

TOXIC SUBSTANCES HYDROLOGY PROGRAM

Prepared in cooperation with the
AIR FORCE CENTER FOR ENGINEERING AND THE ENVIRONMENT

**Groundwater-Quality Data for a Treated-Wastewater
Plume near the Massachusetts Military Reservation,
Ashumet Valley, Cape Cod, Massachusetts, 2006–08**



Data Series 648

**U.S. Department of the Interior
U.S. Geological Survey**



Cover. Northward view of the Ashumet Valley on western Cape Cod, Massachusetts. The valley is distinguishable by the dark green trees and the central part of the golf-course fairways. Ashumet Pond is in the center right of the photo, and Cape Cod Bay is visible in the far distance at the top of the photo. Airfield runways of the Massachusetts Military Reservation can be seen between the bay and the pond. Photograph by Denis R. LeBlanc, USGS, 1984.

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**U.S. Department of the Interior
U.S. Geological Survey**

U.S. Department of the Interior
KEN SALAZAR, Secretary

U.S. Geological Survey
Marcia K. McNutt, Director

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Conversion Factors, Data, and Abbreviations

Multiply	By	To obtain
Length		
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
liter (L)	0.2642	gallon (gal)
mile (mi)	1.609	kilometer (km)
Area		
square inch (in ²)	6.452	square centimeter (cm ²)
Flow rate		
gallon per minute (gal/min)	0.06309	liter per second (L/s)
Concentrations of Chemical Constituents		
Aluminum [Al] (μM)	26.98	Aluminum [Al] (μg/L)
Ammonium [NH ₄] (μM)	14.01	Ammonium [NH ₄] (μg/L)
Arsenic [As] (μM)	74.92	Arsenic [As] (μg/L)
Barium [Ba] (μM)	137.3	Barium [Ba] (μg/L)
Boron [B] (μM)	10.81	Boron [B] (μg/L)
Cadmium [Cd] (μM)	112.4	Cadmium [Cd] (μg/L)
Calcium [Ca] (μM)	40.08	Calcium [Ca] (μg/L)
Carbon, organic, dissolved [DOC] (μM)	12.01	Carbon, organic, dissolved [DOC] (μg/L)
Chloride [Cl] (μM)	35.45	Chloride [Cl] (μg/L)
Cobalt [Co] (μM)	58.93	Cobalt [Co] (μg/L)
Copper [Cu] (μM)	63.54	Copper [Cu] (μg/L)
Iron [Fe] (μM)	55.85	Iron [Fe] (μg/L)
Magnesium [Mg] (μM)	24.31	Magnesium [Mg] (μg/L)
Manganese [Mn] (μM)	54.94	Manganese [Mn] (μg/L)
Nickel [Ni] (μM)	58.71	Nickel [Ni] (μg/L)
Nitrate [NO ₃] (μM)	14.01	Nitrate [NO ₃ as N] (μg/L)
Nitrite [NO ₂] (μM)	14.01	Nitrite [NO ₂ as N] (μg/L)
Nitrous oxide [N ₂ O] (μM)	28.02	Nitrous oxide [N ₂ O as N] (μg/L)
Oxygen, dissolved [O ₂] (μM)	.03200	Oxygen, dissolved [O ₂] (mg/L)
Phosphate [PO ₄] (μM)	.03097	Phosphate [PO ₄ as P] (mg/L)
Phosphorus [P] (μM)	30.97	Phosphorus [P] (μg/L)
Potassium [K] (μM)	39.10	Potassium [K] (μg/L)
Silicon [Si] (μM)	28.09	Silicon [Si] (μg/L)
Sodium [Na] (μM)	22.98	Sodium [Na] (μg/L)
Strontium [Sr] (μM)	87.62	Strontium [Sr] (μg/L)
Sulfate [SO ₄] (μM)	96.06	Sulfate [SO ₄] (μg/L)
Zinc [Zn] (μM)	65.37	Zinc [Zn] (μg/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 coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD29).

Horizontal coordinate information is referenced to the North American Datum of 1927 (NAD27).

Altitude, as used in this report, refers to distance above the vertical datum.

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius ($\mu\text{S}/\text{cm}$ at 25°C).

Concentrations of chemical constituents in water are given in milligrams per liter (mg/L) or micromoles per liter (μM).

Acronyms

AFCEE	Air Force Center for Engineering and the Environment
BOD	Biological oxygen demand
DOC	Dissolved organic carbon
MBAS	Methylene blue active substances
MMR	Massachusetts Military Reservation
MLS	Multilevel sampler
PVC	Polyvinyl chloride
SPEIM	System performance and ecological impact monitoring
USGS	U.S. Geological Survey

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Groundwater-Quality Data for a Treated-Wastewater Plume near the Massachusetts Military Reservation, Ashumet Valley, Cape Cod, Massachusetts, 2006–08

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Abstract

A plume of contaminated groundwater extends from former disposal beds at the Massachusetts Military Reservation's wastewater-treatment plant toward Ashumet Pond, coastal ponds, and Vineyard Sound, Cape Cod, Massachusetts. Treated sewage-derived wastewater was discharged to the rapid-infiltration beds for nearly 60 years before the disposal site was moved to a different location in December 1995.

