

Comparison of Diffusion- and Pumped-Sampling Methods to Monitor Volatile Organic Compounds in Ground Water, Massachusetts Military Reservation, Cape Cod, Massachusetts, July 1999–December 2002

By Stacey A. Archfield and Denis R. LeBlanc

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CONVERSION FACTORS, HORIZONTAL AND VERTICAL DATUMS, WATER-QUALITY INFORMATION, AND ABBREVIATIONS

Multiply	By	To obtain
foot (ft)	0.3048	meter (m)
foot per day (ft/d)	0.3048	meter per day (m/d)
gallon (gal)	3,785	milliliter (mL)
gallon per minute (gal/min)	3.785	liter per minute (L/min)
inch (in.)	2.54	centimeter (cm)
inch per year (in/yr)	0.00696	centimeter per day (cm/d)
mile (mi)	1.609	kilometer (km)
mils (mil)	0.00254	centimeter (cm)

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

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

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83). Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29). Altitude, as used in this report, refers to distance above or below NGVD 29.

Chemical concentration is given in units of milligrams per liter (mg/L) or micrograms per liter ($\mu\text{g/L}$). Milligrams and micrograms per liter are units expressing the mass of the solute per unit volume (liter) of water. One thousand micrograms per liter is equivalent to 1 milligram per liter. Micrograms per liter is approximately equivalent to "parts per billion," and milligrams per liter is approximately equivalent to "parts per million." Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius ($\mu\text{S/cm}$ at 25°C).

AFCEE	Air Force Center for Environmental Excellence
<i>cis</i> 1,2-DCE	<i>cis</i> 1,2-dichloroethene
EDB	1,2-dibromoethane
IRP	Installation Restoration Program
MMR	Massachusetts Military Reservation
MTBE	methyl <i>tertiary</i> butyl ether
PVC	polyvinyl chloride
RPD	relative percent difference
PCE	tetrachloroethene
TCE	trichloroethene
USGS	U.S. Geological Survey
USEPA	U.S. Environmental Protection Agency
VOA	volatile organic analysis
VOC	volatile organic compound

Comparison of Diffusion- and Pumped-Sampling Methods to Monitor Volatile Organic Compounds in Ground Water, Massachusetts Military Reservation, Cape Cod, Massachusetts, July 1999–December 2002

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Abstract

To evaluate diffusion sampling as an alternative method to monitor volatile organic compound (VOC) concentrations in ground water, concentrations in samples collected by traditional pumped-sampling methods were compared to concentrations in samples collected by diffusion-sampling methods for 89 monitoring wells at or near the Massachusetts Military Reservation, Cape Cod. Samples were analyzed for 36 VOCs. There was no substantial difference between the utility of diffusion and pumped samples to detect the presence or absence of a VOC. In wells where VOCs were detected, diffusion-sample concentrations of tetrachloroethene (PCE) and trichloroethene (TCE) were significantly lower than pumped-sample concentrations. Because PCE and TCE concentrations detected in the wells dominated the calculation of many of the total VOC concentrations, when VOC concentrations were summed and compared by sampling method, visual inspection also showed a downward concentration bias in the diffusion-sample concentration.

The degree to which pumped- and diffusion-sample concentrations agreed was not a result of variability inherent within the sampling methods or the diffusion process itself. A comparison of the degree of agreement in the results from the two methods to 13 quantifiable characteristics external to the sampling methods offered only well-screen length as being related to the degree of agreement between the methods; however, there is also evidence to indicate that the flushing rate of water through the well screen affected the agreement between the sampling methods. Despite poor agreement between the concentrations obtained by the two methods at some wells, the degree to which the concentrations agree at a given well is repeatable. A one-time, well-by-well comparison between diffusion- and pumped-sampling methods could determine which wells are good candidates for the use of diffusion samplers. For wells with good method

agreement, the diffusion-sampling method is a time-saving and cost-effective alternative to pumped-sampling methods in a long-term monitoring program, such as at the Massachusetts Military Reservation.

Introduction

The Installation Restoration Program (IRP) at the Massachusetts Military Reservation (MMR) on Cape Cod maintains an extensive, long-term program to monitor concentrations of volatile organic compounds (VOCs) in ground water (Air Force Center for Environmental Excellence, 2004). The traditional sampling methods utilized require trained personnel, expensive equipment, and substantial time in the field. Before a sample is obtained from a monitoring well, water is purged from the well until stability of the chemical and physical properties of the well water is reached. Before the pump is moved from one well to another, the pump and equipment are cleaned to prevent cross-contamination. Simpler and less costly methods to monitor VOC concentrations would greatly reduce the resources needed to carry out the long-term (tens of years) monitoring program at the MMR.

Diffusion bag sampling, or simply diffusion sampling, has been demonstrated to be a viable alternative to pumped sampling to monitor concentrations of VOCs in wells (Vroblesky and Hyde, 1997). Vroblesky (2001) provides a description of diffusion samplers and guidance on their use. Field personnel require minimal instruction to construct, deploy, and retrieve diffusion samplers. In addition, the use of diffusion samplers eliminates the need to purge water from the well, dispose of this purge water, and decontaminate the sampling pump. Huffman (2002) provides an extensive literature review of studies involving the theory and application of diffusion samplers to a variety of laboratory and field environments.

Diffusion samplers are constructed from low-density polyethylene tubing that is filled with deionized water and sealed at both ends. The sampler is attached to a rope or wire and lowered into the well to the screened interval. The sampler is held in place by securing the rope or wire to the top of the well. Initially, a concentration gradient may be present between the uncontaminated water in the diffusion sampler and the surrounding water in the well. This concentration gradient causes VOCs to diffuse through the polyethylene tubing—which is permeable to VOCs—into the water inside the sampler. If there is a free and continuous exchange of water across the well screen, the chemistry of the water surrounding the diffusion sampler reflects that of the ground water outside of the well. The diffusion process continues until equilibrium is reached between the VOC concentrations inside the sampler and in the surrounding water. After the sampler has been deployed long enough for this equilibrium to be reached (usually from days to weeks), the sampler is retrieved. Although equilibration times for individual VOCs in a laboratory setting are known to depend on the chemical structure of the VOCs and the water temperature, Vroblesky (2001) suggests that the samplers be deployed for at least 2 weeks to ensure that VOCs in the sampler have equilibrated with all VOCs in the surrounding water.

There are limitations to the utility of diffusion sampling as a method to measure VOCs. Differences between the results from pumped samples and diffusion samples can be caused by factors that affect the diffusion process, by mixing induced by pumping the well, or by ambient vertical mixing in long-screened wells (usually longer than 5 ft). From laboratory testing, Vroblesky (2001) also notes that diffusion sampling is not a reliable method to measure concentrations of methyl *tertiary* butyl ether (MTBE) and acetone. Vroblesky (2001) provides a comprehensive list of factors that could cause concentrations in the diffusion and pumped samples to differ. Because of these limitations, a one time, well-by-well comparison of the methods could be used to determine the applicability of the diffusion-sampling method to monitor VOC concentrations in a long-term monitoring program.

The applicability of the diffusion-sampling method has been tested at various locations throughout the United States (Church, 2000; Vroblesky and Peters, 2000; Vroblesky and Petkewich, 2000; Vroblesky and others, 2000; Vroblesky and others, 2001; Huffman, 2002; Vroblesky and Pravecek, 2002). These tests have been limited by the number of wells used to compare methods. The results of most studies have indicated that diffusion samplers are a viable alternative to traditional pumped-sampling methods; however, the data sets used in most of these studies were small (fewer than 20 wells), and the wells had long screens.

Purpose and Scope

This report evaluates the applicability of diffusion sampling for monitoring VOC concentrations in ground water collected from monitoring wells on the MMR. The applicability of the diffusion-sampling method is measured by the utility of the method to detect concentrations of VOCs similar to those obtained by the pumped-sampling method. VOC concentrations in samples collected by the diffusion- and pumped-sampling methods are compared with each other; and in cases where the concentrations did not match, bias in the diffusion-sampling method is assessed. Comparisons are made between well, diffusion-sampler, aquifer, and geochemical characteristics, and the degree of agreement of the sampling methods. These comparisons add to the current understanding of diffusion samplers by examining how the samplers work in wells with short screens (2–5 ft long). This study was done cooperatively by the U.S. Geological Survey (USGS) and the Air Force Center for Environmental Excellence (AFCEE). Ground-water samples from 89 monitoring wells were collected from July 1999 through December 2002.

Description of Study Area

The MMR is on a glacial-outwash plain known as the Mashpee Pitted Plain on western Cape Cod, Massachusetts (Oldale and Barlow, 1986). The outwash-plain sediments consist of medium- to coarse-grained glaciofluvial sand and gravel underlain by deposits of fine-to-medium glaciolacustrine sand and silt. The underlying bedrock consists primarily of granodiorite (Oldale and Barlow, 1986) and is considered relatively impermeable (compared to the sediments above) to ground-water flow.

Ground water on western Cape Cod flows radially outward from a water-table high on the MMR and discharges to streams, ponds, and coastal embayments (fig. 1). Estimated ground-water-flow velocities in the sand and gravel range from 0.8 to 2.3 ft/d (LeBlanc, 1984). Recharge from precipitation is the only source of freshwater and is estimated to be about 27 in/yr (Walter and Whealan, 2005). Ground water is the source of drinking water for communities on the western part of Cape Cod.

Sixteen plumes that contain VOCs on the MMR are monitored regularly to assess how VOC concentrations are changing with time and to delineate the extent of the plumes. The Air Force Center for Environmental Excellence (2004) provides further detail regarding the location and characteristics of these plumes.

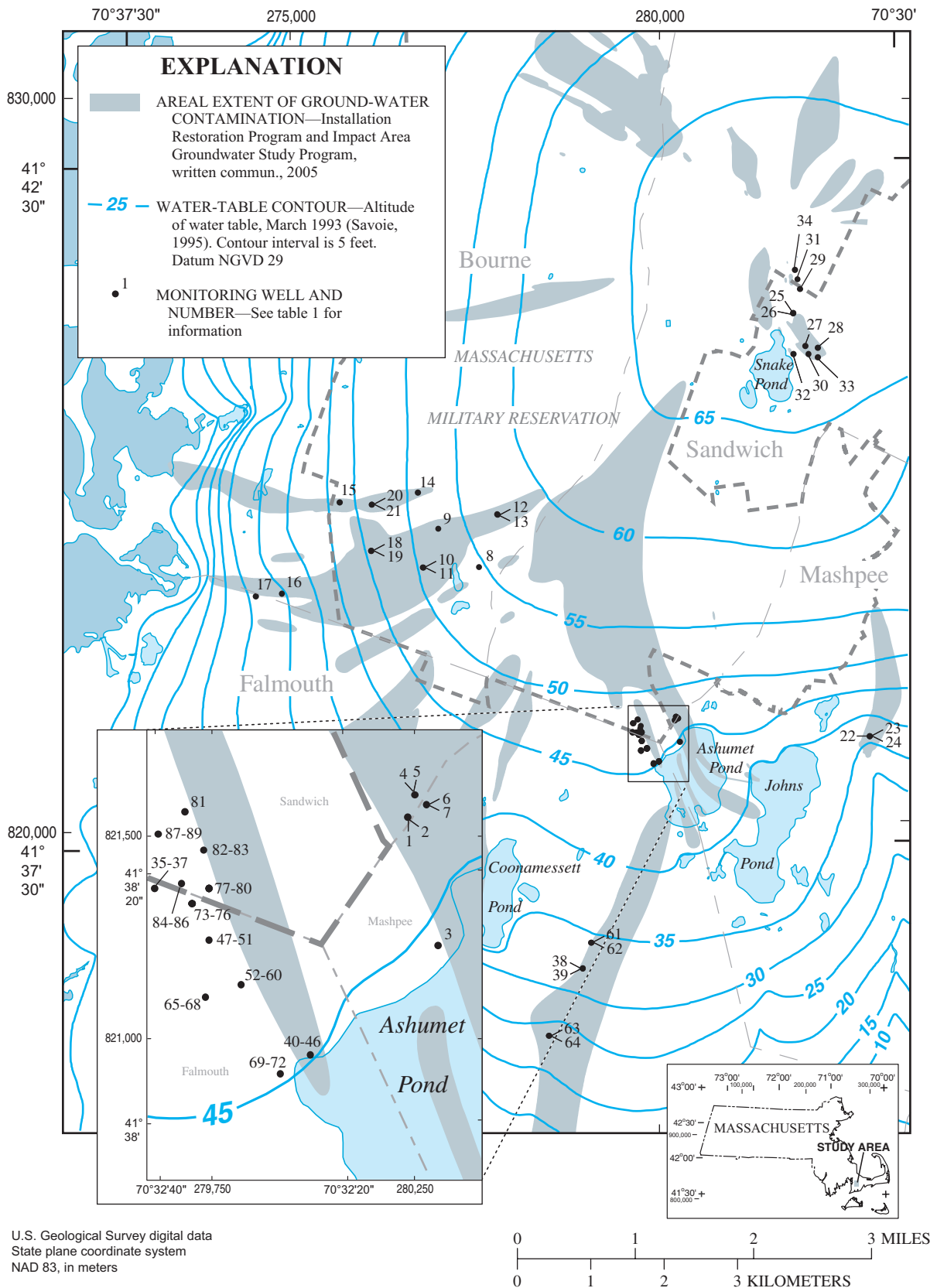


Figure 1. Location of study area and monitoring well sites where ground-water samples were collected by diffusion- and pumped-sampling methods, Massachusetts Military Reservation, Cape Cod, Massachusetts, July 1999–December 2002.

Study Design

Paired diffusion and pumped samples were collected from 89 wells (fig. 1 and table 1) within or near contaminant plumes on or near the MMR. These samples were analyzed for concentrations of VOCs.

Well Selection

Of the 89 total wells, 34 wells were selected because these wells are part of a long-term (tens of years), water-quality-monitoring program at the MMR. AFCEE regularly collects and analyzes pumped samples from wells to monitor VOC concentrations. The diffusion sampling was conducted in conjunction with the regularly scheduled pump sampling, which minimized the effort required to collect the paired results. Wells were also selected on the basis of past detections of VOCs in samples from the wells. This selection was intended to minimize the number of samples with VOC concentrations below the analytical detection limit. During 1999 and 2000, USGS personnel constructed and installed diffusion samplers in these wells (table 1) at least 2 weeks before the wells were scheduled to be sampled by AFCEE.

In 2002, the opportunity arose to collect paired diffusion and pumped samples from an additional 55 wells. Whereas the previously sampled wells have predominately 5-ft screened intervals, the wells in this data set have shorter screened intervals (typically 2 ft) (table 1). Most wells in this data set are arranged in clusters. Well clusters are groups of wells (from four to eight) installed close to one another at various screened depths to provide a vertical profile of concentrations at a particular mapped location. To maintain efficiency and obtain information about the vertical distribution of VOCs, 16 well clusters were selected on the basis of previous VOC detections in at least one well within the cluster, and samplers were installed in all of the wells in the selected cluster regardless of the likelihood of detecting VOC concentrations. For this set of wells, USGS personnel constructed, installed, and retrieved the diffusion samplers and collected the pumped samples.

Monitoring-Well Construction and Installation

The monitoring wells used for this study are constructed of polyvinyl chloride (PVC) plastic casing. The casings generally are 2- or 2.5-in. nominal diameter, flush-joint and threaded, schedule 40 or 80 pipe. The well screens are slotted PVC casing with 0.010-in. (10 slot) openings. The screens are made by various manufacturers and are from 1 to 10 ft long (table 1). No sand pack around the screen is used and the natural sediments are allowed to collapse around the screen.

Three drilling techniques were used to install the wells. Most wells were installed by hollow-stem augering. Some wells were installed by sonic vibratory driving or air-rotary

methods. These methods use only water or air in the drilling process; drilling muds are not used. The wells were developed after installation by submersible or airlift pumping to clear the screens of accumulated fine-grained sediments, and thus, to reduce the turbidity of the pumped water.

Data Collection

For each well included in the study, paired diffusion and pumped samples were collected and analyzed for VOCs. Replicate diffusion and pumped samples were also collected from a limited number of wells. Selected wells were resampled from 2 months to 3 years later by both methods to test the repeatability of the agreement between the diffusion- and pumped-sample concentrations over time. In one well, differences in VOC concentrations in the presumably stagnant water column above the well screen were investigated.

Diffusion and pumped samples were collected from each well. The pumped sample was collected immediately after the diffusion sampler was retrieved, and the paired samples were held and transported to the laboratory together. The USGS constructed and installed the diffusion samplers according to the protocols outlined by Vroblesky (2001). USGS and AFCEE personnel shared the task of retrieving the diffusion samplers and collecting the pumped samples. To ensure uniform collection and handling of the diffusion samplers, AFCEE personnel were trained by USGS personnel to retrieve the diffusion samplers according to the protocols established by Vroblesky (2001).

Diffusion-Sampling Method

To construct the samplers, a 1.5-in.-diameter, 4-mil-thick polyethylene tube was filled with deionized water and sealed at both ends. All samplers were constructed to be 1 ft long between the sealed ends. The length of the diffusion sampler was determined by the amount of sample water needed to fill two 40-mL glass volatile organic analysis (VOA) sample vials. Sample water could be lost during transfer to the vials, so a small amount of additional water was included in the sampler to account for this loss. The diffusion sampler was then placed in a 1.5-in.-diameter polyethylene open-mesh tube to protect the sampler from damage during installation and retrieval and to facilitate attachment of the sampler to the twine used to hang the sampler in the well.

The well depths were measured prior to diffusion-sampler installation to confirm that the current depth agreed with the depth recorded at the time of the well's installation. Validating the well-construction records before sampler installation also provided a means to ensure that the sampler would be hung at the correct depth. On the basis of the records, calculations were made to determine the length of twine needed to hang each diffusion sampler at the midpoint of the well screen.

Table 1. Well construction and sample information for wells with samples collected by diffusion- and pumped-sampling methods, Massachusetts Military Reservation, Cape Cod, Massachusetts, July 1999–December 2002.

[Well ID: See figure 1 for location. ft, foot; ft bls, feet below land surface; ID, identifier; altitudes are above NGVD 29]

Well ID	Well number	Altitude of land surface (ft)	Altitude at the top of the well casing (ft)	Depth to top of screened interval (ft bls)	Depth to bottom of screened interval (ft bls)	Screen length (ft)	Date of diffusion-sampler installation	Date of diffusion-sampler retrieval and collection of pumped sample	At least one volatile organic compound detected
1	03MW0054A	58.9	61.3	130	135	5	7-21-1999	8-12-1999	Yes
2	03MW0054B	58.8	61.3	59	64	5	7-21-1999	8-12-1999	Yes
3	03MW0064	70.8	70.6	231	236	5	7-28-1999	8-16-1999	Yes
4	03MW0214B	58.0	60.5	121	126	5	7-28-1999	8-12-1999	Yes
5	03MW0214F	58.0	60.5	204	209	5	7-28-1999	8-12-1999	Yes
							9-20-2002	11-12-2002	Yes
6	03MW2413A	60.8	60.4	220	225	5	7-28-1999	8-16-1999	Yes
							9-20-2002	11-12-2002	Yes
7	03MW2413B	61.6	61.4	170	175	5	9-20-2002	11-12-2002	Yes
8	27MW0023A	111.2	112.1	119	124	5	7-21-1999	8-04-1999	Yes
							3-20-2000	4-06-2000	Yes
9	27MW0024A	146.7	149.3	188	193	5	7-21-1999	8-09-1999	Yes
10	27MW0026A	106.0	108.3	138	148	10	7-21-1999	8-05-1999	Yes
11	27MW0026B	107.9	110.6	205	210	5	7-21-1999	8-05-1999	Yes
							3-20-2000	4-10-2000	Yes
12	27MW0031A	130.6	132.9	194	199	5	7-21-1999	8-06-1999	Yes
							3-20-2000	4-07-2000	Yes
13	27MW0031B	130.0	131.7	147	152	5	7-21-1999	8-09-1999	Yes
							3-20-2000	4-07-2000	Yes
14	27MW0033	167.5	170.0	177	182	5	7-21-1999	8-05-1999	Yes
15	27MW0037A	179.8	181.9	213	218	5	7-21-1999	8-11-1999	Yes
							3-20-2000	4-04-2000	Yes
16	27MW0038A	72.2	74.7	135	140	5	7-21-1999	8-11-1999	Yes
17	27MW0046	96.4	99.2	144	149	5	7-28-1999	10-11-1999	Yes
18	27MW0102A	236.8	239.3	300	305	5	7-28-1999	8-11-1999	Yes
							3-20-2000	4-05-2000	Yes
19	27MW0102B	236.8	239.3	210	215	5	7-28-1999	8-11-1999	No
20	27MW0108A	188.6	188.2	222	227	5	7-21-1999	8-05-1999	Yes
							3-20-2000	4-05-2000	Yes
21	27MW0108B	189.7	189.3	172	177	5	7-21-1999	8-05-1999	Yes
22	36MW0132A	54.3	54.0	185	190	5	4-11-2000	4-18-2000	Yes
23	36MW0132B	54.3	54.0	135	140	5	4-11-2000	4-18-2000	Yes
24	36MW0132C	54.6	54.0	79	84	5	4-11-2000	4-18-2000	Yes
25	90MW0003	157.4	160.4	144	149	5	8-31-1999	9-14-1999	Yes
26	90MW0005	157.7	160.7	184	189	5	8-31-1999	9-14-1999	Yes
27	90MW0025	152.4	151.9	160	165	5	8-31-1999	9-14-1999	Yes
28	90MW0028	145.5	145.0	177	182	5	8-31-1999	9-14-1999	Yes
29	90MW0034	131.1	133.7	94	99	5	8-31-1999	9-14-1999	No
30	90MW0040	141.2	140.9	188	193	5	8-31-1999	9-14-1999	Yes
31	90MW0041	159.6	161.6	125	130	5	9-01-1999	9-15-1999	No
32	90MW0050	83.0	82.6	86	91	5	8-31-1999	9-15-1999	Yes
33	90MW0053	143.5	143.2	189	194	5	8-31-1999	9-14-1999	Yes

