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Potential for Advection of Volatile Organic Compounds in Ground Water to the Cochato River, Baird & McGuire Superfund Site, Holbrook, Massachusetts, March and April 1998

Water-Resources Investigations Report 98-4257

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Northborough, Massachusetts
1999

U.S. DEPARTMENT OF THE INTERIOR
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(Plate is in pocket)

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CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATIONS

CONVERSION FACTORS

Multiply	By	To obtain
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
foot (ft)	0.3048	meter
foot per day (ft/d)	0.3048	meter per day
gallon per minute (gal/min)	0.06309	liter per second
inch (in.)	25.40	millimeter
mile (mi)	1.609	kilometer
square mile (mi^2)	12.590	square kilometer

Temperature in degrees Fahrenheit (°F) can be converted to degrees Celsius (°C) as follows: °C=5/9(°F-32)

VERTICAL DATUM

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

ABBREVIATIONS

BTEX	benzene, toluene, ethylbenzene, and xylenes
DCE	dichloroethylene
mL	milliliter
PCE	tetrachloroethylene
ppb v	parts per billion by volume
ppm	parts per million
TCE	trichloroethylene
µg/L	micrograms per liter
VOC	volatile organic compound

Potential for Advection of Volatile Organic Compounds in Ground Water to the Cochato River, Baird & McGuire Superfund Site, Holbrook, Massachusetts

By Jennifer G. Savoie, Forest P. Lyford, *and* Scott Clifford

Abstract

In March and April 1998, a network of water-to-vapor diffusion samplers was installed along the Cochato River at the Baird & McGuire Superfund Site in Holbrook, Massachusetts, where a plume of volatile organic compounds (VOCs) is present in ground water. The purpose of installing the sampler network was to determine if VOCs were present in river-bottom sediments while a ground-water extraction system was operating and after the system had been shut down for two weeks. Water-to-water diffusion samplers placed at selected locations provided supplemental information about concentrations of VOCs in pore water in the river-bottom sediments. Water levels in piezometers and river stage were measured concurrently to determine if ground water was discharging to the river.

Benzene, toluene, ethylbenzene and xylenes (BTEX compounds) were detected in water-to-vapor and water-to-water diffusion samplers located in the area where the plume is known to pass beneath the river for both pumping and non-pumping conditions. Concentrations of total BTEX compounds in water-to-vapor diffusion samplers ranged from non-detect upriver and downriver from the plume area to greater than 200 parts per million by volume in the plume area. Concentrations of total BTEX compounds were not significantly different for pumping than for non-pumping conditions. Concentrations of total BTEX compounds in water-to-water diffusion samplers ranged from non-detect to 680 micrograms per liter. The limited number of water-to-water diffusion samplers did not indicate that concentrations were higher for pumping or non-pumping conditions. Trichloroethylene and tetrachloroethylene also were detected in water-to-vapor diffusion samplers downriver from the area where the BTEX compounds were detected. Water levels in four piezometers were consistently higher than the river stage, indicating an upward hydraulic gradient and ground-water discharge to the river. The concentrations of VOCs in river-bottom sediments and the upward hydraulic gradients observed indicate that contaminants from the Baird & McGuire ground-water plume were discharging to the Cochato River during the study period for both pumping and non-pumping conditions.

INTRODUCTION

A plume of ground water containing volatile and semi-volatile organic compounds at the Baird & McGuire Superfund Site in Holbrook, Mass., extends eastward from a former chemical processing plant toward and beneath the Cochato River (pl. 1). The Cochato River was once used to supply water to the towns of Holbrook, Randolph, and Braintree, but use of this source ceased after contaminated ground water near the river was discovered in 1983. In 1993, a ground-water extraction system began operation to remove contaminants and limit the discharge of contaminants to the river. From 1995 to 1997, contaminated sediments were excavated from the river and incinerated to remove the contaminants. The excavated river sediments were replaced with a layer of organic peat-like material about 1 ft thick to facilitate adsorption of contaminants below the river bottom and to limit contaminant seepage into the river. The organic material was covered by a layer of sand and gravel about 1 ft thick (U.S. Environmental Protection Agency, written commun., 1998). Despite the remedial actions, the U.S. Environmental Protection Agency (USEPA) and residents are concerned that problematic contaminant concentrations from the ground-water plume could discharge to the river.

During March and April 1998, the U.S. Geological Survey (USGS), in cooperation with the U.S. Army Corps of Engineers and USEPA, conducted a study at the Baird & McGuire Superfund Site to determine if volatile organic compounds (VOCs) could potentially discharge to the Cochato River. The study was designed to examine conditions during the operation of the ground-water extraction system and while the extraction system was not operating, where the latter represented a possible worst-case condition of a two-week shutdown. During the pumping phase of the study, the ground-water extraction system was pumping at an average rate of 129 gal/min, which is below the target rate of 150 to 200 gal/min (Melissa Taylor, U.S. Environmental Protection Agency, written commun., 1998).

Water-to-vapor and water-to-water diffusion samplers were used to determine if the VOCs were discharging to the river through the river-bottom sediments. Water-to-vapor diffusion samplers are useful to determine the presence, composition, and vapor-phase concentrations of VOCs in pore water of the river-bottom sediments. Vapor-phase concentrations are much higher for the VOCs detected than the corresponding liquid-phase concentrations in the pore water. Water-to-vapor diffusion samplers were chosen as a reconnaisance tool for most of the sampling sites because they are easy to construct, install and retrieve. Water-to-water diffusion samplers were placed in the river-bottom sediments at eight locations to determine liquid-phase concentrations of VOCs in pore water of the river-bottom sediments (pl. 1). Water levels from piezometers placed in the riverbed were compared to river-stage measurements to determine if the river was gaining ground water across the study area and if contaminants could potentially move by advection into the river. Water-to-vapor diffusion samplers also were attached on the outside of the piezometers near the river bottom to determine if VOCs were detectable in the river water. Riverflow was measured at the time samplers were installed and retrieved. This report presents the data collected during the study and discusses the potential for advection of VOCs in ground water into the Cochato River.

STUDY METHODS

A network of water-to-vapor diffusion samplers was chosen as the primary reconnaissance method to determine if contaminants from the Baird & McGuire ground-water plume were discharging to the Cochato River. Water-to-vapor diffusion samplers are inexpensive, easily constructed and deployed. For these reasons, numerous samplers could be installed to define the location of the contaminated zone precisely. The vapor samples were analyzed quickly on site with a field gas chromatograph. While this met the data-quality objectives of the study, only a pre-selected suite of compounds were measured, and the detection limits were higher than could have been achieved using other analytical metods in a laboratory. Water-to-water diffusion samplers also were installed at a few locations to measure the actual liquid-phase concentrations of VOCs in the pore water in the river-bottom sediments. Water-to-water diffusion samplers are more expensive, difficult to construct, and require a more complex laboratory analysis than water-to-vapor diffusion samplers. For these reasons, water-to-water diffusion samplers were deployed only in selected locations. To determine whether contaminated surface water was flowing into the study area from an upriver location, surface-water samples were collected at two locations twice a week by Metcalf & Eddy Services, Inc. Water levels were collected from drive-point piezometers, and river-discharge measurements were made at selected sites to determine if the Cochato River was gaining or losing water across the study area.