Water-quality samples were collected from monitoring wells, multilevel samplers, and profile borings to characterize the nature and extent of the contaminated groundwater and to observe the water-quality changes after the wastewater disposal ceased. Data are presented here for water samples collected in 2007 from 394 wells (at 121 well-cluster locations) and 780 multilevel-sampler ports (at 42 locations) and in 2006–08 at 306 depth intervals in profile borings (at 20 locations) in and near the treated-wastewater plume. Analyses of these water samples for field parameters (specific conductance, pH, dissolved oxygen and phosphate concentrations, and alkalinity); absorbance of ultraviolet/visible light; and concentrations of nitrous oxide, dissolved organic carbon, methylene blue active substances, selected anions and nutrients, including nitrate and ammonium, and selected inorganic solutes, including cations, anions, and minor elements, are presented in tabular format. The natural restoration of the sand and gravel aquifer after removal of the treated-wastewater source, along with interpretations of the water quality in the treated-wastewater plume, have been documented in several published reports that are listed in the references.

Introduction

Treated wastewater was discharged to rapid-infiltration beds at the Massachusetts Military Reservation's (MMR) wastewater-treatment plant on Cape Cod for nearly 60

years before the disposal site was moved to a different location in December 1995. The disposal created a plume of contaminated groundwater that extends southward in the glacial sand and gravel aquifer (LeBlanc and others, 1986) from the former disposal site toward Ashumet Pond, coastal ponds, and Vineyard Sound approximately along the alignment of a topographic feature known locally as the Ashumet Valley. The plume, which was first described by LeBlanc (1984), is about 5 miles (mi) long, 0.6–1.0 mi wide, and 100 feet (ft) thick (fig. 1), as generally defined by concentrations of nitrate-nitrogen, chloride, and boron greater than about 29, 170, and 0.56 micromoles per liter (μM) (0.4, 6.0, and 0.006 milligrams per liter (mg/L)), respectively, in 2007 (J.R. Barbaro, U.S. Geological Survey, written commun., 2010). These concentration thresholds are based on previous studies of groundwater quality on western Cape Cod (LeBlanc, 1984; Frimpter and Gay, 1979; and citations below). The plume of wastewater-contaminated groundwater is composed of a complex mixture of inorganic and organic solutes typical of treated sewage-derived wastewater (Barber, 1998; Barber and others, 1988; Barber and others, 2009; Böhlke and others, 2006; Ceazan and others, 1989; Field and others, 1992; Kent and others, 2000; Kent and Fox, 2004; Kent and Maeder, 1999; LeBlanc, 1984; McCobb and others, 2003; Parkhurst and others, 2003; Repert and others, 2006; Stollenwerk, 1996; Thurman and others, 1986; and Walter and others, 1996). The plume supports a microbial ecosystem that includes bacteria and protozoa (Harvey and Barber, 1992; Harvey and George, 1987; Harvey and others, 1984; Kinner and others, 2002; Kinner and others, 1997; Kinner and others, 1998; and Metge and others, 1993) and has well developed biogeochemical zones (Abrams and Loague, 2000; Abrams and others, 1998; Kent and others, 1994; LeBlanc and others, 1999; Lee and Bennett, 1998; Smith and Duff, 1988; Smith and others, 2004; Smith and others, 1991a; Smith and others, 1991b). Volatile organic compounds that were released from a former fire-training area near the wastewater-treatment plant also are in the plume (Air Force Center for Environmental Excellence, 2005).

