Sediment Quality in the North Coastal Basin of Massachusetts, 2003

By Robert F. Breault, Mary S. Ashman, and Douglas Heath

In cooperation with the
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Contents

Figures

Tables

Conversion Factors, Datums, Sediment-Quality Units, and Abbreviations

Multiply	By	To obtain
foot (ft.)	0.3048	meter (m)
inch (in.)	2.54	centimeter (cm)
inch (in.)	25,400	micrometer (µm)
square mile (mi^2)	2.590	square kilometer (km^2)

Concentrations of sediment-quality constituents are give in percent (%), parts per million (ppm), and parts per billion (ppb).

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

ACEC	Area of Critical Environmental Concern
DDD	dichlorodiphenyldichloroethane
DDE	dichlorodiphenyldichloroethylene
DDT	dichlorodiphenyltrichloroethane
EOEA	Executive Office of Environmental Affairs
EPH	extractable petroleum hydrocarbons
HSSR	Hydrogeochemical and Stream Sediment Reconnaissance
HCl	hydrochloric acid
ICP	inductively coupled plasma
MDEP	Massachusetts Department of Environmental Protection
MDL	method detection limit
mL	milliliter
mg/L	milligram per liter
MRL	minimum reporting level
NAQWA	National Water-Quality Assessment Program
NETLAB	New England Testing Laboratory
NGS	National Geochemical Survey
NURE	National Uranium Resource Evaluation
PAH	polyaromatic hydrocarbon
PEC	probable effects concentration
PES	performance evaluation sample
PCB	polychlorinated biphenyl
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
Σ	sum

Sediment Quality in the North Coastal Basin of Massachusetts, 2003

By Robert F. Breault[1], Mary S. Ashman[1], and Douglas Heath[2]

Abstract

The U.S. Geological Survey, in cooperation with the Massachusetts Department of Environmental Protection, completed a reconnaissance-level study of bottom-sediment quality in selected lakes, rivers, and estuaries in the North Coastal Basin of Massachusetts. Bottom-sediment grab samples were collected from 20 sites in the North River, Lake Quannapowitt, Saugus River, Mill River, Shute Brook, Sea Plane Basin, Pines River, and Bear Creek. The samples were tested for various types of potentially harmful contaminants—including 33 elements, 17 polyaromatic hydrocarbons (PAHs), 22 organochlorine pesticides, and 7 polychlorinated biphenyl (PCB) mixtures (Aroclors)—to benthic organisms (bottom-dwelling) and humans. The results were compared among sampling sites, to background concentrations, and to concentrations measured in other urban rivers, and sediment-quality guidelines were used to predict toxicity at the sampling sites to benthic organisms and humans. Because there are no standards for human toxicity for aquatic sediment, standards for contaminated upland soil were used.

Contaminant concentrations measured in sediment collected from the North Coastal Basin generally were equal to or greater than concentrations in sediment from uncontaminated rivers throughout New England. Contaminants in North Coastal Basin sediment with elevated concentrations (above background levels) included arsenic, chromium, copper, lead, nickel, and zinc, some of the PAHs, dichlorodiphenyltrichloroethane (DDT) and its metabolites, and dieldrin. No PCBs were measured above the detection limits. Measured concentrations of arsenic, chromium, and lead were also generally greater than those measured in other urban rivers throughout the conterminous United States. With one exception (arsenic), local concentrations measured in sediment samples collected from the North Coastal Basin were lower than concentrations measured in sediment collected from two of three urban rivers draining to Boston Harbor.

The probable toxicity to benthic organisms ranged from about 33 to 91 percent across the study area. Of the elements analyzed, antimony, arsenic, beryllium, and lead exceeded the soil standards for risk to human health. Of the PAHs analyzed, four also exceeded soil standards. Organochlorine pesticide concentrations, however, were not high enough relative to the soil standards to pose a risk to human health. Some trace element and some organic compound concentrations in bottom sediment may be toxic to aquatic organisms and may pose a risk to human health.

[1]U.S. Geological Survey.

[2]U.S. Environmental Protection Agency.

Introduction

Coastal Massachusetts watersheds are known for their rocky coastlines, small tidal rivers and estuaries, and picturesque coastal communities. These coastal communities are also known for their long industrial histories. Contaminants from past and present activities that have washed downstream from coastal cities and towns often end up in rivers and estuaries (Breault and Granato, 2000; Breault and others, 2002; Lopes and Dionne, 1998). River and estuarine water continuously interact with the bottom sediment. After contaminants are discharged into the water column, most adhere to fine particles of suspended sediment, are carried downstream or swept inland by tides, and eventually are deposited with the bottom sediment.

Physical or chemical processes—for example, entrainment, resuspension, or chemical and biological transformation—can cause these contaminants to reenter the water column (Baudo and Muntau, 1990; Sly, 1994). Therefore, the chemistry of the river water and that of the sediments are linked. Sediment contamination, a type of non-point-source contamination, can affect a large area over a long period. In historically industrial and urbanized areas, these contaminants typically include elements and various types of anthropogenic (human related) organic compounds.

Contaminated sediment may also directly cause adverse biological effects to benthic (bottom-dwelling) organisms and indirectly affect swimming organisms. Consumption of these contaminated organisms can pose a health risk to organisms higher on the food web, such as predatory fish, terrestrial wildlife, and humans. Direct contact with or accidental ingestion of contaminated sediments may also pose a health risk to humans.

One watershed containing contaminated sediment, the North Coastal Basin (fig. 1) north of metropolitan Boston, has an area of about 168 mi^2 and is home to more than 500,000 people (Executive Office of Environmental Affairs, 2003). The area includes parts of the towns of Revere, Lynn, Lynnfield, Peabody, Saugus, Salem, and Wakefield, and the drainage basins of various small tidal rivers and estuaries, including the Saugus, Mill, North, and Pines Rivers, Shute Brook, and Bear Creek. Also within the area is the Rumney Marsh Reservation, a State-designated Area of Critical Environmental Concern (ACEC). The marsh consists of over 1,000 acres of saltmarsh, tidal mud flats, and tidal creeks. The U.S. Department of Fish and Wildlife considers the marsh to be "one of the most biologically significant estuaries in Massachusetts north of Boston" (Massachusetts Department of Environmental Management, 2000). Although the many rivers, estuaries, marshes, and lakes in the area do not constitute a single continuous drainage basin, for the purposes of this report, the area is referred to as the North Coastal Basin.

The North Coastal Basin is typical of watersheds in Coastal Massachusetts. For example, the Saugus Iron Works, which operated on the Saugus River from 1646 through 1668 (National Park Service, 2003), is one of the oldest industrial sites in the Nation. Environmental managers are concerned that this industrial past and more recent urban sprawl may have degraded environmental quality in the North Coastal watersheds.

In the North Coastal Basin, efforts are currently (2004) underway to assess bottom-sediment quality in the area's rivers, lakes, and estuaries, which support wetlands, swimming beaches, public-water supply, shellfish beds, and lobster fisheries (DeCesare and others, 2000). As part of these efforts, the U.S. Geological Survey (USGS) completed this study of bottom-sediment quality in the North Coastal Basin in 2003 in cooperation with the Massachusetts Department of Environmental Protection (MDEP).

Purpose and Scope

This report discusses detections and concentrations of elements and three types of organic compounds in the bottom sediments of selected rivers, lakes, and estuaries of the North Coastal Basin's drainage basins. Samples of sediment were collected at 20 stations in the North Coastal Basin by sediment grab samplers. These concentrations are evaluated through comparison to background concentrations and to contaminant concentrations in other urban rivers. The report also discusses the potential adverse effects posed by contaminants to benthic organisms and humans by comparing the contaminant concentrations with sediment-quality guidelines and exposure-based soil standards. The results presented in this report represent a reconnaissance-level investigation of sediment-quality data of the North Coastal Basin of Massachusetts. It is not a comprehensive study of sediment quality that definitively would measure the quality of North Coastal Basin sediment.

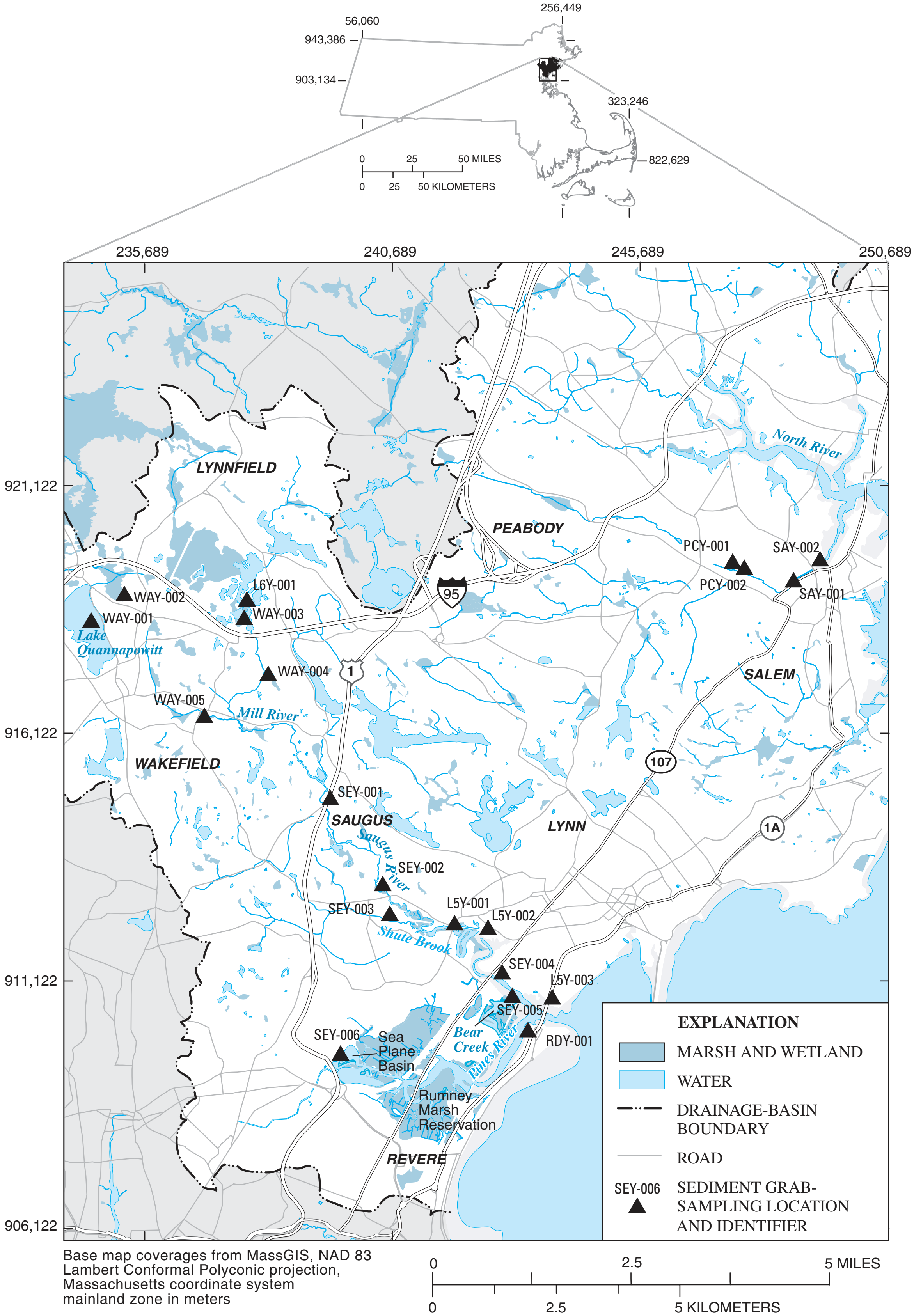

Figure 1. North Coastal Basin sediment-grab sampling locations, Massachusetts.