Construction of Diffusion Samplers

Diffusion samplers operate on the principle that VOCs will diffuse through a semipermeable membrane, such as polyethylene, until concentrations in air inside the water-to-vapor diffusion samplers or in water inside the water-to-water diffusion samplers reach equilibrium with concentrations of the environment outside the sampler. Methods of construction and some applications of diffusion samplers are described by Vroblesky and Hyde (1997) and Vroblesky and others (1996).

A water-to-vapor diffusion sampler is constructed by placing a 40-mL glass vial in a polyethylene bag. The bag is positioned tightly over the opening of the vial so that an airtight polyethylene membrane is formed, and the bag is secured with a cable tie. The vial and bag are then enclosed in a second polyethylene bag to further protect the sampler from water and sediment. Duplicate samplers are constructed by installing two polyethylene-wrapped vials in one outer bag. Finally, the vapor sampler is attached to a wire survey flag. A water-to-water diffusion sampler is constructed using polyethylene tubing filled with deionized, organic-free water, and sealed by tightly knotting both ends. The water samplers are enclosed in a wire cage which is attached to a wire survey flag.

Installation and Retrieval of Diffusion Samplers

Water-to-vapor diffusion samplers were installed on March 2–4, 1998, in pairs at 120 locations along a 1,500-foot reach of the Cochato River (pl. 1). Samplers were installed in 40 sections on the left and right banks (left and right when looking downriver) and at the center (31 sections only) of the river. Downriver from section 31, the center of the river was too deep to wade safely and samplers were not installed in the center of the channel. Sampling sections were spaced 50 ft apart for distances of 500 ft upriver and downriver from the known extent of the contaminated ground water. For the middle 500-foot reach, where the ground-water plume was known to pass beneath the river, sampling sections were spaced 25 ft apart. In the downriver reach, samplers that were not placed in the center of the river were placed on the left bank between the 50-foot spacings to supplement the coverage in that area of the river.

Water-to-vapor diffusion samplers were installed using one of two methods. Most were installed about 6 to 8 in. into the river-bottom sediments by penetrating the bottom sediments with a narrow-bladed shovel, forcing the shovel forward, and inserting the sampler in the gap that was formed between the shovel and sediment. At about 20 percent of the locations, the river was too deep to use this method. In these locations, a driver method was used in which a plastic pipe outfitted with an inner blocked pipe was driven about 1 ft into the sediment with a hand-held slide hammer. The inner pipe was then removed and the sampler was inserted to the bottom of the outer pipe. Finally, the outer pipe was removed, leaving behind the sampler, and the sediments were allowed to collapse around the sampler. Samplers installed by the driver method were typically about 1 ft into the river-bottom sediments. Water-to-vapor diffusion samplers also were attached to the four piezometers about 1 to 2 in. above the river bottom to determine if VOCs were detectable in the river water. Water-to-water diffusion samplers were installed in pairs at eight locations along the study area. The water samplers were installed about 1 to 3 in. into the river-bottom sediments using the shovel method.

On March 18–19, after samplers had been allowed to equilibrate for two weeks under pumping conditions, one vapor sampler and one water sampler were collected at each location. Vapor samplers were capped and analyzed on site by USEPA personnel. Water samplers were transferred into 40-mL glass vials and preserved with hydrochloric acid. Water samples were sent to the USEPA New England Regional Laboratory for analysis.

On March 30, 1998, the ground-water extraction system was temporarily shut down for two weeks. On April 14–15, 1998, after the remaining samplers had been allowed to equilibrate for two weeks under non-pumping conditions, the remaining vapor and water samplers were collected. Vapor and water samples were processed and analyzed as previously described.

Analysis of Vapor and Water Samples

Vapor samples were analyzed on site for VOCs by USEPA personnel using the USEPA Region I standard air screening method (U.S. Environmental Protection Agency, 1998). Vapor samples were analyzed using Photovac gas chromatographs equipped with 4-foot by 1/8-inch SE-30 columns and photo-ionization detectors. Vapor samples were analyzed within 24 hours after sample collection. Target compounds for the vapor sample analyses on the Photovac gas chromatographs were pre-selected (based on historical data) to be benzene, trichloroethylene, toluene, tetrachloroethylene, chlorobenzene, ethylbenzene, meta/para-xylene, and ortho-xylene. Water samples were analyzed in Lexington, Massachusetts, at the USEPA New England Regional Laboratory using gas chromatograph/mass spectrometer purge and trap, USEPA method 8260B (U.S. Environmental Protection Agency, 1996). The compound list for the laboratory method 8260B contains more compounds than the target compounds for the field vapor analytical method. Several more compounds were detected in the water samples because of the method of analysis. The complete list of VOCs for which analyses were performed on the water samples is shown in table 1.

Installation of Piezometers and River-Discharge Measurements

Drive-point piezometers were installed at four locations along the Cochato River within and near the known extent of the ground-water plume (pl. 1). The piezometers were constructed with a 5-inch long, 1.25-inch diameter, wire-wound stainless-steel screen attached to a 5-foot length of 1.25-inch diameter pipe. The piezometers were driven manually with a hand-held slide hammer about 3 ft into the river-bottom sediments. The piezometers were developed by removing several casing volumes of water using a hand-operated pump. The piezometers at locations HQP-001 and HQP-004 yielded water readily, and ground-water levels recovered quickly during development. The piezometers at locations HQP-002 and HQP-003 were pumped dry and required more development time than the other two; water levels in HQP-002 and HQP-003 recovered slowly as compared to HQP-001 and HQP-004. Ground-water level and river stage were measured four times during the study at each piezometer.

The study included river-discharge measurements at three locations to determine if the Cochato River was gaining flow in the study area (pl. 1). High-discharge conditions and tributary inflow made the estimation of river gains or losses difficult.