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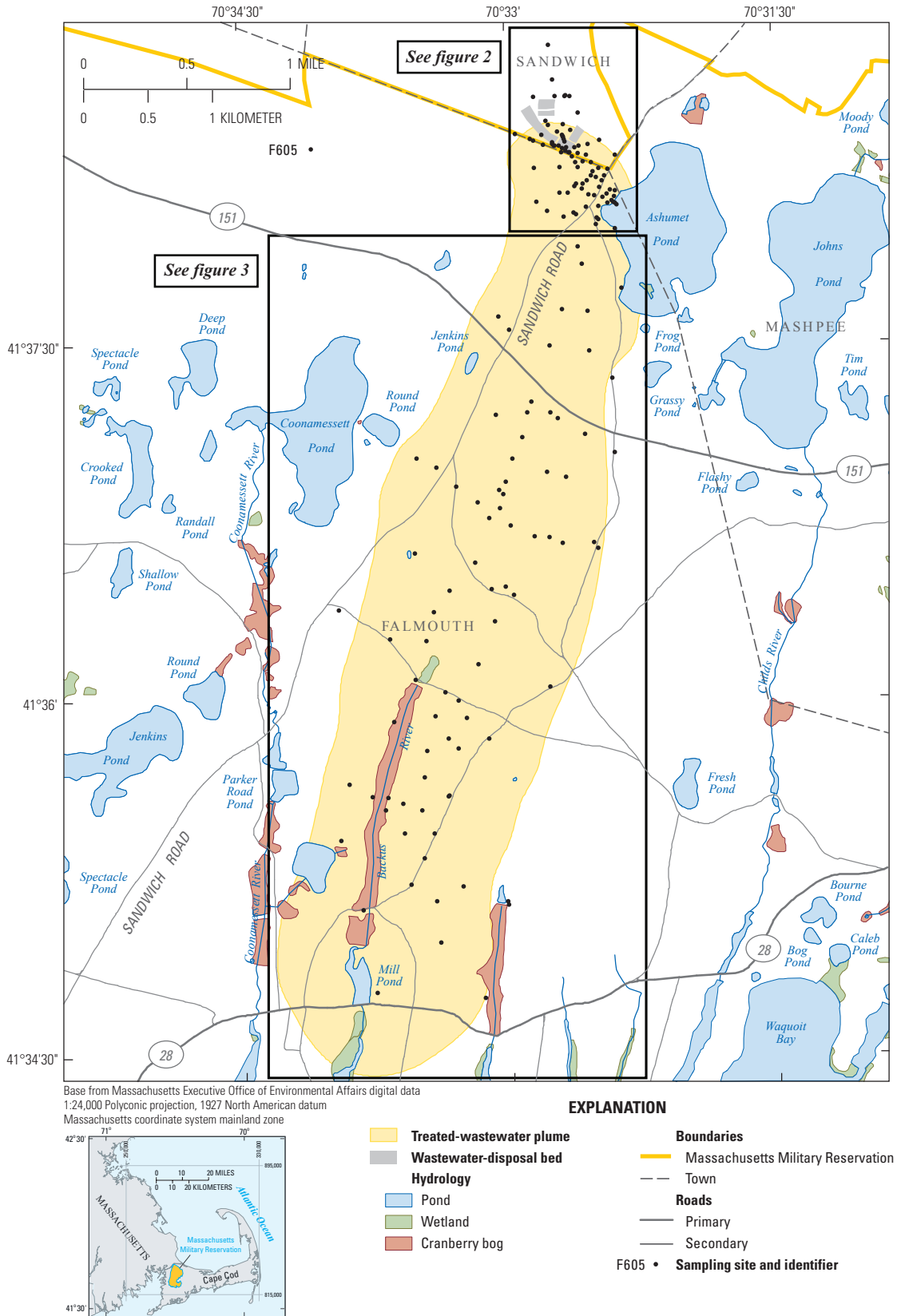


Figure 1. The study area with the locations of monitoring wells, multilevel samplers, and profile borings sampled in 2006–08, and the extent of the treated-wastewater plume in 2007, Ashumet Valley, Cape Cod, Massachusetts. The extent of the plume is defined by concentrations of nitrate-nitrogen, chloride, and boron greater than about 29, 170, and 0.56 micromoles per liter (0.4, 6.0, and 0.006 milligrams per liter), respectively (J.R. Barbaro, U.S. Geological Survey, written commun., 2010).

In an effort to document changes in groundwater quality after wastewater disposal was stopped in December 1995, the U.S. Geological Survey (USGS), with assistance from the Air Force Center for Engineering and the Environment (AFCEE), collected groundwater samples in 2006–08 near the abandoned rapid-infiltration beds and within and near the treated-wastewater plume (figs. 1–3). The samples were analyzed for field parameters (specific conductance, pH, dissolved oxygen and phosphate concentrations, and alkalinity); absorbance of ultraviolet/visible light; concentrations of nitrous oxide, dissolved organic carbon, methylene blue active substances, selected anions and nutrients, including nitrate and ammonium, and selected inorganic solutes, including cations, anions, and minor elements.

This report compiles selected groundwater quality and water-level data that were collected as part of this study. The dataset includes water-quality data from monitoring wells, multilevel samplers (MLSs), and profile boring samples in the area that extends from about 2,000 ft upgradient of the former infiltration beds at monitoring-well cluster S315 (fig. 2) to the toe of the plume near Vineyard Sound at monitoring-well cluster F497 (fig. 3). Previous water-quality data for the treated-wastewater plume can be found in Thurman and others (1984), Savoie and LeBlanc (1998), and Savoie and others (2006). Findings from the first few years of monitoring after disposal to the rapid-infiltration beds ended have been presented elsewhere (Barber and Keefe, 1999; Campo and Hess, 1999; Kent and Maeder, 1999; LeBlanc and others, 1999; Smith and others, 1999). A comprehensive discussion of the effect of natural restoration on nitrogen and dissolved organic carbon (DOC) can be found in Repert and others (2006); on zinc contamination in Kent and others (2000); and on phosphate contamination in Parkhurst and others (2003). Other data, research projects, and reports related to the treated-wastewater plume can be found at the USGS Cape Cod Toxic Substances Hydrology Program Web site (U.S. Geological Survey, 2011).

