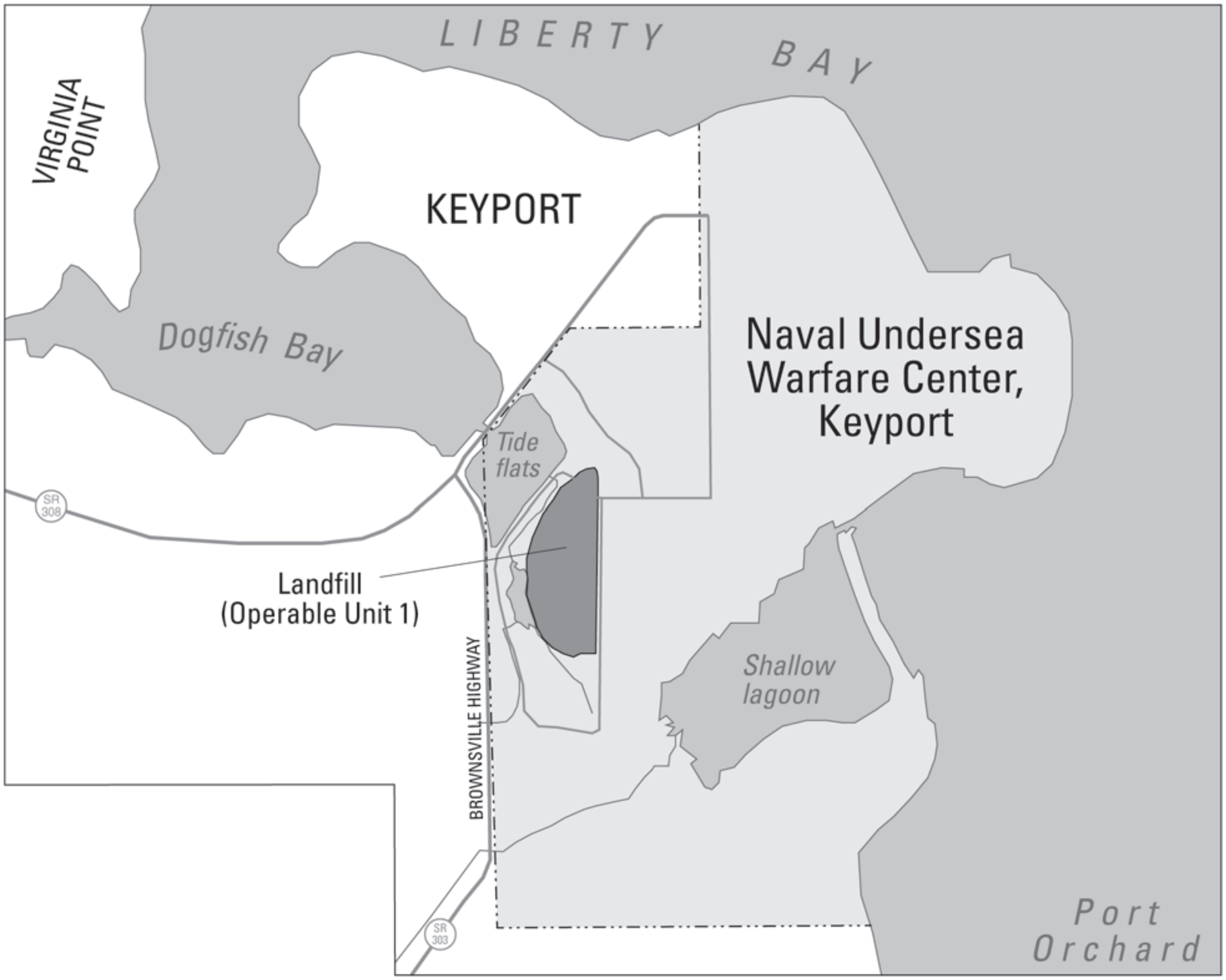
Prepared in cooperation with Department of the Navy,
Naval Facilities Engineering Command, Northwest

Groundwater Geochemical and Selected Volatile Organic Compound Data, Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, June 2009



Data Series 644

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

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KEN SALAZAR, Secretary

U.S. Geological Survey
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Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
foot (ft)	0.3048	meter (m)
acre	4,047	square meter (m^2)
acre	0.4047	hectare (ha)

SI to Inch/Pound

Multiply	By	To obtain
micrometer (µm)	0.001	millimeters (mm)
milliliter (mL)	0.001	liters (L)
liter (L)	33.28	ounce, fluid (fl. oz)

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

$$°F=(1.8\times°C)+32.$$

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

$$°C=(°F-32)/1.8.$$

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

Datums

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1927 (NAD 27).

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

Groundwater Geochemical and Selected Volatile Organic Compound Data, Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, June 2009

By R.L. Huffman and R.S. Dinicola

Abstract

Previous investigations indicate that natural attenuation and biodegradation of chlorinated volatile organic compounds (VOCs) are substantial in groundwater beneath the 9-acre former landfill at Operable Unit 1 (OU 1), Naval Undersea Warfare Center, Division Keyport, Washington. Phytoremediation combined with ongoing natural attenuation processes was the preferred remedy selected by the U.S. Navy, as specified in the Record of Decision for the site. The U.S. Navy planted two hybrid poplar plantations on the landfill in spring 1999 to remove and to control the migration of chlorinated VOCs in shallow groundwater. The U.S. Geological Survey (USGS) has continued to monitor groundwater geochemistry to ensure that conditions remain favorable for contaminant biodegradation as specified in the Record of Decision. This report presents groundwater geochemical and selected VOC data collected at OU 1 by the USGS during June 15–17, 2009, in support of long-term monitoring for natural attenuation.

For 2009, groundwater samples were collected from 13 wells and 9 piezometers. Samples from all wells and piezometers were analyzed for redox sensitive constituents, and samples from 10 of 18 upper-aquifer wells and piezometers and 3 of 4 intermediate-aquifer wells also were analyzed for chlorinated VOCs. Concentrations of redox sensitive constituents measured in 2009 were consistent with previous years, with dissolved hydrogen (H_2) concentrations ranging from less than 0.1 to 1.8 nanomolar (nM), dissolved oxygen concentrations all at 0.6 milligram per liter or less; little to no detectable nitrate; abundant dissolved manganese, iron, and methane; and commonly detected sulfide.

The reductive declorination byproducts—methane, ethane, and ethene—were not detected in samples collected from the upgradient wells in the landfill or the upper aquifer beneath the northern phytoremediation plantation. Chlorinated VOC concentrations in 2009 at most piezometers were similar to or slightly less than chlorinated VOC concentrations measured in previous years. In 2009, concentrations of reductive dechlorination byproducts ethane and ethene were less than those measured in 2008 at most northern plantation wells and piezometers.

For the upper aquifer beneath the southern phytoremediation plantation, chlorinated VOC concentrations in 2009 at the piezometers were extremely high and continued to vary considerably over space and between years. At piezometer P1-9, the total chlorinated VOC concentration increased from 25,000 micrograms per liter in 2008 to more than 172,000 micrograms per liter in 2009. At piezometer P1-7 in 2009, the concentrations of trichloroethene and *cis*-1,2-dichloroethene (*cis*-DCE) were the highest to date. The reductive dechlorination byproducts ethane and ethene were detected at all wells and piezometers in the southern plantation with the exception of piezometer P1-8, although the measured concentrations were not consistently high.

For the intermediate aquifer, concentrations of redox sensitive constituents and VOCs in 2009 at wells MW1-25, MW1-28, and MW1-39 were consistent with concentrations measured in previous years. Concentrations of the reductive dechlorination byproducts ethane and ethene at wells MW1-25 and MW1-28 were equal to or greater than previously measured concentrations.

Introduction

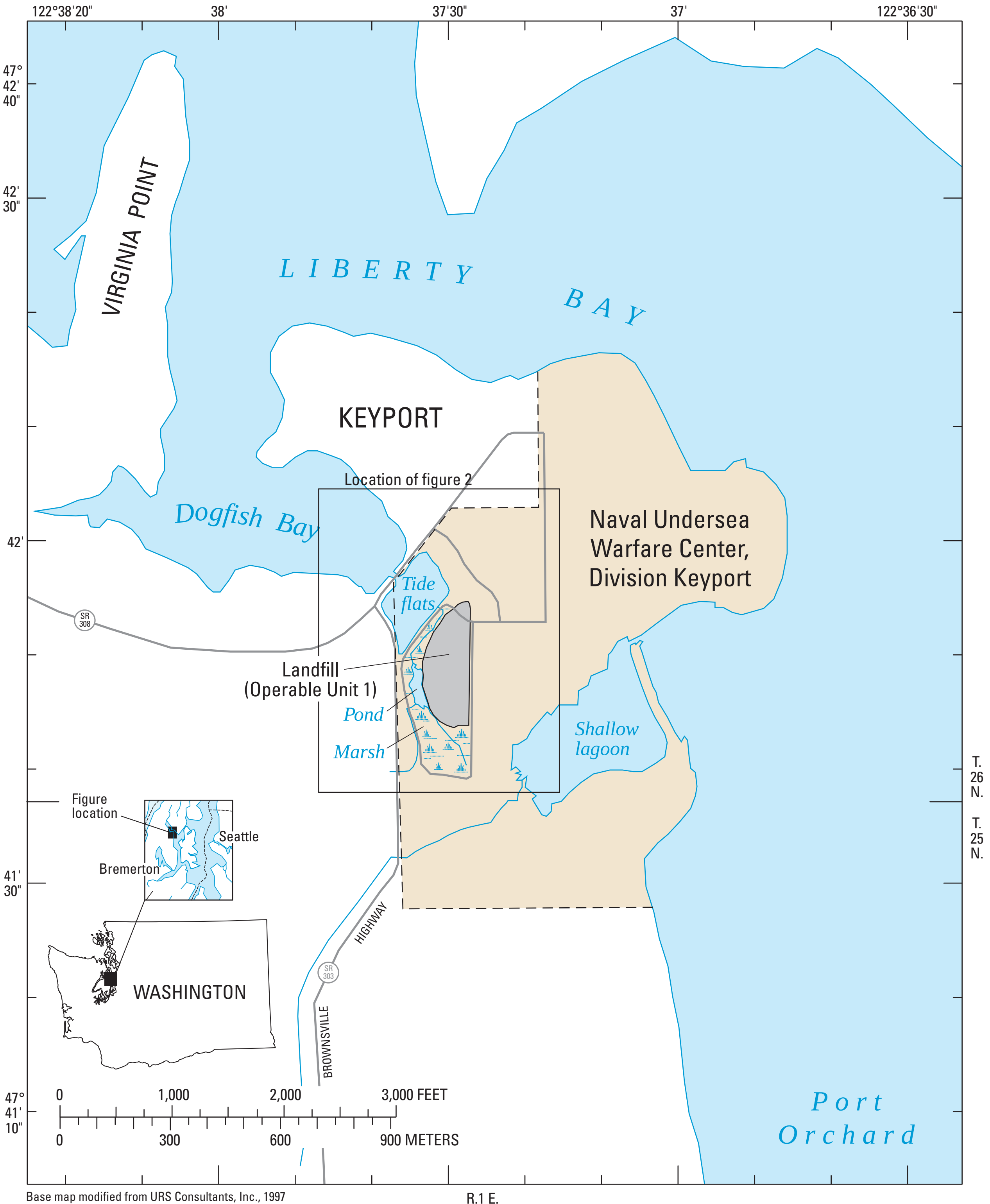
Chlorinated volatile organic compounds (VOCs) are in groundwater beneath the 9-acre former landfill at Operable Unit 1 (OU 1) at the Naval Undersea Warfare Center (NUWC), Division Keyport. The NUWC is on a small peninsula in Kitsap County, Washington, in an extension of Puget Sound called Liberty Bay (fig. 1). The former landfill is on the narrow strip of land connecting the peninsula to the mainland and is adjacent to tidal flats that are an extension of Liberty and Dogfish Bays. The OU 1 landfill was constructed in a former marshland and is unlined at the bottom. The landfill was the primary disposal area for domestic and industrial wastes generated by NUWC Division Keyport from the 1930s through 1973. The landfill received paints, thinners, solvents, acids, dried sludge from a wastewater-treatment plant, and other industrial wastes. The most concentrated disposal area for waste paints and solvents was at the southern end of the landfill.

Groundwater beneath OU 1 is within a series of aquifers that are composed of permeable sand, gravel, or fill materials separated by finer grained silt or clay layers. VOC contamination at OU 1 is only in about the top 60 ft of the unconsolidated deposits in the four hydrogeologic units—the unsaturated zone, the upper aquifer, the middle confining unit, and the intermediate aquifer. Groundwater in the unconfined upper aquifer generally flows from the east to the west toward Dogfish Bay. Groundwater in the predominantly confined intermediate aquifer flows toward the landfill from the south and from the west and then flows northwest beneath the landfill toward Dogfish Bay (Dinicola and others, 2002). Two perennial freshwater creeks drain the marsh adjacent to the landfill and discharge into the tide flats of Dogfish Bay.

Chlorinated VOCs are in the upper and intermediate aquifers and in surface water at OU 1. The predominant contaminants in groundwater beneath OU 1 are trichloroethene (TCE) and degradation byproducts *cis*-1,2-dichloroethene (*cis*-DCE) and vinyl chloride (VC). The compound 1,1,1-trichloroethane (TCA) and degradation byproducts 1,1-dichloroethane (1,1-DCA), 1,1-dichloroethene (1,1-DCE), and chloroethane (CA) have been detected at concentrations of concern at a few locations at OU 1. A need for remedial action was identified because these hazardous compounds are a potential risk to humans (URS Consultants, Inc., 1998). Phytoremediation combined with ongoing natural attenuation processes was the preferred remedy selected by the U.S. Navy as specified in the Record of Decision for the site (URS Consultants, Inc., 1998). The U.S. Navy planted two hybrid poplar plantations on the landfill (fig. 2) in spring 1999 to remove and control the migration of chlorinated VOCs in shallow groundwater (URS Greiner, Inc., 1999). The landfill between the plantations is covered with pavement, although the area north of the northern plantation is permeable.

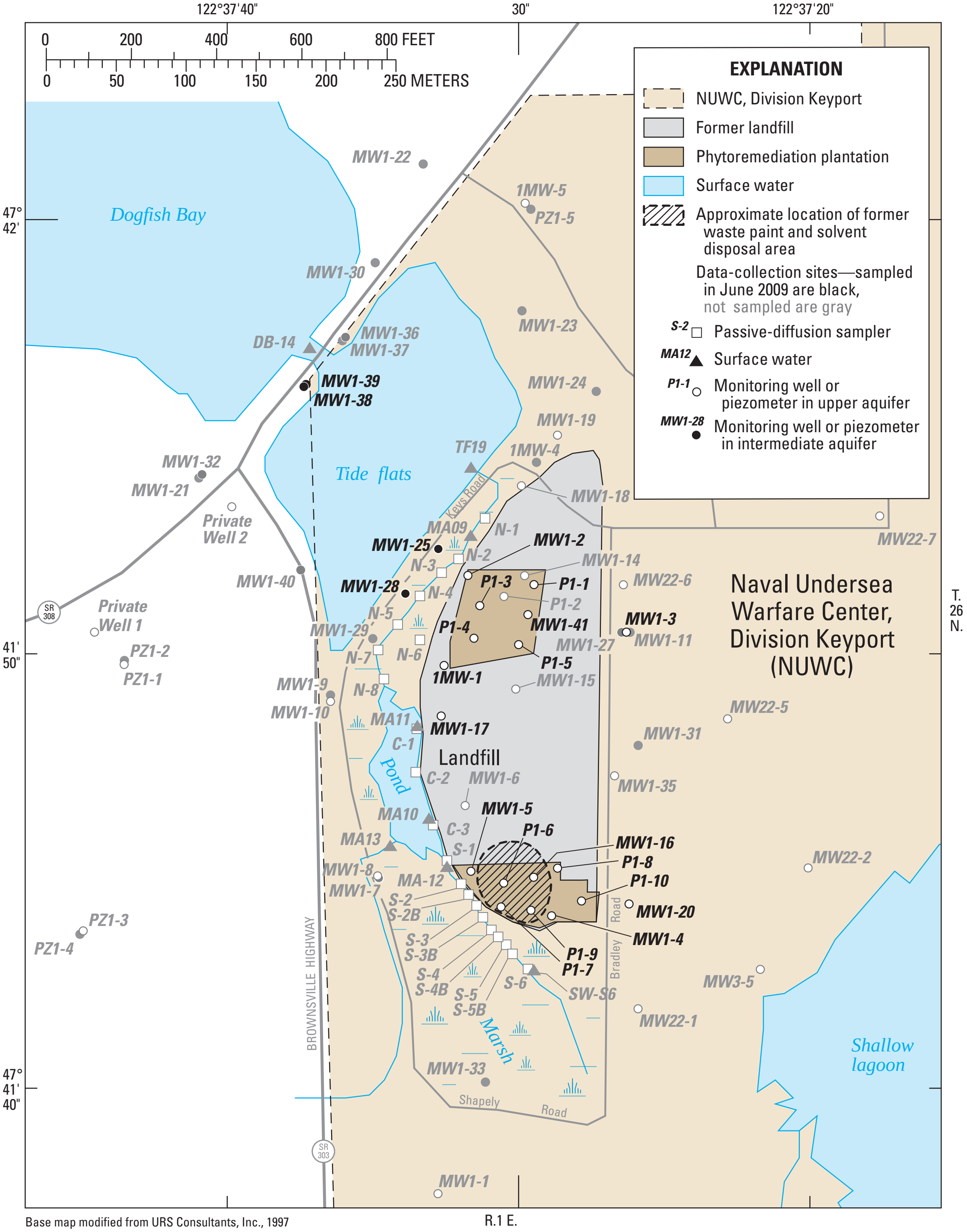
The U.S. Navy began a cooperative effort with the U.S. Geological Survey (USGS) in 1995 to investigate various natural attenuation mechanisms at OU 1. Field and laboratory studies from 1996 through 2000 showed that natural attenuation and biodegradation of chlorinated VOCs in shallow groundwater at OU 1 were substantial (URS Consultants, Inc., 1997; Bradley and others, 1998; Dinicola and others, 2002). The USGS has continued to monitor the geochemistry of groundwater to ensure that conditions remain favorable for contaminant biodegradation. Annual monitoring from 2001 through 2006 confirmed biodegradation (Dinicola and Huffman, 2007). USGS data collected from 1996 through 2006 are in Dinicola and others (2002), Dinicola (2003, 2004, 2006), and Dinicola and Huffman (2004, 2006, 2007, 2009).

