Sediment Studies in the Assabet River, Central Massachusetts, 2003

By Marc J. Zimmerman and Jason R. Sorenson

Part 1
Sediment Distribution and Chemistry in Six Impoundments in the Assabet River, Central Massachusetts

Part 2
Phosphorus Dynamics in a Wastewater-Dominated Impoundment, Hudson, Massachusetts

In cooperation with the
Massachusetts Department of Environmental Protection and the
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Conversion Factors, Datums, Water-Quality Information and Abbreviations

Multiply	By	To obtain
centimeter (cm)	0.3937	inch (in.)
cubic meter (m^3)	35.31	cubic foot (ft^3)
cubic meter (m^3)	1.308	cubic yard (yd^3)
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
kilogram (kg)	2.2046	pound, avoirdupois (lb)
kilometer (km)	0.6214	mile (mi)
liter (L)	61.02	cubic inch (in^3)
meter (m)	3.281	foot (ft)
meter (m)	1.094	yard (yd)
microgram (µg)	3.53×10^{-8}	ounce, avoirdupois (oz)
milligram (mg)	3.53×10^{-5}	ounce, avoirdupois (oz)
milliliter (mL)	0.06102	cubic inch (in^3)

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

$$°F=(1.8\times°C)+32$$

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

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

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

As	arsenic	PCB	polychlorinated biphenyl
Cd	cadmium	PEC	probable effect concentration
Cr	chromium	PEL	probable effect level
Cu	copper	PVC	polyvinyl chloride
DO	dissolved oxygen	RL	reporting level
EPH	extractable petroleum hydrocarbon	TEL	threshold effect level
GC	gas chromatography	TIN	triangular irregular network
GIS	geographic information system	TMDL	total maximum daily load
MS	mass spectrometry	TPH	total petroleum hydrocarbon
Ni	nickel	USEPA	U.S. Environmental Protection Agency
PAH	polycyclic aromatic hydrocarbon	VOC	volatile organic compound
Pb	lead	Zn	zinc

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By Marc J. Zimmerman and Jason R. Sorenson

Abstract

From its headwaters in Westborough, Massachusetts, to its confluence with the Sudbury River, the 53-kilometer-long Assabet River passes through a series of small towns and mixed land-use areas. Along the way, wastewater-treatment plants release nutrient-rich effluents that contribute to the eutrophic state of this waterway. This condition is most obvious where the river is impounded by a series of dams that have sequestered large amounts of sediment and support rooted and floating macrophytes and epiphytic algae. The water in parts of these impoundments may also have low concentrations of dissolved oxygen, another symptom of eutrophication.

All of the impoundments had relatively shallow maximum water depths, which ranged from approximately 2.4 to 3.4 meters, and all had extensive shallow areas. Sediment volumes estimated for the six impoundments ranged from approximately 380 cubic meters in the Aluminum City impoundment to 580,000 cubic meters in the Ben Smith impoundment. The other impoundments had sediment volumes of 120,000 cubic meters (Powdermill), 67,000 cubic meters (Gleasondale), 55,000 cubic meters (Hudson), and 42,000 cubic meters (Allen Street).

The principal objective of this study was the determination of sediment volume, extent, and chemistry, in particular, the characterization of toxic inorganic and organic chemicals in the sediments. To determine the bulk-sediment chemical-constituent concentrations, more than one hundred sediment cores were collected in pairs from the six impoundments. One core from each pair was sampled for inorganic constituents and the other for organic constituents. Most of the cores analyzed for inorganics were sectioned to provide information on the vertical distribution of analytes; a subset of the cores analyzed for organics was also sectioned. Approximately 200 samples were analyzed for inorganic constituents and 100 for organics; more than 10 percent were quality-control replicate or blank samples.

Maximum bulk-sediment phosphorus concentrations in surface samples from the impoundments increased along a downstream gradient, with the exception of samples from the last impoundment, where the concentrations decreased. In addition, the highest phosphorus concentrations were generally in the surface samples; this finding may prove helpful if surface dredging is selected as a means to control phosphorus release from sediments. There is no known relation, however, between bulk-sediment concentration of phosphorus and the concentrations of phosphorus available to biota.

Potentially toxic metals, including arsenic, cadmium, chromium, copper, nickel, lead, and zinc were frequently measured at concentrations that exceeded U.S. Environmental Protection Agency sediment-quality guidelines for the protection of aquatic life and that occasionally exceeded Massachusetts Department of Environmental Protection guidelines governing landfill disposal (reuse). Due to the effects of matrix interference and sample dilution on laboratory analyses, neither pesticides nor volatile organic compounds were detected at any sites. However, samples collected in other studies from nearby streams indicated the possibility that pesticides might have been detected in the impoundments if not for these analytical problems. Although polychlorinated biphenyl concentrations, as individual Aroclors, generally exceeded published U.S. Environmental Protection Agency guideline concentrations for potential effects on aquatic life, the U.S. Environmental Protection Agency guideline concentrations for human contact or the Massachusetts guidelines for landfill reuse were rarely exceeded. Concentrations of polycyclic aromatic hydrocarbons, both individually and total, frequently were greater than guideline concentrations. Concentrations of total extractable petroleum hydrocarbons did not exceed Massachusetts guideline concentrations in any samples.

When the sediment analytes from surface samples are considered together to compare their potential toxicity to aquatic organisms, it is clear that sediment exposure is likely to have harmful effects. By most measures, samples from the first and last impoundments in the sequence had the poorest sediment quality with respect to the degree and the frequency with which guideline concentrations were exceeded.

A consortium of towns along the river has investigated a range of options aimed at controlling concentrations of nutrients, phosphorus in particular, released from wastewater-treatment plants into the river and its impoundments. The second part of this study examined the changes in phosphorus concentrations in surface and pore waters in one impoundment during a 2-month period. The results were used to determine whether the sediments could release sufficient amounts of phosphorus to render ineffective decreased phosphorus releases from treatment plants. Knowledge of sediment characteristics and chemistry will allow local water managers to choose among the sediment-management options that may be considered for the Assabet River: decreasing concentrations of phosphorus released from treatment plants, partial or complete dredging, dam removal or modification, phosphorus sequestration by chemical treatment, and making no changes.

To investigate the dynamics of phosphorus concentrations in the impoundment in Hudson, Massachusetts, water samples were collected weekly at five locations. In addition to ortho- and total phosphorus, some samples were analyzed for chloride, which served as a conservative tracer for waters released from upstream wastewater-treatment plants. At each location, data were collected to provide water-column profiles of temperature, dissolved oxygen, and specific conductance.

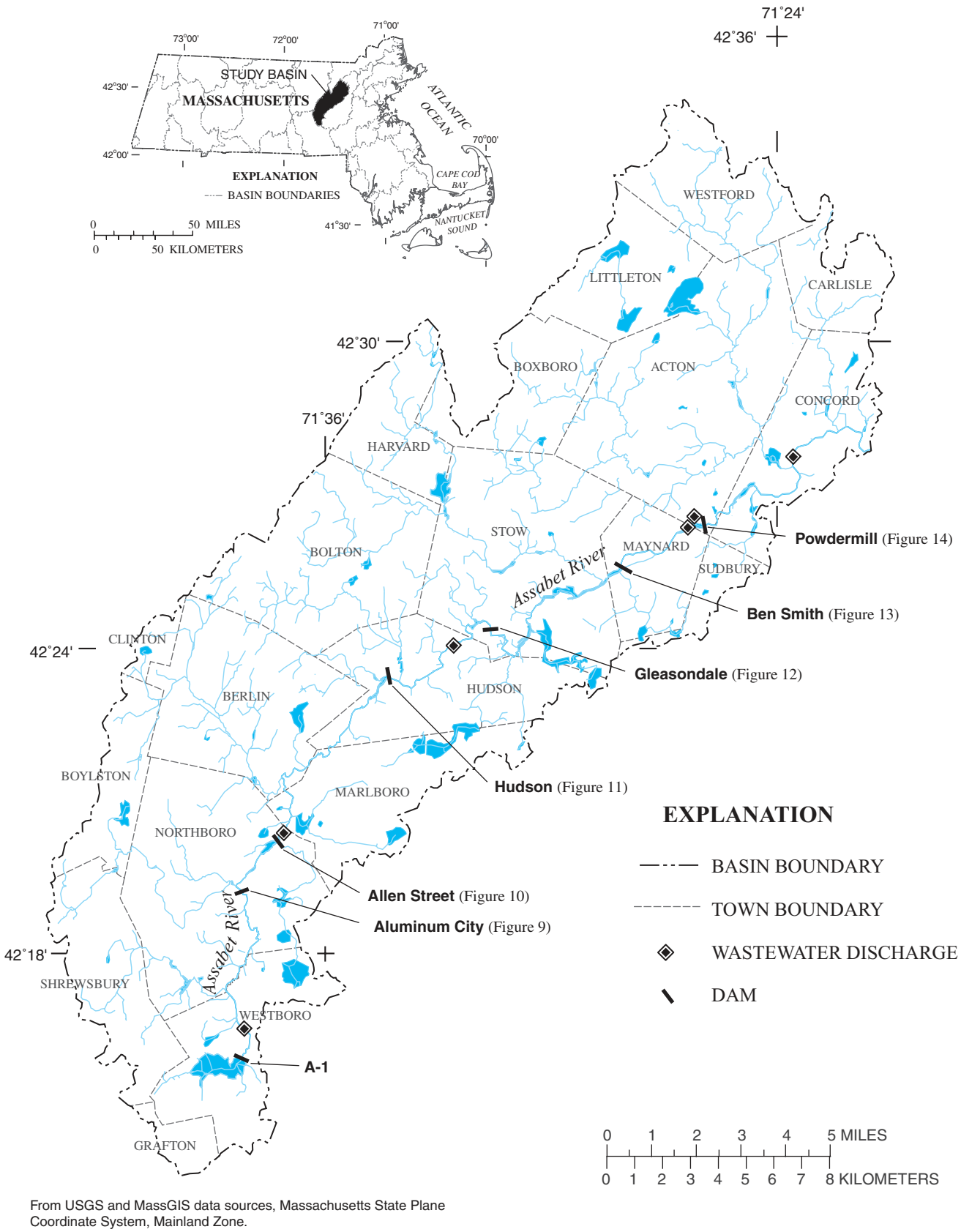
In the study of phosphorus dynamics in the impoundment in Hudson, Massachusetts, phosphorus concentrations varied over time, primarily in bed-sediment samples, at the off-channel sampling locations where the water column was stratified. These variations, including some substantial increases in phosphorus concentrations in pore-water samples, however, did not appear to lead to increases in phosphorus exported from the impoundment. This observation suggests that most of the phosphorus released from the sediments was recycled internally in the impoundment.

Although net phosphorus storage did vary, it did not generally increase with time as total phosphorus entered the water column from sediments in stagnant areas in the Hudson impoundment. Physical and redox processes seem to control phosphorus release from sediments to the water column. These findings and the results of other studies indicate that the amount of phosphorus released from sediments over a yearly cycle was relatively small compared to the amount of phosphorus entering the system from upstream wastewater-treatment plants.

The Assabet River and its Sediments

The 53-km-long Assabet River is impounded by a series of dams as it flows northeastward from its source at the A1 impoundment in Westborough through the towns of Northborough, Marlborough, Hudson, Stow, Maynard, and Acton (fig. 1). Along the way, municipal wastewater-treatment plants in Westborough, Marlborough, Hudson, and Maynard discharge nutrient-rich effluent to the river.

Historically, the Assabet River Basin was characterized by small towns with centers along or near the river. Much of the surrounding land was forested or farmed. Dams impounding reaches of the Assabet River served to power the mills that constituted the economic bases for the towns along the river. Modern industries have also substantially contributed to the area's economic development. Water- and sediment-quality characteristics of the Assabet River reflect this history. The area has become more suburban over time with a rapid increase in the number of single-family homes, roads, and commercial developments. Rapid development in this area of Massachusetts has strained the basin's water resources by diminishing flow and affecting water quality.



From USGS and MassGIS data sources, Massachusetts State Plane Coordinate System, Mainland Zone.

Figure 1. The Assabet River Basin in central Massachusetts.

In spite of the Assabet River's diversity of wildlife, popularity for recreational activities, and recent designation as part of a Wild and Scenic River basin, it is a highly eutrophic system, primarily because of nutrient enrichment from the effluents of wastewater-treatment plants. The extent of eutrophication is evident in the impounded reaches, which support substantial growth of rooted and floating macrophytes.

During the summer and early fall of 2003, the U.S. Geological Survey (USGS), in cooperation with the Massachusetts Department of Environmental Protection (MDEP) and the U.S. Environmental Protection Agency (USEPA), mapped the extent and studied the chemical properties of sediments in six impoundments in the Assabet River Basin. The USGS also studied the dynamics of phosphorus release from sediments in a wastewater-dominated impoundment in Hudson, Massachusetts. This impoundment was one of the original six impoundments.

This two-part report provides the results of the assessment of the sediment extent and chemistry in the six impoundments in the Assabet River and describes the results of the study of the dynamics of phosphorus release. Obtaining data to determine whether there is a relation between the distribution of phosphorus in the sediments and the concentrations of phosphorus in the water column was a link between the two parts of this study.

Sediment was sampled from the following six impoundments along the Assabet River:

1. Route 20, also known as Aluminum City impoundment (Northborough, built in 1925);
2. Allen Street impoundment (Northborough, built in 1900);
3. Hudson (Washington Street) impoundment (Hudson, built in 1860), the site of the phosphorus dynamics study;
4. Gleasondale impoundment (Stow, built in 1924);
5. Ben Smith impoundment (Maynard, built in 1870); and
6. Powdermill impoundment (Maynard/Acton, built in 1921).

The interpretations of bulk-sediment chemistry data in this report include results of analyses for volatile organic compounds (VOCs), polycyclic (or polynuclear) aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), organochlorine pesticides, extractable petroleum hydrocarbons (EPH), reactive sulfide, and a selected group of metals and other elements, including phosphorus. The concentrations of these chemical constituents in the sediments are compared to standards for the disposal of dredged hazardous materials; for human contact; and for potential effects, including toxicity, on aquatic organisms.

The sediment-chemistry data are intended to provide managers and environmental regulators with information required to make informed choices of the best means for improving sediment and surface-water quality in the Assabet River Basin. Possible sediment-management options available to water-resource managers considering river restoration include: (1) reducing concentrations of phosphorus released from treatment plants; (2) dredging sediments (partial or total removal); (3) chemical treatment of sediments to prevent phosphorus release; (4) removal or structural modification of dams; and (5) making no changes.

Part 1. Sediment Distribution and Chemistry in Six Impoundments in the Assabet River, Central Massachusetts

Study Design

To determine the extent and volume of sediments and to create maps for sampling-site selection, the impoundment bathymetry and sediment thickness for the six impoundments affected by wastewater effluent on the Assabet River were delineated by manual probing. Representative physical and chemical properties of the sediment behind each dam were determined from sediment core samples collected at randomly selected sites. Samples were analyzed at laboratories in Massachusetts, Rhode Island, and Ontario, Canada.

Mapping of Bathymetry and Sediment Thickness

Data on water depth and soft-sediment thickness were collected by probing manually with an extendible stainless-steel rod in the reaches behind the six dams (fig. 2). A total of 682 manual water-depth and sediment-thickness soundings were taken in the six impoundments: 34 at Aluminum City dam, 140 at Allen Street, 142 at Hudson, 91 at Gleasondale, 183 at Ben Smith, and 92 at Powdermill.

A Trimble TSC1 GPS unit was used to record depth-sounding coordinates. The Trimble positional data were differentially corrected before being imported as point coverages into the geographic information system (GIS) ArcInfo (ESRI, 2002). Impoundment outlines were created from orthophotos with a resolution of 1:5000 (1/2 meter). An ARC Macro Language script positioned the point coverage of the depth soundings in the coverage of the river outlines, and a triangular irregular network (TIN) data set (a type of spatial coverage) was generated to create preliminary contours of the impoundment bathymetry.

Selection of Sediment-Sampling Sites

Fifty-seven primary sampling sites and 57 matching alternate sampling sites were chosen by using a random-selection subroutine within ARC/INFO GIS software (Scott, 1990). The number and distribution of sediment-sampling sites among the impoundments were determined by the relative size of each impoundment, by the locations of depositional environments, and by the locations of possible contamination source areas. On the basis of past experience with sediment sampling and input from stakeholders, the sampling network was designed to collect a sufficient number of samples to represent the potential sediment variability within the study area.

Collection of Sediment Cores

To achieve the project objectives of physically and chemically characterizing the bed sediments behind the 6 Assabet River impoundments, more than 100 sediment cores were collected from the 57 sampling sites. The two cores taken from each site were considered to be equally representative of the sediment at that site; one core was reserved for analysis of organic chemical constituents, and the other for analysis of inorganic constituents. At each site, field crews retrieved the longest possible soft-sediment core.

The randomly selected sites were identified in the field with a GPS unit. If cores could not be retrieved at the primary site, an alternate site was used. All coring was done from a flat-bottomed john boat equipped with a four-stroke outboard motor. All cores were retrieved with a piston corer (Aquatic Research Instruments, Hope, Idaho).

Figure 2. A probe is used to collect data for a map of sediment thickness and extent.

Figure 3. A piston corer is prepared for collection of a sediment core.

Upon arrival at a sampling location, the field crew anchored and braced the boat to provide a stable work platform against any existing wind or current. Driving steel rods into the sediment allowed the crew to approximate the maximum possible core length and to mark the sampling station. Polycarbonate plastic tubing was cut to the expected core length and secured to the core head with the piston in a ready position at the foot of the plastic core barrel (fig. 3). Polyvinyl chloride (PVC) pipe of 1-in. inner diameter was driven into the sediment to allow measurement of the total drive depth. The corer equipped with an extension rod was positioned at the sediment surface adjacent to the PVC pipe, and aligning marks were put on both the extension rod and the PVC pipe. One crew member held the piston cable in place, while the second manually drove the core barrel into the sediment until stopped by initial refusal. A 5-lb slide hammer was then used to drive the core barrel farther into the sediment until final refusal; with the corer and the PVC pipe in this configuration, the distance between the previously aligned marks on the aluminum extension rod and the stationary PVC pipe represented the total drive depth. The difference between the total drive depth and the water depth provided the drive depth in the sediment and a way to determine the extent of compaction. The core was extracted with gloved hands and capped at both ends with native-water-rinsed polypropylene caps. To minimize any losses from the core sampler, the end cap was secured to the core tube before the end of the tube broke the surface of the water. On the boat, top and bottom polypropylene end caps were secured to the core with vinyl tape and the core was labeled. The second core was obtained in the same manner from a position less than 1 m from the first site.

Cores were secured upright in a cooler and kept cool with ice for transportation to the USGS MA–RI Water Science Center office.

Sample Preparation

At the MA-RI Water Science Center laboratory, cores were placed in 55-gal plastic barrels filled with ice. Cores were extruded with a Teflon piston into a clean, half-section of a 4-in. diameter, 8-ft polycarbonate tube (figs. 4 and 5). The core lengths and lithological data were recorded and photographs were taken. Then, a 5-mL sample for VOC analysis was collected with a syringe (fig. 6). The remainder of the core was put into a precleaned 25-L Teflon bag which was massaged to thoroughly homogenize the core. A corner of the bag was then cut and samples were extruded into labeled glass jars for analysis (fig. 7); some of the cores designated for organic-compound analyses were sectioned into thirds before homogenizing to provide some information about variability with depth. Cores collected for elemental analysis were split into as many as five sections to determine depth variability (table 1). Each section was put into a pre-cleaned 1.5-L Teflon bag and thoroughly homogenized before extrusion into a labeled plastic Whirl-Pak bag for analysis (fig. 8). All samples were stored at 4ºC until transport to their respective laboratories. Grain-size samples were extruded into Whirl-Pak bags and frozen for possible analysis at a later date.

Analytical Methods

Laboratory analyses included VOCs, PAHs, PCBs, organochlorine pesticides, EPH, reactive sulfide, and metals. The analyte list was chosen to correspond with analytes listed in regulations guiding the disposal of sediments.

SGS Canada, Inc., Minerals Services (formerly XRAL Laboratories), of Toronto, Ontario, analyzed sediment samples for 32 elements (mainly metals) by using inductively coupled plasma-emission spectrometry, after the samples were digested by aqua regia. Each element analyzed by this method has its own reporting level (RL).

The USEPA Region I laboratory in Chelmsford, MA, analyzed sediment samples for VOCs by using standard gas chromatography/mass spectrometry (GC/MS) techniques (U.S. Environmental Protection Agency, 1996a). The methodology can quantify the concentrations of 70 compounds in soils or sediments. The USEPA laboratory also analyzed sediment samples for PAHs (U.S. Environmental Protection Agency, 2000). The analytical method, which uses GC with mass selective detector, measures concentrations of 16 PAH compounds. Nominally, project RLs for PAHs were 0.0017 mg/kg. In practice, organic interferences required sample dilutions of up to 100 times with actual RLs as high as 0.620 mg/kg.

Figure 4. A Teflon piston is used to extrude core into a polycarbonate tube.

Figure 5. An extruded core.

Figure 6. A sample is collected for volatile organic compound analysis.

Figure 7. A sample is collected for polychlorinated biphenyl and pesticide analyses.

Figure 8. A sample is prepared for metal analysis.

Table 1. Identifiers and depths for samples collected in six impoundments in the Assabet River, Massachusetts.

[**Map ID:** The identifier associated with a sampling site on a map (figs. 9–14). **Field ID:** core identifier. **Sample ID:** Identifier for a sample collected from a particular core, arranged alphabetically from the top of the core, with Q designating a replicate sample. in., inches]

Map ID	Field ID	Sample ID	Sample depth (in.)
		Aluminum City	
AC1	AC4	5	0–16.3
AC2	AC2	7A	0–6.7
		7B	6.7–13.4
		7C	13.4–20.1
AC3	AC3	6A	0–7.1
		6B	7.1–14.2
		6C	14.2–21.3
AC4	AC1	8A	0–7.9
		8B	7.9–15.7
		8C	15.7–23.2
		Allen Street	
AS5	AS1	1A	0–7.9
		1B	11.8–19.7
		1C	19.7–27.6
		1D	27.6–35.4
AS6	AS3	3A	0–7.9
		3B	7.9–15.7
		3C	15.7–22.4
AS7	AS2	2A	0–7.9
		2B	7.9–15.7
		2C	15.7–23.6
		2D	23.6–30.7
AS8	AS4	4A	0–7.9
		4B	9.8–17.7
		4C	20.5–28.3
		4D	34.6–42.5
		4E	48.8–56.7
		Hudson	
H9	H1	9	0–10.2
H10	H4	12A	0–7.1
		12B	7.1–14.2
		12C	14.2–22.0
		12D	22.0–30.7
		12E	30.7–39.4
H11	H5	13A	0–7.9
		13B	7.9–13.8
		13C	13.8–19.3
		13D	19.3–26.4
H12	H2	11A	0–8.7
		11B	8.7–17.3
H13	H6	14A	0–7.9
		14AQ	0–7.9
		14B	7.9–15.7
		14BQ	7.9–15.7
		14C	15.7–23.6
		14CQ	15.7–23.6
		14D	23.6–31.5
		14DQ	23.6–31.5
		14E	31.5–38.6
		14E	31.5–38.6
		14EQ	31.5–38.6
H14	H3	10A	0–9.1
		10B	9.1–18.1
H15	H7	15A	0–7.9
		15B	7.9–15.7
		15C	15.7–23.6
		15D	23.6–30.7
		Gleasondale	
G16	G10	34A	0–7.5
		34B	7.5–15.0
		34C	15.0–22.8
G17	G2	39A	0–5.9
		39B	7.9–15.7
		39C	15.7–23.6
		39D	23.6–32.7
G18	G5	35A	0–7.9
		35B	11.4–19.3
		35C	22.8–30.7
		35D	34.3–42.1
		35E	45.7–53.5
G19	G11	40A	0–7.9
		40B	17.3–25.2
		40C	34.6–42.5
		40CQ	34.6–42.5
		40D	52.0–59.8
		40E	69.3–77.2
G20	G1	36A	0–7.9
		36AQ	0–7.9
		36B	7.9–15.7
		36C	15.7–23.6
		36D	23.6–31.5
		36E	31.5–39.4
G21	G7	44	0–7.1
G22	G8	41A	0–8.3
		41B	8.3–16.5
		41C	16.5–24.4
G23	G4	37A	0–8.7
		37B	8.7–16.9
		37C	16.9–25.2
		37D	25.2–33.5
G24	G6	42A	0–7.9
		42B	11.8–19.7
G25	G12	45	0–7.1

Table 1. Identifiers and depths for samples collected in six impoundments in the Assabet River, Massachusetts.— Continued

[**Map ID:** The identifier associated with a sampling site on a map (figs. 9–14). **Field ID:** core identifier. **Sample ID:** Identifier for a sample collected from a particular core, arranged alphabetically from the top of the core, with Q designating a replicate sample. in., inches]

MapID	Field ID	Sample ID	Sample depth (in.)
	Gleasondale—Continued		
G26	G9	38A	0–8.7
		38B	8.7–16.9
		38C	16.9–25.5
G27	G3	43	0–9.8
	Ben Smith		
BS28	BS1	16A	0–4.7
		16B	4.7–9.4
BS29	BS6	18A	0–5.9
		18B	5.9–11.8
		18C	11.8–18.1
BS30	BS2	17A	0–6.3
		17B	6.3–13.0
		17C	13.0–19.7
		17D	19.7–26.0
		17E	26.0–34.6
BS31	BS7	19A	0–9.4
		19AQ	0–9.4
		19B	9.4–18.9
		19BQ	9.4–18.9
		19C	18.9–28.7
		19CQ	18.9–28.7
		19D	28.7–36.6
		19DQ	28.7–36.6
		19E	36.6–44.5
		19EQ	36.6–44.5
BS32	BS8	20A	0–7.9
		20B	16.5–24.4
		20C	33.1–40.9
		20D	45.7–57.5
		20E	66.1–74.0
BS33	BS3	21A	0–7.9
		21B	7.9–15.7
		21C	15.7–23.6
		21D	23.6–31.5
		21E	31.5–39.4
BS34	BS4	22A	0–7.9
		22B	7.9–15.7
		22C	15.7–23.2
BS35	BS9	23A	0–7.9
		23B	7.9–15.4
		23C	15.4–22.0
BS36	BS5	27A	0–7.1
	27B	18–35	
		27C	13.8–20.5
		27D	20.5–27.2
BS37	BS10	29A	0–7.9
		29B	7.9–17.7
		29C	15.7–24.0
BS38	BS11	26A	0–7.9
		26B	7.9–15.7
		26C	15.7–23.6
		26D	23.6–31.5
		26E	31.5–40.6
BS39	BS13	25A	0–6.7
		25B	6.7–13.0
BS40	BS12	24A	0–7.9
		24B	7.9–15.7
		24C	15.7–23.2
BS41	BS14	28A	0–8.7
		28AQ	0–8.7
		28B	8.7–17.3
		28BQ	8.7–17.3
BS42	BS16	33A	0–7.5
		33B	7.5–15.0
BS43	BS17	30A	0–7.1
		30B	7.1–14.2
		30C	14.2–21.3
		30D	21.3–28.3
		30E	28.3–35.4
BS44	BS15	31A	0–12.6
		31B	12.6–22.4
BS45	BS18	32A	0–7.9
		32B	7.9–15.7
	Powdermill		
P46	P1	48	0–10.2
		48Q	0–10.2
P47	P3	49	0–5.5
P48	P2	46A	0–7.9
		46B	7.9–15.7
		46C	15.7–20.9
P49	P4	47	0–8.3
P50	P5	52A	0–7.9
		52B	9.8–17.7
		52C	19.3–27.2
		52CQ	19.3–27.2
		52D	28.7–36.6
		52E	38.2–46.1
P51	P8	55A	0–8.7
		55AQ	0–8.7
		55B	8.7–17.3
		55C	17.3–25.6

Table 1. Identifiers and depths for samples collected in six impoundments in the Assabet River, Massachusetts.—Continued

[**Map ID:** The identifier associated with a sampling site on a map (figs. 9–14). **Field ID:** core identifier. **Sample ID:** Identifier for a sample collected from a particular core, arranged alphabetically from the top of the core, with Q designating a replicate sample. in., inches]

MapID	Field ID	Sample ID	Sample depth (in.)
Powdermill—Continued			
P51—Continued			
		55D	25.6–33.9
P52	P6	53A	0–7.9
		53B	15.4–19.3
		53C	26.8–34.6
		53D	42.1–50.0
		53DQ	42.1–50.0
		53E	57.5–65.4
P53	P9	54A	0–8.7
		54B	8.7–16.9
		54C	16.9–25.2
		54CQ	16.9–25.2
P54	P10	56A	0–7.9
		56B	7.9–15.7
		56BQ	7.9–15.7
		56C	15.7–23.6
P55	P11	51A	0–7.9
		51B	9.8–17.7
		51BQ	9.8–17.7
		51C	19.7–27.6
		51D	29.5–37.4
		51E	29.8–47.2
P56	P7	50A	0–7.9
		50AQ	0–7.9
		50B	15.4–23.2
		50C	30.7–38.6
		50D	46.1–53.9
		50E	61.4–69.3
P57	P12	57	0–10.6
		57Q	0–10.6

The EPH method, designed to assess exposure to petroleum hydrocarbons that may cause human health hazards (MDEP, 2002, 2004), measures the concentrations of aliphatic and aromatic hydrocarbons in soils or water by GC with a flame-ionization detector. Some of the petroleum products that this method may detect include kerosene, fuel oils #2, #4, and #6, diesel oil, jet fuel, and some lubricating oils. These are essentially the same compounds targeted by the USEPA's PAH analyses, but the EPH-method RLs are 0.5 mg/kg, which is higher than the 0.0017 mg/kg for the PAH analyses. New England Testing Laboratory, Providence, RI, performed the EPH analyses reported here.

The reactive sulfide method determines the amount of the highly corrosive and toxic vapor hydrogen sulfide which is released when sediment is placed in contact with acid. At present, Massachusetts has no regulatory standard, but the State's policy calls for lime stabilization of dredged sediments with reactive sulfide concentrations greater than 500 parts per million (500 mg/kg). New England Testing Laboratory used a standard procedure (U.S. Environmental Protection Agency, 1996b) with a reporting level of 5 mg/kg to analyze the sediments in this study for reactive sulfide.

Alpha Analytical, Inc., Westborough, MA, used capillary-column gas chromatography (U.S. Environmental Protection Agency, 1996c, d) to analyze sediment samples for PCBs and organochlorine pesticides. The RLs for PCBs (0.017 mg/kg) and organochlorine pesticides (0.0008 mg/kg) were also affected by sample dilutions that may have raised the RLs by a factor of as much as 100.

Quality Assurance and Quality Control

Several precautionary steps were taken to ensure that sediment-sample collection and processing did not introduce contamination to the samples. In the field, sediment cores were collected with freshly manufactured plastic sleeves that were rinsed with ambient water at the site before core collection. Cores were capped and sealed at both ends in the field and returned to the Water Science Center office in plastic containers for processing. The cores were extruded (fig. 4) onto a large-diameter plastic tube that had been cut in half

lengthwise, thoroughly cleaned with methanol and hydrochloric acid, and rinsed with distilled water. All parts of the extrusion apparatus were washed and rinsed with distilled water before samples were collected from a fresh core. All samples were handled with fresh latex gloves that were always discarded between consecutive collections of samples and frequently during the processing of samples from a single core.

Reproducibility of the sample homogenization process was tested with replicate analyses of approximately 10 percent of the samples of each type. Relative Percent Difference (RPD) calculations based on the results for replicate sample pairs rarely exceeded the 50-percent limit. The single pair of PAH-analysis results that exceeded the 50-percent RPD limit was from environmental and quality-control samples that exhibited systematic differences. These two samples, however, were handled differently in the analytical laboratory (one sample was diluted, whereas the other was not), and the individual sample with low PAH concentrations also had low percent recoveries of surrogates that would account for the differences. Other RPDs exceeding the 50-percent limit were distributed randomly among impoundments and within samples. Of the exceedances for the six sample pairs that had RPD limit exceedances, four were represented by a single element (three pairs of measurements of molybdenum at concentrations close to its reporting level and one pair of measurements of chromium). The RPD values that exceeded the RPD limit in two sets of organic-compound samples are attributable to differences in sample dilution at the analytical laboratory. The replicate-sample results showed that the sampling process produced consistently representative data for this study.

Sediment Thickness and Bathymetric Maps

Although sediment-thickness data associated with the core sites were not used to create the sediment maps, data obtained by manual probing indicate the core sites where sediment thicknesses and water depths were greatest. Sediment-core lengths were generally less than the lengths measured by manual probing because a thin, pointed metal rod can penetrate sediments farther than a 2 to 3-in.-diameter flat-edged, plastic tube.

Data collected by manual probing were used to determine the water-depth contour lines on the bathymetric maps of the impoundments (figs. 9 to 14). The maximum water depth was least in the Aluminum City impoundment (3.9 ft) and greatest in the Gleasondale impoundment (11 ft). Water depths were not related to a fixed datum and could change with streamflow.

The Aluminum City impoundment (fig. 9) was found to be rock-bottomed (rip-rapped) near the dam and to have primarily rock and sand refusal in the upstream reach. Its thickest sediments were measured near the dam (core site AC4, 3.3 ft) and close to the farthest upstream core site (AC1, 2.4 ft). The greatest water depth measured at the time of sediment mapping was 3.9 ft.

The thickest sediment deposits in the Allen Street impoundment (fig. 10) were measured near core sites AS6 and AS8 (11 ft). Probe refusal at the Allen Street impoundment was caused by sand and gravel within the channels upstream of AS5 and the area immediately downstream from the Allen Street bridge. The wide depositional area of the impoundment generally had a refusal caused by fine sand, silt, and clay. A maximum water depth of 8.2 ft was measured above thin sediment deposits between sites AS6 and AS8.

In Hudson, the impoundment's thickest sediment (7.5 ft) was measured in the area north of H12 (fig. 11); sediment thicknesses exceeding 6 ft were also measured in the vicinity of H15. The bottom of the Hudson impoundment was characterized by sand and gravel in the river channel and fine materials in lateral depositional areas. Water depths reached more than 10 ft near in the channel leading to the dam.

The deepest manual probes in Gleasondale sediments were made in the upstream areas (fig. 12) in the general vicinity of G18, G19, and G20, where they penetrated farther than 18 ft without reaching refusal; however, the probes may have penetrated preimpoundment sediment deposits. The downstream reach had a relatively steep gradient that may have caused sediment scouring and shallow sediment thicknesses. Water depths approached 11 ft near G22.