Table 1. Volatile organic compounds analyzed and detected in water samples collected from sediments in the Cochato River, Holbrook, Massachusetts, March and April 1998

[Results of compounds detected in water samples are shown in table 2. x, compound detected; --, compound not detected]

Compound name	Compound detected	Compound name	Compound detected
Chloromethane	--	1,1,2,2-Tetrachloroethane	--
Bromomethane	--	Toluene	x
Vinyl Chloride	--	Chlorobenzene	--
Chloroethane	--	Ethylbenzene	x
Methylene Chloride	--	Acrolein	--
Trichlorofluoromethane	--	Acrylonitrile	--
1,1-Dichloroethylene	--	Dichlorobenzene isomers	--
1,1-Dichloroethane	--	1,1,2-Trichloro-1,2,2 trifluoroethane	--
1,2-Dichloroethylene isomers	x	Acetone	x
Chloroform	--	Carbon Disulfide	--
1,2-Dichloroethane	--	2-Butanone (MEK)	--
1,1,1-Trichloroethane	--	Vinyl Acetate	--
Carbon Tetrachloride	--	2-Hexanone	--
Bromodichloromethane	--	4-Methyl-2-Pentanone (MIBK)	--
1,2-Dichloropropane	--	Styrene	--
t-1,3-Dichloropropene	--	Xylenes (total)	x
Trichloroethylene	x	1,2-Dibromoethane (EDB)	--
Dibromochloromethane	--	Tetrahydrofuran	--
c-1,3-Dichloropropene and/or 1,1-Dichloropropene	--	Naphthalene	x
1,1,2-Trichloroethane	--	1,2,4-Trimethylbenzene	x
Benzene	x	1,3,5-Trimethylbenzene	x
2-Chloroethylvinyl ether	--	Isopropylbenzene	x
Bromoform	--	N-Propylbenzene	x
Tetrachloroethylene	--	Para-Isopropyltoluene	x
1,1,1,2-Tetrachloroethane	--		

POTENTIAL FOR ADVECTION OF VOLATILE ORGANIC COMPOUNDS TO THE COCHATO RIVER

VOCs were detected in the river-bottom sediments, and an upward hydraulic gradient from the aquifer to the Cochato River was measured. The combination of the VOCs in the river-bottom sediments and an upward gradient would cause the movement (advection) of VOCs into the river. VOCs were not present in surface-water grab samples collected by Metcalf & Eddy Services, Inc. (M&E) on March 6, 12, 20, and 27, 1998, which indicates that during this period VOCs were not entering the study area from an upstream location. On March 31 and April 3, 1998, surface-water grab samples collected by M&E detected no VOCs with the exception of acetone, which indicates that that surface water may have transported acetone into the study area from an upstream location (Andrew Cunningham, Metcalf and Eddy Services, Inc., written commun., March 1998). This section describes the VOCs that were detected in the river-bottom sediments, water levels in piezometers, river stage, and riverflow data.

Volatile Organic Compounds in Diffusion Samplers

Benzene, toluene, ethylbenzene, meta/para-xylene, and ortho-xylene (BTEX compounds) were detected in water-to-vapor diffusion samples between sections 11 and 26 for the two sets of samples (table 5, at back of report). It is important to note that reported values in table 5 are vapor-phase concentrations, which are much higher for the target VOCs than the corresponding liquid-phase concentrations in the pore water. A few samplers downriver from section 26 also contained low concentrations of BTEX compounds. Highest vapor concentrations were detected in samples installed near the area previously defined with the highest ground-water concentrations. The plume location map was previously defined by sampling conducted in July through September 1997 (J.M. Osborn, Metcalf & Eddy, Inc., written commun., 1998). Graphs showing the concentrations and distributions of contaminants on the left, center, and right banks of the river are shown on plate 1. Vapor concentrations were generally higher on the left bank of the river than in the center and right bank. The highest vapor detection of total BTEX compounds measured on March 18, 1998 (pumping conditions) was 72,200 parts per billion by volume (ppb v) at sampler 15C. The highest vapor detection of total BTEX compounds measured on April 15, 1998 (non-pumping conditions) was 216,000 ppb v at sampler 20L. Mann-Whitney two-sample rank tests of the equality of two population medians (Helsel and Hirsch, 1992; Minitab, Inc., 1997) were performed on the pumping and non-pumping data sets for the left, right, and center locations of the river. The test results indicated that there were no significant differences between medians of the pumping and non-pumping data sets for the BTEX compounds. Large differences in concentrations for some duplicate samples indicate some variability attributable to the sampling method. Some of the variability may have been caused by diffusion through the semipermeable polyethylene membranes to the atmosphere prior to the sample bottle being capped.

Trichloroethylene (TCE) and tetrachloroethylene (PCE) were detected in the water-to-vapor diffusion samples from sections 33 through 40. These detections were mainly downriver from sampling sections where BTEX compounds were detected. The highest vapor concentration of total TCE + PCE measured on March 18, 1998 (pumping conditions), was 1,900 ppb v, at sampler 40L. The highest vapor concentration of total TCE + PCE measured on April 14, 1998 (non-pumping conditions), was 3,000 ppb v at sampler 40aL. Statistical analyses also indicated that there was no significant difference between the pumping and non-pumping data sets for the TCE + PCE compounds. VOCs were not detected in water-to-vapor diffusion samplers placed in the river water at the four piezometers, except at HQP-004, where 252 ppb v of TCE was detected on April 14, 1998 (table 5).

Several BTEX compounds and napthalene were detected in the water-to-water diffusion samples WD-3, WD-4, and WD-5, which were installed near the area previously defined with the highest ground-water concentrations (table 2). Highest concentrations were in sampler WD-5, where total BTEX was 490 µg/L on March 18, 1998, for pumping conditions and 680 µg/L on April 15, 1998, for non-pumping conditions. The compound 1,2-dichloroethylene (DCE) (cis and trans isomers) was detected at 100 µg/L at WD-5, and at 3 µg/L or less at samplers WD-6, -7, and -8. TCE was also detected at sampler WD-8. Acetone was detected in some of the water-to-water diffusion samples collected on April 14, 1998. Acetone also was detected in the associated water blank, trip blank, and laboratory blank. Acetone was detected in the surface water at the site; it is unknown if the acetone detected in the samplers was derived from the site, an upstream location, or the laboratory.

Water Levels, River Stage, and Riverflow

Water-level and river-stage measurements indicate that ground water was discharging to the Cochato River near all piezometers during the study. Piezometers and screen altitudes, water levels, and stage measurements at piezometers in the Cochato River are shown in table 3. The difference between the water-level and river stage was larger at HQP-002 for non-pumping than for pumping conditions, but similar at other piezometers for both conditions. Higher river stages downriver at HQP-002 than upriver at HQP-001 on March 31, 1998, and downriver at HQP-004 than upriver at HQP-003 on March 18, 1998, can be attributed to measurement precision and possibly to changing river stage during the measurement period.