This report presents groundwater chemical and selected VOC data collected by the USGS at OU 1 during June 15–17, 2009, in support of the long-term monitoring for natural attenuation. The USGS collected groundwater samples from 13 wells and 9 piezometers in 2009 (table 1 and fig. 2), and concentrations of various geochemical constituents used to determine redox conditions were determined in all samples. Concentrations of VOCs also were determined by the USGS in samples collected from the nine piezometers and three intermediate aquifer wells in 2009.



Base map modified from URS Consultants, Inc., 1997
Projection: Washington State Plane, North Zone
North American Datum of 1927 (NAD27)

Figure 1. Location of the study area near Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington.



Base map modified from URS Consultants, Inc., 1997
Projection: Washington State Plane, North Zone
North American Datum of 1927 (NAD27)

Figure 2. Locations of data-collection sites used to monitor the natural attenuation of chlorinated volatile organic compounds in groundwater beneath the 9-acre former landfill at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington.

Table 1. Wells and piezometers sampled and groundwater levels measured at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 2009.

[**Well or piezometer site No.:** MW, monitoring well; P, piezometer. **USGS site No.:** Unique number for each site based on latitude and longitude of the site. First six digits are latitude, next seven digits are longitude, and final two digits are a sequence number to uniquely identify each site. **Altitudes of groundwater levels and measuring points** are given in feet above or below (-) North American Vertical Datum of 1988. **Groundwater level** is in feet below measuring point (bmp). **Depth of well and screened interval** are in feet below land surface**. Altitude of measuring point:** Water levels in wells are usually reported as depths below land surface, although the measuring point can be any convenient fixed place near the top of the well. For these wells and piezometers, the measuring points are marked points on the tops of well casings—they vary from being near the land surface to a few feet above land surface. The altitude of the measuring point commonly is recorded so that static water levels also can be reported as altitudes. **Abbreviations:** USGS, U.S. Geological Survey; VOC, volatile organic compound; ft, foot; ft bmp, feet below measuring point; –, not measured]

Well or piezometer site No.	USGS site No.	Date and time measured		Groundwater level altitude (ft)	Groundwater level (ft bmp)	Altitude of measuring point (ft)	Depth of well (ft)	VOCs sampled by USGS
1MW-1	474151122373201	06-15-09	13:30	3.36	6.70	10.06	16.5	No
MW1-2	474153122373101	06-15-09	12:50	1.51	10.38	11.89	18.5	No
MW1-3	474152122372501	06-15-09	10:15	9.66	3.89	13.55	11.5	No
MW1-4	474145122372801	06-16-09	09:50	5.48	6.72	12.20	13.0	No
MW1-5	474146122373201	06-16-09	12:50	4.11	8.97	13.08	12.0	No
MW1-16	474146122372801	06-16-09	09:40	3.83	9.00	12.83	12.0	No
MW1-17	474150122373201	06-15-09	15:30	6.18	5.76	11.94	13.5	No
MW1-20	474145122372501	06-15-09	10:50	6.62	3.82	10.44	16.0	No
MW1-25	474154122373201	06-17-09	11:40	0.67	11.24	11.91	49.0	No
MW1-28	474153122373301	06-17-09	11:10	0.54	12.56	13.10	45.0	No
MW1-38	474156122373701	06-17-09	11:00	0.30	9.53	9.83	50.0	No
MW1-39	474157122373701	06-17-09	10:30	0.23	9.62	9.85	33.7	Yes
MW1-41	474152122372901	06-15-09	15:10	6.00	9.27	15.27	15.0	No
P1-1	474153122372801	06-15-09	13:15	5.11	9.25	14.36	15.0	Yes
P1-3	474153122373102	06-15-09	11:15	7.29	5.50	12.79	15.0	Yes
P1-4	474152122373101	06-15-09	12:00	4.52	8.03	12.55	15.0	Yes
P1-5	474152122372801	06-15-09	14:00	5.42	9.64	15.06	15.0	Yes
P1-6	474146122373001	06-16-09	11:20	2.33	10.43	12.76	15.0	Yes
P1-7	474145122373101	09-16-09	11:20	5.09	7.03	12.12	15.0	Yes
P1-8	474147122372801	06-15-09	1600	–	–	12.06	15.0	Yes
P1-9	474145122372901	06-15-09	1030	1.44	10.47	11.91	15.0	Yes
P1-10	474145122372601	06-15-09	1630	6.26	5.61	11.86	15.0	Yes

Sample Collection and Analysis

Groundwater-level measurements, sample collection and processing, and field analyses were in accordance with applicable procedures described in the USGS National Field Manual (U.S. Geological Survey, variously dated). Geochemical measurements and concentrations determined for all samples included dissolved hydrogen (H_2), dissolved oxygen (DO), filtered organic carbon (referred to as dissolved organic carbon, DOC), filtered nitrate plus nitrite, filtered manganese, filtered ferrous iron (or iron (II)), filtered sulfate, unfiltered sulfide, dissolved methane, dissolved carbon dioxide, pH, specific conductance, oxidation-reduction potential (ORP), and filtered chloride. Concentrations of 64 VOCs were analyzed for samples from nine piezometers and from three wells. Concentrations of the dissolved gases ethane, ethene, and methane were determined for all samples.

After measuring depth to groundwater, all well and piezometer samples were collected with a peristaltic pump and single-use polyethylene tubing. Samples were collected from the mid-screen altitude in each well. Samples were collected after approximately three casing-volumes of water were purged from the wells and after allowing the analytes pH, specific conductance, and DO to stabilize within 0.1 unit, 5 percent, and 0.3 mg/L, respectively. Those three analytes and ORP were measured in a flow-through chamber using temperature-compensated sensors from a Yellow Springs Instruments (YSI) data sonde. The specific conductance sensor was calibrated daily with standard reference solutions; the pH sensor was calibrated daily with two pH standards; and the DO sensor was calibrated daily using the water-saturated air method and occasionally verified with zero DO solution. Dissolved-oxygen analyses were confirmed for most samples using 0 to 1 mg/L CHEMets Rhodazine-D colorimetric ampoules (manufactured by CHEMetrics, Inc., Calverton, Virginia). These ampoules were filled directly from the sampling tube after well purging was completed.

Concentrations of iron (II) were measured in the field in samples that had been filtered through a 0.45-µm membrane filter using a colorimetric 1,10 phenanthroline indicator method and a Hach Model 2010 spectrophotometer following Hach Method 8146 (Hach Company, 1998; adapted from American Public Health Association, 1980). Sulfide concentrations were immediately measured in the field using a colorimetric methylene-blue indicator method using the same spectrophotometer according to Hach Method 8131[(Hach Company, 1998; procedure is equivalent to U.S. Environmental Protection Agency (USEPA) method 376.2 (U.S. Environmental Protection Agency, 1983)]. Methodologies used to determine iron and sulfide concentrations also are described in Hach Company (2011a, 2011b). Dissolved carbon dioxide (CO_2) concentrations were measured in the field with Titret-Sodium hydroxide titrant with a pH indicator (manufactured by CHEMetrics, Inc., Calverton, Virginia).

Samples for H_2 in groundwater were collected using the bubble-strip method of Chapelle and others (1997), and concentrations were measured in the field using a reduction gas analyzer (Trace Analytical model E-001). Initial gas samples from each well were collected and analyzed after at least 20 minutes of stripping; subsequent samples were collected and analyzed at about 5-minute intervals until consecutive H_2 concentrations stabilized to within 10 percent, a process that often required 1 hour or more.

Samples for analysis of nitrate plus nitrite, manganese, sulfate, and chloride concentrations were filtered through a 0.45-µm membrane filter into polyethylene bottles, chilled, and sent to the USGS National Water Quality Laboratory (NWQL) in Lakewood, Colorado. Samples for analysis of manganese were acidified in the field with nitric acid to a pH of less than 2 and then analyzed at NWQL by inductively coupled plasma as described by Fishman (1993). Chloride and sulfate were analyzed using ion chromatography as described by Fishman (1993). Nitrate plus nitrite were analyzed colorimetrically by cadmium reduction and diazotization as described by Fishman (1993). The results for the nitrate plus nitrite analyses are referred to simply as “nitrate” in this report because nitrite was not detected historically at the site (Dinicola and others, 2002).

Samples for DOC analysis were filtered through a 0.45-µm filter, collected in amber glass bottles, acidified in the field with sulfuric acid to a pH of less than 2, chilled to less than 4°C, and shipped to NWQL. DOC concentrations were determined using persulfate oxidation and infrared spectrometry as described by Brenton and Arnett (1993).

Samples for VOC analysis were collected in pre-acidified 40-mL glass vials, placed on ice, and shipped to Test America Laboratories in Denver, Colorado, using purge and trap capillary-column gas chromatography/mass spectrometry according to USEPA Method SW846 8260B (U.S. Environmental Protection Agency, 1996). Samples for analysis of ethane, ethene, and methane were collected in pre-acidified 40-mL glass vials, placed on ice, and shipped to Test America Laboratories in Denver Colorado, for subsequent analysis using gas chromatography with a flame-ionization detector according to USEPA Method RSK SOP-175 (U.S. Environmental Protection Agency, 1994). The reporting limit for a given compound often differed between wells because of different degrees of sample dilution by Test America Laboratories. The VOC and dissolved gas samples were collected in pre-acidified vials supplied by Test America Laboratories; consequently, the vials should not be overfilled during sampling as is recommended in applicable USGS procedures (U.S. Geological Survey, variously dated) to avoid aeration of the sample.

Quality control of geochemical and contaminant sampling for 2009 included the collection of one duplicate sample for selected redox-sensitive analytes and two duplicate sample for VOCs. A field blank for redox-sensitive analytes and VOCs was collected in 2009. No substantial quality issues were identified in those samples (appendix A).

Selected Monitoring Data

The groundwater chemistry data are grouped with regard to aquifer and location of the well or piezometer. Upgradient sites are the two upper aquifer wells (MW1-3 and MW1-20) located east of the former landfill. The former upgradient intermediate aquifer well (MW1-33) located south of the landfill was decommissioned and can no longer be sampled. Northern plantation sites are all in the upper aquifer and include four wells (1MW-1, MW1-2, MW1-17, and MW1-41) and four piezometers (P1-1, P1-3, P1-4, and P1-5) in or near the northern phytoremediation plantation; piezometer P1-2 generally is dry during June and has never been sampled. Southern plantation sites also are all in the upper aquifer and include three wells (MW1-4, MW1–5, and MW1-16) and five piezometers (P1-6, P1-7, P1-8, P1-9, and P1-10) in or near the southern phytoremediation plantation. Intermediate aquifer sites include four wells (MW1-25, MW1-28, MW1-38, and MW1-39) that are downgradient of the landfill; no intermediate aquifer wells are in the footprint of the former landfill.

Geochemical Data

Geochemical data collected by the USGS from piezometers and selected wells at OU 1 from 1996 to 2009 are shown in table 2 (at back of report). Historical geochemical data for wells not sampled in 2009 are not included in table 2, but are available in Dinicola (2003, 2004, and 2006) and Dinicola and Huffman (2004, 2006, 2007, 2009). Overall, concentrations of oxidation-reduction (redox) sensitive constituents measured in 2009 were consistent with previous years, with dissolved H_2 concentrations ranging from less than 0.1 to 1.8 nM, dissolved oxygen concentrations all at 0.6 mg/L or less; little to no detectable nitrate; abundant dissolved manganese, iron, and methane; and commonly detected sulfide.

Concentrations of geochemical compounds in the samples from upgradient wells (MW1-3 and MW1-20) in 2009 were within the range of concentrations measured (0.1–0.2 mg/L) in previous years. The well upgradient from the northern plantation (MW1-3) continued to be characterized by low dissolved oxygen concentrations (0.2 mg/L) and consistent measureable nitrate concentrations (1.0 mg/L). The well upgradient from the southern plantation (MW1-20) continued to be characterized by low dissolved oxygen concentrations (0.1 mg/L) and measurable dissolved manganese (0.19 mg/L) and iron (II) concentrations (0.01 mg/L).

Concentrations of geochemical compounds in the upper aquifer beneath the northern plantation in 2009 were consistent with concentrations measured in previous years, although some concentrations were slightly higher or lower than the range of concentrations measured in previous years. Dissolved oxygen concentrations were 0.6 mg/L or less, and concentrations of manganese, iron and methane generally were greater than those concentrations in upgradient groundwater. DOC concentrations ranged from 6.0 (well MW1-17) to 20 mg/L (piezometer P1-3) and methane concentrations were relatively high in comparison to concentrations in samples from the southern plantation and the intermediate aquifer ranging from 0.77 (well MW1-2) to 24 mg/L (piezometer P1-1). H_2 concentrations were the same as or less than those measured in 2008 ranging from less than 0.1 to 0.9 nM.

Concentrations of geochemical compounds in the upper aquifer beneath the southern plantation in 2009 also were consistent with concentrations measured in previous years, again with some concentrations slightly higher or lower than the range of concentrations measured in previous years. Dissolved oxygen concentrations were 0.4 mg/L or less, DOC ranged from 0.8 (well MW1-4) to 8.3 mg/L (well MW1-5), and concentrations generally were greater than those concentrations in upgradient groundwater. Methane concentrations also ranged from 0.73 (well MW1-4) to 10 mg/L (piezometer P1-8) and commonly were less than concentrations measured at northern plantation wells and piezometers. H_2 concentrations were similar to those measured in 2008, ranging from less than 0.1 to 0.2 nM.

For the intermediate aquifer, concentrations of redox sensitive constituents in 2009 were consistent with concentrations measured in previous years. One notable difference was that filtered chloride concentrations and specific conductance were less than previously measured in wells MW1-25 and MW1-28 at the downgradient margin of the landfill. Dissolved oxygen concentrations in all intermediate aquifer wells downgradient of the landfill were less than 0.5 mg/L. H_2 concentrations were highest in the intermediate aquifer ranging from 0.1 to 1.8 nM, with well MW1-39 consistently having concentrations greater than 1 nM.

Volatile Organic Compounds

VOCs and dissolved ethane and ethene data collected from piezometers and selected intermediate aquifer wells at OU 1 from June 1999 to June 2009 are shown in table 3 (at back of report). The VOC data include concentrations of a subset of the 64 compounds measured using USEPA Method SW846 8260B (U.S. Environmental Protection Agency, 1996). Chemical concentrations are reported as less than the reporting level for samples in which the analyte was neither identified nor detected at concentrations equal to or greater than the reporting level. Historical VOC data for wells not sampled in 2009 and for dates before 1999 are not included in table 3, but are in Dinicola and Huffman (2009) and U.S. Navy (2010). The total chlorinated VOC concentrations calculated for each sample is the sum of concentrations of chlorinated VOCs that were positively detected; concentrations reported as "less than" values were not included in the total. Complete analytical results for the USGS data for 2009 and previous years are available from the U.S. Geological Survey (2011) or Dinicola and others (2002), Dinicola (2003, 2004, 2006), and Dinicola and Huffman (2004, 2006, 2007, 2008). Complete analytical results for the complimentary U.S. Navy VOC data from 1995 through 2009 are available in U.S. Navy (2010).

Volatile Organic Compound Concentrations beneath the Phytoremediation Plantations

For the northern plantation in 2009, chlorinated VOC concentrations at most piezometers were similar or slightly less than concentrations of chlorinated VOC measured in previous years. In 2009, the only chlorinated VOC that was positively detected in a piezometer sample from P1-1 was *cis*-DCE with an estimated concentration of 0.19 µg/L, and a piezometer sample from P1-5 had only one measurable chlorinated VOC, chloroethane, with an estimated concentration of 19 µg/L. At piezometer P1-3, chlorinated VOC concentrations were two to nine times higher than those measured in 2008, but still near the lowest concentrations since monitoring began in 1999. Chlorinated VOC concentrations in piezometer samples for P1-4 were similar to previous years, although concentrations of VC have fluctuated between 280 and 750 µg/L since 2007. Total chlorinated VOC concentrations at piezometer P1-4 continue to be higher than concentrations measured in all other piezometers in the northern plantation. The sum of concentrations of the reductive dechlorination byproducts ethane and ethene were slightly lower or the same in 2009 compared with 2008 in three of the four wells sampled and three of the four piezometers sampled.