Previous Investigations

In the past 5 years, various investigations have focused extensively on sediment quality of Lake Quannapowitt in Wakefield. As much as 11 ft of organic and clastic deposits lie in the center of the lake (Heath, 2001a). On March 11, 1985, Camp, Dresser, & McKee, Inc., collected a mid-lake, composite sample of Lake Quannapowitt sediment as part of a diagnostic and feasibility study on the lake's eutrophic condition. Analyses were completed for elements such as cadmium, chromium, copper, iron, lead, manganese, and zinc; and for total nitrogen, total phosphorus and total carbon. Arsenic was not tested (Camp, Dresser, & McKee, Inc., 1986). On September 9, 1999, Metcalf & Eddy, Inc., on behalf of the Town of Wakefield, collected three shallow-sediment samples in the southwestern cove of the lake in an investigation of coal-tar waste contamination from a coal-gasification plant, which operated from 1859 to 1926. Analyses were completed for 13 priority-pollutant metals, oil, grease, polyaromatic hydrocarbons (PAHs), extractable petroleum hydrocarbons (EPH), and total phosphorus (Metcalf & Eddy, Inc., 1999). In September 2000, the Massachusetts Executive Office of Environmental Affairs (EOEA) and The Friends of Lake Quannapowitt, a local lake-monitoring group, collected 10 sediment samples by Ekman dredge throughout the lake. Analyses were completed for arsenic, lead, PAHs and semivolatile organic compounds. Arsenic concentrations ranged from 95 to 225 parts per million (ppm) and lead concentrations from 164 to 800 ppm (Lawrence Gill, Massachusetts Executive Office of Environmental Affairs, written commun., 2000). In January 2001, the Friends of Lake Quannapowitt collected a 2.6-ft-long core of sediment through the ice at mid-lake. Analyses were completed in discrete core sections for total phosphorus, lead, copper, and arsenic, and provided a historical profile of contaminant variability over time. A small leaf found at the core bottom was carbon-14 dated at about 2,500 years ago; its age indicates an average sediment-accretion rate of about 1 ft per 1,000 years (Heath, 2001b). In April 2000, the MDEP ordered the Town of Wakefield to study contaminated sediment, soil, and ground water in the vicinity of the former coal-gasification plant (Weston & Sampson Engineers, Inc., written commun., 2002). The studies currently (2004) continue. In 2002, Lattanzi (2003) measured arsenic concentrations in water and sediment in nine ponds in eastern Massachusetts, including Lake Quannapowitt and Pillings Pond in Lynnfield, both upstream of Reedy Meadows. Lattanzi (2003) reports an average sediment arsenic concentration in these water bodies of 151 and 75 ppm, respectively, as a result of arsenical herbicides applied in the early 1960s.

Study Methods

Twenty sample locations were determined in consultation with the MDEP, Salem Sound Coastwatch, and the Saugus River Watershed Council on the basis of each locations estimated potential for contamination. In June 2003, samples of more recently deposited sediment (the top 2–4 in. of sediment), referred to as grab samples, were collected from the North River, Lake Quannapowitt (the headwaters of the Saugus River), Saugus River, Mill River, Shute Brook, and the tidal creeks of the Rumney Marshes—Sea Plane Basin, Pines River, and Bear Creek (fig. 1). The samples were analyzed for grain-size distribution, elements, and three types of organic compounds.

Sample Collection

A stainless-steel Ekman dredge was used to collect sediment grab samples in water deeper than about 5 ft. In water less than about 5 ft deep, a stainless-steel scoop was used to collect sediment grab samples. Any water trapped in either the dredge or the scoop was decanted after most of the fine particles settled. The top 2–4 in. of the sample not in contact with the dredge or scoop was removed with a pre-cleaned Teflon spoon. Exposed mud flats (samples collected at low tide) were sampled by using a pre-cleaned Teflon spoon to scrape off the top 2–4 in. of sediment from the surface. At least three samples were collected at each sampling location to characterize conditions at the site (Baudo and Mantau, 1990). Samples were placed on ice in pre-cleaned disposable Teflon bags and transported to the USGS office in Northborough, MA. In the USGS laboratory, the sediment was homogenized with a Teflon spoon. Subsamples were placed in pre-cleaned containers for delivery to the appropriate laboratory for analysis.

Teflon bags were pre-cleaned by rinsing with methanol, 5-percent hydrochloric acid (HCl), and copious amounts of deionized water, in that order. At the sampling sites, all sediment-sampling equipment was cleaned between samplings by scrubbing with a nylon brush and phosphate-free detergent, rinsing with methanol, copious amounts of deionized water, and finally, native water from the sampling sites. After the methanol rinse, the Teflon spoon was rinsed additionally with 5-percent hydrochloric acid (HCl).

Chemical Analysis

Sediment samples were analyzed for a suite of elements and organic compounds commonly found in rivers that drain historically industrial and urban coastal watersheds. The XRAL Laboratory of Ontario, Canada, analyzed the sediment samples for the elements. Inductively coupled plasma (ICP) emission spectroscopy was the analysis method used for elements (table 1). The New England Testing Laboratory (NETLAB) of North Providence, Rhode Island, analyzed sediment samples for the organic compounds. These compounds included polychlorinated biphenyls (PCBs) and organochlorine pesticides, which were analyzed by gas chromatography with electron-capture detection, and PAHs, which were analyzed by gas chromatography with mass spectrometry (table 3, at back of report). Grain-size distributions were measured by the USGS sediment laboratory in Louisville, Kentucky (table 2).

Table 1. Inorganic element concentrations measured in sediment-grab samples collected from the North Coastal Basin, Massachusetts.

[D, field duplicate; LD, laboratory duplicate; ppm, parts per million; %, percent; <, less than value shown]

Station name	Station number	Calcium (%)	Magnesium (%)	Sodium (%)	Potassium (%)	Phosphorus (%)	Aluminum (%)	Antimony (ppm)	Arsenic (ppm)	Barium (ppm)	Beryllium (ppm)	Bismuth (ppm)
North River at Caller Street	PCY-001	0.47	0.44	0.06	0.14	0.06	0.99	10	9	85	0.5	<5
North River at Howley Street	PCY-002	.56	.5	.07	.14	.06	1.09	<5	7	68	.6	<5
North River at Commercial Street	SAY-001	.59	.71	.29	.2	.07	1.45	<5	38	50	.6	<5
North River at Conduit	SAY-002	.58	.72	.89	.29	.12	1.39	11	26	114	.8	<5
Lake Quannapowitt	WAY-001	.59	.34	.17	.15	.12	1.35	<5	154	95	.7	<5
Saugus River at Vernon Street	WAY-002	.64	.36	.07	.14	.2	1.23	<5	51	161	.8	<5
Central Reedy Meadow	L6Y-001	.8	.94	.1	.12	.09	1.35	<5	25	89	.8	<5
Reedy Meadow Pond	WAY-003	1.31	.36	.1	.05	.09	.49	<5	33	89	<.5	<5
Saugus River at Sunset Drive	WAY-004	.32	.51	.04	.07	.06	.72	<5	11	43	<.5	<5
Mill River at Farm Street	WAY-005	.56	.46	.07	.13	.09	1.13	<5	16	86	.7	<5
Saugus River at Route 1	SEY-001	.24	.24	.05	.09	.03	.58	<5	<3	42	<.5	<5
Saugus River at Iron Works	SEY-002	.36	.44	.06	.14	.04	.82	<5	6	37	<.5	<5
Shute Brook at Cemetery	SEY-003	.24	.24	.04	.12	.04	.68	<5	<3	46	<.5	<5
Saugus River at Boston Street	L5Y-001	1.51	.79	.87	.51	.11	1.95	<5	12	76	1	<5
Saugus River at Strawberry Brook	L5Y-002	.42	.67	.83	.41	.09	1.53	<5	16	88	.9	<5
Saugus River at Route 107	SEY-004	.53	.71	.88	.46	.08	1.6	<5	8	86	.8	<5
Bear Creek	SEY-005	.42	.75	1.32	.48	.09	1.6	<5	10	62	.8	<5
Sea Plane Basin	SEY-006	.51	1.03	1.49	.76	.12	2.58	<5	16	91	1.3	<5
Pine River at Gibson Field	RDY-001	.36	.29	.28	.16	.03	.71	<5	<3	25	<.5	<5
Saugus River at Route 1A	L5Y-003	.36	.41	.53	.23	.05	.86	<5	<3	33	<.5	<5
Shute Brook at Cemetery	SEY-003-D	.25	.25	.05	.12	.05	.7	<5	4	52	<.5	<5
Sea Plane Basin	SEY-006-D	.54	1.06	1.51	.79	.12	2.67	<5	16	95	1.3	<5
North River at Commercial Street	SAY-001-LD	.62	.72	.3	.21	.07	1.52	<5	41	51	.8	<5
Saugus River at Iron Works	SEY-002-LD	.39	.45	.07	.15	.04	.87	<5	6	39	<.5	<5

Table 1. Inorganic element concentrations measured in sediment-grab samples collected from the North Coastal Basin, Massachusetts.—Continued

[D, field duplicate; LD, laboratory duplicate; ppm, parts per million; %, percent; <, less than value shown]

