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Occurrence of Organic Compounds and Trace Elements in the Upper Passaic and Elizabeth Rivers and Their Tributaries in New Jersey, July 2003 to February 2004: Phase II of the New Jersey Toxics Reduction Workplan for New York-New Jersey Harbor

Scientific Investigations Report 2007-5136

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

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By Timothy P. Wilson and Jennifer L. Bonin

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Conversion factors, datums, and water-quality abbreviations

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
	Area	
square meter (m^2)	0.0002471	acre
square kilometer (km^2)	0.3861	square mile (mi^2)
	Volume	
liter (L)	0.2642	gallon (gal)
cubic meter (m^3)	264.2	gallon (gal)
	Flow rate	
cubic meter per second (m^3/s)	35.31	cubic foot per second (ft^3/s)
liter per second (L/s)	15.85	gallon per minute (gal/min)
	Mass	
gram (g)	0.03527	ounce, avoirdupois (oz)

Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29)

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

Water-quality abbreviations:	
DOC	Dissolved organic carbon
EDL	Estimated detection limit
FS	Field surrogate
GFF	Glass fiber filter
IS	Internal standard
PAH	Polycyclic aromatic hydrocarbons
PCB	Polychlorinated biphenyl
PCDD	Polychlorinated dibenzo-p-dioxins
PCDF	Polychlorinated dibenzo-p-difurans
POC	Particulate organic carbon
SRM	Standard reference material
SS	Suspended sediment
TOPS	Trace organic platform sampler
TEQ	Toxic equivalency
XAD	Chemical exchange resin
μg	microgram
ng	nanogram
ng/g	nanograms per gram
pg	picogram
pg/g	picograms per gram
pg/L	picograms per liter
^{13}C	Carbon isotope 13

Occurrence of Organic Compounds and Trace Elements in the Upper Passaic and Elizabeth Rivers and Their Tributaries in New Jersey, July 2003 to February 2004: Phase II of the New Jersey Toxics Reduction Workplan for New York-New Jersey Harbor

By Timothy P. Wilson and Jennifer L. Bonin

Abstract

Samples of surface water and suspended sediment were collected from the Passaic and Elizabeth Rivers and their tributaries in New Jersey from July 2003 to February 2004 to determine the concentrations of selected chlorinated organic and inorganic constituents. This sampling and analysis was conducted as Phase II of the New York-New Jersey Harbor Estuary Workplan—Contaminant Assessment and Reduction Program (CARP), which is overseen by the New Jersey Department of Environmental Protection. Phase II of the New Jersey Workplan was conducted to define upstream tributary and point sources of contaminants in those rivers sampled during Phase I work, with special emphasis on the Passaic and Elizabeth Rivers. Samples were collected from three groups of tributaries: (1) the Second, Third, and Saddle Rivers; (2) the Pompton and upper Passaic Rivers; and (3) the West Branch and main stem of the Elizabeth River. The Second, Third, and Saddle Rivers were sampled near their confluence with the tidal Passaic River, but at locations not affected by tidal flooding. The Pompton and upper Passaic Rivers were sampled immediately upstream from their confluence at Two Bridges, N.J. The West Branch and the main stem of the Elizabeth River were sampled just upstream from their confluence at Hillside, N.J. All tributaries were sampled during low-flow discharge conditions using the protocols and analytical methods for organic constituents used in low-flow sampling in Phase I. Grab samples of streamflow also were collected at each site and were analyzed for trace elements (mercury, methylmercury, cadmium, and lead) and for suspended sediment, particulate organic carbon, and dissolved organic carbon. The measured concentrations and available historical suspended-sediment and stream-discharge data (where available) were used to estimate average annual loads of suspended sediment and organic compounds in these rivers.

Total suspended-sediment loads for 1975-2000 were estimated using rating curves developed from historical U.S. Geological Survey (USGS) suspended-sediment and discharge data, where available. Average annual loads of suspended sediment, in millions of kilograms per year (Mkg/yr), were estimated to be 0.190 for the Second River, 0.23 for the Third River, 1.00 for the Saddle River, 1.76 for the Pompton River, and 7.40 for the upper Passaic River.

On the basis of the available discharge records, the upper Passaic River was estimated to provide approximately 60 percent of the water and 80 percent of the total suspended-sediment load at the Passaic River head-of-tide, whereas the Pompton River provided roughly 20 percent of the total suspended-sediment load estimated at the head-of-tide. The combined suspended-sediment loads of the upper Passaic and Pompton Rivers (9.2 Mkg/yr), however, represent only 40 percent of the average annual suspended-sediment load estimated for the head-of-tide (23 Mkg/yr) at Little Falls, N.J. The difference between the combined suspended-sediment loads of the tributaries and the estimated load at Little Falls represents either sediment trapped upriver from the dam at Little Falls, additional inputs of suspended sediment downstream from the tributary confluence, or uncertainty in the suspended-sediment and discharge data that were used.

The concentrations of total suspended sediment-bound polychlorinated biphenyls (PCBs) in the tributaries to the Passaic River were 194 ng/g (nanograms per gram) in the Second River, 575 ng/g in the Third River, 2,320 ng/g in the Saddle River, 200 ng/g in the Pompton River, and 87 ng/g in the upper Passic River. The dissolved PCB concentrations in the tributaries were 563 pg/L (picograms per liter) in the Second River, 2,510 pg/L in the Third River, 2,270 pg/L in the Saddle River, 887 pg/L in the Pompton River, and 1,000 pg/L in the upper Passaic River. Combined with the sediment loads and discharge, these concentrations resulted in annual loads of

suspended sediment-bound PCBs, in grams per year (g/yr), of 37 in the Second River; 132 in the Third River; 2,320 in the Saddle River; 352 in the Pompton River; and 644 in the upper Passaic River. Annual loads of dissolved PCBs, in grams per year, are 9.2 in the Second River; 47 in the Third River; 212 in the Saddle River; 349 in the Pompton River; and 549 in the upper Passaic River.

Concentrations of total suspended sediment-bound polychlorinated dibenzo-p-dioxins and polychlorinated dibenzo-p-difurans (PCDD/PCDFs) were 6,000 pg/g (picograms per gram) in the Second River; 11,300 pg/g in the Third River; 37,700 pg/g in the Saddle River; 7,140 pg/g in the Pompton River; and 9,640 pg/g in the upper Passaic River. Total toxic equivalence quotients (TEQs), which included PCDD/PCDFs and coplanar PCBs, ranged from 2.7 pg/g in the Second River to 132 pg/g (as 2,3,7,8-TCDD) in the Saddle River. Average annual loads of PCDD/PCDFs were from 1.1 g/yr in the Second River to 71 g/yr in the upper Passaic River. The load of TEQs (as 2,3,7,8-TCDD) from PCDD/PCDFs and coplanar PCBs in the tributaries were 0.5 mg/yr (milligrams per year) in the Second River, 5.8 mg/yr in the Third River, 130 mg/yr in the Saddle River, 46 mg/yr in the Pompton River, and 100 mg/yr in the upper Passaic River. These loads represent an addition to the TEQ load estimated to cross the head-of-tide of 0.1 percent by the Second River, 0.7 percent by the Third River, and 15 percent by the Saddle River.