In a separate effort not described in this report, AFCEE collected groundwater samples in 2007–09 from additional wells and profile borings in the area shown in figure 1 as part of investigations and monitoring of contaminant plumes that originated from a former fire-training area and a historical chemical spill. The results, which include concentrations of volatile organic compounds, are documented in AFCEE (2008), AFCEE (2010), and the 2006, 2007, and 2008 annual system performance and ecological impact monitoring (SPEIM) program reports for the Chemical Spill-10 and Ashumet Valley plumes (AFCEE, 2011).

Monitoring Groundwater Quality in the Treated-Wastewater Plume

Groundwater-quality samples included in this report were collected in 2007 from 394 monitoring wells

(at 121 well-cluster locations) and 780 MLS ports (at 42 locations), and in 2006–08 from 306 profile-boring depth intervals (at 20 locations) (figs. 1–3). These sites were selected from a larger set of available sites so that the spatial distribution of the data from the selected sites was sufficient to define the steep geochemical gradients near the disposal beds, describe the distributions of nitrate and ammonium in the distal portions of the plume, and determine historical trends in water quality in the plume since the first comprehensive sampling in 1978 (LeBlanc, 1984). The well, MLS, and profile-boring installation and sampling methods are summarized below. The sampling protocols also are described in more detail in Savoie and LeBlanc (1998); Savoie and others (2006); U.S. Geological Survey (variously dated); and AFCEE (2009).

Monitoring Wells

The monitoring wells were installed by several methods, including hollow-stem-auger, drive-and-wash, sonic, and direct-push drilling. The wells are in clusters containing one to nine wells. Most of the wells (353 of 394) are constructed of 2.0-inch (in.)- or 2.5-in.-diameter polyvinyl chloride (PVC) well casing and slotted PVC screens. The screens of most wells (362 of 394) are 2 to 5 ft long and have 0.010-in. slots. Fifteen wells, including 12 small-diameter (0.62-in.) wells installed in the bottom of Ashumet Pond by using direct-push drilling, are constructed of steel well casing. These wells have 1- to 20-ft-long stainless steel wirewound or slotted screens. Selected monitoring-well information is given in table 1.

Multilevel Samplers

The MLSs were installed by using hollow-stem-auger drilling. The MLSs are constructed with 15 color-coded polyethylene tubes (with a 0.25-in. outside diameter and a 0.17-in. inside diameter) within a 1.25-in.-diameter PVC casing. The color-coded tubes extend from the land surface, down the PVC casing, and out into the aquifer through holes drilled in the PVC at various depths. The bottom of each polyethylene tube, referred to as the sampling port, is open but screened with a fine nylon fabric. Water levels cannot be measured in the MLSs; the water levels at the MLS locations were estimated by interpolation between water levels measured in nearby monitoring wells (table 1). Selected MLS information is given in table 2.

Sample Collection from Wells and Multilevel Samplers

Groundwater samples were collected from the 2.0-in.-diameter or larger monitoring wells by using a Keck SP-81 submersible pump fitted with Teflon tubing and an isolation packer or a Grundfos Redi-Flo2 submersible pump

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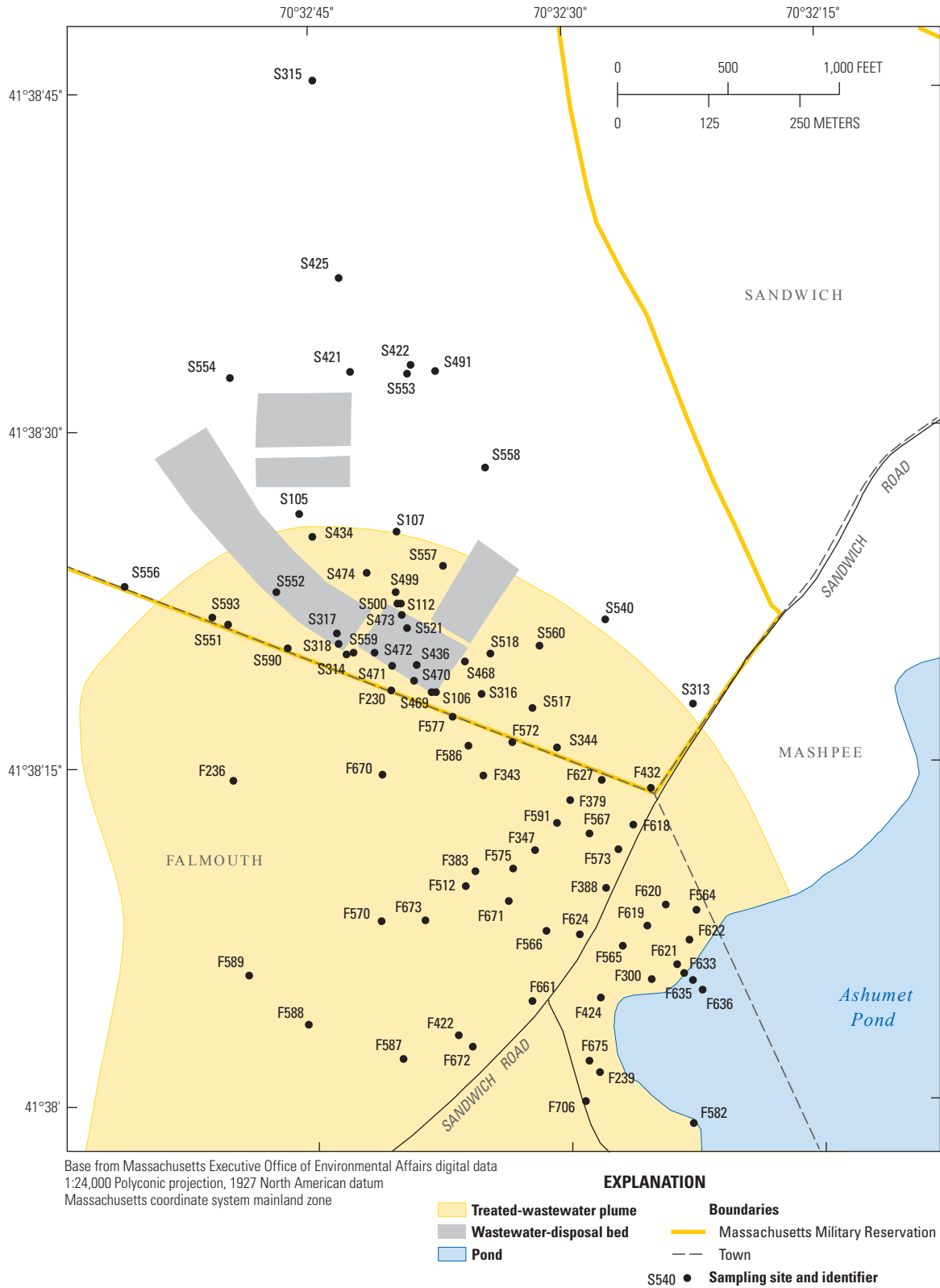