6 Comparison of Diffusion- and Pumped-Sampling Methods to Monitor VOCs in Ground Water, MMR, Cape Cod, MA

Table 1. Well construction and sample information for wells with samples collected by diffusion- and pumped-sampling methods, Massachusetts Military Reservation, Cape Cod, Massachusetts, July 1999–December 2002.—Continued

[Well ID: See figure 1 for location. ft, foot; ft bls, feet below land surface; ID, identifier; altitudes are above NGVD 29]

Well ID	Well number	Altitude of land surface (ft)	Altitude at the top of the well casing (ft)	Depth to top of screened interval (ft bls)	Depth to bottom of screened interval (ft bls)	Screen length (ft)	Date of diffusion-sampler installation	Date of diffusion-sampler retrieval and collection of pumped sample	At least one volatile organic compound detected
34	90WT0013	163.1	166.2	92	102	10	8-31-1999	9-15-1999	Yes
35	FSW 230-0058	85.9	87.4	56	58	2	7-23-2002	8-13-2002	Yes
36	FSW 230-0068	86.3	87.8	66	68	2	7-23-2002	8-13-2002	Yes
37	FSW 230-0078	86.5	88.0	76	78	2	7-23-2002	8-13-2002	Yes
38	FSW 271-0099	35.9	37.4	97	99	2	9-20-2002	10-16-2002	Yes
							11-15-2002	12-09-2002	Yes
39	FSW 271-0114	35.9	36.9	112	114	2	9-20-2002	10-16-2002	Yes
							11-15-2002	12-09-2002	Yes
40	FSW 300-0010	47.2	48.2	8	10	2	7-10-2002	8-01-2002	Yes
41	FSW 300-0030	47.1	48.6	28	30	2	7-10-2002	8-01-2002	Yes
42	FSW 300-0050	47.2	48.6	48	50	2	7-10-2002	8-01-2002	No
43	FSW 300-0073	47.1	47.9	71	73	2	7-10-2002	8-01-2002	No
44	FSW 300-0099	46.9	47.8	97	99	2	7-10-2002	8-01-2002	No
45	FSW 300-0118	46.9	48.4	116	118	2	7-10-2002	8-01-2002	No
46	FSW 300-0138	47.1	48.6	136	138	2	7-10-2002	8-01-2002	No
47	FSW 343-0036	68.9	69.2	34	36	2	7-16-2002	8-07-2002	Yes
48	FSW 343-0057	68.9	69.4	55	57	2	7-16-2002	8-07-2002	Yes
49	FSW 343-0079	68.8	69.8	77	79	2	7-16-2002	8-07-2002	No
50	FSW 343-0099	68.8	69.8	97	99	2	7-16-2002	8-07-2002	No
51	FSW 343-0114	69.2	70.7	112	114	2	7-16-2002	8-07-2002	No
52	FSW 347-0020	59.7	60.7	18	20	2	7-16-2002	8-08-2002	No
53	FSW 347-0031	59.7	61.2	29	31	2	7-16-2002	8-08-2002	Yes
54	FSW 347-0038	59.5	61.0	36	38	2	7-16-2002	8-08-2002	Yes
55	FSW 347-0046	59.8	60.6	44	46	2	7-16-2002	8-08-2002	Yes
56	FSW 347-0067	60.0	60.4	65	67	2	7-16-2002	8-08-2002	No
57	FSW 347-0101	59.7	61.0	99	101	2	7-16-2002	8-08-2002	No
58	FSW 347-0116	60.0	61.5	114	116	2	7-16-2002	8-08-2002	No
59	FSW 347-0131	60.3	61.3	129	131	2	7-16-2002	8-08-2002	No
60	FSW 347-0145	60.0	61.6	143	145	2	7-16-2002	8-08-2002	No
61	FSW 350-0064	37.8	38.8	63	64	1	9-20-2002	10-11-2002	Yes
							11-15-2002	12-09-2002	Yes
62	FSW 350-0110	37.8	38.8	109	110	1	9-20-2002	10-11-2002	Yes
							11-15-2002	12-09-2002	Yes
63	FSW 375-0055	29.2	30.2	53	55	2	9-20-2002	10-24-2002	Yes
							11-15-2002	12-09-2002	Yes
64	FSW 375-0071	29.5	30.5	69	71	2	9-20-2002	10-24-2002	Yes
							11-15-2002	12-09-2002	Yes
65	FSW 383-0040	64.6	66.1	38	40	2	7-23-2002	8-22-2002	Yes
66	FSW 383-0061	64.4	65.9	59	61	2	7-23-2002	8-22-2002	Yes
67	FSW 383-0082	64.3	65.8	80	82	2	7-23-2002	8-22-2002	No
68	FSW 383-0106	64.9	66.4	104	106	2	7-23-2002	8-22-2002	No
69	FSW 424-0020	58.0	58.4	15	20	5	7-10-2002	8-06-2002	No

Table 1. Well construction and sample information for wells with samples collected by diffusion- and pumped-sampling methods, Massachusetts Military Reservation, Cape Cod, Massachusetts, July 1999–December 2002.—Continued

[Well ID: See figure 1 for location. ft, foot; ft bls, feet below land surface; ID, identifier; altitudes are above NGVD 29]

Well ID	Well number	Altitude of land surface (ft)	Altitude at the top of the well casing (ft)	Depth to top of screened interval (ft bls)	Depth to bottom of screened interval (ft bls)	Screen length (ft)	Date of diffusion-sampler installation	Date of diffusion-sampler retrieval and collection of pumped sample	At least one volatile organic compound detected
70	FSW 424-0089	55.7	55.1	84	89	5	7-10-2002	8-06-2002	No
71	FSW 424-0144	56.0	55.6	139	144	5	7-10-2002	8-06-2002	No
72	FSW 424-0183	56.3	55.7	178	183	5	7-10-2002	8-06-2002	No
73	FSW 577-0061	94.7	96.6	59	61	2	7-23-2002	8-14-2002	Yes
74	FSW 577-0071	94.3	96.5	69	71	2	7-23-2002	8-14-2002	Yes
75	FSW 577-0081	94.6	96.5	79	81	2	7-23-2002	8-14-2002	Yes
76	FSW 577-0097	95.2	96.2	95	97	2	7-23-2002	8-14-2002	No
77	SDW 316-0051	95.5	96.5	49	51	2	7-23-2002	8-20-2002	No
78	SDW 316-0066	95.5	96.5	64	66	2	7-23-2002	8-20-2002	Yes
79	SDW 316-0082	95.4	96.4	80	82	2	7-23-2002	8-20-2002	Yes
80	SDW 316-0100	95.4	96.4	98	100	2	7-23-2002	8-20-2002	No
81	SDW 423-0058	87.3	90.5	53	58	5	7-23-2002	8-21-2002	Yes
82	SDW 438-0041	79.1	82.1	31	41	10	7-24-2002	8-13-2002	Yes
83	SDW 440-0078	79.6	81.0	76	78	2	7-24-2002	8-13-2002	No
84	SDW 469-0036	69.0	70.5	34	36	2	7-16-2002	8-06-2002	No
85	SDW 469-0051	69.0	70.5	49	51	2	7-16-2002	8-06-2002	Yes
86	SDW 469-0066	69.0	70.6	64	66	2	7-16-2002	8-06-2002	No
87	SDW 500-0060	79.4	80.9	58	60	2	7-23-2002	8-21-2002	No
88	SDW 500-0070	79.7	81.2	68	70	2	7-23-2002	8-21-2002	No
89	SDW 500-0080	79.5	81.0	78	80	2	7-23-2002	8-21-2002	No

The calculations also were made to determine the height of the free space available below the well screen to accommodate a stainless-steel weight that was typically attached to the bottom of the diffusion sampler. At the time of installation, the sampler was attached to a stainless-steel weight 7 in. long and 1 in. in diameter with braided polypropylene twine. If there was not enough room below the midpoint of the screen to accommodate the stainless-steel weight and the lower half of the diffusion sampler, the weight was installed above the sampler. The weight was installed above the diffusion sampler in three wells: FSW 271-0099, FSW 350-0064, and FSW 350-0110 (fig. 1 and table 1). In all other wells, the weight was installed below the sampler.

Braided polypropylene twine was attached to the diffusion sampler, and the sampler was lowered into the well. As the diffusion sampler was lowered, the twine was measured to the pre-calculated length so that the center of the diffusion sampler hung at the midpoint of the well screen. The twine was then attached to the top of the well and the sampler hung securely in the well at the desired depth.

As recommended by Vroblesky (2001), the diffusion samplers were given a minimum of 2 weeks to reach equilibrium and then retrieved from the well by pulling up the twine. The protective mesh was pulled back and the top of the diffusion sampler was cut open. The contents of the diffusion sampler were poured into two VOA sample vials without air bubbles, capped, and kept cold and dark until analysis.

Pumped-Sampling Method

Pumped samples from 34 wells were collected by AFCEE according to the U.S. Environmental Protection Agency's (USEPA) low-flow sampling protocol (U.S. Environmental Protection Agency, 1996). A Grundfos Redi-Flow 2 submersible pump was set inside the well with the intake positioned in the well screen, and the water in the well was purged. Dissolved oxygen, pH, specific conductance, and turbidity were measured every 5 minutes until the quantities stabilized. The typical purge volume for a 5-ft well screen was 20 gal, and typical pumping rates for sample collection were

8 Comparison of Diffusion- and Pumped-Sampling Methods to Monitor VOCs in Ground Water, MMR, Cape Cod, MA

between 0.1 and 2 L/min [Drew Tingley, Jacobs Engineering (now at CH2M Hill), written commun., 2003]. Samples were collected in two VOA sample vials without air bubbles, capped, chilled, and kept cold and dark until analysis.

The USGS collected the pumped samples from 55 wells by placing a Keck submersible pump 2 ft above the well screen and then inflating an isolation packer in the casing. The volume of water between the packer and the bottom of the well was calculated, and three times that volume of water was purged from the well at a rate of about 1 L/min (Savoie and LeBlanc, 1998). Dissolved oxygen, pH, specific conductance, and turbidity were measured and then two VOA sample vials were filled without air bubbles, capped, chilled and kept dark until analysis.

To verify that the results for the two sets of samples collected by the two pumping methods were similar, both methods were used to sample six wells. Initially, AFCEE retrieved the diffusion samplers and collected the pumped samples after the USGS had installed the diffusion samplers 2 weeks earlier. Approximately 2 weeks after AFCEE sampled these wells, the USGS again installed diffusion samplers in the six wells and waited another 2 weeks for equilibration between the water in the diffusion sampler and the well. Then, the USGS retrieved the diffusion samplers and collected the pumped samples.

Collection of Additional Samples

Replicate samples were collected from seven wells with 5-ft screens: replicate diffusion samples from three wells, replicate pumped samples from three wells, and both replicate diffusion and pumped samples from one well. Replicate diffusion samples were collected by installing two samplers in the well screen, one directly above the other. The water from the upper sampler composed the primary sample, and the water from the lower sampler composed the replicate. To collect pumped-sample replicates, the replicate sample was collected immediately after the primary sample. In addition, quality-assurance samples were collected throughout the duration of the study and analyzed for VOCs: 4 equipment-blank samples, 23 trip-blank samples, and 1 water-blank sample of the deionized water that was used to fill the diffusion samplers.

Fifteen wells were resampled by both methods (appendix). At resampled wells, a diffusion sampler was installed and retrieved, the well was sampled by using pumped-sampling methods, and then some time later, this sampling sequence was repeated. Resampling was done to determine if the agreement between the methods changed with time; two wells were resampled 3 years after the first sampling, seven wells after 8 months, and six wells after about 2 months (table 1).

In well 03MW0214B, where there is a long water column (109 ft) above the well screen, a series of four diffusion

samplers was hung in and above the screen to compare the in-screen VOC concentrations to the VOC concentrations in the presumably stagnant column of water above the screen. Diffusion samplers were installed in the well at the midpoint of the screen (2.5 ft below the top of the screen) and 2, 5.3, and 15 ft above the top of the screen. A pumped sample also was collected immediately after the diffusion samplers were retrieved. The VOC concentrations in the diffusion sample that was collected at the midpoint of the screen were compared to those in the pumped sample, and this data pair was included as part of the larger data set for this study.

Laboratory Analysis

The samples were kept cold and dark until delivery to the MMR's on-site laboratory operated by Severn Trent Laboratories. Samples were analyzed for 36 VOCs within the established holding times for the analytes according to USEPA protocols: USEPA Method 8620B for VOC concentrations, and USEPA Method 504 for 1,2-dibromoethane (EDB) concentrations (U.S. Environmental Protection Agency, 1988, 1995).

Data Analysis

The paired pumped- and diffusion-sample concentrations were compared to assess the utility of diffusion sampling as a method to measure VOC concentrations in ground water at the MMR. Detections of acetone or MTBE were not included in the analysis because laboratory results have shown that diffusion samplers are not a reliable method to measure these VOCs (Vroblesky, 2001).

Assessments were made to determine how VOC concentrations in the diffusion samples matched concentrations in the pumped samples and if the diffusion-sampling method is an unbiased method to measure VOC concentrations. These comparisons assessed the utility of diffusion sampling to detect the presence or absence of a VOC, the utility of diffusion sampling to measure individual VOC concentrations, and the utility of diffusion sampling to measure total VOC concentrations in water from a well. When total VOC concentrations were used in the analysis, data below the analytical detection limit were assigned a value of zero, and then individual VOC concentrations were totaled by sampling method for each well.

Analyses were done by using the relative percent difference (RPD) between the VOC concentrations obtained by the two sampling methods to (1) compare the RPD between results from replicate samples obtained by each sampling method, (2) compare the results from repeated sampling of wells using both sampling methods, and (3) determine if the RPD was related to characteristics external to the sampling methods. RPD (in percent) is calculated by the equation

$$\text{RPD} = 100 \times \frac{|C_p - C_d|}{\frac{1}{2}(C_p + C_d)},$$

where

C_p is the concentration of total VOCs in the pumped sample,
and
 C_d is the concentration of total VOCs in the diffusion sample.

The RPD is a sensitive measure of concentration differences at concentrations less than 10 µg/L because the RPD normalizes concentration differences relative to the mean concentration. For this reason, RPD was not used in the initial assessments of the utility of the diffusion-sampling method to represent VOC concentrations in samples collected by the pumped-sampling method, but rather as a tool to determine if there were patterns in how the diffusion- and pumped-sample concentrations compared.

The number of samples collected was large enough that when the pumped- and diffusion-sample concentrations did not agree, statistical methods could be used to assess if the concentration differences between the methods were random and not due to bias in the diffusion-sampling method. The methods used include the sign test and signed-rank test (Helsel and Hirsch, 1992).

A sign test was applied to make this determination for individual- and total-VOC concentrations. For each data pair, the sign (positive or negative) of the difference in concentrations between the pumped and diffusion samples was calculated. Then, the number of positive signs (the pumped-sample concentration greater than the diffusion-sample concentration) was counted and compared to the total number of negative signs (the diffusion-sample concentration greater than the pumped-sample concentration) (Helsel and Hirsch, 1992).

The purpose of the sign test was to assess whether concentration differences between results from both sampling methods, where these differences were present, were unbiased. For this reason, the sign test compares only the instances where the concentrations in the pumped and diffusion samples do not agree (Helsel and Hirsch, 1992). Therefore, if the difference between the pumped- and diffusion-sample concentrations was zero, or if both methods resulted in concentrations below the analytical detection limit, the data pair was ignored. The sign test allows for inclusion of data below the analytical detection limit for one or the other method in the analysis because the test accounts for only the qualitative difference (positive or negative) between concentrations obtained by both methods and not the numerical differences in concentrations (Helsel and Hirsch, 1992). The sign test returns a p-value, which is used to determine whether

the differences in concentration between results from the two sampling methods are unbiased. P-values were computed with a Web-based application from the University of Amsterdam (2003).

The critical p-value for determining bias in this study is 0.05. A p-value less than 0.05 means that there is less than a 5-percent chance that this result would occur if the concentration differences between the diffusion-sampling method and pumped-sampling method were random and not due to bias (Helsel and Hirsch, 1992).

To compare the agreement between methods with screen length, a signed-rank test was used. The signed-rank test is not based on any assumption about the underlying distribution of either data set (Helsel and Hirsch, 1992); and for this study, it was used to determine if there was better agreement between methods for short-screened wells than for long-screened wells. Like the sign test, the signed-rank test compares the differences in VOC concentration between the pumped- and diffusion-sample concentrations; however, unlike the sign test, the signed-rank test also accounts for the magnitude of the differences between the sampling methods (Helsel and Hirsch, 1992). If the differences in VOC concentrations between the pumped- and diffusion-sampling methods were smaller for the short-screened wells than the differences for the long-screened wells, this difference could help to explain the degree of agreement between VOC concentrations measured by the diffusion- and pumped-sampling methods. The critical p-value used to determine significance in this study is 0.05. A p-value less than 0.05 means there is less than a 5-percent chance that the results from this comparison are due to chance, and screen length did affect the agreement between the concentrations measured by the two methods (Helsel and Hirsch, 1992).

Comparison of Diffusion- and Pumped-Sampling Methods

Initial inspection of the data collected during the study indicated that concentrations in samples obtained by the two methods were in good agreement for some wells but not for others (fig. 2). Furthermore, concentrations obtained by the two methods agreed more closely for some VOCs than for others. The degree of agreement between the methods was compared by VOC and well to determine the applicability of the diffusion-sampling method to the MMR; and in cases where the concentrations obtained by the methods did not agree, to determine why this result was the case.

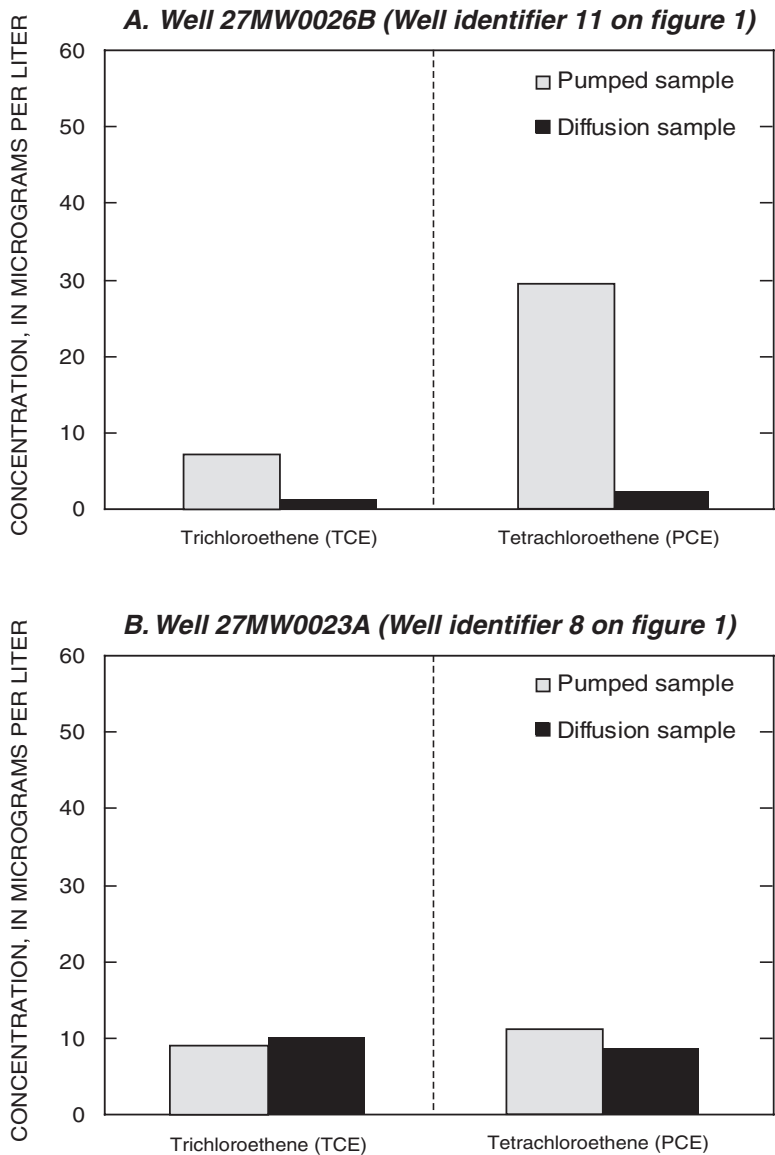


Figure 2. Typical results of pumped- and diffusion-sample concentrations for volatile organic compounds from two wells: A, 27MW0026B; and B, 27MW0023A, at the Massachusetts Military Reservation, Cape Cod, Massachusetts, July 1999–December 2002.

Comparison of Methods by Volatile Organic Compound

Of the 89 wells sampled, 20 of the 36 VOCs were detected in at least 1 well (table 2). There appeared to be no substantial difference in the utility of either sampling method to detect a given VOC (table 2). For the most part, if a VOC was not detected in the pumped sample, it was also not detected in the diffusion sample. Alternatively, if a VOC was detected in the pumped sample, it was also detected for the

most part in the diffusion sample. For the few cases where a VOC was detected by one method but not the other, the detected concentrations were usually just above the analytical detection limit.

The most commonly detected VOC was tetrachloroethene (PCE); PCE was detected in 38 wells (table 2). Trichloroethene (TCE), chloroform, *cis*1,2-dichloroethene (*cis*1,2-DCE), and EDB were detected in 25, 25, 16, and 7 wells, respectively (table 2). Detailed analytical results are presented in the appendix. The concentrations for the five most commonly detected VOCs are compared in figure 3A. Sixty-nine percent of the data points that had at least one of the two samples above the analytical detection limit are below the line of equal concentrations. For these paired concentrations, the pumped-sample concentrations are greater than the diffusion-sample concentrations. Data points for chloroform are clustered near the line of equal concentrations; the data points for PCE and TCE deviate the most from the line of equal concentrations. In other words, chloroform concentrations from the diffusion and pumped samples tended to agree well, whereas concentrations of PCE and TCE in the pumped and diffusion samples did not agree as well. Concentrations of the remaining VOCs detected in fewer than six wells are compared in figure 3B. As in figure 3A, a majority of the points that had at least one sample above the analytical detection limit are below the line of equal concentrations; 66 percent of the pumped-sample concentrations were greater than the diffusion-sample concentrations. The number of wells whose samples yielded no detection of an individual VOC by either sampling method is listed in table 2.