Station name	Station number	Cadmium (ppm)	Chromium (ppm)	Cobalt (ppm)	Copper (ppm)	Iron (%)	Lanthanum (ppm)	Lead (ppm)	Lithium (ppm)	Manganese (ppm)	Mercury (ppm)	Molyb-denum (ppm)
North River at Caller Street	PCY-001	1	935	7	43.9	2.21	14.3	174	14	776	<1	4
North River at Howley Street	PCY-002	<1	310	9	34.7	2.46	15.8	240	15	533	<1	4
North River at Commercial Street	SAY-001	<1	351	8	63.2	2.65	18.5	107	27	340	1	3
North River at Conduit	SAY-002	2	966	11	136	2.69	18.7	339	27	289	<1	5
Lake Quannapowitt	WAY-001	2	162	10	502	2.46	19.1	459	19	1,050	2	4
Saugus River at Vernon Street	WAY-002	4	172	14	75.5	2.91	18.6	688	18	519	1	4
Central Reedy Meadow	L6Y-001	<1	309	17	43.1	2.55	11.8	78	26	557	<1	4
Reedy Meadow Pond	WAY-003	<1	95	9	29.9	1.5	6.3	101	5	700	1	3
Saugus River at Sunset Drive	WAY-004	<1	182	7	14.4	1.53	10.5	80	12	271	<1	2
Mill River at Farm Street	WAY-005	3	275	16	148	2.89	16.5	413	18	509	<1	7
Saugus River at Route 1	SEY-001	<1	305	4	12	.92	9.1	28	9	290	<1	3
Saugus River at Iron Works	SEY-002	<1	252	7	21.6	1.43	13.3	38	13	322	<1	3
Shute Brook at Cemetery	SEY-003	<1	266	4	20.9	1.46	11.4	97	9	307	<1	3
Saugus River at Boston Street	L5Y-001	1	268	11	88.7	2.83	21.4	142	34	303	<1	4
Saugus River at Strawberry Brook	L5Y-002	2	255	9	121	2.44	20	208	29	238	<1	4
Saugus River at Route 107	SEY-004	<1	268	8	57.1	2.5	20.9	114	29	266	<1	3
Bear Creek	SEY-005	<1	199	8	53	2.23	18.7	91	30	240	<1	5
Sea Plane Basin	SEY-006	<1	241	10	74.1	3.39	25.5	117	49	317	<1	4
Pine River at Gibson Field	RDY-001	<1	227	3	11.8	1.1	11.7	19	12	167	<1	3
Saugus River at Route 1A	L5Y-003	<1	153	4	22.7	1.26	13.4	74	18	145	<1	3
Shute Brook at Cemetery	SEY-003-D	<1	208	5	24.1	1.54	12.4	115	10	368	<1	2
Sea Plane Basin	SEY-006-D	<1	219	10	69.1	3.5	26.1	121	51	329	<1	4
North River at Commercial Street	SAY-001-LD	<1	361	8	69.9	2.69	19.4	109	28	349	<1	2
Saugus River at Iron Works	SEY-002-LD	<1	256	7	21	1.48	14.5	39	13	331	<1	3

Table 1. Inorganic element concentrations measured in sediment-grab samples collected from the North Coastal Basin, Massachusetts.—Continued

[D, field duplicate; LD, laboratory duplicate; ppm, parts per million; %, percent; <, less than value shown]

Station name	Station number	Nickel (ppm)	Scandium (ppm)	Silver (ppm)	Strontium (ppm)	Tin (ppm)	Titanium (%)	Tungsten (ppm)	Vanadium (ppm)	Yttrium (ppm)	Zinc (ppm)	Zirconium (ppm)
North River at Caller Street	PCY-001	28	2.8	0.4	40.5	<10	0.07	<10	35	8.5	228	8.9
North River at Howley Street	PCY-002	27	3.2	.3	49.1	<10	.08	<10	47	8.7	129	8.5
North River at Commercial Street	SAY-001	19	4.1	.5	56.4	<10	.08	<10	50	11	253	10.8
North River at Conduit	SAY-002	33	3.6	1.3	69.7	<10	.06	<10	57	11.1	347	11.9
Lake Quannapowitt	WAY-001	33	3.3	.7	31.8	<10	.06	<10	73	10.9	352	5.8
Saugus River at Vernon Street	WAY-002	28	2.9	.4	36.5	<10	.04	<10	86	11.4	380	5.1
Central Reedy Meadow	L6Y-001	155	4.6	.4	38.4	<10	.09	<10	51	9.5	148	6.1
Reedy Meadow Pond	WAY-003	68	1.3	.3	70	<10	.02	<10	29	5.3	182	2.3
Saugus River at Sunset Drive	WAY-004	49	2.1	.3	17	<10	.05	<10	27	7.1	77	3.8
Mill River at Farm Street	WAY-005	42	2.7	3	34.4	13	.07	<10	46	9.7	554	5.9
Saugus River at Route 1	SEY-001	23	1.4	<.2	15.8	<10	.05	<10	14	5	68.9	3.7
Saugus River at Iron Works	SEY-002	27	2.4	.2	23	<10	.08	<10	25	8.8	138	6.9
Shute Brook at Cemetery	SEY-003	18	1.6	.5	19	<10	.05	<10	22	6.1	121	5.7
Saugus River at Boston Street	L5Y-001	32	4.8	1.1	93.3	<10	.09	<10	56	13.1	235	10.9
Saugus River at Strawberry Brook	L5Y-002	32	4	1.2	46.5	19	.08	<10	51	11.3	286	9.6
Saugus River at Route 107	SEY-004	30	4	.9	44	<10	.08	<10	51	11.7	162	9.5
Bear Creek	SEY-005	25	4	1.2	41.2	<10	.09	<10	54	10.9	140	9.9
Sea Plane Basin	SEY-006	30	6.3	1.1	56.8	<10	.12	<10	68	14.7	190	13.1
Pine River at Gibson Field	RDY-001	12	1.8	.3	27.2	<10	.06	<10	20	6.6	35.7	7.3
Saugus River at Route 1A	L5Y-003	15	2.2	.2	28.8	<10	.06	<10	28	7.5	71.1	6.1
Shute Brook at Cemetery	SEY-003-D	17	1.6	.3	19.4	<10	.05	<10	23	6.4	131	5.7
Sea Plane Basin	SEY-006-D	30	6.5	1.1	60.5	<10	.12	<10	71	14.9	194	13.6
North River at Commercial Street	SAY-001-LD	19	4.3	.6	58.8	<10	.09	<10	51	11.4	253	11.1
Saugus River at Iron Works	SEY-002-LD	27	2.6	.2	25.3	<10	.08	<10	26	9.5	139	7.7

Table 2. Grain-size distribution measured in sediment-grab samples collected from the North Coastal Basin, Massachusetts.

[Grain-size distribution given as percent retained. **Granule:** Greater than 2 millimeters. **Medium sand:** Less than 2 millimeters, greater than 0.25 millimeter. **Fine sand:** Less than 0.25 millimeter, greater than 0.15 millimeter. **Very fine sand:** Less than 0.15 millimeter, greater than 0.062 millimeter. **Silt and clay:** Less than 0.062 millimeter]

Station name	Station number	Granule	Sand			Silt and clay
			Medium	Fine	Very fine	
North River at Caller Street	PCY-001	17.05	72.35	4.24	3.20	3.20
North River at Howley Street	PCY-002	13.05	74.56	7.49	2.59	2.30
North River at Commercial Street	SAY-001	69.11	14.19	4.34	3.88	8.50
North River at Conduit	SAY-002	2.34	25.60	19.63	14.58	37.80
Lake Quannapowitt	WAY-001	.00	.00	.10	55.14	44.80
Saugus River at Vernon Street	WAY-002	2.11	9.57	14.86	19.85	53.60
Central Reedy Meadow	L6Y-001	7.00	27.18	7.51	7.67	50.60
Reedy Meadow Pond	WAY-003	27.08	33.11	2.45	.34	37.00
Saugus River at Sunset Drive	WAY-004	2.56	13.37	25.44	39.04	19.60
Mill River at Farm Street	WAY-005	9.08	31.60	9.99	8.88	40.50
Saugus River at Route 1	SEY-001	.83	55.59	21.24	12.84	9.50
Saugus River at Iron Works	SEY-002	13.96	24.34	32.84	15.29	13.60
Shute Brook at Cemetery	SEY-003	1.37	63.21	22.93	7.57	4.90
Saugus River at Boston Street	L5Y-001	.29	4.96	4.20	10.74	79.80
Saugus River at Strawberry Brook	L5Y-002	1.09	12.64	21.30	11.81	53.20
Saugus River at Route 107	SEY-004	7.25	18.83	8.02	13.19	52.70
Bear Creek	SEY-005	5.90	3.30	2.52	9.95	78.30
Sea Plane Basin	SEY-006	2.09	.63	.16	3.79	93.30
Pine River at Gibson Field	RDY-001	13.63	3.54	31.83	41.56	9.40
Saugus River at Route 1A	L5Y-003	.25	7.08	17.16	45.68	29.80

Data Analysis

A variety of statistical methods was used to analyze sediment-quality data. Particular attention was given to censored data, concentrations less than a detection limit. In instances where constituent concentrations were summed, censored data were set to zero, with two exceptions: (1) all values to be summed were censored, and (2) censored data were used to calculate the probable effect concentration (PEC) quotient. In these cases, (1) censored data were substituted with the reported detection limit, and (2) censored data were set to one-half the reported detection limit. Finally, censored data (including summed censored data) can not be compared to guidelines, standards, or other measures of sediment quality, if they are less than the detection limit or the sum of detection limits for the data. In these cases, data from that sample or station were omitted from the data analysis.

Bias and Variability

Sediment-quality data are subject to bias (systematic error) and variability (random error) during sample collection, processing, and analysis. The nature and magnitude of bias and variability can be determined by analysis of different types of quality-control samples, which include laboratory blanks, field duplicates, laboratory duplicates, matrix spikes, matrix-spike duplicates, and performance-evaluation samples (PES; tables 1, and 3). With a few exceptions, bias and variability of sediment-quality data collected during this study were within acceptable limits (Arthur Screpetis, Massachusetts Department of Environmental Protection, written commun., 2003).

Sediment Quality

Local environmental managers in coastal communities assess the quality of their coastal waters. These assessments are used to determine whether specific current and possible future uses of these waters are feasible, as indicated by environmental data; to identify desirable uses of the coastal areas; and to translate these uses into scientifically measurable goals that can serve as the basis for water-resource management (Howarth and others, 2003). Determining the bottom-sediment quality is an important first step in the assessment of coastal waters. Researchers determine sediment quality by comparing the sediment-quality data to a prescribed sediment-management objective. These objectives can be based on goals for water use and on the relation of contaminant concentrations to their potential for adverse biological effect. For example, the objective might be to maintain the present quality of the sediment or to restore contaminant concentrations to the level of background concentrations (those concentrations not affected by anthropogenic activities), to the levels of other urban rivers, or to a level safe enough for specific designated uses (for example, swimming or boating). Comparisons of the contaminant concentrations in North Coastal Basin sediments among sediment-sampling locations to background concentrations, to concentrations from other urban rivers, and to sediment-quality guidelines will help local water-resource managers determine how to evaluate their coastal-river sediments.