For the southern plantation in 2009, chlorinated VOC concentrations measured in most piezometers continued to be extremely high and highly variable from year to year. At piezometer P1-9, the total chlorinated VOC concentration increased from 25,000 µg/L in 2008 to 172,000 µg/L in 2009. At piezometer P1-7, the individual concentrations of TCE and *cis*-DCE were at the highest concentrations measured to date (40,000 and 92,000 µg/L, respectively). Since data collection began in 1999, the total chlorinated VOC concentrations in samples from these two wells remain high and have been the highest measured in samples from all wells in the southern and northern plantations. In contrast, the total CVOC concentrations in piezometer P1-8 remained relatively low at 220 µg/L. In 2009, one or both of the reductive dechlorination byproducts ethane and ethene were detected in samples from all wells and piezometers in the southern plantation with the exception of piezometer P1-8. Samples from piezometer P1-9 had the highest measured ethene concentrations to date with a concentration of 1,300 µg/L.

Volatile Organic Compound Concentrations in the Intermediate Aquifer

In the intermediate aquifer for 2009, total chlorinated VOC concentrations in samples from wells MW1-25 and MW1-28 were consistent with previous years, with vinyl chloride concentrations remaining relatively high in both wells (240 and 730 µg/L, respectively). At well MW1-39 farthest downgradient in the intermediate aquifer, low concentrations of *cis*-DCE and VC were detected in samples, similar to previous years. The sum of estimated concentrations of reductive dechlorination byproducts ethane and ethene were 30 and 41 µg/L in samples from wells MW1-25 and MW1-28, respectively. Those compounds were not detected farther downgradient in the intermediate aquifer beneath State Highway 308 causeway in samples from wells MW1-38 and MW1-39.

Summary

Previous investigations report that natural attenuation and biodegradation of chlorinated volatile organic compounds (VOCs) are substantial in groundwater beneath the 9-acre former landfill at Operable Unit 1 (OU 1), Naval Undersea Warfare Center, Division Keyport, Washington. Phytoremediation combined with ongoing natural attenuation processes was the preferred remedy selected by the U.S. Navy, as specified in the Record of Decision for the site, and the U.S. Navy planted two hybrid poplar plantations on the landfill in spring 1999 to remove and to control the migration of chlorinated VOCs in shallow groundwater. The U.S. Geological Survey (USGS) has continued to monitor groundwater geochemistry to ensure that conditions remain favorable for contaminant biodegradation as specified in the Record of Decision. This report presents groundwater geochemical and selected VOC data collected at OU 1 by the USGS during June 15–17, 2009, in support of long-term monitoring for natural attenuation.

In the upper aquifer beneath the northern plantation concentrations of manganese, iron, and methane were higher than concentrations in upgradient groundwater and were relatively high in comparison to concentrations in samples from the southern plantation and the intermediate aquifer ranging from 0.77 (well MW1-2) to 24 milligrams per liter (piezometer P1-1). Anaerobic conditions existed in all wells and piezometers consistent with previous year samples, and dissolved organic carbon (DOC) concentrations ranged from 6.0 (well MW1-17) to 20 milligrams per liter (piezometer P1-3). Methane concentrations ranged from 0.77 (well MW1-2) to 24 milligrams per liter (piezometer P1-1).

For the southern plantation in 2009, chlorinated VOC concentrations measured in piezometers were often extremely high and varied widely spatially and temporally. At piezometer P1-9, the total chlorinated VOC concentration in samples increased from 25,000 micrograms per liter in 2008 to 172,000 micrograms per liter in 2009. At piezometer P1-7, the individual concentrations of trichloroethene (TCE) and *cis*-1,2-dichloroethene (*cis*-DCE), were at the highest concentrations to date. Methane concentrations also ranged from 0.73 (well MW1-4) to 10 milligrams per liter (piezometer P1-8) and commonly were less than concentrations measured at northern plantation wells and piezometers. Concentrations of dissolved hydrogen (H_2) measured in the upper aquifer generally have been lower than concentrations measured before 2002, with only well MW1-39 having concentrations greater than 1 nanomolar in 2009. Methane and sulfide concentration at most upper aquifer wells and piezometers beneath the landfill have been consistently higher than those measured in upgradient wells and organic carbon concentrations generally have remained the same since 2004.

All intermediate aquifer wells downgradient of the landfill have been consistently anaerobic. Methane concentrations in these wells ranged from 0.77 to 5.1 milligrams per liter and were about twice as high in well MW1-25 compared to well MW1-28. Total chlorinated VOC concentrations in wells MW1-25, MW1-28, and MW1-39 were consistent with previous years, with vinyl chloride concentrations remaining high with 240 µg/L at MW1-25 and 730 µg/L at MW-28. No detectable concentrations of CVOCs were measured at well MW1-39, farthest downgradient in the intermediate aquifer.

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Appendix A. Quality Assurance and Control of U.S. Geological Survey 2009 Geochemical Sampling

Quality assurance and control of geochemical sampling included the collection of duplicate and field blank samples for selected redox-sensitive analytes and volatile organic compounds (VOCs). A field blank was collected by pumping inorganic blank water and VOC-free water through new clean tubing to determine possible sampling contamination. Complete laboratory quality assurance and control data from Test America Laboratories is on file with the U.S. Geological Survey Washington Water Science Center in Tacoma, Washington.

Duplicate sample results compared favorably for all constituents (table A1). A duplicate sample was collected and analyzed by the National Water Quality Laboratory (NWQL) for organic carbon, manganese, nitrate and nitrite, sulfate, and chloride for piezometer P1-7. The duplicate results for these constituents agreed with 12 percent. Duplicate samples were collected and analyzed for VOCs and methane, ethane, and ethene for well MW1-25 and piezometer P1-7 and the concentrations agreed within 62 percent. An additional duplicate for methane, ethane, and ethene was analyzed for well MW1-5 and the results agreed within 3 percent (table A1).

Manganese was detected at an estimated concentration of 0.002 mg/L in the blank sample (well MW1-39), which is small compared to filtered manganese concentrations in environmental samples that were measured at 0.01 mg/L or higher. No VOCs were detected in the field blank sample.

Table A1. Quality assurance data collected by the U.S. Geological Survey at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 2009.

[**Well or piezometer No.:** MW, monitoring well; P, piezometer; D denotes duplicate sample; FB denotes field blank sample. **Volatile organic compounds (VOCs):** PCE, tetrachloroethene; TCE, trichloroethene; *cis*-DCE, *cis*-1,2-dichloroethene; *trans*-DCE, *trans*-1,2-dichloroethene; VC, vinyl chloride; TCA, 1,1,-trichloroethane; 1,1-DCA, 1,1-dichloroethane, CA, chloroethane; 1,1-DCE, 1,1-dichloroethene; BTEX, benzene, toluene, ethylbezene, and xylene; CVOCs, sum of all chloroethenes and chloroethane concentrations shown in table. **Abbreviations:** mg/L, milligrams per liter; ND, not detected; µg/L, micrograms per liter; E, estimated. **Symbols**: <, actual value is less than the value shown; –, not analyzed]

Well or piezometer No.	Date sampled	PCE (µ/L)	TCE (µg/L)	*cis*-DCE (µg/L)	*trans*-DCE (µg/L)	VC (µg/L)	Ethane (µg/L)	Ethene (µg/L)	111-TCA (µg/L)	1,1-DCA (µg/L)	CA (µg/L)	1,1-DCE (µg/L)
MW1-25	06-17-09	<40	E7.3	1,600	49	240	E11	E19	<40	<40	<80	<40
MW1-25D	06-17-09	<40	<40	1,400	E39	220	–	–	<40	<40	<80	<40
P1-7	06-16-09	<2,000	40,000	92,000	3,900	10,000	140	1,100	<2,000	<2,000	<4,000	<2,000
P1-7D	06-16-09	<2,000	39,000	77,000	E910	7,300	140	1,100	<2,000	<2,000	<4,000	<2,000
MW1-5	06-16-09	–	–	–	–	–	E6.0	<50	–	–	–	–
MW1-5D	06-16-09	–	–	–	–	–	E6.0	<50	–	–	–	–
MW1-39 FB	06-17-09	<1.0	<1.0	<1.0	<1.0	<2.0	<5.0	<5.0	<1.0	<1.0	<2.0	<1.0

Well or piezometer No.	Date sampled	Total		Dissolved oxygen (mg/L)	Filtered nitrate + nitrite (mg/L)	Filtered (dissolved) organic carbon (mg/L)	Filtered manga-nese (mg/L)	Filtered iron (II) (mg/L)	Filtered sulfate (mg/L)	Unfiltered sulfide (mg/L)	Dissolved methane (mg/L)	Dissolved carbon dioxide (mg/L)	Filtered chloride (mg/L)
		BTEX (µg/L)	CVOCs (µg/L)										
MW1-25	06-17-09	ND	1,900	0.1	<0.04	6.7	0.15	1.1	6.86	<0.01	5.1	<10	124
MW1-25D	06-17-09	ND	1,660	–	–	–	–	–	–	–	–	–	–
P1-7	06-16-09	ND	146,000	.2	<.04	6.4	2.2	1.3	6.54	.01	6.6	16	53
P1-7D	06-16-09	ND	124,200	.2	<.04	6.4	2.2	1.4	6.58	.01	6.6	18	54
MW1-39 FB	06-17-09	ND	ND	–	<.04	<.4	E.002	–	<.18	–	<.005	–	<.12

Table 2. Predominant redox conditions at wells and piezometers, and groundwater geochemical data collected at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 1996–2009.

[All other data were published in Dinicola and others (2002), Dinicola (2003, 2004, 2006), and Dinicola and Huffman (2004, 2006, 2007, 2009). Prior to 2000, bicarbonate was calculated from an unfiltered sample. Reported concentrations less than the detection limit usually are estimated. A range of dissolved hydrogen concentrations are shown when equilibration at a single value was never achieved. **Well or piezometer No.**: MW, monitoring well; P, piezometer. **Abbreviations:** nM, nanomolar; mg/L, milligram per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; ORP, oxidation-reduction potential; mV, millivolt. **Symbols**: B, sample bottle broken; E, estimated value; R, data rejected (selected 1996 dissolved-oxygen data were rejected because of inadequate well purging; selected 2002 dissolved-hydrogen data were rejected because of interference from downhole instruments); <, actual value is less than value shown; >, actual value is greater than value shown; –, not analyzed]

Well or piezometer No.	Date sampled	Dissolved hydrogen (nM)	Dissolved oxygen (mg/L)	Unfiltered (total) organic carbon (mg/L)	Filtered (dissolved) organic carbon (mg/L)	Filtered nitrate + nitrite (mg/L as N)	Filtered manganese (mg/L)	Filtered iron (II) (mg/L)	Filtered sulfate (mg/L)
Upgradient									
MW1–3	06-09-99	0.8	0.4	–	–	–	0.07	<0.01	–
	06-20-00	.2	.3	2.0	–	0.99	.08	<.01	13
	06-12-01	–	4.0	2.3	1.1	1.1	.04	.02	14
	06-10-02	2.7	.4	–	1.4	1.6	.10	.01	11
	06-17-03	–	4.3	–	1.7	1.8	.09	.05	12
	06-15-04	.2	.2	–	1.6	–	.09	<.01	12
	06-20-05	<.1	.1	–	1.4	1.6	.10	.01	15
	06-12-06	<.1	.1	–	1.4	1.6	.11	<.01	14
	06-18-07	–	.6	–	1.8	1.1	.09	<.01	16
	06-16-08	–	.6	–	2.0	1.1	.10	<.01	18
	06-15-09	<.1	.2	–	1.6	1.0	.12	.01	19
MW1–20	06-08-99	0.9	0.3	–	–	–	0.35	0.03	–
	06-21-00	.4	<.1	2.2	–	<.05	.24	.11	16
	06-13-01	2.1	.2	3.0	1.4	<.05	.28	.01	20
	06-12-02	>100R	.1	–	1.4	<.05	.16	.01	17
	06-17-03	.5	.2	–	1.7	<.06	.24	.05	18
	06-15-04	.1	.9	–	1.6	–	.23	.03	18
	06-20-05	.1	.4	–	1.5	<.06	.25	.21	16
	06-13-06	.1	.1	–	1.7	<.06	.21	.08	16
	06-18-07	–	.2	–	1.8	<.06	.21	.34	14
	06-18-08	–	3.4	–	1.5	<.04	.19	.06	19
	06-15-09	.1	.3	–	1.6	<.04	.19	.16	13
Northern plantation									
1MW-1	09-17-96	0.4	2.8R	7.0	–	<0.02	0.18	0.24	7.5
	04-16-97	.8	.4	–	–	.11	–	8.0	1.4
	03-05-98	.2	.1	8.3	–	–	.39	12	–
	10-09-98	.2	.5	–	–	–	.08	.39	–
	06-21-00	.1	.5	12	–	<.05	.96	13	.9
	06-11-01	.6	.7	13	12	<.05	.24	2.9	2.2
	06-10-02	.4	.2	–	14	<.05	.37	7.3	1.7
	06-17-03	.1	.1	–	10	<.06	.17	1.2	2.2
	06-16-04	.2	.1	–	7.7	–	.09	.38	2.0
	06-21-05	.1	.1	–	9.5	<.06	.12	1.8	1.7
	06-12-06	<.1	.2	–	8.5	<.06	.12	.8	1.9
	06-19-07	.3	.1	–	6.8	E.05	1.3	.72	6.4
	06-17-08	.2	.2	–	9.6	<.04	.13	1.4	1.3
	06-15-09	<.1	.3	–	7.1	<.04	.10	.55	1.4

Table 2. Predominant redox conditions at wells and piezometers, and groundwater geochemical data collected at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 1996–2009.—Continued

[All other data were published in Dinicola and others (2002), Dinicola (2003, 2004, 2006), and Dinicola and Huffman (2004, 2006, 2007, 2009). Prior to 2000, bicarbonate was calculated from an unfiltered sample. Reported concentrations less than the detection limit usually are estimated. A range of dissolved hydrogen concentrations are shown when equilibration at a single value was never achieved. **Well or piezometer No.**: MW, monitoring well; P, piezometer. **Abbreviations:** nM, nanomolar; mg/L, milligram per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; ORP, oxidation-reduction potential; mV, millivolt. **Symbols**: B, sample bottle broken; E, estimated value; R, data rejected (selected 1996 dissolved-oxygen data were rejected because of inadequate well purging; selected 2002 dissolved-hydrogen data were rejected because of interference from downhole instruments); <, actual value is less than value shown; >, actual value is greater than value shown; –, not analyzed]

Well or piezometer No.	Date sampled	Unfiltered sulfide (mg/L)	Dissolved methane (mg/L)	Dissolved carbon dioxide (mg/L)	Filtered bicarbonate (mg/L)	pH (units)	Specific conductance (µS/cm)	ORP (mV)	Filtered chloride (mg/L)
					Upgradient				
MW1-3	06-09-99	<0.01	–	–	81	6.0	202	–	–
	06-20-00	<.01	0.02	–	82	5.9	205	180	8.4
	06-12-01	<.01	.12	–	90	6.1	203	220	10
	06-10-02	<.01	.06	140	80	5.8	182	400	9.7
	06-17-03	–	.02	80	–	6.0	199	200	10
	06-15-04	<.01	.01	–	73	5.7	205	195	9.1
	06-20-05	<.01	–	<50	–	6.0	192	–	7.5
	06-12-06	<.01	.004	40	–	5.5	243	136	7.0
	06-18-07	.01	–	41	–	5.9	209		5.9
	06-16-08	<.01	–	80	–	6.0	198	260	5.1
	06-15-09	.01	.01	80	–	6.0	208	206	7.3
MW1-20	06-08-99	<0.01	–	–	260	6.7	546	–	–
	06-21-00	<.01	0.01	–	240	6.8	530	79	14
	06-13-01	<.01	.27	–	260	6.4	544	250	33
	06-12-02	<.01	.06	97	250	7.0	701	180	29
	06-17-03	–	.09	90	–	6.3	491	290	32
	06-15-04	<.01	.03	–	260	6.4	552	98	35
	06-20-05	<.01	–	80	–	6.3	520	87	28
	06-13-06	<.01	.03	60	–	6.3	574	70	31
	06-18-07	<.01	–	40	–	6.8	508	7.2	25
	06-18-08	–	–	70	–	6.6	517	74	38
	06-15-09	<.01	.05	45	–	6.5	481	–	24
					Northern plantation				
1MW-1	09-17-96	<0.01	10	–	640	7.9	–	–	43
	04-16-97	.01	29	–	1,100	7.2	–	–	–
	03-05-98	.06	–	–	–	–	–	–	–
	10-09-98	.01	–	–	660	7.7	1,080	–	–
	06-21-00	<.01	.39	–	590	7.0	1,070	-92	44
	06-11-01	<.01	5.6	–	550	7.1	974	-110	50
	06-10-02	<.01	14	77	520	7.7	835	-160	54
	06-17-03	<.01	7.1	50	–	7.3	847	–	54
	06-16-04	.03	1.8	18	–	7.0	843	-184	57
	06-21-05	.02	-	20	–	7.1	827	-108	48
	06-12-06	.01	3.4	10	–	7.4	787	-134	48
	06-19-07	.04	1.7	18	–	7.3	753	-164	7.7
	06-17-08	.01	5.4	11	–	7.4	737	–	40
	06-15-09	.02	7.2	10	–	7.4	676	-162	44