Table 2. Results of analyses for volatile organic compounds in trip blanks, a water blank, and water-to-water diffusion samples collected from sediments in the Cochato River, Holbrook, Massachusetts, March and April 1998

[Locations of samplers are shown on plate 1. na, not applicable; No., number; *, estimated value below the reporting limit; <, not detected or below the reporting limit shown]

Sampler No.	Adjacent vapor-diffusion sampler No.	Date	Benzene (µg/L)	Toluene (µg/L)	Para-Iso-propyl-toluene (µg/L)	Ethyl-benzene (µg/L)	Xylenes, total (µg/L)	1,2,4-Tri-methyl-benzene (µg/L)	1,3,5-Tri-methyl-benzene (µg/L)	Isopropyl-benzene (µg/L)	N-Propyl-benzene (µg/L)	1,2-Di-chloro-ethylene (µg/L)	Trichloro-ethylene (µg/L)	Nap-thalene (µg/L)	Acetone (µg/L)
Reporting limit			**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**10**
WD 1	5C	3/18/98	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<10
WD 1	5C	4/14/98	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	*8
WD 2	8L	3/18/98	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<10
WD 2	8L	4/14/98	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	*4
WD 3	11R	3/18/98	*2	<5	<5	51	15	19	*3	*4	*2	<5	<5	180	<10
WD 3	11R	4/14/98	<5	<5	<5	40	<5	20	<5	<5	<5	<5	<5	500	<10
WD 4	16L	3/18/98	7	10	<5	74	52	10	<5	<5	<5	<5	<5	110	<10
WD 4	16L	4/14/98	<5	<5	<5	29	<5	6	<5	<5	<5	<5	<5	92	29
WD 5	21L	3/18/98	20	<5	30	110	230	77	20	<5	<5	<5	<5	1,800	<10
WD 5	21L	4/14/98	<5	<5	<5	200	400	80	<5	<5	<5	100	<5	1,500	<10
WD 6	28L	3/18/98	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<10
WD 6	28L	4/14/98	*1	<5	<5	<5	<5	<5	<5	<5	<5	*3	<5	*1	*8
WD 7	33aL	3/18/98	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<10
WD 7	33aL	4/14/98	<5	<5	<5	<5	<5	<5	<5	<5	<5	*2	<5	<5	*4
WD 8	36aL	3/18/98	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<10
WD 8	36aL	4/14/98	<5	<5	<5	<5	<5	<5	<5	<5	<5	*1	*2	<5	<10
Trip blank	na	3/18/98	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<10
Trip blank	na	4/13/98	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	25
Water blank	na	5/26/98	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	85

Table 3. Water-levels and river-stage at piezometers in the Cochato River, Holbrook, Massachusetts, March and April 1998

[Locations of piezometers are shown in plate 1. Altitudes are in feet above sea level; No., number; n, non-pumping; p, pumping; --, no measurement available]

Piezometer No.	Altitude, top of piezometer	Altitude, top of screen	Altitude, bottom of screen	Depth to bottom of screen below river bottom (feet)	Date	Pumping conditions	Altitude of water level	Altitude of river stage
HQP-001	120.74	115.49	114.99	3.09	3/04/98	p	119.92	119.50
					3/18/98	p	119.78	119.35
					3/31/98	n	119.93	119.29
					4/14/98	n	119.88	119.21
HQP-002	120.75	115.50	115.00	3.46	3/04/98	p	119.84	119.44
					3/18/98	p	119.77	119.30
					3/31/98	n	120.23	119.35
					4/14/98	n	120.35	119.17
HQP-003	120.39	115.14	114.64	3.33	3/04/98	p	--	119.40
					3/18/98	p	119.77	119.27
					3/31/98	n	119.54	119.19
					4/14/98	n	119.40	119.12
HQP-004	120.43	115.18	114.68	2.97	3/04/98	p	119.72	119.39
					3/18/98	p	119.55	119.30
					3/31/98	n	119.56	119.19
					4/14/98	n	119.51	119.09

Riverflows measured during installation and retrieval of samplers at three locations (pl. 1) are reported to provide information about hydrologic conditions during the study (table 4). River-discharge measurements are rated by the USGS technician at the time the measurements are performed. The river-discharge measurements are rated excellent (within 2 percent of actual discharge), good (5 percent), fair (8 percent), and poor (more than 8 percent). Generally, the measurements for this study are rated good to fair, indicating that the measurements could be in error by as much as 5 to 8 percent. Riverflow at measurement site C (pl. 1) ranged from 23 ft^3/s on March 2, 1998, to about 6 ft^3/s on April 14, 1998. The measurement on March 2, 1998, was made shortly after a large rainstorm when the river was over its banks along some of the study area. Gains in riverflow on this date between sites B and C can be largely attributed to flow from an unnamed tributary that enters the river between measuring sites B and C and (to a lesser extent) to overbank flooding. An apparent riverflow gain of 3.5 ft^3/s between measuring site A and B on March 2, 1998, may also be attributed to over-bank flooding. The apparent riverflow gains between measurement sites A and B on other dates are smaller than the measurement accuracy.

Ground-water levels and streamflow near the study area for the month of March and April were considered above normal (within the highest 25 percent of record for the month) based on observation wells: Dedham 231, Weymouth 2, 3, and 4, and USGS streamgaging stations: Neponset River at Norwood and Canton, and Old Swamp River near South Weymouth included in the report "Current Water Resources Conditions in Massachusetts and Rhode Island" (http://ma.water.usgs.gov/current_cond).

Table 4. River-discharge and river-flow gains in the Cochato River across the study area, Holbrook, Massachusetts, March and April 1998

[Locations of measurement sites are shown in plate 1]

Site identifier (see map)	Date	Instantaneous discharge, in cubic feet per second
A	3/02/98	[1]18.1
	3/18/98	7.07
	4/14/98	5.44
B	3/02/98	21.6
	3/18/98	7.09
	4/14/98	5.51
C	3/02/98	23
	3/18/98	8.11
	4/14/98	5.93

	Date	River-flow gain from sites A to B, in cubic feet per second	River-flow gain from sites B to C, in cubic feet per second	River-flow gain from sites A to C, in cubic feet per second
	3/02/98	3.5	1.4	4.9
	3/18/98	.02	1.02	1.04
	4/14/98	.07	.42	.49

[1] Site difficult to measure because river overflowed left bank

INDICATORS OF VOLATILE ORGANIC COMPOUND DISCHARGE TO THE RIVER

The combination of an upward hydraulic gradient and the presence of VOCs and napthalene in river-bottom sediments indicate that contaminants from the Baird & McGuire ground-water plume were discharging to the Cochato River by advection during the study period for pumping and non-pumping conditions. Total VOCs in the vapor samplers were found not to be significantly different between the pumping and non-pumping conditions. River water samples collected by Metcalf & Eddy Services, Inc. also indicate that contamination, other than acetone, was not entering the study area from an upriver location. During the study, one of seven water-to-vapor diffusion samplers placed in the water column above the river bottom indicated the presence of a VOC (TCE), but the field gas chromatograph was limited to eight compounds as indicated previously.