The five most frequently detected VOCs—PCE, TCE, chloroform, *cis*1,2-DCE, and EDB—had enough paired sample concentrations above the analytical detection limits or non-zero differences between the paired concentrations to apply the sign test. PCE and TCE were the only VOCs tested whose difference between the number of positive and negative signs was significant (p-values of 0.003 and 0.043, respectively), and showed downward bias in the utility of the diffusion sample in collecting a sample whose concentrations match those of the pumped sample (table 3). The tendency of PCE to have lower concentrations in diffusion samples than pumped samples has been reported in other studies (Vroblesky and Peters, 2000; Vroblesky and others, 2000), although statistical tests were not used in these studies.

Table 2. Volatile organic compounds and detections of compounds in samples collected by diffusion- and pumped-sampling methods from 89 wells at or near the Massachusetts Military Reservation, Cape Cod, Massachusetts, July 1999–December 2002.

[VOC, volatile organic compound]

VOC	Number of wells with VOC not detected in pumped or diffusion sample	Number of wells with VOC detected in pumped and diffusion sample	Number of wells with VOC detected in pumped sample but not in diffusion sample	Number of wells with VOC detected in diffusion sample but not in pumped sample
Benzene	83	3	2	1
Bromochloromethane	89	0	0	0
Bromodichloromethane	89	0	0	0
Bromoform	89	0	0	0
Bromomethane	89	0	0	0
Carbon tetrachloride	86	2	1	0
Chlorobenzene	89	0	0	0
Chloroethane	89	0	0	0
Chloroform	64	23	0	2
Chloromethane	88	0	1	0
Dibromochloromethane	89	0	0	0
1,2-Dibromochloropropane	89	0	0	0
1,2-Dibromoethane (EDB)	82	6	0	1
1,2-Dichlorobenzene	87	2	0	0
1,3-Dichlorobenzene	89	0	0	0
1,4-Dichlorobenzene	85	3	1	0
1,1-Dichloroethane	84	3	0	2
1,2-Dichloroethane	89	0	0	0
1,1-Dichloroethene	86	2	0	1
<i>cis</i> 1,2-Dichloroethene	73	11	4	1
<i>trans</i> 1,2-Dichloroethene	87	1	1	0
1,2-Dichloropropane	89	0	0	0
<i>cis</i> 1,3-Dichloropropene	89	0	0	0
<i>trans</i> 1,3-Dichloropropene	89	0	0	0
Ethylbenzene	88	1	0	0
Methylene chloride	89	0	0	0
Styrene	89	0	0	0
1,1,2,2-Tetrachloroethane	87	2	0	0
Tetrachloroethene (PCE)	50	35	4	0
1,2,4-Trichlorobenzene	89	0	0	0
1,1,1-Trichloroethane	86	2	1	0
1,1,2-Trichloroethane	88	0	0	1
Trichloroethene (TCE)	64	22	2	1
Toluene	88	1	0	0
Vinyl chloride	86	2	0	1
Total xylenes	88	1	0	0

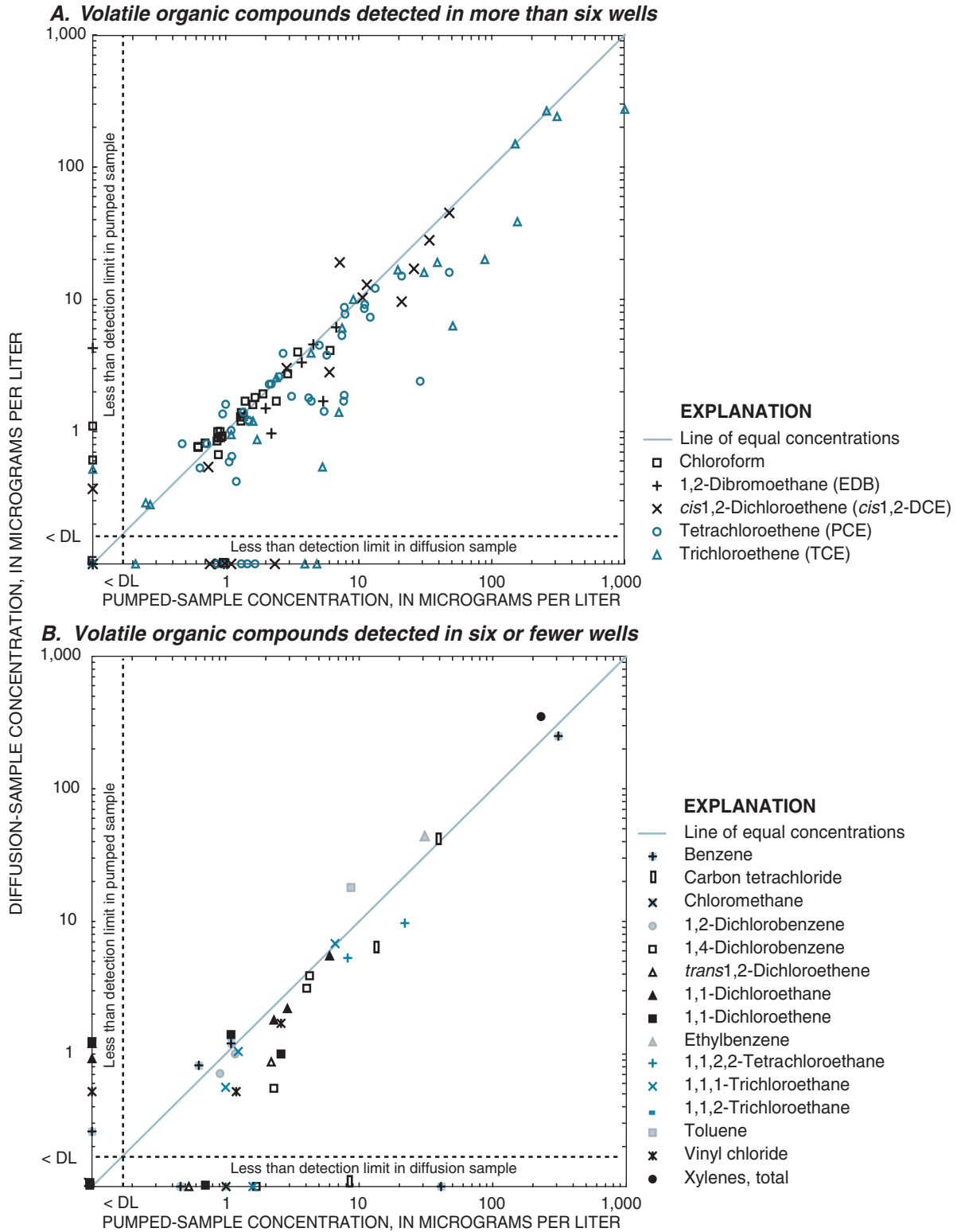


Figure 3. Comparison of pumped- and diffusion-sample concentrations for volatile organic compounds detected in ground water from *A*, more than six wells; and *B*, six or fewer wells at or near the Massachusetts Military Reservation, Cape Cod, Massachusetts, July 1999–December 2002 (< DL, less than detection limit).

Table 3. Results of sign tests applied to determine if total volatile organic compound concentrations in samples collected by the diffusion-sampling method were biased relative to concentrations in samples collected by the pumped-sampling method for wells at or near the Massachusetts Military Reservation, Cape Cod, Massachusetts, July 1999–December 2002.

[S+: Number of cases for which the pumped-sample concentration was greater than the diffusion-sample concentration. S-: Number of cases for which the pumped-sample concentration was less than the diffusion-sample concentration]

Volatile organic compound	S+	S-	p-value
Chloroform	10	15	0.424
1,2-Dibromoethane (EDB)	6	1	.125
<i>cis</i> 1,2-Dichloroethene	12	4	.077
Tetrachloroethene (PCE)	29	10	.003
Trichloroethene (TCE)	18	7	.043

Comparison of Methods by Well

For the next set of comparisons, the individual VOC concentrations were summed to obtain total VOCs for each sampling method by well. Like the comparisons of individual VOCs (fig. 3), most pumped-sample concentrations were greater than the corresponding diffusion-sample concentrations (fig. 4). Whereas totaling VOCs resulted in a majority of the samples having concentrations above the detection limit for both the diffusion- and pumped-sampling methods, in samples from 32 wells, all individual VOC concentrations were below the analytical detection limit, and thus, their sum was equal to zero.

To determine if the differences in total VOC concentrations between the pumped- and diffusion-sampling methods were unbiased, a sign test was applied. The differences in total VOC concentrations were positive for 41 wells and negative for 15 wells; concentrations were below the analytical detection limit or their difference was zero for 33 wells. The p-value of 0.001 from this test indicates that total VOC diffusion-sample concentrations were significantly lower than the total VOC pumped-sample concentrations. The downward concentration bias is not surprising because the concentrations of two of the most commonly detected VOCs—PCE and TCE—were some of the highest concentrations among the VOCs tested, and the degree of agreement between PCE and TCE concentrations for the two methods were among the worst for all of the VOCs (fig. 3).

Comparison of Additional Samples

Additional samples were collected for quality assurance and to characterize the agreement between the methods further. Replicate samples were collected to determine if the degree of agreement between the methods was within the variability of the sampling methods. Repeated sampling was done to determine if the agreement between the methods was consistent and to determine if the use of different pumping protocols to collect the pumped sample affected the agreement between the methods. Other samples were collected to determine how VOC concentrations in diffusion samplers in the presumably stagnant water above the well screen compared to VOC concentrations in the diffusion sampler in the screened interval.

Quality-Assurance Samples

Of the 28 blank samples collected, none had VOC concentrations above the analytical detection limit. Therefore, VOCs at concentrations above the analytical detection limit were not introduced or augmented in the pumped and diffusion samples by the sampling methods or equipment contamination. The quality-assurance data are provided in the appendix.

Replicate Samples

Replicate samples were collected from seven wells: replicate pumped samples from three wells, replicate diffusion samples from three wells, and both types of replicate samples from one well. For the 7 wells with replicate samples, 8 of the 36 VOCs were detected in the set of original and replicate samples, and the replicate concentrations agreed well with those in the original samples (appendix). The average RPD was 7.7 percent between diffusion replicates and 4.6 percent between pumped replicates.

The RPD between the total VOC concentrations in original and replicate samples was compared to the RPD between the total VOC concentrations in pumped and diffusion samples to determine if variability between the replicate samples could explain the concentration differences between samples collected by the diffusion- and pumped-sampling methods. The RPD difference between concentrations obtained by the two sampling methods ranged from 27 to 75 percent, whereas the RPD between concentrations in the replicate pumped samples ranged from 2.1 to 7.3 percent, and the RPD between concentrations in the replicate diffusion samples ranged from 1.6 to 5.5 percent. The close agreement between replicates eliminated variability within each sampling method as an explanation for the observed differences between concentrations obtained by the pumped- and diffusion-sampling methods.

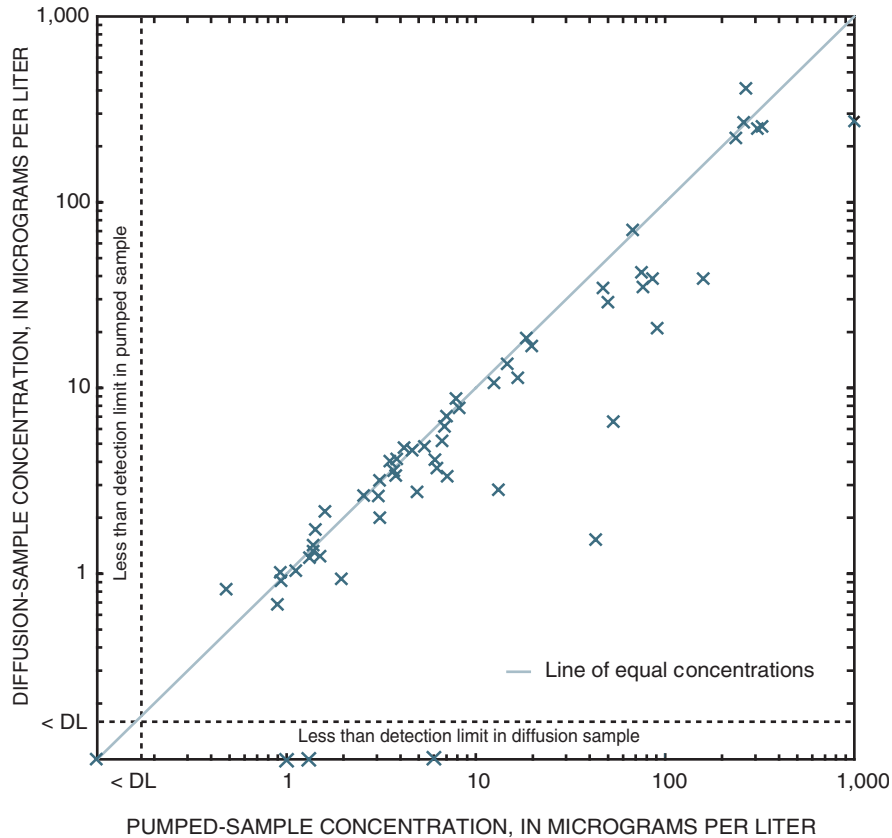


Figure 4. Comparison of total volatile organic compound concentrations for samples collected by pumped- and diffusion-sampling methods in wells at or near the Massachusetts Military Reservation, Cape Cod, Massachusetts, July 1999–December 2002 (<math>< DL</math>, less than detection limit).

Repeated Sampling

Fifteen wells were sampled again by using both sampling methods after the first set of diffusion and pumped samples was collected: two wells were resampled 3 years later, seven wells 8 months later, and six wells about 2 months later (table 1). The total VOC concentrations for the pumped and diffusion samples from each trial were calculated by adding the concentrations of the detected VOCs for each sample for each sampling method (appendix). For each well, this resulted in two pairs of data: total VOC concentrations for the pumped and diffusion samples from the first and second trials. The RPD for each pair of data also was calculated. This calculation reduced the comparison to one pair of data per well: the RPD between the pumped- and diffusion-sample concentrations for the first trial and the RPD between the pumped- and diffusion-sample concentrations for the second trial (fig. 5A).

For a given well, the qualitative agreement between the diffusion-sample concentration and the pumped-sample concentration did not change from the first pair of samples to the second pair of samples (fig. 5A). For example, if the agreement was good between the methods for the first pair of samples from a given well, it was also good for the second pair of samples from the same well. The best example of this finding is well 03MW0214F (fig. 5A), which was re-sampled 2 years after the first set of samples was collected. Concentrations of VOCs in ground water had substantially decreased (appendix); however, the RPD between the pumped- and diffusion-sample concentrations changed by less than 10 percent (fig. 5A).

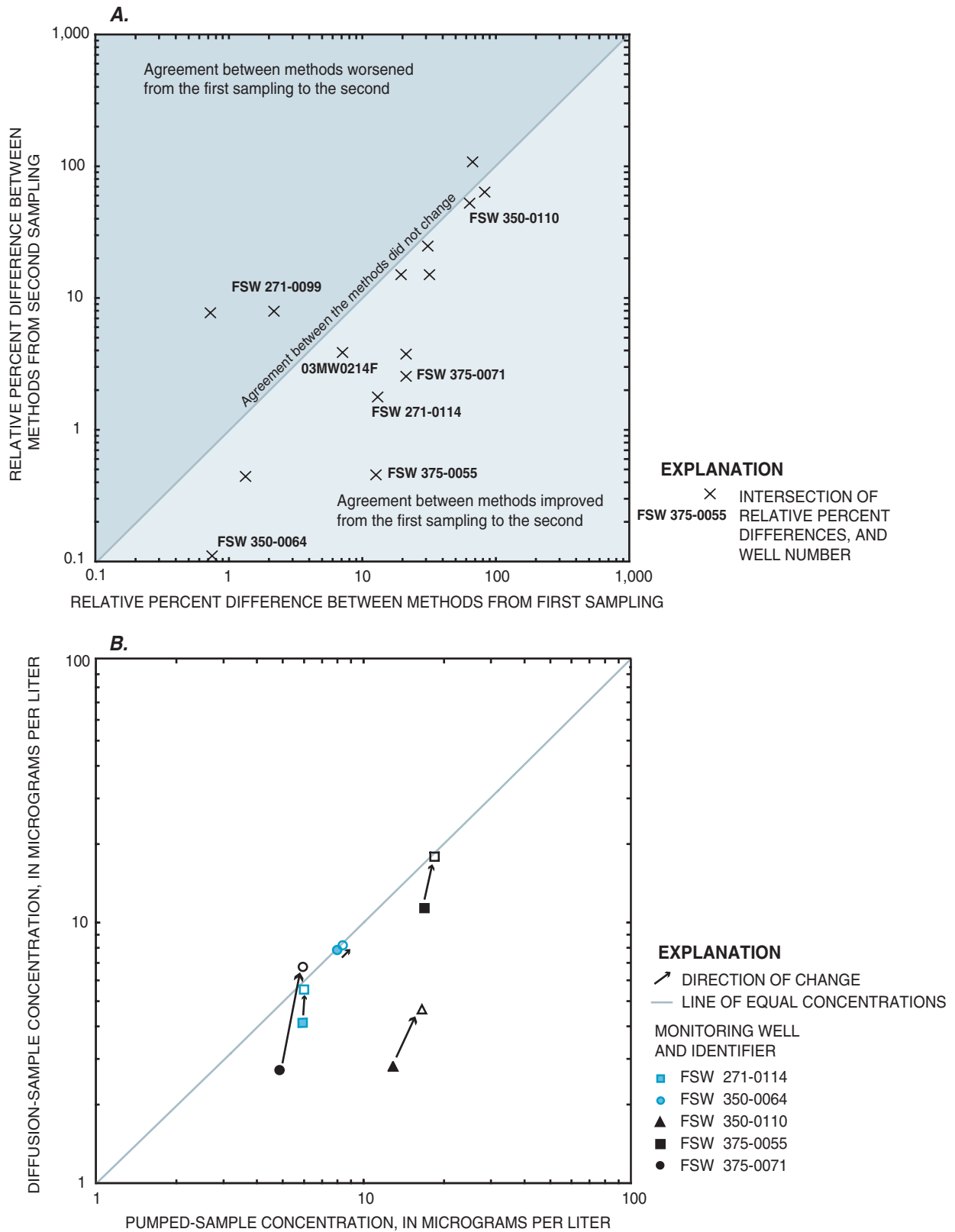


Figure 5. Comparison of *A*, relative percent difference between first and second sampling; and *B*, pumped- and diffusion-sample concentrations from repeated sampling of selected wells at or near the Massachusetts Military Reservation, Cape Cod, July 1999–December 2002.

Comparison of Wells Sampled with Two Pumping Methods

Because two sampling protocols were used to collect the pumped samples, six wells were sampled by both methods to address concerns that the use of different protocols affected the pumped-sample concentration. The RPD between the pumped-sample and diffusion-sample concentrations decreased from the first trial to the second trial for all sampled wells except one, FSW 271-0099 (fig. 5A). Moreover, the difference between RPDs for three wells—FSW 271-0114, FSW 375-0071, and FSW 375-0055—decreased by more than 20 percentage points from the first trial to the second trial (fig. 5A).

The better agreement between the VOC concentrations in the diffusion and pumped samples obtained by using the second pumping protocol may be a function of the sampling order and not the methods used. The average difference in the concentrations of the pumped samples was 1.3 µg/L, whereas the differences in diffusion-sample concentrations were almost twice that value. Furthermore, the data indicate that for the five wells for which the RPD decreased on the second trial, the diffusion-sample concentrations increased in all cases, whereas the pumped-sample concentrations remained relatively constant (fig. 5B). This constant concentration in the pumped sample is evidenced by the near-vertical direction of the arrows in figure 5B. Therefore, the increases in diffusion-sampler concentrations, not changes in the pumped-sample concentrations, caused the lower RPDs for the second trial (fig. 5B).

These wells had been purged 1 month earlier when the first set of samples was collected. The purging could have removed sediment or biological materials clogging the screen,

thereby increasing the movement of ground water through the well screen. Alternatively, the recent sampling could have purged stagnant water within the well and ensured that the water that interacted with the diffusion sampler during the second trial was representative of ground water outside the well. It is important to note that, although the RPD decreased after purging, the general degree of agreement remained the same; the degree of agreement between concentrations obtained by the two methods was good except for well FSW 350-0110, which showed a poor degree of agreement for both samplings (fig. 5B).

Samples Collected above the Well Screen

A vertical series of diffusion samplers was installed above the screen of one well with a long (greater than 100 ft) water column (03MW0214B) so that VOC concentrations from the diffusion sampler installed in the screened interval could be compared with VOC concentrations in the presumably stagnant water column above the well screen (table 4). Three VOCs were detected in every sample: PCE, TCE, and *cis*1,2-DCE. None of the VOC concentrations detected in the diffusion sampler set in the screen matched the respective pumped-sample concentrations (table 4). However, the concentrations in the sample from the diffusion sampler set in the screen matched the concentrations in the diffusion samplers installed in the blank casing above the screened interval (table 4). This result indicates that the VOC concentrations in the screen were similar to the VOC concentrations in the presumably stagnant water above the screen instead of being similar to the concentrations of VOCs in the ground water adjacent to the screen.

Table 4. Analysis of volatile organic compounds for samples collected from well 03MW0214B, Massachusetts Military Reservation, Cape Cod, Massachusetts, July 1999.