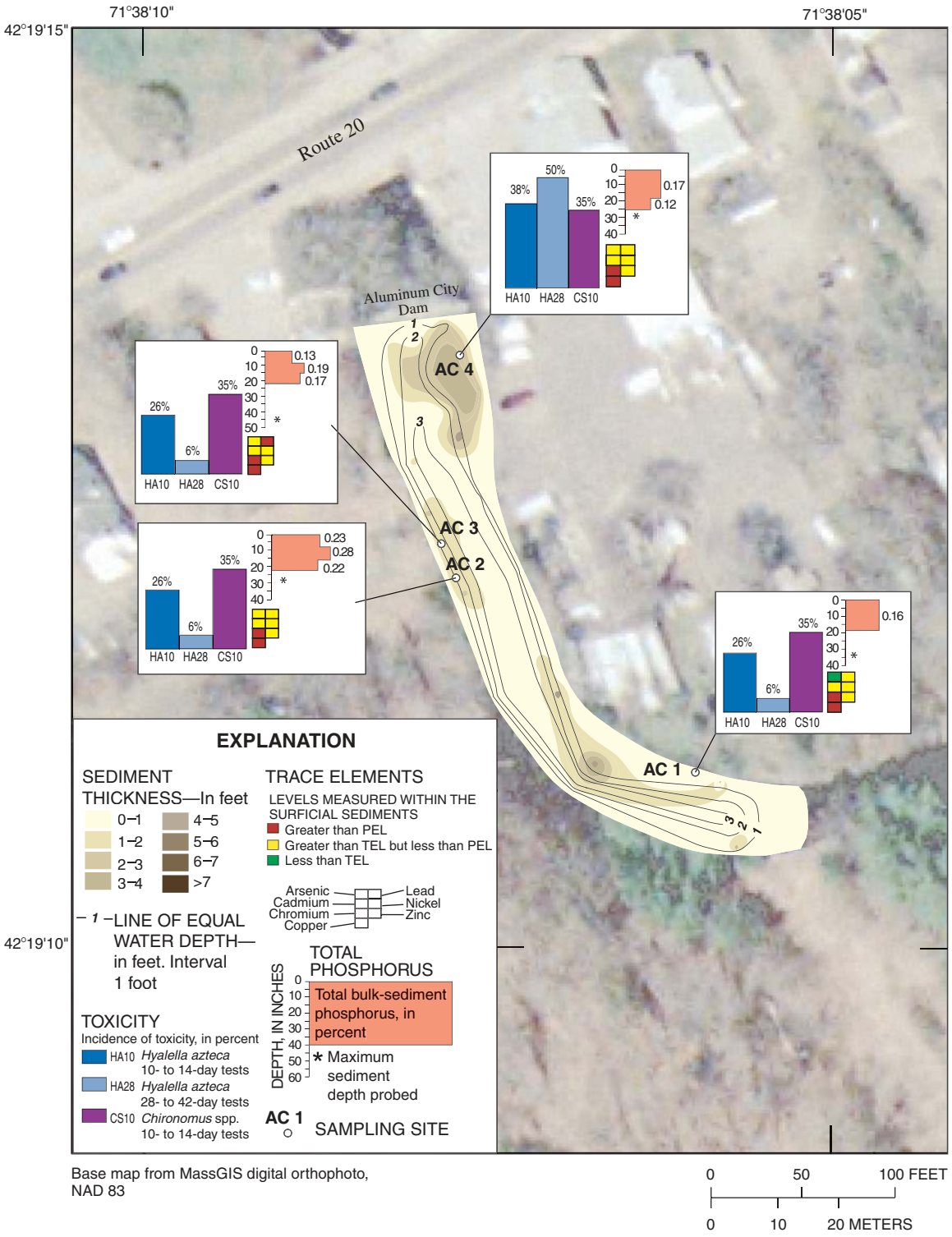


Figure 9. Sediment thickness, phosphorus bulk-sediment profiles, exceedances of TEL (threshold effect level) and PEL (probable effect level) guidelines for toxic trace elements, and potential for sediment toxicity to aquatic life from cores collected in Aluminum City impoundment in Northborough, Massachusetts, 2003.

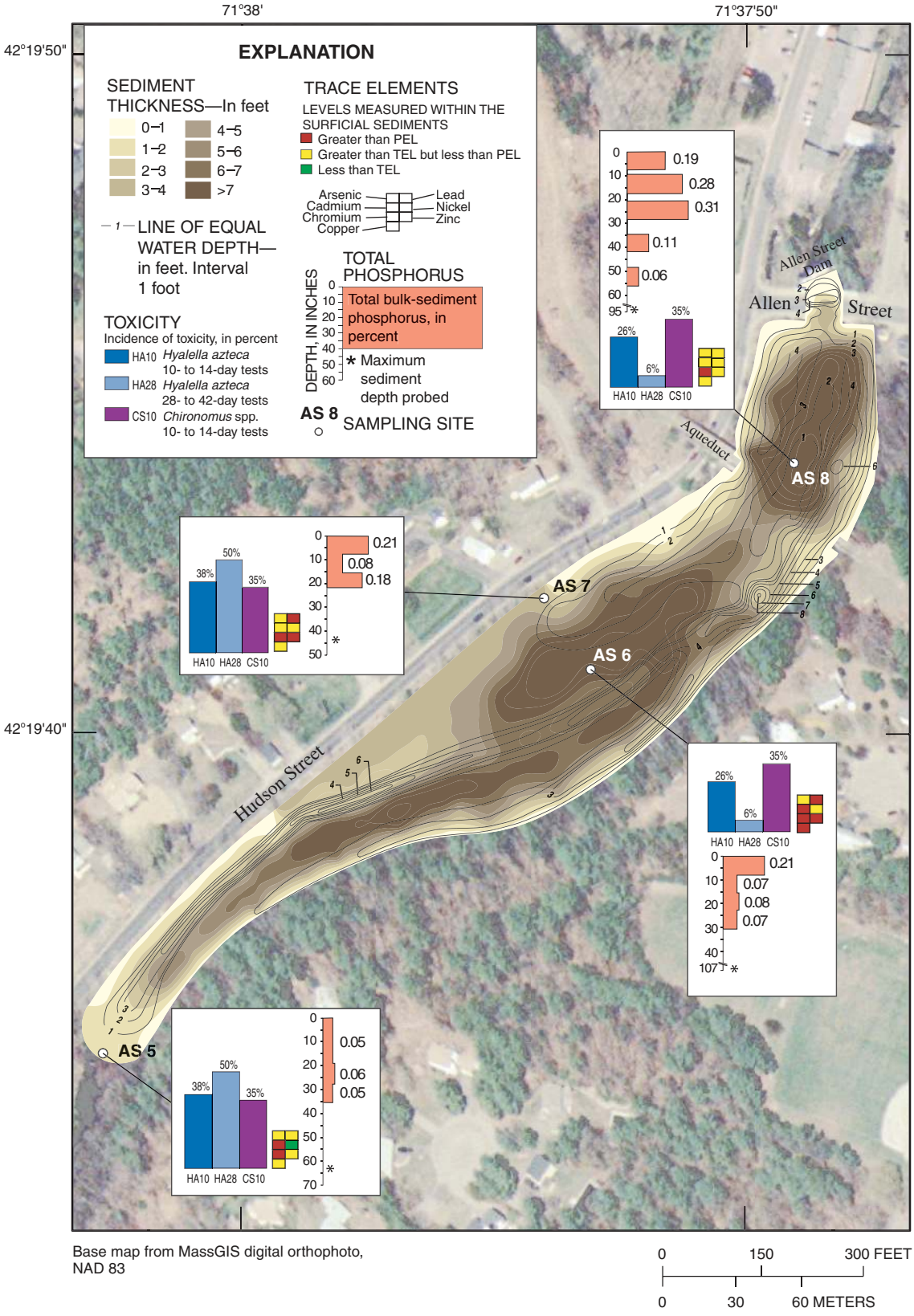


Figure 10. Sediment thickness, phosphorus bulk-sediment profiles, exceedances of TEL (threshold effect level) and PEL (probable effect level) guidelines for toxic trace elements, and potential for sediment toxicity to aquatic life from cores collected in Allen Street impoundment in Northborough, Massachusetts, 2003.

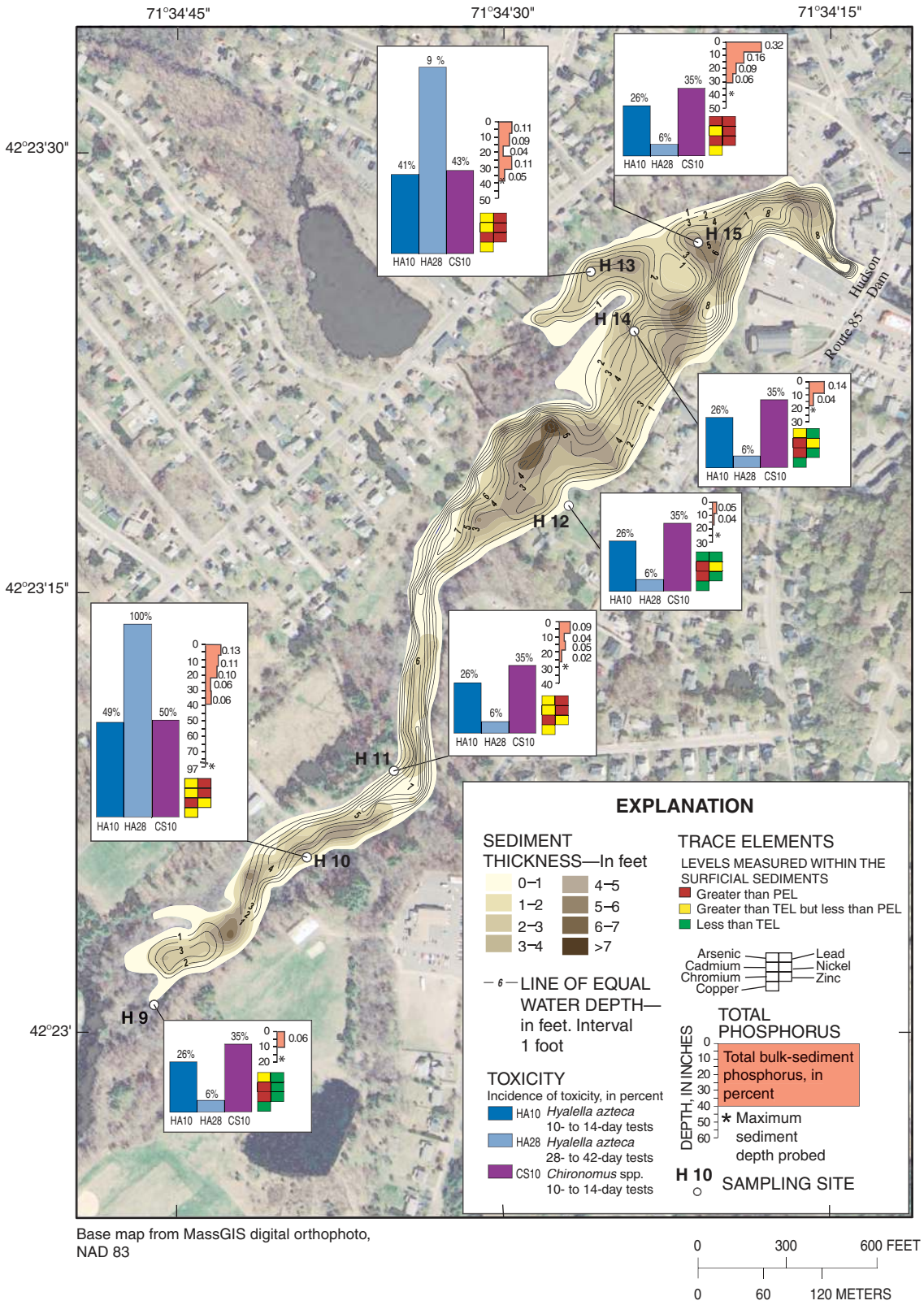


Figure 11. Sediment thickness, phosphorus bulk-sediment profiles, exceedances of TEL (threshold effect level) and PEL (probable effect level) guidelines for toxic trace elements, and potential for sediment toxicity to aquatic life from cores collected in Route 85 impoundment in Hudson, Massachusetts, 2003.

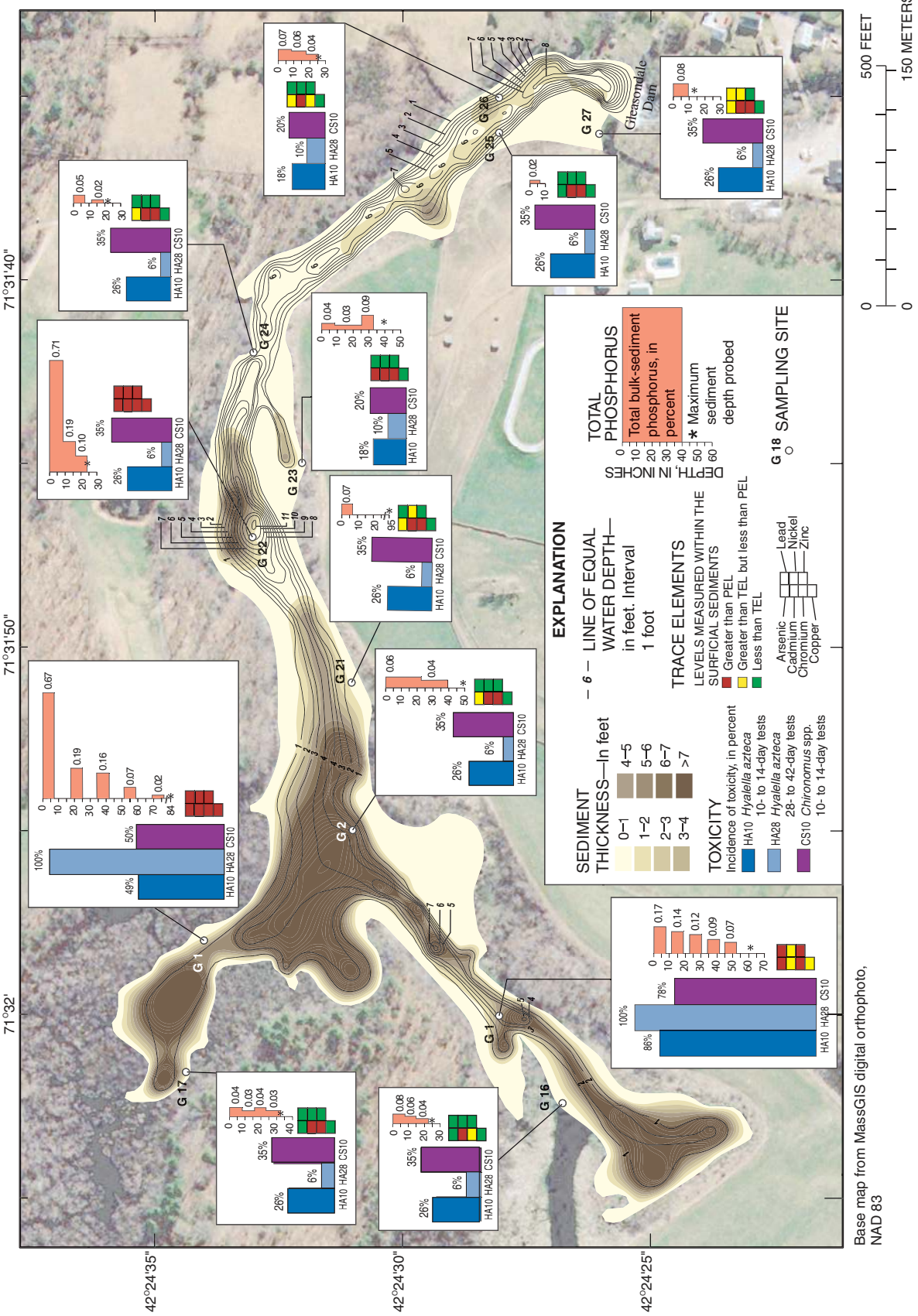
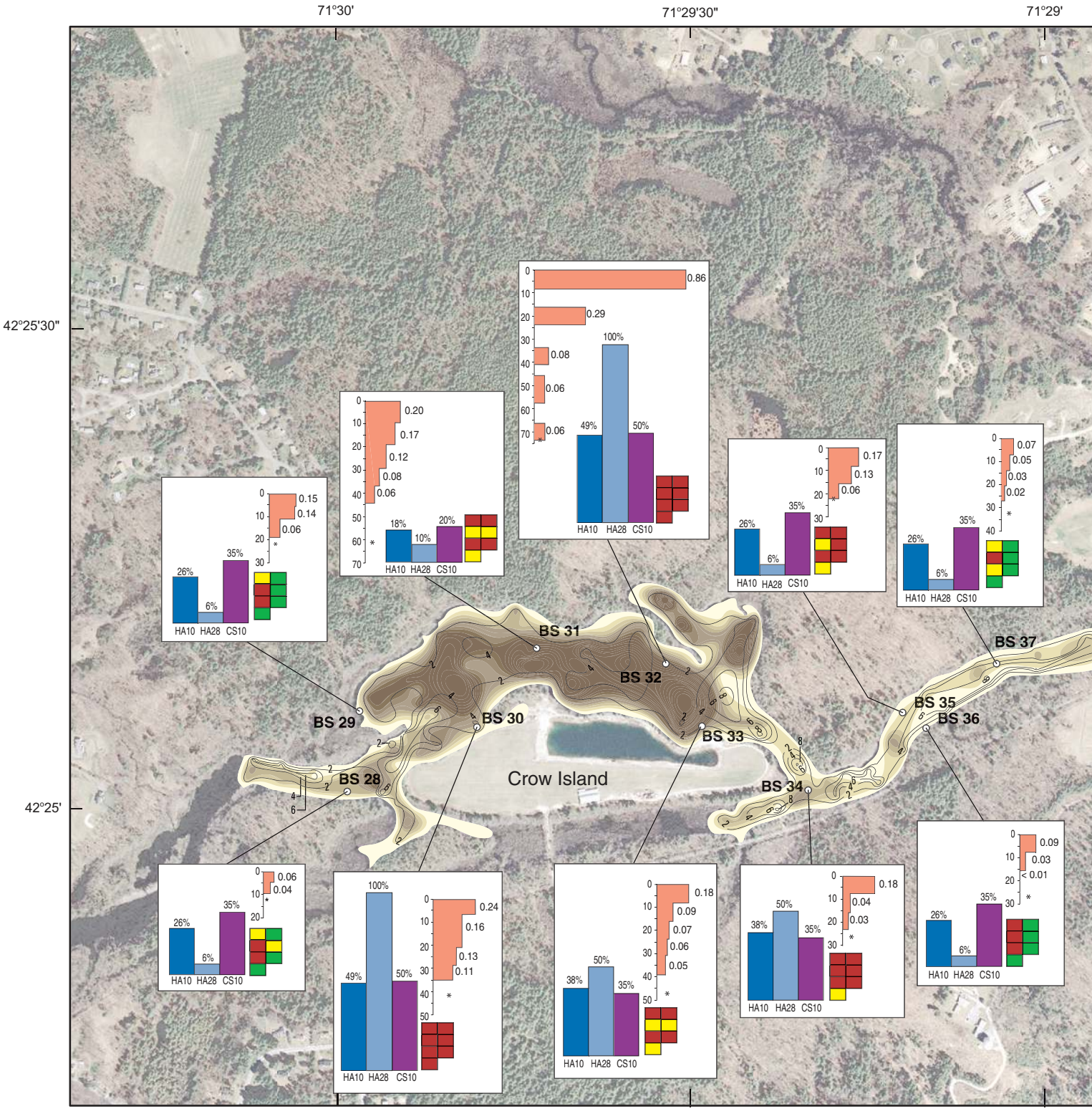
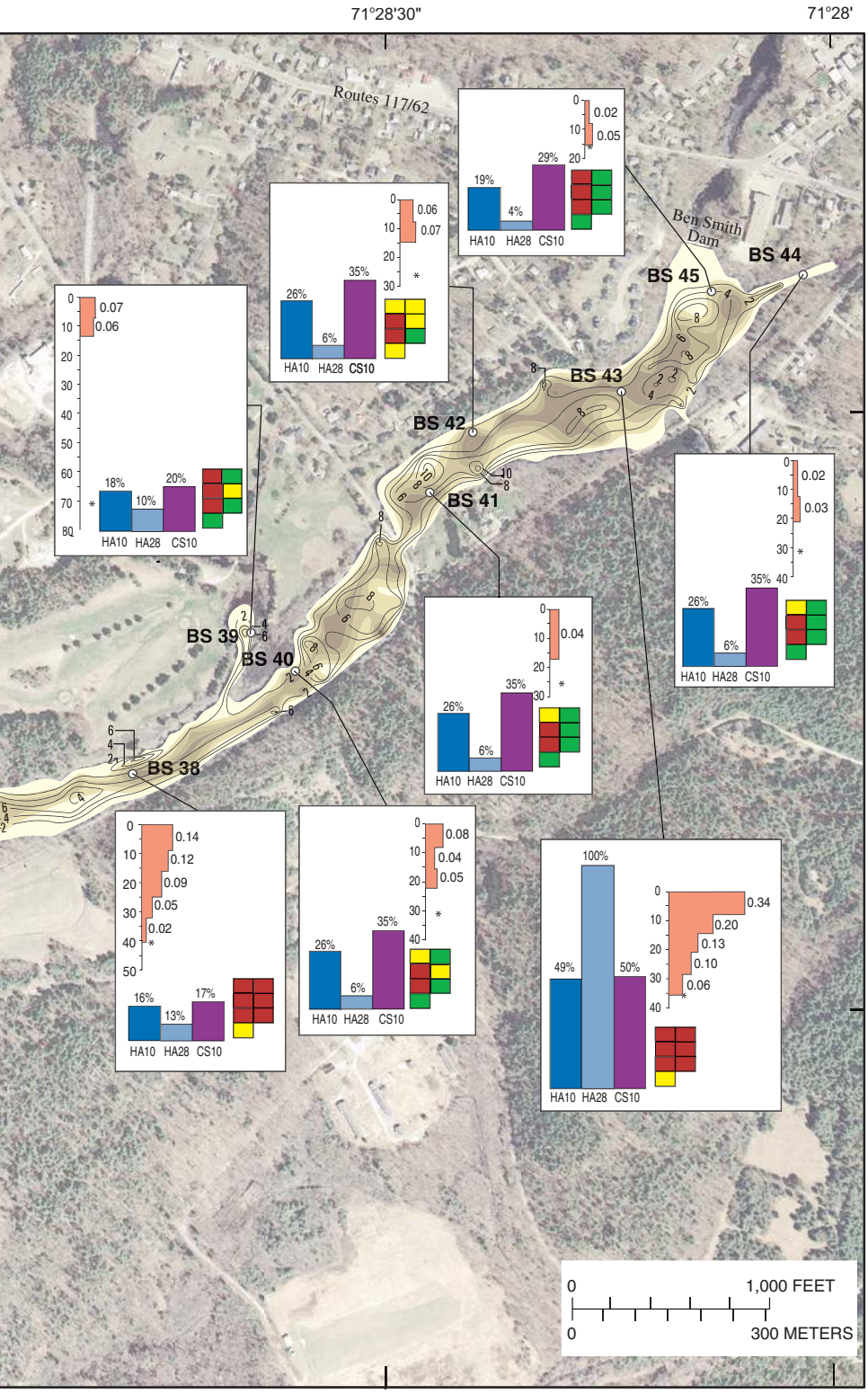


Figure 12. Sediment thickness, phosphorus bulk-sediment profiles, exceedances of TEL (threshold effect level) and PEL (probable effect level) guidelines for toxic trace elements, and potential for sediment toxicity to aquatic life from cores collected in Gleasondale impoundment in Stow, Massachusetts, 2003.



Base map from MassGIS digital orthophoto, NAD 83



EXPLANATION

SEDIMENT THICKNESS—In feet

0–1	4–5
1–2	5–6
2–3	6–7
3–4	>7

TOXICITY
Incidence of toxicity, in percent

- HA10 *Hyalella azteca* 10- to 14-day tests
- HA28 *Hyalella azteca* 28- to 42-day tests
- CS10 *Chironomus* spp. 10- to 14-day tests

– 6 – LINE OF EQUAL WATER DEPTH—in feet. Interval 2 feet

TRACE ELEMENTS

LEVELS MEASURED WITHIN THE SURFICIAL SEDIMENTS

- Greater than PEL
- Greater than TEL but less than PEL
- Less than TEL

Arsenic, Cadmium, Chromium, Copper, Lead, Nickel, Zinc

TOTAL PHOSPHORUS

DEPTH, IN INCHES

Total bulk-sediment phosphorus, in percent

* Maximum sediment depth probed

BS 44 SAMPLING SITE

Figure 13. Sediment thickness, phosphorus bulk-sediment profiles, exceedances of TEL (threshold effect level) and PEL (probable effect level) guidelines for toxic trace elements, and potential for sediment toxicity to aquatic life from cores collected in Ben Smith impoundment in Maynard, Massachusetts, 2003.

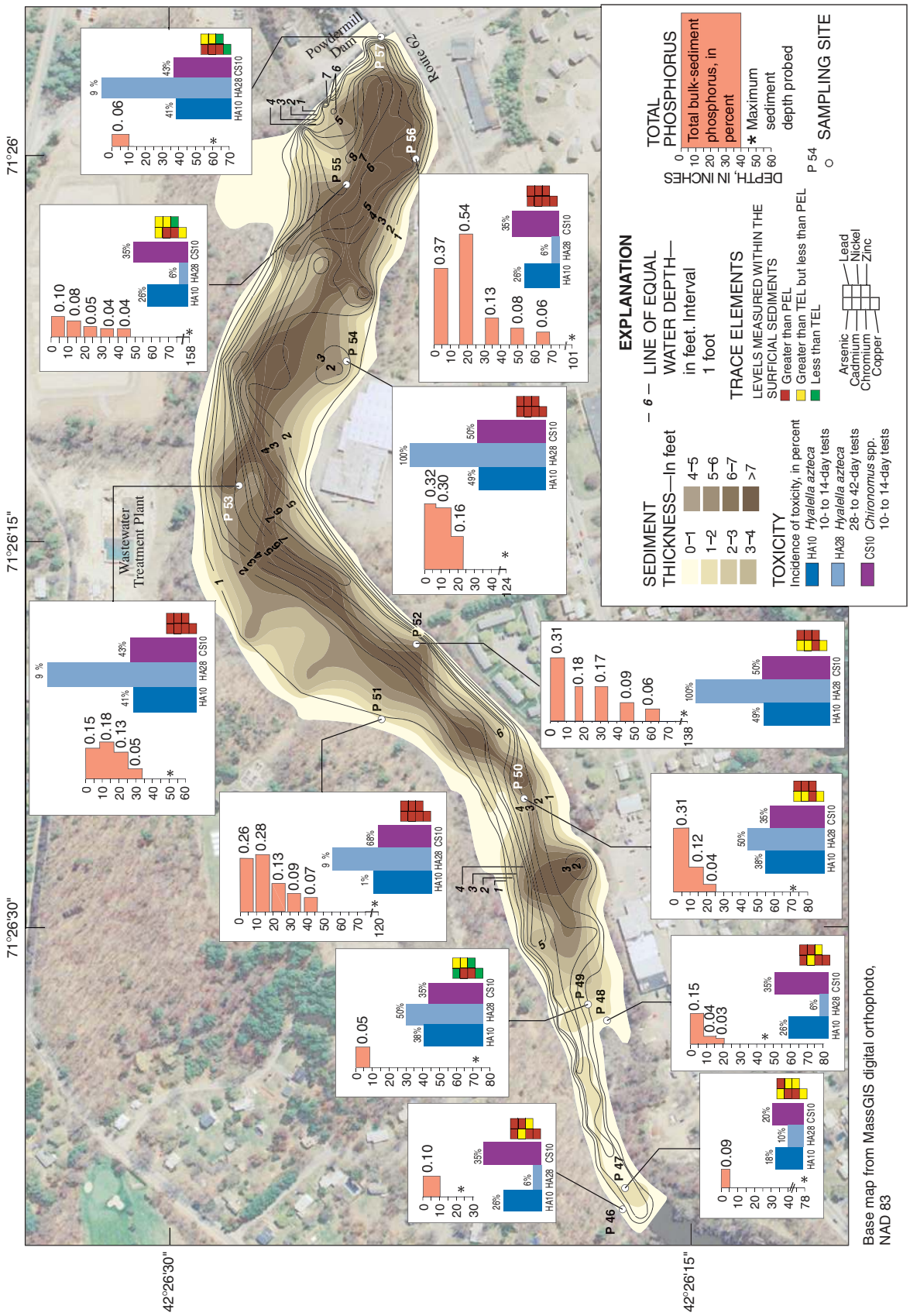


Figure 14. Sediment thickness, phosphorus bulk-sediment profiles, exceedances of TEL (threshold effect level) and PEL (probable effect level) guidelines for toxic trace elements, and potential for sediment toxicity to aquatic life from cores collected in Powdermill impoundment in Maynard and Acton, Massachusetts, 2003.

The elongated Ben Smith impoundment was characterized by extensive, thick sediment deposits in the vicinity of Crow Island (fig. 13). The probe reached through more than 15 ft of sediment at several places and more than 24 ft near BS32. The bottom of the narrow channel section between BS34 and BS41 was sandy with finer materials distributed along the lateral edges. In the vicinity of the dam, the bottom materials were predominantly coarse sand and gravel. Water depths exceeded 8 ft near the dam.

The Powdermill impoundment was characterized by having a narrow, rocky channel upstream from P49. Sediments were distributed uniformly throughout the main body of the impoundment, with the thickest sediments approximately along the impoundment's midline (fig. 14). Sandy conditions dominated the impoundment's bottom. Water depths were more than 8 ft just upstream of the dam.

Ben Smith impoundment had the greatest volume of sediment and Aluminum City the least, as calculated by the TIN computer program. In decreasing order, the impoundments' sediment volumes were: Ben Smith (580,000 m^3), Powdermill (120,000 m^3), Gleasondale (67,000 m^3), Hudson (55,000 m^3), Allen Street (42,000 m^3), and Aluminum City (380 m^3). These sediment-volume estimates may include some preimpoundment material, and thus may overestimate the amount of impounded sediment.

Sediment Chemistry of the Assabet River Impoundments

The concentrations of metals detected were compared among the impoundments and with results from analyses of the chemistry of sediments in other New England rivers (Chalmers, 2002; Robinson and others, 2004). The results were also compared with sediment-quality guidelines (table 2) related to 1) potential effects on freshwater organisms, 2) dangerous levels for human contact, and 3) permitted levels for reuse (disposal) in landfills. The potential effects on freshwater organisms are further organized into three groups: a) threshold effect level (TEL), the concentration below which adverse effects are rarely observed; b) probable effect level (PEL), the concentration above which adverse effects are commonly observed; and c) probable effect concentration (PEC), the concentration above which adverse effects are expected. In general, the PEC is greater than the PEL; the exception is Cu. The TEL and PEL are used in discussions of the effects of metals on biota and the PEC is used in discussions of the combined effects of metals, PAHs, and PCBs on biota.

Elemental Analyses

Dividing the results of the elemental analyses performed by SGS Canada Inc., Minerals Services, into three categories — phosphorus (as a bulk-sediment analyte), toxic metals, and other elements – groups the data in a meaningful way for efficient interpretation. The vertical distribution of phosphorus in sediments throughout the study area (table 3) was investigated because the sediments may serve as a potential phosphorus source. The toxic trace elements constitute a seven-element subset of metals (table 14, at back of report) often referred to as critical contaminants. The remaining elements are not generally considered commonly occurring toxics requiring special attention to minimize potential harm to aquatic life or humans; their concentrations are reported (table 15, at back of report), but not discussed in comparisons among the Assabet impoundments.

Phosphorus

A recent survey of stream sediments in New England (Chalmers, 2002) reported bulk concentrations of phosphorus in samples collected primarily in urban and rural settings. The median concentration from that study is slightly higher than those for the individual impoundments reported here (table 4). The maximum phosphorus concentrations in the Assabet River sediments, however, exceeded the maxima reported in the other study.

Bulk-sediment phosphorus concentrations ranged from less than the RL of 0.01 percent at site BS37 (subsample from approximately 2 ft below the sediment surface) to 0.86 percent at site BS32 (surface sample). Throughout the six-impoundment system, the highest phosphorus concentrations generally were measured in samples collected closest to the sediment surface (table 5; figs. 9 to 14). Three possible explanations for this distribution of phosphorus concentrations are: (1) high concentrations of phosphorus transported in the water column may serve as a continuous supply of phosphorus; (2) rooted macrophytes will take up available phosphorus from surficial sediments, and as these plants die and decay, all or part of their phosphorus will be deposited on the sediment surface, where it may once again become available; (3) phosphorus may dissolve in deep, anaerobic sediment, diffuse upward, and precipitate at the sediment-water interface.

Comparing the means, medians, minima, and maxima of concentrations of all samples and of only surface samples from the impoundments reveals phosphorus-concentration trends with reservoir position (table 5). In the environmental samples, the median phosphorus concentration was 0.08 percent and the mean concentration was 0.12 percent. Sediment samples from Aluminum City, from all impoundments, had the highest median (0.17 percent) and mean (0.18 percent) phosphorus concentrations. Sediment samples from Aluminum City had the lowest maximum (0.28 percent) but the highest minimum (0.12 percent) phosphorus concentrations of samples collected at all depths from all impoundments. Phosphorus-concentration maxima increased downstream from Aluminum City until the Powdermill impoundment, where the maximum concentration decreased. The minima of all samples generally decrease in the downstream direction.

Table 2. Sediment-quality guidelines for freshwater organisms, human contact, and Massachusetts landfill reuse.

[**Sources:** Massachusetts Department of Environmental Protection, 1995; Breault and others, 2000; Ingersoll and others, 2001. EPH, extractable petroleum hydrocarbon; PAH, polycyclic aromatic hydrocarbon; PCB, polychlorinated biphenyl; PEC, Probable Effect Concentration, concentration above which adverse effects are expected; PEL, Probable Effect Level, concentration above which adverse effects are commonly observed; TEL, Threshold Effect Level, concentration below which adverse effects are rarely observed; TPH, total petroleum hydrocarbon; µg/kg, micrograms per kilogram; mg/kg, milligrams per kilogram; <, actual value is less than value shown; --, no value available]

Constituent or class	TEL	PEL	PEC	Human contact	Landfill reuse
			Total organics (µg/kg)		
TPH (~EPH)	--	--	--	800,000	5,000,000
Total PAH	--	--	22,800	--	100,000
Total PCB	34.1	277	676	2,000	<2,000
Total chlordane	4.5	8.9	17.6	1,000	--
			Individual PAHs (µg/kg)		
Acenaphthylene	--	88.9	--	100,000	--
Acenaphthene	--	128	620	1,000,000	--
Anthracene	--	245	845	1,000,000	--
Benzo[*a*]anthracene	--	385	1,050	--	--
Benzo[*k*]fluoranthene	--	240	7,000	--	
Benzo[*g,h,i*]perylene	--	170	1,000,000	--	
Benzo[*a*]pyrene	--	782	1,450	700	--
Chrysene	--	862	1,290	7,000	--
Dibenzo[*a,h*]anthracene	--	135	--	700	--
Fluoranthene	--	2,355	2,230	1,000,000	--
Fluorene	--	144	536	1,000,000	--
Indeno[1,2,3-*cd*]pyrene	--	--	200	700	--
Naphthalene	--	391	561	100,000	--
Phenanthrene	--	515	1,170	1,000,000	--
Pyrene	--	875	1,520	700,000	--
			Individual PCB Aroclors (µg/kg)		
Aroclor-1248	--	--	30	--	--
Aroclor-1254	--	--	60	--	--
Aroclor-1260	--	--	5	--	--
Aroclor-1262	--	--	--	--	--
Aroclor-1268	--	--	--	--	--
			Metals (mg/kg)		
Arsenic	5.9	17	33	30	40
Cadmium	.6	3.53	4.98	30	80
Chromium	37.3	90	111	1,000	1,000
Copper	35.7	197	149	--	--
Lead	35	91.3	128	300	2,000
Nickel	18	35.9	48.6	300	--
Zinc	123	315	459	2,500	--

Table 3. Concentrations of phosphorus, in percent, in bulk sediment samples from six impoundments in the Assabet River Basin, Massachusetts, 2003.

