350C	4.70	4.50	--	37	--
DN1-350B	1.64	2.49	--	18	--
DN1-350A	0.50	1.09	--	15	160.2
DN1-450C	3.50	5.50	--	29	87.8
DN1-450B	2.37	8.40	--	<7	--
DN1-450A	3.22	9.20	--	54	--
DN1-451B	1.99	3.70	--	30	--
DN1-451A	2.35	2.83	--	44	--
DN1-550C	2.82	25.20	--	<7	--
DN1-550B	6.00	7.20	--	27	65.9
DN1-550A	2.42	6.70	--	128	--
DN1-600C	1.39	1.20	<0.01	16	--
DN1-600B	2.14	2.21	<0.01	15	--
DN1-600A	0.45	0.76	<0.01	14	183.9
DN1-650C	1.22	1.80	--	34	--
DN1-650B	3.28	4.50	--	33	--
DN1-650A	1.70	--	--	72	290.6
DN1-650A DUP	3.08	--	--	56	--
DN1-700C	1.91	1.59	<0.01	19	--
DN1-700B	2.13	3.40	<0.01	13	--
DN1-700A	0.90	1.14	<0.01	53	184.7
DN1-750C	--	2.12	--	23	--
DN1-750B	1.17	5.50	--	23	179.3
DN1-750A	1.59	3.27	--	62	--
DN1-800C	1.11	1.00	<0.01	23	--
DN1-800B	1.06	0.86	<0.01	23	82.1
DN1-800B DUP	0.80	0.83	<0.01	23	--
DN1-800A	0.17	0.31	<0.01	18	164.3

Table 5. *Concentrations of field constituents in direct-push ground-water samples collected at the Dover National Test Site, Dover Air Force Base, Delaware, June–July 2001—Continued*

Sample identification number	Ferrous iron (mg/L)	Total iron (mg/L)	Sulfide (mg/L)	Sulfate (mg/L)	Methane (µg/L)
DN1-850C	2.25	9.30	--	36	741.1
DN1-850B	2.10	4.70	--	30	--
DN1-850A	0.57	--	--	21	--
DN2-050B	<0.02	0.03	--	41	<27.0
DN2-050A	1.21	0.32	--	9	--
DN2-150A	0.09	2.15	--	17	--
DN2-250B	1.05	1.81	--	4	<27.1
DN2-250B DUP	1.69	3.12	--	14	--
DN2-250A	0.75	2.68	--	30	--
DN2-350B	0.23	1.63	--	35	--
DN2-350A	0.31	0.93	--	25	--
DN2-400B	2.01	14.30	<0.01	31	--
DN2-400A	2.17	2.50	<0.01	21	97.1
DN2-400A DUP	1.63	2.63	<0.01	22	--
DN2-450B	0.13	1.13	--	13	--
DN2-450A	2.11	2.52	--	34	--
DN2-500C	--	--	--	--	--
DN2-500B	1.49	1.32	<0.01	13	<26.9
DN2-500A	1.27	2.38	<0.01	33	59.3
DN2-550C	0.20	0.15	<0.01	12	--
DN2-550B	0.47	1.17	<0.01	13	--
DN2-550A	0.38	0.55	<0.01	11	--
DN2-600B	0.56	0.73	<0.01	21	--
DN2-600A	1.17	2.20	<0.01	23	121.3
DN2-650B	0.71	1.01	--	25	--
DN2-650A	1.10	1.67	--	45	--
DN2-700C	1.48	2.01	<0.01	9	--
DN2-700B	3.60	5.80	<0.01	33	--
DN2-700A	3.30	5.60	<0.01	28	34.8

Table 5. *Concentrations of field constituents in direct-push ground-water samples collected at the Dover National Test Site, Dover Air Force Base, Delaware, June–July 2001—Continued*