[Samples were collected from four diffusion samplers installed in the well. One sample was collected by the pumped-sampling method. Water level at the time of sample collection was 12.51 ft below land surface and depth to top of screen is 121.4 ft below land surface. ft, foot; µg/L, micrograms per liter; --, no sample collected at this depth]

Height above top of well screen (ft)	Tetrachloroethene (PCE)		Trichloroethene (TCE)		<i>cis</i> 1,2-Dichloroethene (<i>cis</i> 1,2-DCE)	
	Pumped sample (µg/L)	Diffusion sample (µg/L)	Pumped sample (µg/L)	Diffusion sample (µg/L)	Pumped sample (µg/L)	Diffusion sample (µg/L)
15	--	1.49	--	239	--	2.84
5.3	--	1.38	--	244	--	2.66
2	--	1.45	--	259	--	2.93
In screen	5.49	1.42	1,000	274	6.02	2.82

Comparison of Sampling Methods to Characteristics External to the Methods

When the diffusion- and pumped-sampling methods were compared by well, the degree of agreement between the diffusion- and pumped-sample concentrations was good for some wells and poor for others. Furthermore, re-sampling of selected wells showed that the qualitative degree of agreement between the pumped- and diffusion-sample concentrations did not change. These results indicate that the utility of diffusion samplers in collecting samples with concentrations similar to those in pumped samples may be related to characteristics external to the sampling methods.

Thirteen characteristics were tabulated for each well. These characteristics and the reasons why these characteristics may be related to the agreement between the methods

are listed in table 5. Scatter plots (not shown) were used to compare the RPDs between the pumped- and diffusion-sample concentrations for each well and these characteristics; however, none of the characteristics listed in table 5 revealed a relation with RPDs except for screen length.

A further comparison of screen length was warranted because previous studies did not include wells with screened intervals as short as 2 ft. Only four wells in this study did not have 2-ft or 5-ft screens, so there were enough wells in the data set to warrant the use of a signed-rank test. In previous studies, substantial vertical variations in VOC concentrations were measured in samples from multiple diffusion samplers installed along the entire interval of a long well screen (Church, 2000; Vroblesky and others, 2000; Vroblesky and Peters, 2000). A pumped sample might integrate these variations, whereas a diffusion sampler might measure the

Table 5. List of quantitative characteristics explored to determine if a relation was present between the characteristic and the degree of agreement of the diffusion- and pumped-sample concentrations and the reasons why each characteristic might affect the agreement between the methods for this study at the Massachusetts Military Reservation, Cape Cod, Massachusetts.

Characteristic	Possible reasons characteristic may affect the agreement between the methods
Year well installed	Older well screens may clog over time, inhibiting ground-water flow through the well screen.
Diameter of well	Convergence of flow toward the open borehole is directly related to borehole diameter, and therefore, could affect the rate of exchange of water through the well screen ¹ .
Submergence of sampler below top of water column	The length of the water column above sampler could affect volatilization of compounds.
Number of days diffusion sampler deployed	The diffusion sampler must be deployed in the well for a sufficient amount of time to let the water in the sampler equilibrate with the surrounding ground water.
Depth to bottom of screened interval from land surface	Because finer sediments could clog the well screen and inhibit the flow, this characteristic was used as a surrogate for the general fining of the outwash deposits with depth ² .
Horizontal hydraulic conductivity ³ Vertical hydraulic conductivity ³ Anisotropic ratio ³ Average linear ground-water velocity ³	General aquifer characteristics may affect ground-water-flow rates and exchange of water in the well screen.
Dissolved oxygen concentration at time of sample collection pH at time of sample collection Temperature at time of sample collection	A chemical process may be affecting diffusion of volatile organic compounds into the diffusion sampler.
Length of well screen	Long-screened wells have more potential for vertical mixing of water along the screened interval than wells with short screens and more chance for vertical concentration variations along the screened interval ⁴ .

¹Freeze and Cherry, 1979, p. 428–430.

²Masterson and others, 1997.

³Air Force Center for Environmental Excellence, 2001; 2002a; 2002b; 2003a; 2003b.

⁴Church and Granato, 1996.

concentrations only at the location in the well screen where it was installed. Therefore, the 2-ft-screened wells may produce better agreement between concentrations obtained by the two methods.

If the agreement between concentrations in samples collected by the two methods for 2-ft-screened wells was significantly better than the agreement for the 5-ft-screened wells, the RPDs for the 2-ft-screened wells would almost always be lower than for the 5-ft-screened wells. A one-sided signed-rank test was applied to the data set, which included 22 wells with 2-ft screens and 30 wells with 5-ft screens. In this case, the alternative hypothesis was that the 2-ft-screened wells have significantly lower RPDs than the 5-ft-screened wells. With a calculated p-value of 0.0002, the signed-rank test showed that the RPDs for the 2-ft-screened wells were significantly different and lower than the RPDs for the 5-ft-screened wells. This p-value was calculated using the S-PLUS statistical software package (Statistical Science, Inc., 1991).

Study Limitations, Methods Agreement, and Long-Term Monitoring

Comparisons of diffusion- and pumped-sample concentrations indicate that the diffusion-sample concentration approximates the pumped-sample concentration to a good degree for many, but not all, wells and VOCs. The degree of agreement between the concentrations determined by the two methods was repeatable and not likely affected by variability within each sampling method. Quantitative characteristics external to the sampling methods were compared to the RPDs between the pumped- and diffusion-sample concentrations to determine how these characteristics might be related to the degree of agreement in VOC concentrations obtained by means of the two sampling methods; only the screen length indicated a relation with the RPDs.

An important assumption made when comparing diffusion- and pumped-sample concentrations is that the pumped-sample concentration is the true concentration; therefore, in this study, evaluation of the diffusion-sampling method was based on how well the diffusion-sample concentration could represent the pumped-sample concentration. In the diffusion-sampling method, the concentrations of VOCs are measured at the locations where the samplers have been installed; whereas, in the pumped-sampling method, a composite sample of ground water is collected from an unknown contributing zone around the well screen. Pumping could pull ground water from areas of higher hydraulic conductivity above or below the well screen; the pumping action could result in higher or lower concentrations of VOCs in the pumped sample than the concentrations found in the well screen under ambient conditions (Vroblesky, 2001). For example, if the ground water contained higher VOC concentrations above or below the screen, the concentrations

in the diffusion sample would consistently underrepresent the concentrations in the pumped sample, even though the diffusion sample would be correctly measuring VOC concentrations in the ground water moving through the screen at the section where the diffusion sampler was installed (Vroblesky, 2001). Although these uncertainties are present and may explain some of the differences between the pumped- and diffusion-sample concentrations, it is reasonable to assume that the pumped-sample concentrations are representative of ambient ground-water quality at the well site.

Limitations of the Study Design

The selection of wells from the present (1999–2002) long-term water-quality-monitoring program at the MMR was based mostly on the efficiency and cost-effectiveness of the sampling effort. This well-selection method enabled testing the diffusion method for a larger data set than in previous studies; however, the study design led to different combinations of VOCs being detected in each well.

Although assigning a value of zero to all data values below the analytical detection limit is not the best approach to handling this type of data (Helsel and Hirsch, 1992), analytical detection limits were typically less than 0.5 µg/L. Any difference in concentrations below the detection limit obtained by the two methods would be close to zero. Furthermore, because sampling was done during a period of 3 years, analytical detection limits varied for individual VOCs. Assigning a zero value to these data was the most efficient way to include them in the analysis. Furthermore, a Monte Carlo analysis indicated that assigning a zero value instead of the detection limit did not alter the mean or median values of the data. The results of this analysis are not presented here because it is beyond the scope of this report.

Only eight replicate samples were collected, and replicates of both diffusion and pumped samples were collected at only one well. Replicates can be used to determine the total variability of the sampling method. Previous studies have used the variability between VOC concentrations in the original and replicate samples to quantify an acceptable amount of difference between the results from the diffusion and pumped samples (Vroblesky and Peters, 2000; Vroblesky and Pravecek, 2002).

For each well in their study, Vroblesky and Peters (2000) used the variability between results for replicate pumped samples to define an acceptable difference between diffusion- and pumped-sample VOC concentrations. For example, if the VOC concentrations of the original and replicate pumped samples at a given well differed by 15 percent and the diffusion- and pumped-sample concentrations differed by 10 percent, the diffusion- and pumped-sample concentrations would be considered to be in good agreement, even though they were not an exact match; however, an acceptable difference could not be identified in this investigation because too few replicate samples were collected.

Limitations of the Statistical Analyses

Many analyses in this study involved a comparison of paired data, that is, a comparison of the pumped- and diffusion-sample concentrations for a given VOC or well. The VOCs for which the sign test indicated bias in the utility of the diffusion-sampling method to match the pumped-sample concentrations were PCE and TCE; these were also the VOCs whose concentrations were most frequently above the analytical detection limits. Most of the remaining VOC data could not be subjected to any statistical test because of the small sample size. This result does not imply that, given more samples, analyses of the other VOCs would show bias; however, these results make it difficult to draw definitive conclusions about the reliability of the diffusion-sample concentrations for VOCs other than PCE and TCE.

Statistical tests such as the paired-t test and signed-rank test can be used to assess the quantitative differences between paired data. Both tests were considered for use in this study to analyze differences between the sampling methods; however, the conditions required to apply these tests could not be met with the data. Although more powerful statistical tests could not be used, the conclusions of the sign tests were verified by visual observations of the pattern in the data, as shown in the figures.

Factors Affecting the Agreement between Methods

For the wells that were sampled twice by the diffusion- and pumped-sampling methods, the agreement between the concentrations obtained by the two methods remained the same for a given well, even after a long elapsed time between sampling rounds and a substantial change in concentrations of VOCs. This persistent agreement between the methods might be related to some characteristic external to the sampling methods. Of the characteristics investigated, screen length indicated a significant relation to the RPD between the pumped- and diffusion-sample concentrations.

The wells with 2-ft screens had significantly lower RPDs than wells with 5-ft screens; however, it is not clear why this result is the case. One hypothesis is that there is more potential for vertical flow, and therefore, concentration variations along the longer screens than along the shorter screens. Pumping would integrate concentrations over the entire length of the screen, whereas diffusion sampling would measure concentrations only in the discrete section of screen where the sampler was installed. Vertical differences in concentration may be present in the screened interval for some wells; however, replicate diffusion samples collected in three wells with 5-ft screens do not support this explanation. The replicate diffusion samples were obtained from two separate samplers hanging at different heights in the well screen, but the RPDs between the two diffusion samples were small (less than 6 percent). Installation of diffusion samplers along the entire length of the

screened intervals in these and other wells would help determine if this apparent lack of variation in concentrations along the well screens is typical of wells at the MMR.

The diffusion-sampling method has been described by others as a good approximation to the pumped-sampling method in wells with screens that are longer than 5 ft. Huffman (2002) compared the concentrations from the diffusion- and pumped-sampling methods in wells with 10-ft screens and reported no bias in the utility of the diffusion-sampling method in representing the pumped-sample concentrations. Nevertheless, for this study, a difference between the RPDs for total VOC concentrations measured in samples from the 2-ft and 5-ft-screened wells was observed. The RPDs for concentrations in samples from the 2-ft-screened wells were significantly lower than from wells with 5-ft screens.

Samples collected in the blank casing above the screen at one well indicated that the concentrations of VOCs in the diffusion sampler at the screened interval more closely resembled concentrations in the stagnant water above the screen than the concentrations in the pumped sample. Furthermore, at six wells there was better agreement between concentrations measured in the second sampling round (the wells had been purged recently) than in first sampling round (the wells had not been purged recently). These observations support the hypothesis that stagnant water remains in the well screen between sampling rounds unless ground water passes freely through the well screen. Factors that affect this flushing may be particular to each well and may determine how well the methods will agree. Direct measurements of flushing rates in the wells screens would help to determine if the diffusion samplers in particular wells are in direct connection with the ambient ground water adjacent to the well screen or only with the stagnant water above the well screen.

Long-Term Monitoring with Diffusion Samplers at the Study Area

Although diffusion-sample concentrations generally were less than pumped-sample concentrations, the diffusion samples were just as likely to detect the VOCs as the pumped samples. Therefore, with respect to the detection of the presence or absence of a particular VOC, the diffusion-sampling method is as effective as pumped-sampling methods for long-term monitoring and could be used to monitor contaminant-plume boundaries. At a given well, the agreement between the diffusion- and pumped-sample concentrations did not vary unless the diffusion sampling was done soon after the well had been pumped in a previous sampling event. If pumped-sampling methods are replaced by diffusion-sampling methods at a well where the degree of agreement between VOC concentrations obtained by the two methods was good in an initial field comparison, the results of this analysis indicate it is likely that the good degree of agreement will not change. Until there is a better understanding of the factors that

might affect the agreement between the methods, a one-time well-by-well comparison could be used to determine which wells would be good candidates for replacement of traditional pumped-sampling methods by diffusion sampling. Diffusion samplers could be used to monitor VOC concentrations in the water in such wells with confidence.

Summary

Diffusion and pumped samples were collected from 89 monitoring wells at and near the Massachusetts Military Reservation (MMR) and analyzed for 36 volatile organic compounds (VOCs) by the U.S. Geological Survey in cooperation with the Air Force Center for Environmental Excellence. With this data set, various visual and statistical comparisons were made to determine the potential usefulness of diffusion samplers as an alternative method to monitor concentrations of VOCs in ground-water monitoring wells.

There was no substantial difference between the utilities of diffusion sampling and pumped sampling as methods to detect the presence or absence of a particular VOC. Visual inspection of the graphical display of individual VOC concentrations in the pumped sample plotted in relation to the diffusion-sample concentrations—particularly for PCE and TCE—showed a tendency for the diffusion-sample concentration to underpredict the pumped-sample concentration; this bias was confirmed statistically. When individual VOC concentrations were summed and the resulting total VOC concentrations compared by well, the same conclusion was reached. This result was expected because PCE and TCE concentrations detected in the wells dominated the calculation of many of the total VOC concentrations.

Poor agreement between the pumped- and diffusion-sampler concentrations of total VOCs was not likely a result of variability inherent to the sampling methods. The difference between the total VOC concentrations in the original and replicate pumped samples was small; the same observation was true for the original and replicate diffusion samples. Furthermore, the relative percent difference (RPD) between the pumped- and diffusion-sample concentrations for each well was greater than the RPD between the replicate samples for each method.

The agreement between the sampling methods was repeatable. If the diffusion- and pumped-sample concentrations agreed well in the first round, the second

round of sampling produced the same result. This observation was true even for the case of a 3-year interval between the first and second rounds, during which VOC concentrations decreased by a factor of 10.

The signed-rank test showed better agreement between the methods in wells with 2-ft screens as compared to wells with 5-ft screens; however, it is not clear why this is the case. There is evidence from repeated sampling and from the results of diffusion samplers hung in series above the well screen to indicate that the flushing rate of water through the screen affects the degree of agreement between the methods. Direct measurements of well-screen flushing rates could confirm this hypothesis and lead to a better understanding of the applicability of diffusion sampling at the MMR.

Despite poor agreement between the concentrations obtained by the two methods at some wells, the degree to which the concentrations agree at a given well is repeatable. A one-time, well-by-well comparison between diffusion- and pumped-sampling methods could determine which wells are good candidates for use of diffusion samplers. For wells with good agreement, the diffusion-sampler method is a time-saving and cost-effective alternative to pumped-sampling methods in a long-term monitoring program such as at the Massachusetts Military Reservation.

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Appendix: Analytical Results for Selected Volatile Organic Compounds by Well for Diffusion- and Pumped-Sampling Methods, Including Wells with Two Sets of Samples Collected or with Replicate Samples Collected, and Samples Collected for Quality Assurance, Massachusetts Military Reservation, Cape Cod, Massachusetts, July 1999–December 2002

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Table 1-1. Analytical results for volatile organic compounds detected in more than six wells for samples collected by diffusion- and pumped-sampling methods, including wells with two sets of samples collected or with replicate samples collected, Massachusetts Military Reservation, Cape Cod, Massachusetts, July 1999–December 2002.

[Well ID: See figure 1 for location. All concentrations in micrograms per liter. *cis*1,2-DCE, *cis*1,2-dichloroethene; EDB, 1,2-dibromoethane; ID, identifier; NA, not analyzed; PCE, tetrachloroethene; R, second sampling event for well; REP, replicate sample; TCE, trichloroethene; <, less than the analytical detection limit]

Well ID	Well number	Date diffusion sampler retrieved	Sample type	PCE	TCE	<i>cis</i> 1,2-DCE	Chloroform	EDB	1,2-Dichlorobenzene
1	03MW0054A	8-12-1999	Diffusion	1.19	266	3.02	<0.29	<0.28	<0.24
		8-12-1999	Pumped	1.5	258	2.87	<.29	<.28	<.24
2	03MW0054B	8-12-1999	Diffusion	<.22	<.35	<.24	<.29	<.28	<.24
		8-12-1999	Pumped	<.22	<.35	<.24	<.29	<.28	<.24
3	03MW0064	8-16-1999	Diffusion	<.22	16.7	<.24	<.29	<.28	<.24
		8-16-1999	Pumped	<.22	19.7	<.24	<.29	<.28	<.24
4	03MW0214B	8-12-1999	Diffusion	1.42	274	2.82	<.29	<.28	<.24
		8-12-1999	Pumped	5.49	1,000	6.02	<.29	<.28	<.24
5	03MW0214F	8-12-1999	Diffusion	5.32	241	10.3	<.29	<.28	<.24
		8-12-1999	Pumped	7.48	310	10.7	<.29	<.28	<.24
	03MW0214F-R	11-12-2002	Diffusion	.28	2.75	<.347	<.336	<.002	<.305
		11-12-2002	Pumped	.29	3.26	<.347	<.336	<.002	<.305
6	03MW2413A	8-16-1999	Diffusion	<.22	38.6	<.24	<.29	<.28	<.24
		8-16-1999	Pumped	1.66	156	2.34	<.29	<.28	<.24
	03MW2413A-R	11-12-2002	Diffusion	<.146	.53	<.347	<.336	<.002	<.305
		11-12-2002	Pumped	.32	25.6	<.347	<.336	<.002	<.305
7	03MW2413B	11-12-2002	Diffusion	<.146	20	<.347	.82	<.002	<.305
		11-12-2002	Pumped	.86	88.7	.9	.7	<.002	<.305
8	27MW0023A	8-04-1999	Diffusion	8.5	10	<.26	2	<.32	<.24
		8-04-1999	Pumped	11	9.1	<.26	1.8	<.32	<.24
	27MW0023A-R	4-06-2000	Diffusion	3.6	3.3	<.08	.76	<.1	<.08
		4-06-2000	Pumped	3.5	2.6	<.08	.62	<.1	<.08
9	27MW0024A	4-06-2000	Pumped REP	3.7	2.7	<.08	.62	<.1	<.08
		8-09-1999	Diffusion	1.7	1.2	28	<.22	<.32	<.24
		8-09-1999	Pumped	4.4	1.6	34	<.22	<.32	<.24
10	27MW0026A	8-05-1999	Diffusion	1.8	.95	<.13	.9	<.16	<.12
		8-05-1999	Diffusion REP	1.9	.93	<.13	.88	<.16	<.12
		8-05-1999	Pumped	4.2	1.1	<.13	.88	<.16	<.12
		8-05-1999	Pumped REP	4.5	1.2	<.13	.95	<.16	<.12
11	27MW0026B	8-05-1999	Diffusion	2.4	1.4	<.13	2.2	<.16	<.12
		8-05-1999	Pumped	29	7.1	<.26	7.4	<.32	<.24
	27MW0026B-R	4-10-2000	Diffusion	3	2.2	<.08	4.1	<.1	<.08
		4-10-2000	Pumped	24	5.8	.81	6.1	.67	<.08
12	27MW0031A	8-09-1999	Diffusion	15	150	45	<1.1	<1.6	<1.2
		8-09-1999	Pumped	21	150	48	<1.1	<1.6	<1.2
	27MW0031A-R	4-07-2000	Diffusion	11	99	37	<.4	<.5	<.45
		4-07-2000	Pumped	14	91	33	<.4	<.5	<.45
13	27MW0031B	8-06-1999	Diffusion	1.7	16	17	2.6	<.16	<.12
		8-06-1999	Pumped	7.7	31	26	3.3	<.32	<.24
	27MW0031B-R	4-07-2000	Diffusion	2.6	29	20	1.7	<.2	<.16
		4-07-2000	Pumped	5.2	30	24	2.4	<.2	<.16

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Table 1-1. Analytical results for volatile organic compounds detected in more than six wells for samples collected by diffusion- and pumped-sampling methods, including wells with two sets of samples collected or with replicate samples collected, Massachusetts Military Reservation, Cape Cod, Massachusetts, July 1999–December 2002.—Continued

[Well ID: See figure 1 for location. All concentrations in micrograms per liter. *cis*1,2-DCE, *cis*1,2-dichloroethene; EDB, 1,2-dibromoethane; ID, identifier; NA, not analyzed; PCE, tetrachloroethene; R, second sampling event for well; REP, replicate sample; TCE, trichloroethene; <, less than the analytical detection limit]