[**Map ID:** The identifier associated with a sampling site on a map (figs. 9–14). **Sample ID:** Identifier for a sample collected from a particular core, arranged alphabetically from the top of the core. <, actual value is less than value shown]

Map ID	Sample ID	Total phosphorus (percent)
Aluminum City		
AC1	5	0.16
AC2	7A	.23
AC2	7B	.28
AC2	7C	.22
AC3	6A	.13
AC3	6B	.19
AC3	6C	.17
AC4	8A	.17
AC4	8B	.17
AC4	8C	.12
Allen Street		
AS5	1A	0.05
AS5	1B	.05
AS5	1C	.06
AS5	1D	.05
AS6	3A	.21
AS6	3B	.08
AS6	3C	.18
AS7	2A	.21
AS7	2B	.07
AS7	2C	.08
AS7	2D	.07
AS8	4A	.19
AS8	4B	.28
AS8	4C	.31
AS8	4D	.11
AS8	4E	.06
Hudson		
H9	9	0.06
H10	12A	.13
H10	12B	.11
H10	12C	.10
H10	12D	.04
H10	12E	.05
H11	13A	.09
H11	13B	.04
H11	13C	.05
H11	13D	.02
H12	11A	.04
H12	11B	.01
H13	14A	.11
H13	14B	.09
H13	14C	.04
Hudson—Continued		
H13	14D	0.18
H13	14E	.06
H14	10A	.14
H14	10B	.04
H15	15A	.32
H15	15B	.16
H15	15C	.09
H15	15D	.06
Gleasondale		
G16	34A	0.08
G16	34B	.06
G16	34C	.04
G17	39A	.04
G17	39B	.03
G17	39C	.04
G17	39D	.03
G18	35A	.17
G18	35B	.14
G18	35C	.12
G18	35D	.09
G18	35E	.07
G19	40A	.67
G19	40B	.19
G19	40C	.17
G19	40D	.07
G19	40E	.02
G20	36A	.06
G20	36B	.06
G20	36C	.04
G20	36D	.04
G20	36E	.05
G21	44	.07
G22	41A	.71
G22	41B	.19
G22	41C	.10
G23	37A	.04
G23	37B	.03
G23	37C	.03
G23	37D	.09
G24	42A	.05
G24	42B	.02
G25	45	.02
G26	38A	.07
Gleasondale—Continued		
G26	38B	0.06
G26	38C	.04
G27	43	.08
Ben Smith		
BS28	16A	0.06
BS28	16B	.04
BS29	18A	.15
BS29	18B	.14
BS29	18C	.06
BS30	17A	.24
BS30	17B	.16
BS30	17C	.16
BS30	17D	.13
BS30	17E	.11
BS31	19A	.20
BS31	19B	.17
BS31	19C	.12
BS31	19D	.08
BS31	19E	.06
BS32	20A	.86
BS32	20B	.29
BS32	20C	.08
BS32	20D	.06
BS32	20E	.06
BS33	21A	.18
BS33	21B	.09
BS33	21C	.07
BS33	21D	.06
BS33	21E	.05
BS34	22A	.18
BS34	22B	.04
BS34	22C	.03
BS35	23A	.17
BS35	23B	.13
BS35	23C	.06
BS36	27A	.07
BS36	27B	.05
BS36	27C	.03
BS36	27D	.02

Table 3. Concentrations of phosphorus, in percent, in bulk sediment samples from six impoundments in the Assabet River Basin, Massachusetts, 2003.—Continued

[**Map ID:** The identifier associated with a sampling site on a map (figs. 9–14). **Sample ID:** Identifier for a sample collected from a particular core, arranged alphabetically from the top of the core. <, actual value is less than value shown]

Map ID	Sample ID	Total phosphorus (percent)
Ben Smith—Continued		
BS37	29A	0.09
BS37	29B	.03
BS37	29C	<.01
BS38	26A	.14
BS38	26B	.12
BS38	26C	.09
BS38	26D	.05
BS38	26E	.02
BS39	25A	.07
BS39	25B	.06
BS40	24A	.08
BS40	24B	.04
BS40	24C	.05
BS41	28A	.04
BS41	28B	.04
BS42	33A	.06
BS42	33B	.07
BS43	30A	.34
BS43	30B	.20
BS43	30C	.13
BS43	30D	.10
BS43	30E	.06
BS44	31A	.02
BS44	31B	.03
BS45	32A	.02
BS45	32B	.05
Powdermill		
P46	48	0.10
P47	49	.09
P48	46A	.15
P48	46B	.04
P48	46C	.03
P49	47	.05
P50	52A	.26
P50	52B	.28
P50	52C	.12
P50	52D	.09
P50	52E	.07
P51	55A	.15
P51	55B	.18
P51	55C	.13
P51	55D	.05
P52	53A	.31
P52	53B	.18
P52	53C	.17
P52	53D	.09
P52	53E	.06
Powdermill—Continued		
P53	56A	0.32
P53	56B	.30
P53	56C	.16
P54	54A	.31
P54	54B	.12
P54	54C	.04
P55	51A	.10
P55	51B	.08
P55	51C	.05
P55	51D	.04
P55	51E	.04
P56	50A	.37
P56	50B	.54
P56	50C	.13
P56	50D	.08
P56	50E	.06
P57	57	.07

Table 4. Mean and median concentrations of trace metals in New England stream sediments.

[mg/kg, milligrams per kilogram; NA, not available; <, actual value is less than value shown; --, no data]

Trace metal	Previous investigations				Current (2003) investigations			
	Robinson and others, 2004		Chalmers, 2002		Aluminum City		Allen Street	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median
Aluminum, percent	--	--	5.60	5.65	1.22	1.20	0.13	0.08
Antimony, mg/kg	--	--	2.70	2.40	<5	<5	<5	<5
Arsenic, mg/kg	5.08	2.80	39.2	19.0	10.0	9.00	11.0	11.0
Barium, mg/kg	331	315	506	455	183	180	120	87.5
Beryllium, mg/kg	--	--	3.00	2.80	NA	.50	<.5	<.5
Bismuth, mg/kg	--	--	NA	<1	NA	<5	<5	<5
Cadmium, mg/kg	--	--	3.75	2.10	2.00	2.00	NA	1.00
Calcium, percent	--	--	1.34	1.40	.45	.45	.32	.29
Chromium, mg/kg	--	--	134	99.0	336	149	168	154
Cobalt, mg/kg	--	--	19.9	18.0	12.0	12.0	12.0	11.0
Copper, mg/kg	12.1	10.0	121	92.5	397	298	149	55.0
Iron, percent	--	--	4.71	3.90	1.78	1.72	1.61	1.48
Lanthanum, mg/kg	53.7	41.0	50.5	46.0	14.7	15.5	13.3	13.4
Lead, mg/kg	44.1	30.0	229	190	113	82.0	153	150
Magnesium, percent	--	--	.70	.71	.38	.36	1.09	1.02
Manganese, mg/kg	--	--	3,500	1,850	465	481	358	280
Molybdenum, mg/kg	--	--	4.85	2.60	5.50	5.50	NA	2.50
Nickel, mg/kg	--	--	43.4	45.0	25.0	24.0	21.0	19.0
Phosphorus, percent	--	--	.23	.22	.18	.17	.13	.08
Potassium, percent	--	--	1.46	1.40	.17	.16	.17	.17
Scandium, mg/kg	9.78	9.00	8.71	8.50	1.66	1.60	1.79	1.80
Silver, mg/kg	--	--	2.31	1.50	NA	5.20	NA	.35
Sodium, percent	--	--	1.30	1.20	.05	.04	.04	.04
Strontium, mg/kg	157	146	165	170	41.0	43.0	29.0	23.0
Tin, mg/kg	--	--	23.4	18.5	22.9	20.0	25.6	26.0
Titanium, mg/kg	--	--	.41	.42	.03	.03	.05	.05
Vanadium, mg/kg	55.5	53.0	76.8	78.5	25.0	26.0	26.0	25.0
Zinc, mg/kg	49.8	43.0	439	295	379	285	295	216
Zirconium, mg/kg	723	535	--	--	2.79	2.80	2.25	2.00

Table 4. Mean and median concentrations of trace metals in New England stream sediments.—Continued

[mg/kg, milligrams per kilogram; NA, not available; <, actual value is less than value shown; --, no data]

Trace metal	Current (2003) investigations							
	Hudson		Gleasondale		Ben Smith		Powdermill	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median
Aluminum, percent	1.28	1.27	1.03	1.00	1.25	1.32	1.28	1.21
Antimony, mg/kg	<5	<5	<5	<5	<5	<5	NA	<5
Arsenic, mg/kg	17.0	9.00	17.0	11.0	22.0	13.0	22.5	14.0
Barium, mg/kg	73.5	43.0	79.6	53.0	79.2	54.0	133	95.5
Beryllium, mg/kg	NA	.70	NA	<.5	NA	.70	NA	.55
Bismuth, mg/kg	<5	<5	<5	<5	<5	<5	<5	<5
Cadmium, mg/kg	NA	<1	NA	<1	NA	<1	NA	<1
Calcium, percent	1.99	2.15	.31	.29	.27	.27	.43	.29
Chromium, mg/kg	155	155	205	194	177	170	588	322
Cobalt, mg/kg	26.1	22.0	11.0	8.00	1.89	1.62	19.0	13.0
Copper, mg/kg	44.0	14.0	61.0	11.0	49.0	13.0	291	89.2
Iron, percent	1.97	1.66	1.54	1.40	49.3	13.4	1.96	1.94
Lanthanum, mg/kg	22.0	15.3	13.1	12.2	19.6	15.0	15.6	12.9
Lead, mg/kg	95.0	20.0	68.0	16.0	121	16.0	248	171
Magnesium, percent	.30	.27	.30	.32	.25	.27	.31	.32
Manganese, mg/kg	412.2	243	320	245	519	439	348	292
Molybdenum, mg/kg	NA	<.2	4.00	3.00	4.00	4.00	5.81	5.00
Nickel, mg/kg	26.0	22.0	24.0	17.0	25.0	16.0	47.8	30.0
Phosphorus, percent	.12	.08	.11	.06	.11	.07	.15	.11
Potassium, percent	.30	.25	.15	.16	.09	.08	.14	.14
Scandium, mg/kg	1.99	2.15	1.71	1.70	1.82	1.80	1.76	1.70
Silver, mg/kg	NA	<.2	NA	<.2	NA	.20	NA	1.20
Sodium, percent	.30	.27	.04	.04	.04	.04	.04	.04
Strontium, mg/kg	24.0	23.0	22.0	21.0	21.0	20.0	8.13	7.00
Tin, mg/kg	NA	<1	NA	<1	.03	.02	67.6	50.5
Titanium, mg/kg	.04	.04	.03	.03	.03	.02	.04	.04
Vanadium, mg/kg	155	155	.03	.03	23.0	24.0	28.0	28.0
Zinc, mg/kg	132	63.0	134	37.0	144	37.0	319	163
Zirconium, mg/kg	NA	1.60	2.13	2.30	1.41	1.30	2.59	2.15

Table 5. Summary statistics of total bulk phosphorus concentrations in sediment samples from six impoundments in the Assabet River Basin, Massachusetts, 2003.

[All concentrations in percent. <, actual value is less than value shown]

Impoundment	Median, all samples	Mean, all samples	Maximum, all samples	Minimum, all samples	Median, surface samples	Mean, surface samples	Maximum, surface samples	Minimum, surface samples
Aluminum City	0.17	0.18	0.28	0.12	0.17	0.17	0.23	0.13
Allen Street	.08	.13	.31	.05	.21	.17	.21	.05
Hudson	.06	.08	.32	.01	.11	.13	.32	.04
Gleasondale	.06	.10	.71	.02	.07	.17	.71	.02
Ben Smith	.07	.11	.86	<.01	.12	.17	.86	.02
Powdermill	.07	.15	.54	.03	.15	.19	.37	.05

Whereas the medians and means of the surface samples exhibited no trends with reservoir position, the surface-sample phosphorus maxima and minima exhibited trends similar to those for all samples. Three of the maximum surface values were the same as the maximum values for all samples.

Within some of the individual impoundments, the distribution of sediment phosphorus concentrations varied considerably. At Aluminum City (fig. 9), the smallest impoundment, where only four sets of cores were collected, sample concentrations ranged from 0.12 (in the sample from the greatest depth at site AC4) to 0.28 percent (at site AC2 in the sample from the intermediate depth). At Allen Street (fig. 10), the phosphorus concentrations were lowest in the core collected farthest upstream (AS5). The farthest downstream core (AS8) yielded samples with the highest phosphorus concentrations (0.28 and 0.31 percent) measured in this impoundment. In the Hudson impoundment (fig. 11), the highest phosphorus concentrations, 0.16 to 0.32 percent, were found in upper sediment layers at the most downstream sites (H14 and H15). In the Gleasondale impoundment (fig. 12), phosphorus concentrations were generally low, but the surface samples from sites G19 and G22 had high concentrations, 0.67 and 0.71 percent, respectively. Of all the impoundments, the Gleasondale impoundment had the steepest bed-slope gradient, and the downstream sediment thicknesses were not great; it is possible that phosphorus-bearing sediments did not settle out in that section. At Ben Smith (fig. 13), most of the high phosphorus concentrations were found in cores from the upper reaches of the impoundment (BS29 to BS35), although a few comparable concentrations were found in cores BS38 and BS43 from the downstream half of the impoundment. Finally, in the Powdermill impoundment (fig. 14), the highest concentrations of phosphorus were detected in cores P50 through P54 and P56, which were collected between the middle and the downstream end of the impoundment. This area coincides with the outfall from the Maynard wastewater-treatment plant.

The maps provide data useful for deciding the extent of sediment to dredge, both by surface area and by depth, if that option is considered; however, no target bulk-sediment phosphorus concentration that would eliminate or minimize nuisance plant growth has been established. The data indicate that if surficial sediments were removed, the sediments at greater depths would still contain phosphorus.

Toxic Trace Elements

The occurrence, distribution, and potential toxic effects of seven metals—arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), nickel (Ni), lead (Pb), and zinc (Zn), metals that may come from natural weathering, from industrial areas, agricultural applications, or automobile traffic (Robinson and others, 2004)—were assessed in the surficial sediment samples of the six Assabet impoundments (table 14; figs. 9 to 14). Even at low ambient concentrations, these metals can prove harmful to aquatic organisms, because they concentrate through bioaccumulation. Mercury, another commonly cited toxic metal, is not considered here because the required sample storage and analysis methods for mercury were beyond the scope of this investigation.

Results of recent studies generally bracket the concentrations reported in this study (table 4). Robinson and others (2004) studied sediment samples from New England rivers whose watersheds represented a broad range of land uses, including relatively undisturbed areas. Their results generally described streams in which the concentrations of all four (As, Cu, Pb, and Zn) of the seven toxic metals reported had lower concentrations than were detected in the Assabet sediments; exceptions were the high concentrations of strontium and zirconium that they reported. In contrast, the mean and median concentrations of the seven toxic metals calculated from Chalmers's (2002) data, with the exception of chromium, were higher than those determined in the Assabet sediment samples; her study focused on streams whose chemistry was strongly affected by urban land use, a likely source of metal contamination. In both of these studies, surficial-sediment samples were sieved and were not necessarily digested with aqua regia, procedures that could have affected the concentrations measured.

Among the Assabet impoundments, highest average concentrations for the seven metals were found in either the Aluminum City impoundment (Cd, Cu, and Zn) or the Powdermill impoundment (As, Cr, Ni, and Pb); however, sediment samples from many sites in all of the six impoundments had high metal concentrations (table 14). At Aluminum City, extremely high concentrations of Cr (2,070 mg/kg) and Zn (1,220 mg/kg) were found in samples from AC4; samples from AC3 and AC2 also had high metal concentrations. The highest metal concentrations in samples from Allen Street were detected at AS6, AS7, and AS8; in particular, samples from AS8 had high concentrations of Cu (807 mg/kg) and Zn (551 mg/kg) and samples from AS7 and AS6 had high concentrations of Zn (827 and 487 mg/kg, respectively). In the Hudson impoundment, high concentrations of Zn, Pb, Cr, and Cu were detected in samples from H10, H11, H13 and H15; Zn, of these four metals, was generally found in highest concentrations in samples collected from these sites. In Gleasondale, samples from sites G18, G19, and G22 all were characterized by high metal concentrations. Sites with high concentrations of metals were scattered throughout the elongated Ben Smith impoundment (in particular, BS30 to BS35, BS38, and BS43), but these sites were most densely distributed in the wide upstream section of the impoundment (fig. 13). About half the sites within the Powdermill impoundment yielded samples of sediment with high metal concentrations: P46, P48, P51 to P54, and P56. Powdermill yielded 15 detections of metal concentrations higher than 1,000 mg/kg.

Concentrations of metals in many of the sediment samples from the six impoundments exceeded sediment-quality guidelines (table 2; figures 9 to 14 describe which sediment concentrations exceeded the TEL and PEL for surface samples only. See tables 3 and 15 to determine exceedances for all sediment samples.)

Arsenic concentrations in samples from all of the impoundments were generally higher than the TEL of 5.9 mg/kg. At Aluminum City and Allen Street, the PEL was not exceeded; in the Hudson impoundment, the PEL of 17 mg/kg was exceeded at four of seven sites; the human-contact guideline of 30 mg/kg was exceeded at H11 and H15 and the landfill-reuse guideline of 40 mg/kg was exceeded at H15. At Gleasondale, the PEC guideline for As was exceeded at G18-G20 and G22, and the human-contact guideline at G18-G20. At Ben Smith, the PEL or PEC was equaled or exceeded at all but two sites in at least one sample. In the Powdermill impoundment, sites noted previously as having sediment samples with multiple, high-concentration detections (P48, P50 to P54, and P56) also had As concentrations exceeding either or both of the human-contact and the landfill-reuse guidelines.

Most of the Cd analyses returned values below the reporting level of 1 mg/kg, leaving uncertainty about the frequency with which the TEL of 0.6 mg/kg was exceeded. The PEL of 3.53 mg/kg or the PEC of 4.98 mg/kg was exceeded in 1 sediment sample at Aluminum City, 2 at Allen Street, none at Hudson, 2 at Gleasondale, 7 at Ben Smith, and 11 at Powdermill. Human-contact and landfill-disposal guidelines for Cd were not exceeded at any of the impoundments.

Only a single sediment sample had a Cr concentration lower than the TEL of 37.3 mg/kg. Most Cr concentrations were higher than the PEC of 111 mg/kg. Eight samples from sites in the Powdermill impoundment (P48, P51-P54, and P56) had Cr concentrations higher than the 1,000 mg/kg maximum concentration allowable for human contact and landfill disposal.

All but two samples from the Aluminum City impoundment had Cu concentrations higher than the PEL of 197 mg/kg. Half of the samples from Allen Street had concentrations of Cu less than the PEC of 149 mg/kg and higher than the TEL of 35.7 mg/kg. At Hudson, 13 of 23 samples had Cu concentrations lower than the TEL and none exceeded the PEC. At Gleasondale also, 23 of 37 samples had concentrations less than the TEL; in samples from sites G19 and G22, the PEL was exceeded. In the Ben Smith impoundment, the PEC was exceeded in samples from five sites (BS30, BS31, BS32, BS34, and BS43) and the PEL was exceeded in two samples (BS30 and BS32). At Powdermill, the PEL was exceeded at the same seven sites (P46, P48, P51, P52, P53, P54, and P56).

In sediment samples from all the impoundments, sediment concentrations of Ni frequently exceeded the 18 mg/kg TEL. At Aluminum City and Allen Street, the PEL (35.9 mg/kg) was not exceeded. At Hudson, samples from sites H10, H13, and H15 had concentrations higher than the PEC (48.6 mg/kg). In the Gleasondale impoundment, the PEC was exceeded at G19 and G22; at Ben Smith and Powdermill, samples from sites BS30, B32, B34, B35, B38, B43, P46, P48, and P50 to P56 had samples with concentrations higher than either the PEL or PEC.

All the sediment samples collected at Aluminum City and Allen Street had Pb concentrations that exceeded the TEL (35 mg/kg), and more than half had concentrations that also exceeded the PEC (128 mg/kg). More than half of the samples from Hudson, Gleasondale, and Ben Smith had Pb concentrations lower than the TEL. Most of the other sample Pb concentrations, however, were higher than the PEC; one sample from H10 had a Pb concentration of 324 mg/kg, which exceeded the human-contact guideline of 300 mg/kg, and a sample from BS38 had a Pb concentration of 3,800 mg/kg—higher than the maximum for landfill reuse (2,000 mg/kg). At Powdermill, 12 of the sites had samples with Pb concentrations that exceeded the PEC, and 12 samples had concentrations (at P50 to P54 and P56) higher than the human-contact guideline; none exceeded the landfill-disposal guideline.

The sediment-quality guidelines for Zn are higher than the other metals. Nevertheless, all the samples from Aluminum City had Zn concentrations in excess of the 123 mg/kg TEL; four samples had concentrations that exceeded the PEL (315 mg/kg) or PEC (459 mg/kg). Concentrations in 12 of the 16 samples collected at Allen Street also exceeded the TEL and 5 also exceeded the PEC. At Hudson, most of the samples had Zn concentrations lower than the TEL; none exceeded the PEC, but samples from H13 and H15 had Zn concentrations higher than the PEL. At Gleasondale, concentrations in samples from only sites G18, G19, and G22 exceeded the sediment-quality guidelines. In the Ben Smith impoundment, most of the samples whose concentrations exceeded the Zn guidelines were taken from the upstream area, the Zn PEC was exceeded by concentrations in at least one sample from BS30 to BS32, BS34, and BS38. At Powdermill, Zn concentrations in more than half (21) of the samples exceeded the TEL; 8 of those samples also had Zn concentrations greater than the PEC; 4 were in excess of 1,000 mg/kg.

Reactive Sulfide

Only one sample had a reactive sulfide concentration (1,570 mg/kg) that exceeded the minimum reporting level of 5 mg/kg. The sample came from a completely homogenized, 62-cm core from the Gleasondale impoundment, site G22 (fig. 12). Sediment from this site also exhibited higher concentrations of toxic metals than sediment from the other sites at Gleasondale (table 3).

Organic Analyses

Because only a subset of the cores selected for organic-chemistry analyses were sectioned, it is not possible to make broad generalizations about concentration trends with depth. Changes with depth are discussed for individual cores and more general interpretations are based on means or medians of all samples collected within an impoundment.

Volatile Organic Compounds and Organochlorine Pesticides

Matrix interference in all VOC and organochlorine-pesticide samples required sample dilution by factors as great as 100. Such dilutions caused reporting levels to increase by the same factors. As a probable result of these effects, the analytical laboratories reported no detections for either category of compound. The lack of detections, however, should not be interpreted to mean that the compounds were absent in the tested samples because the compounds were detected in New England by Harris (1997) and Chalmers (2002). A regional study of organochlorine pesticides in New England conducted from 1992 to 1994 by Harris (1997) reported the detection of dichlorodiphenyltrichloroethane, chlordane, and some of their metabolites, as well as nonachlor and dieldrin. A more recent study (Chalmers, 2002) reported detections of the same compounds in sediments in a different set of New England streams.

Polycyclic Aromatic Hydrocarbons

PAHs are one of the most frequently detected types of compounds in sediments. As particles from incomplete hydrocarbon combustion and in runoff from roads and parking lots, PAHs eventually enter water bodies, adsorb to other particles, and sink to the bottom. These compounds exhibit carcinogenic and mutagenic properties (Somers and others, 2004), and hence may affect human health and aquatic life.

Among the six impoundments, the highest mean and median total PAH concentrations, 89,500 µg/kg and 16,500 µg/kg, respectively, were found in sediment samples from the Powdermill impoundment. Samples from Ben Smith had the lowest median total PAH concentration (615 µg/kg), and Aluminum City had the lowest mean total PAH concentration (2,850 µg/kg); Ben Smith also had a relatively low mean total PAH concentration (4,520 µg/kg). In samples from Allen Street, Hudson, and Gleasondale, the mean PAH concentrations were similar, whereas the medians differed considerably in samples from these three impoundments (table 6).

No general total PAH vertical-distribution patterns appear obvious among the sectioned samples (table 16, at back of report). Many seem to decrease with increasing depth (for example, AC4, H13, G18, BS30, BS32, BS38, BS43, P54), while others increase (BS31, P48), and some exhibit no clear trend with depth (AS7, G19, P56). These data demonstrate, at minimum, the variability in the distribution of PAH compounds deposited over time.

Concentrations of total PAHs in many (9 of 20) of the samples from the Powdermill impoundment exceed the PEC sediment-quality guideline of 22,800 µg/kg (Ingersoll and others, 2000; table 16). Few samples from the other impoundments exceed this value: Aluminum City (0), Allen Street (1), Hudson (3), Gleasondale (4), and Ben Smith (2) (fig. 15).

Table 6. Median and mean values for total polycyclic aromatic hydrocarbon concentrations detected in sediment samples from six impoundments in the Assabet River Basin, Massachusetts, 2003.

[All values are in micrograms per kilogram]

Impoundment	Median	Mean
Aluminum City	2,950	2,850
Allen Street	12,100	19,000
Hudson	1,140	18,900
Gleasondale	3,000	16,700
Ben Smith	615	4,520
Powdermill	16,500	89,500

A sample from the Powdermill impoundment had the highest total PAH concentration (site P50, 1,100,000 µg/kg); this impoundment had a sample from one additional site (P52) with a total PAH concentration that exceeded the Massachusetts standard of 100,000 µg/kg for sediment reuse at lined landfills. Other impoundment sites exhibiting high total PAH concentrations include AS5 and AS7 (Allen Street), H10 and H13 (Hudson), G18 and G19 (Gleasondale), BS30 and BS31 (Ben Smith), and P46, P47, P48, P53, and P56 (Powdermill).

Many samples had concentrations of individual PAH compounds that exceeded PEL and PEC sediment-quality guidelines (tables 3 and 16). The Powdermill impoundment yielded the largest percentage of samples that exceeded the guidelines; Aluminum City and Ben Smith yielded the smallest percentage of samples.

Polychlorinated Biphenyls

Total PCB concentrations and individual Aroclor concentrations differed substantially within and among the impoundments (table 7; fig. 16). No PCBs were detected in any of the Hudson-impoundment samples. Only Aroclors 1248, 1254, and 1260 were detected in samples from Aluminum City, Allen Street, and Ben Smith impoundments; only Aroclors 1254, 1260, and 1262 were detected in Ben Smith; and only Aroclors 1254, 1260, and 1268 were found in samples from Powdermill.

Only one sample, from Gleasondale impoundment site G18, had a total PCB concentration (3,100 µg/kg) that exceeded the maximum allowable for sediment reuse in lined landfills and for human contact (2,000 µg/kg); however, all samples except for two (AC4 and BS28) with detectable PCB concentrations exceeded the TEL sediment-quality guideline of 34.1 µg/kg; about half of the sites (14 of 30) also had total PCB concentrations greater than the PEL of 277 µg/kg; eight of the sites (G18, G19, BS30, BS33, BS34, BS43, P48, and P56) also had total PCB concentrations that were higher than the PEC of 676 µg/kg. In addition, most of the samples in which Aroclors 1248, 1254, and 1262 were detected exceeded the PEC values for these individual PCB Aroclors (table 2).

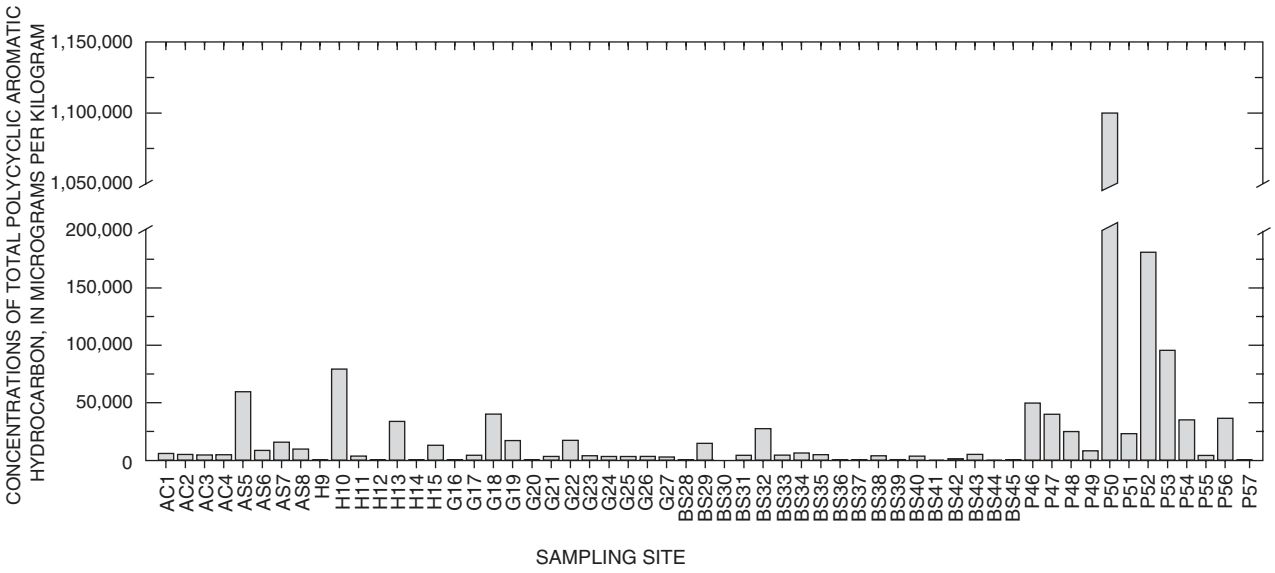


Figure 15. Total polycyclic aromatic hydrocarbon concentrations in core samples from six impoundments in the Assabet River, central Massachusetts, 2003.

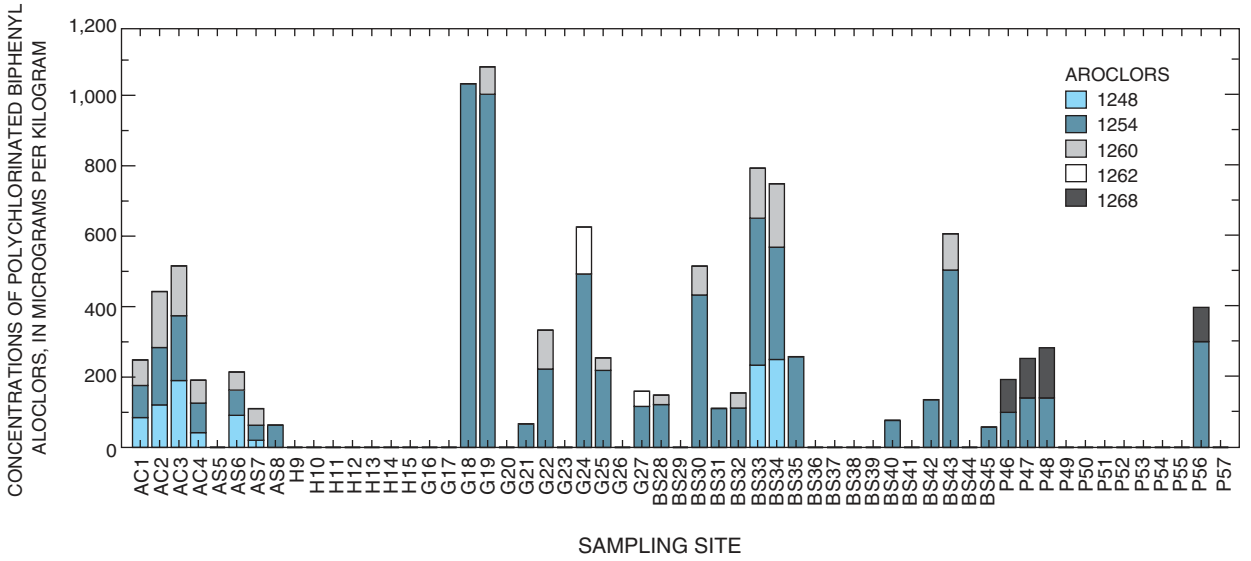


Figure 16. Concentrations of selected polychlorinated biphenyl Aroclors detected in core samples from six impoundments in the Assabet River, central Massachusetts, 2003.

Table 7. Concentrations of polychlorinated biphenyl Aroclors in sediment samples from six impoundments in the Assabet River Basin, Massachusetts, 2003.

[All values are in micrograms per kilogram. Minimum reporting level is 0.17 micrograms per kilogram. **Map ID:** The identifier associated with a sampling site on a map (figs. 9–14). **Sample ID:** Identifier for a sample collected from a particular core, arranged alphabetically from the top of the core, with Q designating a replicate sample. **Total PCB:** Sum of detectable concentrations of Aroclors rounded to three significant figures. Shaded numbers exceed sediment-quality guidelines. PCB, polychlorinated biphenyl, --, not detected]

Map ID	Sample ID	Aroclor					Total PCB
		1248	1254	1260	1262	1268	
Aluminum City							
AC1	5	85.2	91	72.6	--	--	249
AC2	7	121	163	159	--	--	443
AC3	6	190	184	142	--	--	516
AC4	8A	--	126	102	--	--	228
AC4	8B	126	100	69.2	--	--	295.2
AC4	8C	--	24.7	25.2	--	--	49.9
Allen Street							
AS5	1	--	--	--	--	--	--
AS6	3	91.2	71.7	51.6	--	--	214
AS7	2A	61.3	129	142	--	--	332
AS7	2B	--	--	--	--	--	--
AS7	2C	--	--	--	--	--	--
AS8	4	--	63.5	--	--	--	63.5
Hudson							
H9	9	--	--	--	--	--	--
H10	12	--	--	--	--	--	--
H10	12Q	--	--	--	--	--	--
H11	13	--	--	--	--	--	--
H12	11A	--	--	--	--	--	--
H12	11B	--	--	--	--	--	--
H13	14A	--	--	--	--	--	--
H13	14AQ	--	--	--	--	--	--
H13	14B	--	--	--	--	--	--
H13	14BQ	--	--	--	--	--	--
H13	14C	--	--	--	--	--	--
H13	14CQ	--	--	--	--	--	--
H14	10	--	--	--	--	--	--
H15	15	--	--	--	--	--	--
Gleasondale							
G16	34	--	--	--	--	--	--
G17	39	--	--	--	--	--	--
G18	35A	--	3,100	--	--	--	3,100
G18	35B	--	--	--	--	--	--
G18	35C	--	--	--	--	--	--
G19	40A	--	1,960	--	--	--	1,960
G19	40B	--	1,050	234	--	--	1,280
G19	40C	--	--	--	--	--	--
G19	40CQ	--	--	--	--	--	--
G20	36	--	--	--	--	--	--

Table 7. Concentrations of polychlorinated biphenyl Aroclors in sediment samples from six impoundments in the Assabet River Basin, Massachusetts, 2003.—Continued

[All values are in micrograms per kilogram. Minimum reporting level is 0.17 micrograms per kilogram. **Map ID:** The identifier associated with a sampling site on a map (figs. 9–14). **Sample ID:** Identifier for a sample collected from a particular core, arranged alphabetically from the top of the core, with Q designating a replicate sample. **Total PCB:** Sum of detectable concentrations of Aroclors rounded to three significant figures. Shaded numbers exceed sediment-quality guidelines. PCB, polychlorinated biphenyl, --, not detected]

Map ID	Sample ID	Aroclor					Total PCB
		1248	1254	1260	1262	1268	
				Gleasondale—Continued			
G20	36Q	--	--	--	--	--	--
G21	44	--	67.2	--	--	--	67.2
G22	41	--	223	110	--	--	333
G23	37	--	--	--	--	--	--
G24	42	--	493	--	133	--	626
G25	45	--	219	35.5	--	--	254
G26	38	--	--	--	--	--	--
G27	43	--	117	--	42.6	--	160
				Ben Smith			
BS28	16	--	122	26.7	--	--	149
BS29	18	--	--	--	--	--	--
BS30	17A	--	1,300	247	--	--	1,550
BS30	17B	--	--	--	--	--	--
BS30	17C	--	--	--	--	--	--
BS31	19A	--	--	--	--	--	--
BS31	19AQ	--	--	--	--	--	--
BS31	19B	--	--	--	--	--	--
BS31	19BQ	--	--	--	--	--	--
BS31	19C	--	332	--	--	--	332
BS31	19CQ	--	--	--	--	--	352
BS32	20A	--	335	130	--	--	465
BS32	20B	--	--	--	--	--	--
BS32	20C	--	--	--	--	--	--
BS33	21	234	417	142	--	--	793
BS34	22	250	319	180	--	--	749
BS35	23	--	258	--	--	--	258
BS36	27	--	--	--	--	--	--
BS37	29	--	--	--	--	--	--
BS38	26A	--	--	--	--	--	--
BS38	26B	--	--	--	--	--	--
BS38	26C	--	--	--	--	--	--
BS39	25	--	--	--	--	--	--
BS40	24	--	77	--	--	--	77
BS41	28	--	--	--	--	--	--
BS42	33	--	136	--	--	--	136
BS43	30A	--	1,300	309	--	--	1,610
BS43	30B	--	212	--	--	--	212
BS43	30C	--	--	--	--	--	--
BS44	31	--	--	--	--	--	--
BS45	32	--	57.8	--	--	--	57.8

Table 7. Concentrations of polychlorinated biphenyl Aroclors in sediment samples from six impoundments in the Assabet River Basin, Massachusetts, 2003.—Continued

[All values are in micrograms per kilogram. Minimum reporting level is 0.17 micrograms per kilogram. **Map ID:** The identifier associated with a sampling site on a map (figs. 9–14). **Sample ID:** Identifier for a sample collected from a particular core, arranged alphabetically from the top of the core, with Q designating a replicate sample. **Total PCB:** Sum of detectable concentrations of Aroclors rounded to three significant figures. Shaded numbers exceed sediment-quality guidelines. PCB, polychlorinated biphenyl, --, not detected]

Map ID	Sample ID	Aroclor					Total PCB
		1248	1254	1260	1262	1268	
				Powdermill			
P46	48	--	91.7	--	--	116	208
P46	48Q	--	108	--	--	69.3	177
P47	49	--	141	--	--	112	253
P48	46A	--	--	--	--	--	--
P48	46B	--	--	--	--	--	--
P48	46C	--	422	--	--	424	846
P49	47	--	--	--	--	--	--
P50	52	--	--	--	--	--	--
P51	55	--	--	--	--	--	--
P52	53	--	--	--	--	--	--
P53	56	--	--	--	--	--	--
P54	54A	--	--	--	--	--	--
P54	54B	--	--	--	--	--	--
P54	54C	--	--	--	--	--	--
P55	51A	--	--	--	--	--	--
P55	51B	--	--	--	--	--	--
P55	51C	--	--	--	--	--	--
P56	50A	--	631	--	--	177	808
P56	50AQ	--	726	381	--	178	1,280
P56	50B	--	273	--	--	113	386
P56	50C	--	--	--	--	--	--
P57	57	--	--	--	--	--	--

Extractable Petroleum Hydrocarbons

EPH analysis, the measure of the sum of the concentrations of extractable aliphatic (C_9 to C_{18} and C_{19} to C_{36}) and aromatic (C_{11} to C_{22}) petroleum hydrocarbons, provides data used to evaluate the effect of exposure of these compounds on human health. The sum of the concentrations of these compounds for a particular sample, plus the sum of the 17 PAHs also determined by this method, yields the traditional total petroleum hydrocarbon (TPH) value (Massachusetts Department of Environmental Protection, 2004).