Figure 2. The portion of the study area extending from the wastewater-disposal beds at the Massachusetts Military Reservation to Ashumet Pond; the locations of monitoring wells, multilevel samplers, and profile borings sampled in 2006–08; and the extent of the treated-wastewater plume in 2007, Ashumet Valley, Cape Cod, Massachusetts.

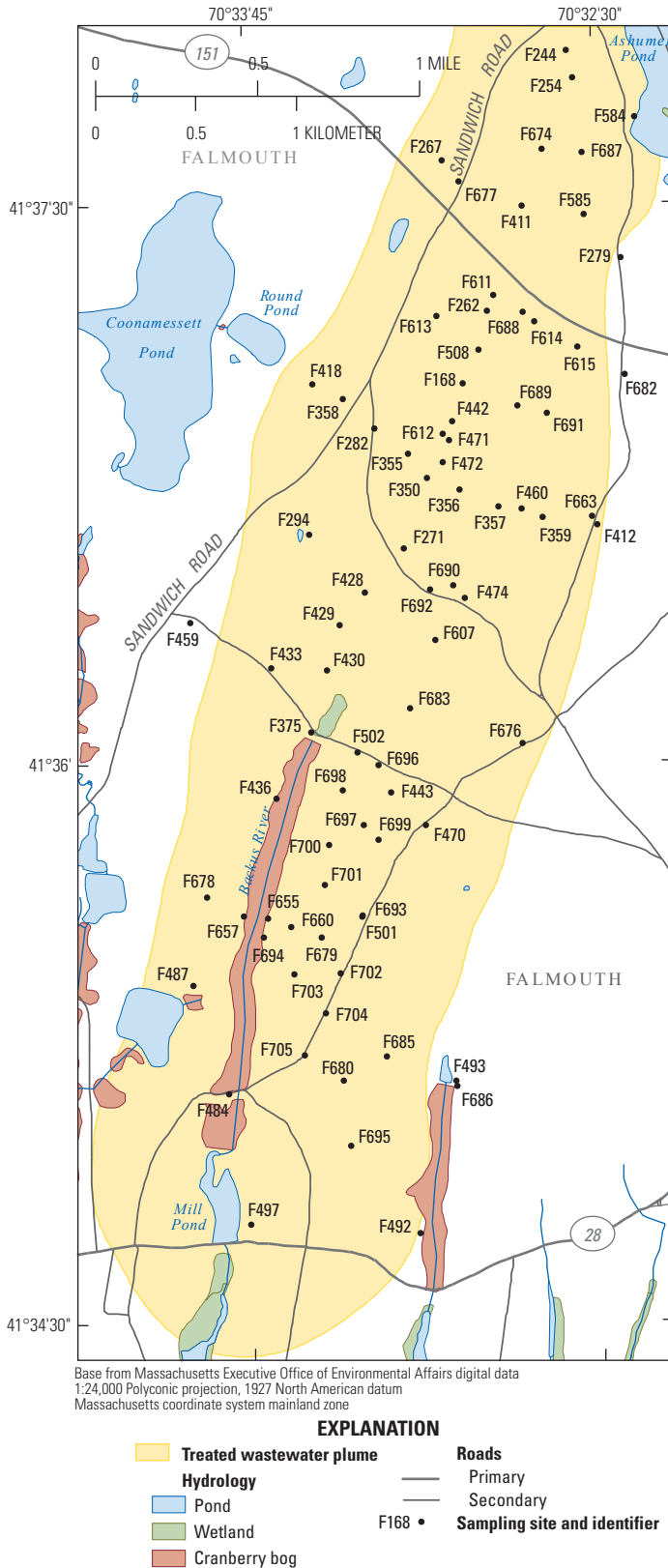


Figure 3. The portion of the study area extending from Ashumet Pond to Route 28; the locations of monitoring wells, multilevel samplers, and profile borings sampled in 2006–08; and the extent of the treated-wastewater plume in 2007, Ashumet Valley, Cape Cod, Massachusetts.

fitted with Teflon-lined polyethylene tubing. The USGS and AFCEE used the Keck and Grundfos pumps, respectively. The Keck pump intake was generally set about 2 ft above the top of the screen, and the packer was inflated to isolate the water in the casing above the packer from the pump intake. A minimum of three volumes of the casing below the packer was evacuated at a pumping rate of about 0.26 to 0.34 gallons per minute (gal/min) before field water-quality measurements were made and samples were collected. The Grundfos pump intake was set at the midpoint of the screened interval. A minimum of three volumes of the screened interval was evacuated at a pumping rate of about 0.026 to 0.53 gal/min, and samples were collected only after field water-quality parameters had stabilized.

Groundwater samples were collected from the 0.62- to 1.25-in.-diameter wells by using a GeoPump2 peristaltic suction pump fitted with Norprene tubing that was connected to 0.25-in.-diameter polyethylene tubing. The open end of the polyethylene tubing was set about 10 ft below the static water level. A minimum of three casing volumes was evacuated at a pumping rate of about 0.26 to 0.53 gal/min before samples were collected. The 0.5-in.-diameter temporary well (FSW 686–0010) was sampled by using a peristaltic pump connected directly to the driven casing.