Well ID	Well number	Date diffusion sampler retrieved	Sample type	PCE	TCE	<i>cis</i> 1,2-DCE	Chloroform	EDB	1,2-Dichlorobenzene
14	27MW0033	8-05-1999	Diffusion	<0.1	<0.12	<0.13	<0.11	<0.16	<0.12
		8-05-1999	Pumped	<.1	4.9	1.1	<.11	<.16	<.12
		8-05-1999	Pumped REP	<.1	4.5	1.2	<.11	<.16	<.12
15	27MW0037A	8-11-1999	Diffusion	3.9	19	<.13	.61	<.16	<.12
		8-11-1999	Diffusion REP	5.2	18	<.13	.79	<.16	<.12
		8-11-1999	Pumped	2.7	39	<.26	<.22	<.32	<.24
	27MW0037A-R	4-04-2000	Diffusion	3.9	15	<.08	<.08	<.1	<.08
		4-04-2000	Pumped	3.6	27	<.16	<.16	<.2	<.16
16	27MW0038A	8-11-1999	Diffusion	<.1	<.12	<.13	<.11	<.16	<.12
		8-11-1999	Pumped	1	2.6	.93	.96	<.16	<.12
17	27MW0046	10-11-1999	Diffusion	1.61	2.56	.54	<.11	<.1	<.12
		10-11-1999	Pumped	1	2.4	.74	<.11	<.1	<.12
18	27MW0102A	8-11-1999	Diffusion	16	6.1	9.6	1.1	<.16	<.12
		8-11-1999	Diffusion REP	14	6.2	9.7	1	<.16	<.12
		8-11-1999	Pumped	48	7.5	21	<.44	<.64	<.48
	27MW0102A-R	4-05-2000	Diffusion	18	5.3	11	<.08	<.1	<.08
		4-05-2000	Pumped	36	5.8	24	<.16	<.2	<.16
19	27MW0102B	8-11-1999	Diffusion	<.1	<.12	<.13	<.11	<.16	<.12
		8-11-1999	Pumped	<.1	<.12	<.13	<.11	<.16	<.12
20	27MW0108A	8-05-1999	Diffusion	.42	6.3	19	<.11	<.16	<.12
		8-05-1999	Pumped	1.2	51	7.2	<.44	<.64	<.48
	27MW0108A-R	4-05-2000	Diffusion	.71	20	1.7	<.08	<.1	<.08
		4-05-2000	Pumped	1.2	31	<.32	<.32	<.4	<.32
		4-05-2000	Pumped REP	1.2	31	<.32	<.32	<.4	<.32
21	27MW0108B	8-05-1999	Diffusion	<.1	<.12	<.13	.9	<.16	<.12
		8-05-1999	Pumped	<.1	<.12	<.13	.92	<.16	<.12
22	36MW0132A	4-18-2000	Diffusion	NA	NA	NA	NA	3.33	NA
		4-18-2000	Pumped	NA	NA	NA	NA	3.73	NA
23	36MW0132B	4-18-2000	Diffusion	NA	NA	NA	NA	6.14	NA
		4-18-2000	Pumped	NA	NA	NA	NA	6.78	NA
24	36MW0132C	4-18-2000	Diffusion	NA	NA	NA	NA	4.56	NA
		4-18-2000	Pumped	NA	NA	NA	NA	4.56	NA
25	90MW0003	9-14-1999	Diffusion	<2.5	<3	<3.2	<2.8	4.28	<3.00
		9-14-1999	Pumped	<2	<2.4	<2.6	<2.2	<.32	<2.4
26	90MW0005	9-14-1999	Diffusion	<.1	<.12	<.13	<.11	1.5	<.12
		9-14-1999	Pumped	<.2	<.24	<2.6	<.22	2	<.24
27	90MW0025	9-14-1999	Diffusion	<.1	<.12	<.13	1.7	<.16	<.12
		9-14-1999	Pumped	<.1	<.12	<.13	1.4	<.16	<.12
28	90MW0028	9-14-1999	Diffusion	<.1	<.12	<.13	1.2	<.16	<.12
		9-14-1999	Pumped	<.1	<.12	<.13	1.3	<.16	<.12

Table 1-1. Analytical results for volatile organic compounds detected in more than six wells for samples collected by diffusion- and pumped-sampling methods, including wells with two sets of samples collected or with replicate samples collected, Massachusetts Military Reservation, Cape Cod, Massachusetts, July 1999–December 2002.—Continued

[Well ID: See figure 1 for location. All concentrations in micrograms per liter. *cis*1,2-DCE, *cis*1,2-dichloroethene; EDB, 1,2-dibromoethane; ID, identifier; NA, not analyzed; PCE, tetrachloroethene; R, second sampling event for well; REP, replicate sample; TCE, trichloroethene; <, less than the analytical detection limit]

Well ID	Well number	Date diffusion sampler retrieved	Sample type	PCE	TCE	<i>cis</i> 1,2-DCE	Chloroform	EDB	1,2-Dichlorobenzene
29	90MW0034	9-14-1999	Diffusion	<0.1	<0.12	<0.13	<0.11	<0.16	<0.12
		9-14-1999	Pumped	<.1	<.12	<.13	<.11	<.16	<.12
30	90MW0040	9-14-1999	Diffusion	<.1	<.12	<.13	1.6	1.7	<.12
		9-14-1999	Pumped	<.1	<.12	<.13	1.6	5.4	<.12
31	90MW0041	9-15-1999	Diffusion	<.1	<.12	<.13	<.11	<.16	<.12
		9-15-1999	Pumped	<.1	<.12	<.13	<.11	<.16	<.12
32	90MW0050	9-15-1999	Diffusion	<.1	<.12	<.13	1	<.16	<.12
		9-15-1999	Pumped	<.1	<.12	<.13	.91	<.16	<.12
33	90MW0053	9-14-1999	Diffusion	<.1	<.12	<.13	1	.97	<.12
		9-14-1999	Pumped	<.1	<.12	<.13	.87	2.2	<.12
34	90WT0013	9-15-1999	Diffusion	<1	<1.2	<1.3	<1.1	<.16	<1.2
		9-15-1999	Pumped	<1	<1.2	<1.3	<1.1	<.16	<1.2
35	FSW 230-0058	7-23-2002	Diffusion	.81	<.138	<.347	2.73	<.002	<.305
		7-23-2002	Pumped	.72	<.138	<.347	2.93	<.002	<.305
36	FSW 230-0068	7-23-2002	Diffusion	<.146	<.138	<.347	3.99	<.002	<.305
		7-23-2002	Pumped	<.146	<.138	<.347	3.48	<.002	<.305
37	FSW 230-0078	7-23-2002	Diffusion	<.146	<.138	<.347	1.3	<.002	<.305
		7-23-2002	Pumped	<.146	<.138	<.347	1.36	<.002	<.305
38	FSW 271-0099	10-16-2002	Diffusion	4.49	.29	<.347	<.336	<.002	<.305
		10-16-2002	Pumped	5.05	.25	<.347	<.336	<.002	<.305
	FSW 271-0099-R	12-09-2002	Diffusion	4.68	<.138	<.347	<.336	<.002	<.305
		12-09-2002	Pumped	5.91	.25	<.347	<.336	<.002	<.305
39	FSW 271-0114	10-16-2002	Diffusion	3.78	.28	<.347	<.336	<.002	<.305
		10-16-2002	Pumped	5.75	.27	<.347	<.336	<.002	<.305
	FSW 271-0114-R	12-09-2002	Diffusion	5.27	.24	<.347	<.336	<.002	<.305
		12-09-2002	Pumped	5.59	.43	<.347	<.336	<.002	<.305
40	FSW 300-0010	8-01-2002	Diffusion	<.146	<.138	<.347	.67	<.002	<.305
		8-01-2002	Pumped	<.146	<.138	<.347	.88	<.002	<.305
41	FSW 300-0030	8-01-2002	Diffusion	8.69	<.138	<.347	<.336	<.002	<.305
		8-01-2002	Pumped	7.8	<.138	<.347	<.336	<.002	<.305
42	FSW 300-0050	8-01-2002	Diffusion	<.146	<.138	<.347	<.336	<.002	<.305
		8-01-2002	Pumped	<.146	<.138	<.347	<.336	<.002	<.305
43	FSW 300-0073	8-01-2002	Diffusion	<.146	<.138	<.347	<.336	<.002	<.305
		8-01-2002	Pumped	<.146	<.138	<.347	<.336	<.002	<.305
44	FSW 300-0099	8-01-2002	Diffusion	<.146	<.138	<.347	<.336	<.002	<.305
		8-01-2002	Pumped	<.146	<.138	<.347	<.336	<.002	<.305
45	FSW 300-0118	8-01-2002	Diffusion	<.146	<.138	<.347	<.336	<.002	<.305
		8-01-2002	Pumped	<.146	<.138	<.347	<.336	<.002	<.305
46	FSW 300-0138	8-01-2002	Diffusion	<.146	<.138	<.347	<.336	<.002	<.305
		8-01-2002	Pumped	<.146	<.138	<.347	<.336	<.002	<.305

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Table 1-1. Analytical results for volatile organic compounds detected in more than six wells for samples collected by diffusion- and pumped-sampling methods, including wells with two sets of samples collected or with replicate samples collected, Massachusetts Military Reservation, Cape Cod, Massachusetts, July 1999–December 2002.—Continued

[Well ID: See figure 1 for location. All concentrations in micrograms per liter. *cis*1,2-DCE, *cis*1,2-dichloroethene; EDB, 1,2-dibromoethane; ID, identifier; NA, not analyzed; PCE, tetrachloroethene; R, second sampling event for well; REP, replicate sample; TCE, trichloroethene; <, less than the analytical detection limit]

Well ID	Well number	Date diffusion sampler retrieved	Sample type	PCE	TCE	<i>cis</i> 1,2-DCE	Chloroform	EDB	1,2-Dichlorobenzene
47	FSW 343-0036	8-07-2002	Diffusion	1.4	<0.138	<0.347	<0.336	<0.002	<0.305
		8-07-2002	Pumped	1.36	<.138	<.347	<.336	<.002	<.305
48	FSW 343-0057	8-07-2002	Diffusion	.59	<.138	12.9	<.336	<.002	1
		8-07-2002	Pumped	1.06	<.138	11.5	<.336	<.002	1.18
49	FSW 343-0079	8-07-2002	Diffusion	<.146	<.138	<.347	<.336	<.002	<.305
		8-07-2002	Pumped	<.146	<.138	<.347	<.336	<.002	<.305
50	FSW 343-0099	8-07-2002	Diffusion	<.146	<.138	<.347	<.336	<.002	<.305
		8-07-2002	Pumped	<.146	<.138	<.347	<.336	<.002	<.305
51	FSW 343-0114	8-07-2002	Diffusion	<.146	<.138	<.347	<.336	<.002	<.305
		8-07-2002	Pumped	<.146	<.138	<.347	<.336	<.002	<.305
52	FSW 347-0020	8-08-2002	Diffusion	<.146	<.138	<.347	<.336	<.002	<.305
		8-08-2002	Pumped	<.146	<.138	<.347	<.336	<.002	<.305
53	FSW 347-0031	8-08-2002	Diffusion	12.1	<.138	<.347	1.29	<.002	<.305
		8-08-2002	Pumped	13.3	<.138	<.347	1.29	<.002	<.305
54	FSW 347-0038	8-08-2002	Diffusion	9.16	<.138	<.347	1.39	<.002	<.305
		8-08-2002	Pumped	11.1	<.138	<.347	1.31	<.002	<.305
55	FSW 347-0046	8-08-2002	Diffusion	2.6	<.138	<.347	<.336	<.002	<.305
		8-08-2002	Pumped	2.52	<.138	<.347	<.336	<.002	<.305
56	FSW 347-0067	8-08-2002	Diffusion	<.146	<.138	<.347	<.336	<.002	<.305
		8-08-2002	Pumped	<.146	<.138	<.347	<.336	<.002	<.305
57	FSW 347-0101	8-08-2002	Diffusion	<.146	<.138	<.347	<.336	<.002	<.305
		8-08-2002	Pumped	<.146	<.138	<.347	<.336	<.002	<.305
58	FSW 347-0116	8-08-2002	Diffusion	<.146	<.138	<.347	<.336	<.002	<.305
		8-08-2002	Pumped	<.146	<.138	<.347	<.336	<.002	<.305
59	FSW 347-0131	8-08-2002	Diffusion	<.146	<.138	<.347	<.336	<.002	<.305
		8-08-2002	Pumped	<.146	<.138	<.347	<.336	<.002	<.305
60	FSW 347-0145	8-08-2002	Diffusion	<.146	<.138	<.347	<.336	<.002	<.305
		8-08-2002	Pumped	<.146	<.138	<.347	<.336	<.002	<.305
61	FSW 350-0064	10-11-2002	Diffusion	7.74	<.138	<.347	<.336	<.002	<.305
		10-11-2002	Pumped	7.89	.21	<.347	<.336	<.002	<.305
	FSW 350-0064-R	12-09-2002	Diffusion	8.21	<.138	<.347	<.336	<.002	<.305
		12-09-2002	Pumped	8.3	<.138	<.347	<.336	<.002	<.305
62	FSW 350-0110	10-11-2002	Diffusion	1.88	.54	.37	<.336	<.002	<.305
		10-11-2002	Pumped	7.77	5.33	<.347	<.336	<.002	<.305
	FSW 350-0110-R	12-09-2002	Diffusion	3.39	.79	.46	<.336	<.002	<.305
		12-09-2002	Pumped	10.5	6.11	<.347	<.336	<.002	<.305
63	FSW 375-0055	10-24-2002	Diffusion	7.33	3.92	<.347	<.336	<.002	<.305
		10-24-2002	Pumped	12.2	4.38	<.347	<.336	<.002	<.305
	FSW 375-0055-R	12-09-2002	Diffusion	12.9	4.48	<.347	.54	<.002	<.305
		12-09-2002	Pumped	13.8	4.18	<.347	.51	<.002	<.305

Table 1-1. Analytical results for volatile organic compounds detected in more than six wells for samples collected by diffusion- and pumped-sampling methods, including wells with two sets of samples collected or with replicate samples collected, Massachusetts Military Reservation, Cape Cod, Massachusetts, July 1999–December 2002.—Continued

[Well ID: See figure 1 for location. All concentrations in micrograms per liter. *cis*1,2-DCE, *cis*1,2-dichloroethene; EDB, 1,2-dibromoethane; ID, identifier; NA, not analyzed; PCE, tetrachloroethene; R, second sampling event for well; REP, replicate sample; TCE, trichloroethene; <, less than the analytical detection limit]

Well ID	Well number	Date diffusion sampler retrieved	Sample type	PCE	TCE	<i>cis</i> 1,2-DCE	Chloroform	EDB	1,2-Dichlorobenzene
64	FSW 375-0071	10-24-2002	Diffusion	1.85	0.87	<0.347	<0.336	<0.002	<0.305
		10-24-2002	Pumped	3.13	1.72	<.347	<.336	<.002	<.305
	FSW 375-0071-R	12-09-2002	Diffusion	4.49	2.23	<.347	<.336	<.002	<.305
		12-09-2002	Pumped	3.95	2.04	<.347	<.336	<.002	<.305
65	FSW 383-0040	8-22-2002	Diffusion	2.29	<.138	<.347	.85	<.002	<.305
		8-22-2002	Pumped	2.2	<.138	<.347	.86	<.002	<.305
66	FSW 383-0061	8-22-2002	Diffusion	.81	<.138	<.347	<.336	<.002	<.305
		8-22-2002	Pumped	.47	<.138	<.347	<.336	<.002	<.305
67	FSW 383-0082	8-22-2002	Diffusion	<.146	<.138	<.347	<.336	<.002	<.305
		8-22-2002	Pumped	<.146	<.138	<.347	<.336	<.002	<.305
68	FSW 383-0106	8-22-2002	Diffusion	<.146	<.138	<.347	<.336	<.002	<.305
		8-22-2002	Pumped	<.146	<.138	<.347	<.336	<.002	<.305
69	FSW 424-0020	8-06-2002	Diffusion	<.146	<.138	<.347	<.336	<.002	<.305
		8-06-2002	Pumped	<.146	<.138	<.347	<.336	<.002	<.305
70	FSW 424-0089	8-06-2002	Diffusion	<.146	<.138	<.347	<.336	<.002	<.305
		8-06-2002	Pumped	<.146	<.138	<.347	<.336	<.002	<.305
71	FSW 424-0144	8-06-2002	Diffusion	<.146	<.138	<.347	<.336	<.002	<.305
		8-06-2002	Pumped	<.146	<.138	<.347	<.336	<.002	<.305
72	FSW 424-0183	8-06-2002	Diffusion	<.146	.52	<.347	<.336	<.002	<.305
		8-06-2002	Pumped	<.146	<.138	<.347	<.336	<.002	<.305
73	FSW 577-0061	8-14-2002	Diffusion	<.146	<.138	<.347	.92	<.002	<.305
		8-14-2002	Pumped	.98	<.138	<.347	.94	<.002	<.305
74	FSW 577-0071	8-14-2002	Diffusion	2.28	<.138	<.347	1.81	<.002	<.305
		8-14-2002	Pumped	2.12	<.138	<.347	1.66	<.002	<.305
75	FSW 577-0081	8-14-2002	Diffusion	1.02	<.138	<.347	<.336	<.002	<.305
		8-14-2002	Pumped	1.1	<.138	<.347	<.336	<.002	<.305
76	FSW 577-0097	8-14-2002	Diffusion	<.146	<.138	<.347	<.336	<.002	<.305
		8-14-2002	Pumped	<.146	<.138	<.347	<.336	<.002	<.305
77	SDW 316-0051	8-20-2002	Diffusion	<.146	<.138	<.347	<.336	<.002	<.305
		8-20-2002	Pumped	<.146	<.138	<.347	<.336	<.002	<.305
78	SDW 316-0066	8-20-2002	Diffusion	1.22	<.138	<.347	<.336	<.002	<.305
		8-20-2002	Pumped	1.48	<.138	<.347	<.336	<.002	<.305
79	SDW 316-0082	8-20-2002	Diffusion	.53	<.138	<.347	<.336	<.002	.71
		8-20-2002	Pumped	.64	<.138	.76	<.336	<.002	.91
80	SDW 316-0100	8-20-2002	Diffusion	<.146	<.138	<.347	<.336	<.002	<.305
		8-20-2002	Pumped	<.146	<.138	<.347	<.336	<.002	<.305
81	SDW 423-0058	8-21-2002	Diffusion	1.36	<.138	<.347	.77	<.002	<.305
		8-21-2002	Pumped	.95	<.138	<.347	.62	<.002	<.305
82	SDW 438-0041	8-13-2002	Diffusion	<.146	<.138	<.347	<.336	<.002	<.305
		8-13-2002	Pumped	1.31	<.138	<.347	<.336	<.002	<.305

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Table 1-1. Analytical results for volatile organic compounds detected in more than six wells for samples collected by diffusion- and pumped-sampling methods, including wells with two sets of samples collected or with replicate samples collected, Massachusetts Military Reservation, Cape Cod, Massachusetts, July 1999–December 2002.—Continued

[Well ID: See figure 1 for location. All concentrations in micrograms per liter. *cis*1,2-DCE, *cis*1,2-dichloroethene; EDB, 1,2-dibromoethane; ID, identifier; NA, not analyzed; PCE, tetrachloroethene; R, second sampling event for well; REP, replicate sample; TCE, trichloroethene; <, less than the analytical detection limit]

Well ID	Well number	Date diffusion sampler retrieved	Sample type	PCE	TCE	<i>cis</i> 1,2-DCE	Chloroform	EDB	1,2-Di-chloro-benzene
83	SDW 440-0078	8-13-2002	Diffusion	<0.146	<0.138	<0.347	<0.336	<0.002	<0.305
		8-13-2002	Pumped	<.146	<.138	<.347	<.336	<.002	<.305
84	SDW 469-0036	8-06-2002	Diffusion	<.146	<.138	<.347	<.336	<.002	<.305
		8-06-2002	Pumped	<.146	<.138	<.347	<.336	<.002	<.305
85	SDW 469-0051	8-06-2002	Diffusion	.65	<.138	<.347	1.93	<.002	<.305
		8-06-2002	Pumped	1.11	<.138	<.347	1.91	<.002	<.305
86	SDW 469-0066	8-06-2002	Diffusion	<.146	<.138	<.347	<.336	<.002	<.305
		8-06-2002	Pumped	<.146	<.138	<.347	<.336	<.002	<.305
87	SDW 500-0060	8-21-2002	Diffusion	<.146	<.138	<.347	<.336	<.002	<.305
		8-21-2002	Pumped	<.146	<.138	<.347	<.336	<.002	<.305
88	SDW 500-0070	8-21-2002	Diffusion	<.146	<.138	<.347	<.336	<.002	<.305
		8-21-2002	Pumped	<.146	<.138	<.347	<.336	<.002	<.305
89	SDW 500-0080	8-21-2002	Diffusion	<.146	<.138	<.347	<.336	<.002	<.305
		8-21-2002	Pumped	<.146	<.138	<.347	<.336	<.002	<.305

Table 1-2. Analytical results for volatile organic compounds detected in six or fewer wells for samples collected by diffusion- and pumped-sampling methods, including wells with two sets of samples collected or with replicate samples collected, Massachusetts Military Reservation, Cape Cod, Massachusetts, July 1999–December 2002.