The sources of petroleum hydrocarbons are atmospheric, and include incomplete combustion as well as direct releases of petroleum hydrocarbons. The EPH-method analyses are reported at levels greater than those required for cleanup in drinking-water-resources areas. Because this report previously considered the results of more sensitive analyses for individual PAHs, and because the Massachusetts EPH toxicological approach focuses on human health concerns, this section does not refer to specific PAHs determined by the EPH method.

The Powdermill impoundment had the highest median and mean total EPH concentrations along with the highest concentrations measured in individual samples in this study (table 8). The highest measured total EPH concentration (438 mg/kg from the surface sample at site P54) was at least an order of magnitude less than the maximum allowable concentration for landfill reuse of approximately 5,000 mg/kg (the TPH maximum of 5,000 mg/kg implicitly includes the PAH maximum of 100 mg/kg).

Few samples had individual PAH concentrations that were high enough to be detected by the EPH method (concentration data not included in this report). In the Powdermill impoundment, samples with concentrations high enough to allow detection of individual PAHs by means of the EPH method were taken from sites P46 to P54; the three remaining downstream sites (P55 to P57) were close to the dam and a diversion outlet through which hydraulic conditions may have carried particles with high PAH concentrations out of the impoundment. Two sites at Hudson (H10 and H13) and one at Ben Smith (BS30) also had a few PAHs that were detectable by the EPH method.

Potential for Adverse Biological Effects

Sediment-quality guidelines (Ingersoll and others, 2001; McDonald and others, 2000) were used to evaluate the potential for bottom sediments from the six impoundments to have toxic effects on aquatic biota. The chemical compositions of the Assabet River impoundment sediment samples were compared with the chemistry of sediments known to have toxic effects from a database of 1,657 previous North American sediment-toxicity studies; the guidelines were derived from this database (Ingersoll and others, 2001). Because none of the samples in this database were from New England, regional variability was not considered in interpreting results. The likelihood that any one sample will have a toxic effect, the "incidence of toxicity," refers to the percentage of sediment samples having any negative effect on the growth or survivability of test organisms.

The sediment-quality database incorporates measures by test assays of the growth and survivability of two benthic organisms: the amphipod, *Hyalella azteca* (HA10 and HA28, 10 and 28-day tests, respectively) and an aquatic insect larva, *Chironomous* spp. (CS10 day test). The longer HA28 test is generally more sensitive and provides a higher incidence of toxicity values than the short-term test (Ingersoll and others, 2001).

The USEPA determined PECs for 28 freshwater-sediment contaminants of concern in the major chemical groups of trace metals, PAHs, PCBs, and pesticides (MacDonald and others, 2000; Ingersoll and others, 2001); these contaminants are considered to be reliable predictors of sediment toxicity. PEC values are used to estimate sediment toxicity where adverse conditions for biota are expected. In the development of the sediment-quality guidelines, toxicity predictions were considered reliable if the toxicity was correctly predicted for more than 75% of the sediment samples.

Data from sediment samples were processed as described by MacDonald and others (2000) and Ingersoll and others (2001). Censored data from a particular site were given values equal to one half of the RL. If all data from a site were censored, then concentrations equal to the RL were assigned. After these data filters were applied, individual concentrations of trace elements, PAHs, and PCBs at a particular site were added within their respective groups to yield total values. If the total of nondetected values (that is, the sum of the assigned RLs) at a site was greater than that chemical group's PEC value, then that total was excluded from the calculations. Total values not excluded were divided by their respective PEC values to obtain a PEC quotient.

The PEC quotients of the chemical groups for each site were then summed and averaged and referred to as mean MPP values for that site (MPP refers to **M**etals, **P**AHs, and **P**CBs). In this study, mean MPPs were determined by two methods: (1) an equal-weight mean of the three chemical groups, referred to as *MPP(and)*, and (2) *MPP(or)*, a mean calculated only for metals and PAHs (shown in boldface type in table 9). Because of analytical interferences reported by the laboratory, pesticide values were all less than RLs and were omitted entirely from the toxicity estimations. The mean MPP values were compared to five PEC-quotient ranges developed by Ingersoll and others (2001) to establish a relation between the ranges and the incidences of sediment toxicity determined by the organism tests; the PEC-quotient ranges are: <0.1, 0.1 to <0.5, 0.5 to <1.0, 1.0 to <5.0, and >5.0. For example, a mean MPP range of 0.5 to 1.0 is associated with a 50-percent incidence of toxicity in the HA28 test (Zimmerman and Breault, 2003).

Table 8. Concentrations of extractable petroleum hydrocarbons in sediment samples from six impoundments in the the Assabet River Basin, Massachusetts, 2003.

[All concentrations are shown in milligrams per kilogram. Minimum reporting level is 10 milligrams per kilogram. Total EPH and means and medians for each impoundment were calculated using 10 as an estimate for all <10 values where other values were 10 or greater. **Map ID:** The identifier associated with a sampling site on a map (figs. 9–14). **Sample ID:** Identifier of a sample collected from a particular core, arranged alphabetically from the top of the core. EPH, extractable petroleum hydrocarbon; <, actual value is less than value shown]

Map ID	Sample ID	C9-C18 aliphatic hydrocarbons	C19-C36 aliphatic hydrocarbons	C11-C22 aromatic hydrocarbons	Total EPH
		Aluminum City			
AC1	5	<10	10	20	40
AC2	7	<10	15	32	57
AC3	6	<10	14	29	53
AC4	8A	<10	<10	26	46
AC4	8B	<10	21	30	61
AC4	8C	<10	<10	12	32
Mean		<10	13	25	38
Median		<10	12.0	27.5	39.5
		Allen Street			
AS5	1	<10	85	53	148
AS6	3	<10	14	18	42
AS7	2A	<10	38	24	72
AS7	2B	<10	22	22	54
AS7	2C	<10	49	47	106
AS8	4	<10	29	38	77
Mean		<10	40	34	73
Median		<10	33.5	31.0	64.5
		Hudson			
H9	9	<10	<10	20	40
H10	12	<10	<10	27	47
H11	13	<10	<10	14	34
H12	11A	<10	<10	14	34
H12	11B	<10	<10	13	33
H13	14A	<10	<10	26	46
H13	14B	<10	<10	16	36
H13	14C	<10	<10	<10	30
H14	10	<10	<10	14	34
H15	15	<10	<10	<10	30
Mean		<10	<10	17	27
Median		<10	<10	15.0	35.0
		Gleasondale			
G16	34	<10	<10	13	33
G17	39	<10	<10	<10	30
G18	35A	71	115	78	264
G18	35B	<10	37	28	75
G18	35C	<10	25	21	56
G19	40A	12	38	43	93
G19	40B	33	76	90	199
G19	40C	<10	<10	17	37
G20	36	<10	11	32	52
G21	44	<10	11	15	36

Table 8. Concentrations of extractable petroleum hydrocarbons in sediment samples from six impoundments in the the Assabet River Basin, Massachusetts, 2003.—Continued

[All concentrations are shown in milligrams per kilogram. Minimum reporting level is 10 milligrams per kilogram. Total EPH and means and medians for each impoundment were calculated using 10 as an estimate for all <10 values where other values were 10 or greater. **Map ID:** The identifier associated with a sampling site on a map (figs. 9–14). **Sample ID:** Identifier of a sample collected from a particular core, arranged alphabetically from the top of the core. EPH, extractable petroleum hydrocarbon; <, actual value is less than value shown]

Map ID	Sample ID	C9-C18 aliphatic hydrocarbons	C19-C36 aliphatic hydrocarbons	C11-C22 aromatic hydrocarbons	Total EPH
		Gleasondale—Continued			
G22	41	<10	31	30	71
G23	37	<10	22	23	55
G24	42	<10	15	12	37
G25	45	<10	<10	<10	30
G26	38	<10	<10	62	82
G27	43	<10	<10	10	30
Mean		15	26	30	71
Median		<10	12.5	22.0	34.5
		Ben Smith			
BS28	16	<10	<10	<10	30
BS29	18	<10	11	26	47
BS30	17A	<10	47	39	96
BS30	17B	<10	13	39	62
BS30	17C	<10	14	30	54
BS31	19A	<10	70	38	118
BS31	19B	<10	54	<10	74
BS31	19C	<10	43	<10	63
BS32	20A	11	75	80	166
BS32	20B	<10	31	54	95
BS32	20C	<10	31	58	99
BS33	21	<10	21	49	80
BS34	22	<10	<10	59	79
BS35	23	<10	40	48	98
BS36	27	<10	<10	<10	30
BS37	29	<10	<10	12	32
BS38	26A	<10	15	36	61
BS38	26B	<10	<10	21	41
BS38	26C	<10	<10	11	31
BS39	25	<10	<10	38	58
BS40	24	<10	<10	31	51
BS41	28	<10	<10	<10	30
BS42	33	<10	<10	21	41
BS43	30A	<10	13	34	57
BS43	30B	<10	<10	24	44
BS43	30C	<10	<10	<10	30
BS44	31	<10	<10	11	31
BS45	32	<10	<10	13	33
Mean		<10	64	45	120
Median		<10	46.5	31.0	77.5

Table 8. Concentrations of extractable petroleum hydrocarbons in sediment samples from six impoundments in the the Assabet River Basin, Massachusetts, 2003.—Continued

[All concentrations are shown in milligrams per kilogram. Minimum reporting level is 10 milligrams per kilogram. Total EPH and means and medians for each impoundment were calculated using 10 as an estimate for all <10 values where other values were 10 or greater. **Map ID:** The identifier associated with a sampling site on a map (figs. 9–14). **Sample ID:** Identifier of a sample collected from a particular core, arranged alphabetically from the top of the core. EPH, extractable petroleum hydrocarbon; <, actual value is less than value shown]

Map ID	Sample ID	C9-C18 aliphatic hydrocarbons	C19-C36 aliphatic hydrocarbons	C11-C22 aromatic hydrocarbons	Total EPH
		Powdermill			
P46	48	<10	83	61	154
P47	49	<10	12	41	63
P48	46A	<10	<10	<10	30
P48	46B	<10	<10	12	32
P48	46C	<10	101	75	186
P49	47	<10	14	31	55
P50	52	14	54	92	160
P51	55	14	178	31	223
P52	53	<10	24	55	89
P53	56	22	41	118	181
P54	54A	<10	253	175	438
P54	54B	26	171	29	226
P54	54C	10	52	12	74
P55	51A	<10	<10	<10	30
P55	51B	<10	<10	<10	30
P55	51C	<10	<10	<10	30
P56	50A	12	75	45	132
P56	50B	13	142	77	232
P56	50C	10	10	<10	30
P57	57	<10	<10	<10	30
Mean		11.9	64.3	44.9	121
Median		<10	46.5	31.0	77.5

Table 9. Incidence of toxicity, in percent, and mean MPP values calculated from Probable Effect Concentration quotients for sediment samples from the six impoundments in the Assabet River Basin, Massachusetts, 2003.

[**Map ID:** The identifier associated with a sampling site on a map (figs. 9–14). Data for HA10, HA28, and CS10 toxicity tests from the U.S. Environmental Protection Agency (2000) and Ingersoll and others (2001). Boldface type indicates Mean MPP (or) method was used because of censored data. All other Mean MPP data were calculated by the Mean MPP (and) method. Sites H13, P46, and P54 were sampled at three depths in the cores indicated by the letter A, B, C appended to the Map ID]

Map ID	Mean MPP	HA10	HA28	CS10
Aluminum City				
AC1	0.22	26	6	35
AC2	.36	26	6	35
AC3	.37	26	6	35
AC4	.51	38	50	35
Allen Street				
AS5	0.82	38	50	35
AS6	.24	26	6	35
AS7	.84	38	50	35
AS8	.24	26	6	35
Hudson				
H9	0.22	26	6	35
H10	1.12	49	100	50
H11	.18	26	6	35
H12	.12	26	6	35
H13A	**1.09**	**41**	**97**	**43**
H13B	.57	38	50	35
H13C	.25	26	6	35
H14	.12	26	6	35
H15	.34	26	6	35
Gleasondale				
G16	0.30	26	6	35
G17	.13	26	6	35
G18	5.31	86	100	78
G19	3.49	49	100	50
G20	.29	26	6	35
G21	.11	26	6	35
G22	.48	26	6	35
G23	**.04**	**18**	**10**	**20**
G24	.42	26	6	35
G25	.19	26	6	35
G26	**.05**	**18**	**10**	**20**
G27	.18	26	6	35
Ben Smith				
BS28	0.12	26	6	35
BS29	.33	26	6	35
BS30	1.28	49	100	50
BS31	**.05**	**18**	**10**	**20**
Ben Smith—Continued				
BS32	1.47	49	100	50
BS33	.56	38	50	35
BS34	.56	38	50	35
BS35	.35	26	6	35
BS36	.14	26	6	35
BS37	.16	26	6	35
BS38	**.18**	**16**	**13**	**17**
BS39	**.01**	**18**	**10**	**20**
BS40	.18	26	6	35
BS41	.13	26	6	35
BS42	.19	26	6	35
BS43	1.61	49	100	50
BS44	.13	26	6	35
BS45	.08	19	4	29
Powdermill				
P46A	0.11	26	6	35
P46B	.16	26	6	35
P46C	1.17	49	100	50
P47	.72	38	50	35
P48	.18	26	6	35
P49	**.00**	**18**	**10**	**20**
P50	2.41	49	100	50
P51	.24	26	6	35
P52	**3.29**	**41**	**97**	**43**
P53	.29	26	6	35
P54A	1.13	49	100	50
P54B	.07	19	4	29
P54C	**.03**	**18**	**10**	**20**
P55	**19.36**	**71**	**97**	**68**
P56	.60	38	50	35
P57	**1.75**	**41**	**97**	**43**

Sediment-sample mean MPP values indicated an increasing trend downstream. For simplicity's sake, the incidences of toxicity that were used for comparison were from the HA-28 test, a more sensitive test than the HA10 and CS10 tests. From the Aluminum City impoundment, the highest mean MPP from site AC4 (0.51) was associated with an incidence of toxicity of 50 percent. Allen Street sediment samples from sites AS5 and AS7 both had mean MPP values greater than 0.80 and incidences of toxicity of 50 percent. Two Hudson impoundment sites, H10 and H13, gave samples with high mean MPPs and incidences of toxicity of 100 and 97 percent, respectively. Samples from sites G18 and G19 in the Gleasondale impoundment gave some of the largest mean MPPs of the study: 5.31 and 3.49, respectively, with 100 percent incidences of toxicity. The Ben Smith impoundment had five sites that gave samples with mean MPPs greater than 0.5 and incidences of toxicity of 50 or 100 percent: BS30 (1.28), BS32 (1.47), BS33 (0.56), BS34 (0.56), and BS43 (1.61). A sample from a site in the Powdermill impoundment had the highest mean MPP of the study: P55 (19.36). The Powdermill impoundment also had seven other sites that gave samples with high mean MPPs and incidences of toxicity greater than 50 percent: sites P46 (1.17, in the deepest sediment sample), P47 (0.72), P56 (0.60), P50 (2.41), P52 (3.29), P54 (1.13, in the surface sample), and P57 (1.75).

As a result of the sediment-processing procedures, all incidence-of-toxicity results (figs. 9 to 14) represent the entire core sample except for the results for stations H13, P46, and P54, which include the toxicity at three individual depths within the cores. The incidences of toxicity for the surface sediments at these three sites appear to be higher than for some of the completely homogenized samples (with the exception of site P46, which was effectively a surface-sediment core sample because its total length was less than 30 cm). Likewise, the deepest sediments appear to have lower toxicities than some of the completely homogenized samples. An entire core with retrieval depths more than 60 cm may include preimpoundment sediments that have not been affected by human activities; thus, analytical results of tests on such a core may show a bias toward a lower toxicity. If this hypothesis is valid, the incidences of toxicity presented in this report (with the exception of sites H13, P46, and P54) may be underestimated.

Sediment Distribution and Chemistry—Possible Implications for Sediment Management

The six Assabet River impoundments differed greatly in size and sediment volume, with Aluminum City having a sediment volume of only 380 m^3 and Ben Smith 580,000 m^3 (table 10). Results of chemical analyses of sediment differed considerably within and among the impoundments. In general, guideline exceedances increased in the downstream direction. The chemical analyses revealed that toxic metal and PAH concentrations exceeded quantitative sediment-quality guidelines in almost all samples. PCBs were not detected in as many samples as metals and PAHs were, but all PCB detections exceeded at least one guideline. Chemical-matrix interference was cited by two laboratories to explain why they did not detect VOCs and organochlorine pesticides in any samples; failure to detect these compounds, however, does not imply their absence.

Regional variability was not taken into consideration in interpreting incidence of toxicity data; nevertheless, there is no reason to expect that the incidence of toxicity data calculated from contaminant concentrations in New England sediments would be different from data calculated from contaminant concentrations in any other region. Approximately one third of the sediment samples could be expected to exhibit toxic effects (lethality, growth inhibition, or reproductive diminution) on test organisms with a likelihood of 50 percent or more. Although USEPA guidelines that focus on the health of aquatic organisms were commonly exceeded in the impoundments, the MDEP guidelines for landfill disposal of dredged materials were exceeded in only a small percentage of samples. If sediment dredging were undertaken, it may be possible to dilute sediments that exceed MDEP disposal standards with less contaminated sediments to produce an acceptable mixture. Selective dam removal or modification (partial removal or lowering of dam crests) might improve aesthetics and, to some extent, restore natural conditions, but could still leave toxic sediments intact or allow them to be transported downstream to the next impoundment.

If adequate disposal areas can be found, these results could be interpreted to suggest that extensive dredging might improve the aquatic habitat of the Assabet River. Dredging could also remove much of the sediment phosphorus, which is most highly concentrated in surficial sediments, but whether this removal would reverse the eutrophic conditions in the impoundments is unknown because the relation between bulk-sediment phosphorus concentrations and phosphorus availability as an algal nutrient is not well understood. Dredging could create deeper pools with increased thermal stratification and additional potential for sediment-phosphorus release. In addition, the high nutrient concentrations in wastewater effluent from treatment plants may still be sufficient to support nuisance growths of rooted and floating macrophytes and epiphytic algae in the impounded and free-flowing reaches of the river, in which case the dredging would only provide short-term benefits.

Table 10. Selected characteristics of six impoundments in the Assabet River Basin, Massachusetts. Exceedances listed reflect one or more samples in an impoundment.

[PEC, probable effect concentration; PEL, probable effect level; m^3, cubic meter; m, meter; m^2, square meter]

Impoundment	Maximum water depth (m)	Maximum sediment thickness (m)	Sediment volume (m^3)	Approximate impoundment length (m)	Impound-ment area (m^2)	Chemical groups that exceeded aquatic-life guidelines (PEL or PEC)	Chemical groups that exceeded landfill-reuse guidelines
Aluminum City	1.2	1.0	380	110	1,600	Cr, Cu, Pb, PCB, PAH	Cr
Allen Street	2.5	3.6	42,000	890	28,000	Cd, Cr, Cu, Pb, Zn, PCB, PAH	
Hudson	3.0	2.3	55,000	5,300	89,000	As, Cd, Cr, Cu, Pb, Ni, Zn, PAH	As
Gleasondale	3.3	5.6	67,000	990	55,000	As, Cd, Cr, Cu, Pb, Ni, Zn, PCB, PAH	As, PCB
Ben Smith	3.3	7.5	580,000	11,000	590,000	As, Cd, Cr, Cu, Pb, Ni, Zn, PCB, PAH	As, Pb
Powdermill	2.5	2.7	120,000	4,800	110,000	As, Cd, Cr, Cu, Pb, Ni, Zn, PCB, PAH	As, Cr, Pb, PAH

Part 2. Phosphorus Dynamics in a Wastewater-Dominated Impoundment, Hudson, Massachusetts

Introduction

Nutrient total maximum daily loads (TMDLs) are being developed for streams in Massachusetts, many of which have water-quality-impairment issues similar to those of the Assabet River. Recent TMDL assessment and modeling studies of the Assabet River have documented the extent of eutrophication of the river's impoundments and free-flowing reaches, and suggested that phosphorus releases from bed sediments may continue to promote excessive plant growth in the river even if loads from wastewater-treatment plants and other point sources were eliminated (ENSR International, 2001, 2004). Data from environmental-assessment and laboratory studies of phosphorus release from sediments were used by ENSR International to develop and test the model that developed several management scenarios to provide acceptable alternatives for improving water quality enough to meet standards. All alternatives included reductions in phosphorus loadings from treatment plants and from sediments. According to the ENSR International study recommendations, attainment of water-quality standards may entail a combination of removal of the bed sediments, chemical treatment to immobilize sediment phosphorus, or dam removal or breaching to increase flows and disperse some of the sediments. More detailed information on the distribution, transport, and internal cycling of phosphorus between sediments and surface water as well as on external phosphorus loading would help managers select the most cost-effective course of action. A judgment could then be made whether annual fluxes of sediment phosphorus in the river are of sufficient magnitude to require dredging, or if dam removal or breaching can be used to achieve water-quality and other environmental goals.

The relation between bulk-sediment phosphorus concentrations, discussed elsewhere in this report, and the release of phosphorus from sediments remains uncertain. Sediment pore water may contain phosphorus in high enough concentrations to become available to aquatic plants as a nutrient in the water column if conditions permit. Mortimer (1971), Boström and others (1982), and Nürnberg (1988) describe many factors that combine to control the release of sediment phosphorus to the water column. Foremost among these are the oxidation-reduction (redox) conditions at the sediment-water interface that control the availability of loosely bound, or adsorbed, phosphorus, and phosphorus that is bound to iron hydroxides. As reducing conditions intensify, phosphorus unbinds and may move into the water column in the form of a dissolved phosphate ion that is available for absorption by aquatic plants. Anoxic conditions are most likely to develop in the deep parts of impoundments during summer and early autumn low-flow periods and perhaps in areas where floating macrophytes (for example, *Lemna* sp.) completely cover the surface; the combination of biochemical oxygen demand in the water column and macrophytes blocking light needed to support oxygen-yielding photosynthesis by algae could create this situation. However, the presence of nitrate is known to suppress the release of phosphorus by maintaining a high redox potential (Golterman, 2004; Tiren and Petterson, 1985; Andersen, 1982); high ambient nitrate concentrations sustained by releases from treatment plants along the Assabet River might produce this effect.

Recent laboratory studies by ENSR International (2001) to determine the potential for Assabet River sediments to release phosphorus sufficient to constitute a substantial fraction of the measured water-column phosphorus mass yielded mixed results. The water column actually lost phosphorus to sediment cores collected in March 2000 and incubated at ambient temperatures. Phosphorus release was observed from cores that were incubated at temperatures elevated above ambient; however, phosphorus released from the sediments amounted to less than 3 percent of the water-column phosphorus. When the water overlying cores collected in September 2000 was allowed to become anaerobic, however, the study reported that the sediments released as much as 170 percent of the pre-existing water-column phosphorus concentrations into the water column. On the other hand, the report noted that the waters in the impoundments rarely became anaerobic. Sediments never previously exposed to anaerobic conditions may have substantial amounts of iron-bound phosphorus that would not have been released under normal (aerobic) conditions.

To resolve uncertainty inherent in extrapolating laboratory results to field conditions, a field study examining changes in concentrations of total phosphorus and orthophosphorus took place from July to September 2003. The purpose of the field study was to determine whether phosphorus was likely to be released from the sediments in concentrations sufficient to negate improved wastewater treatment. Because the project was innovative and funding was limited, only one impoundment was studied.

Site Selection and Sample Collection

The Hudson impoundment was selected for this study because available data indicated that its summer ambient phosphorus concentrations were among the lowest of the six impoundments (ENSR International, 2001); substantial releases of phosphorus would be more easily detected there than in an impoundment with higher ambient concentrations. Furthermore, point sources and tributaries do not contribute significantly to streamflow in this impoundment during low-flow periods.

In this study, field measurements of water-column temperature, dissolved oxygen (DO), and specific conductance were made to determine the extent of hypoxia. In addition, samples were collected from multiple depths in the water column for analyses of chloride, ortho-, and total phosphorus; ortho- and total phosphorus samples were also collected from sediment pore water at selected sites. Different forms of phosphorus were analyzed to determine the proportion of labile (available for plant uptake) phosphate. Estimates of sediment phosphorus fluxes obtained in this way are inherently more realistic than measurements made under laboratory conditions. Thus, this approach was considered better than repeating the TMDL experiments on cores in the laboratory or measuring benthic phosphorus flux rates directly in the impoundments; the latter method would likely give a large range of flux rates and would also be prohibitively expensive.

Reconnaissance and Site Selection

One week before the start of the study, a reconnaissance consisting of preliminary measurements in the water column of DO, specific conductance, pH, and temperature was made at 37 locations to determine sites where sampling would most clearly reveal variations in the water quality. At all sites along the preimpoundment river channel, or thalweg, water-quality measurements showed no stratification. Some areas that did not lie along the thalweg, however, showed signs of potential stratification that could lead to anaerobic conditions and possibly phosphorus release.

Five sites were selected for use in this part of the study (fig. 17): one near the upstream end (17), one at the outlet (37); one off the main channel in a shallow embayment covered with *Lemna* (20); one in a deeper offchannel embayment with rooted macrophytes and some *Lemna (27)*; and one in the middle of the impoundment off the main channel in dense, rooted macrophyte beds (29). All rooted macrophytes had heavy coatings of epiphytic algae.

Field Measurements and Collection of Phosphorus and Chloride Samples

From July 16 to September 8, 2003, the Hudson impoundment was monitored once each week in a study to determine whether phosphorus release from sediments could be evaluated in spite of the high background concentrations. Each day, after the water-column-profile measurements were made, water samples for total phosphorus and orthophosphorus and chloride analyses were collected with a stainless-steel pushpoint sampler.

Water samples were collected from the water column at approximately 0.5-m or smaller intervals at five locations with a peristaltic pump attached to pushpoint samplers, stainless-steel rods about 1- or 2-m long that are screened at the tip. The pushpoint samplers are normally used for shallow ground-water sampling. For pore-water sampling, a platform was attached to the bottom of the sampler (fig. 18). When the platform was resting on the sediment surface, the screened tip of the sampler was stabilized at a depth of 5 cm below the surface.

Samples were analyzed for total phosphorus, dissolved phosphorus, and chloride by standard methods (Patten and Truitt, 1992; Fishman, 1993; Strickland and Parsons, 1968; Stauffer, 1983). Total phosphorus and chloride samples were analyzed by the USGS National Water Quality Laboratory, and orthophosphorus samples were analyzed in the USGS Massachusetts-Rhode Island Water Science Center office's laboratory. Differences in phosphorus concentrations in samples from the main river channel and the backwater areas were examined to determine if there was a measurable net release of phosphorus from the sediments. The chloride served as a conservative tracer and check on the calculations of the phosphorus generation from the sediments; a larger upstream than downstream ratio of chloride to total phosphorus would suggest net phosphorus release in the impoundment. It was assumed that there were no unaccounted-for sources of chloride or water in the impoundment.

Quality Control

To ensure quality control of the samples, replicate and blank samples were collected during the study (table 17, at back of report). Replicate samples demonstrated that the method yielded consistent results and supported their reliability. Field-blank analyses showed that neither the equipment nor the procedures employed caused any contamination of the samples that would lead to misinterpretation of data.

Figure 17. Hudson, Massachusetts, impoundment with sampling sites for phosphorus-release dynamics study, July to September 2003.

Figure 18. Platform attached to pushpoint sampler in preparation for pore-water sampling. The sampler's screened tip protrudes through a hole in the bottom of the platform.

Field Study of Phosphorus Dynamics

Vertical-profile data collected in 2003 at the five study sites in the Hudson impoundment for total phosphorus, orthophosphorus, and DO concentrations were plotted in relation to time and compared with rainfall data to reveal the relations among phosphorus concentrations in the water column and sediment, DO concentrations in the water column, and the effects of rainfall on total phosphorus storage in the impoundment (fig. 19).

On the first sampling date, July 16, all field measurements indicated minimal, if any, stratification in the water column at any of the sampling stations (table 17; fig. 19). DO profiles were similar, too, with all concentrations approximately 6 to 7 mg/L. As the study period progressed, DO profiles at stations 17 and 37 demonstrated little stratification, while at stations 20, 27, and 29, DO concentrations frequently showed marked stratification.

The mean total phosphorus concentrations of all water-column samples were approximately twice the orthophosphorus concentrations at each station (table 11). Mean total phosphorus and orthophosphorus concentrations were generally higher at the midimpoundment stations, 20, 27, and 29, than at 17 and 37. Station 20 had the highest mean total phosphorus and orthophosphorus concentrations, 0.3890 mg/L and 0.155 mg/L, respectively. Medians of total phosphorus concentrations were also approximately twice the orthophosphorus median concentrations. The median total phosphorus concentrations, however, did not differ as much as the mean total phosphorus concentrations, and the median orthophosphorus concentrations ranged only from 0.0550 to 0.0690 mg/L.

Table 11. Mean and median total phosphorus and orthophosphorus concentrations, in milligrams per liter, of all samples in the water column or pore water at each sampling station in the Hudson, Massachusetts, impoundment, July to September 2003.

Station number	Mean		Median	
	Total phosphorus	Ortho phosphorus	Total phosphorus	Ortho phosphorus
Water Column				
17	0.1365	0.0687	0.1283	0.0550
20	.3890	.1548	.1524	.0605
27	.1483	.0839	.1209	.0660
29	.1860	.0629	.1434	.0690
37	.1246	.0676	.1122	.0590
Pore Water				
20	2.192	1.148	1.676	0.660
27	.8381	.3244	.6540	.323
29	1.245	.4309	1.2090	.271

Total phosphorus and orthophosphorus concentrations in the sediment pore water were substantially higher than in the water column, with mean orthophosphorus concentrations several times greater than concentrations in the overlying water. The highest mean and median concentrations of orthophosphorus in sediment pore water were found at station 20, the shallowest station and the one where the surface was always covered with *Lemna*.

Site-Specific Profiles

At stations 17 and 37, the impoundment inflow and outflow stations, respectively, total phosphorus and orthophosphorus concentrations were approximately the same on any given date; total phosphorus generally ranged from 0.10 to 0.15 mg/L and orthophosphorus concentrations were generally about two-thirds the concentration of the total. At station 17, on September 8, the sample collected nearest the bottom had the highest concentration of total phosphorus at the site, 0.4200 mg/L, and the DO concentration was 6.56 mg/L (table 17). The total phosphorus concentrations at station 37 were particularly consistent, and indicated a well-mixed condition throughout the water column; on July 16, the bottom sample had a total phosphorus concentration of approximately 0.3 mg/L; otherwise, concentrations were not greater than 0.15 mg/L (fig. 19).

At stations 20, 27, and 29, the bottom and pore-water phosphorus concentrations were higher and varied more with time than concentrations at other depths in the water column (fig. 19). The highest pore-water total phosphorus and orthophosphorus concentrations, approximately 5 and 7 mg/L, respectively, were detected on July 24 at station 20, where total phosphorus concentrations in the pore water had been measured as above 2 mg/L twice. At station 27, measured pore-water total phosphorus concentrations were higher than 1 mg/L twice and were generally about 0.5 mg/L. At station 29, total phosphorus concentrations in the pore water commonly approached or exceeded 1.0 mg/L. Phosphorus concentrations at the lowest levels of the water column and in the pore water did not appear to correlate well among the stations. Low DO concentrations in the water column did not correlate strongly with high phosphorus concentrations in the surface or pore waters. In addition, higher phosphorus concentrations in the samples taken from the greatest depth did not seem to be mirrored by increased concentrations elsewhere in the water column at any given station (fig. 19). This last finding indicated that phosphorus released from the sediments was taken up quickly, adsorbed onto particles, or precipitated when it entered the oxidized zone.

In general, the phosphorus concentrations detected in this study were not as great as previously detected in the ENSR International (2001) study. Hydrologic conditions differed substantially between summers, with 2000 (the ENSR study) being extremely dry and 2003 (this USGS study) moderately wet. ENSR International cited discharges less than 0.57 m^3/s, whereas discharges during the present study were about 2.8 m^3/s. The higher discharges in 2003 probably contributed to greater dilution of phosphorus, and probably affected flushing rates and stratification dynamics as well.

Changes in Phosphorus Storage

By combining the knowledge gained during the initial bathymetric mapping with the data obtained on phosphorus distribution in the water column, it was also possible to estimate the amount of phosphorus generated internally from the impounded sediment; that is, it was possible to calculate the mass of phosphorus at different depths within the water column to determine if increases were caused by sediment release.

To examine the magnitude of phosphorus release throughout the impoundment during the study period, a geographic information system (GIS) was used to divide the bathymetric map into five sections, each represented by one of the stations in the study, and to estimate the volume of water in a series of 0.5-m-thick vertical layers in each section. The concentration of phosphorus in each layer was multiplied by the layer's volume to give an estimate of the mass of phosphorus in that layer. The masses of phosphorus in the layers were added for each section, as were the sums for all sections, to give the total mass of phosphorus in the impoundment on a given sampling date. This series of estimates was intended to enable a visualization of the hydrologic effect of rainfall on the mass of phosphorus during the summer study period (table 12; fig. 19). Although rains fell frequently during the summer, there were no large storms with torrential rains, which could have destratified and flushed the impoundment. In addition, there were no extended drought-like periods. Storms in late July and early August seemed to precede increases in the mass of total phosphorus; possibly the increases were the result of nonpoint runoff. In August, the one period with frequent rainfall exhibited an increase in phosphorus mass and, after the rainy period ended, the mass of total phosphorus decreased. The rise could be a result of runoff and the drop may be attributable to dilution and flushing of phosphorus from the impoundment. Overall, the data acquired for this study and the estimated areas selected and delineated as representative of the conditions at the five sampling stations indicated no strong relations between rainfall and phosphorus mass. More frequent collection of samples, however, would be needed to establish a definite cause-and-effect relation between the two variables.

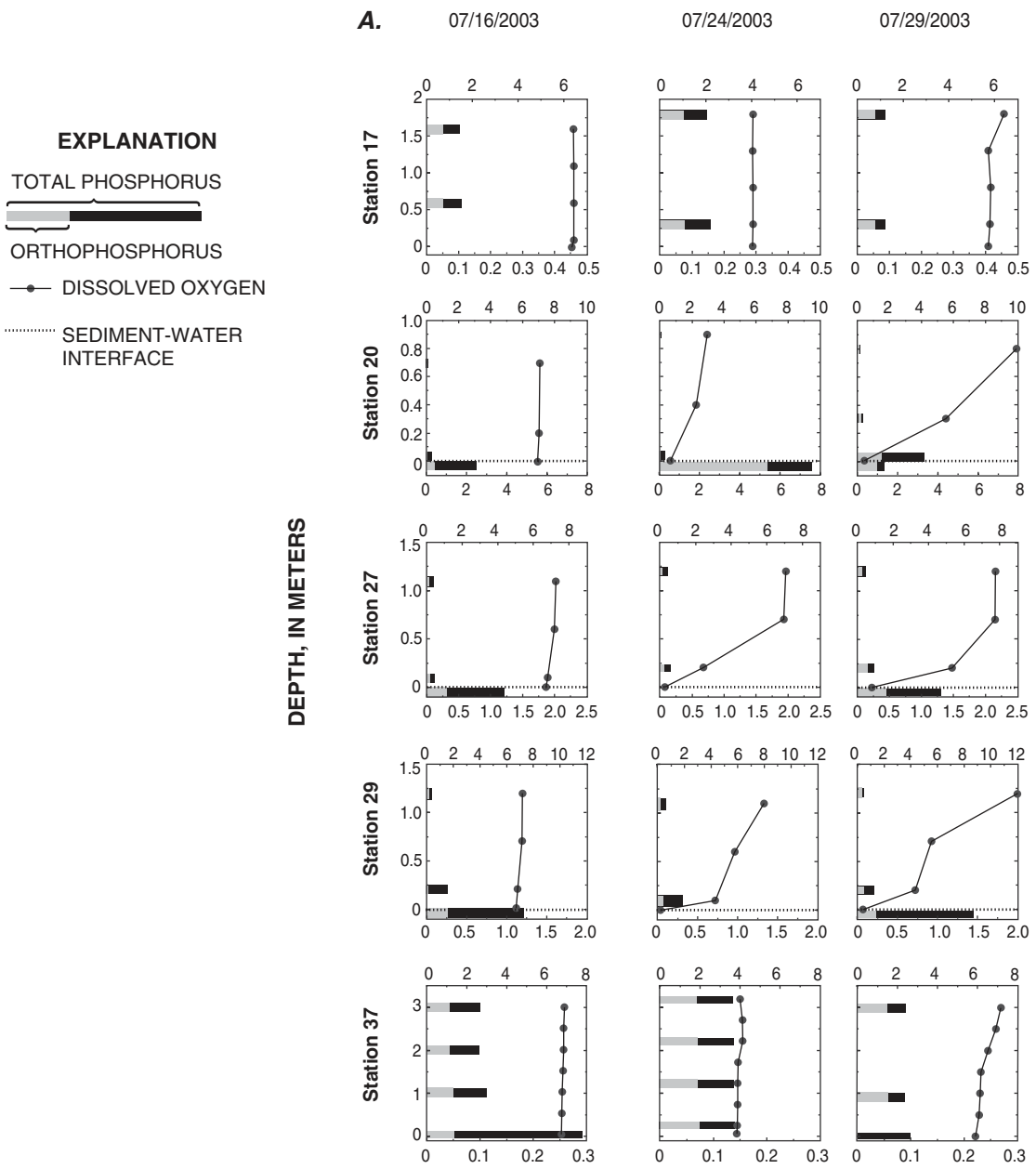


Figure 19. *A*, Total and orthophosphorus and dissolved oxygen water-column profiles at five stations in the Hudson impoundment, July to September 2003. Depth is given as vertical distance from sediment surface to water surface. *B*, Rainfall and changes in estimated total phosphorus storage in the Hudson impoundment, July to September 2003.