Groundwater samples were collected from the MLSs by using a GeoPump2 peristaltic suction pump fitted with Norprene tubing that was connected directly to the MLS tubing. The pumping rate was about 0.079 gal/min, and a minimum of three tubing volumes was evacuated before field water-quality measurements were made and water samples were collected.

Sample Collection from Profile Borings

The profile borings were drilled by direct-push and sonic methods (table 3). For the direct-push borings, a GeoProbe model 6620DT was used to advance 1.5-in.-diameter steel probe rods to each sampling interval sequentially; the bottom 5-ft-long rod was milled with 0.010-in. slots. At each sampling interval, 0.5-in.-diameter polyethylene tubing fitted with a Watera inertial-pump check valve was set into the slotted section at the bottom of the probe rods. Groundwater was pumped from the boring by using a reciprocating action; the pumping rate was highly dependent on depth to water and the aquifer material at the sampled interval, but generally was about 0.079 to 0.79 gal/min. The pumped water tended to be turbid because of the surging caused by the reciprocating action. A minimum of three volumes of the probe rods was evacuated, and samples were collected only after field water-quality parameters had stabilized.

For the sonic borings, a Boart Longyear sonic drilling rig was used to advance a 7.68-in.-diameter steel casing to the bottom of the sampling interval. Water from a municipal water supply was pumped down the casing during drilling to prevent sediments from entering the casing. A 5-ft-long

stainless steel wirewound screen attached to a 5.5-in.-diameter steel drill casing was lowered to the bottom of the boring, and the larger outer casing was pulled back about 5 ft to expose the screen to the aquifer. A 4-in.-diameter submersible pump and packer assembly fitted to polyethylene tubing was lowered to just above the screen, and the packer was inflated to isolate the screened interval from the water in the casing above the screen. A minimum of three volumes of the casing below the packer was evacuated at a pumping rate of about 0.26 to 0.79 gal/min, and water samples were collected after field water-quality parameters had stabilized.