[Well identifier: See figure 1 for location. All concentrations in micrograms per liter. ID, identifier; NA, not analyzed; R, second sampling event for well; REP, replicate sample; *trans*1,2-DCE, *trans*1,2-dichloroethene; 1,1-DCE, 1,1-dichloroethene; 1,1,2,2-TeCA, 1,1,2,2-tetrachloroethane; 1,1,1-TCA, 1,1,1-trichloroethane; 1,1,2-TCA, 1,1,2-trichloroethane; 1,1-DCA, 1,1-dichloroethane; <, less than the analytical detection limit]

Well ID	Well number	Date diffusion sampler retrieved	Sample type	<i>trans</i> -1,2-DCE	1,1-DCE	Benzene	1,4-Di-chloro-benzene	1,1,2,2-TeCA	1,1,1-TCA	1,1,2-TCA
1	03MW0054A	8-12-1999	Diffusion	<0.24	<0.24	<0.28	<0.26	<0.32	<0.23	<0.33
		8-12-1999	Pumped	<.24	<.24	<.28	<.26	<.32	<.23	<.33
2	03MW0054B	8-12-1999	Diffusion	<.24	<.3	<.28	<.26	<.32	<.23	<.33
		8-12-1999	Pumped	<.24	<.3	<.28	<.26	<.32	<.23	<.33
3	03MW0064	8-16-1999	Diffusion	<.24	<.3	<.28	<.26	<.32	<.23	<.33
		8-16-1999	Pumped	<.24	<.3	<.28	<.26	<.32	<.23	<.33
4	03MW0214B	8-12-1999	Diffusion	<.24	<.3	<.28	<.26	<.32	<.23	<.33
		8-12-1999	Pumped	<.24	<.3	<.28	<.26	<.32	<.23	<.33
5	03MW0214F	8-12-1999	Diffusion	<.24	<.3	<.28	<.26	<.32	<.23	<.33
		8-12-1999	Pumped	.531	<.3	<.28	<.26	<.32	<.23	<.33
	03MW0214F-R	11-12-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		11-12-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40
6	03MW2413A	8-16-1999	Diffusion	<.24	<.3	<.28	<.38	<.32	<.23	<.33
		8-16-1999	Pumped	<.24	<.3	<.28	<.38	<.32	<.23	<.33
	03MW2413A-R	11-12-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		11-12-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40
7	03MW2413B	11-12-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		11-12-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40
8	27MW0023A	8-04-1999	Diffusion	<.24	1.4	<.2	<.19	<.28	6.8	<.2
		8-04-1999	Pumped	<.24	1.1	<.2	<.19	<.28	6.6	<.2
	27MW0023A-R	4-06-2000	Diffusion	<.09	.68	<.11	<.09	<.13	3.5	<.11
		4-06-2000	Pumped	<.09	<.09	<.11	<.09	<.13	2.9	<.11
		4-06-2000	Pumped REP	<.09	<.09	<.11	<.09	<.13	2.8	<.11
9	27MW0024A	8-09-1999	Diffusion	<.24	<.26	<.2	<.19	<.28	<.19	<.2
		8-09-1999	Pumped	<.24	<.26	.46	1.7	<.28	<.19	<.2
10	27MW0026A	8-05-1999	Diffusion	<.12	<.13	<.099	<.097	<.14	<.094	<.098
		8-05-1999	Diffusion REP	<.12	<.13	<.099	<.097	<.14	<.094	<.098
		8-05-1999	Pumped	<.12	<.13	<.099	<.097	<.14	<.094	<.098
		8-05-1999	Pumped REP	<.12	<.13	<.099	<.097	<.14	<.094	<.098
11	27MW0026B	8-05-1999	Diffusion	<.12	<.13	<.099	<.097	<.14	<.094	<.098
		8-05-1999	Pumped	<.24	<.26	<.2	<.19	<.28	1.6	<.2
	27MW0026B-R	4-10-2000	Diffusion	<.09	<.09	<.11	<.1	<.13	<.09	<.11
		4-10-2000	Pumped	<.09	.54	<.11	<.1	<.13	1.5	<.11
12	27MW0031A	8-06-1999	Diffusion	<1.2	<1.3	<.99	<.97	<1.4	<.94	<.98
		8-06-1999	Pumped	<1.2	<1.3	<.99	<.97	<1.4	<.94	<.98
	27MW0031A-R	4-07-2000	Diffusion	<.45	<.45	<.55	6.4	<.65	<.45	<.55
		4-07-2000	Pumped	<.45	<.45	<.55	5.9	<.65	<.45	<.55
13	27MW0031B	8-09-1999	Diffusion	<.12	<.13	1.2	.55	<.14	.56	<.098
		8-09-1999	Pumped	<.25	<.26	1.1	2.3	<.28	1	<.2
	27MW0031B-R	4-07-2000	Diffusion	<.18	<.18	<.22	1.6	<.26	<.18	<.22
		4-07-2000	Pumped	<.18	<.18	<.22	2.3	<.26	<.18	<.22

34 Comparison of Diffusion- and Pumped-Sampling Methods to Monitor VOCs in Ground Water, MMR, Cape Cod, MA

Table 1-2. Analytical results for volatile organic compounds detected in six or fewer wells for samples collected by diffusion- and pumped-sampling methods, including wells with two sets of samples collected or with replicate samples collected, Massachusetts Military Reservation, Cape Cod, Massachusetts, July 1999–December 2002.—Continued

[Well identifier: See figure 1 for location. All concentrations in micrograms per liter. ID, identifier; NA, not analyzed; R, second sampling event for well; REP, replicate sample; *trans*1,2-DCE, *trans*1,2-dichloroethene; 1,1-DCE, 1,1-dichloroethene; 1,1,2,2-TeCA, 1,1,2,2-tetrachloroethane; 1,1,1-TCA, 1,1,1-trichloroethane; 1,1,2-TCA, 1,1,2-trichloroethane; 1,1-DCA, 1,1-dichloroethane; <, less than the analytical detection limit]

Well ID	Well number	Date diffusion sampler retrieved	Sample type	<i>trans</i> -1,2-DCE	1,1-DCE	Benzene	1,4-Di-chloro-benzene	1,1,2,2-TeCA	1,1,1-TCA	1,1,2-TCA
14	27MW0033	8-05-1999	Diffusion	<0.12	<0.13	<0.099	<0.097	<0.14	<0.094	<0.098
		8-05-1999	Pumped	<.12	<.13	<.099	<.097	<.14	<.094	<.098
		8-05-1999	Pumped REP	<.12	<.13	<.099	<.097	<.14	<.094	<.098
15	27MW0037A	8-11-1999	Diffusion	<.12	<.13	<.099	<.097	5.3	<.094	<.098
		8-11-1999	Diffusion REP	<.12	<.13	<.099	<.097	5.4	<.094	<.098
		8-11-1999	Pumped	<.24	<.26	<.2	<.19	8.2	<.19	<.2
	27MW0037A-R	4-04-2000	Diffusion	<.09	<.09	<.11	<.1	4.6	<.09	<.11
		4-04-2000	Pumped	<.18	<.18	<.22	<.2	5.9	<.18	<.22
16	27MW0038A	8-11-1999	Diffusion	<.12	<.13	<.099	<.097	<.14	<.094	<.098
		8-11-1999	Pumped	<.12	<.13	<.099	<.097	<.14	<.094	<.098
17	27MW0046	10-11-1999	Diffusion	<.12	<.532	<.099	<.097	<.14	1.15	<.098
		10-11-1999	Pumped	<.168	.67	<.371	<.097	<.14	1.3	<.098
18	27MW0102A	8-11-1999	Diffusion	<.12	<.13	.26	<.097	<.14	<.094	<.098
		8-11-1999	Diffusion REP	<.12	<.13	.25	<.097	<.14	<.094	<.098
		8-11-1999	Pumped	<.48	<.523	<.4	<.39	<.56	<.38	<.39
	27MW0102A-R	4-05-2000	Diffusion	<.09	<.09	<.11	<.1	<.13	<.09	<.11
		4-05-2000	Pumped	<.18	<.18	<.22	<.2	<.26	<.18	<.22
19	27MW0102B	8-11-1999	Diffusion	<.12	<.13	<.099	<.097	<.14	<.094	<.098
		8-11-1999	Pumped	<.12	<.13	<.099	<.097	<.14	<.094	<.098
20	27MW0108A	8-05-1999	Diffusion	.87	1	<.099	<.097	9.7	<.094	<.098
		8-05-1999	Pumped	2.2	2.6	<.4	<.39	22	<.38	<.39
	27MW0108A-R	4-05-2000	Diffusion	<.09	<.09	<.11	<.1	7.3	<.09	<.11
		4-05-2000	Pumped	<.36	<.36	<.44	<.4	14	<.36	<.44
		4-05-2000	Pumped REP	<.36	<.36	<.44	<.4	15	<.36	<.44
21	27MW0108B	8-05-1999	Diffusion	<.12	<.13	<.099	<.097	<.14	<.094	<.098
		8-05-1999	Pumped	<.12	<.13	<.099	<.097	<.14	<.094	<.098
22	36MW0132A	4-18-2000	Diffusion	NA	NA	NA	NA	NA	NA	NA
		4-18-2000	Pumped	NA	NA	NA	NA	NA	NA	NA
23	36MW0132B	4-18-2000	Diffusion	NA	NA	NA	NA	NA	NA	NA
		4-18-2000	Pumped	NA	NA	NA	NA	NA	NA	NA
24	36MW0132C	4-18-2000	Diffusion	NA	NA	NA	NA	NA	NA	NA
		4-18-2000	Pumped	NA	NA	NA	NA	NA	NA	NA
25	90MW0003	9-14-1999	Diffusion	<3	<3.2	250	<2.4	<3.5	<2.4	<2.4
		9-14-1999	Pumped	<2.4	<2.6	310	<1.9	<2.8	<1.9	<2
26	90MW0005	9-14-1999	Diffusion	<.12	<.13	<.099	<.097	<.14	<.094	<.098
		9-14-1999	Pumped	<.24	<.26	41	<1.9	<.28	<.19	<.2
27	90MW0025	9-14-1999	Diffusion	<.12	<.13	<.099	<.097	<.14	<.094	<.098
		9-14-1999	Pumped	<.12	<.13	<.099	<.097	<.14	<.094	<.098
28	90MW0028	9-14-1999	Diffusion	<.12	<.13	<.099	<.097	<.14	<.094	<.098
		9-14-1999	Pumped	<.12	<.13	<.099	<.097	<.14	<.094	<.098

Table 1-2. Analytical results for volatile organic compounds detected in six or fewer wells for samples collected by diffusion- and pumped-sampling methods, including wells with two sets of samples collected or with replicate samples collected, Massachusetts Military Reservation, Cape Cod, Massachusetts, July 1999–December 2002.—Continued

[Well identifier: See figure 1 for location. All concentrations in micrograms per liter. ID, identifier; NA, not analyzed; R, second sampling event for well; REP, replicate sample; *trans*1,2-DCE, *trans*1,2-dichloroethene; 1,1-DCE, 1,1-dichloroethene; 1,1,2,2-TeCA, 1,1,2,2-tetrachloroethane; 1,1,1-TCA, 1,1,1-trichloroethane; 1,1,2-TCA, 1,1,2-trichloroethane; 1,1-DCA, 1,1-dichloroethane; <, less than the analytical detection limit]

Well ID	Well number	Date diffusion sampler retrieved	Sample type	<i>trans</i> -1,2-DCE	1,1-DCE	Benzene	1,4-Di-chloro-benzene	1,1,2,2-TeCA	1,1,1-TCA	1,1,2-TCA
29	90MW0034	9-14-1999	Diffusion	<0.12	<0.13	<0.099	<0.097	<0.14	<0.094	<0.098
		9-14-1999	Pumped	<.12	<.13	<.099	<.097	<.14	<.094	<.098
30	90MW0040	9-14-1999	Diffusion	<.12	<.13	<.099	<.097	<.14	<.094	<.098
		9-14-1999	Pumped	<.12	<.13	<.099	<.097	<.14	<.094	<.098
31	90MW0041	9-15-1999	Diffusion	<.12	<.13	<.099	<.097	<.14	<.094	<.098
		9-15-1999	Pumped	<.12	<.13	<.099	<.097	<.14	<.094	<.098
32	90MW0050	9-15-1999	Diffusion	<.12	<.13	<.099	<.097	<.14	<.094	<.098
		9-15-1999	Pumped	<.12	<.13	<.099	<.097	<.14	<.094	<.098
33	90MW0053	9-14-1999	Diffusion	<.12	<.13	<.099	<.097	<.14	<.094	<.098
		9-14-1999	Pumped	<.12	<.13	<.099	<.097	<.14	<.094	<.098
34	90WT0013	9-15-1999	Diffusion	<1.2	<1.3	<.99	<.97	<1.4	<.094	<.98
		9-15-1999	Pumped	<1.2	<1.3	<.99	<.97	<1.4	<.094	<.98
35	FSW 230-0058	7-23-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		7-23-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40
36	FSW 230-0068	7-23-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		7-23-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40
37	FSW 230-0078	7-23-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		7-23-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40
38	FSW 271-0099	10-16-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		10-16-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40
	FSW 271-0099-R	12-09-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		12-09-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40
39	FSW 271-0114	10-16-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		10-16-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40
	FSW 271-0114-R	12-09-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		12-09-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40
40	FSW 300-0010	8-01-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		8-01-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40
41	FSW 300-0030	8-01-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		8-01-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40
42	FSW 300-0050	8-01-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		8-01-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40
43	FSW 300-0073	8-01-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		8-01-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40
44	FSW 300-0099	8-01-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		8-01-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40
45	FSW 300-0118	8-01-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		8-01-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40
46	FSW 300-0138	8-01-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		8-01-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40

Table 1-2. Analytical results for volatile organic compounds detected in six or fewer wells for samples collected by diffusion- and pumped-sampling methods, including wells with two sets of samples collected or with replicate samples collected, Massachusetts Military Reservation, Cape Cod, Massachusetts, July 1999–December 2002.—Continued

[Well identifier: See figure 1 for location. All concentrations in micrograms per liter. ID, identifier; NA, not analyzed; R, second sampling event for well; REP, replicate sample; *trans*1,2-DCE, *trans*1,2-dichloroethene; 1,1-DCE, 1,1-dichloroethene; 1,1,2,2-TeCA, 1,1,2,2-tetrachloroethane; 1,1,1-TCA, 1,1,1-trichloroethane; 1,1,2-TCA, 1,1,2-trichloroethane; 1,1-DCA, 1,1-dichloroethane; <, less than the analytical detection limit]

Well ID	Well number	Date diffusion sampler retrieved	Sample type	<i>trans</i> -1,2-DCE	1,1-DCE	Benzene	1,4-Dichlorobenzene	1,1,2,2-TeCA	1,1,1-TCA	1,1,2-TCA
47	FSW 343-0036	8-07-2002	Diffusion	<0.271	<0.226	<0.216	<0.38	<0.477	<0.528	<0.40
		8-07-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40
48	FSW 343-0057	8-07-2002	Diffusion	<.271	<.226	.82	3.13	<.477	<.528	<.40
		8-07-2002	Pumped	<.271	<.226	.63	4.06	<.477	<.528	<.40
49	FSW 343-0079	8-07-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		8-07-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40
50	FSW 343-0099	8-07-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		8-07-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40
51	FSW 343-0114	8-07-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		8-07-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40
52	FSW 347-0020	8-08-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		8-08-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40
53	FSW 347-0031	8-08-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		8-08-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40
54	FSW 347-0038	8-08-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		8-08-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40
55	FSW 347-0046	8-08-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		8-08-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40
56	FSW 347-0067	8-08-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		8-08-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40
57	FSW 347-0101	8-08-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		8-08-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40
58	FSW 347-0116	8-08-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		8-08-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40
59	FSW 347-0131	8-08-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		8-08-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40
60	FSW 347-0145	8-08-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		8-08-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40
61	FSW 350-0064	10-11-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		10-11-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40
	FSW 350-0064-R	12-09-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		12-09-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40
62	FSW 350-0110	10-11-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		10-11-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40
	FSW 350-0110-R	12-09-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		12-09-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40

Table 1-2. Analytical results for volatile organic compounds detected in six or fewer wells for samples collected by diffusion- and pumped-sampling methods, including wells with two sets of samples collected or with replicate samples collected, Massachusetts Military Reservation, Cape Cod, Massachusetts, July 1999–December 2002.—Continued

[Well identifier: See figure 1 for location. All concentrations in micrograms per liter. ID, identifier; NA, not analyzed; R, second sampling event for well; REP, replicate sample; *trans*1,2-DCE, *trans*1,2-dichloroethene; 1,1-DCE, 1,1-dichloroethene; 1,1,2,2-TeCA, 1,1,2,2-tetrachloroethane; 1,1,1-TCA, 1,1,1-trichloroethane; 1,1,2-TCA, 1,1,2-trichloroethane; 1,1-DCA, 1,1-dichloroethane; <, less than the analytical detection limit]

Well ID	Well number	Date diffusion sampler retrieved	Sample type	<i>trans</i> -1,2-DCE	1,1-DCE	Benzene	1,4-Dichlorobenzene	1,1,2,2-TeCA	1,1,1-TCA	1,1,2-TCA
63	FSW 375-0055	10-24-2002	Diffusion	<0.271	<0.226	<0.216	<0.38	<0.477	<0.528	<0.40
		10-24-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40
	FSW 375-0055-R	12-09-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		12-09-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40
64	FSW 375-0071	10-24-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		10-24-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40
	FSW 375-0071-R	12-09-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		12-09-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40
65	FSW 383-0040	8-22-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		8-22-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40
66	FSW 383-0061	8-22-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		8-22-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40
67	FSW 383-0082	8-22-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		8-22-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40
68	FSW 383-0106	8-22-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		8-22-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40
69	FSW 424-0020	8-06-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		8-06-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40
70	FSW 424-0089	8-06-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		8-06-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40
71	FSW 424-0144	8-06-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		8-06-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40
72	FSW 424-0183	8-06-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		8-06-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40
73	FSW 577-0061	8-14-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		8-14-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40
74	FSW 577-0071	8-14-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		8-14-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40
75	FSW 577-0081	8-14-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		8-14-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40
76	FSW 577-0097	8-14-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		8-14-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40
77	SDW 316-0051	8-20-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		8-20-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40
78	SDW 316-0066	8-20-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		8-20-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40

Table 1-2. Analytical results for volatile organic compounds detected in six or fewer wells for samples collected by diffusion- and pumped-sampling methods, including wells with two sets of samples collected or with replicate samples collected, Massachusetts Military Reservation, Cape Cod, Massachusetts, July 1999–December 2002.—Continued

[Well identifier: See figure 1 for location. All concentrations in micrograms per liter. ID, identifier; NA, not analyzed; R, second sampling event for well; REP, replicate sample; *trans*1,2-DCE, *trans*1,2-dichloroethene; 1,1-DCE, 1,1-dichloroethene; 1,1,2,2-TeCA, 1,1,2,2-tetrachloroethane; 1,1,1-TCA, 1,1,1-trichloroethane; 1,1,2-TCA, 1,1,2-trichloroethane; 1,1-DCA, 1,1-dichloroethane; <, less than the analytical detection limit]

Well ID	Well number	Date diffusion sampler retrieved	Sample type	<i>trans</i> -1,2-DCE	1,1-DCE	Benzene	1,4-Dichlorobenzene	1,1,2,2-TeCA	1,1,1-TCA	1,1,2-TCA
79	SDW 316-0082	8-20-2002	Diffusion	<0.271	<0.226	<0.216	3.89	<0.477	<0.528	<0.40
		8-20-2002	Pumped	<.271	<.226	<.216	4.26	<.477	<.528	<.40
80	SDW 316-0100	8-20-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		8-20-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40
81	SDW 423-0058	8-21-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		8-21-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40
82	SDW 438-0041	8-13-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		8-13-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40
83	SDW 440-0078	8-13-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		8-13-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40
84	SDW 469-0036	8-06-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		8-06-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40
85	SDW 469-0051	8-06-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		8-06-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40
86	SDW 469-0066	8-06-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		8-06-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40
87	SDW 500-0060	8-21-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		8-21-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40
88	SDW 500-0070	8-21-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		8-21-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40
89	SDW 500-0080	8-21-2002	Diffusion	<.271	<.226	<.216	<.38	<.477	<.528	<.40
		8-21-2002	Pumped	<.271	<.226	<.216	<.38	<.477	<.528	<.40

Table 1-2. Analytical results for volatile organic compounds detected in six or fewer wells for samples collected by diffusion- and pumped-sampling methods, including wells with two sets of samples collected or with replicate samples collected, Massachusetts Military Reservation, Cape Cod, Massachusetts, July 1999–December 2002.—Continued

[Well ID: See figure 1 for location. All concentrations in micrograms per liter. ID, identifier; NA, not analyzed; R, second sampling event for well; REP, replicate sample; *trans*1,2-DCE, *trans*1,2-dichloroethene; 1,1-DCE, 1,1-dichloroethene; 1,1,2,2-TeCA, 1,1,2,2-tetrachloroethane; 1,1,1-TCA, 1,1,1-trichloroethane; 1,1,2-TCA, 1,1,2-trichloroethane; 1,1-DCA, 1,1-dichloroethane; <, less than the analytical detection limit]

Well ID	Well number	Date diffusion sampler retrieved	Sample type	1,1-DCA	Ethyl benzene	Toluene	Carbon tetrachloride	Vinyl chloride	Methyl chloride	Xylenes, total
1	03MW0054A	8-12-1999	Diffusion	<0.29	<0.21	<0.29	<0.27	<0.27	<0.28	<0.79
		8-12-1999	Pumped	<.29	<.21	<.29	<.27	<.27	<.28	<.79
2	03MW0054B	8-12-1999	Diffusion	<.29	<.21	<.29	<.27	<.27	<.28	<.79
		8-12-1999	Pumped	<.29	<.21	<.29	<.27	<.27	1.01	<.79
3	03MW0064	8-16-1999	Diffusion	<.29	<.21	<.29	<.27	<.27	<.28	<.79
		8-16-1999	Pumped	<.29	<.21	<.29	<.27	<.27	<.28	<.79
4	03MW0214B	8-12-1999	Diffusion	<.29	<.21	<.29	<.27	<.27	<.28	<.79
		8-12-1999	Pumped	<.29	<.21	<.29	<.27	<.27	<.28	<.79
5	03MW0214F	8-12-1999	Diffusion	<.29	<.21	<.29	<.27	<.27	<.28	<.79
		8-12-1999	Pumped	<.29	<.21	<.29	<.27	<.27	<.28	<.79
	03MW0214F-R	11-12-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	<.486	NA
		11-12-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA
6	03MW2413A	8-16-1999	Diffusion	<.29	<.21	<.29	<.27	<.27	<.28	<.79
		8-16-1999	Pumped	<.29	<.21	<.29	<.27	<.27	<.28	<.79
	03MW2413A-R	11-12-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	<.486	NA
		11-12-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA
7	03MW2413B	11-12-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	<.486	NA
		11-12-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA
8	27MW0023A	8-04-1999	Diffusion	<.26	<.19	<.26	42	<.26	<.26	<.58
		8-04-1999	Pumped	<.26	<.19	<.22	38	<.26	<.26	<.58
	27MW0023A-R	4-06-2000	Diffusion	.58	<.1	<.09	11	<.08	<.1	<.11
		4-06-2000	Pumped	<.07	<.1	<.09	8.3	<.08	<.1	<.11
4-06-2000	Pumped REP	.5	<.1	<.09	8.3	<.08	<.1	<.11		
9	27MW0024A	8-09-1999	Diffusion	1.8	<.19	<.22	<.2	1.7	<.26	<.58
		8-09-1999	Pumped	2.3	<.19	<.22	<.2	2.6	<.26	<.58
10	27MW0026A	8-05-1999	Diffusion	<.13	<.096	<.11	<.1	<.13	<.13	<.29
		8-05-1999	Diffusion REP	<.13	<.096	<.11	<.1	<.13	<.13	<.29
		8-05-1999	Pumped	<.13	<.096	<.11	<.1	<.13	<.13	<.29
		8-05-1999	Pumped REP	<.13	<.096	<.11	<.1	<.13	<.13	<.29
11	27MW0026B	8-05-1999	Diffusion	<.13	<.096	<.11	<.1	<.13	<.13	<.29
		8-05-1999	Pumped	<.26	<.19	<.22	<.200	<.26	<.26	<.58
	27MW0026B-R	4-10-2000	Diffusion	<.07	<.1	.68	<.08	<.08	<.1	<.11
		4-10-2000	Pumped	.5	<.1	<.09	6.2	<.08	.91	<.11
12	27MW0031A	8-06-1999	Diffusion	5.5	<.96	<1.1	6.4	<1.3	<1.3	<2.9
		8-06-1999	Pumped	6	<.96	<1.1	13	<1.3	<1.3	<2.9
	27MW0031A-R	4-07-2000	Diffusion	4.3	<.5	<.45	6	<.4	<.5	<.55
		4-07-2000	Pumped	3.8	<.5	<.45	11	<.4	<.5	<.55
13	27MW0031B	8-09-1999	Diffusion	2.2	<.096	<.11	<.1	<.13	<.13	<.29
		8-09-1999	Pumped	2.9	<.19	<.22	<.2	<.26	<.26	<.58
	27MW0031B-R	4-07-2000	Diffusion	2.2	<.2	<.18	<.16	<.16	<.2	<.22
		4-07-2000	Pumped	2.7	<.2	<.18	<.16	<.16	<.2	<.22