Table 2. Predominant redox conditions at wells and piezometers, and groundwater geochemical data collected at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 1996–2009.—Continued

[All other data were published in Dinicola and others (2002), Dinicola (2003, 2004, 2006), and Dinicola and Huffman (2004, 2006, 2007, 2009). Prior to 2000, bicarbonate was calculated from an unfiltered sample. Reported concentrations less than the detection limit usually are estimated. A range of dissolved hydrogen concentrations are shown when equilibration at a single value was never achieved. **Well or piezometer No.**: MW, monitoring well; P, piezometer. **Abbreviations:** nM, nanomolar; mg/L, milligram per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; ORP, oxidation-reduction potential; mV, millivolt. **Symbols**: B, sample bottle broken; E, estimated value; R, data rejected (selected 1996 dissolved-oxygen data were rejected because of inadequate well purging; selected 2002 dissolved-hydrogen data were rejected because of interference from downhole instruments); <, actual value is less than value shown; >, actual value is greater than value shown; –, not analyzed]

Well or piezometer No.	Date sampled	Dissolved hydrogen (nM)	Dissolved oxygen (mg/L)	Unfiltered (total) organic carbon (mg/L)	Filtered (dissolved) organic carbon (mg/L)	Filtered nitrate + nitrite (mg/L as N)	Filtered manganese (mg/L)	Filtered iron (II) (mg/L)	Filtered sulfate (mg/L)
				Northern plantation—Continued					
MW1–2	09-17-96	0.5	2.4R	6.0	–	<0.02	0.05	0.23	4.6
	04-16-97	.7	.2	–	–	<.02	–	.13	4.6
	03-02-98	.3	–	–	–	–	–	.16	–
	10-07-98	.1	.1	–	–	–	.05	.14	–
	06-09-99	.9	.2	–	–	–	.08	.09	–
	06-21-00	.3	.1	6.0	–	<.05	.06	.10	4.3
	06-12-01	3.5	.3	5.3	5.0	<.05	.08	.29	5.4
	06-11-02	>20R	.1	–	45	<.05	.09	.27	4.2
	06-18-03	.2	.1	–	6.0	<.06	.10	.29	4.3
	06-17-04	.2	.2	–	6.7	–	.10	1.0	4.3
	06-22-05	<.1	<.1	–	20	<.06	.10	.44	4.4
	06-12-06	.1	.1	–	5.9	<.06	.10	.76	3.7
	06-19-07	.2	<.1	–	6.0	<.06	.11	.84	3.8
	06-17-08	<.1	.1	–	6.3	<.04	.11	.64	3.4
	06-15-09	<.1	.3	–	6.3	<.04	.12	1.2	3.6
MW1–17	09-17-96	0.7	<0.1	23	–	<0.02	1.3	62	4.3
	04-16-97	.6	<.1	–	–	<.02	–	37	68
	10-09-98	–	<.1	–	–	–	.80	56	–
	06-22-00	1.2	<.1	11	–	–	1.2	68	–
	06-12-01	2.0–2.7	.4	9.2	8.0	<.05	1.2	48	12
	06-17-04	2.5	<.1	–	7.5	–	.68	>10	18
	06-20-05	1.5	<.1	–	6.1	<.06	.43	27	7.8
	06-20-07	1.0	<.1	–	8.1	<.06	.40	22	11
	06-18-08	1.1	<.1	–	6.1	<.04	.33	17	7.3
	06-15-09	.9	<.1	–	6.0	<.04	.49	8.5	8.1
MW1–41	06-09-99	1.0	0.3	–	–	–	2.2	60	–
	06-21-00	1.2	.1	22	–	<0.05	3.5	55	<0.3
	06-11-01	2.0	.3	14	14	<.05	3.7	66	30
	06-10-02	2.2	.8	–	20	<.05	3.6	52	.4
	06-18-03	1.9	<.1	–	19	<.06	3.9	50	<.2
	06-17-04	2.2	.1	–	19	–	4.0	57	<.2
	06-20-05	.8	.1	–	17	<.06	3.9	73	<.2
	06-12-06	.7	<.1	–	18	<.06	3.8	28	<.2
	06-19-07	.4	<.1	–	20	<.06	3.8	66	<.18
	06-16-08	.4	<.1	–	20	<.04	3.4	41	<.18
	06-15-09	.3	.1	–	19	<.04	4.2	29	<.2

Table 2. Predominant redox conditions at wells and piezometers, and groundwater geochemical data collected at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 1996–2009.—Continued

[All other data were published in Dinicola and others (2002), Dinicola (2003, 2004, 2006), and Dinicola and Huffman (2004, 2006, 2007, 2009). Prior to 2000, bicarbonate was calculated from an unfiltered sample. Reported concentrations less than the detection limit usually are estimated. A range of dissolved hydrogen concentrations are shown when equilibration at a single value was never achieved. **Well or piezometer No.**: MW, monitoring well; P, piezometer. **Abbreviations:** nM, nanomolar; mg/L, milligram per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; ORP, oxidation-reduction potential; mV, millivolt. **Symbols**: B, sample bottle broken; E, estimated value; R, data rejected (selected 1996 dissolved-oxygen data were rejected because of inadequate well purging; selected 2002 dissolved-hydrogen data were rejected because of interference from downhole instruments); <, actual value is less than value shown; >, actual value is greater than value shown; –, not analyzed]

Well or piezometer No.	Date sampled	Unfiltered sulfide (mg/L)	Dissolved methane (mg/L)	Dissolved carbon dioxide (mg/L)	Filtered bicarbonate (mg/L)	pH (units)	Specific conductance (µS/cm)	ORP (mV)	Filtered chloride (mg/L)
Northern plantation—Continued									
MW1-2	09-17-96	<0.01	1.2	–	510	6.9	–	–	50
	04-16-97	<.01	2.5	–	1,100	6.7	–	–	–
	03-02-98	–	–	–	–	–	–	–	–
	10-07-98	<.01	–	–	300	6.7	868	–	–
	06-09-99	<.01	–	–	490	6.8	901	–	–
	06-21-00	<.01	.04	–	460	6.8	870	37	36
	06-12-01	<.01	.78	–	470	6.5	853	27	48
	06-11-02	<.01	.92	200	500	6.6	829	200	37
	06-18-03	<.01	.98	160	–	6.4	870	62	41
	06-17-04	–	.33	50	–	6.6	858	-	40
	06-22-05	<.01	–	75	–	6.3	720	-14	35
	06-12-06	<.01	.50	115	–	6.5	815	-47	34
	06-19-07	<.01	.26	45	–	6.4	820	-50	30
	06-17-08	<.01	.43	40	–	6.6	797		26
	06-15-09	.01	.77	45	–	6.6	814	-0.4	30
MW1–17	09-17-96	<0.01	8.9	–	760	6.5	–	–	61
	04-16-97	.02	23	–	1,200	6.6	–	–	–
	10-09-98	.02	–	–	510	6.4	1,740	–	–
	06-22-00	.02	2.8	–	450	6.5	1,260	-41	160
	06-12-01	.01	9.4	–	500	6.5	1,200	-280	120
	06-17-04	–	.37	70	–	6.5	318	-	150
	06-20-05	.04	–	80	–	6.3	563	-144	74
	06-20-07	.03	2.9	55	–	6.5	635	-123	96
	06-18-08	.04	5.5	26	–	6.6	551	-109	59
	06-15-09	.03	8.3	40	–	6.3	523	-115	68
MW1–41	06-09-99	0.01	–	–	860	6.6	1,260	–	–
	06-21-00	<.01	1.9	–	1,000	6.5	1,500	-75	8.3
	06-11-01	.02	25	–	980	6.3	1,330	-89	9.9
	06-10-02	.04	21	540	830	6.3	1,190	-68	7.9
	06-18-03	.03	14	500	–	6.3	1,280	93	9.5
	06-17-04	.02	7.4	450	–	6.1	1,300	-165	11
	06-20-05	.01	–	500	–	6.4	1,300	–	8.7
	06-12-06	.02	8.5	310	–	6.3	1,240	-103	8.4
	06-19-07	.01	6.3	350	–	6.7	1,280	-124	8.7
	06-16-08	.01	9.9	300	–	6.4	1,240	-93	11
	06-15-09	<.01	18	400	–	6.2	1,200	-99	16

Table 2. Predominant redox conditions at wells and piezometers, and ground-water geochemical data collected at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 1996–2009.—Continued

[All other data were published in Dinicola and others (2002), Dinicola (2003, 2004, 2006), and Dinicola and Huffman (2004, 2006, 2007, 2009). Prior to 2000, bicarbonate was calculated from an unfiltered sample. Reported concentrations less than the detection limit usually are estimated. A range of dissolved hydrogen concentrations are shown when equilibration at a single value was never achieved. **Well or piezometer No.**: MW, monitoring well; P, piezometer. **Abbreviations:** nM, nanomolar; mg/L, milligram per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; ORP, oxidation-reduction potential; mV, millivolt. **Symbols**: B, sample bottle broken; E, estimated value; R, data rejected (selected 1996 dissolved-oxygen data were rejected because of inadequate well purging; selected 2002 dissolved-hydrogen data were rejected because of interference from downhole instruments); <, actual value is less than value shown; >, actual value is greater than value shown; –, not analyzed]

Well or piezometer No.	Date sampled	Dissolved hydrogen (nM)	Dissolved oxygen (mg/L)	Unfiltered (total) organic carbon (mg/L)	Filtered (dissolved) organic carbon (mg/L)	Filtered nitrate + nitrite (mg/L as N)	Filtered manganese (mg/L)	Filtered iron (II) (mg/L)	Filtered sulfate (mg/L)
				Northern plantation—Continued					
P1–1	06-09-99	0.7	0.4	–	–	–	4.0	59	–
	06-11-02	1.4	<.1	–	17	<0.05	2.7	40	<0.1
	06-18-03	1.5	<.1	–	18	<.06	3.4	32	<.2
	06-17-04	1.9	.1	–	16	–	3.1	39	<.2
	06-22-05	.6	<.1	–	15	<.06	3.1	68	<.2
	06-12-06	.3	<.1	–	16	<.06	2.9	54	<.2
	06-19-07	.3	<.1	–	15	<.06	2.0	49	<.18
	06-16-08	.6	.1	–	14	<.04	2.1	32	<.18
	06-15-09	.5	<.1	–	11	<.04	2.3	38	<.2
P1–3	06-09-99	0.4	0.2	–	–	–	1.0	19	–
	06-11-02	.3	<.1	–	45	<0.05	2.6	39	1.0
	06-18-03	.3	.1	–	19	<.06	2.0	29	1.8
	06-17-04	.7	<.1	–	21	–	2.8	>10	.55
	06-22-05	.2	<.1	–	20	<.06	2.8	60	.38
	06-12-06	.2	<.1	–	20	<.06	2.5	39	.2
	06-19-07	.3	<.1	–	22	<.06	2.5	40	.24
	06-17-08	.9	<.1	–	23	<.04	2.9	32	<.18
	06-15-09	.5	.2	–	20	<.04	3.0	2.6	E.1
P1–4	06-09-99	0.7	0.3	–	–	–	0.34	2.6	–
	06-13-01	.1	.5	9.8	8.7	<0.05	.38	3.4	3.8
	06-11-02	.2	.1	–	8.0	<.05	2.6	3.7	3.5
	06-18-03	.2	.1	–	7.0	<.06	.43	4.1	4.0
	06-17-04	.1	.1	–	7.6	–	.42	3.0	4.0
	06-21-05	.1	.1	–	6.7	<.06	.38	2.3	4.6
	06-12-06	.1	<.1	–	6.8	<.06	.35	1.8	4.3
	06-19-07	.3	<.1	–	7.1	<.06	.35	3.2	4.7
	06-16-08	<.1	<.1	–	7.7	<.04	.35	3.5	4.4
	06-15-09	<.1	.6	–	7.5	<.04	.39	2.4	4.1
P1–5	06-08-99	3.0	0.3	–	–	–	3.1	72	–
	06-10-02	1.7	.1	–	25	<0.05	2.6	62	<0.6
	06-18-03	2.2	.1	–	24	<.06	3.1	54	<.2
	06-17-04	2.1	<.1	–	23	–	3.1	>10	<.2
	06-21-05	.8	.1	–	22	<.06	3.5	74	E.1
	06-12-06	.8	<.1	–	21	<.06	3.6	66	E.1
	06-19-07	.3	<.1	–	22	<.06	3.2	48	<.2
	06-16-08	1.0	<.1	–	21	<.04	3.6	44	<.2
	06-15-09	.4	<.1	–	19	<.04	4.3	33	E.2

Table 2. Predominant redox conditions at wells and piezometers, and groundwater geochemical data collected at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 1996–2009.—Continued

[All other data were published in Dinicola and others (2002), Dinicola (2003, 2004, 2006), and Dinicola and Huffman (2004, 2006, 2007, 2009). Prior to 2000, bicarbonate was calculated from an unfiltered sample. Reported concentrations less than the detection limit usually are estimated. A range of dissolved hydrogen concentrations are shown when equilibration at a single value was never achieved. **Well or piezometer No.**: MW, monitoring well; P, piezometer. **Abbreviations:** nM, nanomolar; mg/L, milligram per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; ORP, oxidation-reduction potential; mV, millivolt. **Symbols**: B, sample bottle broken; E, estimated value; R, data rejected (selected 1996 dissolved-oxygen data were rejected because of inadequate well purging; selected 2002 dissolved-hydrogen data were rejected because of interference from downhole instruments); <, actual value is less than value shown; >, actual value is greater than value shown; –, not analyzed]

Well or piezometer No.	Date sampled	Unfiltered sulfide (mg/L)	Dissolved methane (mg/L)	Dissolved carbon dioxide (mg/L)	Filtered bicarbonate (mg/L)	pH (units)	Specific conductance (µS/cm)	ORP (mV)	Filtered chloride (mg/L)
Northern plantation—Continued									
P1–1	06-09-99	<0.01	–	–	930	6.4	1,350	–	–
	06-11-02	<.01	29	400	650	6.3	987	-80	9.3
	06-18-03	.02		450	–	6.2	1,030	78	11
	06-17-04	.02	3.7	430	–	6.0	987	-153	9.2
	06-22-05	<.01	10	370	–	6.3	847	-72	7.1
	06-12-06	.01	7.8	225	–	6.2	979	-108	7.2
	06-19-07	.02	8.1	160	–	6.1	920	-139	5.7
	06-16-08	.02	12	350	–	6.5	914	-76	4.4
	06-15-09	.02	24	325	–	6.3	830	-99	3.7
P1–3	06-09-99	0.04	–	–	730	6.8	1,470	–	–
	06-11-02	.03	24	400	820	6.4	1,340	-73	61
	06-18-03	.03	–	350	–	6.4	1,400	73	90
	06-17-04	<.01	5.7	330	–	6.5	1,350	–	57
	06-22-05	.03	8.4	320	–	6.4	1,200	-88	68
	06-12-06	.03	7.1	330		6	1,440	-152	51
	06-19-07	.03	7.1	260	–	6.5	1,420	-136	55
	06-17-08	.03	14	200	–	6.4	1,230		31
	06-15-09	.03	18	180	–	6.2	1,220	-160	45
P1–4	06-09-99	0.02	–	–	450	6.9	867	–	–
	06-13-01	<.01	0.93	–	390	6.6	761	-78	53
	06-11-02	<.01	5.9	90	380	6.7	734	-86	56
	06-18-03	.01	4.2	70	–	6.6	778	65	59
	06-17-04	.02	1.8	60	–	6.4	782	-163	48
	06-21-05	<.01	1.8	42	–	6.6	750	-83	47
	06-12-06	<.01	1.7	32	–	6.4	823	-94	44
	06-19-07	<.01	2.5	26	–	6.7	745	-99	44
	06-16-08	.01	3.1	20	–	6.9	749	-86	40
	06-15-09	.01	6.4	25	–	6.8	724	-100	39
P1–5	06-08-99	0.01	–	–	850	6.2	1,320	–	–
	06-10-02	.02	23	400	730	6.2	1,200	-59	17
	06-18-03	.02	18	650	–	6.2	1,150	65	16
	06-17-04	–	5.8	450	–	6.4	1,160	-	14
	06-21-05	.04	9.4	400	–	6.3	1,150	-65	13
	06-12-06	.05	6.8	370	–	5.8	1,100	-106	9.9
	06-19-07	.04	8.5	350	–	6.3	1,030	-104	9.3
	06-16-08	.04	14	275	–	6.3	1,080	29	10
	06-15-09	.12	22	500	–	6.3	1,050	-165	13