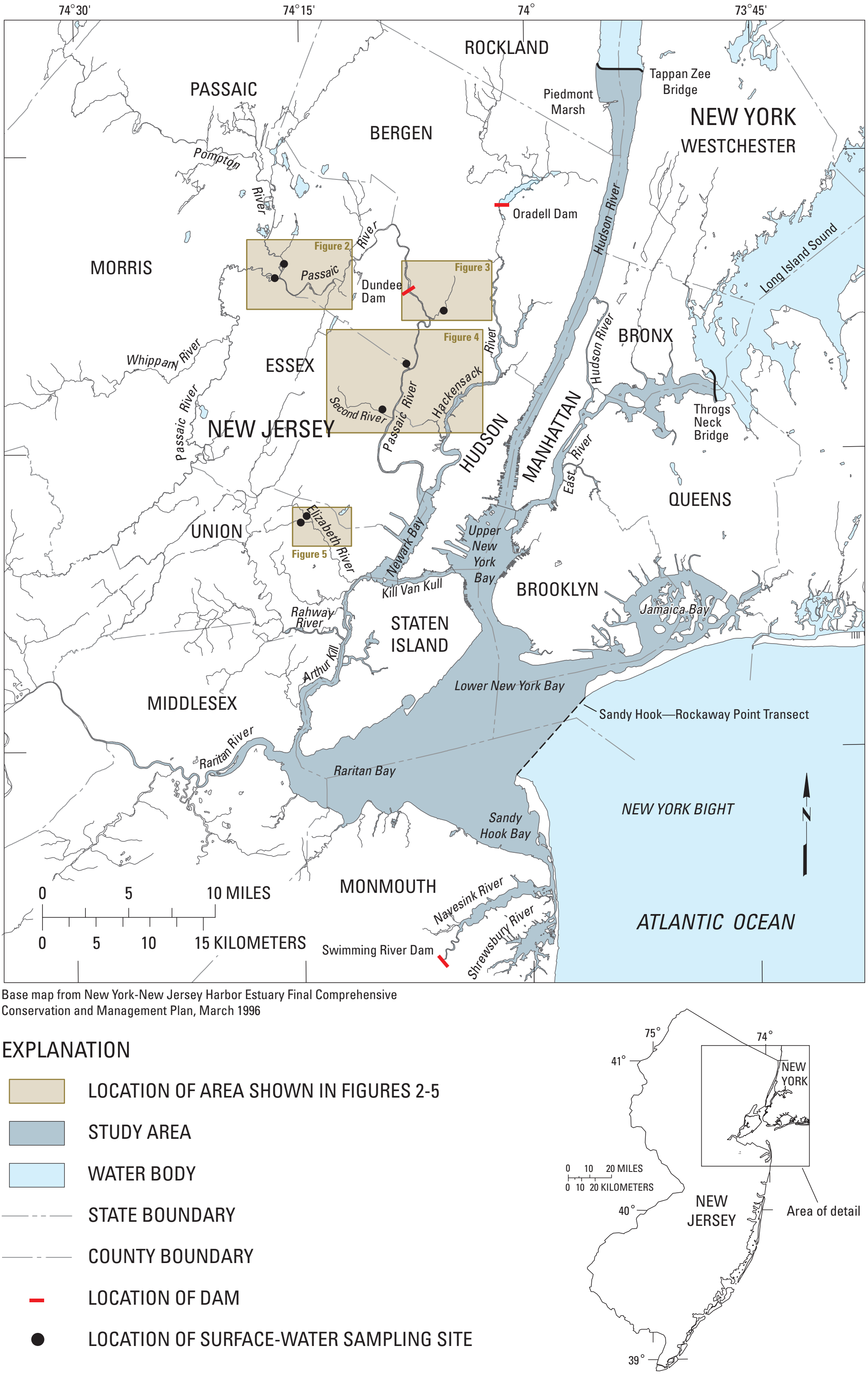
Loads of sediment-bound trace elements mercury, methylmercury, lead, and cadmium were calculated using concentrations obtained from grab samples, which were assumed to represent average annual concentrations in these rivers. Loads of sediment-bound mercury were estimated to be 1,200 g/yr in the Second River; 130 g/yr in the Third River; 4,200 g/yr in the Saddle River; 3,400 g/yr in the Pompton River; and 6,500 g/yr in the upper Passaic River. Loads of sediment-bound lead were estimated to be 56 kg/yr (kilograms per year) in the Second River; 89 kg/yr in the Third River; 1,140 kg/yr in the Saddle River; 310 kg/yr in the Pompton River; and 1,040 kg/yr in the upper Passaic River. Loads of sediment-bound cadmium were estimated to be 1 kg/yr in the Second River; 0.59 kg/yr in the Third River; 60 kg/yr in the Saddle River; 16 kg/yr in the Pompton River; and 11 kg/yr in the upper Passaic River. These loads indicate the importance of the sediment-bound contributions of organic compounds and trace elements to the upper Passaic and Saddle Rivers.

Concentrations of suspended sediment-bound PCBs in the main stem and the West Branch of the Elizabeth River were 806 ng/g and 3,100 ng/g, respectively, representing loads of 40 g/yr and 1,150 g/yr, respectively. These loads were estimated using assumed discharge conditions. Concentrations of suspended sediment-bound PCDD/PCDFs were 7,270 pg/g and 9,980 pg/g in the main stem and West Branch, respectively, representing average annual loads of 0.36 g/yr and 3.7 g/yr, respectively. Total TEQ loads (sum of PCDD/PCDFs and PCBs) were 2.1 mg/yr (as 2,3,7,8-TCDD) in the main stem and 34 mg/yr in the West Branch, respectively. These load estimates, however, were directly related to the assumed annual discharge for the two branches. Long-term measurement of stream discharge and suspended-sediment concentrations would be needed to verify these loads. On the basis of the concentrations measured in this work, it appears that the West Branch is the principal source of PCBs, PCDD/PCDFs, total TEQs, and metals to the main stem of the Elizabeth River. Additional sources of these constituents may exist between the confluence and the head-of-tide.

Introduction

The New Jersey Department of Environmental Protection (NJDEP), as part of its Toxics Reduction Workplan for the New York-New Jersey Harbor (NJTRWP, the New Jersey component of the New York-New Jersey Harbor Estuary Program Contaminant Assessment and Reduction Program (CARP)) conducted an extensive Phase I sampling program in cooperation with other agencies to determine the concentrations and loads in the tributaries, estuaries, and kills associated with Newark and Raritan Bays during 2000-04 (N.J. Department of Environmental Protection, 2001; New York-New Jersey Harbor Estuary Program, 1996) (fig. 1). The role of the U.S. Geological Survey (USGS) in that program was to determine concentrations and mass loads of organic compounds and trace elements that originate above the heads-of-tide in the Passaic, Raritan, Rahway, Elizabeth, and Hackensack Rivers, the main tributaries to Newark and Raritan Bay (Bonin and Wilson, 2006; Wilson and Bonin, 2007). Other researchers concurrently measured concentrations in the lower estuarine/tidal parts of these rivers. These studies demonstrated that the Passaic River accounted for the major loads to Newark Bay and that high concentrations of selected organic and inorganic compounds were present at the head-of-tide of the Elizabeth River (Wilson and Bonin, 2007).