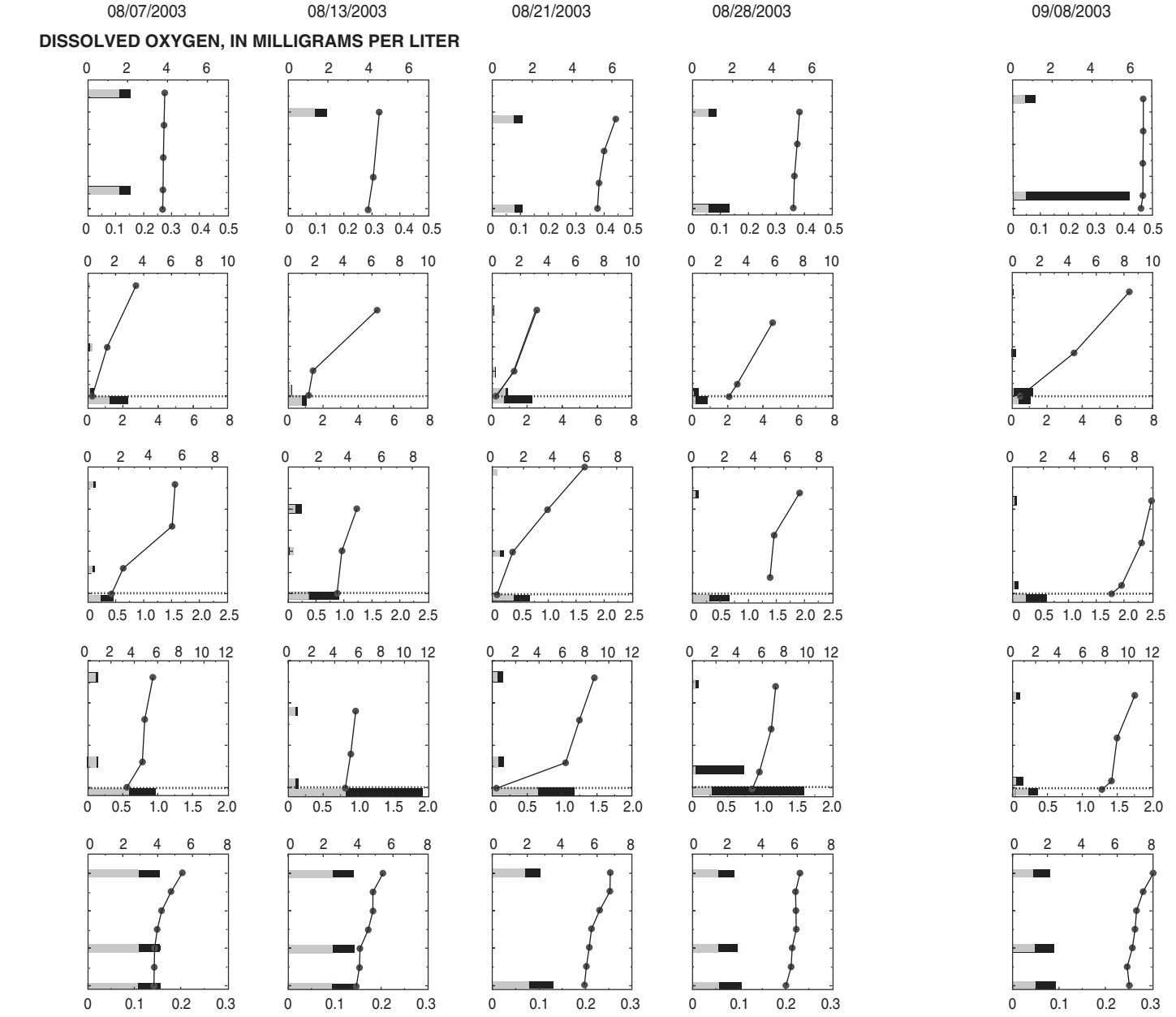

08/07/2003
08/13/2003
08/21/2003
08/28/2003
09/08/2003
DISSOLVED OXYGEN, IN MILLIGRAMS PER LITER
PHOSPHORUS AS P, IN MILLIGRAMS PER LITER
TOTAL PHOSPHORUS AS P, IN KILOGRAMS
8/23/2003
9/12/2003
2003

Table 12. Estimated phosphorus storage in the Hudson, Massachusetts, impoundment sections, July to September 2003.

[m^3, cubic meter]

Station number/ range of layer thickness	Layer volume (m^3)	Total phosphorus mass, in kilograms, on sampling date							
		7-16-03	7-24-03	7-29-03	8-07-03	8-13-03	8-21-03	8-28-03	9-08-03
Station 17									
0–0.5	15,000	1.52	2.18	1.27	2.28	2.05	1.58	1.23	1.23
0.5–1.0	9,400	.95	1.36	.80	1.43	1.28	.99	.77	.77
1.0–1.5	5,600	.60	.84	.48	.84	.76	.59	.59	1.40
1.5–2.0	2,200	.24	.35	.19	.33	.30	.23	.28	.92
2.0–2.3	220	.02	.03	.02	.03	.03	.02	.03	.09
Total		3.33	4.76	2.75	4.92	4.43	3.43	2.90	4.42
Station 20									
0–0.5	4,000	0.42	0.30	0.31	0.40	0.29	0.39	0.23	0.22
0.5–1.0	3,100	.60	.51	.68	.47	.38	.47	.59	.66
1.0–1.5	340	.10	.09	1.06	.11	.06	.28	.11	.38
Total		1.11	0.90	2.05	0.98	0.73	1.13	0.93	1.27
Station 27									
0– 0.5	5,100	0.49	0.61	0.65	0.70	0.07	0.59	0.53	0.38
0.5–1.0	7,400	.81	1.08	1.42	.93	.37	1.17	.76	.67
1.0–1.5	920	.11	.16	.24	.10	.08	.18	.23	.10
1.5–2.0	440	.05	.08	.11	.05	.04	.09	.17	.05
Total		1.47	1.92	2.43	1.79	0.56	2.04	1.69	1.20
Station 29									
0– 0.5	3,900	0.28	0.43	0.30	0.56	0.50	0.62	0.31	0.36
0.5–1.0	1,900	.31	.40	.27	.28	.25	.31	.77	.22
1.0–1.5	590	.16	.18	.12	.09	.08	.10	.43	.08
Total		0.75	1.02	0.69	0.93	0.84	1.03	1.51	0.67
Station 37									
0–0.5	9,200	0.91	1.26	0.84	1.40	1.29	0.95	0.80	0.74
0.5–1.0	7,900	.78	1.09	.72	1.21	1.12	.86	.64	.65
1.0–1.5	6,600	.66	.91	.60	1.01	.93	.76	.54	.56
1.5–2.0	3,200	.36	.44	.29	.50	.46	.38	.31	.28
2.0–2.5	900	.12	.13	.09	.14	.13	.02	.09	.08
2.5–2.8	90	.01	.01	.01	.01	.01	.01	.01	.01
Total		2.84	3.84	2.54	4.28	3.94	2.99	2.38	2.31
Total in all sections		9.49	12.44	10.46	12.90	10.50	10.62	9.42	9.88

Mass Balance (Chloride:Total Phosphorus)

To determine whether there was a net export of phosphorus from the Hudson impoundment as a result of sediment release, the ratio of chloride to total phosphorus in the water column was traced during the study (table 13). With no known inputs of phosphorus or chloride besides inflowing water or sediment, sediment release would be expected to cause increases in total P concentrations and a lowering of the ratio. Comparison of the ratio for the upstream, influent site (station 17) with the downstream outflow site (station 37) demonstrated no decreasing trend from upstream to downstream, as would be expected if sediments released phosphorus that was transported to the outflow; the values were not statistically different ($p= 0.3551$). This information suggests that there was no net gain of total phosphorus in the water column from the upstream to the downstream end of the impoundment. However, the data leave open the possibility that any phosphorus releases were rapidly cycled internally, either taken up by rooted or floating plant life or settled to the bottom as particulate matter.

Phosphorus Dynamics in the Hudson Impoundment

Phosphorus release from sediments is largely limited to those parts of the impoundment in which DO becomes depleted near the sediment-water interface; this depletion mainly occurs in offchannel areas where advection does not cause mixing. Because the temperature profiles do not indicate strong stratification, these low DO conditions probably do not persist for long periods of time; they may easily be disrupted by wind-induced mixing or light rain storms that increase local flows. The results of the phosphorus-dynamics study in the Hudson impoundment suggest that sediment release of phosphorus does not substantially affect the mass of phosphorus in the impoundment's water column; from the hypoxic zone nearest the impoundment bottom, the DO concentrations increase toward the water surface. Two phenomena may prevent sediment phosphorus from mixing throughout the water column. First, high concentrations of nitrate may maintain high redox potentials and keep the iron in an oxidized state. Second, any phosphorus that is not taken up by plants after being released from the sediments may form colloids with iron hydroxides in the vicinity of the sediment-water interface; the precipitation of the colloids would inhibit phosphorus movement from sediments to the water column. However, the elevated mean and median concentrations of total phosphorus and orthophosphorus in the embayment areas of the impoundment in comparison to the main channel suggest that morphology and hydrodynamics play a large role in phosphorus dynamics in these impoundments. A more detailed phosphorus-budget study, including phosphorus transport and deposition and detailed analysis of the forms of phosphorus, might help define the effect of sediment phosphorus on the overall water quality in this and the other Assabet River impoundments.

Table 13. Ratios of chloride to total phosphorus at the inflow and outflow of the Hudson, Massachusetts, impoundment, July to September 2003.

Date	Inflow (station 17)	Outflow (station 37)
7-24-03	810	890
7-29-03	1,700	1,600
8-07-03	720	720
8-13-03	820	820
8-21-03	1,200	1,200
8-28-03	2,000	1,700
9-08-03	1,800	1,800

Summary

This study of the quantity, distribution, and chemistry of sediments in six impoundments on the Assabet River was undertaken during the summer and early fall of 2003 in cooperation with the Massachusetts Department of Environmental Protection and the U.S. Environmental Protection Agency. The results of the study provide information to enable managers, regulators, and other stakeholders to make informed decisions regarding the management of sediment to improve the river's sediment and water quality.

This two-part report provides the results of an assessment of the sediment extent and chemistry in six impoundments in the Assabet River and describes the study of the potential for the release of phosphorus from sediment to affect water quality in the Hudson impoundment. Obtaining data about the distribution of phosphorus in the sediments and the concentrations of phosphorus in the water column links the two parts of this study. Sediment volumes in the impoundments ranged from 380 cubic meters to 580,000 cubic meters. The interpretations of bulk-sediment chemistry data in this report include results of analyses for polycyclic (or polynuclear) aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), extractable petroleum hydrocarbons (EPH), reactive sulfide, and a selected group of metals and other elements, including phosphorus. Contract laboratories were unable to obtain data for organochlorine pesticides and volatile organic compounds (VOCs) because of matrix interference and sample dilution. The concentrations of these chemical constituents in the sediments are compared to standards for the disposal of dredged hazardous materials, for human contact, and for potential effects, including toxicity, on aquatic organisms.

The incidence of toxicity calculations show that approximately one third of the surficial sediment samples may be expected to have some toxic effect on test organisms. These effects may include mortality, diminished growth, and reduced reproductive capacity. Although the database used to estimate the incidence of toxicity did not contain results of toxicity testing for New England sediments, the calculated values are based on contaminant concentrations and should not be affected by regional differences. If no action is taken to mitigate the effects of sediment toxicity, efforts to restore the Assabet River may not be fully successful.

Bulk-sediment phosphorus concentrations generally decreased with depth below the sediment surface and generally increased in the downstream direction. Concentrations of phosphorus in the bulk-sediment samples ranged from less than 0.1 percent to 0.86 percent. If the amount of sediment removal required to deplete the mass of phosphorus to levels that will not adversely affect water-column concentrations of phosphorus can be calculated, then the bulk-sediment-phosphorus data should prove useful in mapping the areas to be dredged. However, the relations between bulk-sediment-phosphorus concentrations and phosphorus availability as an aquatic-plant nutrient have not been determined in the six impoundments that are the subjects of this study.

The analytical results of the first part of the study show that the distribution of potentially hazardous or toxic materials in the sediments is extremely complex. Concentrations of toxic metals, PAHs, and PCBs exceeded U.S. Environmental Protection Agency guidelines for the protection of aquatic life in most of the impoundments. PCBs were not detected only in the Hudson impoundment. The Powdermill impoundment had the largest number of contaminants exceeding Massachusetts Department of Environmental Protection guidelines for landfill disposal of sediments.

During the two-month period of the study of the Hudson impoundment, the water column in the areas of the impoundment studied did not stratify long enough to allow substantial amounts of phosphorus to be released from underlying sediments. High concentrations of nitrate in the water column may also have prevented favorable conditions for phosphorus release. A comparison of changes in phosphorus storage did not indicate that the total mass of phosphorus increased with time, only to be dispersed by storm-generated increases in streamflow; rather, there was a suggestion that increases in the calculated mass of phosphorus were associated with storm runoff into the impoundment. On the basis of the ratio of chloride to total phosphorus, changes in phosphorus concentrations in the stratified areas of the impoundment did not lead to increases in the mass of phosphorus in the water column and to increases in the net phosphorus transport out of the impoundment. This result indicates that phosphorus was either released from the sediments in less than measurable amounts or that it was absorbed quickly before it could be transported out of the impoundment.

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Table 14. Concentrations of selected metals in sediment samples from six impoundments in the Assabet River Basin, Massachusetts, 2003.

[Quantity in brackets is detection limit. All values are in milligrams per kilogram. **Map ID:** The identifier associated with a sampling site on a map (figs. 9–14). **Sample ID:** Identifier for a sample collected from a particular core, arranged alphabetically from the top of the core, with Q designating a replicate sample. NA, not applicable because of nondetects; <, actual value is less than value shown]

Map ID	Sample ID	Arsenic [3]	Cadmium [1]	Chromium [1]	Copper [0.5]	Lead [2]	Nickel [1]	Zinc [0.5]
				Aluminum City				
AC1	5	5	1	145	309	85	22	183
AC2	7A	9	2	96	256	74	22	249
AC2	7B	9	3	124	768	182	28	397
AC2	7C	7	1	171	189	67	18	155
AC3	6A	10	2	145	286	95	22	278
AC3	6B	16	4	174	844	180	30	495
AC3	6C	15	2	183	362	238	24	296
AC4	8A	12	2	103	262	65	24	223
AC4	8B	7	2	153	502	78	24	291
AC4	8C	6	3	2,070	196	65	31	1,220
Mean		10	2	336	397	113	25	379
Median		9	2	149	298	82	24	285
				Allen Street				
AS5	1A	8	<1	177	42.9	84	17	211
AS5	1B	11	1	209	55.3	149	14	184
AS5	1C	10	<1	85	44.8	113	16	136
AS5	1D	6	<1	97	25.5	143	16	83.4
AS6	3A	11	4	142	515	229	33	487
AS6	3B	16	<1	224	53.7	150	19	182
AS6	3C	7	<1	149	16.9	58	17	78.3
AS7	2A	13	3	340	110	241	30	827
AS7	2B	11	3	242	59.2	146	18	474
AS7	2C	12	2	137	60.4	154	17	351
AS7	2D	8	<1	128	29.6	185	19	87.3
AS8	4A	12	2	152	188	90	24	281
AS8	4B	11	4	208	807	176	31	551
AS8	4C	12	3	158	300	201	27	515
AS8	4D	14	1	155	51.5	110	23	221
AS8	4E	9	<1	90	18	218	15	54
Mean		11	NA	168	149	153	21	295
Median		11	1	154	55	150	19	216
				Hudson				
H9	9	8	<1	129	12.7	12	14	35
H10	12A	15	2	104	119	324	41	212
H10	12B	20	2	130	78.9	243	24	300
H10	12C	8	<1	114	92.6	118	22	122
H10	12D	5	<1	28	8.2	8	8	14.6
H10	12E	9	<1	54	14.4	9	12	16
H11	13A	24	1	228	131	129	38	288
H11	13B	8	<1	164	7.2	12	14	19.4
H11	13C	27	<1	93	5.9	9	22	38.7
H11	13D	38	1	111	5.4	9	33	62.7

Table 14. Concentrations of selected metals in sediment samples from six impoundments in the Assabet River Basin, Massachusetts, 2003.—Continued

[Quantity in brackets is detection limit. All values are in milligrams per kilogram. **Map ID:** The identifier associated with a sampling site on a map (figs. 9–14). **Sample ID:** Identifier for a sample collected from a particular core, arranged alphabetically from the top of the core, with Q designating a replicate sample. NA, not applicable because of nondetects; <, actual value is less than value shown]

Map ID	Sample ID	Arsenic [3]	Cadmium [1]	Chromium [1]	Copper [0.5]	Lead [2]	Nickel [1]	Zinc [0.5]
				Hudson—Continued				
H12	11A	4	<1	155	7	6	20	28.1
H12	11B	3	<1	186	3.3	3	14	18.9
H13	14A	14	3	161	120	266	57	410
H13	14B	21	2	213	67.4	274	36	422
H13	14C	9	<1	304	22.9	146	29	66.1
H13	14D	5	<1	220	7.6	5	14	12.7
H13	14E	3	<1	144	4.3	4	11	16.2
H14	10A	9	<1	237	27.3	20	32	77
H14	10B	5	<1	134	4.1	6	12	20.7
H15	15A	20	2	208	141	283	86	406
H15	15B	25	1	193	96.1	218	29	365
H15	15C	17	<1	159	40.3	65	22	69
H15	15D	101	<1	85	3.4	20	11	21.8
Mean		17	NA	155	44	95	26	132
Median		9	<1	155	14	20	22	63
				Gleasondale				
G16	34A	4	<1	77	7.2	16	12	18.6
G16	34B	<3	<1	127	8	13	16	32.1
G16	34C	3	<1	114	3.5	8	17	27.6
G17	39A	5	<1	173	8.2	6	16	29.2
G17	39B	<3	<1	158	7.6	4	15	22.3
G17	39C	6	<1	155	9.5	4	16	28.5
G17	39D	6	<1	191	8.2	3	17	24.3
G18	35A	34	3	404	115	186	33	369
G18	35B	32	2	203	111	221	23	484
G18	35C	46	1	313	122	186	22	315
G18	35D	19	1	99	125	141	18	262
G18	35E	17	<1	333	128	125	22	180
G19	40A	19	12	326	261	254	91	464
G19	40B	75	3	195	162	232	26	518
G19	40C	50	2	257	144	198	24	358
G19	40D	7	<1	237	72	69	19	101
G19	40E	3	<1	209	5.6	4	12	19.6
G20	36A	7	<1	125	8.7	9	15	31.4
G20	36B	5	<1	118	7	6	14	24.2
G20	36C	<3	<1	125	7.7	5	15	38.7
G20	36D	10	<1	112	13.2	6	18	31.2
G20	36E	41	1	39	38.8	5	28	93.8
G21	44	8	<1	373	24.8	30	22	71
G22	41A	17	7	284	405	233	149	485
G22	41B	20	3	367	102	145	44	248

Table 14. Concentrations of selected metals in sediment samples from six impoundments in the Assabet River Basin, Massachusetts, 2003.—Continued

[Quantity in brackets is detection limit. All values are in milligrams per kilogram. **Map ID:** The identifier associated with a sampling site on a map (figs. 9–14). **Sample ID:** Identifier for a sample collected from a particular core, arranged alphabetically from the top of the core, with Q designating a replicate sample. NA, not applicable because of nondetects; <, actual value is less than value shown]

Map ID	Sample ID	Arsenic [3]	Cadmium [1]	Chromium [1]	Copper [0.5]	Lead [2]	Nickel [1]	Zinc [0.5]
				Gleasondale—Continued				
G22	41C	14	<1	409	81.6	87	22	142
G23	37A	<3	<1	219	10.2	17	15	31.7
G23	37B	7	<1	246	9.2	12	13	36.8
G23	37C	5	<1	192	17.7	23	13	47.6
G23	37D	14	<1	286	153	147	23	191
G24	42A	14	<1	101	7.1	20	17	33.7
G24	42B	9	<1	149	4.6	9	17	25.3
G25	45	5	<1	223	7	9	11	23.7
G26	38A	11	<1	64	7.9	11	9	15
G26	38B	16	<1	96	10.7	8	9	15.9
G26	38C	16	<1	194	7.8	4	24	34.2
G27	43	7	<1	295	33.3	66	24	84.2
Mean		17	NA	205	61	68	24	134
Median		11	<1	194	11	16	17	37
				Ben Smith				
BS28	16A	9	<1	157	23.2	30	20	82.8
BS28	16B	8	<1	195	11.4	15	15	50.1
BS29	18A	7	<1	157	19.2	26	14	43.9
BS29	18B	6	<1	100	5.4	13	9	5.7
BS29	18C	5	<1	174	3.5	12	16	9.8
BS30	17A	24	7	293	201	204	98	515
BS30	17B	52	3	250	118	188	31	617
BS30	17C	64	3	353	128	179	31	637
BS30	17D	18	<1	241	102	95	23	165
BS30	17E	<3	<1	79	5.8	10	8	3.2
BS31	19A	82	2	397	121	178	32	479
BS31	19B	35	<1	298	167	166	29	281
BS31	19C	17	<1	210	72.6	74	23	112
BS31	19D	5	<1	197	7.5	9	20	21.6
BS31	19E	6	<1	236	8.3	6	22	16.8
BS32	20A	17	7	170	318	192	132	492
BS32	20B	35	5	173	124	263	36	481
BS32	20C	6	<1	116	14.8	12	16	34.4
BS32	20D	6	<1	48	9.4	6	12	23
BS32	20E	9	<1	165	10.6	6	19	29.8
BS33	21A	35	2	179	123	144	26	334
BS33	21B	8	<1	85	14.4	20	16	30.9
BS33	21C	4	<1	85	7.5	8	14	21.6
BS33	21D	4	<1	132	8.9	7	17	25.1
BS33	21E	3	<1	151	8.3	6	16	26.6

Table 14. Concentrations of selected metals in sediment samples from six impoundments in the Assabet River Basin, Massachusetts, 2003.—Continued

[Quantity in brackets is detection limit. All values are in milligrams per kilogram. **Map ID:** The identifier associated with a sampling site on a map (figs. 9–14). **Sample ID:** Identifier for a sample collected from a particular core, arranged alphabetically from the top of the core, with Q designating a replicate sample. NA, not applicable because of nondetects; <, actual value is less than value shown]

Map ID	Sample ID	Arsenic [3]	Cadmium [1]	Chromium [1]	Copper [0.5]	Lead [2]	Nickel [1]	Zinc [0.5]
				Ben Smith—Continued				
BS34	22A	34	7	249	175	213	59	484
BS34	22B	9	<1	195	15.4	18	15	38.3
BS34	22C	<3	<1	94	6.6	7	14	19.4
BS35	23A	39	3	175	116	160	47	446
BS35	23B	61	2	213	101	164	27	458
BS35	23C	11	<1	135	18.9	72	15	37.5
BS36	27A	8	<1	58	3.9	10	14	26.4
BS36	27B	19	<1	176	4	10	18	27.8
BS36	27C	55	<1	88	3.2	12	18	26.8
BS36	27D	82	<1	54	2.7	11	14	24.2
BS37	29A	17	<1	152	23.2	32	16	62.2
BS37	29B	8	<1	99	2.2	10	12	18.4
BS37	29C	4	<1	130	1.7	11	13	18.7
BS38	26A	71	4	160	131	3,800	46	483
BS38	26B	59	2	245	122	160	28	390
BS38	26C	19	<1	167	67.8	80	22	110
BS38	26D	11	<1	147	5.8	13	23	13.7
BS38	26E	9	<1	75	5.1	10	28	44.6
BS39	25A	17	<1	184	13.6	25	25	53.7
BS39	25B	11	<1	246	11.1	11	26	29
BS40	24A	14	<1	216	13.4	16	27	36.9
BS40	24B	8	<1	130	3.5	8	17	23.8
BS40	24C	14	<1	151	4.6	9	25	27
BS41	28A	14	<1	237	4.5	8	18	23.4
BS41	28B	83	<1	91	2.7	14	18	22.3
BS42	33A	12	<1	239	38.6	50	21	81.1
BS42	33B	10	<1	383	41.2	29	19	43.4
BS43	30A	21	5	132	167	160	68	386
BS43	30B	41	4	182	117	157	47	422
BS43	30C	36	<1	167	94.2	125	22	213
BS43	30D	19	<1	140	21.4	32	17	47
BS43	30E	8	<1	94	2.8	11	11	13.3
BS44	31A	6	<1	254	5.5	5	12	16.6
BS44	31B	5	<1	271	11.7	18	11	22.6
BS45	32A	<3	<1	180	3.8	3	11	14.9
BS45	32B	4	<1	228	10.3	8	14	18.9
Mean		22	NA	177	49	121	25	144
Median		13	<1	170	13	16	19	37

Table 14. Concentrations of selected metals in sediment samples from six impoundments in the Assabet River Basin, Massachusetts, 2003.—Continued

[Quantity in brackets is detection limit. All values are in milligrams per kilogram. **Map ID:** The identifier associated with a sampling site on a map (figs. 9–14). **Sample ID:** Identifier for a sample collected from a particular core, arranged alphabetically from the top of the core, with Q designating a replicate sample. NA, not applicable because of nondetects; <, actual value is less than value shown]

Map ID	Sample ID	Arsenic [3]	Cadmium [1]	Chromium [1]	Copper [0.5]	Lead [2]	Nickel [1]	Zinc [0.5]
				Powdermill				
P46	48	21	2	899	280	233	40	289
P47	49	8	<1	394	50.9	110	30	152
P48	46A	34	1	1,290	257	259	26	162
P48	46B	20	<1	238	31.6	23	31	75.2
P48	46C	62	<1	129	17.2	11	45	47
P49	47	5	<1	268	19.4	58	27	59.3
P50	52A	15	2	272	109	231	54	331
P50	52B	13	2	339	123	261	77	298
P50	52C	11	1	311	78.3	244	41	183
P50	52D	22	4	478	128	174	35	306
P50	52E	36	<1	291	55	318	20	93.2
P51	55A	31	5	1,060	839	594	60	1,140
P51	55B	58	3	1,830	386	343	24	1,010
P51	55C	<3	<1	97	22.4	12	51	10.8
P51	55D	6	<1	128	40	7	52	17.5
P52	53A	16	2	399	100	167	56	354
P52	53B	13	4	404	184	371	53	339
P52	53C	101	7	2,270	330	621	29	726
P52	53D	20	<1	421	194	115	21	163
P52	53E	10	<1	302	26.8	71	25	44.8
P53	56A	18	6	416	669	580	272	379
P53	56B	47	4	1,550	277	515	54	424
P53	56C	66	8	1,970	545	419	26	1,010
P54	54A	44	7	1,530	3430	1,030	69	905
P54	54B	6	<1	148	49.8	29	14	388
P54	54C	<3	<1	106	14.6	14	10	62.6
P55	51A	9	<1	248	78	54	46	99.6
P55	51B	6	<1	179	10.5	11	21	33.2
P55	51C	9	<1	173	6.2	7	22	31.4
P55	51D	6	<1	274	5.5	7	29	28.7
P55	51E	4	<1	240	5.9	7	30	29.3
P56	50A	17	6	332	720	411	179	572
P56	50B	28	10	786	910	1,250	84	1,200
P56	50C	48	9	1,320	459	305	28	703
P56	50D	9	<1	187	23.7	40	26	48.2
P56	50E	<3	<1	221	9.1	7	13	10.3
P57	57	<3	<1	272	18	45	30	66.9
Mean		25	NA	588	284	242	47	319
Median		17	<1	311	78	167	30	163

Table 15. Results of all elemental analyses performed by SGS Canada, Inc., Mineral Services, Toronto, Ontario, Canada, of sediment samples from six impoundments in the Assabet River Basin, Massachusetts, 2003.

[Quantity in brackets is detection limit. **Map ID:** The identifier associated with a sampling site on a map (figs. 9–14). **Sample ID:** Identifier for a sample collected from a particular core, arranged alphabetically from the top of the core, with Q designating a replicate sample; DUP, SGS laboratory duplicate quality-control sample. %, percent; ppm, parts per million; <, actual value is less than value shown; --, not reported]

Map ID	Sample ID	Aluminum (%) [0.01]	Antimony (ppm) [5]	Arsenic (ppm) [3]	Barium (ppm) [1]	Beryllium (ppm) [0.5]	Bismuth (ppm) [5]	Cadmium (ppm) [1]	Calcium (%) [0.01]	Chromium (ppm) [1]	Cobalt (ppm) [1]	Copper (ppm) [0.5]	Iron (%) [0.01]	Lanthanum (ppm) [0.5]	Lead (ppm) [2]	Lithium (ppm) [1]	Magnesium (%) [0.01]
Aluminum City																	
AC1	5	1.12	<5	5	137	<0.5	<5	1	0.35	145	9	309	1.87	15.4	85	2	0.45
AC2	7A	1.2	<5	9	210	<.5	<5	2	.55	96	11	256	1.75	15.5	74	1	.36
AC2	7B	1.28	<5	9	230	.8	8	3	.53	124	11	768	1.87	15.6	182	2	.41
AC2	7C	1.25	<5	7	154	<.5	<5	1	.55	171	12	189	1.5	10.4	67	<1	.29
AC3	6A	1.15	<5	10	162	<.5	<5	2	.46	145	10	286	1.63	15.6	95	<1	.34
AC3	6B	1.47	<5	16	198	.6	9	4	.49	174	13	844	2.15	18.1	180	5	.45
AC3	6C	1.35	<5	15	247	.5	<5	2	.41	183	16	362	2.2	16.4	238	3	.43
AC4	8A	1.21	<5	12	193	.5	<5	2	.43	103	11	262	1.51	15.2	65	2	.36
AC4	8B	1.17	<5	7	166	<.5	<5	2	.41	153	12	502	1.62	14.1	78	<1	.36
AC4	8B-DUP	1.14	<5	6	169	<.5	<5	2	.41	150	12	501	1.6	13.9	78	1	.35
AC4	8C	.96	6	6	135	<.5	<5	3	.29	2,070	13	196	1.68	11.1	65	<1	.35
Allen Street																	
AS5	1A	0.87	<5	8	71	<0.5	<5	<1	0.23	177	8	42.9	1.48	10.4	84	<1	0.34
AS5	1A-DUP	.83	<5	9	69	<.5	<5	<1	.23	172	7	42.7	1.43	10.7	80	<1	.32
AS5	1B	.77	<5	11	68	<.5	<5	1	.29	209	6	55.3	1.16	9.2	149	<1	.28
AS5	1C	.94	<5	10	74	<.5	<5	<1	.23	85	11	44.8	1.47	11.7	113	<1	.35
AS5	1D	.89	<5	6	63	<.5	<5	<1	.2	97	8	25.5	1.37	10.4	143	<1	.34
AS6	3A	1.4	<5	11	265	.6	<5	4	.52	142	21	515	1.93	17.2	229	3	.44
AS6	3B	.99	<5	16	90	<.5	<5	<1	.29	224	11	53.7	1.46	12.4	150	<1	.34
AS6	3C	1.25	<5	7	62	.5	<5	<1	.21	149	8	16.9	1.45	13.6	58	<1	.3
AS7	2A	1.36	<5	13	176	<.5	<5	3	.39	340	18	110	2.35	15.6	241	1	.43
AS7	2B	.95	<5	11	90	<.5	<5	3	.23	242	10	59.2	1.46	12.7	146	<1	.34
AS7	2C	1.01	<5	12	88	<.5	<5	2	.28	137	10	60.4	1.5	13.2	154	<1	.33
AS7	2D	1.12	<5	8	74	<.5	<5	<1	.23	128	10	29.6	1.39	14	185	<1	.38
AS8	4A	1	<5	12	183	<.5	<5	2	.5	152	13	188	1.93	13.8	90	<1	.32
AS8	4B	1.29	<5	11	265	.6	8	4	.51	208	14	807	2	16.9	176	<1	.39
AS8	4B-DUP	1.28	<5	11	275	.7	8	4	.49	224	15	820	2.05	17.6	185	3	.43
AS8	4C	1.17	<5	12	210	.5	<5	3	.4	158	18	300	1.83	14.5	201	<1	.37
AS8	4D	1.37	<5	14	87	<.5	<5	1	.28	155	14	51.5	1.86	15.4	110	4	.47
AS8	4E	1.02	<5	9	55	<.5	<5	<1	.33	90	6	18	1.12	11.6	218	<1	.32

Table 15. Results of all elemental analyses performed by SGS Canada, Inc., Mineral Services, Toronto, Ontario, Canada, of sediment samples from six impoundments in the Assabet River Basin, Massachusetts, 2003.—Continued

[Quantity in brackets is detection limit. **Map ID:** The identifier associated with a sampling site on a map (figs. 9–14). **Sample ID:** Identifier for a sample collected from a particular core, arranged alphabetically from the top of the core, with Q designating a replicate sample; DUP, SGS laboratory duplicate quality-control sample. %, percent; ppm, parts per million; <, actual value is less than value shown; --, not reported]