40 Comparison of Diffusion- and Pumped-Sampling Methods to Monitor VOCs in Ground Water, MMR, Cape Cod, MA

Table 1-2. Analytical results for volatile organic compounds detected in six or fewer wells for samples collected by diffusion- and pumped-sampling methods, including wells with two sets of samples collected or with replicate samples collected, Massachusetts Military Reservation, Cape Cod, Massachusetts, July 1999–December 2002.—Continued

[Well ID: See figure 1 for location. All concentrations in micrograms per liter. ID, identifier; NA, not analyzed; R, second sampling event for well; REP, replicate sample; *trans*1,2-DCE, *trans*1,2-dichloroethene; 1,1-DCE, 1,1-dichloroethene; 1,1,2,2-TeCA, 1,1,2,2-tetrachloroethane; 1,1,1-TCA, 1,1,1-trichloroethane; 1,1,2-TCA, 1,1,2-trichloroethane; 1,1-DCA, 1,1-dichloroethane; <, less than the analytical detection limit]

Well ID	Well number	Date diffusion sampler retrieved	Sample type	1,1-DCA	Ethyl benzene	Toluene	Carbon tetra-chloride	Vinyl chloride	Methyl chloride	Xylenes, total
14	27MW0033	8-05-1999	Diffusion	<0.13	<0.096	<0.11	<0.1	<0.13	<0.13	<0.29
		8-05-1999	Pumped	<.13	<.096	<.11	<.1	<.13	<.13	<.29
		8-05-1999	Pumped REP	<.13	<.096	<.11	<.1	<.13	<.13	<.29
15	27MW0037A	8-11-1999	Diffusion	<.13	<.096	<.11	<.1	<.13	<.13	<.29
		8-11-1999	Diffusion REP	<.13	<.096	<.11	<.1	<.13	<.13	<.29
		8-11-1999	Pumped	<.26	<.19	<.22	<.2	<.26	<.26	<.58
	27MW0037A-R	4-04-2000	Diffusion	<.07	<.1	<.09	<.08	<.08	<.1	<.11
		4-04-2000	Pumped	<.14	<.2	<.18	<.16	<.16	<.2	<.22
16	27MW0038A	8-11-1999	Diffusion	<.13	<.096	<.11	<.1	<.13	<.13	<.29
		8-11-1999	Pumped	<.13	<.096	<.11	<.1	<.13	<.13	<.29
17	27MW0046	10-11-1999	Diffusion	<.13	<.096	<.11	<.222	<.13	<.16	<.29
		10-11-1999	Pumped	<.13	<.282	<.197	.64	<.13	<.16	<.29
18	27MW0102A	8-11-1999	Diffusion	1.2	<.096	<.11	<.1	.52	<.13	<.29
		8-11-1999	Diffusion REP	1.2	<.096	<.11	<.1	.56	<.13	<.29
		8-11-1999	Pumped	<.52	<.38	<.44	<.4	<.52	<.52	<1.2
	27MW0102A-R	4-05-2000	Diffusion	<.07	<.1	<.09	<.08	<.08	<.1	<.11
		4-05-2000	Pumped	<.14	<.2	<.18	<.16	<.16	<.2	<.22
19	27MW0102B	8-11-1999	Diffusion	<.13	<.096	<.11	<.1	<.13	<.13	<.29
		8-11-1999	Pumped	<.13	<.096	<.11	<.1	<.13	<.13	<.29
20	27MW0108A	8-05-1999	Diffusion	<.13	<.096	<.11	<.1	<.13	<.13	<.29
		8-05-1999	Pumped	<.52	<.38	<.44	<.4	<.52	<.64	<1.2
	27MW0108A-R	4-05-2000	Diffusion	<.07	<.1	<.09	<.08	<.08	<.1	<.11
		4-05-2000	Pumped	<.28	<.4	<.36	<.32	<.32	<.32	<.44
		4-05-2000	Pumped REP	<.28	<.4	<.36	<.32	<.32	<.32	<.44
21	27MW0108B	8-05-1999	Diffusion	<.13	<.096	<.11	<.1	<.13	<.13	<.29
		8-05-1999	Pumped	<.13	<.096	<.11	<.1	<.13	<.13	<.29
22	36MW0132A	4-18-2000	Diffusion	NA	NA	NA	NA	NA	NA	NA
		4-18-2000	Pumped	NA	NA	NA	NA	NA	NA	NA
23	36MW0132B	4-18-2000	Diffusion	NA	NA	NA	NA	NA	NA	NA
		4-18-2000	Pumped	NA	NA	NA	NA	NA	NA	NA
24	36MW0132C	4-18-2000	Diffusion	NA	NA	NA	NA	NA	NA	NA
		4-18-2000	Pumped	NA	NA	NA	NA	NA	NA	NA
25	90MW0003	9-14-1999	Diffusion	<3.2	<2.4	<2.8	<2.5	<3.2	<3.2	<7.2
		9-14-1999	Pumped	<2.6	<1.9	<2.2	<2	<2.6	<3.2	<5.8
26	90MW0005	9-14-1999	Diffusion	<.13	<.096	<.11	<.1	<.13	<.13	<.29
		9-14-1999	Pumped	<.26	<.19	<.22	<.2	<.26	<.26	<.58
27	90MW0025	9-14-1999	Diffusion	<.13	<.096	<.11	<.1	<.13	<.13	<.29
		9-14-1999	Pumped	<.13	<.096	<.11	<.1	<.13	<.13	<.29
28	90MW0028	9-14-1999	Diffusion	<.13	<.096	<.11	<.1	<.13	<.13	<.29
		9-14-1999	Pumped	<.13	<.096	<.11	<.1	<.13	<.13	<.29

Table 1-2. Analytical results for volatile organic compounds detected in six or fewer wells for samples collected by diffusion- and pumped-sampling methods, including wells with two sets of samples collected or with replicate samples collected, Massachusetts Military Reservation, Cape Cod, Massachusetts, July 1999–December 2002.—Continued

[Well ID: See figure 1 for location. All concentrations in micrograms per liter. ID, identifier; NA, not analyzed; R, second sampling event for well; REP, replicate sample; *trans*1,2-DCE, *trans*1,2-dichloroethene; 1,1-DCE, 1,1-dichloroethene; 1,1,2,2-TeCA, 1,1,2,2-tetrachloroethane; 1,1,1-TCA, 1,1,1-trichloroethane; 1,1,2-TCA, 1,1,2-trichloroethane; 1,1-DCA, 1,1-dichloroethane; <, less than the analytical detection limit]

Well ID	Well number	Date diffusion sampler retrieved	Sample type	1,1-DCA	Ethyl benzene	Toluene	Carbon tetra-chloride	Vinyl chloride	Methyl chloride	Xylenes, total
29	90MW0034	9-14-1999	Diffusion	<0.13	<0.096	<0.11	<0.1	<0.13	<0.13	<0.29
		9-14-1999	Pumped	<.13	<.096	<.11	<.1	<.13	<.13	<.29
30	90MW0040	9-14-1999	Diffusion	<.13	<.096	<.11	<.1	<.13	<.13	<.29
		9-14-1999	Pumped	<.13	<.096	<.11	<.1	<.13	<.13	<.29
31	90MW0041	9-15-1999	Diffusion	<.13	<.096	<.11	<.1	<.13	<.13	<.29
		9-15-1999	Pumped	<.13	<.096	<.11	<.1	<.13	<.13	<.29
32	90MW0050	9-15-1999	Diffusion	<.13	<.096	<.11	<.1	<.13	<.13	<.29
		9-15-1999	Pumped	<.13	<.096	<.11	<.1	<.13	<.13	<.29
33	90MW0053	9-14-1999	Diffusion	<.13	<.096	<.11	<.1	<.13	<.13	<.29
		9-14-1999	Pumped	<.13	<.096	<.11	<.1	<.13	<.13	<.29
34	90WT0013	9-15-1999	Diffusion	<.13	44	18	<1	<1.3	<1.3	350
		9-15-1999	Pumped	<.13	31	8.7	<1	<1.3	<1.3	230
35	FSW 230-0058	7-23-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	<.486	NA
		7-23-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA
36	FSW 230-0068	7-23-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	<.486	NA
		7-23-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA
37	FSW 230-0078	7-23-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	<.486	NA
		7-23-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA
38	FSW 271-0099	10-16-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	<.486	NA
		10-16-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA
	FSW 271-0099-R	12-09-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	<.486	NA
		12-09-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA
39	FSW 271-0114	10-16-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	<.486	NA
		10-16-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA
	FSW 271-0114-R	12-09-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	<.486	NA
		12-09-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA
40	FSW 300-0010	8-01-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	<.486	NA
		8-01-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA
41	FSW 300-0030	8-01-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	<.486	NA
		8-01-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA
42	FSW 300-0050	8-01-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	<.486	NA
		8-01-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA
43	FSW 300-0073	8-01-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	<.486	NA
		8-01-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA
44	FSW 300-0099	8-01-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	<.486	NA
		8-01-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA
45	FSW 300-0118	8-01-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	<.486	NA
		8-01-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA

Table 1-2. Analytical results for volatile organic compounds detected in six or fewer wells for samples collected by diffusion- and pumped-sampling methods, including wells with two sets of samples collected or with replicate samples collected, Massachusetts Military Reservation, Cape Cod, Massachusetts, July 1999–December 2002.—Continued

[Well ID: See figure 1 for location. All concentrations in micrograms per liter. ID, identifier; NA, not analyzed; R, second sampling event for well; REP, replicate sample; *trans*1,2-DCE, *trans*1,2-dichloroethene; 1,1-DCE, 1,1-dichloroethene; 1,1,2,2-TeCA, 1,1,2,2-tetrachloroethane; 1,1,1-TCA, 1,1,1-trichloroethane; 1,1,2-TCA, 1,1,2-trichloroethane; 1,1-DCA, 1,1-dichloroethane; <, less than the analytical detection limit]

Well ID	Well number	Date diffusion sampler retrieved	Sample type	1,1-DCA	Ethyl benzene	Toluene	Carbon tetra-chloride	Vinyl chloride	Methyl chloride	Xylenes, total
46	FSW 300-0138	8-01-2002	Diffusion	<0.156	<0.178	<0.185	<0.618	<0.413	<0.486	NA
		8-01-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA
47	FSW 343-0036	8-07-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	.486	NA
		8-07-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA
48	FSW 343-0057	8-07-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	<.486	NA
		8-07-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA
49	FSW 343-0079	8-07-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	<.486	NA
		8-07-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA
50	FSW 343-0099	8-07-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	<.486	NA
		8-07-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA
51	FSW 343-0114	8-07-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	<.486	NA
		8-07-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA
52	FSW 347-0020	8-08-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	<.486	NA
		8-08-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA
53	FSW 347-0031	8-08-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	<.486	NA
		8-08-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA
54	FSW 347-0038	8-08-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	<.486	NA
		8-08-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA
55	FSW 347-0046	8-08-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	<.486	NA
		8-08-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA
56	FSW 347-0067	8-08-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	<.486	NA
		8-08-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA
57	FSW 347-0101	8-08-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	<.486	NA
		8-08-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA
58	FSW 347-0116	8-08-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	<.486	NA
		8-08-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA
59	FSW 347-0131	8-08-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	<.486	NA
		8-08-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA
60	FSW 347-0145	8-08-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	<.486	NA
		8-08-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA
61	FSW 350-0064	10-11-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	<.486	NA
		10-11-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA
	FSW 350-0064-R	12-09-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	<.486	NA
		12-09-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA
62	FSW 350-0110	10-11-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	<.486	NA
		10-11-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA
	FSW 350-0110-R	12-09-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	<.486	NA
		12-09-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA

Table 1-2. Analytical results for volatile organic compounds detected in six or fewer wells for samples collected by diffusion- and pumped-sampling methods, including wells with two sets of samples collected or with replicate samples collected, Massachusetts Military Reservation, Cape Cod, Massachusetts, July 1999–December 2002.—Continued

[Well ID: See figure 1 for location. All concentrations in micrograms per liter. ID, identifier; NA, not analyzed; R, second sampling event for well; REP, replicate sample; *trans*1,2-DCE, *trans*1,2-dichloroethene; 1,1-DCE, 1,1-dichloroethene; 1,1,2,2-TeCA, 1,1,2,2-tetrachloroethane; 1,1,1-TCA, 1,1,1-trichloroethane; 1,1,2-TCA, 1,1,2-trichloroethane; 1,1-DCA, 1,1-dichloroethane; <, less than the analytical detection limit]

Well ID	Well number	Date diffusion sampler retrieved	Sample type	1,1-DCA	Ethyl benzene	Toluene	Carbon tetra-chloride	Vinyl chloride	Methyl chloride	Xylenes, total
63	FSW 375-0055	10-24-2002	Diffusion	<0.156	<0.178	<0.185	<0.618	<0.413	<0.486	NA
		10-24-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA
	FSW 375-0055-R	12-09-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	<.486	NA
		12-09-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA
64	FSW 375-0071	10-24-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	<.486	NA
		10-24-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA
	FSW 375-0071-R	12-09-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	<.486	NA
		12-09-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA
65	FSW 383-0040	8-22-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	<.486	NA
		8-22-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA
66	FSW 383-0061	8-22-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	<.486	NA
		8-22-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA
67	FSW 383-0082	8-22-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	<.486	NA
		8-22-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA
68	FSW 383-0106	8-22-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	<.486	NA
		8-22-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA
69	FSW 424-0020	8-06-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	<.486	NA
		8-06-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA
70	FSW 424-0089	8-06-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	<.486	NA
		8-06-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA
71	FSW 424-0144	8-06-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	<.486	NA
		8-06-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA
72	FSW 424-0183	8-06-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	<.486	NA
		8-06-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA
73	FSW 577-0061	8-14-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	<.486	NA
		8-14-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA
74	FSW 577-0071	8-14-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	<.486	NA
		8-14-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA
75	FSW 577-0081	8-14-2002	Diffusion	<.156	<.17	<.185	<.618	<.413	<.486	NA
		8-14-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA
76	FSW 577-0097	8-14-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	<.486	NA
		8-14-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA
77	SDW 316-0051	8-20-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	<.486	NA
		8-20-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA
78	SDW 316-0066	8-20-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	<.486	NA
		8-20-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA

Table 1-2. Analytical results for volatile organic compounds detected in six or fewer wells for samples collected by diffusion- and pumped-sampling methods, including wells with two sets of samples collected or with replicate samples collected, Massachusetts Military Reservation, Cape Cod, Massachusetts, July 1999–December 2002.—Continued

[Well ID: See figure 1 for location. All concentrations in micrograms per liter. ID, identifier; NA, not analyzed; R, second sampling event for well; REP, replicate sample; *trans*1,2-DCE, *trans*1,2-dichloroethene; 1,1-DCE, 1,1-dichloroethene; 1,1,2,2-TeCA, 1,1,2,2-tetrachloroethane; 1,1,1-TCA, 1,1,1-trichloroethane; 1,1,2-TCA, 1,1,2-trichloroethane; 1,1-DCA, 1,1-dichloroethane; <, less than the analytical detection limit]

Well ID	Well number	Date diffusion sampler retrieved	Sample type	1,1-DCA	Ethyl benzene	Toluene	Carbon tetra-chloride	Vinyl chloride	Methyl chloride	Xylenes, total
79	SDW 316-0082	8-20-2002	Diffusion	<0.156	<0.178	<0.185	<0.618	<0.413	<0.486	NA
		8-20-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA
80	SDW 316-0100	8-20-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	<.486	NA
		8-20-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA
81	SDW 423-0058	8-21-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	<.486	NA
		8-21-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA
82	SDW 438-0041	8-13-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	<.486	NA
		8-13-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA
83	SDW 440-0078	8-13-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	<.486	NA
		8-13-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA
84	SDW 469-0036	8-06-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	<.486	NA
		8-06-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA
85	SDW 469-0051	8-06-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	<.486	NA
		8-06-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA
86	SDW 469-0066	8-06-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	<.486	NA
		8-06-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA
87	SDW 500-0060	8-21-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	<.486	NA
		8-21-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA
88	SDW 500-0070	8-21-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	<.486	NA
		8-21-2002	Pumped	<.156	<.17	<.185	<.618	<.413	<.486	NA
89	SDW 500-0080	8-21-2002	Diffusion	<.156	<.178	<.185	<.618	<.413	<.486	NA
		8-21-2002	Pumped	<.156	<.178	<.185	<.618	<.413	<.486	NA

Table 1-3. Total volatile organic compound concentrations by well with two sets of samples collected or with replicate samples collected, Massachusetts Military Reservation, Cape Cod, Massachusetts, July 1999–December 2002.

[Well ID: See figure 1 for location. All concentrations are in micrograms per liter. Total volatile organic compound concentrations were calculated by assigning a zero value to all concentrations below the analytical detection limit. ID, identifier; ND, no volatile organic compounds detected; R, second sampling event for well; REP, replicate sample; VOCs, volatile organic compound]

Well ID	Well number	Date diffusion sampler retrieved	Sample type	Total VOCs detected	Total VOCs used in analysis
1	03MW0054A	8-12-1999	Diffusion	270.21	270.21
		8-12-1999	Pumped	262.37	262.37
2	03MW0054B	8-12-1999	Diffusion	ND	0
		8-12-1999	Pumped	1.01	1.01
3	03MW0064	8-16-1999	Diffusion	16.7	16.7
		8-16-1999	Pumped	19.7	19.7
4	03MW0214B	8-12-1999	Diffusion	278.24	278.24
		8-12-1999	Pumped	1,011.51	1,011.51
5	03MW0214F	8-12-1999	Diffusion	256.62	256.62
		8-12-1999	Pumped	328.711	328.711
	03MW0214F-R	11-12-2002	Diffusion	3.03	3.03
		11-12-2002	Pumped	3.55	3.55
6	03MW2413A	8-16-1999	Diffusion	38.6	38.6
		8-16-1999	Pumped	160	160
	03MW2413A-R	11-12-2002	Diffusion	.53	.53
		11-12-2002	Pumped	25.92	25.92
7	03MW2413B	11-12-2002	Diffusion	20.82	20.82
		11-12-2002	Pumped	91.16	91.16
8	27MW0023A	8-04-1999	Diffusion	70.7	70.7
		8-04-1999	Pumped	67.6	67.6
	27MW0023A-R	4-06-2000	Diffusion	23.42	23.42
		4-06-2000	Pumped	17.92	17.92
9	27MW0024A	8-09-1999	Diffusion	34.4	34.4
		8-09-1999	Pumped	47.06	47.06
10	27MW0026A	8-05-1999	Diffusion	3.65	3.65
		8-05-1999	Diffusion REP	3.71	3.71
		8-05-1999	Pumped	6.18	6.18
		8-05-1999	Pumped REP	6.65	6.65
11	27MW0026B	8-05-1999	Diffusion	6	6
		8-05-1999	Pumped	45.1	45.1
		27MW0026B-R	4-10-2000	Diffusion	9.98
12	27MW0031A	8-06-1999	Diffusion	221.9	221.9
		8-06-1999	Pumped	238	238
13	27MW0031B	4-07-2000	Diffusion	163.7	163.7
		4-07-2000	Pumped	158.7	158.7
13	27MW0031B-R	8-09-1999	Diffusion	41.81	41.81
		8-09-1999	Pumped	75.3	75.3
		4-07-2000	Diffusion	57.1	57.1
		4-07-2000	Pumped	66.6	66.6

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Table 1-3. Total volatile organic compound concentrations by well with two sets of samples collected or with replicate samples collected, Massachusetts Military Reservation, Cape Cod, Massachusetts, July 1999–December 2002.—Continued

[Well ID: See figure 1 for location. All concentrations are in micrograms per liter. Total volatile organic compound concentrations were calculated by assigning a zero value to all concentrations below the analytical detection limit. ID, identifier; ND, no volatile organic compounds detected; R, second sampling event for well; REP, replicate sample; VOCs, volatile organic compound]