As a follow-up to Phase I, the NJDEP, in cooperation with other agencies, initiated a Phase II study. For Phase II, the USGS collected samples from tributaries to the Passaic River (the upper Passaic and Pompton Rivers (fig. 2), the Saddle River (fig. 3), the Second and Third Rivers (fig. 4), and the Elizabeth River (the West Branch and main stem, upstream from their confluence (fig. 5))) with the goal of determining the concentrations of polychlorinated biphenyls (PCBs), chloro-p-dibenzodioxins and difurans (PCDD/PCDFs), and trace elements (mercury, cadmium, and lead) in water and suspended sediment in these tributaries. These data, collected in part to identify the sources of these compounds, were used in this report to estimate loads of suspended sediment and organic and inorganic compounds delivered by these tributaries to the main stem branches of the Passaic and Elizabeth Rivers. Comparisons of constituent concentrations and loads were made among the tributaries and main stems of the Passaic and Elizabeth Rivers, and compounds were identified that could serve as markers for sediment from each tributary.



Base map from New York-New Jersey Harbor Estuary Final Comprehensive Conservation and Management Plan, March 1996

Figure 1. Location of study area and surface-water sampling sites in New Jersey.

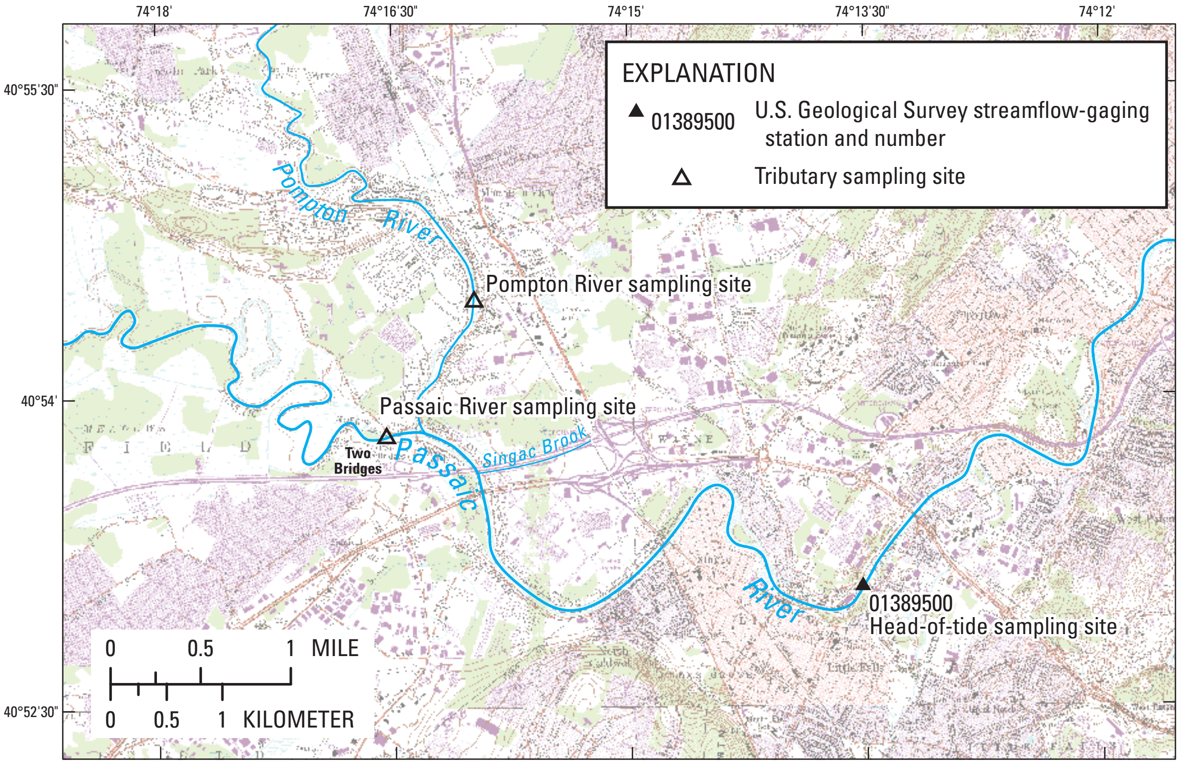


Figure 2. Location of sampling sites on the Passaic and Pompton Rivers, Two Bridges, New Jersey. (See figure 1 for location of this figure.)

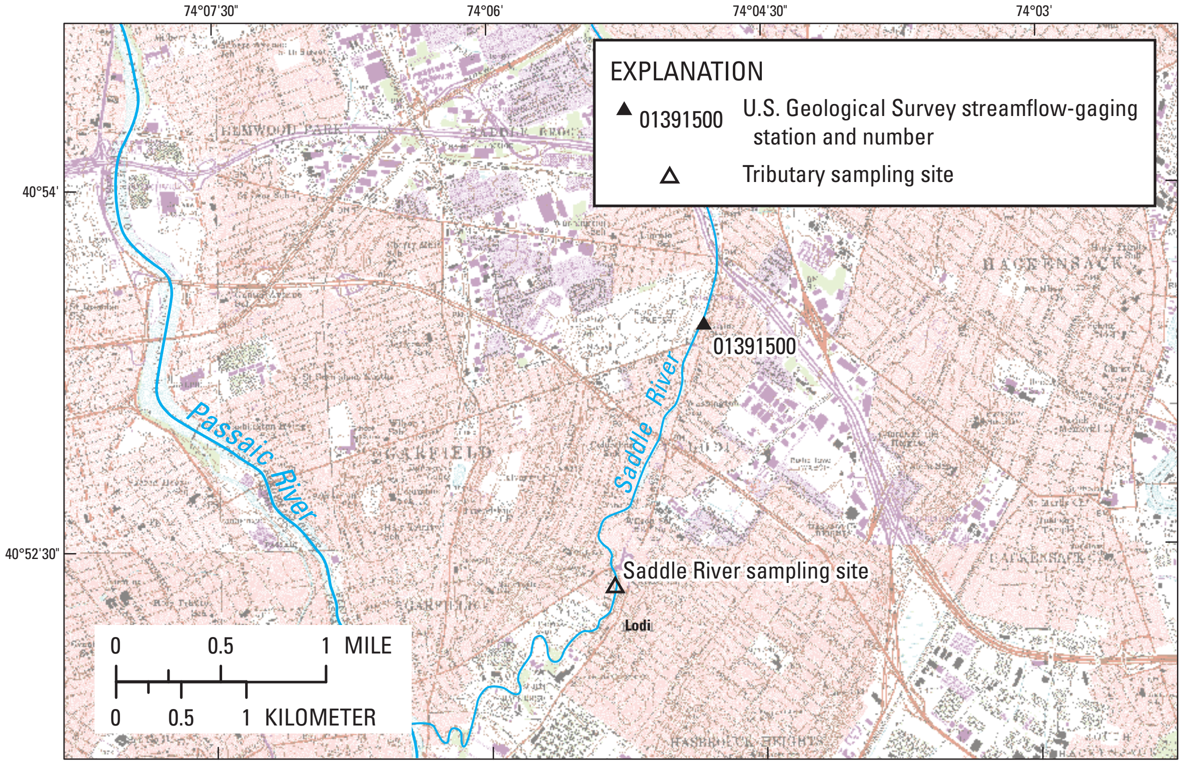


Figure 3. Location of sampling site on the Saddle River, Lodi, New Jersey. (See figure 1 for location of this figure.)