Water levels in four piezometers were consistently higher than stage in the river, indicating a potential for advection of VOCs in river-bottom sediments to the river. The concentrations of VOCs in river-bottom sediments and the upward hydraulic gradients observed may represent extreme conditions because of unusually high precipitation prior to and during the study period. Ground-water recharge during the period of high precipitation could have raised ground-water levels above the river stage, thereby causing upward hydraulic gradients and movement of VOCs from the aquifer below the river into river-bottom sediments. Water-level and river-stage data from the site for periods of normal precipitation, however, are not available for comparison to data collected during the study.

SUMMARY

Volatile organic compounds are present in a ground-water plume that underlies the Cochato River at the Baird & McGuire Superfund Site in Holbrook, Massachusetts. Although contaminated river-bottom sediments have been removed and a ground-water extraction system is operating to remediate contaminated ground water, the U.S. Environmental Protection Agency and residents are concerned that problematic concentrations of contaminated ground water could potentially discharge to the Cochato River. In March and April 1998, the U.S. Geological Survey, in cooperation with the U.S. Army Corps of Engineers and U.S. Environmental Protection Agency used water-to-vapor and water-to-water diffusion samplers to determine if volatile organic compounds were present in the river-bottom sediments while the ground-water extraction system was operating and after the system had been shut down for a period of two weeks. Concurrently, water levels in piezometers placed along the river were compared to river stage to determine if there was an upward vertical gradient of ground water into the river.

The water-to-vapor and water-to-water diffusion samplers detected primarily benzene, toluene, ethylbenzene, and xylenes (BTEX compounds) over the known extent of the plume for both pumping and non-pumping conditions. Statistical analyses of the data sets indicate that there is no significant difference in diffusion sampler concentrations between the pumping and non-pumping conditions. Concentrations of total BTEX in vapor ranged from non-detect at upriver sampling locations to over 200 ppm by volume in the plume area and then back to non-detect at downriver sampling locations. Concentrations of total BTEX in the water-to-water diffusion samplers ranged from non-detect to 680 µg/L. Three water-to-water diffusion samplers also detected napthalene. The number of water-to-water diffusion samplers were insufficient to demonstrate increased concentrations for pumping or non-pumping conditions. Trichloroethylene, tetrachloroethylene, and 1,2-dichloroethylene also were detected in water-to-vapor and water-to-water diffusion samplers primarily downriver from the area where BTEX compounds were detected.

The upward hydraulic gradient observed in the piezometers and the presence of contaminants in the river-bottom sediments indicate that contaminants from the Baird & McGuire Superfund Site ground-water plume were discharging into the Cochato River at the time of this study for both pumping and non-pumping conditions.

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TABLE

Table 5. Results of analyses for volatile organic compounds in water-to-vapor diffusion samples collected from sediments in the Cochato River, Holbrook, Massachusetts, March (pumping conditions) and April (non-pumping conditions) 1998

[Locations of samplers are shown in plate 1. **Sampler No.:** L, left river bank (looking downriver); C, center of river; R, right river bank (looking downriver); -D, duplicate sample. **Method of installation:** s, shovel; d, driver; na, not applicable; nd, not detected or below reporting limit; ndd, not detected because of dilution prior to analysis; No., number; ppb v, part per billion by volume; *, estimated value below reporting limit; --, not analyzed because sampler was lost before or during retrieval]

Sampler No.	Sample date	Method of installation	Benzene (ppb v)	Toluene (ppb v)	Ethylbenzene (ppb v)	Meta/Para-xylene (ppb v)	Orthoxylene (ppb v)	Trichloro-ethylene (TCE) (ppb v)	Tetrachloro-ethylene (PCE) (ppb v)
Reporting limit			**15**	**35**	**90**	**90**	**100**	**15**	**20**
1 L	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
1 L	4/15/98	s	nd	nd	nd	nd	nd	nd	nd
1 C	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
1 C	4/15/98	s	nd	nd	nd	nd	nd	nd	nd
1 R	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
1 R	4/15/98	s	nd	nd	nd	nd	nd	nd	nd
1 R-D	4/15/98	s	nd	nd	nd	nd	nd	nd	nd
2 L	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
2 L	4/15/98	s	nd	nd	nd	nd	nd	nd	nd
2 L-D	4/15/98	s	nd	nd	nd	nd	nd	nd	nd
2 C	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
2 C	4/15/98	s	nd	nd	nd	nd	nd	nd	nd
2 R	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
2 R	4/15/98	s	nd	nd	nd	nd	nd	nd	nd
3 L	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
3 L	4/15/98	s	nd	nd	nd	nd	nd	nd	nd
3 C	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
3 C	4/15/98	s	nd	nd	nd	nd	nd	nd	nd
3 R	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
3 R	4/15/98	s	nd	nd	nd	nd	nd	nd	nd
3 R-D	4/15/98	s	nd	nd	nd	nd	nd	nd	nd
4 L	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
4 L	4/15/98	s	nd	nd	nd	nd	nd	nd	nd
4 C	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
4 C	4/15/98	s	--	--	--	--	--	--	--
4 R	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
4 R	4/15/98	s	nd	nd	nd	nd	nd	nd	nd
5 L	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
5 L-D	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
5 L	4/15/98	s	nd	nd	nd	nd	nd	nd	nd
5 C	3/18/98	d	nd	nd	nd	nd	nd	nd	nd
5 C	4/14/98	d	--	--	--	--	--	--	--
5 R	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
5 R	4/15/98	s	nd	nd	nd	nd	nd	nd	nd
6 L	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
6 L	4/15/98	s	nd	nd	nd	nd	nd	nd	nd
6 C	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
6 C	4/15/98	s	nd	nd	nd	nd	nd	nd	nd
6 R	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
6 R-D	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
6 R	4/15/98	s	nd	nd	nd	nd	nd	nd	nd

Table 5. Results of analyses for volatile organic compounds in water-to-vapor diffusion samples collected from sediments in the Cochato River, Holbrook, Massachusetts, March (pumping conditions) and April (non-pumping conditions) 1998—*Continued*