Map ID	Sample ID	Aluminum (%) [0.01]	Antimony (ppm) [5]	Arsenic (ppm) [3]	Barium (ppm) [1]	Beryllium (ppm) [0.5]	Bismuth (ppm) [5]	Cadmium (ppm) [1]	Calcium (%) [0.01]	Chromium (ppm) [1]	Cobalt (ppm) [1]	Copper (ppm) [0.5]	Iron (%) [0.01]	Lanthanum (ppm) [0.5]	Lead (ppm) [2]	Lithium (ppm) [1]	Magnesium (%) [0.01]
							Hudson										
H9	9	0.83	<5	8	36	1.3	<5	<1	0.25	129	4	12.7	0.63	19.7	12	<1	0.11
H10	12A	1.34	<5	15	157	.6	<5	2	.26	104	12	119	1.69	15	324	2	.42
H10	12B	1.39	<5	20	111	.6	<5	2	.18	130	13	78.9	1.63	15.3	243	2	.37
H10	12C	1.86	<5	8	102	.6	<5	<1	.18	114	12	92.6	1.83	18.8	118	6	.51
H10	12D	.58	<5	5	33	.5	<5	<1	.33	28	4	8.2	.76	13.6	8	<1	.1
H10	12E	1.33	<5	9	29	3.4	<5	<1	.2	54	4	14.4	.86	148	9	<1	.19
H11	13A	1.19	<5	24	93	.6	<5	1	.3	228	24	131	1.66	14	129	<1	.27
H11	13A-DUP	1.19	<5	26	98	.5	<5	2	.28	222	26	138	1.59	15	134	2	.25
H11	13B	1.1	<5	8	37	.7	<5	<1	.25	164	12	7.2	1.21	30.8	12	<1	.16
H11	13C	2.08	<5	27	36	1.7	<5	<1	.23	93	31	5.9	2.45	38.7	9	3	.36
H11	13D	2.19	<5	38	122	.8	<5	1	.11	111	38	5.4	3.25	21.2	9	10	.52
H12	11A	.78	<5	4	37	<.5	<5	<1	.14	155	7	7	1.03	11.4	6	<1	.22
H12	11B	.78	<5	3	27	<.5	<5	<1	.09	186	6	3.3	1.15	15.3	3	<1	.24
H13	14A	1.27	<5	14	109	.7	8	3	.67	161	15	120	2.37	15.6	266	13	.34
H13	14A-DUP	1.26	<5	14	119	.7	<5	3	.68	153	13	125	2.25	15.7	264	14	.34
H13	14AQ	1.33	<5	15	114	.7	<5	2	.66	180	16	130	2.49	14.8	279	14	.36
H13	14B	1.6	<5	21	81	.7	<5	2	.6	213	14	67.4	2.46	14.4	274	18	.43
H13	14BQ	1.59	<5	19	78	.7	<5	2	.56	227	14	69	2.43	14.1	247	19	.44
H13	14C	1.1	<5	9	41	<.5	<5	<1	.28	304	7	22.9	1.7	9.3	146	17	.42
H13	14CQ	1.15	<5	8	47	<.5	<5	<1	.26	287	7	22.5	1.78	9.3	234	18	.46
H13	14D	.39	<5	5	18	<.5	<5	<1	.81	220	3	7.6	.56	7.8	5	2	.12
H13	14DQ	.43	<5	4	20	<.5	<5	<1	.83	298	2	9.9	.64	7.6	8	3	.12
H13	14E	.84	<5	3	20	<.5	<5	<1	.23	144	3	4.3	.92	12.1	4	12	.25
H13	14EQ	.85	<5	3	20	<.5	<5	<1	.2	223	2	5.5	1.01	12.1	5	12	.26
H14	10A	.79	<5	9	88	<.5	<5	<1	.35	237	11	27.3	1.44	11.3	20	<1	.22
H14	10B	.76	<5	5	30	<.5	<5	<1	.14	134	6	4.1	.93	17	6	<1	.2
H15	15A	1.77	<5	20	250	1	<5	2	.46	208	33	141	3.1	16.4	283	20	.46
H15	15B	1.93	<5	25	119	.9	<5	1	.42	193	19	96.1	2.47	16.6	218	23	.47
H15	15C	1.53	<5	17	71	.7	<5	<1	.36	159	15	40.3	2.5	12.4	65	16	.31
H15	15C-DUP	1.46	<5	16	71	.7	<5	<1	.36	147	13	38.6	2.36	13.4	61	16	.3
H15	15D	2	<5	101	43	1.5	10	<1	.14	85	14	3.4	8.78	11.7	20	15	.26

Table 15. Results of all elemental analyses performed by SGS Canada, Inc., Mineral Services, Toronto, Ontario, Canada, of sediment samples from six impoundments in the Assabet River Basin, Massachusetts, 2003.—Continued

[Quantity in brackets is detection limit. **Map ID:** The identifier associated with a sampling site on a map (figs. 9–14). **Sample ID:** Identifier for a sample collected from a particular core, arranged alphabetically from the top of the core, with Q designating a replicate sample; DUP, SGS laboratory duplicate quality-control sample. %, percent; ppm, parts per million; <, actual value is less than value shown; --, not reported]

Map ID	Sample ID	Aluminum (%) [0.01]	Antimony (ppm) [5]	Arsenic (ppm) [3]	Barium (ppm) [1]	Beryllium (ppm) [0.5]	Bismuth (ppm) [5]	Cadmium (ppm) [1]	Calcium (%) [0.01]	Chromium (ppm) [1]	Cobalt (ppm) [1]	Copper (ppm) [0.5]	Iron (%) [0.01]	Lanthanum (ppm) [0.5]	Lead (ppm) [2]	Lithium (ppm) [1]	Magnesium (%) [0.01]
								Gleasondale									
G16	34A	1.04	<5	4	51	<0.5	<5	<1	0.39	77	4	7.2	0.65	11.9	16	11	0.2
G16	34B	1.39	<5	<3	54	.6	<5	<1	.29	127	6	8	.98	17	13	19	.32
G16	34C	1.48	<5	3	57	.6	<5	<1	.2	114	6	3.5	1.03	19.1	8	22	.4
G16	34C-DUP	1.38	<5	<3	54	.6	<5	<1	.2	107	6	3.5	.97	18.1	8	21	.38
G17	39A	.94	<5	5	38	<.5	<5	<1	.11	173	5	8.2	1.69	1.6	6	22	.42
G17	39B	.75	<5	<3	35	<.5	<5	<1	.13	158	5	7.6	1.16	9.8	4	14	.35
G17	39C	.93	<5	6	37	<.5	<5	<1	.24	155	5	9.5	1.36	12.2	4	16	.4
G17	39D	.81	<5	6	35	<.5	<5	<1	.12	191	4	8.2	1.3	9.6	3	18	.37
G18	35A	1.29	<5	34	125	.7	<5	3	.33	404	22	115	2.26	16.4	186	15	.34
G18	35B	1.41	<5	32	128	.7	<5	2	.29	203	15	111	1.88	16.6	221	16	.36
G18	35C	1.45	<5	46	115	.7	<5	1	.3	313	13	122	1.89	16.8	186	16	.38
G18	35D	1.32	<5	19	132	.5	<5	1	.36	99	11	125	1.49	13.7	141	16	.38
G18	35E	1.44	<5	17	91	.6	<5	<1	.29	333	13	128	1.85	16.6	125	18	.39
G19	40A	1.43	<5	19	264	1.3	<5	12	.55	326	47	261	3.11	17.5	254	15	.35
G19	40B	1.51	<5	75	142	.7	<5	3	.45	195	16	162	2.18	14.5	232	15	.38
G19	40B-DUP	1.47	<5	71	140	.8	<5	3	.45	192	16	160	2.13	14.9	228	15	.37
G19	40C	1.52	<5	50	128	.7	<5	2	.44	257	14	144	2.02	16.6	198	17	.42
G19	40CQ	1.51	<5	47	124	.7	<5	2	.44	309	14	141	2.05	16.3	191	17	.41
G19	40D	.96	<5	7	60	<.5	<5	<1	.23	237	10	72	1.4	11.4	69	14	.31
G19	40E	.54	<5	3	28	<.5	<5	<1	.09	209	3	5.6	.96	9	4	11	.23
G20	36A	1.04	<5	7	53	<.5	<5	<1	.32	125	4	8.7	1.13	11.9	9	18	.32
G20	36AQ	1.05	<5	4	65	<.5	<5	<1	.32	554	6	13.8	1.55	15.6	11	15	.27
G20	36B	.91	<5	5	51	<.5	<5	<1	.33	118	6	7	.92	11.6	6	12	.25
G20	36C	1.04	<5	<3	61	<.5	<5	<1	.3	125	8	7.7	1.12	12.8	5	15	.29
G20	36D	.84	<5	10	52	<.5	<5	<1	.43	112	11	13.2	1.36	13.4	6	10	.21
G20	36E	.6	<5	41	50	<.5	<5	1	.94	39	23	38.8	2.4	21.3	5	2	.08
G21	44	.68	<5	8	64	<.5	<5	<1	.2	373	7	24.8	1.66	8.2	30	11	.22
G22	41A	1.51	<5	17	351	1.2	<5	7	.6	284	32	405	3.39	16.7	233	17	.37
G22	41B	1	<5	20	114	.5	<5	3	.29	367	19	102	1.87	11.3	145	14	.28
G22	41C	1.15	<5	14	81	<.5	<5	<1	.32	409	11	81.6	1.88	12.8	87	15	.34

Table 15. Results of all elemental analyses performed by SGS Canada, Inc., Mineral Services, Toronto, Ontario, Canada, of sediment samples from six impoundments in the Assabet River Basin, Massachusetts, 2003.—Continued

[Quantity in brackets is detection limit. **Map ID:** The identifier associated with a sampling site on a map (figs. 9–14). **Sample ID:** Identifier for a sample collected from a particular core, arranged alphabetically from the top of the core, with Q designating a replicate sample; DUP, SGS laboratory duplicate quality-control sample. %, percent; ppm, parts per million; <, actual value is less than value shown; --, not reported]

Map ID	Sample ID	Aluminum (%) [0.01]	Antimony (ppm) [5]	Arsenic (ppm) [3]	Barium (ppm) [1]	Beryllium (ppm) [0.5]	Bismuth (ppm) [5]	Cadmium (ppm) [1]	Calcium (%) [0.01]	Chromium (ppm) [1]	Cobalt (ppm) [1]	Copper (ppm) [0.5]	Iron (%) [0.01]	Lanthanum (ppm) [0.5]	Lead (ppm) [2]	Lithium (ppm) [1]	Magnesium (%) [0.01]
Gleasondale—Continued																	
G23	37A	0.53	<5	<3	45	<0.5	<5	<1	0.08	219	4	10.2	1.01	7.8	17	10	0.2
G23	37A-DUP	.54	<5	3	44	<.5	<5	<1	.08	226	3	10.2	1.02	8.5	18	10	.21
G23	37B	.57	<5	7	38	<.5	<5	<1	.09	246	4	9.2	1.16	8	12	11	.22
G23	37C	.52	<5	5	42	<.5	<5	<1	.19	192	4	17.7	.97	7.9	23	9	.2
G23	37D	1.4	<5	14	114	.6	<5	<1	.44	286	10	153	1.72	16	147	18	.39
G24	42A	1.55	<5	14	43	.7	<5	<1	.1	101	14	7.1	2.33	17.2	20	20	.32
G24	42B	1.21	<5	9	42	.6	<5	<1	.08	149	7	4.6	1.72	21	9	19	.29
G25	45	.53	<5	5	30	<.5	<5	<1	.06	223	3	7	1.06	9.6	9	12	.21
G25	45-DUP	.53	<5	3	30	<.5	<5	<1	.06	215	3	6.9	1.03	9.4	9	12	.21
G26	38A	.82	<5	11	45	.5	<5	<1	.77	64	2	7.9	.64	10.9	11	8	.19
G26	38B	.6	<5	16	34	<.5	<5	<1	.66	96	2	1.7	.62	7.6	8	5	.15
G26	38C	.93	<5	16	39	<.5	<5	<1	.45	194	18	7.8	1.23	10.5	4	14	.28
G27	43	.62	<5	7	77	<.5	<5	<1	.15	295	8	33.3	1.48	8.4	66	10	.22
Ben Smith																	
BS28	16A	0.6	<5	9	47	<0.5	<5	<1	0.13	157	13	23.2	1.11	7.1	30	9	0.2
BS28	16B	.78	<5	8	35	<.5	<5	<1	.07	195	9	11.4	1.45	9.2	15	13	.31
BS29	18A	1.03	<5	7	62	2.3	<5	<1	.51	157	4	19.2	.94	50.3	26	3	.07
BS29	18B	1.08	<5	6	47	2.5	<5	<1	.44	100	3	5.4	.79	61.2	13	2	.05
BS29	18C	1.72	<5	5	36	3.6	<5	<1	.15	174	2	3.5	.79	112	12	9	.15
BS29	19A	1.49	<5	82	154	.8	<5	2	.39	397	31	121	2.44	16	178	14	.32
BS30	17A	1.43	<5	24	209	1	<5	7	.45	293	41	201	2.58	15.2	204	15	.33
BS30	17B	1.46	<5	52	131	.8	5	3	.43	250	24	118	2.28	14.7	188	14	.31
BS30	17C	1.55	<5	64	127	.8	<5	3	.4	353	28	128	2.14	16.5	179	15	.32
BS30	17D	1.35	<5	18	85	.7	<5	<1	.38	241	19	102	1.44	14.8	95	11	.23
BS30	17E	.94	<5	<3	26	.9	<5	<1	.31	79	3	5.8	.39	28.5	10	2	.03
BS31	19A-DUP	1.42	<5	69	152	.8	<5	3	.4	381	26	115	2.24	16.4	168	14	.3
BS31	19AQ	1.46	<5	78	151	.8	<5	2	.38	432	29	123	2.41	15.4	174	14	.32
BS31	19B	1.61	<5	35	141	.8	<5	<1	.36	298	27	167	2.16	16.3	166	16	.34
BS31	19BQ	1.58	<5	37	137	.8	<5	<1	.36	366	27	165	2.19	16.3	165	15	.33

Table 15. Results of all elemental analyses performed by SGS Canada, Inc., Mineral Services, Toronto, Ontario, Canada, of sediment samples from six impoundments in the Assabet River Basin, Massachusetts, 2003.—Continued

[Quantity in brackets is detection limit. **Map ID:** The identifier associated with a sampling site on a map (figs. 9–14). **Sample ID:** Identifier for a sample collected from a particular core, arranged alphabetically from the top of the core, with Q designating a replicate sample; DUP, SGS laboratory duplicate quality-control sample. %, percent; ppm, parts per million; <, actual value is less than value shown; --, not reported]

Map ID	Sample ID	Aluminum (%) [0.01]	Antimony (ppm) [5]	Arsenic (ppm) [3]	Barium (ppm) [1]	Beryllium (ppm) [0.5]	Bismuth (ppm) [5]	Cadmium (ppm) [1]	Calcium (%) [0.01]	Chromium (ppm) [1]	Cobalt (ppm) [1]	Copper (ppm) [0.5]	Iron (%) [0.01]	Lanthanum (ppm) [0.5]	Lead (ppm) [2]	Lithium (ppm) [1]	Magnesium (%) [0.01]
Ben Smith—Continued																	
BS31	19C	1.42	<5	17	86	0.6	<5	<1	0.28	210	21	72.6	1.67	14.1	74	14	0.27
BS31	19CQ	1.43	<5	15	85	.6	<5	<1	.28	220	22	64.6	1.65	14.2	71	14	.27
BS31	19D	1.28	<5	5	54	<.5	<5	<1	.16	197	7	7.5	1.27	15.8	9	15	.28
BS31	19DQ	1.18	<5	5	50	<.5	<5	<1	.16	165	7	7.9	1.25	13.9	11	14	.28
BS31	19E	1.09	<5	6	54	<.5	<5	<1	.19	236	6	8.3	1.11	14.1	6	13	.23
BS31	19EQ	1.12	<5	5	55	<.5	<5	<1	.21	190	7	8.6	1.18	14.2	6	14	.28
BS32	20A	1.41	<5	17	415	1.1	<5	7	.54	170	48	318	3.71	15	192	14	.3
BS32	20B	1.38	<5	35	194	.8	<5	5	.48	173	34	124	2.34	13.7	263	14	.3
BS32	20C	.81	<5	6	73	<.5	<5	<1	.57	116	9	14.8	1.07	10.9	12	7	.17
BS32	20C-DUP	.76	<5	6	71	<.5	<5	<1	.57	110	7	13.9	.99	10.8	11	7	.16
BS32	20D	.77	<5	6	65	<.5	<5	<1	.5	48	11	9.4	.93	12.3	6	5	.12
BS32	20E	.75	<5	9	60	<.5	<5	<1	.41	165	12	10.6	1.12	11.3	6	6	.15
BS33	21A	1.54	<5	35	121	1	<5	2	.43	179	29	123	1.95	14.5	144	15	.3
BS33	21B	1.36	<5	8	71	.6	<5	<1	.32	85	9	14.4	1.22	14.1	20	14	.27
BS33	21C	1.18	<5	4	65	<.5	<5	<1	.31	85	8	7.5	1.1	13.7	8	14	.26
BS33	21D	1.09	<5	4	68	.5	<5	<1	.36	132	9	8.9	1.15	13.3	7	13	.26
BS33	21E	1.08	<5	3	67	<.5	<5	<1	.34	151	8	8.3	1.25	13.3	6	14	.28
BS34	22A	1.44	<5	34	187	1	<5	7	.32	249	40	175	2.13	15.4	213	12	.28
BS34	22B	.89	<5	9	35	<.5	<5	<1	.18	195	5	15.4	1.02	12.4	18	12	.23
BS34	22C	.76	<5	<3	23	<.5	<5	<1	.09	94	2	6.6	.96	11.4	7	14	.29
BS35	23A	1.23	<5	39	149	.8	5	3	.37	175	31	116	2.38	13.3	160	11	.24
BS35	23B	1.32	<5	61	89	.8	<5	2	.34	213	27	101	1.93	14.7	164	11	.22
BS35	23B-DUP	1.27	<5	56	89	.7	<5	2	.35	206	24	100	1.83	14.2	159	10	.22
BS35	23C	1.19	<5	11	41	.9	<5	<1	.29	135	6	18.9	1.34	21.3	72	12	.18
BS36	27A	1.4	<5	8	43	.7	<5	<1	.19	58	12	3.9	1.67	17.2	10	17	.31
BS36	27B	1.86	<5	19	43	1.2	<5	<1	.15	176	26	4	2.71	26	10	22	.37
BS36	27C	1.72	<5	55	39	1.2	<5	<1	.13	88	25	3.2	4.78	25.3	12	23	.37
BS36	27D	1.32	<5	82	37	1	<5	<1	.1	54	41	2.7	6.12	19.1	11	21	.32
BS36	27D-DUP	1.26	<5	78	36	1	<5	<1	.1	51	39	2.5	5.83	18.6	10	21	.31
BS37	29A	1.3	<5	17	60	.7	<5	<1	.19	152	8	23.2	1.7	15.5	32	14	.24

Table 15. Results of all elemental analyses performed by SGS Canada, Inc., Mineral Services, Toronto, Ontario, Canada, of sediment samples from six impoundments in the Assabet River Basin, Massachusetts, 2003.—Continued

[Quantity in brackets is detection limit. **Map ID:** The identifier associated with a sampling site on a map (figs. 9–14). **Sample ID:** Identifier for a sample collected from a particular core, arranged alphabetically from the top of the core, with Q designating a replicate sample; DUP, SGS laboratory duplicate quality-control sample. %, percent; ppm, parts per million; <, actual value is less than value shown; --, not reported]

Map ID	Sample ID	Aluminum (%) [0.01]	Antimony (ppm) [5]	Arsenic (ppm) [3]	Barium (ppm) [1]	Beryllium (ppm) [0.5]	Bismuth (ppm) [5]	Cadmium (ppm) [1]	Calcium (%) [0.01]	Chromium (ppm) [1]	Cobalt (ppm) [1]	Copper (ppm) [0.5]	Iron (%) [0.01]	Lanthanum (ppm) [0.5]	Lead (ppm) [2]	Lithium (ppm) [1]	Magnesium (%) [0.01]
								Ben Smith—Continued									
BS37	29B	1.41	<5	8	33	0.7	<5	<1	0.1	99	5	2.2	1.47	20.2	10	16	0.25
BS37	29C	1.42	<5	4	39	.5	<5	<1	.09	130	4	1.7	1.59	27.1	11	21	.3
BS38	26A	1.25	44	71	144	.8	<5	4	.36	160	29	131	2.25	13.7	3,800	11	.23
BS38	26B	1.3	<5	59	111	.8	<5	2	.26	245	24	122	2.15	13.9	160	11	.21
BS38	26C	1.43	<5	19	68	.8	<5	<1	.15	167	16	67.8	1.82	18.6	80	12	.22
BS38	26D	1.46	<5	11	24	2.4	<5	<1	.12	147	6	5.8	1.87	60	13	9	.14
BS38	26E	2.03	<5	9	37	1.3	<5	<1	.06	75	13	5.1	2.15	41.1	10	24	.45
BS39	25A	1.29	<5	17	54	.6	<5	<1	.39	184	12	13.6	1.59	14	25	16	.32
BS39	25B	1.26	<5	11	38	.5	<5	<1	.23	246	7	11.1	1.62	13.9	11	17	.33
BS40	24A	1.32	<5	14	51	.6	<5	<1	.18	216	12	13.4	1.84	15.7	16	17	.33
BS40	24B	1.17	<5	8	26	.6	<5	<1	.11	130	13	3.5	1.71	17.4	8	16	.31
BS40	24C	1.51	<5	14	29	.9	<5	<1	.12	151	22	4.6	3.17	23.3	9	21	.37
BS41	28A	1.55	<5	14	34	.9	<5	<1	.14	237	17	4.5	2.68	22.7	8	16	.3
BS41	28AQ	1.5	<5	17	29	1	<5	<1	.12	106	18	3	2.58	20.5	9	16	.29
BS41	28B	1.92	<5	83	41	1.5	11	<1	.11	91	29	2.7	6.94	18.2	14	18	.28
BS41	28BQ	1.85	<5	73	39	1.4	<5	<1	.11	76	31	2.7	6.64	17	14	19	.29
BS42	33A	1.05	<5	12	47	<.5	<5	<1	.27	239	9	38.6	1.25	10.5	50	11	.24
BS42	33B	1.4	<5	10	43	.6	<5	<1	.36	383	5	41.2	1.46	14.2	29	14	.29
BS43	30A	1.34	<5	21	278	.9	<5	5	.47	132	37	167	2.52	15	160	14	.31
BS43	30B	1.34	<5	41	169	.8	<5	4	.38	182	29	117	2.21	15.1	157	13	.28
BS43	30B-DUP	1.3	<5	37	169	.8	<5	4	.38	178	27	117	2.16	14.6	159	13	.27
BS43	30C	1.42	<5	36	108	.7	<5	<1	.3	167	24	94.2	1.91	14.9	125	14	.27
BS43	30D	1.37	<5	19	62	.6	<5	<1	.21	140	13	21.4	1.62	15.8	32	14	.25
BS43	30E	1.15	<5	8	38	.7	<5	<1	.14	94	5	2.8	1.14	19.6	11	11	.16
BS44	31A	.51	<5	6	32	<.5	<5	<1	.13	254	3	5.5	1.06	8	5	9	.18
BS44	31B	.51	<5	5	23	.5	<5	<1	.09	271	3	11.7	.78	12.1	18	6	.12
BS45	32A	.56	<5	<3	32	<.5	<5	<1	.07	180	2	3.8	.93	7.8	3	12	.22
BS45	32B	.77	<5	4	33	<.5	<5	<1	.11	228	3	1.3	1.09	16.2	8	12	.23

Table 15. Results of all elemental analyses performed by SGS Canada, Inc., Mineral Services, Toronto, Ontario, Canada, of sediment samples from six impoundments in the Assabet River Basin, Massachusetts, 2003.—Continued

[Quantity in brackets is detection limit. **Map ID:** The identifier associated with a sampling site on a map (figs. 9–14). **Sample ID:** Identifier for a sample collected from a particular core, arranged alphabetically from the top of the core, with Q designating a replicate sample; DUP, SGS laboratory duplicate quality-control sample. %, percent; ppm, parts per million; <, actual value is less than value shown; --, not reported]

Map ID	Sample ID	Aluminum (%) [0.01]	Antimony (ppm) [5]	Arsenic (ppm) [3]	Barium (ppm) [1]	Beryllium (ppm) [0.5]	Bismuth (ppm) [5]	Cadmium (ppm) [1]	Calcium (%) [0.01]	Chromium (ppm) [1]	Cobalt (ppm) [1]	Copper (ppm) [0.5]	Iron (%) [0.01]	Lanthanum (ppm) [0.5]	Lead (ppm) [2]	Lithium (ppm) [1]	Magnesium (%) [0.01]
								Powdermill									
P46	48	1.06	7	21	94	<0.5	<5	2	0.3	899	13	280	1.86	10.6	233	13	0.32
P46	48Q	1.03	8	19	90	<.5	<5	2	.28	942	13	274	1.84	10	226	13	.32
P47	49	.81	<5	8	78	<.5	<5	<1	.27	394	10	50.9	1.62	9.8	110	11	.25
P48	46A	1.58	10	34	85	<.5	<5	1	.2	1,290	12	257	1.65	10.7	259	13	.3
P48	46A-DUP	1.56	15	40	86	.5	<5	<1	.2	1,260	11	254	1.61	10.8	254	12	.3
P48	46B	1.52	<5	20	49	<.5	<5	<1	.13	238	27	31.6	2.41	14.4	23	16	.37
P48	46C	2.26	<5	62	69	.8	<5	<1	.06	129	60	17.2	4.4	20.2	11	20	.34
P49	47	.76	<5	5	46	<.5	<5	<1	.16	268	6	19.4	1.79	9.4	58	13	.32
P50	52A	1.04	5	15	180	.7	<5	2	.43	272	23	109	2.76	10.7	231	15	.35
P50	52B	1.09	<5	13	181	.5	<5	2	.28	339	20	123	2.75	11.3	261	15	.37
P50	52C	.7	<5	11	133	<.5	<5	1	.18	311	15	78.3	2.28	7.8	244	10	.25
P50	52CQ	.7	<5	9	126	<.5	<5	1	.17	242	15	90.3	2.51	7.2	239	10	.25
P50	52D	1.09	<5	22	107	<.5	<5	4	.28	478	12	128	2.22	11.9	174	12	.33
P50	52E	.92	<5	36	99	<.5	<5	<1	.23	291	9	55	1.62	9.2	318	11	.25
P50	52E-DUP	.9	<5	35	96	<.5	<5	<1	.22	288	8	54.3	1.56	10.1	326	11	.24
P51	55A	1.27	7	31	139	.7	<5	5	.6	1,060	23	839	1.77	10.8	594	10	.26
P51	55AQ	1.23	10	29	144	.7	<5	5	.61	1,020	22	886	1.84	11.2	626	10	.29
P51	55B	1.98	15	58	69	.6	<5	3	.8	1,830	11	386	1.33	10.5	343	9	.26
P51	55B-DUP	1.98	15	58	69	.6	<5	3	.8	1,810	9	385	1.33	11.7	346	9	.27
P51	55C	.8	<5	<3	83	.8	<5	<1	2.07	97	6	22.4	.66	21.7	12	2	.18
P51	55D	1.13	<5	6	64	.9	<5	<1	.67	128	7	40	.69	50.5	7	16	.22
P52	53A	1.05	<5	16	193	.6	<5	2	.47	399	25	100	3.07	11.1	167	15	.35
P52	53B	1.06	<5	13	214	<.5	<5	4	.3	404	21	184	2.22	12.9	371	13	.34
P52	53C	1.8	17	101	134	<.5	<5	7	.35	2,270	7	330	2.27	9.2	621	12	.35
P52	53D	1.32	<5	20	104	<.5	<5	<1	.26	421	8	194	1.92	11.7	115	11	.37
P52	53DQ	1.29	<5	15	101	<.5	<5	<1	.25	427	8	185	1.88	11.7	109	11	.36
P52	53E	1.07	<5	10	57	<.5	<5	<1	.17	302	16	26.8	1.65	11.1	71	13	.3
P53	56A	1.57	<5	18	310	1.3	<5	6	.32	416	50	669	2.45	17.7	580	17	.42
P53	56B	1.73	11	47	226	.7	<5	4	.21	1,550	20	277	2.05	15.1	515	15	.34
P53	56BQ	1.79	12	52	216	.7	<5	4	.21	1,590	18	275	2.01	14.5	511	15	.34

Table 15. Results of all elemental analyses performed by SGS Canada, Inc., Mineral Services, Toronto, Ontario, Canada, of sediment samples from six impoundments in the Assabet River Basin, Massachusetts, 2003.—Continued

[Quantity in brackets is detection limit. **Map ID:** The identifier associated with a sampling site on a map (figs. 9–14). **Sample ID:** Identifier for a sample collected from a particular core, arranged alphabetically from the top of the core, with Q designating a replicate sample; DUP, SGS laboratory duplicate quality-control sample. %, percent; ppm, parts per million; <, actual value is less than value shown; --, not reported]

Map ID	Sample ID	Aluminum (%) [0.01]	Antimony (ppm) [5]	Arsenic (ppm) [3]	Barium (ppm) [1]	Beryllium (ppm) [0.5]	Bismuth (ppm) [5]	Cadmium (ppm) [1]	Calcium (%) [0.01]	Chromium (ppm) [1]	Cobalt (ppm) [1]	Copper (ppm) [0.5]	Iron (%) [0.01]	Lanthanum (ppm) [0.5]	Lead (ppm) [2]	Lithium (ppm) [1]	Magnesium (%) [0.01]
Powdermill—Continued																	
P53	56C	1.82	19	66	109	0.9	7	8	0.26	1,970	12	545	1.8	10.5	419	11	0.33
P54	54A	1.61	5	44	456	.7	--	7	.53	1,530	19	3430	2.1	12.9	1,030	13	.33
P54	54B	.6	<5	6	97	.7	<5	<1	1.45	148	7	49.8	1.08	11.6	29	1	.12
P54	54C	.89	<5	<3	65	1.6	<5	<1	1.46	106	2	14.6	.78	30.7	14	3	.11
P54	54CQ	.77	<5	<3	56	1.1	<5	<1	1.18	135	2	11.7	.71	24.1	13	4	.1
P55	51A	1.15	<5	9	77	<.5	<5	<1	.32	248	17	78	1.96	14.4	54	14	.32
P55	51B	1.26	<5	6	31	<.5	<5	<1	.2	179	17	10.5	1.72	18.6	11	15	.31
P55	51BQ	1.28	<5	6	33	<.5	<5	<1	.2	134	20	10.8	1.82	20.6	10	15	.32
P55	51C	1.32	<5	9	22	.5	<5	<1	.14	173	21	6.2	2.06	19	7	16	.33
P55	51D	1.23	<5	6	22	.5	<5	<1	.11	274	10	5.5	2.06	21.5	7	16	.34
P55	51E	1.27	<5	4	29	1	<5	<1	.11	240	8	5.9	1.54	20.6	7	18	.31
P56	50A	1.79	<5	17	323	1	<5	6	.59	332	88	720	3.09	18	411	22	.47
P56	50AQ	1.73	<5	17	312	1	<5	6	.59	291	83	675	3	17.4	393	21	.46
P56	50B	2.03	7	28	589	1.4	<5	10	.53	786	57	910	2.9	21	1,250	19	.44
P56	50C	1.81	11	48	136	.6	<5	9	.36	1,320	12	459	2.16	13	305	15	.44
P56	50D	1.39	<5	9	73	<.5	<5	<1	.33	187	15	23.7	1.61	14.4	40	16	.32
P56	50E	.65	<5	<3	49	.7	<5	<1	.26	221	3	9.1	.54	25.5	7	4	.07
P56	50E-DUP	.65	<5	<3	48	.7	<5	<1	.26	235	3	8.9	.54	26.4	9	5	.07
P57	57	1.18	<5	<3	54	<.5	<5	<1	.2	272	7	18	2	16.8	45	25	.53
P57	57Q	1.28	<5	4	48	<.5	<5	<1	.16	209	6	16.2	2.03	15.6	15	27	.73

Table 15. Results of all elemental analyses performed by SGS Canada, Inc., Mineral Services, Toronto, Ontario, Canada, of sediment samples from six impoundments in the Assabet River Basin, Massachusetts, 2003.—Continued

[Quantity in brackets is detection limit. **Map ID:** The identifier associated with a sampling site on a map (figs. 9–14). **Sample ID:** Identifier for a sample collected from a particular core, arranged alphabetically from the top of the core, with Q designating a replicate sample; DUP, SGS laboratory duplicate quality-control sample. %, percent; ppm, parts per million; <, actual value is less than value shown; --, not reported]

MapID	Sample ID	Manganese (ppm) [2]	Molybdenum (ppm) [1]	Nickel (ppm) [1]	Phosphorus (%) [0.01]	Potassium (%) [0.01]	Scandium (ppm) [0.5]	Silver (ppm) [0.2]	Sodium (%) [0.01]	Strontium (ppm) [0.5]	Tin (ppm) [10]	Titanium (%) [0.01]	Tungsten (ppm) [10]	Vanadium (ppm) [2]	Yttrium (ppm) [0.5]	Zinc (ppm) [0.5]	Zirconium (ppm) [0.5]
Aluminum City																	
AC1	5	481	5	22	0.16	0.25	1.9	4.9	0.04	27.7	13	0.05	<10	27	7.3	183	2.8
AC2	7A	605	8	22	.23	.14	1.6	5.2	.05	49.1	<10	.03	<10	26	9.2	249	3.2
AC2	7B	617	5	28	.28	.19	1.8	>10	.04	49.5	34	.03	<10	26	9.4	397	3.2
AC2	7C	633	1	18	.22	.11	1.7	1.4	.1	39.3	14	.03	<10	20	6.6	155	1.3
AC3	6A	266	7	22	.13	.14	1.5	5.6	.03	45.6	14	.03	<10	26	8.5	278	3.1
AC3	6B	235	5	30	.19	.2	1.5	>10	.03	53.2	30	.03	<10	29	10.6	495	3.5
AC3	6C	380	5	24	.17	.21	2.1	2.5	.03	50.9	26	.04	<10	30	9.5	296	2.8
AC4	8A	481	6	24	.17	.14	1.6	5.4	.05	39.8	<10	.03	<10	23	9	223	2.8
AC4	8B	557	7	24	.17	.15	1.3	9.8	.05	33.9	12	.03	<10	22	8.5	291	2.7
AC4	8B-DUP	557	6	23	.17	.15	1.4	9.5	.05	33.8	13	.03	<10	22	8.4	280	2.8
AC4	8C	392	6	31	.12	.17	1.6	2.1	.04	25.6	40	.04	<10	16	6.1	1,220	2.5
Allen Street																	
AS5	1A	169	3	17	0.05	0.18	1.7	0.2	0.04	21.1	24	0.05	<10	22	4.8	211	2
AS5	1A-DUP	170	3	16	.05	.18	1.6	.2	.04	20.6	23	.05	<10	21	4.9	199	1.8
AS5	1B	135	<1	14	.05	.13	1.3	.3	.04	27	47	.05	<10	21	4.8	184	1.5
AS5	1C	193	3	16	.06	.17	1.8	.3	.03	22.3	45	.06	<10	25	5.6	136	1.9
AS5	1D	146	<1	16	.05	.17	1.8	<.2	.03	22.7	19	.06	<10	23	4.4	83.4	1.7
AS6	3A	395	4	33	.21	.22	2	4.8	.05	46.7	33	.04	<10	29	10.4	487	3.2
AS6	3B	294	4	19	.08	.16	1.8	.4	.05	25.1	30	.05	<10	24	6.3	182	2
AS6	3C	323	2	17	.18	.13	1.3	<.2	.03	18	<10	.05	<10	26	4.2	78.3	1
AS7	2A	600	5	30	.21	.19	2.3	.7	.04	32.3	25	.06	<10	32	8.3	827	3.2
AS7	2B	213	<1	18	.07	.15	1.8	.4	.03	20.4	53	.05	<10	24	5.9	474	2.1
AS7	2C	222	3	17	.08	.16	1.8	.4	.03	23.8	33	.05	<10	26	6.6	351	2
AS7	2D	202	<1	19	.07	.18	2.1	<.2	.02	19.6	11	.06	<10	27	6.2	87.3	1.9
AS8	4A	844	9	24	.19	.16	1.6	2.9	.05	42.5	12	.03	<10	24	8	281	3.4
AS8	4B	669	3	31	.28	.19	1.4	>10	.05	55.2	30	.03	<10	26	9.8	551	4.1
AS8	4B-DUP	669	4	35	.31	.2	1.6	>10	.06	59.3	28	.03	<10	27	10.3	604	4.2
AS8	4C	737	2	27	.31	.17	1.9	2.3	.04	44.1	27	.04	<10	25	8.7	515	2.4
AS8	4D	320	<1	23	.11	.22	2.6	.3	.03	21	19	.07	<10	34	8.1	221	2.2
AS8	4E	266	2	15	.06	.12	1.4	<.2	.04	21.9	<10	.05	<10	23	5.9	54	1.4

Table 15. Results of all elemental analyses performed by SGS Canada, Inc., Mineral Services, Toronto, Ontario, Canada, of sediment samples from six impoundments in the Assabet River Basin, Massachusetts, 2003.—Continued

[Quantity in brackets is detection limit. **Map ID:** The identifier associated with a sampling site on a map (figs. 9–14). **Sample ID:** Identifier for a sample collected from a particular core, arranged alphabetically from the top of the core, with Q designating a replicate sample; DUP, SGS laboratory duplicate quality-control sample. %, percent; ppm, parts per million; <, actual value is less than value shown; --, not reported]