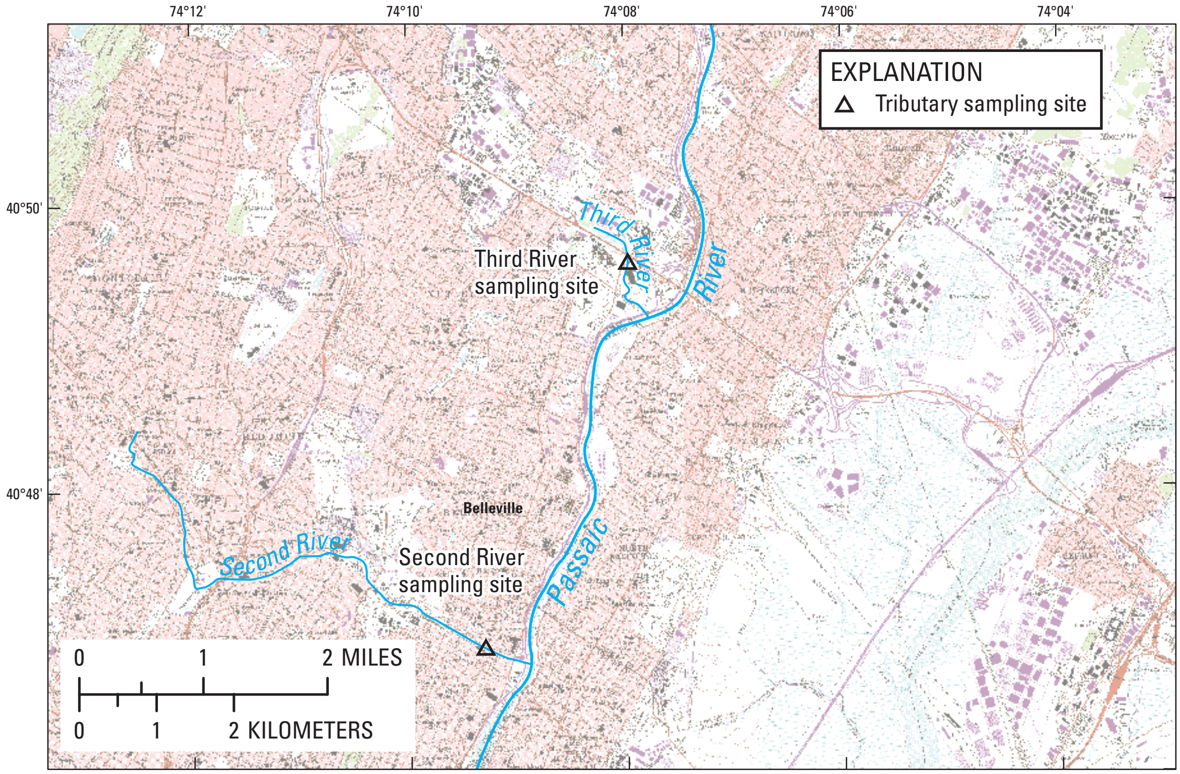


Figure 4. Location of sampling sites on the Second and Third Rivers, Belleville, New Jersey. (See figure 1 for location of this figure.)

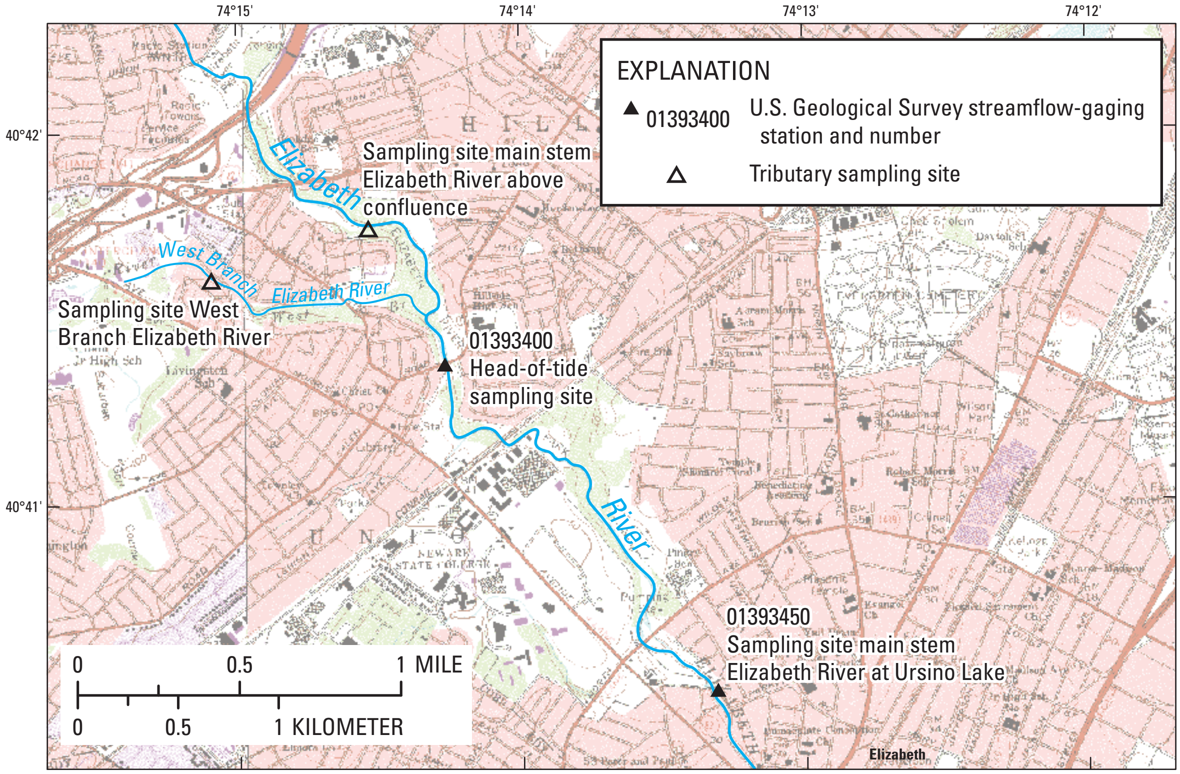


Figure 5. Location of sampling sites on the West Branch and main stem of the Elizabeth River, Elizabeth, New Jersey. (See figure 1 for location of this figure.)

Purpose and Scope

The purpose of this report is to present concentrations and estimates of loads for suspended sediment; dissolved and particulate organic carbon; PCBs; PCDD/PCDFs; and the trace elements mercury, cadmium, and lead in the Elizabeth and Passaic Rivers. Also presented are comparisons of the water quality among the rivers, and the suspended-sediment chemistry in the main stems of these rivers. Samples were collected at seven sites from July 2003 to February 2004. Field characteristics and raw and normalized concentrations of constituents are included in this report.

Description of Study Area

The study area consists of the Passaic, Second, Third, and Saddle Rivers, which combine and flow into Newark Bay; and the main and West Branch of the Elizabeth River, which flows into the Arthur Kill (fig. 1, table 1). The Passaic River drains a large basin of more than 700 mi^2. The Saddle, Second, Third, and Elizabeth Rivers drain small, highly urbanized basins of less than 100 mi^2 , and consequently have small discharges (less than 100 ft^3/s). Flow in all of these rivers is affected by inputs from sewers and other outfalls, several small dams, and wetland areas, all of which greatly affect the hydrologic responses of these rivers.

Land use in these river basins, as determined from the NJDEP Geographic Information Systems Database for the part of the basin upstream from the sampling sites, provides useful insight into the characteristics of these basins. All of the basins are classified as urban, although 36 percent of the land in the Passaic River Basin is forested. The high degree of urbanization is reflected in the large number of dischargers and waste-treatment plants that are permitted to release effluent into the surface-water system in each basin (Bonin and Wilson, 2006).