Field Water-Quality Measurements

Field water-quality parameters for samples collected by the USGS were measured in unfiltered grab samples. The specific conductance was measured with a Thermo Orion model 130A conductivity meter. The pH was measured with an Orion model 250A meter, an Orion Ross Sure-Flow model 81–72 pH electrode, and an Orion stainless steel, temperature-compensating probe. Dissolved oxygen concentrations greater than 31 μM were generally measured in samples collected in well flushed glass biological oxygen demand (BOD) bottles that were stoppered and chilled until measurement in the lab (within 6 hours of collection) with a YSI model 58 dissolved oxygen meter and YSI model 5905 probe. Dissolved oxygen concentrations less than 31 μM were generally measured in the field by using a quantitative colorimetric method (CHEMetrics V–2000 photometer and K–7553 Vacu-vial self-filling reagent ampoules) with a practical detection limit of 3.1 μM (0.10 mg/L) (CHEMetrics, Inc., 2011). Phosphate also was measured colorimetrically in selected samples in the field (CHEMetrics VVR photometer, K–8513 ampoules, and practical detection limit of 3.2 μM (0.10 mg/L PO_4 as P)). Temperature was measured by using the Orion stainless steel probe in conjunction with the pH probe. Turbidity was measured with a HACH model 2100P portable turbidimeter. Alkalinity was determined in the field for selected samples with expected elevated concentrations of iron(II) or in the laboratory for most samples by an incremental titration method (Fishman and Freidman, 1989) with the endpoint determined by using Gran plots. Iron concentrations were measured colorimetrically in selected samples in the field (CHEMetrics VVR photometer, K–6003 ampoules, and practical detection limit of 3.6 μM (0.20 mg/L)). The iron values were used only to check that the appropriate method was used to measure alkalinity. Most samples in which iron was detected also had concentrations that exceeded the method's maximum reporting level; for this reason, the field-measured iron values are not presented in this report.

Field water-quality parameters for samples collected by AFCEE were measured by using a field YSI multiparameter model 6820 sonde. The parameters included specific conductance, pH, dissolved oxygen concentration, turbidity,

temperature, and oxidation-reduction potential. For samples collected from the monitoring wells and sonic profile borings, the sonde was placed in a flow-through chamber. For samples collected from the direct-push profile borings, the sonde was placed in a 1-L beaker filled with a grab sample because the flow rate generally was too low for use of the flow-through chamber. The dissolved oxygen concentrations were higher than expected for some samples, perhaps because of oxygen contamination during filling of the 1-L beaker. The pH was also anomalously high for some samples, particularly the first few samples collected each day. Possible reasons include the persistent effects of the pH 7 and 10 buffers used during calibration of the YSI sonde at the start of each day, and the large potential errors associated with pH measurements in poorly buffered, low-conductivity water unless rigorous procedures tailored to this geochemical condition are used (Busenberg and Plummer, 1987; Kent and Maeder, 1999). For these reasons, dissolved oxygen concentrations and pH measured with the YSI sonde in samples collected from the direct-push profiles are not included in this report. These data are available in the databases of the AFCEE Installation Restoration Program.

Sample Preservation and Chemical Analysis

Samples for analysis of absorbance of ultraviolet/visible light, and concentrations of DOC, selected anions and nutrients, including nitrate and ammonium, and selected inorganic solutes, including cations, anions, and minor elements, were filtered through an inline polyvinylidene filter with a diameter of 33 millimeters (mm) and a pore size of 0.45 micrometers (μm) (Millipore Millex SLHV 033 NK). A new filter was used at each well, MLS port, or profile-boring interval. For samples that were especially turbid, an inline polysulfone disk filter with a pore size of 0.45 μm , polyester reinforcement, and an effective filtration area of 20 square centimeters (cm^2) was used instead (Pall AquaPrep 4270). The samples for analysis of selected inorganic solutes, including cations, anions, and minor elements, were preserved with trace-metal-grade nitric acid to a pH less than 2, the samples for analysis of ammonium were preserved with sulfuric acid to a pH less than 2, and the samples for analysis of selected anions, including nitrate, were frozen. Filtered and unfiltered samples for analysis of methylene blue active substances (MBAS) by field photometer and commercial laboratory, respectively, were chilled. The nitrous oxide samples were collected by using a syringe and serum bottles that had been pretreated with potassium hydroxide, fitted with thick butyl rubber septa, and flushed with helium of ultra-high-purity grade for 15 minutes. The pumps and sampling equipment were decontaminated with laboratory-grade deionized water after each well or MLS had been sampled. This method for decontamination had been shown in other studies to be sufficient (Savoie and LeBlanc,

1998). Samples of the deionized water (rinsewater blank) and the rinsewater from the Keck submersible pump (equipment rinsewater) were collected following the collection of groundwater samples from monitoring well FSW 355–0104. Duplicate analysis was performed on about 10 percent of the samples collected. At selected wells or MLS ports, an aliquot of the filtered sample was passed through a cartridge containing Chelex. Chelex is a cation exchanger that has a high selectivity for multivalent cations and therefore retains free metal ions while allowing strongly complexed metal ions to pass through (Kent and Maeder, 1999).

Concentrations of selected anions and nutrients, DOC, and nitrous oxide were analyzed by the USGS National Research Program laboratory in Boulder, Colorado (Repert and others, 2006). The selected anions and nutrients, including nitrate, nitrite, and ammonium, were analyzed by using a flow-injection autoanalyzer and ion chromatography. DOC was converted to carbon dioxide by heated-persulfate oxidation, and concentrations were determined with infrared or conductivity detection. Concentrations of nitrous oxide were determined by gas chromatography after equilibration at 35°C. Aqueous concentrations of the gas were calculated by using temperature-corrected Bunsen solubility coefficients. Concentrations of selected inorganic solutes, including cations, anions, and minor elements, were determined by using inductively coupled plasma atomic emission spectroscopy by the USGS National Research Program laboratory in Menlo Park, California. The descriptions of methods, limits of quantitation, precision, and accuracy for results of analyses for the selected inorganic solutes are described in Savoie and others (2004).