MapID	Sample ID	Manganese (ppm) [2]	Molybdenum (ppm) [1]	Nickel (ppm) [1]	Phosphorus (%) [0.01]	Potassium (%) [0.01]	Scandium (ppm) [0.5]	Silver (ppm) [0.2]	Sodium (%) [0.01]	Strontium (ppm) [0.5]	Tin (ppm) [10]	Titanium (%) [0.01]	Tungsten (ppm) [10]	Vanadium (ppm) [2]	Yttrium (ppm) [0.5]	Zinc (ppm) [0.5]	Zirconium (ppm) [0.5]
								Hudson									
H9	9	98	<1	14	0.06	0.04	0.9	<0.2	0.03	24.3	<10	<0.01	<10	13	10.6	35	<0.5
H10	12A	243	2	41	.13	.17	2.2	.9	.04	26.9	<10	.05	<10	36	8.5	212	2.2
H10	12B	232	<1	24	.11	.2	2.3	.3	.03	23.3	<10	.05	<10	31	8	300	2.1
H10	12C	258	<1	22	.1	.31	2.8	<.2	.03	15.5	<10	.08	<10	37	8.7	122	2.7
H10	12D	167	<1	8	.04	.03	<.5	<.2	.03	24	<10	.01	<10	11	7.4	14.6	<.5
H10	12E	89	<1	12	.05	.08	2.3	<.2	.02	17.6	<10	.02	<10	13	78.8	16	<.5
H11	13A	733	2	38	.09	.11	1.5	.4	.03	23.1	<10	.03	<10	24	8.9	288	1.5
H11	13A-DUP	745	2	38	.09	.11	1.6	.5	.03	25.2	<10	.03	<10	22	9.1	263	1.7
H11	13B	1,100	<1	14	.04	.05	1.2	<.2	.02	17.5	<10	.03	<10	25	13.7	19.4	<.5
H11	13C	1,590	2	22	.05	.04	2.8	<.2	.02	15.7	<10	.05	<10	49	36.5	38.7	1.6
H11	13D	949	2	33	.02	.08	4.2	<.2	.03	8.9	<10	.1	<10	53	21.6	62.7	4.1
H12	11A	237	2	20	.04	.05	1	<.2	.02	10.8	<10	.03	<10	17	4.7	28.1	<.5
H12	11B	148	1	14	.01	.06	1.2	<.2	.03	7.4	<10	.04	<10	18	4.3	18.9	.9
H13	14A	146	7	57	.11	.16	2.1	1.2	.06	52.2	34	.03	<10	26	7.9	410	3.8
H13	14A-DUP	146	7	52	.11	.17	2	.8	.07	54.3	31	.04	<10	27	8.1	380	2.8
H13	14AQ	148	7	62	.11	.17	1.9	.4	.07	54.6	38	.03	<10	26	8	418	1.3
H13	14B	139	5	36	.09	.2	2.5	<.2	.05	51.5	26	.05	<10	30	7.1	422	2.6
H13	14BQ	139	5	38	.08	.21	2.5	.7	.05	49	29	.05	<10	31	7	389	2.7
H13	14C	141	7	29	.04	.25	1.7	<.2	.04	22.4	74	.04	<10	21	3.5	66.1	1.9
H13	14CQ	154	7	29	.04	.25	1.9	<.2	.04	20.5	145	.05	<10	22	3.6	69	1.7
H13	14D	49	5	14	.18	.04	.9	<.2	.04	55.5	<10	.02	<10	12	2.7	12.7	.9
H13	14DQ	48	8	17	.04	.05	.9	<.2	.05	64.2	<10	.02	<10	14	3.1	12.4	.6
H13	14E	87	1	11	.06	.09	1.6	<.2	.03	17.6	<10	.03	<10	10	4.3	16.2	<.5
H13	14EQ	97	6	19	.04	.09	1.6	<.2	.03	16.7	<10	.03	<10	11	4.3	16.4	<.5
H14	10A	776	3	32	.14	.08	1	.6	.03	22.6	<10	.02	<10	17	6.1	77	1
H14	10B	287	<1	12	.04	.04	.9	<.2	.03	9.1	<10	.02	<10	15	8.7	20.7	<.5
H15	15A	869	4	86	.32	.23	2.7	1.5	.07	39.9	14	.04	<10	35	9.8	406	1.9
H15	15B	460	3	29	.16	.22	2.9	.8	.06	33.8	13	.05	<10	33	8.9	365	2.3
H15	15C	364	5	22	.09	.11	2.2	.3	.06	25.7	<10	.03	<10	34	6.6	69	<.5
H15	15C-DUP	352	5	21	.08	.11	2.1	<.2	.06	25.2	<10	.04	<10	33	6.6	64.3	1.4
H15	15D	318	12	11	.06	.05	2.8	.3	.03	12	<10	.04	<10	87	6.6	21.8	3.2

Table 15. Results of all elemental analyses performed by SGS Canada, Inc., Mineral Services, Toronto, Ontario, Canada, of sediment samples from six impoundments in the Assabet River Basin, Massachusetts, 2003.—Continued

[Quantity in brackets is detection limit. **Map ID:** The identifier associated with a sampling site on a map (figs. 9–14). **Sample ID:** Identifier for a sample collected from a particular core, arranged alphabetically from the top of the core, with Q designating a replicate sample; DUP, SGS laboratory duplicate quality-control sample. %, percent; ppm, parts per million; <, actual value is less than value shown; --, not reported]

MapID	Sample ID	Manganese (ppm) [2]	Molybdenum (ppm) [1]	Nickel (ppm) [1]	Phosphorus (%) [0.01]	Potassium (%) [0.01]	Scandium (ppm) [0.5]	Silver (ppm) [0.2]	Sodium (%) [0.01]	Strontium (ppm) [0.5]	Tin (ppm) [10]	Titanium (%) [0.01]	Tungsten (ppm) [10]	Vanadium (ppm) [2]	Yttrium (ppm) [0.5]	Zinc (ppm) [0.5]	Zirconium (ppm) [0.5]
								Gleasondale									
G16	34A	119	2	12	0.08	0.05	1	0.3	0.03	31.8	<10	0.01	<10	17	6.5	18.6	0.6
G16	34B	115	3	16	.06	.07	1.7	.4	.03	22.6	<10	.02	<10	23	8.4	32.1	.8
G16	34C	111	1	17	.04	.06	2.2	<.2	.02	14.8	<10	.03	<10	20	8.3	27.6	.7
G16	34C-DUP	107	1	16	.04	.05	2	<.2	.02	14.3	<10	.03	<10	20	8.1	26.9	.7
G17	39A	188	3	16	.04	.25	1.6	<.2	.03	6.2	<10	.03	<10	16	3.6	29.2	3.1
G17	39B	132	<1	15	.03	.26	1.5	<.2	.04	7.6	<10	.04	<10	15	3.2	22.3	2.9
G17	39C	161	3	16	.04	.26	1.8	<.2	.05	10.1	<10	.05	<10	18	4.3	28.5	3.9
G17	39D	163	1	17	.03	.27	1.5	<.2	.05	7.1	<10	.04	<10	15	3.5	24.3	3.4
G18	35A	492	10	33	.17	.2	2.3	1.5	.05	27.7	20	.04	14	29	8	369	2.9
G18	35B	330	3	23	.14	.18	2.3	1.6	.03	24	23	.04	<10	28	8.8	484	2.4
G18	35C	263	4	22	.12	.22	2.4	.8	.03	22.8	19	.04	<10	29	8.9	315	2.8
G18	35D	272	1	18	.09	.21	2.3	.6	.02	21.3	15	.05	<10	26	7.6	262	4.3
G18	35E	407	5	22	.07	.22	2.4	.9	.04	17.5	<10	.05	<10	26	8.2	180	2.6
G19	40A	1,420	11	91	.67	.2	2.1	2.5	.06	57.7	27	.03	14	34	12.1	464	2.5
G19	40B	516	7	26	.19	.24	2.7	.9	.05	37	21	.03	13	31	8.1	518	2.3
G19	40B-DUP	511	7	26	.19	.23	2.6	.9	.05	36.5	20	.03	12	30	8	506	2.9
G19	40C	453	3	24	.17	.24	2.6	.3	.04	32.3	15	.04	<10	29	9	358	3.4
G19	40CQ	436	3	26	.15	.25	2.7	.3	.04	31.4	15	.04	<10	30	9	346	3.4
G19	40D	245	2	19	.07	.18	1.8	<.2	.03	14.1	<10	.04	<10	18	4.8	101	1.9
G19	40E	127	3	12	.02	.15	1	<.2	.03	5.3	<10	.02	<10	10	2.8	19.6	2.2
G20	36A	262	2	15	.06	.09	1.3	<.2	.06	21.7	<10	.02	<10	15	4.8	31.4	1.1
G20	36AQ	326	9	22	.06	.15	1.6	<.2	.08	21.5	<10	.02	<10	17	6	29.7	1.7
G20	36B	310	2	14	.06	.05	1.3	.2	.06	19.1	<10	.02	<10	18	5.7	24.2	.8
G20	36C	294	3	15	.04	.05	1.7	<.2	.04	17.1	<10	.03	<10	18	6.2	38.7	.8
G20	36D	375	3	18	.04	.04	1.5	<.2	.03	21.3	<10	.03	<10	15	7.5	31.2	1.5
G20	36E	727	7	28	.05	.02	1.7	<.2	.03	41.5	<10	.02	<10	13	14.2	93.8	2.9
G21	44	206	4	22	.07	.16	1	<.2	.05	16	97	.02	<10	12	3	71	2.2
G22	41A	1,600	8	149	.71	.22	2.1	4.5	.07	52	21	.03	<10	32	10.5	485	3.2
G22	41B	488	5	44	.19	.17	1.7	.9	.05	25.6	16	.03	<10	22	5.6	248	2.1
G22	41C	368	6	22	.1	.23	1.9	<.2	.05	22.6	<10	.04	<10	23	5.8	142	2.3

Table 15. Results of all elemental analyses performed by SGS Canada, Inc., Mineral Services, Toronto, Ontario, Canada, of sediment samples from six impoundments in the Assabet River Basin, Massachusetts, 2003.—Continued

[Quantity in brackets is detection limit. **Map ID:** The identifier associated with a sampling site on a map (figs. 9–14). **Sample ID:** Identifier for a sample collected from a particular core, arranged alphabetically from the top of the core, with Q designating a replicate sample; DUP, SGS laboratory duplicate quality-control sample. %, percent; ppm, parts per million; <, actual value is less than value shown; --, not reported]

MapID	Sample ID	Manganese (ppm) [2]	Molybdenum (ppm) [1]	Nickel (ppm) [1]	Phosphorus (%) [0.01]	Potassium (%) [0.01]	Scandium (ppm) [0.5]	Silver (ppm) [0.2]	Sodium (%) [0.01]	Strontium (ppm) [0.5]	Tin (ppm) [10]	Titanium (%) [0.01]	Tungsten (ppm) [10]	Vanadium (ppm) [2]	Yttrium (ppm) [0.5]	Zinc (ppm) [0.5]	Zirconium (ppm) [0.5]
Gleasondale—Continued																	
G23	37A	123	2	15	0.04	0.14	0.9	<0.2	0.04	7.4	<10	0.02	<10	9	2.3	31.7	1.8
G23	37A-DUP	125	1	16	.04	.14	.9	<.2	.04	7.5	<10	.02	<10	9	2.3	32.1	2.4
G23	37B	130	4	13	.03	.16	1	<.2	.04	6.4	<10	.02	<10	10	2.4	36.8	2.4
G23	37C	134	2	13	.03	.12	.9	<.2	.03	9.7	<10	.02	<10	9	2.6	47.6	1.6
G23	37D	301	4	23	.09	.24	2.3	.4	.05	22.5	12	.04	<10	24	7.5	191	3.5
G24	42A	190	5	17	.05	.06	2.9	<.2	.02	9	<10	.03	<10	39	10.5	33.7	.5
G24	42B	110	3	17	.02	.09	2.8	<.2	.03	6.9	<10	.03	<10	29	9.3	25.3	2.5
G25	45	164	4	11	.02	.13	1	<.2	.03	5.6	<10	.02	<10	10	2.7	23.7	2.5
G25	45-DUP	159	3	11	.02	.13	.9	<.2	.03	5.5	<10	.02	<10	9	2.6	23.3	2.1
G26	38A	67	3	9	.07	.05	.9	<.2	.03	55.2	<10	.01	<10	17	6	15	.6
G26	38B	60	4	9	.06	.04	.8	<.2	.03	45.9	<10	.01	<10	11	3.9	15.9	.7
G26	38C	102	5	24	.04	.07	1.4	<.2	.03	32	<10	.02	<10	19	5.4	34.2	.6
G27	43	299	6	24	.08	.14	1.1	<.2	.04	14	<10	.02	<10	13	2.9	84.2	2.5
Ben Smith																	
BS28	16A	190	4	20	0.06	0.09	1.1	0.3	0.03	9.3	<10	.02	<10	11	3.3	82.8	0.8
BS28	16B	161	2	15	.04	.16	1.2	<.2	.03	5.7	13	.02	<10	13	2.9	50.1	1.6
BS29	18A	137	3	14	.15	.04	.8	<.2	.04	49.2	<10	<.01	<10	8	31.2	43.9	.8
BS29	18B	92	1	9	.14	.04	.9	<.2	.04	40.6	<10	<.01	<10	6	37.5	5.7	1.5
BS29	18C	70	4	16	.06	.06	1.9	<.2	.02	13.3	<10	<.01	<10	10	58.8	9.8	.7
BS29	19A	750	5	32	.2	.16	2.1	1.3	.05	33.7	53	.03	<10	29	10.2	479	2
BS30	17A	679	7	98	.24	.15	2.2	2.6	.07	39.3	40	.03	<10	27	10.1	515	2.5
BS30	17B	521	3	31	.16	.16	2.3	1.3	.07	34.6	42	.02	<10	26	8.9	617	2.5
BS30	17C	491	5	31	.16	.17	2.1	.9	.06	32.2	68	.03	<10	27	10	637	2.3
BS30	17D	399	3	23	.13	.11	1.6	<.2	.05	28.1	160	.02	<10	21	8.9	165	.5
BS30	17E	118	1	8	.11	.03	.8	.3	.02	22	<10	<.01	<10	9	14.7	3.2	.8
BS31	19A-DUP	730	4	30	.19	.16	2.1	.2	.05	33	46	.03	<10	28	9.9	454	2.1
BS31	19AQ	734	5	34	.2	.16	2.1	.8	.05	32.9	51	.02	<10	28	9.9	481	1.9
BS31	19B	761	3	29	.17	.17	2.2	.8	.04	28.2	111	.03	<10	28	9.5	281	1.9
BS31	19BQ	762	5	32	.17	.16	2.2	.8	.04	27.8	113	.03	<10	28	9.4	277	2

Table 15. Results of all elemental analyses performed by SGS Canada, Inc., Mineral Services, Toronto, Ontario, Canada, of sediment samples from six impoundments in the Assabet River Basin, Massachusetts, 2003.—Continued

[Quantity in brackets is detection limit. **Map ID:** The identifier associated with a sampling site on a map (figs. 9–14). **Sample ID:** Identifier for a sample collected from a particular core, arranged alphabetically from the top of the core, with Q designating a replicate sample; DUP, SGS laboratory duplicate quality-control sample. %, percent; ppm, parts per million; <, actual value is less than value shown; --, not reported]

MapID	Sample ID	Manganese (ppm) [2]	Molybdenum (ppm) [1]	Nickel (ppm) [1]	Phosphorus (%) [0.01]	Potassium (%) [0.01]	Scandium (ppm) [0.5]	Silver (ppm) [0.2]	Sodium (%) [0.01]	Strontium (ppm) [0.5]	Tin (ppm) [10]	Titanium (%) [0.01]	Tungsten (ppm) [10]	Vanadium (ppm) [2]	Yttrium (ppm) [0.5]	Zinc (ppm) [0.5]	Zirconium (ppm) [0.5]
Ben Smith—Continued																	
BS31	19C	537	3	23	0.12	0.11	1.8	0.2	0.04	20.2	215	0.02	<10	24	8.1	112	0.6
BS31	19CQ	533	5	25	.12	.1	1.8	<.2	.04	20.4	217	.02	<10	24	8.2	104	<.5
BS31	19D	284	6	20	.08	.06	1.6	<.2	.03	11.3	<10	.02	<10	22	7.2	21.6	1.2
BS31	19DQ	281	2	16	.08	.06	1.6	<.2	.02	10.8	<10	.02	<10	21	6.5	21.6	.5
BS31	19E	254	5	22	.06	.05	1.5	<.2	.02	12.8	<10	.02	<10	17	6.6	16.8	.8
BS31	19EQ	270	3	18	.05	.06	1.7	<.2	.02	13.6	<10	.02	<10	21	6.8	19.3	1
BS32	20A	3,040	9	132	.86	.17	2	5	.08	51.2	30	.02	<10	26	10.9	492	2.1
BS32	20B	1,020	3	36	.29	.14	2	1.9	.06	44.3	38	.03	<10	28	9.2	481	1.9
BS32	20C	578	4	16	.08	.04	1.1	<.2	.04	36.7	<10	.01	<10	13	6.4	34.4	.8
BS32	20C-DUP	553	3	15	.08	.04	.9	<.2	.04	35.4	<10	.02	<10	12	6.2	32	.7
BS32	20D	596	3	12	.06	.03	1.1	<.2	.04	31.1	<10	.01	<10	13	7.6	23	1.3
BS32	20E	527	4	19	.06	.04	1.2	<.2	.03	25	<10	.02	<10	14	6.7	29.8	1.3
BS33	21A	541	3	26	.18	.15	2.2	.9	.06	33.7	126	.02	<10	25	9.4	334	1.2
BS33	21B	401	3	16	.09	.05	1.5	<.2	.04	21.6	15	.02	<10	24	7.7	30.9	<.5
BS33	21C	397	1	14	.07	.04	1.4	<.2	.03	19.7	<10	.02	<10	19	7.1	21.6	<.5
BS33	21D	439	4	17	.06	.04	1.6	<.2	.03	22.4	<10	.02	<10	17	7	25.1	.5
BS33	21E	450	2	16	.05	.07	1.8	.3	.02	21.1	<10	.03	<10	17	6.6	26.6	.9
BS34	22A	470	7	59	.18	.14	1.8	1.9	.04	30.1	30	.02	<10	27	11.1	484	1
BS34	22B	234	2	15	.04	.07	1.4	<.2	.03	11.7	10	.02	<10	15	5.8	38.3	1.3
BS34	22C	186	3	14	.03	.11	1.3	<.2	.02	5.3	<10	.03	<10	13	5.4	19.4	1
BS35	23A	441	4	47	.17	.12	1.7	1.4	.03	29.5	23	.02	<10	26	9.1	446	2
BS35	23B	280	5	27	.13	.11	1.7	.8	.03	27.2	39	.02	<10	26	9.3	458	1.8
BS35	23B-DUP	277	5	25	.12	.11	1.5	<.2	.02	27.2	34	.02	<10	25	9.2	445	1.3
BS35	23C	162	3	15	.06	.05	1.3	<.2	.03	23.4	<10	.02	<10	16	12.6	37.5	<.5
BS36	27A	423	3	14	.07	.05	2.2	.3	.04	14	<10	.03	<10	29	10.3	26.4	<.5
BS36	27B	477	6	18	.05	.09	3.3	<.2	.05	11.9	<10	.05	<10	41	15.4	27.8	1.3
BS36	27C	1,170	7	18	.03	.05	3.6	.2	.04	9.7	<10	.05	<10	56	16.6	26.8	2.8
BS36	27D	1,250	9	14	.02	.03	2.5	.5	.02	8.8	<10	.05	<10	49	11.8	24.2	3.1
BS36	27D-DUP	1,240	9	14	.02	.03	2.5	<.2	.02	8.7	<10	.05	<10	48	11.6	23.7	3.5
BS37	29A	232	4	16	.09	.08	1.7	<.2	.04	15.7	<10	.02	<10	21	8.5	62.2	.9

Table 15. Results of all elemental analyses performed by SGS Canada, Inc., Mineral Services, Toronto, Ontario, Canada, of sediment samples from six impoundments in the Assabet River Basin, Massachusetts, 2003.—Continued

[Quantity in brackets is detection limit. **Map ID:** The identifier associated with a sampling site on a map (figs. 9–14). **Sample ID:** Identifier for a sample collected from a particular core, arranged alphabetically from the top of the core, with Q designating a replicate sample; DUP, SGS laboratory duplicate quality-control sample. %, percent; ppm, parts per million; <, actual value is less than value shown; --, not reported]

MapID	Sample ID	Manganese (ppm) [2]	Molybdenum (ppm) [1]	Nickel (ppm) [1]	Phosphorus (%) [0.01]	Potassium (%) [0.01]	Scandium (ppm) [0.5]	Silver (ppm) [0.2]	Sodium (%) [0.01]	Strontium (ppm) [0.5]	Tin (ppm) [10]	Titanium (%) [0.01]	Tungsten (ppm) [10]	Vanadium (ppm) [2]	Yttrium (ppm) [0.5]	Zinc (ppm) [0.5]	Zirconium (ppm) [0.5]
								Ben Smith—Continued									
BS37	29B	107	1	12	0.03	0.05	2.3	<0.2	0.02	9.2	<10	0.02	<10	24	10.1	18.4	0.6
BS37	29C	95	2	13	<.01	.07	3.3	<.2	.03	9.3	<10	.03	<10	48	11	18.7	2.6
BS38	26A	822	3	46	.14	.13	1.7	1.8	.05	29.6	28	.02	<10	27	9.2	483	1.6
BS38	26B	1,060	4	28	.12	.12	1.6	.6	.03	22.7	53	.02	<10	26	9.4	390	1
BS38	26C	1,130	3	22	.09	.07	1.8	.2	.03	12.4	73	.02	<10	24	10.6	110	1.3
BS38	26D	1,550	4	23	.05	.03	1.6	<.2	.02	6.9	<10	.01	<10	23	41.2	13.7	.9
BS38	26E	461	2	28	.02	.06	2.7	<.2	.02	3.9	<10	.07	<10	29	41.1	44.6	1.4
BS39	25A	208	3	25	.07	.09	1.8	<.2	.04	23.3	<10	.04	<10	22	7.3	53.7	1
BS39	25B	173	7	26	.06	.08	1.8	.3	.03	13.9	<10	.04	<10	21	6.1	29	1.4
BS40	24A	469	7	27	.08	.07	2	<.2	.03	11.7	<10	.04	<10	23	7.1	36.9	1.5
BS40	24B	377	2	17	.04	.03	2	.2	.02	7.4	<10	.03	<10	23	8.9	23.8	.7
BS40	24C	1,090	6	25	.05	.04	2.8	<.2	.02	7.6	<10	.05	<10	32	13.3	27	1.3
BS41	28A	589	6	18	.04	.09	3.1	.2	.06	13.9	<10	.05	<10	33	15.8	23.4	1.9
BS41	28AQ	605	3	15	.04	.06	3	<.2	.04	12.4	<10	.04	<10	33	16	23	1.3
BS41	28B	1,100	9	18	.04	.05	3.3	.3	.04	12.7	<10	.04	<10	66	13.6	22.3	3.6
BS41	28BQ	1,180	8	17	.04	.04	3.1	.4	.03	12.3	<10	.04	<10	64	12.8	22.3	3.1
BS42	33A	107	3	21	.06	.12	1.4	.2	.04	28.5	21	.04	<10	18	5.5	81.1	1.6
BS42	33B	139	7	19	.07	.14	1.8	<.2	.05	35.2	42	.05	<10	24	7.2	43.4	1.6
BS43	30A	1,220	5	68	.34	.18	2.1	2.4	.06	40.2	21	.03	<10	26	10.2	386	1.9
BS43	30B	747	4	47	.2	.15	2	1.5	.04	30.8	24	.03	<10	27	9.4	422	1.8
BS43	30B-DUP	747	4	46	.2	.15	1.9	.7	.04	30.5	22	.03	<10	26	9.4	421	1.6
BS43	30C	505	2	22	.13	.13	1.9	.4	.03	22.8	82	.03	<10	26	8.6	213	1.2
BS43	30D	303	4	17	.1	.08	1.7	<.2	.03	14.9	32	.02	<10	25	8.2	47	.7
BS43	30E	173	2	11	.06	.04	1.7	<.2	.03	11	<10	<.01	<10	19	9.7	13.3	<.5
BS44	31A	157	4	12	.02	.12	.9	<.2	.04	8.4	<10	.02	<10	9	2.8	16.6	1.3
BS44	31B	88	5	11	.03	.11	1.2	.2	.04	9.5	<10	.02	<10	8	3.4	22.6	2.1
BS45	32A	95	1	11	.02	.15	.8	<.2	.04	6.2	<10	.01	<10	8	2.3	14.9	2.2
BS45	32B	163	4	14	.05	.2	1.4	.3	.04	8.2	<10	.04	<10	13	5.5	18.9	2.4

Table 15. Results of all elemental analyses performed by SGS Canada, Inc., Mineral Services, Toronto, Ontario, Canada, of sediment samples from six impoundments in the Assabet River Basin, Massachusetts, 2003.—Continued

[Quantity in brackets is detection limit. **Map ID:** The identifier associated with a sampling site on a map (figs. 9–14). **Sample ID:** Identifier for a sample collected from a particular core, arranged alphabetically from the top of the core, with Q designating a replicate sample; DUP, SGS laboratory duplicate quality-control sample. %, percent; ppm, parts per million; <, actual value is less than value shown; --, not reported]

MapID	Sample ID	Manganese (ppm) [2]	Molybdenum (ppm) [1]	Nickel (ppm) [1]	Phosphorus (%) [0.01]	Potassium (%) [0.01]	Scandium (ppm) [0.5]	Silver (ppm) [0.2]	Sodium (%) [0.01]	Strontium (ppm) [0.5]	Tin (ppm) [10]	Titanium (%) [0.01]	Tungsten (ppm) [10]	Vanadium (ppm) [2]	Yttrium (ppm) [0.5]	Zinc (ppm) [0.5]	Zirconium (ppm) [0.5]
								Powdermill									
P46	48	268	5	40	0.1	0.16	1.6	1.4	0.04	25.9	46	0.04	<10	27	5.5	289	3.3
P46	48Q	263	7	41	.1	.15	1.5	1.5	.04	24.7	48	.04	<10	26	5.5	288	2.9
P47	49	343	4	30	.09	.13	1.1	1.1	.04	22.7	43	.04	<10	22	4.6	152	1.6
P48	46A	422	3	26	.15	.11	1.5	2.7	.03	18.9	61	.04	<10	28	5.8	162	2.3
P48	46A-DUP	417	4	25	.15	.11	1.5	<.2	.04	19	65	.04	<10	25	4.7	155	2.9
P48	46B	655	8	31	.04	.13	1.4	.5	.04	10.6	<10	.05	<10	30	5.2	75.2	1.8
P48	46C	901	7	45	.03	.11	3	.4	.03	5.5	<10	.08	<10	38	8.7	47	3.6
P49	47	199	7	27	.05	.2	1.1	.6	.04	13.4	23	.04	<10	18	3.6	59.3	3.5
P50	52A	842	9	54	.26	.19	1.7	2	.04	35.2	42	.05	<10	34	6.8	331	2.5
P50	52B	702	5	77	.28	.21	1.6	2	.03	25.9	59	.05	<10	38	6.3	298	1.9
P50	52C	356	8	41	.12	.14	1	1.7	.03	17.6	64	.04	<10	30	4.2	183	2.1
P50	52CQ	378	3	35	.13	.14	1	1.9	.02	18.1	75	.04	<10	30	4.3	174	1.2
P50	52D	256	8	35	.09	.18	1.9	1.4	.03	18.1	62	.06	<10	33	5.8	306	6.7
P50	52E	218	3	20	.07	.13	1.2	1.1	.03	17.7	234	.04	<10	21	4.6	93.2	1.8
P50	52E-DUP	212	3	19	.07	.13	1.1	.9	.02	17.3	227	.04	<10	21	4.6	91.4	2.3
P51	55A	117	9	60	.15	.09	1	> 10	.05	49.7	110	.02	<10	24	7.3	1,140	1.4
P51	55AQ	135	12	69	.14	.09	1	> 10	.06	49.4	112	.03	<10	24	7.1	963	1.6
P51	55B	86	4	24	.18	.09	1.1	2.8	.06	67	94	.03	<10	22	6.3	1,010	1.5
P51	55B-DUP	87	4	25	.18	.1	1.2	3	.06	67.2	90	.03	<10	22	6.5	999	2.4
P51	55C	53	4	51	.13	.04	.6	.5	.08	149	<10	<.01	<10	7	11.7	10.8	.5
P51	55D	72	5	52	.05	.1	1.7	<.2	.04	51.7	<10	.02	<10	12	22.9	17.5	.6
P52	53A	924	11	56	.31	.2	1.5	2	.05	40.9	38	.05	<10	33	7.1	354	2.8
P52	53B	424	5	53	.18	.18	1.6	2.9	.04	30.6	82	.05	<10	40	6.9	339	2.7
P52	53C	289	6	29	.17	.19	1.7	2.7	.04	37.6	89	.04	<10	30	5.7	726	4.6
P52	53D	235	2	21	.09	.22	2.7	.9	.03	20.7	85	.07	<10	37	6.5	163	8.6
P52	53DQ	230	4	23	.09	.21	2.6	.7	.03	20.1	68	.07	<10	36	6.3	158	8.4
P52	53E	196	4	25	.06	.14	1.4	.5	.03	11.4	55	.05	<10	23	4.8	44.8	1.2
P53	56A	306	7	272	.32	.19	2.6	8.6	.06	41.8	193	.05	134	49	11.4	379	2.8
P53	56B	260	7	54	.3	.17	2	4.6	.04	37.2	91	.04	<10	39	8.4	424	2.5
P53	56BQ	261	5	49	.3	.17	2	4.4	.04	36.9	90	.04	<10	39	8.3	430	2.2

Table 15. Results of all elemental analyses performed by SGS Canada, Inc., Mineral Services, Toronto, Ontario, Canada, of sediment samples from six impoundments in the Assabet River Basin, Massachusetts, 2003.—Continued

[Quantity in brackets is detection limit. **Map ID:** The identifier associated with a sampling site on a map (figs. 9–14). **Sample ID:** Identifier for a sample collected from a particular core, arranged alphabetically from the top of the core, with Q designating a replicate sample; DUP, SGS laboratory duplicate quality-control sample. %, percent; ppm, parts per million; <, actual value is less than value shown; --, not reported]

MapID	Sample ID	Manganese (ppm) [2]	Molybdenum (ppm) [1]	Nickel (ppm) [1]	Phosphorus (%) [0.01]	Potassium (%) [0.01]	Scandium (ppm) [0.5]	Silver (ppm) [0.2]	Sodium (%) [0.01]	Strontium (ppm) [0.5]	Tin (ppm) [10]	Titanium (%) [0.01]	Tungsten (ppm) [10]	Vanadium (ppm) [2]	Yttrium (ppm) [0.5]	Zinc (ppm) [0.5]	Zirconium (ppm) [0.5]
Powdermill—Continued																	
P53	56C	299	3	26	0.16	0.16	2.2	0.3	0.02	32.9	83	0.04	<10	27	6.3	1,010	3.4
P54	54A	294	15	69	.31	.17	1.5	> 10	.04	51.6	560	.03	<10	28	8.3	905	3.2
P54	54B	355	3	14	.12	.03	.7	<.2	.04	109	15	<.01	<10	10	6.6	388	<.5
P54	54C	243	4	10	.04	.04	3.2	.4	.03	119	<10	.01	<10	11	14.2	62.6	.7
P54	54CQ	210	3	10	.03	.04	2.5	.2	.02	96.2	<10	.01	<10	9	10.5	73	.9
P55	51A	384	6	46	.1	.12	1.6	1.3	.05	25.5	14	.04	<10	26	6.5	99.6	1.8
P55	51B	330	3	21	.08	.06	1.8	.4	.04	14.5	<10	.04	<10	28	9.7	33.2	.5
P55	51BQ	342	4	19	.08	.06	1.8	.4	.04	14.8	<10	.05	<10	29	10.1	34.1	<.5
P55	51C	323	3	22	.05	.06	1.9	.4	.04	9.4	<10	.05	<10	31	9.9	31.4	.9
P55	51D	282	8	29	.04	.07	2.1	.4	.04	6.9	<10	.06	<10	28	9	28.7	1.1
P55	51E	267	4	30	.04	.05	2.8	.6	.04	7.1	<10	.05	<10	25	8.7	29.3	1.3
P56	50A	583	9	179	.37	.26	2.3	> 10	.08	58	125	.05	117	40	11.7	572	2.2
P56	50AQ	573	8	164	.36	.25	2.3	> 10	.07	56.3	116	.04	114	39	11.4	555	2.7
P56	50B	704	14	84	.54	.23	2.4	> 10	.06	77.8	83	.04	<10	53	15.6	1,200	2.1
P56	50C	308	4	28	.13	.26	2.8	2.2	.04	32.8	55	.06	<10	39	8.3	703	7
P56	50D	262	5	26	.08	.12	1.7	.2	.04	24	16	.04	<10	25	7.4	48.2	1.3
P56	50E	148	2	13	.06	.05	.7	.3	.03	19.5	<10	<.01	<10	6	9.5	10.3	<.5
P56	50E-DUP	148	2	13	.06	.05	.7	.3	.02	19.5	<10	<.01	<10	6	9.6	9.4	.8
P57	57	272	3	30	.07	.31	1.9	.5	.04	9.6	<10	.07	<10	28	6.1	66.9	4.2
P57	57Q	252	4	36	.05	.3	2.3	.3	.04	7.6	<10	.08	<10	31	5.5	67.5	4

Table 16. Concentrations of polycyclic aromatic hydrocarbons detected in sediment samples from six impoundments in the Assabet River Basin, Massachusetts, 2003.