Methods

Sampling and analytical methods used in this work are consistent with those used in the Phase I work of the NJDEP Workplan. Detailed descriptions of the sampling and analytical methods used in Phase I can be found in Bonin and Wilson (2006) and Wilson and Bonin (2007). Phase I sampling was performed during storms and low-flow discharge conditions at the head-of-tide in each tributary.

In Phase II work, the tributaries were sampled during low-flow discharge using the large-volume sampling methods developed for Phase I. Large-volume (50-L) samples were collected over 4 to 6 hours at selected sites where tributaries converge to form the main branches of the Passaic and Elizabeth Rivers, and where the Second, Third, and Saddle Rivers enter the Passaic River (figs. 1–5). These samples are considered to be representative of the streams during low-flow discharge conditions, as they were collected during times of steady low discharge. Sampling was conducted under similar conditions in the Phase I work, although flow-weighted composite samples were also collected during storms in Phase I.

Filtration was used to collect suspended sediment and XAD-2 resin was used to sequester dissolved organic compounds. The collected samples were analyzed using U.S. Environmental Protection Agency (USEPA) Method 1668A for PCBs and Method 1613 for PCDD/PCDFs (U.S. Environmental Protection Agency, 1994). Grab samples of river water also were collected and analyzed for the dissolved and whole-water trace elements mercury, cadmium, and lead, along with suspended sediment (SS), particulate organic carbon (POC), and dissolved organic carbon (DOC). Mercury was measured using cold-vapor atomic absorption spectrometry (CVAA) and cadmium and lead were measured using inductively coupled plasma-mass spectrometry (ICP-MS). Details of the analytical program used in this work can be found in the Phase I reports of Bonin and Wilson (2006) and Wilson and Bonin (2007), and in NJDEP documentation (N.J. Department of Environmental Protection, 2001).

Sampling Sites

Descriptions of the Phase II sampling sites are presented in table 1, general locations are shown in figure 1, and specific sampling sites are shown in figures 2 to 5 along with the associated USGS streamflow-gaging stations referenced in this work**.** Samples collected from the upper Passaic River and the Pompton River were collected upstream (4,400 ft and 1,290 ft, respectively) from their confluence at Two Bridges, N.J (fig. 2). These sites are approximately 3.9 river miles upstream from the Phase I head-of-tide sampling and streamflow-gaging station on the Passaic River at Little Falls, N.J. (Bonin and Wilson, 2006). Discharge in the upper Passaic River was measured at Pine Brook, N.J., and discharge in the Pompton River was measured at Pompton, N.J. Both of these stations are upstream from the confluence.

Three tributaries to the lower tidal Passaic River were sampled: the Second, Third, and Saddle Rivers (figs. 3 and 4). The Saddle River (fig. 3) was sampled 1.7 river miles upstream from its confluence with the tidal Passaic River and approximately 1.5 miles downstream from the USGS streamflow-gaging station at Lodi, N.J. Sampling locations on the Second and Third Rivers (fig. 4) were selected at accessible road crossings as near to their confluence with the Passaic River as possible, but at locations not affected by tidal flooding from the Passaic River.

The West Branch and the main stem of the Elizabeth River were sampled 1,460 ft and 3,000 ft, respectively, upstream from their confluence at Hillside, N.J. (fig. 5). The confluence is approximately 1,200 ft upstream from the Phase I head-of-tide sampling station on the main stem of the Elizabeth River at Hillside, which, in turn, is approximately 1.5 river miles upstream from the USGS streamflow-gaging station at Ursino Lake, N.J. The East Branch of the Elizabeth River is encased in a storm drain and could not be sampled.

Table 1. Description of sampling sites and characteristics of selected rivers in New Jersey, 2003-04.

[USGS, U.S. Geological Survey; ft^3/s, cubic feet per second; Mgal, million gallons; NA, not applicable; --, no data]

Characteristic	Main stem Elizabeth River	West Branch Elizabeth River	Second River	Third River	Saddle River	Pompton River	Passaic River above confluence
Date sampled	July 31, 2003	August 7, 2003	Oct. 22, 2003	Oct. 23, 2003	Feb. 10, 2004	Dec. 9, 2003	Nov. 18, 2003
Survey number	2003-IICA	2003-IICA	2003-IICB	2003-IICB	2004-IICA	2003-IICB	2003-IICB
Condition/type	Low flow	Low flow	Low flow	Low flow	Low flow	Low flow	Low flow
Latitude of site	40° 41’ 44”	40° 41’ 35”	40° 46’ 53.5”	40° 49’ 33.6”	40 ° 52’ 20.2”	40° 54’ 27.7”	40° 53’ 51.3”
Longitude of site	74° 14’ 32”	74° 15’ 06”	74° 09’ 18.4”	74° 07’ 58.4”	74 ° 05’ 19.2”	74° 15’ 59.1”	74° 16’ 37.9”
USGS streamflow-gaging-station name	Elizabeth River at Ursino Lake	Elizabeth River at Ursino Lake	Second River at Bellville, NJ	Third River at Passaic	Saddle River at Lodi	Pompton River	Pine Brook
USGS streamflow-gaging-station number	01393450	01393450	01392500	01392210	1391500	1388500	1381900
Location of sampling site in relation to existing station	Upstream	Upstream	NA	Downstream	Downstream	Downstream	Downstream
Location of sampling site in relation to USGS head-of-tide sampling station[1]	Upstream	Upstream	NA	NA	NA	Upstream	Upstream
Time sampling initiated	1300	1315	1330	1300	1210	1330	1415
Time sampling ended	1715	1715	1715	1645	1615	1625	1645
Estimated discharge, ft^3/s	[2]12	[2]17.6	[2]22.3	[3]--	NA	NA	NA
Mean discharge at USGS streamflow-gaging station (at time of sampling), ft^3/s	[4]9.3	[4]20	NA	[3]--	[5]99.7	[5]488	[5]624
Total volume of discharge during sampling, Mgal	[2]1.127	[2]2.276	2.252	4.039	13.277	50.2409	29.5507

[1] The USGS head-of-tide sampling station is the sampling station used in the N.J. Toxics Reduction Workplan, Phase I.

[2] Discharge estimated in field at time of sampling.

[3] The discharge value is unknown because there is no streamflow-gaging station at the site, and discharge could not be measured or estimated during the time samples were being collected.

[4] This value is the discharge at the Elizabeth River at Ursino Lake station during the time of sampling. It represents the sum of the discharges in the East and West Branches and the main stem of the Elizabeth River.

[5] Annual average discharge for the USGS streamflow-gaging station listed above. The annual average discharge for the Elizabeth River at Ursino Lake station is 25.9 ft^3/s.

Sampling and Analysis

Sampling was conducted at each of the seven sites with a Trace Organic Platform Sampler (TOPS) equipped with a 50-ft length of pre-cleaned 3/8-inch-diameter Teflon tubing that was run into the center of flow of each stream. On the smaller rivers (Second, Third, Saddle, and Elizabeth), the tubing was held by a cement block that kept the intake approximately 6 inches above the streambed and approximately 3 ft out from the weight. In the Pompton and Passaic Rivers, the tubing was supported by a buoy that kept the intake approximately 1.5 ft below the river surface and approximately 3 ft out from the buoy. One dedicated TOPS sampler was used for all of the sampling and was cleaned between uses by pumping hot, soapy water through the sampler, followed by a rinse with deionized (DI) water, methanol, and a final DI water rinse. The tubing was cleaned between sites by washing with hot soapy water for a minimum of 1 hour, followed by two rinses with DI water, a 1-hour soak in a 10-percent solution of hydrochloric acid, and a final rinse with DI water.