Sampler No.	Sample date	Method of installation	Benzene (ppb v)	Toluene (ppb v)	Ethylbenzene (ppb v)	Meta/Para-xylene (ppb v)	Orthoxylene (ppb v)	Trichloro-ethylene (TCE) (ppb v)	Tetrachloro-ethylene (PCE) (ppb v)
Reporting limit			**15**	**35**	**90**	**90**	**100**	**15**	**20**
7 L	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
7 L-D	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
7 L	4/15/98	s	nd	nd	nd	nd	nd	nd	nd
7 C	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
7 C	4/15/98	s	nd	nd	nd	nd	nd	nd	nd
7 R	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
7 R	4/15/98	s	nd	nd	nd	nd	nd	nd	nd
8 L	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
8 L	4/15/98	s	nd	nd	nd	nd	nd	nd	nd
8 L-D	4/15/98	s	nd	nd	nd	nd	nd	nd	nd
8 C	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
8 C	4/15/98	s	nd	nd	nd	nd	nd	nd	nd
8 R	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
8 R	4/15/98	s	nd	nd	nd	nd	nd	nd	nd
9 L	3/18/98	d	nd	nd	nd	nd	nd	nd	nd
9 L	4/15/98	d	nd	nd	nd	nd	nd	nd	nd
9 C	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
9 C	4/15/98	s	nd	nd	nd	nd	nd	nd	nd
9 R	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
9 R-D	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
9 R	4/15/98	s	nd	nd	nd	nd	nd	nd	nd
10 L	3/18/98	d	nd	nd	nd	nd	nd	nd	nd
10 L	4/15/98	d	nd	nd	nd	nd	nd	nd	nd
10 C	3/18/98	d	nd	nd	nd	nd	nd	nd	nd
10 C	4/15/98	d	nd	nd	nd	nd	nd	nd	nd
10 R	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
10 R	4/15/98	s	nd	nd	nd	nd	nd	nd	nd
11 L	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
11 L	4/15/98	s	nd	nd	nd	nd	nd	nd	nd
11 C	3/18/98	s	50	nd	nd	nd	nd	nd	nd
11 C	4/15/98	s	28	nd	nd	nd	nd	nd	nd
11 R	3/18/98	d	nd	nd	nd	nd	nd	nd	nd
11 R	4/15/98	d	nd	nd	nd	nd	nd	nd	nd
12 L	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
12 L	4/15/98	s	20	nd	nd	nd	nd	nd	nd
12 C	3/18/98	s	140	nd	nd	1,600	nd	nd	nd
12 C	4/15/98	s	227	60	nd	2,080	nd	nd	nd
12 R	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
12 R-D	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
12 R	4/15/98	s	nd	nd	nd	nd	nd	nd	nd

Table 5. Results of analyses for volatile organic compounds in water-to-vapor diffusion samples collected from sediments in the Cochato River, Holbrook, Massachusetts, March (pumping conditions) and April (non-pumping conditions) 1998—*Continued*

Sampler No.	Sample date	Method of installation	Benzene (ppb v)	Toluene (ppb v)	Ethylbenzene (ppb v)	Meta/Para-xylene (ppb v)	Orthoxylene (ppb v)	Trichloro-ethylene (TCE) (ppb v)	Tetrachloro-ethylene (PCE) (ppb v)
Reporting limit			**15**	**35**	**90**	**90**	**100**	**15**	**20**
13 L	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
13 L	4/15/98	s	nd	nd	nd	nd	nd	nd	nd
13 C	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
13 C	4/15/98	s	30	40	nd	nd	nd	nd	nd
13 R	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
13 R	4/15/98	s	22	nd	186	nd	nd	nd	nd
13 R-D	4/15/98	s	35	nd	nd	nd	nd	nd	nd
14 L	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
14 L	4/15/98	s	nd	nd	nd	nd	nd	nd	nd
14 C	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
14 C	4/15/98	s	34	109	*80	880	nd	nd	nd
14 R	3/18/98	s	87	*33	930	540	780	nd	nd
14 R-D	3/18/98	s	72	53	750	500	1,400	nd	nd
14 R	4/15/98	s	63	80	332	nd	nd	nd	nd
15 L	3/18/98	s	27	nd	nd	nd	nd	nd	nd
15 L	4/15/98	s	25	nd	nd	nd	nd	nd	nd
15 C	3/18/98	s	1,200	3,700	21,300	32,000	14,000	nd	nd
15 C	4/15/98	s	--	--	--	--	--	--	--
15 R	3/18/98	s	810	nd	4,400	3,600	1,500	nd	nd
15 R	4/15/98	s	109	nd	nd	nd	nd	nd	nd
16 L	3/18/98	s	37	140	130	280	360	nd	nd
16 L	4/15/98	s	68	nd	*60	100	225	nd	nd
16 C	3/18/98	s	700	nd	530	720	nd	nd	nd
16 C	4/15/98	s	1,830	nd	798	880	nd	nd	nd
16 R	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
16 R	4/15/98	s	nd	nd	nd	nd	nd	nd	nd
17 L	3/18/98	s	40	nd	nd	nd	nd	nd	nd
17 L	4/15/98	s	291	nd	140	nd	100	nd	nd
17 C	3/18/98	s	1,500	nd	nd	2,200	nd	nd	nd
17 C	4/15/98	s	nd	nd	nd	nd	nd	nd	nd
17 R	3/18/98	s	250	nd	nd	2,400	1,100	nd	nd
17 R	4/15/98	s	2,380	750	6,650	9,000	450	nd	nd
17 R-D	4/15/98	s	2,200	ndd	9,310	9,000	ndd	nd	nd
18 L	3/18/98	s	1,200	5,300	nd	24,000	8,100	nd	nd
18 L	4/15/98	s	1,070	7,030	31,000	36,400	9,000	nd	nd
18 C	3/18/98	d	1,800	nd	2,200	4,000	nd	nd	nd
18 C	4/15/98	d	2,680	nd	8,870	13,300	nd	nd	nd
18 R	3/18/98	s	1,100	210	nd	6,900	3,600	nd	nd
18 R	4/15/98	s	2,640	1,510	31,000	36,400	13,200	nd	nd
18 R-D	4/15/98	s	2,890	1,670	31,000	33,400	12,000	nd	nd

Table 5. Results of analyses for volatile organic compounds in water-to-vapor diffusion samples collected from sediments in the Cochato River, Holbrook, Massachusetts, March (pumping conditions) and April (non-pumping conditions) 1998—*Continued*