Sediment Quality at Sediment-Grab Sampling Locations

Concentrations of the 33 elements are shown in table 1 by sampling location. The elements most often present in concentrations greater than 1,000 ppm are considered major elements: these include calcium, iron, manganese, phosphorus, aluminum, potassium, sodium, titanium, and carbon. Concentrations of all of these elements vary greatly in the sediment samples collected, but this variation is not unexpected because samples were collected at freshwater, estuarine, and saltwater environments.

Conversely, trace elements are those elements that typically occur in concentrations less than 1,000 ppm in uncontaminated sediment. Because of the toxicity of the elements, the U.S. Environmental Protection Agency (USEPA) has classified some of these trace elements as priority pollutants (U.S. Environmental Protection Agency, 2002). These trace elements include antimony, arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, thallium, and zinc. In this study, chromium, copper, lead, nickel, and zinc were detected in every sample. Concentrations greater than the detection limit of silver, arsenic, beryllium, cadmium, mercury, and antimony were measured in 95, 80, 65, 35, 20, and 10 percent of the samples tested, respectively. Selenium and thallium were not tested in this study.

The greatest concentrations of both antimony (11 ppm) and chromium (966 ppm) were measured in sediment collected from the North River at the North River Conduit (SAY-002). In fact, antimony was detected at only one other site (10 ppm), which was also on the North River (North River at Caller Street, PCY-001). Arsenic (154 ppm), copper (502 ppm), and mercury (2.0 ppm) concentrations were greatest in sediment collected from Lake Quannapowitt (WAY-001, fig. 2). Because of the history of herbicide usage in the lake, and because arsenic and copper are commonly major ingredients of herbicides, these concentrations are not unexpected. Silver (3.0 ppm) and zinc (554 ppm) concentrations measured in sediment collected from site WAY-005 (Mill River at Farm Street, fig. 2) were greater than concentrations measured in sediment collected from the other sites; nickel (155 ppm) concentration was greatest in sediment collected from Central Reedy Meadow (L6Y-001); lead (688 ppm) and cadmium (4.0 ppm) concentrations were greatest in sediment collected from the Saugus River at Vernon Street (WAY-002); and beryllium (1.3 ppm) concentration was greatest in sediment collected from Sea Plane Basin (SEY-006).

The trace element detections in many of the sediment samples were not unexpected because (1) trace elements in bottom sediment may be derived naturally from the weathering of rocks, or (2) human activities can introduce them into the environment. For example, after railroad construction in Wakefield in 1845, numerous manufacturers flourished in the Saugus River watershed, and they discharged industrial waste in nearby streams over many decades (Massachusetts State Board of Health, 1909; Peterson, 1948; Heath, 2003). To determine whether or not the detected elements can be attributed to human activities, however, measured bottom-sediment trace element concentrations must be compared to concentrations that approximate those that could be expected in the absence of humans, otherwise known as background concentrations.

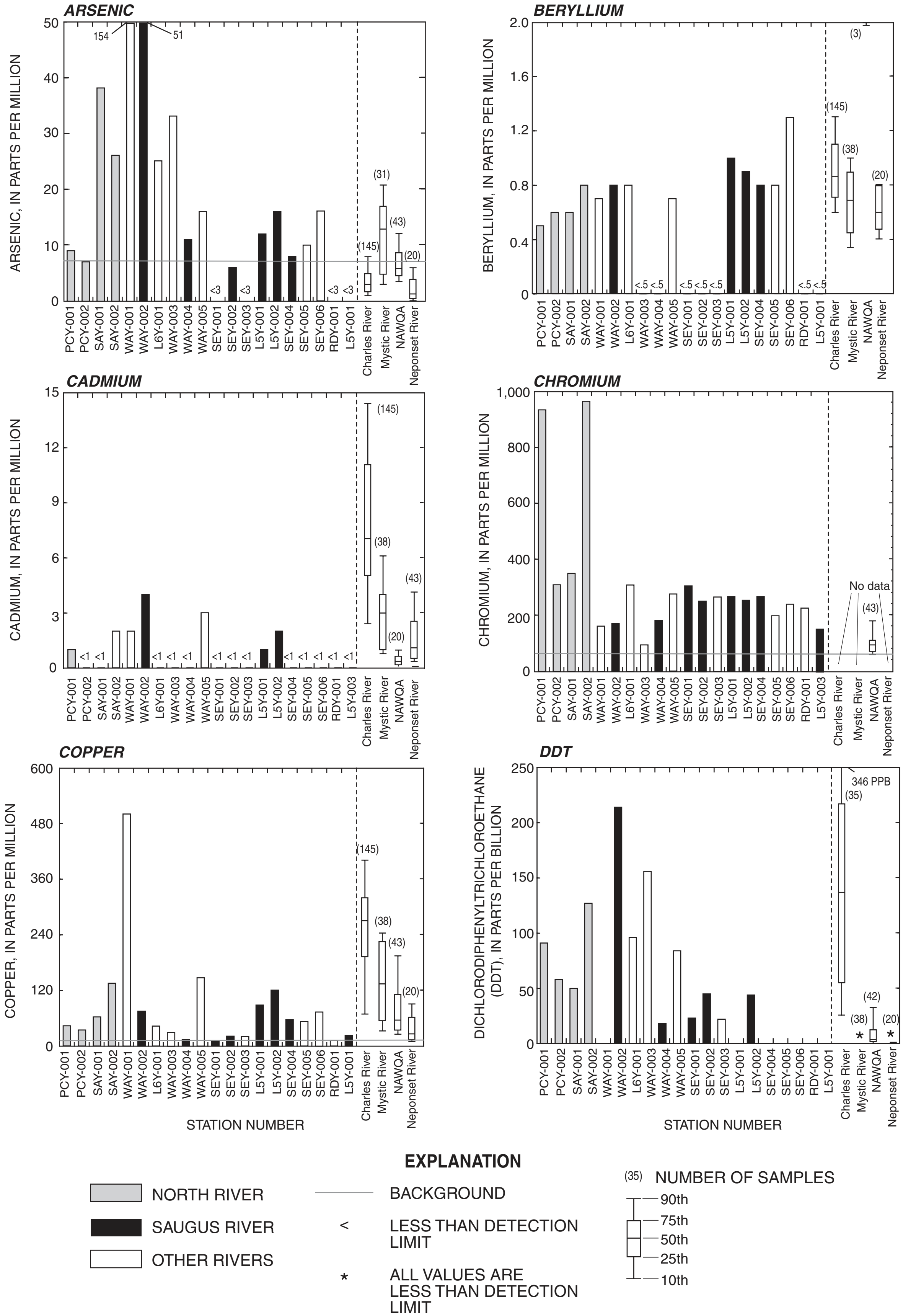

Figure 2. Concentrations of selected contaminants in bottom sediment collected from the North Coastal Basin and from other urban rivers, Massachusetts. (NAWQA, National Water Quality Assessment Program.)

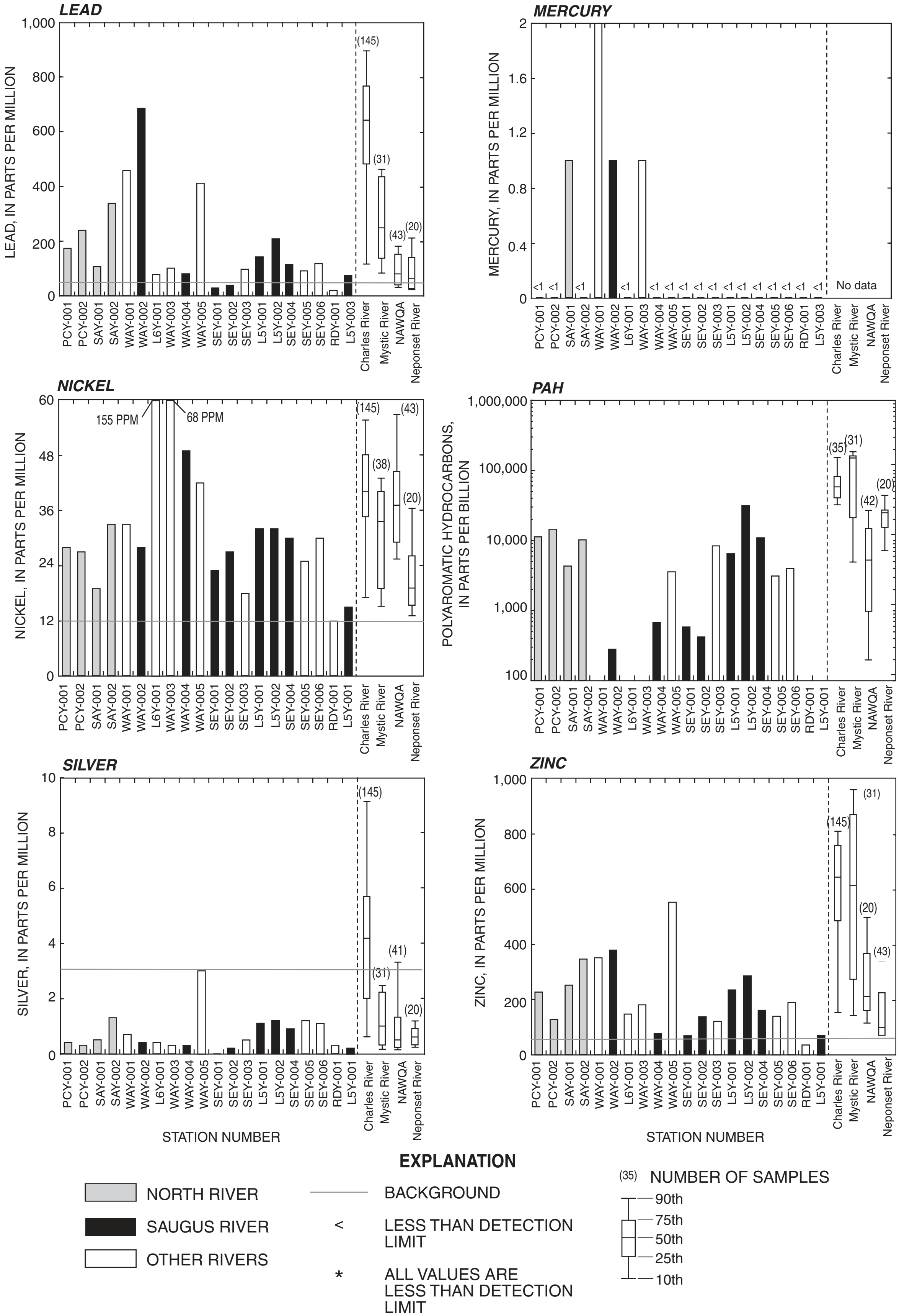

Figure 2—Continued. Concentrations of selected contaminants in bottom sediment collected from the North Coastal Basin and from other urban rivers, Massachusetts. (NAWQA, National Water Quality Assessment Program.)