Well ID	Well number	Date diffusion sampler retrieved	Sample type	Total VOCs detected	Total VOCs used in analysis
14	27MW0033	8-05-1999	Diffusion	ND	0
		8-05-1999	Pumped	6	6
		8-05-1999	Pumped REP	5.7	5.7
15	27MW0037A	8-11-1999	Diffusion	28.81	28.81
		8-11-1999	Diffusion REP	29.39	29.39
		8-11-1999	Pumped	49.9	49.9
	27MW0037A-R	4-04-2000	Diffusion	23.5	23.5
		4-04-2000	Pumped	36.5	36.5
16	27MW0038A	8-11-1999	Diffusion	ND	0
		8-11-1999	Pumped	5.49	5.49
17	27MW0046	10-11-1999	Diffusion	5.86	5.86
		10-11-1999	Pumped	6.75	6.75
18	27MW0102A	8-11-1999	Diffusion	34.78	34.78
		8-11-1999	Diffusion REP	32.91	32.91
		8-11-1999	Pumped	76.5	76.5
	27MW0102A-R	4-05-2000	Diffusion	34.3	34.3
		4-05-2000	Pumped	65.8	65.8
19	27MW0102B	8-11-1999	Diffusion	ND	0
		8-11-1999	Pumped	ND	0
20	27MW0108A	8-05-1999	Diffusion	37.29	37.29
		8-05-1999	Pumped	86.2	86.2
	27MW0108A-R	4-05-2000	Diffusion	29.71	29.71
		4-05-2000	Pumped	46.2	46.2
		4-05-2000	Pumped REP	47.2	47.2
21	27MW0108B	8-05-1999	Diffusion	.9	.9
		8-05-1999	Pumped	.92	.92
22	36MW0132A	4-18-2000	Diffusion	3.33	3.33
		4-18-2000	Pumped	3.73	3.73
23	36MW0132B	4-18-2000	Diffusion	6.14	6.14
		4-18-2000	Pumped	6.78	6.78
24	36MW0132C	4-18-2000	Diffusion	4.56	4.56
		4-18-2000	Pumped	4.56	4.56
25	90MW0003	9-14-1999	Diffusion	254.28	254.28
		9-14-1999	Pumped	310	310
26	90MW0005	9-14-1999	Diffusion	1.5	1.5
		9-14-1999	Pumped	43	43
27	90MW0025	9-14-1999	Diffusion	1.7	1.7
		9-14-1999	Pumped	1.4	1.4
28	90MW0028	9-14-1999	Diffusion	1.2	1.2
		9-14-1999	Pumped	1.3	1.3

Table 1-3. Total volatile organic compound concentrations by well with two sets of samples collected or with replicate samples collected, Massachusetts Military Reservation, Cape Cod, Massachusetts, July 1999–December 2002.—Continued

[Well ID: See figure 1 for location. All concentrations are in micrograms per liter. Total volatile organic compound concentrations were calculated by assigning a zero value to all concentrations below the analytical detection limit. ID, identifier; ND, no volatile organic compounds detected; R, second sampling event for well; REP, replicate sample; VOCs, volatile organic compound]

Well ID	Well number	Date diffusion sampler retrieved	Sample type	Total VOCs detected	Total VOCs used in analysis
29	90MW0034	9-14-1999	Diffusion	ND	0
		9-14-1999	Pumped	ND	0
30	90MW0040	9-14-1999	Diffusion	3.3	3.3
		9-14-1999	Pumped	7	7
31	90MW0041	9-15-1999	Diffusion	ND	0
		9-15-1999	Pumped	ND	0
32	90MW0050	9-15-1999	Diffusion	1	1
		9-15-1999	Pumped	.91	.91
33	90MW0053	9-14-1999	Diffusion	1.97	1.97
		9-14-1999	Pumped	3.07	3.07
34	90WT0013	9-15-1999	Diffusion	412	412
		9-15-1999	Pumped	269.7	269.7
35	FSW 230-0058	7-23-2002	Diffusion	3.54	3.54
		7-23-2002	Pumped	3.65	3.65
36	FSW 230-0068	7-23-2002	Diffusion	3.99	3.99
		7-23-2002	Pumped	3.48	3.48
37	FSW 230-0078	7-23-2002	Diffusion	1.3	1.3
		7-23-2002	Pumped	1.36	1.36
38	FSW 271-0099	10-16-2002	Diffusion	4.78	4.78
		10-16-2002	Pumped	5.3	5.3
	FSW 271-0099-R	12-09-2002	Diffusion	4.68	4.68
		12-09-2002	Pumped	6.16	6.16
39	FSW 271-0114	10-16-2002	Diffusion	4.06	4.06
		10-16-2002	Pumped	6.02	6.02
	FSW 271-0114-R	12-09-2002	Diffusion	5.51	5.51
		12-09-2002	Pumped	6.02	6.02
40	FSW 300-0010	8-01-2002	Diffusion	.67	.67
		8-01-2002	Pumped	.88	.88
41	FSW 300-0030	8-01-2002	Diffusion	8.69	8.69
		8-01-2002	Pumped	7.8	7.8
42	FSW 300-0050	8-01-2002	Diffusion	ND	0
		8-01-2002	Pumped	ND	0
43	FSW 300-0073	8-01-2002	Diffusion	ND	0
		8-01-2002	Pumped	ND	0
44	FSW 300-0099	8-01-2002	Diffusion	ND	0
		8-01-2002	Pumped	ND	0
45	FSW 300-0118	8-01-2002	Diffusion	ND	0
		8-01-2002	Pumped	ND	0
46	FSW 300-0138	8-01-2002	Diffusion	ND	0
		8-01-2002	Pumped	ND	0

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Table 1-3. Total volatile organic compound concentrations by well with two sets of samples collected or with replicate samples collected, Massachusetts Military Reservation, Cape Cod, Massachusetts, July 1999–December 2002.—Continued

[Well ID: See figure 1 for location. All concentrations are in micrograms per liter. Total volatile organic compound concentrations were calculated by assigning a zero value to all concentrations below the analytical detection limit. ID, identifier; ND, no volatile organic compounds detected; R, second sampling event for well; REP, replicate sample; VOCs, volatile organic compound]

Well ID	Well number	Date diffusion sampler retrieved	Sample type	Total VOCs detected	Total VOCs used in analysis
47	FSW 343-0036	8-07-2002	Diffusion	1.4	1.4
		8-07-2002	Pumped	1.36	1.36
48	FSW 343-0057	8-07-2002	Diffusion	18.44	18.44
		8-07-2002	Pumped	18.43	18.43
49	FSW 343-0079	8-07-2002	Diffusion	ND	0
		8-07-2002	Pumped	ND	0
50	FSW 343-0099	8-07-2002	Diffusion	ND	0
		8-07-2002	Pumped	ND	0
51	FSW 343-0114	8-07-2002	Diffusion	ND	0
		8-07-2002	Pumped	ND	0
52	FSW 347-0020	8-08-2002	Diffusion	ND	0
		8-08-2002	Pumped	ND	0
53	FSW 347-0031	8-08-2002	Diffusion	13.39	13.39
		8-08-2002	Pumped	14.59	14.59
54	FSW 347-0038	8-08-2002	Diffusion	10.55	10.55
		8-08-2002	Pumped	12.41	12.41
55	FSW 347-0046	8-08-2002	Diffusion	2.6	2.6
		8-08-2002	Pumped	2.52	2.52
56	FSW 347-0067	8-08-2002	Diffusion	ND	0
		8-08-2002	Pumped	ND	0
57	FSW 347-0101	8-08-2002	Diffusion	ND	0
		8-08-2002	Pumped	ND	0
58	FSW 347-0116	8-08-2002	Diffusion	ND	0
		8-08-2002	Pumped	ND	0
59	FSW 347-0131	8-08-2002	Diffusion	ND	0
		8-08-2002	Pumped	ND	0
60	FSW 347-0145	8-08-2002	Diffusion	ND	0
		8-08-2002	Pumped	ND	0
61	FSW 350-0064	10-11-2002	Diffusion	7.74	7.74
		10-11-2002	Pumped	8.1	8.1
	FSW 350-0064-R	12-09-2002	Diffusion	8.21	8.21
		12-09-2002	Pumped	8.3	8.3
62	FSW 350-0110	10-11-2002	Diffusion	2.79	2.79
		10-11-2002	Pumped	13.1	13.1
	FSW 350-0110-R	12-09-2002	Diffusion	4.64	4.64
		12-09-2002	Pumped	16.61	16.61
63	FSW 375-0055	10-24-2002	Diffusion	11.25	11.25
		10-24-2002	Pumped	16.58	16.58
	FSW 375-0055-R	12-09-2002	Diffusion	17.92	17.92
		12-09-2002	Pumped	18.49	18.49

Table 1-3. Total volatile organic compound concentrations by well with two sets of samples collected or with replicate samples collected, Massachusetts Military Reservation, Cape Cod, Massachusetts, July 1999–December 2002.—Continued

[Well ID: See figure 1 for location. All concentrations are in micrograms per liter. Total volatile organic compound concentrations were calculated by assigning a zero value to all concentrations below the analytical detection limit. ID, identifier; ND, no volatile organic compounds detected; R, second sampling event for well; REP, replicate sample; VOCs, volatile organic compound]

Well ID	Well number	Date diffusion sampler retrieved	Sample type	Total VOCs detected	Total VOCs used in analysis
64	FSW 375-0071	10-24-2002	Diffusion	2.72	2.72
		10-24-2002	Pumped	4.85	4.85
	FSW 375-0071-R	12-09-2002	Diffusion	6.72	6.72
		12-09-2002	Pumped	5.99	5.99
65	FSW 383-0040	8-22-2002	Diffusion	3.14	3.14
		8-22-2002	Pumped	3.06	3.06
66	FSW 383-0061	8-22-2002	Diffusion	.81	.81
		8-22-2002	Pumped	.47	.47
67	FSW 383-0082	8-22-2002	Diffusion	ND	0
		8-22-2002	Pumped	ND	0
68	FSW 383-0106	8-22-2002	Diffusion	ND	0
		8-22-2002	Pumped	ND	0
69	FSW 424-0020	8-06-2002	Diffusion	ND	0
		8-06-2002	Pumped	ND	0
70	FSW 424-0089	8-06-2002	Diffusion	ND	0
		8-06-2002	Pumped	ND	0
71	FSW 424-0144	8-06-2002	Diffusion	ND	0
		8-06-2002	Pumped	ND	0
72	FSW 424-0183	8-06-2002	Diffusion	.52	.52
		8-06-2002	Pumped	ND	0
73	FSW 577-0061	8-14-2002	Diffusion	.92	.92
		8-14-2002	Pumped	1.92	1.92
74	FSW 577-0071	8-14-2002	Diffusion	4.09	4.09
		8-14-2002	Pumped	3.78	3.78
75	FSW 577-0081	8-14-2002	Diffusion	1.02	1.02
		8-14-2002	Pumped	1.1	1.1
76	FSW 577-0097	8-14-2002	Diffusion	ND	0
		8-14-2002	Pumped	ND	0
77	SDW 316-0051	8-20-2002	Diffusion	ND	0
		8-20-2002	Pumped	ND	0
78	SDW 316-0066	8-20-2002	Diffusion	1.22	1.22
		8-20-2002	Pumped	1.48	1.48
79	SDW 316-0082	8-20-2002	Diffusion	5.13	5.13
		8-20-2002	Pumped	6.57	6.57
80	SDW 316-0100	8-20-2002	Diffusion	ND	0
		8-20-2002	Pumped	ND	0
81	SDW 423-0058	8-21-2002	Diffusion	2.13	2.13
		8-21-2002	Pumped	1.57	1.57
82	SDW 438-0041	8-13-2002	Diffusion	ND	0
		8-13-2002	Pumped	1.31	1.31

Table 1-3. Total volatile organic compound concentrations by well with two sets of samples collected or with replicate samples collected, Massachusetts Military Reservation, Cape Cod, Massachusetts, July 1999–December 2002.—Continued

[Well ID: See figure 1 for location. All concentrations are in micrograms per liter. Total volatile organic compound concentrations were calculated by assigning a zero value to all concentrations below the analytical detection limit. ID, identifier; ND, no volatile organic compounds detected; R, second sampling event for well; REP, replicate sample; VOCs, volatile organic compound]

Well ID	Well number	Date diffusion sampler retrieved	Sample type	Total VOCs detected	Total VOCs used in analysis
83	SDW 440-0078	8-13-2002	Diffusion	ND	0
		8-13-2002	Pumped	ND	0
84	SDW 469-0036	8-06-2002	Diffusion	ND	0
		8-06-2002	Pumped	ND	0
85	SDW 469-0051	8-06-2002	Diffusion	2.58	2.58
		8-06-2002	Pumped	3.02	3.02
86	SDW 469-0066	8-06-2002	Diffusion	ND	0
		8-06-2002	Pumped	ND	0
87	SDW 500-0060	8-21-2002	Diffusion	ND	0
		8-21-2002	Pumped	ND	0
88	SDW 500-0070	8-21-2002	Diffusion	ND	0
		8-21-2002	Pumped	ND	0
89	SDW 500-0080	8-21-2002	Diffusion	ND	0
		8-21-2002	Pumped	ND	0

Table 1-4. Analytical results for volatile organic compounds detected in more than six wells for samples collected for quality assurance, Massachusetts Military Reservation, Cape Cod, Massachusetts, August 1999–December 2002.

[All concentrations in micrograms per liter. *cis*1,2-DCE, *cis*1,2-dichloroethene; EDB, 1,2-dibromoethane; PCE, tetrachloroethene; TCE, trichloroethene; <, less than the analytical detection limit]

Quality assurance sample type	Date collected	PCE	TCE	<i>cis</i> 1,2-DCE	Chloroform	EDB	1,2-Dichlorobenzene
Equipment blank	8-05-1999	<0.1	<0.12	<0.13	<0.11	<0.11	<0.12
	9-14-1999	<.1	<.12	<.13	<.11	<.11	<.12
	4-07-2000	<.11	<.09	<.08	<.08	<.08	<.08
	12-17-2002	<.146	<.138	<.347	<.336	<.493	<.305
Trip blank	8-04-1999	<.1	<.12	<.13	<.11	<.11	<.12
	8-05-1999	<.1	<.12	<.13	<.11	<.11	<.12
	8-06-1999	<.1	<.12	<.13	<.11	<.11	<.12
	8-09-1999	<.1	<.12	<.13	<.11	<.11	<.12
	8-11-1999	<.1	<.12	<.13	<.11	<.11	<.12
	8-12-1999	<.22	<.35	<.24	<.29	<.29	<.24
	8-16-1999	<.22	<.35	<.24	<.29	<.29	<.24
	9-14-1999	<.1	<.12	<.13	<.11	<.11	<.12
	10-11-1999	<.1	<.12	<.13	<.11	<.11	<.12
	3-31-2000	<.11	<.09	<.08	<.08	<.08	<.08
	4-04-2000	<.11	<.09	<.08	<.08	<.08	<.08
	4-05-2000	<.11	<.09	<.08	<.08	<.08	<.08
	4-06-2000	<.11	<.09	<.08	<.08	<.08	<.08
	4-07-2000	<.11	<.09	<.08	<.08	<.08	<.08
	4-10-2000	<.11	<.09	<.08	<.08	<.08	<.08
	10-11-2002	<.146	<.138	<.347	<.336	<.336	<.305
	10-16-2002	<.146	<.138	<.347	<.336	<.336	<.305
	10-24-2002	<.146	<.138	<.347	<.336	<.336	<.305
	11-12-2002	<.146	<.138	<.347	<.336	<.336	<.305
	8-13-2002	<.146	<.138	<.347	<.336	<.493	<.305
8-20-2002	<.146	<.138	<.347	<.336	<.493	<.305	
8-22-2002	<.146	<.138	<.347	<.336	<.493	<.305	
12-17-2002	<.146	<.138	<.347	<.336	<.493	<.305	
Water blank	8-07-2002	<.146	<.138	<.347	<.336	<.493	<.305

Table 1-5. Analytical results for volatile organic compounds detected in six or fewer wells for samples collected for quality assurance, Massachusetts Military Reservation, Cape Cod, Massachusetts, August 1999–December 2002.

[All concentrations in micrograms per liter. 1,1-DCE, 1,1-dichloroethene; 1,1,2,2-TeCA, 1,1,2,2-tetrachloroethane; 1,1,1-TCA, 1,1,1-trichloroethane; 1,1,2-TCA, 1,1,2-trichloroethane; 1,1-DCA, 1,1-dichloroethane; *trans*1,2-DCE, *trans*1,2-dichloroethene; <, less than the analytical detection limit; NA, not analyzed]

Quality assurance sample type	Date collected	<i>trans</i> 1,2-DCE	1,1-DCE	Benzene	1,4-Dichloro-benzene	1,1,2,2-TeCA	1,1,1-TCA	1,1,2-TCA
Equipment blank	8-05-1999	<0.12	<0.13	<0.099	<.097	<0.14	<0.094	<0.098
	9-14-1999	<.12	<.13	<.099	<.097	<.14	<.094	<.098
	4-07-2000	<.09	<.09	<.11	<.1	<.13	<.09	<.11
	12-17-2002	<.271	<.226	<.216	<.38	<.477	<.528	<.4
Trip blank	8-04-1999	<.12	<.13	<.099	<.097	<.14	<.094	<.098
	8-05-1999	<.12	<.13	<.099	<.097	<.14	<.094	<.098
	8-06-1999	<.12	<.13	<.099	<.097	<.14	<.094	<.098
	8-09-1999	<.12	<.13	<.099	<.097	<.14	<.094	<.098
	8-11-1999	<.12	<.13	<.099	<.097	<.14	<.094	<.098
	8-12-1999	<.24	<.3	<.28	<.26	<.32	<.23	<.33
	8-16-1999	<.24	<.3	<.28	<.26	<.32	<.23	<.33
	9-14-1999	<.12	<.13	<.099	<.097	<.14	<.094	<.098
	10-11-1999	<.12	<.13	<.099	<.097	<.14	<.094	<.098
	3-31-2000	<.09	<.09	<.11	<.1	<.13	<.09	<.11
	4-04-2000	<.09	<.09	<.11	<.1	<.13	<.09	<.11
	4-05-2000	<.09	<.09	<.11	<.1	<.13	<.09	<.11
	4-06-2000	<.09	<.09	<.11	<.1	<.13	<.09	<.11
	4-07-2000	<.09	<.09	<.11	<.1	<.13	<.09	<.11
	4-10-2000	<.09	<.09	<.11	<.1	<.13	<.09	<.11
	10-11-2002	<.271	<.226	<.216	<.38	<.477	<.528	<.4
	10-16-2002	<.271	<.226	<.216	<.38	<.477	<.528	<.4
	10-24-2002	<.271	<.226	<.216	<.38	<.477	<.528	<.4
	11-12-2002	<.271	<.226	<.216	<.38	<.477	<.528	<.4
	8-13-2002	<.271	<.226	<.216	<.38	<.477	<.528	<.4
8-20-2002	<.271	<.226	<.216	<.38	<.477	<.528	<.4	
8-22-2002	<.271	<.226	<.216	<.38	<.477	<.528	<.4	
12-17-2002	<.271	<.226	<.216	<.38	<.477	<.528	<.4	
Water blank	8-07-2002	<.271	<.226	<.216	<.38	<.477	<.528	<.4

Table 1-5. Analytical results for volatile organic compounds detected in six or fewer wells for samples collected for quality assurance, Massachusetts Military Reservation, Cape Cod, Massachusetts, August 1999–December 2002.—Continued

[All concentrations in micrograms per liter. 1,1-DCE, 1,1-dichloroethene; 1,1,2,2-TeCA, 1,1,2,2-tetrachloroethane; 1,1,1-TCA, 1,1,1-trichloroethane; 1,1,2-TCA, 1,1,2-trichloroethane; 1,1-DCA, 1,1-dichloroethane; *trans*1,2-DCE, *trans*1,2-dichloroethene; <, less than the detection limit; NA, concentration is less than the analytical detection limit]

Quality assurance sample type	Date collected	1,1-DCA	Ethylbenzene	Toluene	Carbon tetra-chloride	Vinyl chloride	Methyl chloride	Xylenes, total
Equipment blank	8-05-1999	<0.13	<0.096	<0.11	<0.1	<0.13	<0.16	<0.29
	9-14-1999	<.13	<.096	<.11	<.1	<.13	<.16	NA
	4-07-2000	<.07	<.1	<.09	<.08	<.08	<.08	<.11
	12-17-2002	<.156	<.178	<.185	<.618	<.413	<.429	NA
Trip blank	8-04-1999	<.13	<.096	<.11	<.1	<.13	<.16	<.29
	8-05-1999	<.13	<.096	<.11	<.1	<.13	<.16	<.29
	8-06-1999	<.13	<.096	<.11	<.1	<.13	<.16	<.29
	8-09-1999	<.13	<.096	<.11	<.1	<.13	<.16	<.29
	8-11-1999	<.13	<.096	<.11	<.1	<.13	<.16	<.29
	8-12-1999	<.29	<.21	<.29	<.27	<.27	<.28	<.79
	8-16-1999	<.29	<.21	<.29	<.27	<.27	<.28	<.79
	9-14-1999	<.13	<.096	<.11	<.1	<.13	<.16	<.29
	10-11-1999	<.13	<.096	<.11	<.1	<.13	<.16	<.29
	3-31-2000	<.07	<.1	<.09	<.08	<.08	<.08	<.11
	4-04-2000	<.07	<.1	<.09	<.08	<.08	<.08	<.11
	4-05-2000	<.07	<.1	<.09	<.08	<.08	<.08	<.11
	4-06-2000	<.07	<.1	<.09	<.08	<.08	<.08	<.11
	4-07-2000	<.07	<.1	<.09	<.08	<.08	<.08	<.11
	4-10-2000	<.07	<.1	<.09	<.08	<.08	<.08	<.11
	10-11-2002	<.156	<.178	<.185	<.618	<.413	<.429	NA
	10-16-2002	<.156	<.178	<.185	<.618	<.413	<.429	NA
	10-24-2002	<.156	<.178	<.185	<.618	<.413	<.429	NA
	11-12-2002	<.156	<.178	<.185	<.618	<.413	<.429	NA
	8-13-2002	<.156	<.178	<.185	<.618	<.413	<.429	NA
8-20-2002	<.156	<.178	<.185	<.618	<.413	<.429	NA	
8-22-2002	<.156	<.178	<.185	<.618	<.413	<.429	NA	
12-17-2002	<.156	<.178	<.185	<.618	<.413	<.429	NA	
Water blank	8-07-2002	<.156	<.178	<.185	<.618	<.413	<.429	NA