Sample identification number	Ferrous iron (mg/L)	Total iron (mg/L)	Sulfide (mg/L)	Sulfate (mg/L)	Methane (µg/L)
DN2-750B	0.46	0.55	--	23	--
DN2-750B DUP	0.72	0.84	--	19	--
DN2-750A	3.60	1.17	--	26	--
DN2-800C	1.86	2.82	<0.01	13	--
DN2-800B	0.07	1.05	<0.01	22	<26.3
DN2-800A	1.04	1.05	<0.01	17	--
DN2-850C	0.12	<0.02	<0.01	20	--
DN2-850B	1.54	1.40	<0.01	23	<26.3
DN2-850A	0.24	0.21	<0.01	30	37.5
DN2-900C	0.79	0.90	<0.01	30	--
DN2-900B	0.87	1.77	<0.01	23	--
DN2-900A	0.36	2.83	<0.01	12	83.4
DN2-950C	3.04	3.70	<0.01	26	<26.7
DN2-950B	0.79	1.16	<0.01	29	31.5
DN2-950B DUP	0.75	1.21	<0.01	28	--
DN2-950A	1.16	2.51	<0.01	15	--
DN2-1000C	0.72	0.61	<0.01	15	--
DN2-1000B	1.10	1.10	<0.01	23	--
DN2-1000A	0.21	<0.02	<0.01	16	--
DN3-100B	0.55	1.65	--	--	--
DN3-100A	0.50	0.87	--	16	<26.4
DN3-250B	1.01	3.09	--	36	--
DN3-250A	0.61	2.28	--	32	--
DN3-350B	0.34	0.04	--	25	--
DN3-350B DUP	0.34	0.09	--	26	--
DN3-350A	0.66	1.25	--	25	<26.0
DN3-400B	0.34	0.40	<0.01	37	--
DN3-400A	0.36	0.10	0.03	30	--
DN3-450B	<0.02	0.03	<0.01	23	--
DN3-450A	1.23	1.99	0.29	28	--
DN3-500B	0.43	1.83	<0.01	20	--
DN3-500A	1.27	2.38	<0.01	33	--

Table 5. *Concentrations of field constituents in direct-push ground-water samples collected at the Dover National Test Site, Dover Air Force Base, Delaware, June–July 2001—Continued*

Sample identification number	Ferrous iron (mg/L)	Total iron (mg/L)	Sulfide (mg/L)	Sulfate (mg/L)	Methane (µg/L)
DN3-550B	<0.02	0.44	<0.01	22	--
DN3-550A	1.41	1.94	<0.01	16	40.6
DN3-600B	1.41	2.63	<0.01	24	--
DN3-600A	4.30	5.10	<0.01	<7	164.7
DN3-650B	1.70	1.88	<0.01	23	--
DN3-650A	1.69	2.86	<0.01	10	81.8
DN3-700B	0.55	0.97	<0.01	149	--
DN3-700A	0.22	1.16	<0.01	57	<25.9
DN3-750B	1.64	1.60	<0.01	21	21.0
DN3-750A	1.16	2.01	<0.01	<7	--
DN3-800B	<0.02	0.03	--	21	--
DN3-800A	0.75	1.58	<0.01	13	--
DN3-850B	1.22	1.89	<0.01	12	<26.8
DN3-850A	--	--	--	--	46.6
DN3-950B	0.21	0.90	<0.01	36	--
DN3-950A	<0.02	1.87	<0.01	12	<26.7
DN4-000A	--	--	--	--	--
DN4-100C	--	--	--	--	--
DN4-100B	--	--	--	--	--
DN4-100A	<0.02	1.41	<0.01	36	--
DN4-200B	0.64	0.88	<0.01	70	--
DN4-200A	0.11	0.60	<0.01	13	--
DN4-300B	4.5	8.90	<0.01	17	<26.4
DN4-300A	2.68	3.21	<0.01	19	154.9
DN4-500B	<0.02	1.23	<0.01	<7	--
DN4-500A	0.44	2.12	<0.01	23	--

Table 6. *Ground-water level measurements in the surficial aquifer, Dover National Test Site, Dover Air Force Base, Delaware, July 1, 2001*

[msl, mean sea level; --, no data available]