Concentrations of the 46 organic compounds are shown by site in table 3. These organic compounds comprise three major groups: PAHs, organochlorine pesticides, and PCBs. These groups contain constituents on the USEPA's priority pollutant list (U.S. Environmental Protection Agency, 2002). Group concentrations are expressed as the sum (Σ) of concentrations of various related compounds; ΣPAH, for example, is the sum of all detectable PAHs (with the exception of calculating the PEC quotient); ΣDDT is the sum of detectable concentrations of DDT, DDD, and DDE; and ΣPCBs is the sum of the nine Aroclors or mixtures of commercially produced PCBs.

Sixteen of the PAHs were detected at the sampling sites. Of the samples from locations where organic compounds were detected, the Saugus River at Strawberry Brook (L5Y-002) had the highest ΣPAH concentration (about 31,000 ppb). Many PAHs were also detected in samples from locations in the North River (fig. 2; table 3). Dichlorodiphenyltrichloroethane (commonly referred to as DDT), an insecticide banned in the United States in 1973, or one of its metabolites (DDD and DDE) was detected in many of the samples. ΣDDT concentration was greatest (about 210 ppb) in the samples collected at site WAY-002 (Saugus River at Vernon Street, fig. 1); however, the sediment sample collected from Lake Quannapowitt (WAY-001) may have a ΣDDT concentration of equal or greater magnitude (estimated ΣDDT concentration equal to less than 537 ppb). With the exception of DDT, DDD, DDE, and two detections of dieldrin (an insecticide banned in 1985), no other organochlorine pesticides were detected. Of the Aroclors tested, none were detected in any of the samples collected.

Detections of PAHs and DDT and its metabolites in the North Coastal Basin are not unexpected. Because of vehicular use, PAHs are ubiquitous in urban environments (Van Metre and others, 2000). Organochlorine insecticides like DDT, despite being banned for over 30 years, persist and are still commonly detected in urban environments.

It is important to note that a detection indicates only that the constituent concentration is greater than the minimum reporting level (MRL) for a given analytical technique. A non-detection, however, can indicate two possibilities: (1) the constituent is not in the sample, or (2) the constituent is in the sample at a concentration less than the MRL. Nondetection of a constituent, therefore, does not unequivocally indicate the absence of that constituent. This result can profoundly affect data analysis. For example, sediment samples collected from Lake Quannapowitt (WAY-001), Central Reedy Meadow (L6Y-001), and Reedy Meadow Pond (WAY-003), were such that organic analysis of these samples resulted in relatively high MRLs when compared to the other samples; organic compound data from these sampling stations, therefore, are of limited use. Finally, relatively high PCB MRLs compared to the method detection limit (MDL) at all sampling stations also limits interpretation of PCB data.

Effects of Human Activities on Sediment Quality

Selected trace element concentrations (the priority pollutants) measured in sediment samples from the 20 sites were compared to median concentrations measured in sediment samples collected from uncontaminated rivers in Connecticut, Maine, Massachusetts, New Hampshire, New York, and Rhode Island. These sediment samples were collected between 1977 and 1980 as part of the National Uranium Resource Evaluation (NURE) program, specifically the Hydrogeochemical and Stream Sediment Reconnaissance (HSSR) Program (Smith, 1998), and reanalyzed with modern (2000) methods by the National Geochemical Survey (NGS; Grossman, 1998; U.S. Geological Survey, 2003). The USGS MDL computer program was used to calculate summary statistics for NURE HSSR data when concentrations were below the detection limit (Helsel and Cohn, 1998).

The NURE HSSR program's standard operating procedure instructed researchers to collect bottom-sediment samples from small uncontaminated streams (Ferguson and others 1977). In other words, samples were purposely collected in areas assumed to be unaffected by humans; therefore, element concentrations measured from these sediment samples may approximate non-urban background concentrations of New England streams.

The samples collected during the NURE HSSR Program and the samples collected in this study were processed with different methods (Ferguson and others 1977). The NURE HSSR samples were sieved with a 150-micrometer sieve; however, samples collected in this study were not sieved. This difference in methods could artificially bias concentrations high because fine-grained sediments have much larger surface area per unit weight than coarser sediments; contaminants typically adhere to sediment in proportion with surface area (Horowitz, 1991). The samples collected during the NURE HSSR Program and the samples collected in this study were also analyzed with different methods (Ferguson and others 1977). The methods used by the NURE HSSR Program included a more robust digestion than that used in this study. A more robust digestion probably also gives the NURE HSSR Program trace element data a high bias.

Selected trace element concentrations in North Coastal Basin samples (excluding antimony, cadmium, and mercury, for which NURE provided no chemical background data) were generally greater than background concentrations (fig. 2). Concentrations of arsenic, chromium, copper, lead, nickel, or zinc were greater than background at 70 percent or more of the sites. In fact, concentrations of all of these constituents were greater than background concentrations at 14 sampling sites. There were no measured concentrations of beryllium or silver that were greater than background concentrations. Comparisons to background concentrations indicate that human activities may have caused high concentrations of arsenic, chromium, copper, lead, nickel, and zinc at nearly every sampling location in the North Coastal Basin.

Many natural processes can cause bottom sediments to be enriched with trace elements. Some of these processes include differential weathering (related to solubilities of individual elements), physical fractionation (for example, the removal of fine particles by wind and water), chemical fractionation, deposition of enriched atmospheric dust, and biogenic dust (Reimann and De Caritat, 2000). Researchers may erroneously conclude that enrichment is caused by human activity, when it may actually be caused by these natural processes. Nonetheless, enrichment factors might serve as a good first approximation to determine how human activities affect sediment quality.

In contrast to the natural occurrence of trace elements in bottom sediments, many organic compounds are in sediment only as a result of human activities. PAHs can occur naturally, but usually not in high concentrations in bottom sediment (Massachusetts Department of Environmental Protection, 2002). Accordingly, the contamination of sediment by PAHs and many other organic compounds can be attributed to human activities.

Comparison of North Coastal Basin Sediment Quality to that of Other Urban Rivers

It is unlikely that sediment from urban environments will be free of trace elements or organic compounds produced by human activities, and it may be unrealistic to expect the sediment quality from urban areas to be similar to background sediment quality. A more achievable sediment-management objective might be restoring sediment trace element and organic compound concentrations to levels equal to or below levels measured in other urban rivers.

In accordance with the objective described above, measured concentrations of the selected trace elements (with the exception of mercury) and organic compounds were compared with concentrations of these constituents collected from other urban rivers throughout the conterminous United States as part of the National Water-Quality Assessment (NAWQA) Program of the USGS (Rice, 1999). Like the NURE HSSR sediment samples, samples collected by the NAWQA Program for analysis of trace metals and organic compounds were sieved through a 63-micrometer sieve and a 2-mm sieve, respectively. The procedure used by the NAWQA Program, however, includes a more robust digestion than that used in this study. A more robust digestion probably also gives the NAWQA trace element data a high bias.

Some concentrations for the selected trace elements (arsenic, beryllium, cadmium, chromium, copper, lead, nickel, silver, or zinc) were greater than the median concentrations for those elements measured in sediment collected by the USGS NAWQA Program at about one-half of the sample locations (fig. 2). Specifically, arsenic, chromium, or lead concentrations were greater than the NAWQA median concentrations for these elements at 80 percent of the sites. Concentrations of the other selected trace elements were also greater than the NAWQA median concentrations at some of the sites (about 40 percent each), with one exception. Beryllium concentrations from the North Coastal Basin were less than the median NAWQA beryllium concentration at all of the sites.

Concentrations of organic compounds measured at many of the sites were less than the median concentrations of those compounds measured in sediment collected by the USGS NAWQA Program, with a few exceptions. Concentrations of ΣDDT in samples collected from 13 of the sampling sites were greater than the NAWQA median ΣDDT concentration. Seven sites, however, had samples with ΣDDT detection limits that were greater than the NAWQA median concentration. The concentration of ΣDDT measured in sediment collected from the Saugus River at Vernon Street (WAY-002) was more than twice the maximum concentration of ΣDDT measured in sediment collected from other urban rivers, or about 50 times the median concentration for the other urban rivers (fig. 2). Again, sediment collected from Lake Quannapowitt (WAY-001) may have a ΣDDT concentration of equal or greater magnitude (estimated ΣDDT concentration equal to less than 537 ppb).

Concentrations of some of the individual PAHs were greater than their corresponding median NAWQA concentrations at a few sites. At seven of the sites from the North Coastal Basin, ΣPAH concentrations were greater than the median NAWQA ΣPAH concentration. Three other sediment samples from the North Coastal Basin had ΣPAH MRLs greater than the NAWQA ΣPAH median. The maximum ΣPAH concentration (Saugus River at Strawberry Brook) was about six times the NAWQA median (fig. 2).

A comparison of measured contaminant concentrations in the North Coastal Basin with those of other urban rivers from across the United States is useful for assessing sediment quality in the North Coastal Basin, but a better comparison might be between concentrations in the North Coastal Basin and other urban rivers in Massachusetts. Better yet, a comparison of concentrations in the basin with those of other coastal Massachusetts rivers would be the most valuable. Summary statistics of selected element and organic compound concentrations in bottom sediment collected from the Upper Mystic, Lower Charles, and Neponset Rivers, three urban tributaries to Boston Harbor just south of the North Coastal Basins (Breault and Harris 1997, Breault and others 2000, 2004, and R.F. Breault, U.S. Geological Survey, unpublished data, 2004), demonstrate the quality of North Coastal sediments in relation to those of these other coastal rivers (fig. 2).

Concentrations of the selected trace elements (chromium and mercury were not included in the comparison to other coastal rivers because data for these elements from the other rivers were not available) and organic compounds in sediment from the North Coastal Basin sites were less than or equal to concentrations measured in sediment collected from the Lower Charles River and the Upper Mystic River, and were greater than concentrations from the Neponset River (fig. 2). There are, however, some exceptions: (1) arsenic concentrations from 16 of the 20 sites in the North Coastal Basin were greater than the median arsenic concentration measured in the Lower Charles River; (2) silver concentrations at 12 sites were less than the median value from samples collected from the Neponset River; (3) ΣDDT concentrations at 11 of the sites were greater than the median ΣDDT concentration measured in samples from the Upper Mystic River—the total of ΣDDT detection limits was greater than the median ΣDDT concentration at 6 other sites; and (4) ΣPAH concentrations were lower at all but 1 of the sites in the North Coastal Basin (Saugus River at Strawberry Brook) when compared to the median ΣPAH concentrations in sediment from the Neponset River (excluding Lake Quannapowitt, where ΣPAH was equal to less than 27,200 ppb).