The TOPS contained a 0.5-micron (nominal) glass-fiber canister filter; a 1-micron, pre-baked glass-fiber flat filter; and two cartridges, each containing 150 g of XAD-2 resin (fig. 6). These filters and cartridges were identical to those used in the Phase I sampling. In the TOPS sampler, water is pumped through the canister filter at a rate of 1 to 2 L/min. The filtered water stream is split with one line going to waste and the second passing through a 1-micron flat filter, then through two inline XAD cartridges at a rate not exceeding 200 mL/min (fig. 6). A target volume of 50 L was used for the XAD sample, which required filtering of 300 to 500 L per sample, which was sufficient to capture at least 0.5 g of sediment on the canister filter (if it is assumed that the stream water contained 1 to 2 mg/L of suspended sediment). The one canister filter and the associated flat filters that were used at each site were combined in the laboratory for extraction and analysis. Water that was processed through the filters and XAD columns was collected, and the volume was measured using a Class A glass graduated cylinder. The volumes of water processed for each sample and the suspended sediment and carbon content of the processed water are listed in table 2.

Samples for analysis for trace elements were collected directly from a tee in the inlet line located immediately in front of the TOPS sampler. Samples were collected by attaching a piece of pre-cleaned silicon pump tubing to the tee and placing the tubing through the rotary head of a small peristaltic pump. This line removed water from the inlet to the TOPS, and was pumped for at least 5 minutes before a sample was collected. Filtered samples were collected by attaching a 0.45-micron canister filter (Gelman) to the pump tubing and filling sample bottles directly from the filter outlet. Unfiltered samples were collected by removing the filter and filling the sample bottle directly from the tubing outlet. Equipment blanks were prepared at each site immediately before collecting the river samples by pumping laboratory-grade DI water through the tubing and filter that were to be used for sampling. All tubing, bottles, and filters were precleaned and supplied by the contract laboratory.

Samples were stored on ice during transport to the USGS New Jersey Water Science Center (NJWSC) laboratory in West Trenton, N.J., where the XAD columns were refrigerated and the filters were stored frozen until being sent for analysis. Concentrations of PCBs and dioxin/furans in the dissolved and particulate phases were determined by Severn Trent Laboratories, Knoxville, Tenn., using the Phase I methods (N.J. Department of Environmental Protection, 2001; Bonin and Wilson, 2006). Concentrations of the individual PCB congeners were measured using USEPA Method 1668A–modified (U.S. Environmental Protection Agency, 1999b) and dioxins and difurans were measured following USEPA Method 1613B (U.S. Environmental Protection Agency, 1994). Both of these methods are isotope dilution methods that use high-resolution mass spectrometry to identify and quantify the individual congeners. Concentrations of total and dissolved trace elements were measured by Frontier Geosciences, Seattle, Wash. Cadmium (Cd) and lead (Pb) were measured using USEPA Method 1638 (U.S. Environmental Protection Agency, 1996b), which uses ICP-MS. Concentrations of mercury (Hg) were measured using cold-vapor atomic fluorescence spectrometry (CV-AFS) with USEPA Method 1631B (U.S. Environmental Protection Agency, 1999a), and concentrations of methylmercury (MeHg) were measured using aqueous phase methylation, isothermal gas chromatography (GC) separation, and CV-AFS detection with USEPA Method 1630 (U.S. Environmental Protection Agency, 1998b).

In addition to the samples collected for organic and inorganic analysis, at least four pairs of grab samples were collected at each site for analysis for SS, POC, and DOC. These samples were collected directly from the sampling line at approximately equally spaced intervals throughout the TOPS sampling. The concentration of suspended sediment in these samples was measured at the USGS Kentucky Water Science Center Suspended Sediment Laboratory in Louisville, Kentucky (Sholar and Shreve, 1998). Particulate organic carbon was separated by filtering 60 mL of river water through 25-mm-diameter 1-micron pore-size glass fiber filters. Filtering was performed upon return from the field in the USGS NJWSC laboratory. The filtered water was collected and preserved with 2 mL of concentrated sulfuric acid. The filter was frozen and sent along with the filtered water for analysis of POC and DOC at the USGS National Water Quality Laboratory in Denver, Colo. POC and DOC were analyzed using USEPA Method 440.0 (Zimmerman and others, 1997).

The mass of suspended sediment and carbon trapped on the TOPS filter was calculated by multiplying the volume of water filtered by the mean concentrations of SS (or POC) in the grab samples (Bonin and Wilson, 2006). Early trials in the Phase I sampling had demonstrated that the canister filters allowed approximately 10 percent (by weight) of particles to pass through the filters (consistent with the manufacturer's specifications). Therefore, it was assumed that 10 percent of the calculated mass of suspended sediment broke through the