Upper part of the surficial aquifer		Lower part of the surficial aquifer	
Well identification number	Ground-water elevation (msl)	Well identification number	Ground-water elevation (msl)
CPT-08MW	11.40	--	--
--	--	CPT-29MW	11.40
D-3082	10.29	--	--
--	--	D-3083	10.19
DM335S	10.34	DM335D	10.37
DM337S	10.19	DM337D	9.77
DM338S	14.37	DM338D	14.38
DM342S	17.11	DM342D	16.97
DM346S	15.43	DM346D	15.42
DM347S	15.37	DM347D	15.37
DM348S	18.21	DM348D	14.63
DM349S	10.65	DM349D	10.65
MW60S	16.78	MW60D	16.71
--	--	MW-7	12.12
MW75S	14.47	MW75D	14.48
MW77S	18.54	MW77D	14.65
MW78S	13.91	MW78D	13.90
MW223S	11.09	MW223D	11.07

Table 7. Concentrations of volatile organic compounds in quality-control blank samples collected at the Dover National Test Site, Dover Air Force Base, Delaware, June–July 2001

[*cis*-1,2-DCE, *cis*-1,2-dichloroethene; TCE, trichloroethene; PCE, tetrachloroethene; MTBE, methyl *tert*-butyl ether; µg/L, micrograms per liter; ND, not detected; <, less than]

Sample identification number	<i>cis</i> -1,2-DCE (µg/L)	TCE (µg/L)	PCE (µg/L)	Vinyl chloride (µg/L)	MTBE (µg/L)	Benzene (µg/L)	Toluene (µg/L)	Ethylbenzene (µg/L)	<i>p,m</i> -xylene (µg/L)	<i>o</i> -xylene (µg/L)
DN1-450-F00	ND	ND	ND	ND	Equipment Blank					
					ND	ND	ND	ND	ND	ND
DN1-250-F36	ND	<0.8	<1.3	ND	Field Blanks					
DN1-550-F20	ND	<0.8	<1.3	ND	ND	ND	ND	ND	ND	ND
DN1-600-F40	ND	<0.8	<1.3	ND	ND	ND	ND	ND	ND	ND
DN2-350-F40	ND	<0.8	<1.3	ND	ND	ND	ND	ND	ND	ND
DN2-550-F40	ND	ND	<1.3	ND	ND	ND	ND	ND	ND	ND
DN2-650-F32	ND	<0.8	ND	ND	ND	ND	ND	ND	ND	ND
DN2-800-F40	ND	<0.8	<1.3	ND	ND	ND	ND	ND	ND	ND
DN2-850-F40	ND	<0.8	<1.3	ND	ND	ND	ND	ND	ND	ND
DN3-250-F32	ND	<0.8	<1.3	ND	ND	ND	ND	ND	ND	ND
DN3-500-F50	ND	<0.8	ND	ND	ND	ND	ND	ND	ND	ND
DN3-650-F40	ND	<0.8	<1.3	ND	ND	ND	ND	ND	ND	ND
DN3-750-F40	ND	<0.8	<1.3	ND	ND	ND	ND	ND	ND	ND
DN3-800-F40	ND	<0.8	<1.3	ND	ND	ND	ND	ND	ND	ND
DN4-300-F50	ND	<0.8	<1.3	ND	ND	ND	ND	ND	ND	ND
DN1-750-SC	ND	ND	ND	ND	Screen Blanks					
					7.77					
DN1-800-SC	ND	<0.8	<1.3	ND	ND	ND	ND	ND	ND	ND
DN2-650-SC	ND	<0.8	<1.3	ND	ND	ND	ND	ND	ND	ND
DN2-850-SC	ND	<0.8	ND	ND	ND	ND	ND	ND	ND	ND
DN3-600-SC	ND	<0.8	<1.3	ND	ND	ND	ND	ND	ND	ND
DN3-650-SC	ND	<0.8	<1.3	ND	ND	ND	ND	ND	ND	ND
DN4-000-SC	ND	<0.8	<1.3	ND	ND	ND	ND	ND	ND	ND

Table 8. *Relative percent differences (RPDs) from duplicate ground-water samples collected at the Dover National Test Site, Dover Air Force Base, Delaware, June–July 2001*

[--, Data not shown in concentrations where one or both replicates were below minimum reporting limit; values in **bold** are RPDs; %, percent; *cis*-1,2-DCE, *cis*-1,2-dichloroethene; TCE, trichloroethene; PCE, tetrachloroethene; MTBE, methyl *tert*-butyl ether; µg/L, micrograms per liter; ND, not detected]