Table 2. Predominant redox conditions at wells and piezometers, and groundwater geochemical data collected at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 1996–2009.—Continued

[All other data were published in Dinicola and others (2002), Dinicola (2003, 2004, 2006), and Dinicola and Huffman (2004, 2006, 2007, 2009). Prior to 2000, bicarbonate was calculated from an unfiltered sample. Reported concentrations less than the detection limit usually are estimated. A range of dissolved hydrogen concentrations are shown when equilibration at a single value was never achieved. **Well or piezometer No.**: MW, monitoring well; P, piezometer. **Abbreviations:** nM, nanomolar; mg/L, milligram per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; ORP, oxidation-reduction potential; mV, millivolt. **Symbols**: B, sample bottle broken; E, estimated value; R, data rejected (selected 1996 dissolved-oxygen data were rejected because of inadequate well purging; selected 2002 dissolved-hydrogen data were rejected because of interference from downhole instruments); <, actual value is less than value shown; >, actual value is greater than value shown; –, not analyzed]

Well or piezometer No.	Date sampled	Dissolved hydrogen (nM)	Dissolved oxygen (mg/L)	Unfiltered (total) organic carbon (mg/L)	Filtered (dissolved) organic carbon (mg/L)	Filtered nitrate + nitrite (mg/L as N)	Filtered manganese (mg/L)	Filtered iron (II) (mg/L)	Filtered sulfate (mg/L)
					Southern plantation				
MW1–4	09-17-96	0.5	2.8R	2.0	–	<0.02	0.28	1.8	7.1
	04-16-97	.6	.4	–	–	.24	–	<.01	8.6
	03-03-98	1.7	.2	4.0	–	–	.10	.01	–
	10-08-98	.2	.5	–	–	–	–	.28	–
	06-07-99	.9	.1	–	–	–	.20	1.2	–
	06-22-00	.2	.1	8.6	–	–	.70	–	5.5
	06-14-01	0.9–3.2	.5	2.9	2.5	.08	.54	1.6	5.4
	06-13-02	2.4	.1	–	3.8	.08	.47	1.2	5.5
	06-20-03	.8	.1	–	2.5	<.06	.53	.22	5.7
	06-18-04	.2	.1	–	2.7	–	.61	.12	5.9
	06-23-05	.3	.1	–	.7	<.06	.14	.03	8.8
	06-13-06	<.1	.1	–	3.9	<.06	.79	.19	5.7
	06-20-07	.1	<.1	–	1.4	<.06	.29	.23	7.5
	06-18-08	<.1	.1	–	2.6	E.03	.42	.19	7.1
	06-16-09	<.1	.4	–	.8	<.04	.19	<.01	8.7
MW1–5	09-17-96	1.2	<0.1	15	–	<0.02	1.6	19	6.4
	04-16–97	.5	<.1	–	–	.08	–	3.1	2.8
	03-04-98	.7	<.1	12	–	–	1.3	4.5	–
	10-08-98	2.4	<.1	–	–	–	1.5	11	–
	06-08-99	.6	.3	–	–	–	1.2	31	–
	06-22-00	–	<.1	17	–	–	1.5	39	6.4
	06-13-01	.8	.3	10	9.6	.12	1.5	25	6.0
	06-13-02	3.4	.5	–	11	.14	1.5	20	6.3
	06-20-03	.1	.1	–	11	<.06	1.5	30	6.8
	06-18-04	.1	.4	–	7.2	–	1.8	>10	5.6
	06-22-05	<.1	<.1	–	8.2	.16	1.2	27	6.7
	06-13-06	<.1	.1	–	7.8	.08	1.3	14	6.0
	06-20-07	.1	<.1	–	8.0	<.06	.10	21	1.7
	06-18-08	<.1	.3	–	5.9	.15	1.0	16	7.3
	06-16-09	<.1	.2	–	8.3	.09	1.8	14	5.7

Table 2. Predominant redox conditions at wells and piezometers, and groundwater geochemical data collected at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 1996–2009.—Continued

[All other data were published in Dinicola and others (2002), Dinicola (2003, 2004, 2006), and Dinicola and Huffman (2004, 2006, 2007, 2009). Prior to 2000, bicarbonate was calculated from an unfiltered sample. Reported concentrations less than the detection limit usually are estimated. A range of dissolved hydrogen concentrations are shown when equilibration at a single value was never achieved. **Well or piezometer No.**: MW, monitoring well; P, piezometer. **Abbreviations:** nM, nanomolar; mg/L, milligram per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; ORP, oxidation-reduction potential; mV, millivolt. **Symbols**: B, sample bottle broken; E, estimated value; R, data rejected (selected 1996 dissolved-oxygen data were rejected because of inadequate well purging; selected 2002 dissolved-hydrogen data were rejected because of interference from downhole instruments); <, actual value is less than value shown; >, actual value is greater than value shown; –, not analyzed]

Well or piezometer No.	Date sampled	Unfiltered sulfide (mg/L)	Dissolved methane (mg/L)	Dissolved carbon dioxide (mg/L)	Filtered bicarbonate (mg/L)	pH (units)	Specific conduc-tance (µS/cm)	ORP (mV)	Filtered chloride (mg/L)
				Southern plantation					
MW1–4	09-17-96	<0.01	1.2	–	130	6.9	–	–	15
	04-16-97	<.01	.70	–	270	7.3	–	–	–
	03-03-98	<.01	–	–	–	–	–	–	–
	10-08-98	<.01	–	–	170	6.7	368	–	–
	06-07-99	<.01	–	–	180	6.6	350	–	–
	06-22-00	<.01	.56	–	230	6.8	412	-26	19
	06-14-01	<.01	3.7	–	180	6.5	360	-8	22
	06-13-02	<.01	5.2	60	190	6.6	442	-14	20
	06-20-03	<.01	3.7	40	–	6.7	324	–	17
	06-18-04	<.01	1.1	50	–	6.0	320	91	23
	06-23-05	<.01	–	<10	–	7.9	203	45	7.3
	06-13-06	.01	2.1	30	–	6.6	362	-1	20
	06-20-07	<.01	.53	14	–	7.0	252	-58	11
	06-18-08	<.01	1.7	12	–	7.2	279		15
	06-16-09	<.01	.73	<10	–	7.7	250	-95	9.0
MW1–5	09-17-96	<0.01	2.4	–	410	6.7	–	–	21
	04-16–97	.03	18	–	1,400	6.6	–	–	–
	03-04-98	<.01	–	–	–	–	–	–	–
	10-08-98	<.01	–	–	410	6.4	1,740	–	–
	06-08-99	.01	–	–	510	6.5	855	–	–
	06-22-00	<.01	1.1	–	460	6.6	790	-80	19
	06-13-01	.01	2.4	–	470	6.4	766	-70	12
	06-13-02	.02	7.4	180	740	6.5	608	-77	9.6
	06-20-03	.03	4.9	180	–	6.4	711	–	10
	06-18-04	–	2.4	200	–	6.5	795	–	9.8
	06-22-05	.02	-	70	–	6.3	520	-95	9.5
	06-13-06	.02	1.9	50	–	6.5	603	-85	8.5
	06-20-07	.03	1.1	100	–	6.5	603	-106	44
	06-18-08	.01	1.8	100	–	6.6	562	–	8.4
	06-16-09	.02	3.5	500	–	6.4	684	-110	11

Table 2. Predominant redox conditions at wells and piezometers, and groundwater geochemical data collected at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 1996–2009.—Continued

[All other data were published in Dinicola and others (2002), Dinicola (2003, 2004, 2006), and Dinicola and Huffman (2004, 2006, 2007, 2009). Prior to 2000, bicarbonate was calculated from an unfiltered sample. Reported concentrations less than the detection limit usually are estimated. A range of dissolved hydrogen concentrations are shown when equilibration at a single value was never achieved. **Well or piezometer No.**: MW, monitoring well; P, piezometer. **Abbreviations:** nM, nanomolar; mg/L, milligram per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; ORP, oxidation-reduction potential; mV, millivolt. **Symbols**: B, sample bottle broken; E, estimated value; R, data rejected (selected 1996 dissolved-oxygen data were rejected because of inadequate well purging; selected 2002 dissolved-hydrogen data were rejected because of interference from downhole instruments); <, actual value is less than value shown; >, actual value is greater than value shown; –, not analyzed]

Well or piezometer No.	Date sampled	Dissolved hydrogen (nM)	Dissolved oxygen (mg/L)	Unfiltered (total) organic carbon (mg/L)	Filtered (dissolved) organic carbon (mg/L)	Filtered nitrate + nitrite (mg/L as N)	Filtered manganese (mg/L)	Filtered iron (II) (mg/L)	Filtered sulfate (mg/L)
Southern plantation—Continued									
MW1–16	09-17-96	2.1	<0.1	480	–	<0.02	3.9	130	0.2
	04-16-97	.8	<.1	–	–	<.02	–	120	2.2
	03-04-98	.7	.3	350	–	–	18	100	–
	10-08-98	9.6	<.1	–	–	–	5.4	180	–
	06-07-99	6.8	.6	–	–	–	>5	140	–
	06-22-00	–	.1	61	–	–	1.9	60	1.2
	06-14-01	1.7	.2	64	66	.33	2.4	56	1.1
	06-13-02	4.6–7.6	.9	–	71	<.05	3.2	38	.4
	06-20-03	2.2	.2	–	29	<.6	2.1	37	.6
	06-22-04	–	.1	–	36	–	2.1	>10	.1
	06-23-05	.5	.1	–	20	<.06	2.0	66	.4
	06-13-06	–	.1	–	17	<.06	1.7	14	20
	06-20-07	–	<.1	–	18	<.06	1.8	44	9.7
	06-18-08	.1	.1	–	17	<.04	2.2	28	10
	06-16-09	–	.2	–	B	<.04	2.6	44	88
P1–6	06-08-99	1.8	0.1	–	–	–	0.12	0.02	–
	06-14-01	1.8	.2	34	34	0.23	.45	.95	4.9
	06-13-02	1.6	<.1	–	26	<.05	.88	1.0	4.3
	06-20-03	.3	.2	–	4.1	<.06	.08	.13	7.5
	06-18-04	1.5	.1	–	10	–	.11	1.0	7.2
	06-23-05	.3	.1	–	5.8	<.06	.17	.15	6.3
	06-13-06	1.1	.1	–	26	<.06	.91	1.4	3.4
	06-20-07	.2	<.1	–	3.9	<.06	.08	.08	7.1
	06-18-08	.2	.1	–	10	<.04	.15	.10	5.5
	06-16-09	.1	.1	–	3.2	<.04	.08	.07	6.1
P1–7	06-08-99	1.2	0.1	–	–	–	0.61	2.1	–
	06-22-00	–	.1	19	–	–	2.6	3.2	24
	06-14-01	.2	.2	11	11	<0.05	2.3	2.0	18
	06-14-02	.2	1.3	–	8.9	<.05	2.2	1.9	12
	06-20-03	.1	.1	–	5.6	<.06	1.9	1.3	7.5
	06-18-04	.1	<.1	–	6.9	–	2.4	2.0	9.8
	06-22-05	<.1	.1	–	8.8	<.06	2.1	1.9	26
	06-13-06	<.1	.5	–	7.6	<.06	2.0	1.8	20
	06-20-07	.2	.1	–	5.7	<.06	2.1	1.2	6.0
	06-18-08	<.1	<.1	–	6.7	<.04	2.1	1.3	6.9
	06-16-09	<.1	.2	–	6.4	<.04	2.2	1.3	6.5

Table 2. Predominant redox conditions at wells and piezometers, and groundwater geochemical data collected at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 1996–2009.—Continued

[All other data were published in Dinicola and others (2002), Dinicola (2003, 2004, 2006), and Dinicola and Huffman (2004, 2006, 2007, 2009). Prior to 2000, bicarbonate was calculated from an unfiltered sample. Reported concentrations less than the detection limit usually are estimated. A range of dissolved hydrogen concentrations are shown when equilibration at a single value was never achieved. **Well or piezometer No.**: MW, monitoring well; P, piezometer. **Abbreviations:** nM, nanomolar; mg/L, milligram per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; ORP, oxidation-reduction potential; mV, millivolt. **Symbols**: B, sample bottle broken; E, estimated value; R, data rejected (selected 1996 dissolved-oxygen data were rejected because of inadequate well purging; selected 2002 dissolved-hydrogen data were rejected because of interference from downhole instruments); <, actual value is less than value shown; >, actual value is greater than value shown; –, not analyzed]

Well or piezometer No.	Date sampled	Unfiltered sulfide (mg/L)	Dissolved methane (mg/L)	Dissolved carbon dioxide (mg/L)	Filtered bicarbonate (mg/L)	pH (units)	Specific conductance (µS/cm)	ORP (mV)	Filtered chloride (mg/L)
				Southern Plantation—Continued					
MW1–16	09-17-96	<0.01	4.3	–	1,400	6.5	–	–	150
	04-16-97	.06	29	–	1,800	6.5	–	–	–
	03-04-98	.01	–	–	–	–	–	–	–
	10-08-98	<.01	–	–	1,600	6.3	3,370	–	–
	06-07-99	.01	–	–	1,200	6.7	1,820	–	–
	06-22-00	.02	1.2	–	510	6.7	902	-130	43
	06-14-01	.08	10	–	610	6.4	953	–	40
	06-13-02	.04	24	270	700	6.5	1,400	-140	17
	06-20-03	.06	9.7	240	–	6.5	835	–	6.8
	06-22-04	.50	4.3	230	–	6.3	817	–	6.9
	06-23-05	.12	–	225	–	6.6	767	-110	3.8
	06-13-06	.06	3.0	70	–	6.7	737	-139	3.5
	06-20-07	.13	2.1	190	–	6.4	763	-124	6.5
	06-18-08	.08	3.3	40	–	6.4	770	-62	16
	06-16-09	.45	8.8	80	–	6.4	880	-80	21
P1–6	06-08-99	0.04	–	–	300	6.8	574	–	–
	06-14-01	.12	6.3	–	350	6.4	657	-38	47
	06-13-02	.11	11	170	380	6.4	604	-11	37
	06-20-03	.07	4.8	40	–	8.1	278	–	13
	06-18-04	.10	.37	<10	–	8.6	268	–	18
	06-23-05	.12	1.4	24	–	7.1	332	-53	24
	06-13-06	.14	2.6	30	–	6.6	757	-85	35
	06-20-07	.07	.38	16	–	8.3	249	-274	10
	06-18-08	.07	2.2	<10	–	8.3	291	218	22
	06-16-09	.06	2.2	<10	–	8.2	318	-133	16
P1-7	06-08-99	<0.01	–	–	310	6.7	627	–	–
	06-22-00	<.01	1.5	–	400	6.8	851	-35	55
	06-14-01	<.01	4.0	–	320	6.5	666	-32	41
	06-14-02	<.01	6.0	87	300	6.6	601	-41	60
	06-20-03	<.01	4.8	50	–	6.6	498	–	42
	06-18-04	<.01	1.7	40	–	6.7	613	–	56
	06-22-05	<.01	2.3	37	–	6.5	637	-20	55
	06-13-06	<.01	2.1	–	–	6.6	639	-60	49
	06-20-07	<.01	2.4	12	–	6.6	494	-57	43
	06-18-08	<.01	3.8	14	–	6.7	556	-19	49
	06-16-09	.01	6.6	16	–	6.7	566	-62	53

Table 2. Predominant redox conditions at wells and piezometers, and groundwater geochemical data collected at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 1996–2009.—Continued

[All other data were published in Dinicola and others (2002), Dinicola (2003, 2004, 2006), and Dinicola and Huffman (2004, 2006, 2007, 2009). Prior to 2000, bicarbonate was calculated from an unfiltered sample. Reported concentrations less than the detection limit usually are estimated. A range of dissolved hydrogen concentrations are shown when equilibration at a single value was never achieved. **Well or piezometer No.**: MW, monitoring well; P, piezometer. **Abbreviations:** nM, nanomolar; mg/L, milligram per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; ORP, oxidation-reduction potential; mV, millivolt. **Symbols**: B, sample bottle broken; E, estimated value; R, data rejected (selected 1996 dissolved-oxygen data were rejected because of inadequate well purging; selected 2002 dissolved-hydrogen data were rejected because of interference from downhole instruments); <, actual value is less than value shown; >, actual value is greater than value shown; –, not analyzed]