[All values are in micrograms per kilogram. Minimum reporting level is 0.017 micrograms per kilogram. Data are rounded to two significant figures. **Map ID:** The identifier associated with a sampling site on a map (figs. 9–14). **Sample ID:** Identifier for a sample collected from a particular core, arranged alphabetically from the top of the core, with Q designating a replicate sample. Shaded numbers exceed sediment-quality guidelines (table 2). There are no guidelines for benzo[*b*]fluoranthene. PAH, polycyclic aromatic hydrocarbon; --, not detected]

Map ID	Sample ID	Acenaphthene	Acenaphthylene	Anthracene	Benzo[*a*]anthracene	Benzo[*a*]pyrene	Benzo[*b*]fluoranthene	Benzo[*g,h,i*]perylene	Benzo[*k*]fluoranthene	Chrysene
					Aluminum City					
AC1	5	23	5.2	77	290	220	310	110	130	330
AC2	7	21	8.8	25	220	210	330	120	180	360
AC3	6	19	9.9	29	150	190	400	110	130	250
AC4	8A	27	--	44	440	390	670	220	320	640
AC4	8B	16	5.5	18	110	120	210	76	120	160
AC4	8C	4.7	--	16	67	42	70	23	34	65
					Allen Street					
AS5	1	540	70	1,100	7,100	5,600	6,200	2,200	2,400	7,100
AS6	3	43	17	120	840	510	650	230	360	740
AS7	2A	74	39	290	1,500	1,200	1,500	560	760	1,300
AS7	2B	200	57	600	2,000	1,600	2,200	600	800	2,300
AS7	2C	20	15	76	540	290	380	140	200	480
AS8	4	58	19	160	750	560	780	260	380	840
					Hudson					
H9	9	--	--	30	12	--	23	12	9.0	19
H10	12	130	590	830	5,800	7,000	8,400	3,700	4,200	8,400
H10	12Q	120	520	740	5,400	6,000	7,900	3,600	3,100	7,700
H11	13	--	13	16	160	160	250	130	110	250
H12	11A	--	--	--	12	--	14	10	11	20
H12	11B	--	--	--	6.7	--	11	6.5	5.4	9.2
H13	14A	81	380	660	5,300	6,000	9,600	2,100	2,900	6,400
H13	14AQ	76	390	610	4,500	5,200	8,100	2,000	3,400	5,500
H13	14B	32	230	310	2,600	2,900	3,900	1,200	1,800	3,000
H13	14BQ	33	240	360	3,200	3,500	5,400	1,400	2,500	3,800
H13	14C	--	--	--	--	--	[1]17	--	--	[1]11
H13	14CQ	--	--	--	--	--	[1]33	--	--	[1]31
H14	10	--	--	--	5.0	--	9.6	5.31	5.33	10
H15	15	--	82	120	920	970	1,500	760	570	1,400
					Gleasondale					
G16	34	--	--	--	20	--	32	13	15	30
G17	39	14	11	51	220	260	310	140	220	350
G18	35A	410	610	1,500	7,400	7,800	10,000	4,400	5,500	11,000
G18	35B	220	270	1,200	6,400	5,700	6,100	2,800	3,800	8,800
G18	35C	34	41	190	920	740	770	370	640	1,300

Table 16. Concentrations of polycyclic aromatic hydrocarbons detected in sediment samples from six impoundments in the Assabet River Basin, Massachusetts, 2003.—Continued

[All values are in micrograms per kilogram. Minimum reporting level is 0.017 micrograms per kilogram. Data are rounded to two significant figures. **Map ID:** The identifier associated with a sampling site on a map (figs. 9–14). **Sample ID:** Identifier for a sample collected from a particular core, arranged alphabetically from the top of the core, with Q designating a replicate sample. Shaded numbers exceed sediment-quality guidelines (table 2). There are no guidelines for benzo[*b*]fluoranthene. PAH, polycyclic aromatic hydrocarbon; --, not detected]

Map ID	Sample ID	Acenaphthene	Acenaphthylene	Anthracene	Benzo[*a*]anthracene	Benzo[*a*]pyrene	Benzo[*b*]fluoranthene	Benzo[*g,h,i*]perylene	Benzo[*k*]fluoranthene	Chrysene
					Gleasondale—Continued					
G19	40A	47	46	160	770	800	1,200	470	440	1,200
G19	40B	150	120	470	2,500	2,500	3,200	1,300	2,100	3,800
G19	40C	10	8.41	57	220	190	260	110	160	320
G19	40CQ	14	11	86	310	270	350	140	220	440
G20	36	--	--	--	20	--	19	--	14	28
G20	36Q	--	--	--	14	--	16	7.10	12	26
G21	44	6.1	6.2	31	140	140	190	78	140	220
G22	41	63	60	210	1,300	1,300	1,700	700	1,200	2,000
G23	37	6.0	9.3	36	260	190	190	97	130	260
G24	42	9.8	14	32	230	230	310	140	210	380
G25	45	--	--	8.6	74	81	120	51	76	120
G26	38	--	--	60	190	190	290	160	180	330
G27	43	--	--	54	180	210	330	140	210	320
					Ben Smith					
BS28	16	--	--	--	55	47	[1]84	39	37	[1]79
BS29	18	--	--	--	[1]45	--	[1]96	74	54	89
BS30	17A	--	150	270	2,200	2,300	3,500	1,900	1,500	3,400
BS30	17B	--	--	150	1,200	880	1,500	750	650	1,600
BS30	17C	--	--	--	--	--	[1]36	--	--	[1]38
BS31	19A	--	--	--	--	--	[1]33	35	--	27
BS31	19AQ	--	--	--	--	--	[1]15	9.8	--	--
BS31	19B	--	--	--	220	160	330	160	130	440
BS31	19BQ	--	--	58	210	120	[1]230	100	100	380
BS31	19C	--	--	270	2,000	1,700	3,200	1,400	1,100	3,400
BS31	19CQ	--	91	240	1,600	1,500	2,500	1,200	1,300	2,600
BS32	20A	--	--	59	550	550	930	470	460	940
BS32	20B	--	--	--	42	--	52	28	45	70
BS32	20C	--	--	--	18	--	22	--	19	28
BS33	21	--	--	94	410	460	690	410	510	690
BS34	22	--	28	39	350	380	590	320	360	610
BS35	23	--	--	26	84	--	120	70	100	160
BS36	27	--	--	--	18	--	18	--	20	34
BS37	29	--	--	--	8.01	--	15	--	14	12
BS38	26A	--	--	90	740	690	1,300	640	630	1,500

Table 16. Concentrations of polycyclic aromatic hydrocarbons detected in sediment samples from six impoundments in the Assabet River Basin, Massachusetts, 2003.—Continued

[All values are in micrograms per kilogram. Minimum reporting level is 0.017 micrograms per kilogram. Data are rounded to two significant figures. **Map ID:** The identifier associated with a sampling site on a map (figs. 9–14). **Sample ID:** Identifier for a sample collected from a particular core, arranged alphabetically from the top of the core, with Q designating a replicate sample. Shaded numbers exceed sediment-quality guidelines (table 2). There are no guidelines for benzo[*b*]fluoranthene. PAH, polycyclic aromatic hydrocarbon; --, not detected]

Map ID	Sample ID	Acenaphthene	Acenaphthylene	Anthracene	Benzo[*a*]anthracene	Benzo[*a*]pyrene	Benzo[*b*]fluoranthene	Benzo[*g,h,i*]perylene	Benzo[*k*]fluoranthene	Chrysene
					Ben Smith—Continued					
BS38	26B	--	--	8.3	54	--	78	42	58	110
BS38	26C	--	--	--	--	--	--	--	--	--
BS39	25	--	--	--	42	--	50	29	43	63
BS40	24	--	16	26	230	240	410	200	200	440
BS41	28	--	--	--	--	--	--	--	--	--
BS42	33	--	--	--	97	92	130	75	87	140
BS43	30A	--	--	--	680	760	940	590	870	1,100
BS43	30B	--	--	--	520	400	630	310	460	740
BS43	30C	--	--	--	--	--	11	--	--	10
BS44	31	--	--	--	6.0	--	8.3	--	5.0	8.2
BS45	32	--	--	--	26	25	51	22	20	35
					Powdermill					
P46	48	270	160	1,100	4,100	4,500	4,400	2,200	2,300	5,000
P46	48Q	250	150	1,400	4,600	4,900	5,000	1,800	2,900	5,600
P47	49	270	120	590	3,100	4,100	3,700	1,800	2,700	3,800
P48	46A	--	--	--	--	--	--	--	--	--
P48	46B	--	13	38	700	740	680	320	280	730
P48	46C	140	300	730	7,400	8,400	6,800	5,800	2,600	7,200
P49	47	69	30	170	600	670	730	360	490	590
P50	52	7,500	780	81,000	120,000	74,000	82,000	25,000	38,000	10,000
P51	55	110	67	400	2,400	1,700	2,100	630	1,200	2,700
P52	53	2,800	--	8,600	15,000	13,000	9,300	8,200	5,200	14,000
P53	56	790	360	3,000	9,400	8,700	6,700	3,900	5,200	11,000
P54	54A	260	230	1,500	10,000	9,300	10,000	4,300	3,700	13,000
P54	54B	--	--	120	510	380	300	270	260	550
P54	54C	--	--	16	50	38	110	64	43	140
P55	51A	75	25	320	1,100	1,200	930	710	350	1,200
P55	51B	7.1	--	5.2	6.5	5.5	4.4	3.2	3.0	7.2
P55	51C	--	--	7.1	15	18	9.9	7.2	6.9	13
P56	50A	150	95	350	2,000	2,400	3,000	1,200	2,300	2,900
P56	50AQ	22	16	46	300	310	450	270	170	400
P56	50B	730	140	3,300	6,600	5,300	6,000	2,900	2,100	7,600
P56	50C	22	--	54	130	95	90	48	76	130
P57	57	--	--	2.0	11	14	21	10	12	20

Table 16. Concentrations of polycyclic aromatic hydrocarbons detected in sediment samples from six impoundments in the Assabet River Basin, Massachusetts, 2003.—Continued

[All values are in micrograms per kilogram. Minimum reporting level is 0.017 micrograms per kilogram. Data are rounded to two significant figures. **Map ID:** The identifier associated with a sampling site on a map (figs. 9–14). **Sample ID:** Identifier for a sample collected from a particular core, arranged alphabetically from the top of the core, with Q designating a replicate sample. Shaded numbers exceed sediment-quality guidelines (table 2). There are no guidelines for benzo[*b*]fluoranthene. PAH, polycyclic aromatic hydrocarbon; --, not detected]

Map ID	Sample ID	Dibenzo[*a,h*]-anthracene	Fluoran-thene	Fluorene	Indeno-[1,2,3-*cd*]-pyrene	Naphthalene	Phenanthrene	Pyrene	Total PAH
				Aluminum City					
AC1	5	28	570	60	100	16	390	650	3,300
AC2	7	27	530	35	110	25.0	270	710	3,200
AC3	6	31	490	37	100	26	220	490	2,700
AC4	8A	52	960	41	200	29	410	1,100	5,500
AC4	8B	16	300	22	68	22	150	320	1,700
AC4	8C	5.2	130	10	20	5.0	74	150	720
				Allen Street					
AS5	1	710	7,300	670	2,000	460	3,400	11,000	58,000
AS6	3	61	1,100	73	220	37	550	1,200	6,800
AS7	2A	140	2,700	150	520	75	1,700	3,300	16,000
AS7	2B	170	3,200	330	600	130	2,500	4,000	21,000
AS7	2C	36	700	36	130	55	440	920	4,500
AS8	4	64	1,300	86	250	55	970	1,700	8,200
				Hudson					
H9	9	--	24	--	9.6	--	30	24	190
H10	12	900	9,900	740	3,500	420	6,600	16,000	77,000
H10	12Q	900	11,000	610	3,200	370	6,100	13,000	70,000
H11	13	25	310	11	110	11	140	370	2,100
H12	11A	--	21	--	8.7	--	12	26	130
H12	11B	--	15	--	5.3	--	8.4	15	82
H13	14A	610	12,000	410	2,400	220	3,800	14,000	67,000
H13	14AQ	570	11,000	340	2,200	130	3,500	13,000	61,000
H13	14B	330	3,900	180	1,300	160	1,700	6,400	30,000
H13	14BQ	380	7,200	190	1,500	170	2,000	8,200	40,000
H13	14C	--	[1]18	--	--	--	13	[1]17	13
H13	14CQ	--	[1]46	--	--	--	40	[1]42	40
H14	10	--	17	--	4.2	--	11	14	82
H15	15	140	1,700	71	670	69	950	2,000	12,000
				Gleasondale					
G16	34	--	63	--	12	--	45	48	280
G17	39	45	460	29	130	20	290	650	3,200
G18	35A	620	14,000	1,000	4,200	690	9,700	20,000	99,000
G18	35B	470	12,000	720	2,800	380	7,800	16,000	75,000
G18	35C	55	1,700	76	340	100	1100	2,200	11,000
G19	40A	85	1,400	96	430	82	880	2,200	10,000
G19	40B	420	5,600	420	1,300	290	3,800	7,100	35,000
G19	40C	36	400	24	100	32	260	520	2,700
G19	40CQ	46	550	34	130	45	350	740	3,700
G20	36	--	37	--	--	--	20	40	180

Table 16. Concentrations of polycyclic aromatic hydrocarbons detected in sediment samples from six impoundments in the Assabet River Basin, Massachusetts, 2003.—Continued

[All values are in micrograms per kilogram. Minimum reporting level is 0.017 micrograms per kilogram. Data are rounded to two significant figures. **Map ID:** The identifier associated with a sampling site on a map (figs. 9–14). **Sample ID:** Identifier for a sample collected from a particular core, arranged alphabetically from the top of the core, with Q designating a replicate sample. Shaded numbers exceed sediment-quality guidelines (table 2). There are no guidelines for benzo[*b*]fluoranthene. PAH, polycyclic aromatic hydrocarbon; --, not detected]

Map ID	Sample ID	Dibenzo[*a,h*]-anthracene	Fluoran-thene	Fluorene	Indeno-[1,2,3-*cd*]-pyrene	Naphthalene	Phenanthrene	Pyrene	Total PAH
				Gleasondale—Continued					
G20	36Q	--	35	--	7.8	--	19	39	180
G21	44	23	260	10	74	7.10	120	320	1,800
G22	41	210	2,500	140	660	120	1,600	3,600	17,000
G23	37	18	330	15	95	15	190	530	2,400
G24	42	45	430	22	120	20	290	700	3,200
G25	45	15	140	5.7	46	5.98	54	220	1,000
G26	38	38	450	--	130	--	250	550	2,800
G27	43	47	420	21	120	17	190	500	2,800
				Ben Smith					
BS28	16	10	[1]87	--	34	--	37	[1]140	260
BS29	18	--	[1]110	--	43	--	69	[1]130	330
BS30	17A	360	4,100	230	1,600	150	2,600	6,300	31,000
BS30	17B	140	1,800	110	650	97	1,100	2,600	13,000
BS30	17C	--	[1]70	--	--	--	39	[1]44	39
BS31	19A	--	[1]25	--	28	--	--	--	90
BS31	19AQ	--	[1]16	--	--	--	14	[1]12	24
BS31	19B	--	390	--	140	--	280	650	2,900
BS31	19BQ	--	410	--	81	--	300	660	2,400
BS31	19C	280	3,500	220	1,300	200	2,100	5,400	26,000
BS31	19CQ	250	2,900	180	1,100	130	1,700	4,000	21,000
BS32	20A	80	910	46	390	--	570	1,300	7,300
BS32	20B	--	76	--	23	--	45	120	500
BS32	20C	--	27	--	--	--	13	22	150
BS33	21	130	780	37	350	--	430	820	5,800
BS34	22	90	600	31	280	35	350	1,100	5,200
BS35	23	--	160	--	60	--	100	280	1,200
BS36	27	--	--	--	--	--	--	15	110
BS37	29	--	13	--	--	--	12	15	89
BS38	26A	150	1,400	79	560	89	670	2,200	11,000
BS38	26B	13	69	11	35	9.59	64	150	700
BS38	26C	--	--	--	--	--	--	--	--
BS39	25	--	82	--	25	--	69	130	530
BS40	24	50	460	21	170	21	270	740	3,500
BS41	28	--	--	--	--	--	--	--	--
BS42	33	--	150	--	67	--	79	260	1,200
BS43	30A	--	1,300	--	560	--	770	2,000	9,600
BS43	30B	--	770	--	280	--	450	1,100	5,700
BS43	30C	--	19	--	--	--	13	17	70
BS44	31	--	--	--	--	--	5.88	12	45
BS45	32	--	47	--	20	--	21	67	330

Table 16. Concentrations of polycyclic aromatic hydrocarbons detected in sediment samples from six impoundments in the Assabet River Basin, Massachusetts, 2003.—Continued

[All values are in micrograms per kilogram. Minimum reporting level is 0.017 micrograms per kilogram. Data are rounded to two significant figures. **Map ID:** The identifier associated with a sampling site on a map (figs. 9–14). **Sample ID:** Identifier for a sample collected from a particular core, arranged alphabetically from the top of the core, with Q designating a replicate sample. Shaded numbers exceed sediment-quality guidelines (table 2). There are no guidelines for benzo[*b*]fluoranthene. PAH, polycyclic aromatic hydrocarbon; --, not detected]

Map ID	Sample ID	Dibenzo[*a,h*]-anthracene	Fluoran-thene	Fluorene	Indeno-[1,2,3-*cd*]-pyrene	Naphthalene	Phenanthrene	Pyrene	Total PAH
					Powdermill				
P46	48	580	6,100	350	1,800	710	3,000	11,000	48,000
P46	48Q	470	6,500	360	1,600	700	3,300	10,000	50,000
P47	49	480	5,500	310	1,600	350	3,800	7,800	40,000
P48	46A	--	3.4	--	--	--	--	3.8	7.2
P48	46B	71	300	10	240	16	110	940	5,200
P48	46C	1,200	5,900	260	4,200	550	3,000	11,000	65,000
P49	47	92	1,100	84	310	78	770	1,600	7,700
P50	52	10,000	200,000	18,000	29,000	1,300	150,000	210,000	1,100,000
P51	55	140	2,900	140	540	200	700	4,700	21,000
P52	53	1,600	20,000	3,500	5,400	2,200	29,000	40,000	180,000
P53	56	1,100	12,000	1,100	320	920	9,200	22,000	96,000
P54	54A	930	12,000	500	3,500	590	5,700	23,000	99,000
P54	54B	--	700	--	180	--	560	1,500	5,300
P54	54C	--	210	--	22	--	74	460	1,200
P55	51A	130	1,500	67	460	70	550	3,600	12,000
P55	51B	--	11	--	--	3.5	12	25	94
P55	51C	--	17	--	5.3	--	15	29	140
P56	50A	310	4,100	210	1,100	260	2,200	6,900	29,000
P56	50AQ	54	550	29	220	29	290	810	4,000
P56	50B	580	10,000	1,000	2,100	1,200	9,700	19,000	78,000
P56	50C	9.6	150	20	30	11	180	480	1,500
P57	57	--	25	--	9.3	--	12	26	160

[1]Indicates suspected laboratory contamination

Table 17. Water-quality data collected during study of phosphorus dynamics in the Hudson, Massachusetts, impoundment, 2003.

[cm, centimeter; m, meter; mg/L, milligram per liter; µS/cm, microsiemens per centimeter; °C, degrees Celsius; --, no data]

Date	Time	Depth (m)	Specific conductance (µS/cm)	pH	Temperature (°C)	Dissolved oxygen (mg/L)	Chloride (mg/L)	Total phosphorus (mg/L)	Ortho-phosphorus (mg/L)	Remarks
Station 17										
7-16-03	9:00	0.00	594	6.86	21.8	6.4	--	0.1010	0.051	
7-16-03		.50	594	6.83	21.8	6.4	--	--	--	
7-16-03	9:10	1.00	594	6.83	21.8	6.4	--	.1081	.051	
7-16-03		1.50	594	6.82	21.8	6.4	--	--	--	
7-16-03		1.60	594	6.81	21.8	6.3	--	--	--	
7-24-03	8:40	.00	514	--	22.0	4.1	118.02	.1451	.075	
7-24-03		.50	515	--	22.0	4.1	--	--	--	
7-24-03		1.00	515	--	22.0	4.1	--	--	--	
7-24-03	8:50	1.50	515	--	22.0	4.1	--	.1582	.077	
7-24-03		1.80	515	--	22.0	4.1	--	--	--	
7-29-03	8:50	.00	601	--	23.3	6.4	142.44	.0846	.054	
7-29-03		.50	601	--	23.3	5.7	--	--	--	
7-29-03		1.00	600	--	23.3	5.8	--	--	--	
7-29-03	9:00	1.50	600	--	23.3	5.8	--	.0861	.055	
7-29-03		1.80	601	--	23.3	5.7	--	--	--	
8-07-03	9:10	.00	485	6.42	23.2	3.8	109.64	.1523	.109	
8-07-03	9:11		--	--	--	--	109.37	.1526	.108	Replicate
8-07-03		.50	486	6.44	23.2	3.8	--	--	--	
8-07-03		1.00	486	6.45	23.2	3.8	--	--	--	
8-07-03	9:20	1.50	486	6.47	23.2	3.7	--	.1498	.109	
8-07-03		1.80	486	6.47	23.2	3.7	--	--	--	
8-13-03	9:40	.00	500	6.56	23.9	4.6	111.83	.1365	.095	
8-13-03	9:55	.50	499	6.62	23.9	4.2	.2	.002	.001	
8-13-03		1.00	499	6.62	23.9	4.2	--	--	--	
8-13-03		1.50	499	6.65	23.9	4.0	--	--	--	
8-21-03	9:25	.00	528	6.57	21.7	6.2	122.15	.1056	.075	
8-21-03		.50	525	6.6	22.8	5.6	--	--	--	
8-21-03		1.00	522	6.63	22.8	5.4	--	--	--	
8-21-03	9:35	1.40	523	6.64	22.8	5.3		.1068	.076	
8-28-03	9:40	.00	687	6.4	21.5	5.4	162.2	.0821	.055	
8-28-03		.50	687	6.43	21.6	5.2	--	--	--	
8-28-03		1.00	687	6.51	21.5	5.1	--	--	--	
8-28-03	9:50	1.50	687	6.56	21.5	5.1		.1283	.055	
9-08-03	9:00	.00	631	6.48	19.4	6.6	146.58	.0823	.046	
9-08-03		.50	631	6.49	19.4	6.6	--	--	--	
9-08-03		1.00	631	6.5	19.4	6.6	--	--	--	
9-08-03	9:20	1.50	631	6.5	19.4	6.6	--	.4200	.047	
9-08-03	9:21		--	--	--	--	<.2	.0029	.000	Blank
9-08-03		1.70	631	6.5	19.4	6.5	--	--	--	

Table 17. Water-quality data collected during study of phosphorus dynamics in the Hudson, Massachusetts, impoundment, 2003.—Continued

[cm, centimeter; m, meter; mg/L, milligram per liter; µS/cm, microsiemens per centimeter; °C, degrees Celsius; --, no data]

Date	Time	Depth (m)	Specific conductance (µS/cm)	pH	Temperature (°C)	Dissolved oxygen (mg/L)	Chloride (mg/L)	Total phosphorus (mg/L)	Orthophosphorus (mg/L)	Remarks
Station 20										
7-16-03	9:45	0.00	578	7.53	22.5	7.1	--	0.1044	0.040	
7-16-03		.50	578	7.57	22.5	7.0	--	--	--	
7-16-03	9:55	.70	583	6.92	22.5	7.0	--	.2800	.060	
7-16-03	10:00	[1]-.05	--	--	--	--	--	2.3350	.383	
7-24-03	9:15	.00	576	--	22.1	3.0	137.17	.0750	.033	
7-24-03		.50	574	--	22.7	2.3	--	--	--	
7-24-03	9:25	.70	602	--	22.5	.7	--	.2550	.054	
7-24-03	9:35	[1]-.05	--	--		--	--	7.0770	5.016	
7-29-03	9:20	.00	529	--	23.9	9.9	128.64	.0764	.049	
7-29-03	9:30	.50	527	--	23.5	5.5	--	.2200	.108	
7-29-03	9:40	.80	590	--	23.1	.4	--	3.1220	1.153	
7-29-03	9:50	[1]-.05	--	--	--	--	--	1.2210	.873	
8-07-03	10:00	.00	470	6.63	24.0	3.4	107.41	.1006	.070	
8-07-03	10:10	.50	473	6.49	23.6	1.3	--	.1524	.096	
8-07-03	10:20	.90	537	6.41	23.0	.2	--	.3130	.135	
8-07-03	10:30	[1]-.05	--	--	--	--	--	2.1320	1.153	
8-13-03	10:25	.00	485	6.91	25.6	6.4	110.8	.0717	.053	
8-13-03		.50	501	6.68	24.6	1.8	--	--	--	
8-13-03	10:35	.70	505	6.64	24.4	1.5	--	.1731	.126	
8-13-03	10:45	[1]-.05	--	--	--	--	--	.9490	.716	
8-21-03	10:00	.00	501	6.73	24.0	4.1	118.2	.0969	.057	
8-21-03	10:10	.50	499	6.51	23.1	2.0	--	.1507	.088	
8-21-03	10:15	.70	516	6.29	22.8	.3	--	.8120	.713	
8-21-03	10:20	[1]-.05	--	--	--	--	--	2.1320	.605	
8-28-03	10:15	.00	562	6.94	21.8	5.7	128.18	.0569	.037	
8-28-03		.50	567	6.73	21.1	3.2	--	--	--	
8-28-03	10:25	.70	567	6.66	21.1	2.6	--	.3350	.061	
8-28-03	10:35	[1]-.05	--	--	--	--	--	.7740	.145	
9-08-03	10:00	.00	602	6.78	19.8	8.4	139.43	.0562	.023	
9-08-03	10:10	.50	604	6.52	19.4	4.4	139.41	.2140	.047	
9-08-03	10:20	.85	631	6.36	19.0	.6	--	1.1150	.093	
9-08-03	10:30	[1]-.05	--	--	--	--	--	.9120	.296	
9-08-03	10:31	[1]-.05	--	--	--	--	--	.9400	.292	
Station 27										
7-16-03	10:35	0.00	600	7.9	22.7	7.2	--	0.0968	0.036	
7-16-03		.50	595	7.72	22.6	7.1	--	--	--	
7-16-03	10:45	1.00	572	5.62	22.2	6.7	--	.1213	.049	
7-16-03		1.10	571	5.08	22.2	6.6	--	--	--	
7-16-03	10:55	[1]-.05	--	--	--	--	--	1.2060	.310	

Table 17. Water-quality data collected during study of phosphorus dynamics in the Hudson, Massachusetts, impoundment, 2003.—Continued

[cm, centimeter; m, meter; mg/L, milligram per liter; µS/cm, microsiemens per centimeter; °C, degrees Celsius; --, no data]

Date	Time	Depth (m)	Specific conductance (µS/cm)	pH	Temperature (°C)	Dissolved oxygen (mg/L)	Chloride (mg/L)	Total phosphorus (mg/L)	Ortho-phosphorus (mg/L)	Remarks
Station 27—Continued										
7-24-03	10:00	0.00	609	--	22.9	7.0	147.49	0.1204	0.031	
7-24-03		.50	601	--	22.8	7.0	--	--	--	
7-24-03	10:05	1.00	638	--	22.3	2.5	--	.1713	.057	
7-24-03		1.20	638	--	22.2	.3	--	--	--	
7-29-03	10:10	.00	571	--	24.4	7.7	136.3	.1280	.076	
7-29-03		.50	576	--	24.0	7.7	--	--	--	
7-29-03	10:20	1.00	552	--	23.6	5.3	--	.2570	.155	
7-29-03		1.20	571	--	23.5	.8	--	--	--	
7-29-03	10:30	[1]-.05	--	--	--	--		1.2980	.446	
8-07-03	10:40	.00	491	6.63	24.4	5.6	111.71	.1380	.095	
8-07-03		.50	515	6.61	24.0	5.4	--	--	--	
8-07-03	10:50	1.00	585	6.45	23.4	2.3	--	.1133	.072	
8-07-03		1.30	565	6.42	23.0	1.5	--	--	--	
8-07-03	11:00	[1]-.05	--	--	--	--	--	.5470	.216	
8-07-03	11:01	[1]-.05	--	--	--	--	--	.3630	.236	Replicate
8-13-03	11:00	.00	501	6.7	25.1	4.4	118.29	.1369	.085	
8-13-03	11:10	.50	510	6.7	24.6	3.4	--	.0899	.066	
8-13-03		1.00	544	6.71	23.6	3.1	--	--	--	
8-13-03	11:20	[1]-.05	--	--	--	--	--	.9030	.371	
8-21-03	10:50	.00	483	6.59	23.8	5.9	120.12	.1166	.082	
8-21-03		.50	491	6.44	23.1	3.5	--	--	--	
8-21-03	11:00	1.00	487	6.29	22.7	1.3	--	.2010	.128	
8-21-03		1.50	514	6.31	22.5	.3	--	--	--	
8-21-03	11:10	[1]-.05	--	--	--	--	--	.6480	.368	
8-28-03	10:50	.00	575	7.08	22.3	6.9	133.7	.1032	.047	
8-28-03		.50	559	6.93	21.5	5.2	--	--	--	
8-28-03		1.00	565	6.8	21.3	5.0	--	--	--	
8-28-03	11:00	1.20	--	--	--	--	--	.3900	.295	
8-28-03	11:10	[1]-.05	--	--	--	--	--	.6540	.323	
9-08-03	11:15	.00	610	6.84	20.5	8.9	143.02	.0747	.030	
9-08-03		.50	613	6.73	20.2	8.3	--	--	--	
9-08-03	11:25	1.00	621	6.62	19.9	7.0	--	.1136	.038	
9-08-03		1.10	620	6.6	20.0	6.4	--	--	--	
9-08-03	11:35	[1]-.05	--	--	--	--	--	.6110	.237	
Station 29										
7-16-03	11:10	0.00	602	8.2	22.7	7.1	--	0.0720	0.028	
7-16-03		.50	601	8.38	22.7	7.1	--	--	--	
7-16-03	11:20	1.00	604	5.45	22.4	6.8	--	.2650	.027	
7-16-03		1.20	606	4.34	22.2	6.7	--	--	--	
7-16-03	11:30	[1]-.05	--	--	--	--	--	1.2090	.267	

Table 17. Water-quality data collected during study of phosphorus dynamics in the Hudson, Massachusetts, impoundment, 2003.—Continued

[cm, centimeter; m, meter; mg/L, milligram per liter; µS/cm, microsiemens per centimeter; °C, degrees Celsius; --, no data]

Date	Time	Depth (m)	Specific conductance (µS/cm)	pH	Temperature (°C)	Dissolved oxygen (mg/L)	Chloride (mg/L)	Total phosphorus (mg/L)	Ortho-phosphorus (mg/L)	Remarks
Station 29—Continued										
7-24-03	10:48		--	--	--	--	0.2	0.0040	0.005	Blank
7-24-03	11:00	0.00	535	--	22.7	8.0	127.26	.1100	.044	
7-24-03		.50	528	--	22.4	5.8	--	--	--	
7-24-03	11:10	1.00	527	--	22.2	4.3	--	.3130	.071	
7-24-03		1.10	848	--	22.0	.2	--	--	--	
7-29-03	10:50	.00	593	--	26.1	12.1	142.29	.0770	.049	
7-29-03		.50	599	--	24.3	5.5	--	--	--	
7-29-03	11:00	1.00	604	--	24.1	4.3	--	.2070	.075	
7-29-03		1.20	642	--	24.0	.4	--	--	--	
7-29-03	11:10	[1]-.05	--	--		--		1.4460	.222	
8-07-03	11:20	.00	485	6.59	24.2	5.6	109.23	.1446	.101	
8-07-03		.50	487	6.53	23.8	4.9	--	--	--	
8-07-03	11:30	1.00	487	6.55	23.7	4.7	--	.1494	.123	
8-07-03		1.30	496	6.54	23.6	3.4	--	--	--	
8-07-03	11:40	[1]-.05	--	--	--	--	--	.9550	.578	
8-13-03	11:40	.00	504	6.72	25.6	5.8	116.28	.1279	.090	
8-13-03		.50	508	6.78	24.4	5.4	--	--	--	
8-13-03	11:50	.90	513	6.81	24.2	4.9	--	.1405	.092	
8-13-03	12:00	[1]-.05	--	--	--	--	--	1.9810	.811	
8-21-03	12:10	.00	499	7.11	24.8	8.7	121	.1601	--	
8-21-03		.50	492	6.86	23.6	7.4	--	--	.065	
8-21-03	12:20	1.00	494	6.67	23.3	6.2	--	.1657	.085	
8-21-03		1.30	626	6.27	23.0	.2	--	--	--	
8-21-03	12:30	[1]-.05	--	--	--	--	--	1.1860	.659	
8-28-03	11:35	.00	653	7.16	22.9	7.1	150.21	.0806	.039	
8-28-03		.50	649	7.13	22.5	6.7	--	--	--	
8-28-03	11:45	1.00	637	7.01	22.1	5.7	--	.7290	.039	
8-28-03		1.20	637	6.95	22.0	5.1	--			
8-28-03	11:55	[1]-.05	--	--	--	--	--	1.5830	.271	
9-08-03	12:00	.00	619	7.36	22.1	10.5	142.26	.0927	.039	
9-08-03		.50	610	6.9	20.3	9.0	--	--	--	
9-08-03	12:10	1.00	608	6.81	20.0	8.5	--	.1421	.039	
9-08-03		1.10	608	6071	20.0	7.7	--	--	--	
9-08-03	12:20	[1]-.05	--	--	--	--	--	.3550	.208	
Station 37										
7-16-03	12:00	0.00	600	7.43	22.6	6.9	--	0.0990	0.042	
7-16-03		.50	602	7.41	22.5	6.9	--	--	--	
7-16-03	12:05	1.00	606	7.14	22.4	6.9	--	.0993	.044	
7-16-03		1.50	608	6.84	22.2	6.9	--	--	--	
7-16-03	12:10	2.00	608	6.45	22.0	6.8	--	.1122	.050	

Table 17. Water-quality data collected during study of phosphorus dynamics in the Hudson, Massachusetts, impoundment, 2003.—Continued

[cm, centimeter; m, meter; mg/L, milligram per liter; µS/cm, microsiemens per centimeter; °C, degrees Celsius; --, no data]

Date	Time	Depth (m)	Specific conductance (µS/cm)	pH	Temperature (°C)	Dissolved oxygen (mg/L)	Chloride (mg/L)	Total phosphorus (mg/L)	Ortho-phosphorus (mg/L)	Remarks
Station 37—Continued										
7-16-03		2.50	607	6.22	22.0	6.8	--	--	--	
7-16-03	12:15	3.00	607	6.13	22.0	6.8	--	0.2930	0.052	
7-24-03	11:50	.00	529	--	22.4	4.1	121.72	.1372	.070	
7-24-03		.50	531	--	22.5	4.2	--	--	--	
7-24-03	12:00	1.00	531	--	22.4	4.2	--	.1378	.070	
7-24-03		1.50	529	--	22.3	4.0	--	--	--	
7-24-03	12:05	2.00	528	--	22.3	3.9	--	.1395	.072	
7-24-03		2.50	528	--	22.2	3.9	--	--	--	
7-24-03	12:10	3.00	527	--	22.2	3.9	--	.1411	.073	
7-24-03		3.20	527	--	22.2	3.9	--	--	--	
7-29-03	11:30	.00	601	--	25.4	7.2	141.89	.0911	.055	
7-29-03		.50	602	--	24.9	6.9	--	--	--	
7-29-03		1.00	602	--	24.4	6.6	--	--	--	
7-29-03		1.50	599	--	24.2	6.2	--	--	--	
7-29-03	11:40	2.00	600	--	24.1	6.2	--	.0906	.059	
7-29-03		2.50	601	--	24.1	6.1	--	--	--	
7-29-03	11:50	3.00	601	--	24.0	5.9	--	.1000	--	
8-07-03	12:00	.00	483	6.32	24.8	5.4	108.93	.1520	.107	
8-07-03		.50	484	6.3	24.3	4.8	--	--	--	
8-07-03		1.00	486	6.19	23.9	4.2	--	--	--	
8-07-03		1.50	486	6.24	23.8	4.0	--	--	--	
8-07-03	12:10	2.00	487	6.26	23.6	3.8	--	.1554	.109	
8-07-03		2.50	487	6.26	23.6	3.8	--	--	--	
8-07-03	12:20	3.00	488	6.31	23.6	3.8	111.38	.1553	.109	
8-13-03	12:30	.00	506	6.71	25.3	5.4	115.66	.1407	.094	
8-13-03		.50	504	6.73	25.2	4.9	--	--	--	
8-13-03		1.00	505	6.74	24.7	4.9	--	--	--	
8-13-03		1.50	506	6.74	24.4	4.6	--	--	--	
8-13-03	12:40	2.00	506	6.73	24.4	4.1	--	.1423	.095	
8-13-03		2.50	550	6.72	24.4	4.1	--	--	--	
8-13-03	12:50	3.00	506	6.72	24.3	3.9	114.08	.1456	.095	
8-21-03	12:45	.00	497	6.79	25.1	6.8	120.69	.1038	.070	
8-21-03		.50	497	6.77	25.1	6.7	--	--	--	
8-21-03		1.00	493	6.7	23.9	6.2	--	--	--	
8-21-03		1.50	491	6.64	23.4	5.7	--	--	--	
8-21-03		2.00	491	6.61	23.3	5.5	--	--	--	
8-21-03		2.50	490	6.59	23.2	5.4	--	--	--	
8-21-03	13:00	3.00	490	6.59	23.2	5.3	--	.1316	.079	
8-28-03	12:10	.00	656	7.03	22.8	6.1	150.53	.0867	.053	
8-28-03		.50	659	6.99	22.6	5.8	--	--	--	

Table 17. Water-quality data collected during study of phosphorus dynamics in the Hudson, Massachusetts, impoundment, 2003.—Continued

[cm, centimeter; m, meter; mg/L, milligram per liter; µS/cm, microsiemens per centimeter; °C, degrees Celsius; --, no data]

Date	Time	Depth (m)	Specific conductance (µS/cm)	pH	Temperature (°C)	Dissolved oxygen (mg/L)	Chloride (mg/L)	Total phosphorus (mg/L)	Ortho-phosphorus (mg/L)	Remarks
Station 37—Continued										
8-28-03		1.00	656	6.97	22.5	5.9	--	--	--	
8-28-03		1.50	652	6.95	22.3	5.9	--	--	--	
8-28-03	12:20	2.00	644	6.93	22.1	5.6	--	0.0963	0.055	
8-28-03		2.50	644	6.91	22.0	5.6	--	--	--	
8-28-03	12:30	3.00	644	6.89	22.0	5.3	--	.1059	.056	
9-08-03	12:45	.00	--	--	--	--	<0.2	.0037	.003	Blank
9-08-03	12:50	.00	623	6.76	21.2	8.0	143.79	.0805	.044	
9-08-03		.50	623	6.7	20.2	7.4	--	--	--	
9-08-03		1.00	623	6.67	20.1	7.0	--	--	--	
9-08-03		1.50	625	6.65	19.9	7.0	--	--	--	
9-08-03	13:00	2.00	628	6.64	19.8	6.8	--	.0883	.047	
9-08-03		2.50	627	6.63	19.8	6.5	--	--	--	
9-08-03	13:10	3.00	626	6.63	19.8	6.7	--	.0907	.048	

[1]-0.05, sample of pore water collected from 5 cm below sediment surface.

For additional information write to:

Director,

USGS Massachusetts–Rhode Island Water Science Center
10 Bearfoot Road
Northborough, MA 01532

or visit our Web site at
http://ma.water.usgs.gov