Toxicity of Bottom Sediments

For a lake, river, or estuary to be fishable and swimmable, its sediment must pose little health risk to organisms that live in it or contact it. In this study, contaminant concentrations were compared to sediment-quality guidelines and to exposure-based soil standards to assess the potential health risks posed by the North Coastal Basin sediments to bottom-dwelling organisms and to humans.

Benthic Organisms

One way to assess whether a lake, river, or estuary can support a healthy and diverse population of fish is to test the health of their food source, particularly benthic organisms. Benthic organisms (for example, amphipods, mussels, and worms), upon which some fish feed, are those organisms that live and feed on the river bottom. These organisms can come in direct contact with contaminated sediment. Contaminants can accumulate in the tissues of these organisms as they ingest contaminated sediment or they can sorb the contaminants directly from sediment and water (Forstner and Whittmann, 1979). Eventually, the accumulation of these contaminants in the tissues of benthic organisms can cause toxicity and death to the organisms. Subsequent ingestion of contaminated benthic organisms by fish and other organisms that are higher on the food web can cause adverse health effects.

The potential toxicity of North Coastal Basin sediment to benthic organisms can be estimated by comparing measured contaminant concentrations to a set of sediment-quality guidelines known as probable-effect concentrations (PECs). Concentrations above the PECs are known to cause toxicity because of their effect on the survival or growth of laboratory test organisms, such as the amphipod *Hyalella azteca* and the insect larva *Chironomus spp.* (Ingersoll and others, 2000). The predicted potential for toxicity depends on the organism and the test conditions. First, a measured contaminant concentration is divided by its corresponding PEC to yield a PEC quotient:

$$\overline{Q}_x = \frac{\sum \frac{C_{x,y}}{PEC_y}}{n_x}, \qquad (1)$$

where
$\overline{Q}_x$ is equal to the average PEC quotient for sample x;
$C_{x,y}$ is equal to the concentration of contaminant type y in sample x;
PEC_y is equal to the PEC for contaminant y (Ingersoll and others, 2000); and
n_x is equal to the number of contaminant types available for sample x (n equals 1-9).

In this study, the PEC quotients for nine types of contaminants were computed and then averaged for each sample (equation 1). Contaminant types are the ΣPAHs: 2-methylnaphthalene, acenaphthylene, acenaphthene, dibenzo(a,h)anthracene, anthracene, benzo(a)anthracene, benzo(a)pyrene, chrysene, fluoranthene, fluorene, naphthalene, phenanthrene, and pyrene; DDE; and arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), nickel (Ni), and zinc (Zn).

Finally, the average PEC quotients are compared to PEC-quotient ranges associated with different toxicity potentials (Ingersoll and others, 2000). Potential toxicity of ΣPCBs could not be assessed because summed MRLs were greater than the PEC for ΣPCBs.

The potential for toxicity was determined for the top 2–4 in. of bottom sediment, which can be considered the biologically active sediment layer (Baudo and Muntau, 1990). The potentials for toxicity by test organism (*Hyalella azteca* and *Chironomus spp.*) and test condition (10- to 14-day test and 28- to 42-day test) are shown in figure 3 for each site. The potential for toxicity in figure 3 refers to the potential for toxicity compared to a control or reference sediment (Ingersoll and others, 2000). For example, a sediment sample with an estimated potential toxicity of 20 percent means that 20 out of 100 toxicity tests are likely to show some level of toxicity for the concentration of contaminants measured in that sediment sample for a particular organism and a particular set of test conditions.

The predicted potential for toxicity of North Coastal Basin sediment, regardless of test or organism, ranged from about 33 percent to over 91 percent among the sampling locations (fig. 3). The largest average PEC quotients for all contaminants and contaminant groups were calculated for samples taken from Lake Quannapowitt (WAY-001) and the North River at the North River Conduit (SAY-002). Arsenic and chromium accounted for about 31 and 52 percent of the average PEC quotient at these sites (with one-half the detection limit used for censored data), respectively.

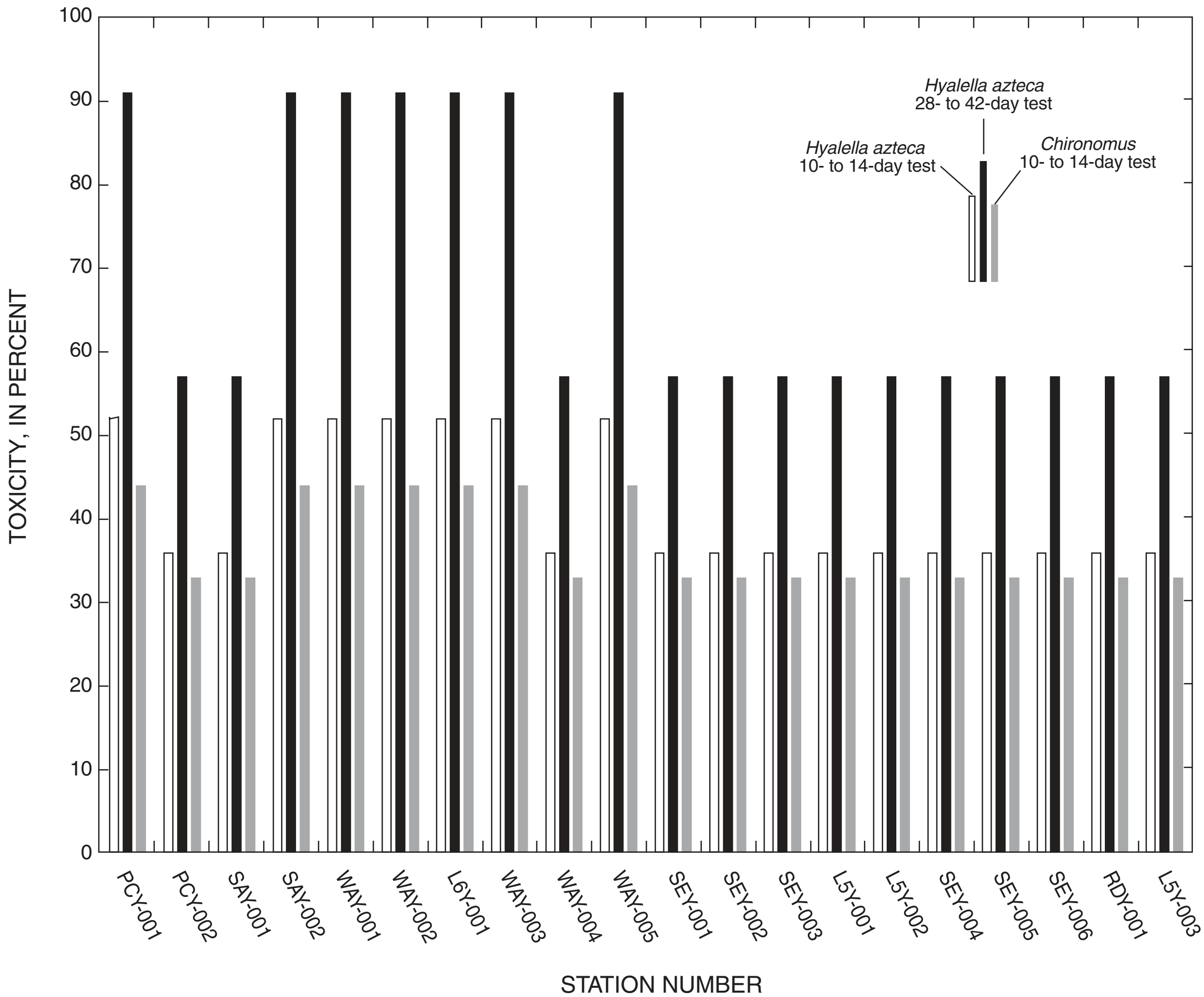

Figure 3. Sediment toxicity to *Hyallela azteca* and *Chironomus spp.* in the North Coastal Basin, Massachusetts, estimated by using consensus-based freshwater sediment-quality guidelines.

The trace elements arsenic, cadmium, chromium, copper, lead, nickel, and zinc accounted for about 87 percent of the predicted toxicity, on average. Chromium concentrations measured in samples from 19 of the 20 sites were greater than the PEC for chromium, with the greatest exceedence (about nine times the PEC) calculated for sediment collected from the North River at the North River Conduit (SAY-002). The greatest average value of the trace element PEC quotients was calculated for samples collected from the North River at the North River Conduit (SAY-002) and Lake Quannapowitt (WAY-001). Statistical methods described previously for estimating ΣPAHs and DDE from censored data indicated that PAHs and DDE, on average, accounted for about 3 and 10 percent, respectively, of the predicted toxicity for the entire study area.

This method of evaluating potential toxicity is only an informal screening to distinguish groups of chemicals and sampling locations that are likely to be associated with adverse biological effects. It is important to note that both MRLs and the method by which toxicity is calculated greatly affects which constituent is considered "most accountable" for predicted toxicity as well as the potential for toxicity. This method is intended to supplement, not replace, direct measures of sediment toxicity. Finally, although these sediment-quality guidelines were initially written for freshwater, it has been shown that these guidelines work equally well in estuarine environments (MacDonald and Others, 2002).

Humans

As more people interact with lakes, rivers, and estuaries, they will likely come in contact with sediment. Information about the human-health risks associated with direct contact or incidental ingestion of contaminated sediment may help communities like those in the North Coastal Basin. These risks can be assessed by comparing sediment-contaminant concentrations with exposure-based guidelines for those contaminants. The guidelines can be applied only indirectly to aquatic sediment, however, because they are formulated for contaminated upland soil. In the absence of aquatic-sediment guidelines, comparison with direct-contact, exposure-based soil standards for many trace elements and organic compounds may suffice (Massachusetts Department of Environmental Protection, 1996, method 2, soil category S-1).

Only a few of the constituents were detected at concentrations near or above their respective human-health standards. Of the trace elements, antimony, arsenic, beryllium, and lead concentrations were the highest and were closest to their respective standards. Beryllium exceeded its soil standard at many sites, but only slightly, on average. Of particular interest is the arsenic concentration measured at Lake Quannapowitt (WAY-001), which was more than five times the standard. This concentration may result from the more than 15,000 kg of sodium arsenite that was applied in the 1960s to control weed growth in the lake (Heath, 2001b).

Of the organic compounds tested, four PAHs—benzo(a)-anthracene, benzo(b)fluoranthene, benzo(a)pyrene, and indeno(1,2,3-cd)pyrene—were closest to human-health standards. When analyzed by using methods described previously for censored data, all of the organochlorine pesticides and PCBs tested showed no potential for adverse human-health risk. Sediment collected from Lake Quannapowitt (WAY-001), Central Reedy Meadow (L6Y-001), and Reedy Meadow Pond (WAY-003), however, could not be assessed for potential risk to humans who come in contact with sediment contaminated with some of the PAHs, organochlorine pesticides, and PCBs because of relatively high MRLs compared to human-health standards.