Well or piezometer No.	Date sampled	Dissolved hydrogen (nM)	Dissolved oxygen (mg/L)	Unfiltered (total) organic carbon (mg/L)	Filtered (dissolved) organic carbon (mg/L)	Filtered nitrate + nitrite (mg/L as N)	Filtered manganese (mg/L)	Filtered iron (II) (mg/L)	Filtered sulfate (mg/L)
Southern plantation—Continued									
P1–8	06-07-99	1.8	<0.1	–	–	–	0.20	0.08	–
	06-14-01	.7	.1	5	4.7	0.06	.16	.22	0.1
	06-13-02	.6	.3	–	8.8	<.05	.21	.38	.3
	06-20-03	.6	.1	–	2.3	<.06	.09	.12	.4
	06-18-04	.3	.4	–	3.0	–	.13	.01	.4
	06-23-05	.2	.2	–	14	<.06	.12	.12	<.2
	06-13-06	.3	<.1	–	3.2	<.06	.14	.02	.4
	06-20-07	.3	.1	–	3.9	<.06	.15	.14	<.18
	06-18-08	.1	<.1	–	4.1	<.04	.15	.16	.38
	06-15-09	.2	<.1	–	3.5	<.04	.17	.02	.34
P1–9	06-08-99	19	0.3	–	–	–	0.90	0.03	–
	06-22-00	–	.1	10	–	–	.69	.20	6.6
	06-14-01	6.7	.1	2.3	1.7	<.05	.19	.05	7.6
	06-13-02	–	.6	–	9.8	<.05	1.2	.42	5.6
	06-20-03	.2	.1	–	3.7	<.06	.24	<.01	7.0
	06-18-04	.2	.1	–	4.0	–	.26	.14	7.3
	06-23-05	<.1	.1	–	1.4	<.06	.11	.01	8.7
	06-13-06	4.4	.2	–	9.6	<.06	1.4	.33	5.3
	06-20-07	.2	.1	–	4.5	<.06	.28	.13	7.04
	06-18-08	.1-.5	<.1	–	10	<.04	.17	.07	7.89
	06-16-09	<.1	.2	–	6.0	<.04	.60	.15	5.4
P1–10	06-07-99	0.7	0.3	–	–	–	0.10	0.11	–
	06-22-00	–	<.1	7.2	–	–	.07	.25	<.3
	06-13-01	2.0	.2	3.0	4.2	<.05	.07	.20	.06
	06-12-02	.3	.1	–	3.5	<.05	.05	.41	<.1
	06-19-03	.2	.1	–	3.5	<.06	.42	.34	2.6
	06-18-04	.1	.1	–	3.5	–	.58	.35	<.2
	06-22-05	.1	.1	–	3.3	<.06	.74	.24	<.2
	06-13-06	<.1	.1	–	3.4	<.06	.92	.15	<.2
	06-20-07	E.1	<.1	–	4.2	<.06	.10	.31	<.18
	06-18-08	<.1	<.1	–	4.2	<.04	.12	.23	<.18
	06-15-09	.1	.1	–	4.0	<.04	.24	.28	<.2

Table 2. Predominant redox conditions at wells and piezometers, and groundwater geochemical data collected at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 1996–2009.—Continued

[All other data were published in Dinicola and others (2002), Dinicola (2003, 2004, 2006), and Dinicola and Huffman (2004, 2006, 2007, 2009). Prior to 2000, bicarbonate was calculated from an unfiltered sample. Reported concentrations less than the detection limit usually are estimated. A range of dissolved hydrogen concentrations are shown when equilibration at a single value was never achieved. **Well or piezometer No.**: MW, monitoring well; P, piezometer. **Abbreviations:** nM, nanomolar; mg/L, milligram per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; ORP, oxidation-reduction potential; mV, millivolt. **Symbols**: B, sample bottle broken; E, estimated value; R, data rejected (selected 1996 dissolved-oxygen data were rejected because of inadequate well purging; selected 2002 dissolved-hydrogen data were rejected because of interference from downhole instruments); <, actual value is less than value shown; >, actual value is greater than value shown; –, not analyzed]

Well or piezometer No.	Date sampled	Unfiltered sulfide (mg/L)	Dissolved methane (mg/L)	Dissolved carbon dioxide (mg/L)	Filtered bicarbonate (mg/L)	pH (units)	Specific conduc-tance (µS/cm)	ORP (mV)	Filtered chloride (mg/L)
				Southern Plantation—Continued					
P1-8	06-07-99	0.01	–	–	210	7.6	381	–	–
	06-14-01	.02	6.9	–	200	7.0	363	-73	18
	06-13-02	.02	11	40	104	6.9	482	-46	35
	06-20-03	<.01	9.6	<10	–	7.2	285	–	3.3
	06-18-04	.01	1.7	<10	–	7.4	336	-218	5.9
	06-23-05	<.01	3.4	<10	–	7.5	308	-147	4.2
	06-13-06	<.01	4.5	<10	–	7.5	332	-124	8.0
	06-20-07	<.01	6.6	9	–	7.5	348	-149	5.9
	06-18-08	<.01	7.9	<10	–	8.0	358	-136	8.7
	06-15-09	<.01	10	<10	–	7.9	356	-164	6.7
P1-9	06-08-99	<0.01	–	–	270	6.6	680	–	–
	06-22-00	<.01	1.7	–	250	6.8	548	-17	59
	06-14-01	<.01	1.4	–	200	7.8	289	-120	14
	06-13-02	<.01	7.5	91	280	6.5	601	17	71
	06-20-03	.01	2.5	27	–	7.0	353	–	23
	06-18-04	<.01	.71	35	–	6.7	330	-97	26
	06-23-05	<.01	.02	<10	–	8.3	202	22	12
	06-13-06	.01	3.2	37	–	6.6	728	-9	112
	06-20-07	<.01	1.4	10	–	7.4	325	-110	31
	06-18-08	<.01	.74	<10	–	7.6	235	–	28
	06-16-09	<.01	6.7	14	–	6.8	507	-27	72
P1-10	06-07-99	<0.01	–	–	300	6.7	560	–	–
	06-22-00	<.01	1.3	–	290	7.1	500	-19	15
	06-13-01	<.01	4.9	–	290	7.2	476	-24	15
	06-12-02	<.01	18	51	270	6.8	438	8	14
	06-19-03	<.01	8.2	30	–	6.6	425	–	16
	06-18-04	<.01	.33	45	–	6.3	422	-69	9.5
	06-23-05	<.01	.71	40	–	6.6	420	4	11
	06-13-06	<.01	6.3	29	–	6.6	437	-15	26
	06-20-07	<.01	6.1	15	–	6.3	391	-21	15
	06-18-08	<.01	4.7	11	–	6.8	358	14	7.3
	06-15-09	<.01	3.4	35	–	6.7	406	-6.1	6.6

Table 2. Predominant redox conditions at wells and piezometers, and groundwater geochemical data collected at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 1996–2009.—Continued

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Well or piezometer No.	Date sampled	Dissolved hydrogen (nM)	Dissolved oxygen (mg/L)	Unfiltered (total) organic carbon (mg/L)	Filtered (dissolved) organic carbon (mg/L)	Filtered nitrate + nitrite (mg/L as N)	Filtered manganese (mg/L)	Filtered iron (II) (mg/L)	Filtered sulfate (mg/L)
Intermediate aquifer									
MW1–25	09-17-96	0.4	2.7R	7.4	–	0.14	0.16	0.74	16
	04-17-97	.8	.1	–	–	<.02	–	.88	15
	03-05-98	.3	.3	7.9	–	–	.20	.73	–
	10-05-98	.2	.1	–	–	–	.19	.99	–
	06-22-00	.4	.2	6.5	–	–	.16	.80	13
	06-12-01	2.8–4.3	.2	7.1	6.8	<.05	.16	.99	13
	06-14-02	0.7–2.4	.1	–	6.2	<.05	.18	1.1	9.7
	06-19-03	.3	.1	–	6.5	<.06	.18	1.1	11
	06-16-04	.2	.1	–	6.2	–	.17	1.0	10
	06-21-05	.1	.1	–	5.9	<.06	.16	1.0	9.5
	06-14-06	.1	.1	–	6.3	<.06	.14	.97	8.1
	06-18-07	.2	<.1	–	6.6	<.06	.14	.87	7.1
	06-17-08	<.1	.1	–	6.4	<.04	.13	.86	6.9
	06-17-09	.2	.1	–	6.7	<.04	.15	1.1	6.9
MW1–28	09-16-96	0.3	2.1R	7.2	–	<0.02	0.20	1.0	48
	04-17-97	1.0	<.1	–	–	.04	–	.99	51
	03-05-98	.4	.5	7.7	–	–	.20	.67	–
	10-07-98	.6	<.1	–	–	–	.19	1.0	–
	06-22-00	.3	<.1	13	–	–	.16	.66	44
	06-12-01	4.1–5.7	.5	10	6.9	<.05	.16	.90	45
	06-14-02	>100R	.1	–	7.0	<.05	.16	.92	39
	06-19-03	2.5	.1	–	6.8	<.06	.16	.66	39
	06-16-04	.2	.1	–	5.9	–	.18	<.01	36
	06-21-05	.1	.2	–	6.3	<.06	.16	.98	37
	06-14-06	.1	.1	–	6.1	<.06	.16	.78	35
	06-18-07	.1	<.1	–	6.7	<.06	.16	.87	33
	06-17-08	.1	<.1	–	7.1	<.04	.15	.85	33
	06-17-09	.1	.2	–	6.5	<.04	.16	.96	33
MW1–38	10-09-98	–	0.1	–	–	–	0.20	0.08	–
	06-20-00	0.1	.2	5.6	–	<0.05	.08	.10	2.3
	06-12-02	1.4	<.1	5.0	–	<.05	.08	.42	2.9
	06-16-04	.2	.1	–	4.9	–	.06	.04	1.2
	06-24-05	.3	.1	–	4.4	<.06	.06	.09	3.3
	06-14-06	.1	.1	–	2.4	<.06	.01	.05	1.0
	06-21-07	.2	.6	–	4.7	<.06	.04	.04	3.1
	06-17-08	<.1	.1	–	5.0	<.04	.04	.03	2.5
	06-17-09	.1	.4	–	4.5	<.04	.05	.1	3.4

Table 2. Predominant redox conditions at wells and piezometers, and groundwater geochemical data collected at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 1996–2009.—Continued

[All other data were published in Dinicola and others (2002), Dinicola (2003, 2004, 2006), and Dinicola and Huffman (2004, 2006, 2007, 2009). Prior to 2000, bicarbonate was calculated from an unfiltered sample. Reported concentrations less than the detection limit usually are estimated. A range of dissolved hydrogen concentrations are shown when equilibration at a single value was never achieved. **Well or piezometer No.**: MW, monitoring well; P, piezometer. **Abbreviations:** nM, nanomolar; mg/L, milligram per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; ORP, oxidation-reduction potential; mV, millivolt. **Symbols**: B, sample bottle broken; E, estimated value; R, data rejected (selected 1996 dissolved-oxygen data were rejected because of inadequate well purging; selected 2002 dissolved-hydrogen data were rejected because of interference from downhole instruments); <, actual value is less than value shown; >, actual value is greater than value shown; –, not analyzed]

Well or piezometer No.	Date sampled	Unfiltered sulfide (mg/L)	Dissolved methane (mg/L)	Dissolved carbon dioxide (mg/L)	Filtered bicarbonate (mg/L)	pH (units)	Specific conduc-tance (µS/cm)	ORP (mV)	Filtered chloride (mg/L)
Intermediate aquifer									
MW1-25	09-17-96	<0.01	3.6	–	360	7.1	–	–	140
	04-17-97	<.01	7.9	–	1,000	7.0	–	–	–
	03-05-98	<.01	–	–	–	–	–	–	–
	10-05-98	<.01	–	–	450	6.9	1,240	–	–
	06-22-00	<.01	.79	–	380	6.9	1,230	-49	170
	06-12-01	<.01	4.7	–	440	6.7	1,180	-36	160
	06-14-02	<.01	7.0	83	370	6.7	1,030	-60	170
	06-19-03	<.01	8.1	65	–	6.7	1,180	-17	170
	06-16-04	<.01	1.4	40	–	7.1	1,210	–	160
	06-21-05	<.01	2.1	33	–	6.9	1,150	-9	160
	06-14-06	<.01	2.4	27	–	6.9	1,090	-71	140
	06-18-07	<.01	1.3	27	–	6.6	1,040	-152	140
	06-17-08	<.01	2.8	35	–	6.9	1,040	-45	140
	06-19-09	–	5.1	<10	–	6.5	923	-100	124
MW1–28	09-16-96	<0.01	1.7	–	350	–	–	–	380
	04-17-97	<.01	5.3	–	1,100	7.4	–	–	–
	03-05-98	<.01	–	–	–	–	–	–	–
	10-07-98	.02	–	–	320	6.6	2,630	–	–
	06-22-00	<.01	.45	–	480	7.3	2,460	-87	510
	06-12-01	<.01	4.1	–	480	7.4	2,200	-220	490
	06-14-02	<.01	3.9	40	470	7.2	2,580	-110	460
	06-19-03	<.01	1.7	32	–	7.1	2,440	-40	490
	06-16-04	<.01	.77	21	–	7.2	2,280	–	450
	06-21-05	<.01	1.0	23	–	6.9	2,210	-124	472
	06-14-06	.01	.83	21	–	7.0	2,110	-127	443
	06-18-07	.02	.67	25	–	7.1	2,060	–	430
	06-17-08	<.01	1.5	13	–	7.1	2,080	-112	420
	06-17-09	<.01	2.2	<10	–	7.2	1,860	-104	415
MW1–38	10-09-98	0.02	–	–	310	7.8	1,460	–	–
	06-20-00	.03	0.10	–	300	7.8	1,240	-130	230
	06-12-02	.04	1.1	7.7	310	7.6	1,350	-160	230
	06-16-04	.03	.13	11	–	7.4	1,130	–	200
	06-24-05	.03	.05	<10	–	7.7	1,210	-116	230
	06-14-06	<.01	.41	<10	–	7.5	1,120	-55	62
	06-21-07	.05	.31	9.0	–	7.4	1,190	-114	230
	06-17-08	.02	.32	<10	–	7.7	1,140	-43	220
	06-17-09	.03	.77	<10	–	7.7	1,140	-150	214

Table 2. Predominant redox conditions at wells and piezometers, and groundwater geochemical data collected at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 1996–2009.—Continued

[All other data were published in Dinicola and others (2002), Dinicola (2003, 2004, 2006), and Dinicola and Huffman (2004, 2006, 2007, 2009). Prior to 2000, bicarbonate was calculated from an unfiltered sample. Reported concentrations less than the detection limit usually are estimated. A range of dissolved hydrogen concentrations are shown when equilibration at a single value was never achieved. **Well or piezometer No.**: MW, monitoring well; P, piezometer. **Abbreviations:** nM, nanomolar; mg/L, milligram per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; ORP, oxidation-reduction potential; mV, millivolt. **Symbols**: B, sample bottle broken; E, estimated value; R, data rejected (selected 1996 dissolved-oxygen data were rejected because of inadequate well purging; selected 2002 dissolved-hydrogen data were rejected because of interference from downhole instruments); <, actual value is less than value shown; >, actual value is greater than value shown; –, not analyzed]

Well or piezometer No.	Date sampled	Dissolved hydrogen (nM)	Dissolved oxygen (mg/L)	Unfiltered (total) organic carbon (mg/L)	Filtered (dissolved) organic carbon (mg/L)	Filtered nitrate + nitrite (mg/L as N)	Filtered manganese (mg/L)	Filtered iron (II) (mg/L)	Filtered sulfate (mg/L)
Intermediate aquifer—Continued									
MW1–39	09-16-96	0.6	2.0R	4.4	–	<0.02	0.02	<0.01	0.7
	04-17-97	4.5	<.1	–	–	<.02	–	.05	13
	03-03-98	.3	.3	3.7	–	–	.10	.03	–
	10-09-98	.5	<.1	–	–	–	<.01	.04	–
	06-07-99	1.0	.3	–	–	–	.10	.02	–
	06-20-00	.5	.1	2.4	–	<.05	.01	.07	.2
	06-12-01	1.4	.3	3.4	3.3	<.05	.01	<.01	.1
	06-12-02	>30R	<.1	–	2.8	<.05	.01	.10	.1
	06-19-03	1.8	.1	–	2.5	<.06	.01	<.01	1.2
	06-16-04	2.0	.1	–	2.4	–	.01	.05	.1
	06-14-06	.7	.1	–	4.5	<.06	.05	.05	1.7
	06-21-07	1.0	<.1	–	2.3	<.06	.01	.04	.98
	06-17-08	1.8	.6	–	2.7	<.04	.01	.04	1.0
	06-17-09	1.8	.4	–	2.0	<.04	<.01	<.01	1.0

Table 2. Predominant redox conditions at wells and piezometers, and groundwater geochemical data collected at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 1996–2009.—Continued

[All other data were published in Dinicola and others (2002), Dinicola (2003, 2004, 2006), and Dinicola and Huffman (2004, 2006, 2007, 2009). Prior to 2000, bicarbonate was calculated from an unfiltered sample. Reported concentrations less than the detection limit usually are estimated. A range of dissolved hydrogen concentrations are shown when equilibration at a single value was never achieved. **Well or piezometer No.**: MW, monitoring well; P, piezometer. **Abbreviations:** nM, nanomolar; mg/L, milligram per liter; µS/cm, microsiemens per centimeter at 25 degrees Celsius; ORP, oxidation-reduction potential; mV, millivolt. **Symbols**: B, sample bottle broken; E, estimated value; R, data rejected (selected 1996 dissolved-oxygen data were rejected because of inadequate well purging; selected 2002 dissolved-hydrogen data were rejected because of interference from downhole instruments); <, actual value is less than value shown; >, actual value is greater than value shown; –, not analyzed]

Well or piezometer No.	Date sampled	Unfiltered sulfide (mg/L)	Dissolved methane (mg/L)	Dissolved carbon dioxide (mg/L)	Filtered bicarbonate (mg/L)	pH (units)	Specific conduc-tance (µS/cm)	ORP (mV)	Filtered chloride (mg/L)
Intermediate aquifer—Continued									
MW1–39	09-16-96	0.04	1.6	–	140	–	–	–	85
	04-17-97	.06	6.1	–	360	7.9	–	–	–
	03-03-98	.05	–	–	–	–	–	–	–
	10-09-98	.07	–	–	170	8.1	502	–	–
	06-07-99	<.01	–	–	180	8.0	512	–	–
	06-20-00	.08	.41	–	180	8.0	481	-130	61
	06-12-01	.05	2.7	–	170	7.8	472	-130	61
	06-12-02	.06	4.8	2.4	180	7.9	464	-120	60
	06-19-03	.05	5.4	<10	–	7.7	456	32	58
	06-16-04	.07	.72	<10	–	7.4	451	-216	58
	06-14-06	.06	1.2	<10	–	8.0	461	-138	210
	06-21-07	.05	1.3	<10	–	7.7	453	-195	60
	06-17-08	.06	1.9	<10	–	7.9	451	-163	59
	06-17-09	.04	3.2	<10	–	8.0	450	-184	56

Table 3. Concentrations of selected volatile organic compounds in groundwater samples from monitoring wells and piezometers collected by the U.S. Geological Survey at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 1999–2009.