Sampler No.	Sample date	Method of installation	Benzene (ppb v)	Toluene (ppb v)	Ethylbenzene (ppb v)	Meta/Para-xylene (ppb v)	Orthoxylene (ppb v)	Trichloro-ethylene (TCE) (ppb v)	Tetrachloro-ethylene (PCE) (ppb v)
Reporting limit			**15**	**35**	**90**	**90**	**100**	**15**	**20**
19 L	3/18/98	s	710	nd	9,300	17,000	3,600	nd	nd
19 L-D	3/18/98	s	380	nd	nd	7,200	2,700	nd	nd
19 L	4/15/98	s	1,380	1,000	nd	21,800	3,600	nd	nd
19 C	3/18/98	d	1,040	nd	1,060	1,920	nd	nd	nd
19 C	4/15/98	d	--	--	--	--	--	--	--
19 R	3/18/98	s	3,000	110	5,500	9,000	2,600	nd	nd
19 R	4/15/98	s	2,080	556	4,000	6,280	3,600	nd	nd
20 L	3/18/98	s	870	1,700	10,600	12,800	6,000	nd	nd
20 L	4/15/98	s	3,440	14,700	77,400	96,000	24,000	nd	nd
20 C	3/18/98	d	1,050	nd	1,100	2,000	nd	nd	nd
20 C	4/15/98	d	453	*33	nd	*30	nd	nd	nd
20 R	3/18/98	s	nd	nd	nd	640	660	nd	nd
20 R	4/15/98	s	2,520	nd	8,870	13,300	1,200	nd	nd
20 R-D	4/15/98	s	2,830	nd	6,210	9,330	1,200	nd	nd
21 L	3/18/98	s	670	40	nd	2,200	540	nd	nd
21 L	4/15/98	s	50	*33	nd	236	*90	nd	nd
21 L-D	4/15/98	s	982	67	4,640	6,690	720	nd	nd
21 C	3/18/98	d	150	nd	nd	140	nd	nd	nd
21 C	4/15/98	d	--	--	--	--	--	--	--
21 R	3/18/98	s	32	nd	*75	nd	nd	nd	nd
21 R	4/15/98	s	31	nd	100	nd	nd	nd	nd
22 L	3/18/98	s	210	90	nd	4,800	1,800	nd	nd
22 L	4/15/98	s	1,460	1,590	18,620	19,300	nd	nd	nd
22 L-D	4/15/98	s	1,460	1,590	6,140	8,680	nd	nd	nd
22 C	3/18/98	d	150	nd	*80	*50	nd	nd	nd
22 C	4/15/98	d	113	nd	nd	240	nd	nd	nd
22 R	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
22 R	4/15/98	s	nd	nd	nd	nd	nd	nd	nd
23 L	3/18/98	s	nd	nd	nd	*40	nd	nd	nd
23 L	4/15/98	s	2,610	nd	6,380	3,560	1,080	nd	nd
23 C	3/18/98	d	180	nd	nd	nd	nd	nd	nd
23 C	4/15/98	d	680	nd	nd	270	270	nd	nd
23 R	3/18/98	d	nd	nd	nd	nd	nd	nd	nd
23 R	4/15/98	d	62	nd	nd	nd	nd	nd	nd
24 L	3/18/98	s	120	nd	5,800	4,800	1,300	nd	nd
24 L	4/15/98	s	--	--	--	--	--	--	--
24 C	3/18/98	d	100	nd	nd	200	nd	nd	nd
24 C	4/15/98	d	--	--	--	--	--	--	--
24 R	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
24 R	4/15/98	s	*8	nd	nd	nd	nd	nd	nd
24 R-D	4/15/98	s	nd	nd	nd	nd	nd	nd	nd

Table 5. Results of analyses for volatile organic compounds in water-to-vapor diffusion samples collected from sediments in the Cochato River, Holbrook, Massachusetts, March (pumping conditions) and April (non-pumping conditions) 1998—*Continued*

Sampler No.	Sample date	Method of installation	Benzene (ppb v)	Toluene (ppb v)	Ethylbenzene (ppb v)	Meta/Para-xylene (ppb v)	Orthoxylene (ppb v)	Trichloro-ethylene (TCE) (ppb v)	Tetrachloro-ethylene (PCE) (ppb v)
Reporting limit			**15**	**35**	**90**	**90**	**100**	**15**	**20**
25 L	3/18/98	s	260	210	1,330	870	180	nd	nd
25 L	4/14/98	s	1,210	713	3,800	900	1,370	nd	nd
25 C	3/18/98	d	nd	nd	nd	nd	nd	nd	nd
25 C	4/15/98	d	--	--	--	--	--	--	--
25 R	3/18/98	s	38	nd	nd	nd	nd	nd	nd
25 R	4/14/98	s	24	nd	133	nd	nd	nd	nd
25 R-D	4/14/98	s	38	nd	133	nd	nd	nd	nd
26 L	3/18/98	s	43	35	270	200	210	nd	nd
26 L	4/14/98	s	302	nd	266	*50	150	nd	nd
26 C	3/18/98	d	190	nd	*70	nd	nd	nd	nd
26 C	4/14/98	d	279	58	nd	*60	nd	nd	nd
26 R	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
26 R-D	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
26 R	4/14/98	s	23	nd	nd	nd	nd	nd	nd
27 L	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
27 L	4/14/98	s	nd	nd	nd	nd	nd	nd	nd
27 C	3/18/98	d	nd	nd	nd	nd	nd	nd	nd
27 C	4/14/98	d	118	nd	nd	nd	nd	nd	nd
27 R	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
27 R-D	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
27 R	4/14/98	s	nd	nd	nd	nd	nd	nd	nd
28 L	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
28 L-D	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
28 L	4/14/98	s	nd	nd	nd	nd	nd	nd	nd
28 C	3/18/98	d	nd	nd	nd	nd	nd	nd	nd
28 C	4/14/98	d	17	nd	nd	nd	nd	nd	nd
28 R	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
28 R	4/14/98	s	nd	nd	nd	nd	nd	nd	nd
29 L	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
29 L	4/14/98	s	nd	nd	nd	nd	nd	nd	nd
29 C	3/18/98	d	nd	nd	nd	nd	nd	nd	nd
29 C	4/14/98	d	29	nd	nd	nd	nd	16	nd
29 R	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
29 R-D	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
29 R	4/14/98	s	19	nd	nd	nd	nd	*13	nd
30 L	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
30 L	4/14/98	s	nd	nd	nd	nd	nd	nd	nd
30 C	3/18/98	d	nd	nd	nd	nd	nd	*11	nd
30 C	4/15/98	d	--	--	--	--	--	--	--
30 R	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
30 R	4/14/98	s	nd	nd	nd	nd	nd	nd	nd

Table 5. Results of analyses for volatile organic compounds in water-to-vapor diffusion samples collected from sediments in the Cochato River, Holbrook, Massachusetts, March (pumping conditions) and April (non-pumping conditions) 1998—*Continued*