Comparing sediment concentrations to soil-based, human-health standards likely overestimates the potential human-health risk. As people wade or swim near contaminated sediment, the sediment is washed quickly from their skin. On the other hand, people exposed to contaminated soils have extended contact with the soil; therefore, the contaminant is more likely to enter the body. Nonetheless, the comparison can provide a sense of the risk associated with contacting the sediment. These comparisons, however, are not intended to replace direct measures of the health risk (Breault and others, 2004).

Summary

Potential contamination of lakes, rivers, and estuaries in the North Coastal Basin, north of Boston Harbor in Massachusetts, has raised concerns about bottom-sediment quality in these areas. In response to these concerns, the U.S. Geological Survey, in cooperation with the Massachusetts Department of Environmental Protection, tested sediment quality at selected sites in the North Coastal Basin, which includes the Rumney Marshes, a Massachusetts Area of Critical Environmental Concern.

In June 2003, grab samples of the top 2–4 in. of sediment, which represent more recent deposition, were collected from the North River, Lake Quannapowitt, Saugus River, Mill River, Shute Brook, and the tidal creeks of the Rumney Marshes—Sea Plane Basin, Pines River, and Bear Creek. Collection devices included an Eckman dredge, a stainless-steel scoop, and a Teflon spoon.

Chemical analyses were done for 33 elements, such as antimony, arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, silver, and zinc; and for three types of organic compounds, including polyaromatic hydrocarbons (PAHs), organochlorine pesticides, and polychlorinated biphenyls (PCBs). In addition, the grain-size distribution in each sample was determined through standard laboratory sieving procedures.

Constituent concentrations from the North Coastal Basin were then compared with background concentrations from areas assumed to be unaffected by humans, and with concentrations from other urban rivers and other coastal rivers in Massachusetts. Contaminant concentrations measured in sediment collected from the North Coastal Basin generally were greater than background concentrations. Contaminants with high concentrations included arsenic, chromium, copper, nickel, zinc, some of the PAHs, dichlorodiphenyltrichloroethane (DDT) and its metabolites, and dieldrin. Measured contaminant concentra-tions were generally equal to or greater than those measured in other urban rivers throughout the conterminous United States. Locally, however, concentrations measured in samples collected from the North Coastal Basin were generally less than concentrations measured in sediment collected from two of three urban rivers draining to Boston Harbor, just south of the North Coastal Basin.

Some constituent concentrations may pose a risk to benthic organisms, with potential toxicity ranging from about 33 percent to nearly 91 percent among the sites. Moreover, when considered in relation to the direct-contact, exposure-based soil standards, exposure to some constituents in bottom sediment from the North Coastal Basin also may cause human-health risks if humans come in contact with the sediment. This work is not a comprehensive study of sediment quality that would definitively would measure the quality of North Coastal Basin sediment.

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Table 3

Table 3. Organic compound concentrations measured in sediment grab samples collected from the North Coastal Basin, Massachusetts.

[D, duplicate; Rec, recovery; ppb, parts per billion; <, less than value shown; %, percent; --, not done]

Station Name	Station number	Polyaromatic hydrocarbons										
		Acenaphthene (ppb)	Acenaphthylene (ppb)	Anthracene (ppb)	Benzo(a)-anthracene (ppb)	Benzo(a)-pyrene (ppb)	Benzo(b)-fluoranthene (ppb)	Benzo(g,h,i)-perylene (ppb)	Benzo(k)-fluoranthene (ppb)	Chrysene (ppb)	Dibenzo(a,h)-anthracene (ppb)	Fluoranthene (ppb)
North River at Caller Street	PCY-001	<90	95	250	1,100	910	1,300	430	460	860	160	2,300
North River at Howley Street	PCY-002	150	110	460	1,400	1,100	1,500	470	390	1,100	200	2,900
North River at Commercial Street	SAY-001	<120	<120	140	390	340	480	180	130	340	<120	880
North River at Conduit	SAY-002	<140	<140	220	910	760	1,200	410	310	850	150	2,200
Lake Quannapowitt	WAY-001	<1,600	<1,600	<1,600	<1,600	<1,600	<1,600	<1,600	<1,600	<1,600	<1,600	<1,600
Saugus River at Vernon Street	WAY-002	<260	<260	<260	<260	<260	<260	<260	<260	<260	<260	280
Central Reedy Meadow	L6Y-001	<800	<800	<800	<800	<800	<800	<800	<800	<800	<800	<800
Reedy Meadow Pond	WAY-003	<940	<940	<940	<940	<940	<940	<940	<940	<940	<940	<940
Saugus River at Sunset Drive	WAY-004	<160	<160	<160	<160	<160	190	<160	<160	<160	<160	280
Mill River at Farm Street	WAY-005	<220	<220	<220	390	360	560	270	<220	350	<220	710
Saugus River at Route 1	SEY-001	<170	<170	<170	<170	<170	<170	<170	<170	<170	<170	330
Saugus River at Iron Works	SEY-002	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	230
Shute Brook at Cemetery	SEY-003	<130	<130	150	780	730	1,000	450	320	750	170	1,700
Saugus River at Boston Street	L5Y-001	<230	<230	<230	750	780	1,100	<230	320	740	<230	1,500
Saugus River at Strawberry Brook	L5Y-002	<200	<200	660	2,700	2,500	3,700	1500	850	2,500	560	6,800
Saugus River at Route 107	SEY-004	<200	<200	370	1,000	670	1,300	560	310	950	<200	2,000
Bear Creek	SEY-005	<220	<220	<220	330	320	460	<220	<220	320	<220	620
Sea Plane Basin	SEY-006	<240	<240	<240	340	360	550	300	<240	410	<240	790
Pine River at Gibson Field	RDY-001	<110	<110	<110	<110	<110	<110	<110	<110	<110	<110	<110
Saugus River at Route 1A	L5Y-003	<98	<98	<98	<98	<98	<98	<98	<98	<98	<98	<98
Shute Brook at Cemetery	SEY-003-D	<86	<86	210	820	790	1,100	650	370	820	300	1,900
Sea Plane Basin	SEY-006-D	<240	<240	<240	<240	<240	300	<240	<240	<240	<240	390
Blank	--	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Blank	--	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Blank	--	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Matrix Spike (% Rec)	--	78	96	76	80	78	76	84	80	80	84	84
Matrix Spike (% Rec)	--	74	82	70	74	74	76	78	78	72	78	84
Matrix Spike (% Rec)	--	74	86	72	80	84	78	90	90	78	94	86

Table 3. Organic compound concentrations measured in sediment-grab samples collected from the North Coastal Basin, Massachusetts.—Continued

[D, duplicate; Rec, recovery; ppb, parts per billion; <, less than value shown; %, percent; --, not done]

Station Name	Station number	Polyaromatic hydrocarbons									Organochlorine pesticides	
								Surrogates				
		Fluorene (ppb)	Indeno-(1,2,3-cd)-pyrene (ppb)	Naptha-lene (ppb)	Phenan-threne (ppb)	Pyrene (ppb)	2-Methyl-naphtha-lene (ppb)	Nitro-benzene-d5 (% Rec)	2-Fluoro-biphenyl (% Rec)	Terphenyl-d14 (% Rec)	Aldrin (ppb)	alpha-BHC (ppb)
North River at Caller Street	PCY-001	99	500	<90	1,100	1,700	<90	55	54	58	<5	<5
North River at Howley Street	PCY-002	150	550	<84	1,800	2,200	<84	65	62	67	<5	<5
North River at Commercial Street	SAY-001	<120	200	<120	540	700	<120	63	64	70	<5	<5
North River at Conduit	SAY-002	<140	450	<140	1,100	1,600	<140	66	63	69	<5	<5
Lake Quannapowitt	WAY-001	<1,600	<1,600	<1,600	<1,600	<1,600	<1,600	74	78	80	<90	<90
Saugus River at Vernon Street	WAY-002	<260	<260	<260	<260	<260	<260	68	76	71	<17.5	<18
Central Reedy Meadow	L6Y-001	<800	<800	<800	<800	<800	<800	72	77	76	<48	<48
Reedy Meadow Pond	WAY-003	<940	<940	<940	<940	<940	<940	54	62	59	<68	<68
Saugus River at Sunset Drive	WAY-004	<160	<160	<160	<160	200	<160	67	75	81	<9	<9
Mill River at Farm Street	WAY-005	<220	280	<220	<220	650	<220	70	78	80	<15	<15
Saugus River at Route 1	SEY-001	<170	<170	<170	<170	250	<170	58	62	68	<8	<8
Saugus River at Iron Works	SEY-002	<150	<150	<150	<150	190	<150	68	72	79	<9	<9
Shute Brook at Cemetery	SEY-003	<130	510	<130	700	1,100	<130	69	73	63	<7	<7
Saugus River at Boston Street	L5Y-001	<230	610	<230	640	<230	<230	72	79	77	<5	<13
Saugus River at Strawberry Brook	L5Y-002	<200	1,700	350	3,300	4,300	<200	67	74	68	<10	<10
Saugus River at Route 107	SEY-004	<200	580	<200	1,400	1,800	<200	74	81	82	<11	<11
Bear Creek	SEY-005	<220	240	<220	260	550	<220	36	32	70	<14	<14
Sea Plane Basin	SEY-006	<240	310	<240	280	610	<240	31	26	54	<5	<15
Pine River at Gibson Field	RDY-001	<110	<110	<110	<110	<110	<110	40	43	47	<7	<7
Saugus River at Roue 1A	L5Y-003	<98	<98	<98	<98	<98	<98	60	61	76	<8	<8
Shute Brook at Cemetery	SEY-003-D	110	690	<86	980	1,200	<86	53	56	49	<6	<6
Sea Plane Basin	SEY-006-D	<240	<240	<240	<240	310	<240	33	27	39	<14	<14
Blank	--	<50	<50	<50	<50	<50	<50	66	64	77	<5	<5
Blank	--	<50	<50	<50	<50	<50	<50	55	60	66	<5	<5
Blank	--	<50	<50	<50	<50	<50	<50	57	64	68	--	--
Matrix Spike (% Rec)	--	82	82	82	80	86	--	71	62	77	84	99
Matrix Spike (% Rec)	--	76	78	74	76	74	--	64	58	57	77	74
Matrix Spike (% Rec)	--	82	96	74	80	72	--	61	64	64	--	--

Table 3. Organic compound concentrations measured in sediment-grab samples collected from the North Coastal Basin, Massachusetts.—Continued

[D, duplicate; Rec, recovery; ppb, parts per billion; <, less than value shown; %, percent; --, not done]