[All data except those shaded were published previously in Dinicola and others (2002), Dinicola (2003, 2004, 2006), and Dinicola and Huffman (2004, 2006, 2007, 2009). Laboratory data qualifier codes, such as "D" for dilution, are not shown. **Well or piezometer No:** MW, monitoring well; P, piezometer. **Volatile organic compounds (VOCs)**; PCE, tetrachloroethene; TCE, trichloroethene; *cis*-DCE, *cis*-1,2-dichloroethene; *trans*-DCE, *trans*-1,2-dichloroethene; VC, vinyl chloride; 1,1,1-TCA, 1,1,1-trichloroethane; 1,1-DCA, 1,1-dichloroethane; CA, chloroethane; 1,1-DCE, 1,1-dichloroethene; total BTEX, sum of benzene, toluene, ethylbenzene, and xylene; total CVOCs, sum of chlorinated volatile organic compounds. **Abbreviations:** E, estimated value; M, presence verified but not quantified; µg/L, microgram per liter; <, actual value is less than value shown; ND, not detected; –, not analyzed]

Well or piezometer No.	Date sampled	PCE (µg/L)	TCE (µg/L)	*cis*-DCE (µg/L)	*trans*-DCE (µg/L)	VC (µg/L)	Ethane (µg/L)	Ethene (µg/L)
Upgradient								
MW1-3	06-20-00	–	–	–	–	–	–	0.12
	06-15-04	–	–	–	–	–	<5.0	<5.0
	06-12-06	–	–	–	–	–	<5.0	<5.0
	06-15-09	–	–	–	–	–	<5.0	<5.0
MW1-20	06-21-00	–	–	–	–	–	–	<.10
	06-12-02	<0.20	<0.20	<0.20	<0.20	<0.20	–	–
	06-15-04	–	–	–	–	–	<5.0	<5.0
	06-13-06	–	–	–	–	–	<5.0	<5.0
	06-15-09	–	–	–	–	–	<5.0	<5.0
Northern plantation								
1MW-1	06-21-00	–	–	–	–	–	–	8.6
	06-16-04	<20	<20	130	130	730	E10	50
	06-12-06	–	–	–	–	–	E21	61
	06-19-07	–	–	–	–	–	E9.0	E38
	06-17-08	–	–	–	–	–	E47	110
	06-15-09	–	–	–	–	–	E19	E95
MW1-2	06-21-00	–	–	–	–	–	–	0.26
	06-18-03	<2.0	<2.0	58	4.0	79	–	–
	06-17-04	<50	E12	630	E13	110	6.0	E1.1
	06-12-06	–	–	–	–	–	5.0	<5.0
	06-19-07	–	–	–	–	–	E4.0	<5.0
	06-17-08	–	–	–	–	–	7.0	E.70
	06-15-09	–	–	–	–	–	E10	<25
MW1-17	06-22-00	–	–	–	–	–	–	<0.10
	06-17-04	<1.0	<1.0	E0.68	E0.23	E0.48	E2.0	<5.0
	06-20-07	–	–	–	–	–	E11	<50
	06-18-08	–	–	–	–	–	E17	E13
	06-15-09	–	–	–	–	–	E21	<250
MW1-41	06-21-00	–	–	–	–	–	–	<0.10
	06-17-04	<1.0	<1.0	E0.27	<1.0	E0.23	E10	<100
	06-12-06	–	–	–	–	–	<100	<100
	06-19-07	–	–	–	–	–	<100	<100
	06-16-08	–	–	–	–	–	<120	<120
	06-15-09	–	–	–	–	–	<250	<250

Table 3. Concentrations of selected volatile organic compounds in groundwater samples from monitoring wells and piezometers collected by the U.S. Geological Survey at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 1999–2009. —Continued

[All data except those shaded were published previously in Dinicola and others (2002), Dinicola (2003, 2004, 2006), and Dinicola and Huffman (2004, 2006, 2007, 2009). Laboratory data qualifier codes, such as "D" for dilution, are not shown. **Well or piezometer No:** MW, monitoring well; P, piezometer. **Volatile organic compounds (VOCs)**; PCE, tetrachloroethene; TCE, trichloroethene; *cis*-DCE, *cis*-1,2-dichloroethene; *trans*-DCE, *trans*-1,2-dichloroethene; VC, vinyl chloride; 1,1,1-TCA, 1,1,1-trichloroethane; 1,1-DCA, 1,1-dichloroethane; CA, chloroethane; 1,1-DCE, 1,1-dichloroethene; total BTEX, sum of benzene, toluene, ethylbenzene, and xylene; total CVOCs, sum of chlorinated volatile organic compounds. **Abbreviations:** E, estimated value; M, presence verified but not quantified; µg/L, microgram per liter; <, actual value is less than value shown; ND, not detected; –, not analyzed]

Well or piezometer No.	Date sampled	1,1,1-TCA (µg/L)	1,1-DCA (µg/L)	CA (µg/L)	1,1-DCE (µg/L)	Total BTEX (µg/L)	Total CVOCs (µg/L)
			Upgradient				
MW1-3	06-20-00	–	–	–	–	–	–
	06-15-04	–	–	–	–	–	–
	06-12-06	–	–	–	–	–	–
	06-15-09	–	–	–	–	–	–
MW1-20	06-21-00	–	–	–	–	–	–
	06-12-02	<0.20	<0.20	<0.20	<0.20	ND	ND
	06-15-04	–	–	–	–	–	–
	06-13-06	–	–	–	–	–	–
	06-15-09	–	–	–	–	–	–
			Northern plantation				
1MW-1	06-21-00	–	–	–	–	–	–
	06-16-04	<20	E11	<40	<20	ND	880
	06-12-06	–	–	–	–	–	–
	06-19-07	–	–	–	–	–	–
	06-17-08	–	–	–	–	–	–
	06-15-09	–	–	–	–	–	–
MW1-2	06-21-00	–	–	–	–	–	–
	06-18-03	<2.0	M	5.0	<2.0	E2.0	150
	06-17-04	<50	<50	<100	<50	ND	760
	06-12-06	–	–	–	–	–	–
	06-19-07	–	–	–	–	–	–
	06-17-08	–	–	–	–	–	–
	06-15-09	–	–	–	–	–	–
MW1-17	06-22-00	–	–	–	–	–	–
	06-17-04	<1.0	<1.0	<2.0	<1.0	E3.1	E1.4
	06-20-07	–	–	–	–	–	–
	06-18-08	–	–	–	–	–	–
	06-15-09	–	–	–	–	–	–
MW1-41	06-21-00	–	–	–	–	–	–
	06-17-04	<1.0	<1.0	E1.7	<1.0	E.27	E2.2
	06-12-06	–	–	–	–	–	–
	06-19-07	–	–	–	–	–	–
	06-16-08	–	–	–	–	–	–
	06-15-09	–	–	–	–	–	–

Table 3. Concentrations of selected volatile organic compounds in groundwater samples from monitoring wells and piezometers collected by the U.S. Geological Survey at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 1999–2009. —Continued

[All data except those shaded were published previously in Dinicola and others (2002), Dinicola (2003, 2004, 2006), and Dinicola and Huffman (2004, 2006, 2007, 2009). Laboratory data qualifier codes, such as "D" for dilution, are not shown. **Well or piezometer No:** MW, monitoring well; P, piezometer. **Volatile organic compounds (VOCs)**; PCE, tetrachloroethene; TCE, trichloroethene; *cis*-DCE, *cis*-1,2-dichloroethene; *trans*-DCE, *trans*-1,2-dichloroethene; VC, vinyl chloride; 1,1,1-TCA, 1,1,1-trichloroethane; 1,1-DCA, 1,1-dichloroethane; CA, chloroethane; 1,1-DCE, 1,1-dichloroethene; total BTEX, sum of benzene, toluene, ethylbenzene, and xylene; total CVOCs, sum of chlorinated volatile organic compounds. **Abbreviations:** E, estimated value; M, presence verified but not quantified; µg/L, microgram per liter; <, actual value is less than value shown; ND, not detected; –, not analyzed]

Well or piezometer No.	Date sampled	PCE (µg/L)	TCE (µg/L)	*cis*-DCE (µg/L)	*trans*-DCE (µg/L)	VC (µg/L)	Ethane (µg/L)	Ethene (µg/L)
				Northern plantation—Continued				
P1-1	06-09-99	<2.0	11	6.1	<1.0	<4.0	–	–
	06-11-02	<.20	<.20	.20	.10	<.20	–	–
	06-18-03	<1.0	<1.0	E.30	<1.0	<1.0	–	–
	06-17-04	<1.0	<1.0	<1.0	<1.0	<1.0	E29	E8.6
	06-22-05	<1.0	<1.0	E.16	<1.0	<1.0	<100	<100
	06-12-06	<1.0	<1.0	<1.0	<1.0	<1.0	<100	<100
	06-19-07	–	–	–	–	–	<100	<100
	06-16-08	<1.0	<1.0	E.18	<1.0	<2.0	<250	<250
	06-15-09	<1.0	<1.0	E.19	<1.0	<2.0	<500	<500
P1-3	06-09-99	<16	35	450	20	120	–	–
	06-11-02	<.20	<.20	53	4.3	72	–	–
	06-18-03	<2.0	<2.0	58	4.0	79	–	–
	06-17-04	<1.0	<1.0	15	2.4	41	E33	E27
	06-22-05	<1.0	<1.0	11	1.3	35	E44	E30
	06-12-06	<1.0	<1.0	4.6	1.2	16	E35	E21
	06-19-07	<1.0	<1.0	1.8	1.0	15	E42	E27
	06-17-08	<1.0	<1.0	E.17	E.31	E.67	E64	E20
	06-15-09	<1.0	<1.0	E.73	E.71	5.8	E60	<500
P1-4	06-09-99	<130	160	4,800	56	540	–	–
	06-13-01	<20	<20	4,900	46	652	–	–
	06-11-02	<.20	1.2	3,600	41	640	–	–
	06-18-03	<100	<100	3,200	E42	440	–	–
	06-17-04	<130	<130	2,300	E29	370	E7.0	E29
	06-21-05	<67	<67	2,100	E30	360	E7.0	E20
	06-12-06	<50	<50	1,600	E24	280	E6.0	E19
	06-19-07	<40	<40	15,00	E24	280	E11	E29
	06-16-08	<50	<50	1,600	E24	750	E14	E29
	06-15-09	<40	<40	1,300	E34	350	E21	E50
P1-5	06-08-99	<13	440	400	4.0	11	–	–
	06-10-02	<.20	<.20	.30	.80	.40	–	–
	06-18-03	<25	<25	E7.8	<25	<25	–	–
	06-17-04	<10	<10	<10	<10	<10	23	<10
	06-21-05	<10	<10	<10	<10	<10	E23	<100
	06-12-06	<10	<10	<10	<10	<10	E16	<100
	06-19-07	–	–	–	–	–	E19	<100
	06-16-08	<50	<50	<50	<50	<100	E45	<100
	06-15-09	<20	<20	<20	<20	<40	E25	<250

Table 3. Concentrations of selected volatile organic compounds in groundwater samples from monitoring wells and piezometers collected by the U.S. Geological Survey at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 1999–2009. —Continued

[All data except those shaded were published previously in Dinicola and others (2002), Dinicola (2003, 2004, 2006), and Dinicola and Huffman (2004, 2006, 2007, 2009). Laboratory data qualifier codes, such as “D” for dilution, are not shown. **Well or piezometer No:** MW, monitoring well; P, piezometer. **Volatile organic compounds (VOCs)**; PCE, tetrachloroethene; TCE, trichloroethene; *cis*-DCE, *cis*-1,2-dichloroethene; *trans*-DCE, *trans*-1,2-dichloroethene; VC, vinyl chloride; 1,1,1-TCA, 1,1,1-trichloroethane; 1,1-DCA, 1,1-dichloroethane; CA, chloroethane; 1,1-DCE, 1,1-dichloroethene; total BTEX, sum of benzene, toluene, ethylbenzene, and xylene; total CVOCs, sum of chlorinated volatile organic compounds. **Abbreviations:** E, estimated value; M, presence verified but not quantified; µg/L, microgram per liter; <, actual value is less than value shown; ND, not detected; –, not analyzed]

Well or piezometer No.	Date sampled	1,1,1-TCA (µg/L)	1,1-DCA (µg/L)	CA (µg/L)	1,1-DCE (µg/L)	Total BTEX (µg/L)	Total CVOCs (µg/L)
Northern plantation—Continued							
P1-1	06-09-99	<2.0	M	<4.0	<2.0	18	17
	06-11-02	<.20	0.50	<.20	<.20	6.8	.80
	06-18-03	<1.0	M	<2.0	<1.0	4.0	E.30
	06-17-04	<1.0	<1.0	<2.0	<1.0	4.4	ND
	06-22-05	<1.0	<1.0	E.19	<1.0	3.5	.35
	06-12-06	<1.0	<1.0	<2.0	<1.0	3.1	ND
	06-19-07	–	–	–	–	–	–
	06-16-08	<1.0	<1.0	<2.0	<1.0	3.9	E.18
	06-15-09	<1.0	<1.0	<2.0	<1.0	3.5	E.19
P1-3	06-09-99	<16	<16	4.0	<16	ND	630
	06-11-02	<.20	.60	9.9	.20	3.3	140
	06-18-03	<2.0	M	5.0	<2.0	E2.0	150
	06-17-04	<1.0	E.38	6.9	<1.0	2.4	66
	06-22-05	<1.0	E.31	2.6	<1.0	2.3	50
	06-12-06	<1.0	E.32	4.4	<1.0	2.2	26
	06-19-07	<1.0	E.42	5.6	<1.0	2.2	24
	06-17-08	<1.0	E.24	9.1	<1.0	3.9	10
	06-15-09	<1.0	E.26	6.4	<1.0	2.3	14
P1-4	06-09-99	<130	<130	<270	<130	ND	5,600
	06-13-01	<20	<20	<20	<20	ND	5,600
	06-11-02	<.20	<10	.80	9.9	1.1	4,300
	06-18-03	<100	<100	<200	<100	ND	3,700
	06-17-04	<130	<130	<270	<130	ND	2,700
	06-21-05	<67	<67	<130	<67	ND	2,500
	06-12-06	<50	<50	<100	<50	ND	1,900
	06-19-07	<40	<40	<80	<40	66	1,800
	06-16-08	<50	<50	<100	<50	ND	2,400
	06-15-09	<40	<40	<80	<40	ND	1,680
P1-5	06-08-99	<13	<13	15	<13	47	470
	06-10-02	<.20	.30	21	<.20	18	23
	06-18-03	<25	<25	E19	<25	ND	E27
	06-17-04	<10	<10	23	<10	E4.5	23
	06-21-05	<10	<10	21	<10	8.2	21
	06-12-06	<10	<10	E14	<10	E4.2	E14
	06-19-07	–	–	–	–	–	–
	06-16-08	<50	<50	<100	<50	ND	ND
	06-15-09	<20	<20	E19	<20	ND	E19

Table 3. Concentrations of selected volatile organic compounds in groundwater samples from monitoring wells and piezometers collected by the U.S. Geological Survey at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 1999–2009. —Continued