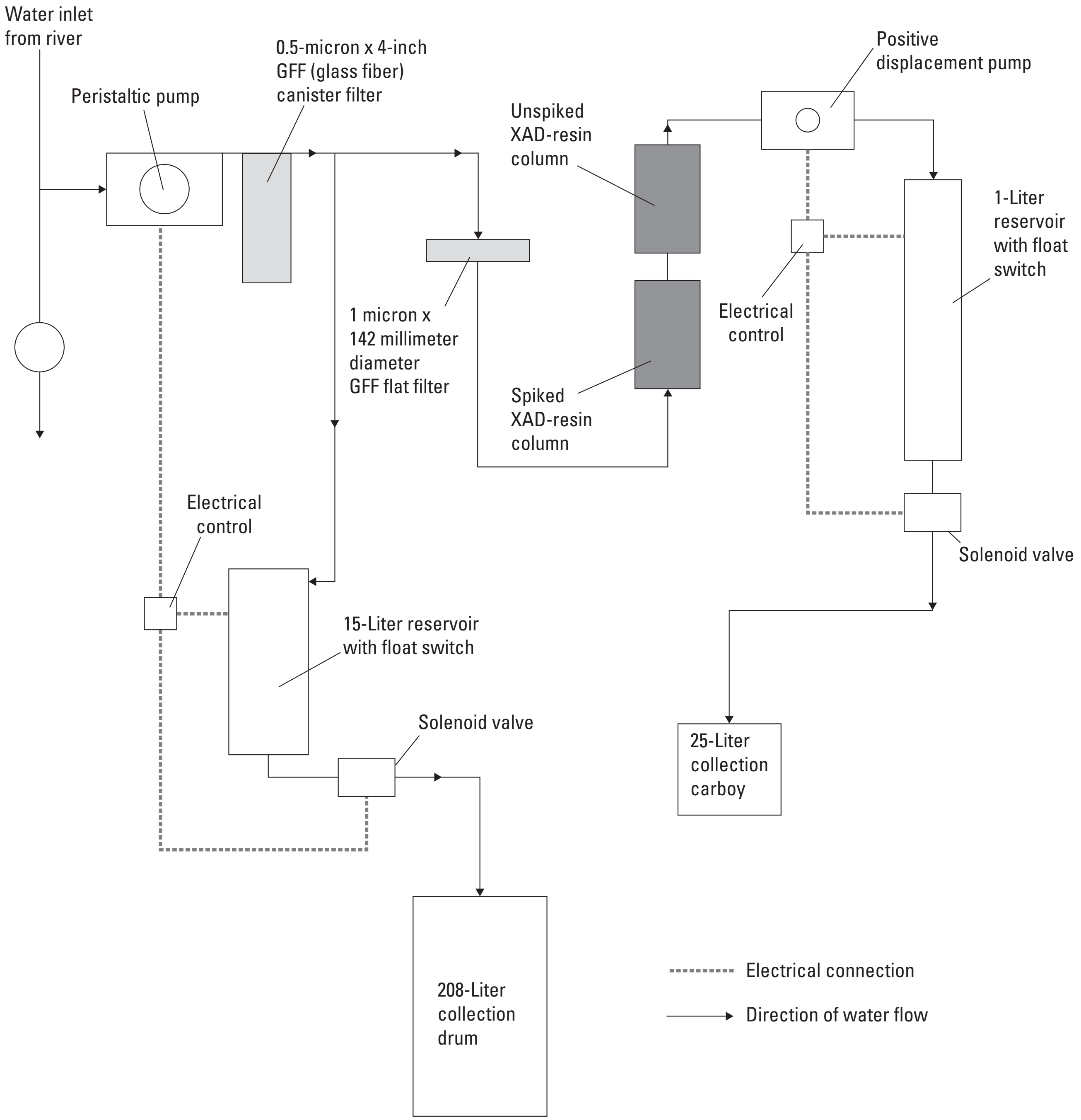


Figure 6. Schematic diagram of a Trace Organic Platform Sampler (TOPS). (From Bonin and Wilson, 2006)

Table 2. Field characteristics of samples collected from selected rivers in New Jersey, 2003-04.

[XAD, chemical exchange resin; L, liters; mg/L, milligrams per liter; mgC/L, milligrams of carbon per liter; SS, suspended sediment; POC, particulate organic carbon; DOC, dissolved organic carbon]

Characteristic	Main stem Elizabeth River	West Branch Elizabeth River	Second River	Third River	Saddle River	Pompton River	Passaic River above confluence
Date sampled	July 31, 2003	August 7, 2003	Oct. 22, 2003	Oct. 23, 2003	Feb. 10, 2004	Dec. 9, 2003	Nov. 18, 2003
Survey number	2003-IICA	2003-IICA	2003-IICB	2003-IICB	2004-IICA	2003-IICB	2003-IICB
Volume through XAD, in liters (measured)	75	50	50	50	50	50	50
Total volume of water through filters sent for analysis, in liters (measured)	634.5	289.74	400	400	375.4	721	690.7
Mean[1] SS concentration, in mg/L (measured)	1.81	4.22	.570	1.19	1.03	2.04	4.79
Corrected mass of SS, in grams (calculated)	1.03	1.10	.21	.43	.35	1.32	2.98
Mean[1] POC concentration, in mgC/L (measured)	.309	1.44	.253	.273	.664	.399	.445
Corrected mass of carbon, in grams (calculated)	.18	.38	.09	.10	.22	.26	.28
Mean[1] DOC concentration, in mg/L (measured)	2.24	8.69	1.55	1.83	3.48	2.56	4.94

[1] Mean suspended sediment, particulate organic carbon, and dissolved organic carbon concentrations are geometric means of the grab sample concentrations.

canister filter and went either to waste or to the flat filters. Because most of the water that passed through the filter was ultimately sent to the waste line (and not to the XAD columns), no further numerical adjustment could be made to the calculated trapped mass of sediment. Therefore, to calculate the mass of suspended sediment (and carbon) trapped on the filters sent for analysis, the geometric mean of the SS (and POC) concentrations in the grab samples that were collected, multiplied by the volume of water filtered, was multiplied by a filter capture efficiency factor of 0.9. The normalized concentrations of sediment-bound chemicals then were calculated by dividing the mass of each individual (or total) chemical species recovered from the filter analysis by the adjusted mass of captured sediment. The concentrations of dissolved constituents were calculated by dividing the reported mass of each constituent recovered from the XAD resin by the volume of water that had been passed through the columns. The volumes of water processed through the filters and columns, the suspended-sediment and carbon concentrations, and the calculated masses of suspended sediment that were recovered on the filters are presented in table 2.

CARP and USGS identifiers were assigned to each sample and field blank collected, using the same convention used for the Phase I sampling except that the first digit of the sample was changed to “2” (for example, 2USGXXXSA) (table 3). The raw and normalized analytical results for PCBs and PCDD/PCDFs as reported by the laboratory in units of nanograms (ng) or picograms (pg) per sample are available from the NJDEP.

Reporting of Analytical Results

The raw data for dissolved and suspended sediment-bound PCBs were blank-corrected in the same manner used in the NJTRWP Phase I sampling program. Raw PCB congener data were removed from the data set if the reported mass was less than three times the mass measured in the method blank. PCDD/PCDF congener data were removed if the reported sample mass was less than five times the mass measured in the method blank. Field and equipment blanks for PCBs and PCDD/PCDFs were not collected in this study due to budget contraints. The samples collected from the Elizabeth River (West Branch and main stem) were analyzed for suspended sediment-bound PCBs and PCDD/PCDFs only, whereas the samples from the other rivers were analyzed for suspended-sediment and dissolved-phase PCBs and for suspended sediment-bound PCDD/PCDFs. Because of the low SS content in the water, less than 1 g of suspended sediment was ultimately collected in the Second, Third, and Saddle River samples (table 2), which is below the minimum target mass (1 g) used in Phase I. Nearly 1,000 L of water would have to be filtered to collect the target mass of 1 g of sediment, which could not be accomplished in the available time. The small mass of suspended sediment that was collected made it difficult to quantify the trace concentrations of PCDD/PCDFs; this also resulted in nearly equal masses of congeners being recovered from the samples and blanks. This ultimately resulted in the reporting of a number of PCDD/PCDF congeners in some samples as “not detected.” Raw trace-element data were reported by the analytic laboratory corrected for method blanks by subtraction. In addition, dissolved trace elements were removed from the data set if the reported sample concentration was less than five times the concentration measured in the associated field equipment blanks.

Occurrence of Organic Compounds and Trace Elements in Water and Suspended Sediment

Summaries of the PCB, PCDD/PCDF, and metal concentrations in samples are presented in tables 4 and 5. The concentrations of the PCBs on a homolog basis are presented in table 6, and the concentrations and toxic equivalencies of the coplanar PCBs are listed in table 7. Concentrations and toxic equivalencies of the dioxin and difuran congeners are listed in table 8.

Polychlorinated Biphenyls and Dioxin-Furans

The concentrations of total dissolved PCBs ranged from 563 pg/L in the water sample from the Second River to 2,510 pg/L in the water sample from the Third River (table 4). The concentrations of total dissolved PCBs in the samples from the Third and the Saddle Rivers were nearly identical (2,510 and 2,270 pg/L, respectively) and were approximately four times the lowest concentration, measured in the Second River (563 pg/L). Concentrations of total suspended sediment-bound PCBs ranged from 87 ng/g (926 ng/g carbon) in the sample from the upper Passaic River to 3,100 ng/g (8,970 ng/g carbon) in the West Branch of the Elizabeth River. Of the three lower Passaic River tributaries sampled, the Saddle River had the highest concentration of suspended sediment-bound total PCBs (2,320 ng/g), followed by the Third River (575 ng/g) and the Second River (194 ng/g) (table 4).