Sampler No.	Sample date	Method of installation	Benzene (ppb v)	Toluene (ppb v)	Ethylbenzene (ppb v)	Meta/Para-xylene (ppb v)	Orthoxylene (ppb v)	Trichloro-ethylene (TCE) (ppb v)	Tetrachloro-ethylene (PCE) (ppb v)
Reporting limit			**15**	**35**	**90**	**90**	**100**	**15**	**20**
31 L	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
31 L-D	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
31 L	4/15/98	s	nd	nd	nd	nd	nd	nd	nd
31 C	3/18/98	d	nd	nd	nd	nd	nd	nd	nd
31 C	4/14/98	d	nd	nd	nd	nd	nd	nd	nd
31 R	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
31 R	4/14/98	s	nd	nd	nd	nd	nd	nd	nd
32 L	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
32 L	4/14/98	s	nd	nd	nd	nd	nd	nd	nd
32 L-D	4/14/98	s	nd	nd	nd	nd	nd	nd	nd
32 R	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
32 R	4/14/98	s	nd	nd	nd	nd	nd	nd	nd
32a L	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
32a L	4/14/98	s	nd	nd	nd	nd	nd	nd	nd
33 L	3/18/98	s	nd	nd	nd	nd	nd	nd	nd
33 L	4/14/98	s	nd	nd	nd	nd	nd	nd	nd
33 R	3/18/98	s	nd	nd	nd	nd	nd	53	nd
33 R	4/14/98	s	--	--	--	--	--	--	--
33a L	3/18/98	s	nd	nd	160	nd	nd	170	nd
33a L	4/14/98	s	nd	nd	nd	nd	nd	*11	nd
33a L-D	4/14/98	s	nd	nd	nd	nd	nd	19	nd
34 L	3/18/98	d	nd	nd	nd	nd	nd	160	nd
34 L	4/14/98	d	nd	nd	nd	nd	nd	84	nd
34 R	3/18/98	s	nd	nd	nd	nd	nd	20	nd
34 R	4/14/98	s	nd	nd	nd	nd	nd	44	nd
34 R-D	4/14/98	s	nd	nd	nd	nd	nd	97	nd
34a L	3/18/98	d	nd	nd	nd	nd	nd	81	nd
34a L	4/14/98	d	nd	nd	nd	nd	nd	126	nd
35 L	3/18/98	s	nd	nd	nd	nd	nd	170	nd
35 L	4/14/98	s	nd	nd	nd	nd	nd	359	31
35 R	3/18/98	d	nd	nd	nd	nd	nd	46	nd
35 R	4/14/98	d	nd	nd	nd	nd	nd	134	22
35a L	3/18/98	s	nd	nd	nd	nd	nd	140	nd
35a L	4/14/98	s	nd	nd	nd	nd	nd	33	nd
36 L	3/18/98	s	nd	nd	nd	nd	nd	130	27
36 L	4/14/98	s	nd	nd	nd	nd	nd	124	nd
36 L-D	4/14/98	s	nd	nd	nd	nd	nd	85	nd
36 R	3/18/98	s	nd	nd	nd	nd	nd	180	nd
36 R	4/14/98	s	nd	nd	nd	nd	nd	104	*16
36a L	3/18/98	s	nd	nd	nd	nd	nd	28	nd
36a L	4/14/98	s	nd	nd	nd	nd	nd	27	nd

Table 5. Results of analyses for volatile organic compounds in water-to-vapor diffusion samples collected from sediments in the Cochato River, Holbrook, Massachusetts, March (pumping conditions) and April (non-pumping conditions) 1998—*Continued*

Sampler No.	Sample date	Method of installation	Benzene (ppb v)	Toluene (ppb v)	Ethylbenzene (ppb v)	Meta/Para-xylene (ppb v)	Orthoxylene (ppb v)	Trichloro-ethylene (TCE) (ppb v)	Tetrachloro-ethylene (PCE) (ppb v)
Reporting limit			**15**	**35**	**90**	**90**	**100**	**15**	**20**
37 L	3/18/98	s	nd	nd	nd	nd	nd	52	nd
37 L-D	3/18/98	s	nd	nd	nd	nd	nd	55	nd
37 L	4/15/98	s	--	--	--	--	--	--	--
37 R	3/18/98	s	nd	nd	nd	nd	nd	140	nd
37 R	4/14/98	s	nd	nd	nd	nd	nd	308	nd
37a L	3/18/98	s	nd	nd	nd	nd	nd	71	nd
37a L	4/14/98	s	nd	nd	nd	nd	nd	68	nd
38 L	3/18/98	s	nd	nd	nd	nd	nd	105	nd
38 L-D	3/18/98	s	nd	nd	nd	nd	nd	115	nd
38 L	4/14/98	s	nd	nd	nd	nd	nd	93	nd
38 R	3/18/98	d	nd	nd	nd	nd	nd	240	nd
38 R	4/15/98	d	--	--	--	--	--	--	--
38a L	3/18/98	s	nd	nd	nd	nd	nd	97	nd
38a L	4/14/98	s	nd	nd	nd	nd	nd	100	nd
39 L	3/18/98	s	nd	nd	nd	nd	nd	28	nd
39 L-D	3/18/98	s	nd	nd	nd	nd	nd	24	nd
39 L	4/14/98	s	nd	nd	nd	nd	nd	21	nd
39 R	3/18/98	d	--	--	--	--	--	--	--
39 R	4/14/98	d	nd	nd	nd	nd	nd	37	*14
39a L	3/18/98	s	nd	nd	nd	nd	nd	810	nd
39a L	4/14/98	s	nd	nd	nd	nd	nd	546	nd
40 L	3/18/98	s	nd	nd	nd	nd	nd	1,900	nd
40 L	4/14/98	s	nd	nd	nd	nd	nd	nd	nd
40 R	3/18/98	d	--	--	--	--	--	--	--
40 R	4/14/98	d	nd	nd	nd	nd	nd	50	39
40aL	3/18/98	s	nd	nd	nd	nd	nd	170	42
40aL	4/14/98	s	nd	nd	nd	nd	nd	1,080	1,920
HQP 001	3/18/98	na	nd	nd	nd	nd	nd	nd	nd
HQP 001	4/15/98	na	nd	nd	nd	nd	nd	nd	nd
HQP 002	3/18/98	na	nd	nd	nd	nd	nd	nd	nd
HQP 002-D	3/18/98	na	nd	nd	nd	nd	nd	nd	nd
HQP 002	4/15/98	na	nd	nd	nd	nd	nd	nd	nd
HQP 003	3/18/98	na	nd	nd	nd	nd	nd	nd	nd
HQP 003	4/14/98	na	nd	nd	nd	nd	nd	nd	nd
HQP 004	4/14/98	na	nd	nd	nd	nd	nd	252	nd

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Savoie and others–POTENTIAL FOR ADVECTION OF VOLATILE ORGANIC COMPOUNDS IN GROUND WATER TO THE COCHATO RIVER, BAIRD & McGUIRE SUPERFUND SITE, HOLBROOK, MASSACHUSETTS, MARCH AND APRIL 1998—WRIR 98-4257