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Well or piezometer No.	Date sampled	PCE (µg/L)	TCE (µg/L)	*cis*-DCE (µg/L)	*trans*-DCE (µg/L)	VC (µg/L)	Ethane (µg/L)	Ethene (µg/L)
				Southern plantation				
MW1-4	06-22-00	–	–	–	–	–	–	12
	06-18-04	<1,000	32,000	15,000	<1,000	1,600	E32	200
	06-13-06	–	–	–	–	–	E39	200
	06-20-07	–	–	–	–	–	6.0	32
	06-18-08	–	–	–	–	–	30	120
	06-16-09	–	–	–	–	–	5.0	28
MW1-5	06-22-00	–	–	–	–	–	–	8.6
	06-18-04	<1.0	E0.26	E0.29	<1.0	E0.74	E7.0	<50
	06-13-06	–	–	–	–	–	E9.0	E30
	06-20-07	–	–	–	–	–	E3.0	<25
	06-18-08	–	–	–	–	–	E6.0	E7.2
	06-15-09	–	–	–	–	–	E6.0	<50
MW1-16	06-22-00	–	–	–	–	–	–	70
	06-22-04	<10	<10	E2.3	E4.2	E2.2	E38	E33
	06-13-06	–	–	–	–	–	E23	E6.8
	06-20-07	–	–	–	–	–	E24	E18
	06-18-08	–	–	–	–	–	E19	E6.3
	06-16-09	–	–	–	–	–	E53	<250
P1-6	06-08-99	<400	74	16,000	170	5,400	–	–
	06-14-01	<20	370	16,000	220	9,900	–	–
	06-13-02	<20	<20	3,700	170	5,100	–	–
	06-20-03	<50	470	1,100	E39	1,300	–	–
	06-18-04	<20	<20	220	E11	570	7.0	210
	06-22-05	<130	<130	4,200	E90	2,900	E30	590
	06-13-06	<100	<100	300	E77	770	82	1,300
	06-20-07	<8.0	<8.0	84	E5.4	140	7.0	180
	06-18-08	<200	<200	8,800	E130	9,700	57	720
	06-16-09	<100	180	3,900	E93	2,600	E40	450
P1-7	06-08-99	<670	26,000	35,000	210	3,100	–	–
	06-22-00	3.6	27,000	44,000	220	3,800	–	68
	06-14-01	<20	26,000	37,000	190	4,000	–	–
	06-14-02	<20	37,000	62,000	400	5,700	–	–
	06-20-03	<2,000	28,000	35,000	<2000	2,800	–	–
	06-18-04	<3,300	37,000	61,000	<3300	5,100	E36	520
	06-22-05	<2,000	28,000	59,000	E330	5,000	E45	480
	06-13-06	<2,000	24,000	43,000	<2000	3,800	E44	400
	06-20-07	<2,000	33,000	44,000	E320	4,000	E47	460
	06-18-08	<2,000	38,000	65,000	E370	14,000	88	850
	06-16-09	<2,000	40,000	92,000	3,900	10,000	140	1,100

Table 3. Concentrations of selected volatile organic compounds in groundwater samples from monitoring wells and piezometers collected by the U.S. Geological Survey at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 1999–2009. —Continued

[All data except those shaded were published previously in Dinicola and others (2002), Dinicola (2003, 2004, 2006), Dinicola and Huffman (2004, 2006, 2007, 2009). Laboratory data qualifier codes, such as "D" for dilution, are not shown. **Well or piezometer No:** MW, monitoring well; P, piezometer. **Volatile organic compounds (VOCs)**; PCE, tetrachloroethene; TCE, trichloroethene; *cis*-DCE, *cis*-1,2-dichloroethene; *trans*-DCE, *trans*-1,2-dichloroethene; VC, vinyl chloride; 1,1,1-TCA, 1,1,1-trichloroethane; 1,1-DCA, 1,1-dichloroethane; CA, chloroethane; 1,1-DCE, 1,1-dichloroethene; total BTEX, sum of benzene, toluene, ethylbenzene, and xylene; total CVOCs, sum of chlorinated volatile organic compounds. **Abbreviations:** E, estimated value; M, presence verified but not quantified; µg/L, microgram per liter; <, actual value is less than value shown; ND, not detected; –, not analyzed]

Well or piezometer No.	Date sampled	1,1,1-TCA (µg/L)	1,1-DCA (µg/L)	CA (µg/L)	1,1-DCE (µg/L)	Total BTEX (µg/L)	Total CVOCs (µg/L)
			Southern plantation				
MW1-4	06-22-00	–	–	–	–	–	–
	06-18-04	<1,000	<1,000	<2,000	<1,000	ND	49,000
	06-13-06	–	–	–	–	–	–
	06-20-07	–	–	–	–	–	–
	06-18-08	–	–	–	–	–	–
	06-16-09	–	–	–	–	–	–
MW1-5	06-22-00	–	–	–	–	–	–
	06-18-04	<1.0	E0.36	3.0	<1.0	E0.92	E1.6
	06-13-06	–	–	–	–	–	–
	06-20-07	–	–	–	–	–	–
	06-18-08	–	–	–	–	–	–
	06-16-09	–	–	–	–	–	–
MW1-16	06-22-00	–	–	–	–	–	–
	06-22-04	<10	590	290	<10	367	890
	06-13-06	–	–	–	–	–	–
	06-20-07	–	–	–	–	–	–
	06-18-08	–	–	–	–	–	–
	06-16-09	–	–	–	–	–	–
P1-6	06-08-99	<400	1,500	300	<400	E87	23,000
	06-14-01	<20	4,800	600	12	88	32,000
	06-13-02	<20	4,300	1,400	<20	63	15,000
	06-20-03	<50	380	270	<50	ND	3,600
	06-18-04	<20	200	88	<20	ND	1,100
	06-22-05	<130	370	400	<130	ND	8,000
	06-13-06	<100	1,200	2,600	<100	E68	5,000
	06-20-07	<8.0	69	78	<8.0	E1.4	380
	06-18-08	<200	400	1,200	<200	E46	20,000
	06-16-09	<100	130	310	<100	ND	7,200
P1-7	06-08-99	<670	<670	<1,300	<670	ND	64,000
	06-22-00	.24	17	8.4	72		75,000
	06-14-01	<20	<20	<20	44	ND	67,000
	06-14-02	<20	14	<20	64	ND	105,000
	06-20-03	<2,000	<2,000	<4,000	<2,000	ND	66,000
	06-18-04	<3,300	<3,300	<6,700	<3,300	ND	103,000
	06-22-05	<2,000	<2,000	<4,000	<2,000	ND	92,000
	06-13-06	<2,000	<2,000	<4,000	<2,000	ND	71,000
	06-20-07	<2,000	<2,000	<4,000	<2,000	ND	81,000
	06-18-08	<2,000	<2,000	<4,000	<2,000	ND	117,000
	06-16-09	<2,000	<2,000	<4,000	<2,000	ND	146,000

Table 3. Concentrations of selected volatile organic compounds in groundwater samples from monitoring wells and piezometers collected by the U.S. Geological Survey at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 1999–2009.—Continued

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Well or piezometer No.	Date sampled	PCE (µg/L)	TCE (µg/L)	*cis*-DCE (µg/L)	*trans*-DCE (µg/L)	VC (µg/L)	Ethane (µg/L)	Ethene (µg/L)
Southern plantation—Continued								
P1-8	06-07-99	<710	190	25,000	210	3,400	–	–
	06-14-01	<20	810	8,600	62	4,200	–	–
	06-13-02	<20	<20	24,000	190	7,700	–	–
	06-20-03	<10	230	31	<10	E7.0	–	–
	06-18-04	<1.0	E.26	2.7	<1.0	23	<50	E4.2
	06-23-05	<1.0	<1.0	7.0	<1.0	21	<50	<50
	06-13-06	<20	<20	620	E4.0	58	<50	E9.5
	06-20-07	<4.0	E2.4	29	<4.0	41	<100	E13
	06-18-08	<10	<10	160	<10	280	E6.0	E16
	06-15-09	<5.0	<5.0	97	<5.0	120	<250	<250
P1-9	06-08-99	<2,000	48,000	88,000	470	7,200	–	–
	06-22-00	E5.0	88,000	64,000	320	5,800	–	37
	06-14-01	<40	29,000	7,300	32	450	–	–
	06-13-02	<20	90,000	79,000	590	7,900	–	–
	06-20-03	<1,000	60,000	27,000	<1,000	1,800	–	–
	06-18-04	<1,300	50,000	23,000	<1,300	2,100	16	200
	06-23-05	<20	230	700	E3.2	97	<5.0	E4.0
	06-13-06	<5,000	74,000	140,000	E850	10,000	66	1,200
	06-20-07	<1,000	55,000	40,000	E200	4,200	32	340
	06-18-08	<400	9700	13,000	E80	2,000	12	160
	06-16-09	<2,500	62,000	100,000	E1,100	8,700	100	1,300
P1-10	06-07-99	<1,000	14,000	34,000	270	2,500	–	–
	06-22-00	1.0	8,700	13,000	100	2,300	–	2.3
	06-13-01	<20	6,600	12,000	68	1,800	–	–
	06-12-02	<20	4,600	7,000	55	2,000	–	–
	06-19-03	<400	2,300	9,400	<400	1,100	–	–
	06-18-04	<200	1,600	3,900	<200	890	E12	E46
	06-23-05	<100	1,100	3,000	E29	700	E3.0	7.0
	06-13-06	<1,000	2,200	27,000	E160	2,500	E19	E53
	06-20-07	<500	1,500	14,000	E130	1,700	E24	E34
	06-18-08	<200	490	5,800	E60	1,100	E20	E23
	06-15-09	<20	250	1,000	34	140	E11	E18

Table 3. Concentrations of selected volatile organic compounds in groundwater samples from monitoring wells and piezometers collected by the U.S. Geological Survey at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 1999–2009.—Continued

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Well or piezometer No.	Date sampled	1,1,1-TCA (µg/L)	1,1-DCA (µg/L)	CA (µg/L)	1,1-DCE (µg/L)	Total BTEX (µg/L)	Total CVOCs (µg/L)
Southern plantation—Continued							
P1-8	06-07-99	<710	<710	<1,400	<710	ND	29,000
	06-14-01	<20	<20	<20	<20	ND	14,000
	06-13-02	<20	<20	<20	16	ND	32,000
	06-20-03	<10	E4	<20	<10	ND	270
	06-18-04	<1.0	<1.0	<2.0	<1.0	ND	26
	06-23-05	<1.0	<1.0	<2.0	<1.0	ND	28
	06-13-06	<20	<20	<40	<20	ND	680
	06-20-07	<4.0	<4.0	<8.0	<4.0	ND	72
	06-18-08	<10	<10	<20	<10	ND	440
	06-15-09	<5.0	<5.0	<10	<5.0	ND	220
P1-9	06-08-99	<2,000	<2,000	<4,000	<2,000	ND	144,000
	06-22-00	<10	E2.6	<20	47	22	158,000
	06-14-01	<40	<40	<40	<40	ND	37,000
	06-13-02	<20	<20	<20	54	11	178,000
	06-20-03	<1,000	<1,000	<2,000	<1,000	ND	89,000
	06-18-04	<1,300	<1,300	<2,700	<1,300	ND	75,000
	06-23-05	<20	<20	<40	<20	ND	1,000
	06-13-06	<5,000	<5,000	<10,000	<5,000	ND	225,000
	06-20-07	<1,000	<1,000	<2,000	<1,000	ND	99,000
	06-18-08	<400	<400	<800	<400	ND	25,000
	06-16-09	<2,500	<2,500	<5,000	<2,500	ND	172,000
P1-10	06-07-99	<1,000	<1,000	<2,000	<1,000	ND	51,000
	06-22-00	<.10	1.2	E.10	16	8.6	24,000
	06-13-01	<20	<20	<20	11	ND	20,000
	06-12-02	<20	<20	<20	<20	ND	14,000
	06-19-03	<400	<400	<800	<400	ND	13,000
	06-18-04	<200	<200	<400	<200	ND	6,400
	06-23-05	<100	<100	<200	<100	ND	4,800
	06-13-06	<1,000	<1,000	<2,000	<1,000	ND	32,000
	06-20-07	<500	<500	<1,000	<500	ND	17,000
	06-18-08	<200	<200	<400	<200	ND	7,400
	06-15-09	<20	<20	<40	<20	ND	1,400

Table 3. Concentrations of selected volatile organic compounds in groundwater samples from monitoring wells and piezometers collected by the U.S. Geological Survey at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 1999–2009. —Continued

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Well or piezometer No.	Date sampled	PCE (µg/L)	TCE (µg/L)	*cis*-DCE (µg/L)	*trans*-DCE (µg/L)	VC (µg/L)	Ethane (µg/L)	Ethene (µg/L)
				Intermediate aquifer				
MW1-25	06-22-00	–	–	–	–	–	–	5.8
	06-14-02	<20	276	1,830	31	278	–	–
	06-19-03	<67	E14	1,800	E34	210	–	–
	06-16-04	–	–	–	–	–	E5.0	E15
	06-21-05	<67	<67	1,700	E30	220	E6.0	E13
	06-14-06	–	–	–	–	–	E7.0	E14
	06-18-07	–	–	–	–	–	E4.0	E8.1
	06-17-08	<50	<50	1,700	E28	510	E9.0	E15
	06-17-09	<40	E7.3	1,600	49	240	E11	E19
MW1-28	06-22-00	–	–	–	–	–	–	2.6
	06-14-02	<20	69	1,600	72	700	–	–
	06-19-03	<50	<50	1,200	68	470	–	–
	06-16-04	–	–	–	–	–	E4.0	26
	06-21-05	<67	<67	1,500	84	650	E4.0	E22
	06-14-06	–	–	–	–	–	<50	E18
	06-18-07	–	–	–	–	–	E3.0	E15
	06-17-08	<50	<50	1,400	64	930	E6.0	28
	06-17-09	<40	<40	1,400	84	730	E6.0	E35
MW1-38	06-20-00	–	–	–	–	–	–	0.57
	06-12-02	<0.20	<0.20	<0.20	<0.20	<0.20	–	–
	06-16-04	–	–	–	–	–	<5.0	<5.0
	06-24-05	<1.0	<1.0	<1.0	<1.0	<1.0	<5.0	<5.0
	06-14-06	–	–	–	–	–	<5.0	<5.0
	06-21-07	–	–	–	–	–	<5.0	<5.0
	06-17-08	–	–	–	–	–	M	<5.0
	06-17-09	–	–	–	–	–	<25	<25
MW1-39	06-07-99	<1.0	<1.0	0.30	<0.50	1.0	–	–
	06-20-00	–	–	–	–	–	–	0.26
	06-12-01	–	–	–	–	–	–	–
	06-12-02	–	–	–	–	–	–	–
	06-19-03	<1.0	<1.0	E.60	<1.0	1.0	–	–
	06-16-04	–	–	–	–	–	<5.0	<5.0
	06-14-06	–	–	–	–	–	<50	<50
	06-21-07	–	–	–	–	–	<25	<25
	06-17-08	<1.0	<1.0	E.53	<1.0	3.0	<20	<20
	06-17-09	<1.0	<1.0	E.42	<1.0	2.1	<50	<50

Table 3. Concentrations of selected volatile organic compounds in groundwater samples from monitoring wells and piezometers collected by the U.S. Geological Survey at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 1999–2009. —Continued

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Well or piezometer No.	Date sampled	1,1,1-TCA (µg/L)	1,1-DCA (µg/L)	CA (µg/L)	1,1-DCE (µg/L)	Total BTEX (µg/L)	Total CVOCs (µg/L)
Intermediate aquifer							
MW1-25	06-22-00	–	–	–	–	–	–
	06-14-02	<20	<20	<20	<20	ND	2,400
	06-19-03	<67	<67	<130	<67	ND	2,100
	06-16-04	–	–	–	–	–	–
	06-21-05	<67	<67	<130	<67	ND	1,900
	06-14-06	–	–	–	–	–	–
	06-18-07	–	–	–	–	–	–
	06-17-08	<50	<50	<100	<50	ND	2,200
	06-17-09	<40	<40	<80	<40	ND	1,900
MW1-28	06-22-00	–	–	–	–	–	–
	06-14-02	<20	<20	<20	<20	ND	2,400
	06-19-03	<50	<50	<100	<50	ND	1,700
	06-16-04	–	–	–	–	–	–
	06-21-05	<67	<67	<130	<67	ND	2,200
	06-14-06	–	–	–	–	–	–
	06-18-07	–	–	–	–	–	–
	06-17-08	<50	<50	<100	<50	ND	2,400
	06-17-09	<40	<40	<80	<40	ND	2,900
MW1-38	06-20-00	–	–	–	–	–	–
	06-12-02	<0.20	<0.20	<0.20	<0.20	ND	ND
	06-16-04	–	–	–	–	–	–
	06-24-05	<1.0	<1.0	<2.0	<1.0	ND	ND
	06-14-06	–	–	–	–	–	–
	06-21-07	–	–	–	–	–	–
	06-17-08	–	–	–	–	–	–
	06-17-09	–	–	–	–	–	–
MW1-39	06-07-99	<1.0	<1.0	<2.0	<1.0	ND	1.0
	06-20-00	–	–	–	–	–	–
	06-12-01	–	–	–	–	–	–
	06-12-02	–	–	–	–	–	–
	06-19-03	<1.0	<1.0	<2.0	<1.0	ND	1.6
	06-16-04	–	–	–	–	–	–
	06-14-06	–	–	–	–	–	–
	06-21-07	–	–	–	–	–	–
	06-17-08	<1.0	<1.0	<2.0	<1.0	ND	3.5
	06-17-09	<1.0	<1.0	<2.0	<1.0	ND	E.42

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