Station Name	Station number	Organochlorine pesticides										
		beta-BHC (ppb)	delta-BHC (ppb)	gamma-BHC (ppb)	alpha-Chlordane (ppb)	gamma-Chlordane (ppb)	Chlordane (ppb)	4,4′-DDD (ppb)	4,4′-DDE (ppb)	4,4′-DDT (ppb)	Dieldrin (ppb)	Endo-sulfan I (ppb)
North River at Caller Street	PCY-001	<5	<5	<5	<5	<5	<100	62	<10	29	<10	<5
North River at Howley Street	PCY-002	<5	<5	<5	<5	<5	<100	22	<10	36	<10	<5
North River at Commercial Street	SAY-001	<5	<5	<5	<5	<5	<100	12	13	25	<10	<5
North River at Conduit	SAY-002	<5	<5	<5	<5	<5	<100	34	48	45	<10	<5
Lake Quannapowitt	WAY-001	<90	<90	<90	<90	<90	<1,790	<179	<179	<179	<179	<90
Saugus River at Vernon Street	WAY-002	<18	<18	<18	<18	<18	<350	102	75	37	<35	<18
Central Reedy Meadow	L6Y-001	<48	<48	<48	<48	<48	<960	<96	96	<96	<96	<48
Reedy Meadow Pond	WAY-003	<68	<68	<68	<68	<68	<1,350	<135	156	<135	<135	<68
Saugus River at Sunset Drive	WAY-004	<9	<9	<9	<9	<9	<9	18	<17	<17	<17	<9
Mill River at Farm Street	WAY-005	<15	<15	<15	<15	<15	<15	48	36	<29	<29	<15
Saugus River at Route 1	SEY-001	<8	<8	<8	<8	<8	<157	<16	23	<16	18	<8
Saugus River at Iron Works	SEY-002	<9	<9	<9	<9	<9	<170	24	21	<17	<17	<9
Shute Brook at Cemetery	SEY-003	<7	<7	<7	<7	<7	<130	22	<13	<13	24	<7
Saugus River at Boston Street	L5Y-001	<13	<13	<13	<13	<13	<260	<26	<26	<26	<26	<13
Saugus River at Strawberry Brook	L5Y-002	<10	<10	<10	<10	<10	<200	44	<20	<20	<20	<10
Saugus River at Route 107	SEY-004	<11	<11	<11	<11	<11	<210	<21	<21	<21	<21	<11
Bear Creek	SEY-005	<14	<14	<14	<14	<14	<270	<27	<27	<27	<27	<14
Sea Plane Basin	SEY-006	<15	<15	<15	<15	<15	<292	<29	<29	<29	<29	<15
Pine River at Gibson Field	RDY-001	<7	<7	<7	<7	<7	<130	<13	<13	<13	<13	<7
Saugus River at Route 1A	L5Y-003	<8	<8	<8	<8	<8	<157	<16	<16	<16	<16	<8
Shute Brook at Cemetery	SEY-003-D	<6	<6	<6	<6	<6	<120	34	<12	20	21	<6
Sea Plane Basin	SEY-006-D	<14	<14	<14	<14	<14	<288	<29	<29	<29	<29	<14
Blank	--	<5	<5	<5	<5	<5	<100	<10	<10	<10	<10	<5
Blank	--	<5	<5	<5	<5	<5	<100	<10	<10	<10	<10	<5
Blank	--	--	--	--	--	--	--	--	--	--	--	--
Matrix Spike (% Rec)	--	103	109	88	84	108	--	89	93	100	88	116
Matrix Spike (% Rec)	--	98	84	90	78	90	--	81	89	82	79	97
Matrix Spike (% Rec)	--	--	--	--	--	--	--	--	--	--	--	--

Table 3. Organic compound concentrations measured in sediment-grab samples collected from the North Coastal Basin, Massachusetts.—Continued

[D, duplicate; Rec, recovery; ppb, parts per billion; <, less than value shown; %, percent; --, not done]

Station Name	Station number	Organochlorine pesticides										
		Endo-sulfan II (ppb)	Endosulfan sulfate (ppb)	Endrin (ppb)	Endrin aldehyde (ppb)	Endrin ketone (ppb)	Hepta-chlor (ppb)	Heptachlor epoxide (ppb)	Methoxy-chlor (ppb)	Toxa-phene (ppb)	Surrogates TCMX (% Rec)	Surrogates DCBP (% Rec)
North River at Caller Street	PCY-001	<10	<10	<10	<10	<10	<5	<5	<50	<5,000	90	111
North River at Howley Street	PCY-002	<10	<10	<10	<10	<10	<5	<5	<50	<5,000	110	136
North River at Commercial Street	SAY-001	<10	<10	<10	<10	<10	<5	<5	<50	<5,000	94	122
North River at Conduit	SAY-002	<10	<10	<10	<10	<10	<5	<5	<50	<5,000	95	119
Lake Quannapowitt	WAY-001	<179	<179	<179	<179	<179	<90	<90	<895	<89,500	91	84
Saugus River at Vernon Street	WAY-002	<35	<35	<35	<35	<35	<18	<18	<175	<17,500	111	138
Central Reedy Meadow	L6Y-001	<96	<96	<96	<96	<96	<48	<48	<480	<48,000	87	86
Reedy Meadow Pond	WAY-003	<135	<135	<135	<135	<135	<68	<68	<675	<67,500	115	121
Saugus River at Sunset Drive	WAY-004	<17	<17	<17	<17	<17	<9	<9	<85	<8,500	97	110
Mill River at Farm Street	WAY-005	<29	<29	<29	<29	<29	<15	<15	<145	<14,500	94	110
Saugus River at Route 1	SEY-001	<16	<16	<16	<16	<16	<8	<8	<80	<8,000	99	103
Saugus River at Iron Works	SEY-002	<17	<17	<17	<17	<17	<9	<9	<85	<8,500	106	129
Shute Brook at Cemetery	SEY-003	<13	<13	<13	<13	<13	<7	<7	<65	<6,500	89	115
Saugus River at Boston Street	L5Y-001	<26	<26	<26	<26	<26	<13	<13	<130	<13,000	97	110
Saugus River at Strawberry Brook	L5Y-002	<20	<20	<20	<20	<20	<10	<10	<100	<10,000	87	113
Saugus River at Route 107	SEY-004	<21	<21	<21	<21	<21	<11	<11	<105	<10,500	96	95
Bear Creek	SEY-005	<27	<27	<27	<27	<27	<14	<14	<135	<13,500	104	110
Sea Plane Basin	SEY-006	<29	<29	<29	<29	<29	<15	<15	<146	<14,600	94	98
Pine River at Gibson Field	RDY-001	<13	<13	<13	<13	<13	<7	<7	<67	<6,700	82	85
Saugus River at Route 1A	L5Y-003	<16	<16	<16	<16	<16	<8	<8	<79	<7,900	100	104
Shute Brook at Cemetery	SEY-003-D	<12	<12	<12	<12	<12	<6	<6	<60	<6,000	80	103
Sea Plane Basin	SEY-006-D	<29	<29	<29	<29	<29	<14	<14	<144	<14,400	86	85
Blank	--	<10	<10	<10	<10	<10	<5	<5	<50	<5,000	82	84
Blank	--	<10	<10	<10	<10	<10	<5	<5	<50	<5,000	100	101
Blank	--	--	--	--	--	--	--	--	--	--	--	--
Matrix Spike (% Rec)	--	85	98	125	95	83	95	88	104	--	99	102
Matrix Spike (% Rec)	--	76	74	86	82	73	88	73	76	--	91	92
Matrix Spike (% Rec)	--	--	--	--	--	--	--	--	--	--	--	--

Table 3. Organic compound concentrations measured in sediment-grab samples collected from the North Coastal Basin, Massachusetts.—Continued

[D, duplicate; Rec, recovery; ppb, parts per billion; <, less than value shown; %, percent; --, not done]

Station Name	Station number	Polychlorinated biphenyl aroclors								
		1016 (ppb)	1221 (ppb)	1232 (ppb)	1242 (ppb)	1248 (ppb)	1254 (ppb)	1260 (ppb)	Surrogates	
									TCMX (% Rec)	DCBP (% Rec)
North River at Caller Street	PCY-001	<100	<200	<100	<100	<100	<100	<100	65	103
North River at Howley Street	PCY-002	<100	<200	<100	<100	<100	<100	<100	78	105
North River at Commercial Street	SAY-001	<100	<200	<100	<100	<100	<100	<100	70	90
North River at Conduit	SAY-002	<100	<200	<100	<100	<100	<100	<100	70	100
Lake Quannapowitt	WAY-001	<1790	<3582	<1,790	<1790	<1,790	<1,790	<1,790	90	93
Saugus River at Vernon Street	WAY-002	<349	<697	<349	<349	<349	<349	<349	108	118
Central Reedy Meadow	L6Y-001	<957	<1,915	<957	<957	<957	<957	<957	93	88
Reedy Meadow Pond	WAY-003	<1,300	<2,600	<1,300	<1,300	<1,300	<1,300	<1,300	110	110
Saugus River at Sunset Drive	WAY-004	<173	<345	<173	<173	<173	<173	<173	93	98
Mill River at Farm Street	WAY-005	<288	<575	<288	<288	<288	<288	<288	98	113
Saugus River at Route 1	SEY-001	<157	<314	<157	<157	<157	<157	<157	95	95
Saugus River at Iron Works	SEY-002	<171	<342	<171	<171	<171	<171	<171	98	105
Shute Brook at Cemetery	SEY-003	<128	<256	<128	<128	<128	<128	<128	88	103
Saugus River at Boston Street	L5Y-001	<261	<521	<261	<261	<261	<261	<261	108	98
Saugus River at Strawberry Brook	L5Y-002	<200	<400	<200	<200	<200	<200	<200	93	100
Saugus River at Route 107	SEY-004	<211	<422	<211	<211	<211	<211	<211	85	85
Bear Creek	SEY-005	<275	<549	<275	<275	<275	<275	<275	108	110
Sea Plane Basin	SEY-006	<292	<583	<292	<292	<292	<292	<292	90	85
Pine River at Gibson Field	RDY-001	<134	<269	<134	<134	<134	<134	<134	83	83
Saugus River at Route 1A	L5Y-003	<157	<314	<157	<157	<157	<157	<157	100	100
Shute Brook at Cemetery	SEY-003-D	<127	<255	<127	<127	<127	<127	<127	85	108
Sea Plane Basin	SEY-006-D	<288	<577	<288	<288	<288	<288	<288	80	78
Blank	--	<100	<200	<100	<100	<100	<100	<100	73	83
Blank	--	<100	<200	<100	<100	<100	<100	<100	95	88
Blank	--	--	--	--	--	--	--	--	--	--
Matrix Spike (% Rec)	--	--	67	--	--	--	--	--	88	88
Matrix Spike (% Rec)	--	--	--	57	--	--	--	--	73	63
Matrix Spike (% Rec)	--	--	--	--	--	--	--	--	--	--