Sample identification number	<i>cis</i> -1,2-DCE (µg/L)	TCE (µg/L)	PCE (µg/L)	MTBE (µg/L)	Benzene (µg/L)	Toluene (µg/L)	Ethylbenzene (µg/L)
DN1-650A	0.9	ND	ND	6.27	ND	ND	ND
DN1-650A.DUP	2.84	ND	ND	5.45	ND	ND	ND
RPD (%)	104			14.0			
DN1-800B	ND	ND	ND	74.1	3.06	1.66	ND
DN1-800B.DUP	ND	ND	ND	72.2	2.89	1.33	ND
RPD (%)				2.6	5.7	22.1	
DN1-850A	ND	ND	ND	290	4.36	1.67	ND
DN1-850A.DUP	ND	ND	ND	327	5.42	ND	ND
RPD (%)				11.7	21.7		
DN1-850B	ND	--	--	1,070	3.81	ND	ND
DN1-850B.DUP	ND	--	--	1,018	ND	ND	ND
RPD (%)				5.0			
DN2-250B	ND	ND	ND	ND	ND	ND	ND
DN2-250B.DUP	ND	ND	ND	ND	ND	ND	ND
RPD (%)							
DN2-400A	ND	<0.8	ND	25.6	1.41	ND	ND
DN2-400A.DUP	ND	ND	ND	26.5	1.42	ND	ND
RPD (%)				3.5	0.7		
DN2-750B	ND	ND	ND	ND	ND	ND	ND
DN2-750B.DUP	ND	ND	ND	ND	ND	ND	ND
RPD (%)							
DN2-950B	ND	ND	ND	2.15	ND	ND	ND
DN2-950B.DUP	ND	ND	ND	2.18	ND	ND	ND
RPD (%)				1.4			
DN3-350B	ND	<0.8	ND	ND	ND	ND	ND
DN3-350B.DUP	ND	<0.8	ND	ND	ND	ND	ND
RPD (%)							
DN4-300B	4.79	ND	ND	ND	ND	ND	ND
DN4-300B.DUP	5.96	ND	ND	ND	ND	ND	ND
RPD (%)	21.8						

Summary

The objectives of this study were to determine the distribution of organic contaminants in the surficial aquifer, and to use this information to improve existing conceptual models and plan additional site-characterization work. This report presents the analytical results from ground-water samples collected during a direct-push ground-water sampling investigation. A total of 147 ground-water samples were collected from various depths at 48 locations from June 27 through July 18, 2001. The 147 samples included 115 volatile organic compound samples and 32 quality-control samples.

Drilling was performed with a direct-push Geoprobe drilling rig. Ground-water samples and associated quality-control samples were analyzed for volatile organic compounds, ferrous iron, total iron, sulfate, sulfide, dissolved oxygen, pH, specific conductance, temperature, and methane. Volatile organic compound samples were analyzed at the Dover National Test Site, Groundwater Remediation Field Laboratory at Dover Air Force Base. Water-level measurements were collected in July 2001 from wells in and around the Dover National Test Site.

Concentrations of volatile organic compounds were detected above the method reporting limits in 59 of the ground-water samples. The concentrations ranged from below detection limits to maximum values of 12.4 micrograms per liter of *cis*-1,2-dichloroethene, 1.14 micrograms per liter of trichloroethene, 2.65 micrograms per liter of tetrachloroethene, 1,070 micrograms per liter of methyl *tert*-butyl ether, 4.36 micrograms per liter of benzene, and 1.8 micrograms per liter of toluene. Vinyl chloride, ethylbenzene, *p,m*-xylene, and *o*-xylene were not detected in any of the samples collected during this investigation. Methyl *tert*-butyl ether was detected above the method reporting limit in 47 of the 115 ground-water samples. Ferrous iron concentrations ranged from less than 0.02 to 6.0 milligrams per liter. Total iron concentrations ranged from less than 0.02 to 25.2 milligrams per liter. Sulfide concentrations were below the method detection limit for all samples, except for those from sites DN3-400A and DN3-450A. Sulfate concentrations ranged from less than 7 to 149 milligrams per liter. Methane concentrations ranged from below method reporting limit to 741.1 micrograms per liter. pH values ranged from 4.3 to 5.9. Dissolved oxygen concentrations ranged from below the method detection limit to 7.0 milligrams per liter.

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