Concentrations of MBAS in replicate samples were analyzed by using a colorimetric method (method 425.1, U.S. Environmental Protection Agency, 1983). MBAS analysis is a measurement of total anionic surfactants, including linear- and branch-chained alkylbenzenesulfonates. Concentrations of MBAS were analyzed at the USGS office in Northborough, Massachusetts, several days after the samples were collected by using a CHEMetrics model I–2017 single analyte meter and R–9423 Vacu-vial self-filling reagent ampoules. The practical detection limit of the method is 0.25 mg/L. Replicate samples for MBAS were analyzed by Test America, a commercial laboratory in Savannah, Georgia.

Water-Quality Data

Water samples collected in 2007 from 394 monitoring wells (at 121 well-cluster locations) and 780 MLS ports (at 42 locations) and in 2006–08 from 306 profile-boring depth intervals (at 20 locations) were analyzed for field water-quality parameters (table 4); concentrations of selected anions, ammonium, and nitrous oxide (table 5); concentrations of DOC and MBAS, and absorbance of ultraviolet/visible light

(table 6); and concentrations of selected inorganic solutes, including cations, anions, and minor elements (table 7). Water samples collected in 2006–08 from 306 profile-boring depth intervals (at 20 locations) were analyzed for field water-quality parameters (table 8); concentrations of selected anions and ammonium (table 9); and concentrations of selected inorganic solutes, including cations, anions, and minor elements (table 10). Duplicate analyses for the analytes are included in the data tables and designated by “-D”. Samples that were filtered through the Chelex filter are designated by “-X” in table 7. Analyses of the rinsewater blank and equipment-rinsewater samples are shown at the bottoms of tables 5 and 7.

The entries in the data tables are sorted by sampling site, which can include one or more wells and MLSs. The sites are shown in figures 2 and 3 with short labels that include only the first letter of the town code (for example, the label “MA-FSW” in the town of Falmouth is shown as “F”), followed by the three-digit sequential site number for that town. The tables list the sampling points at a site in order of descending altitude rather than in alphanumeric order so that the vertical distributions of concentrations and water-quality parameters are evident.

The temperature was measured at land surface in either a beaker along with the pH measurements or in a flow cell with the YSI sonde. The temperature measured by these methods may differ substantially from the temperature in the aquifer at the sampling point because of warming or cooling during passage of the water up the sample-collection tube and through the pump.

Lithium concentrations were below quantitation limits in all samples but are reported in tables 7 and 10 for completeness (the method used to develop the limits of quantitation for the inorganic solutes is described in Savoie and LeBlanc (1998)). Zinc concentrations less than 0.2 μM in table 7 are subject to large random errors that may be related to contamination during sampling. The source of contamination was not identified.

The field water-quality data in table 8 for the profile borings made by using the direct-push method were commonly affected by turbid samples resulting from the reciprocating action of the inertial pump. The data also were affected by low pumping rates resulting from the small surface area open to the aquifer on the slotted steel probe rods and the difficulty of developing the slots to obtain greater yields. The high turbidity in some samples also may have affected the measurements made colorimetrically in the field for dissolved oxygen and phosphate concentrations. Because of the high turbidity, the generally challenging sampling environment during drilling operations, and the collection of samples directly from probe rods and drill casings made of steel, the profile-boring samples were not analyzed for minor elements such as iron, manganese, and boron. Despite these considerations, the borehole profiles provide valuable data on the vertical distributions of chemical parameters in areas of the plume that have few permanent sampling locations.

Summary

During the period 2006–08, the U.S. Geological Survey and the Air Force Center for Engineering and the Environment collected groundwater samples from 394 wells, 780 multilevel-sampler ports, and 306 profile-boring depth intervals in and near the treated-wastewater plume that originates from rapid-infiltration disposal beds at the Massachusetts Military Reservation, Cape Cod, Massachusetts. The beds were used for about 60 years ending in December 1995. The natural restoration of the sand and gravel aquifer as uncontaminated groundwater flushes through the area of the treated-wastewater plume is being studied by the U.S. Geological Survey. This report provides data to support research on the natural restoration of the plume and transport of contaminants such as nitrate and ammonium in the sand and gravel aquifer. The groundwater samples described in this report were collected from points in and adjacent to the 5-mi-long plume. The chemical data presented include field water-quality parameters (specific conductance, pH, dissolved oxygen concentration, turbidity, temperature, and alkalinity); concentrations of selected anions and nutrients, including nitrate and ammonium, dissolved organic carbon, nitrous oxide, methylene blue active substances, and selected inorganic solutes, including cations, anions, and minor elements; and absorbance of ultraviolet/visible light.

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Tables

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2. Location coordinates, land-surface and screen altitudes, and estimated water-table altitudes for multilevel samplers, Ashumet Valley treated-wastewater plume, Cape Cod, Massachusetts [[Click here](#)]
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