Concentrations of total suspended sediment-bound PCDD/PCDFs ranged from 6,000 pg/g in the Second River to 37,700 pg/g in the Saddle River (table 4). As in the NJTWRP Phase I head-of-tide samples, the suite of congeners was dominated (by weight) by the PCDDs for all rivers. The concentration of total suspended sediment-bound PCDD/PCDFs from the West Branch of the Elizabeth River (9,880 pg/g) was about 35 percent greater than the concentration from the main stem (7,270 pg/g), a concentration similar to that in the suspended sediment from the Pompton River (7,140 pg/g). The concentration of 2,3,7,8-TCDD was less than the EDL in all of these samples; however, two other congeners (1,2,3,7,8-PeCDD and 2,3,7,8-TCDF) that have high toxic equivalence factors (TEF), and thus are of particular interest, were present in the samples

Table 3. Description of sample identifiers for samples collected from selected rivers in New Jersey, 2003–04.

[USGS, U.S. Geological Survey; XAD, chemcial exchange resin; GFF, glass fiber filter; —, not collected]

Characteristic	Main stem Elizabeth River	West Branch Elizabeth River	Second River	Third River	Saddle River	Pompton River	Passaic River above confluence
Date sampled	July 31, 2003	August 7, 2003	Oct. 22, 2003	Oct. 23, 2003	Feb. 10, 2004	Dec. 9, 2003	Nov. 18, 2003
Survey number	2003-IICA	2003-IICA	2003-IICB	2003-IICB	2004-IICA	2003-IICB	2003-IICB
USGS identifier	EBER073103	WBER080703	SECND102203	THIRD102303	SADDL021004	POMP120903	UPPASS111803
GFF filter pack identifier- particulate suspended sediment	2USG10002SA	2USG10005SA	2USG10008SA	2USG10011SA	2USG10017SA	2USG10014SA	2USG10020SA
XAD identifier- dissolved concentrations	—	—	2USG10007SA	2USG10010SA	2USG10016SA	2USG10013SA	2USG10019SA
Metal sample identifier	2USG10003SA	2USG10006SA	2USG10009SA	2USG10012SA	2USG10018SA	2USG10015SA	2USG10021SA

Table 4. Concentrations of total organic compounds in water and suspended-sediment samples from selected rivers in New Jersey, 2003-04.

[XAD, chemical exchange resin; PCBs, polychlorinated biphenyls; PCDD/PCDFs, polychlorinated dibenzo-p-dioxins and difurans; pg/L, picograms per liter; ng/g, nanograms per gram; pg/g, picograms per gram; ng/gC, nanograms per gram of carbon; TEQ, toxic equivalency; <, less than]

Characteristic	Main stem Elizabeth River	West Branch Elizabeth River	Second River	Third River	Saddle River	Pompton River	Passaic River above confluence
Date	July 31, 2003	Aug. 7, 2003	Oct. 22, 2003	Oct. 23, 2003	Feb. 10, 2004	Dec. 9, 2003	Nov. 18, 2003
Sample identifier	EBEL073103	WBEL080703	SECDR102203	THRD102303	SADD021004	POMP120903	PASS111803
Liters through filters	634.5	289.7	400	400	375.4	721	690.7
Liters through XAD columns	75	50	50	50	50	50	50
Mass of suspended sediment collected, in grams	1.03	1.10	0.21	0.43	0.35	1.32	2.98
Total dissolved PCBs, in pg/L	NA	NA	563	2,510	2,270	788	1,000
Total sediment-bound PCBs, in ng/g	806	3,100	194	575	2,320	200	87
Total sediment-bound PCBs, in ng/gC	4,610	8,970	450	2,470	3,690	1,020	926
Total sediment-bound PCDD/PCDFs, in pg/g	7,270	9,880	6,000	11,300	37,700	7,140	9,640
Total sediment-bound PCDD, in pg/g	6,680	8,860	6,000	11,000	34,300	6,490	9,340
Total sediment-bound PCDF, in pg/g	590	1,020	[1]<1	325	3,470	643	300
Sediment-bound 2,3,7,8-TCDD, in pg/g	[1]<8.0	[1]<10	[1]<55.7	[1]<22	[1]<26	[1]<8.0	[1]<3.7
TEQ from PCDD/PCDFs, in pg/g	22	20	.6	19	95	23.5	12
TEQ from PCBs, in pg/g	19	71	2.1	6.3	37	2.8	1.5
Total TEQ, in pg/g as 2,3,7,8-TCDD	41	91	2.7	25	132	26	13.5

[1] Value reported is the estimated detection limit on concentration scale.

Table 5. Concentrations of trace elements in water and suspended-sediment samples from selected rivers in New Jersey, 2003-04.

[Hg, mercury; MeHg, methylmercury; Pb, lead; Cd, cadmium; ng/L, nanograms per liter; mg/L, milligrams per liter; ng/g, nanograms per gram, --, value not calculated or not set; <, less than; BE, blank eliminated]

	Main stem Elizabeth River	West Branch Elizabeth River	Second River	Third River	Saddle River	Passaic River	Pompton River
Sample identifier	2USG1003SA	2USG1006SA	2USG10009SA	2USG10012SA	2USG10018SA	2USG10021SA	2USG10015SA
Date sampled	July 31, 2003	Aug. 7, 2003	Oct. 22, 2003	Oct. 23, 2003	Feb. 10, 2004	Nov. 18, 2003	Dec. 9, 2003
Suspended sediment (mg/L)	1.80	4.22	0.57	1.19	0.93	4.79	2.04
Particulate organic carbon (mg/L)	0.33	1.44	0.25	0.27	0.66	0.45	0.40
Total Hg (ng/L)	3.44	12.2	3.54	3.12	5.15	4.24	3.93
Dissolved Hg (ng/L)	2.45	7.66	[1]BE	2.46	1.26	[1]BE	[1]BE
Suspended sediment Hg (ng/L)	0.99	4.54	[2]3.54	0.66	3.89	[2]4.24	[2]3.93
Suspended sediment Hg (ng/g)	548	1,080	6,210	556	4,180	[2]885	[2]1,930
Total MeHg (ng/L)	<0.025	0.098	<.025	0.028	0.077	0.172	0.058
Dissolved MeHg (ng/L)	<0.025	0.079	<.025	0.025	<.025	0.164	0.036
Suspended sediment MeHg (ng/L)	--	0.019	--	.003	<.077	0.008	0.022
Suspended sediment MeHg (ng/g)	--	4.5	--	2.5	<8.3	1.7	10.8
Total Pb (ng/L)	1,020	2,820	295	606	1,060	675	356
Dissolved Pb (ng/L)	[1]BE	1,490	126	148	[1]BE	[1]BE	[1]BE
Suspended sediment Pb (ng/L)	[2]1,020	1,330	169	458	[2]1,060	[2]675	[2]356
Suspended sediment Pb (ng/g)	567,000	315,000	297,000	386,000	1,140,000	141,000	175,000
Total Cd (ng/L)	133	41	82	22	56	40	18
Dissolved Cd (ng/L)	107	27	79	19	[1]BE	33	[1]BE
Suspended sediment Cd (ng/L)	26	14	3.0	3.0	[2]56	7.0	[2]18
Suspended sediment Cd (ng/g)	14,400	3,310	5,260	2,530	60,200	1,460	8,820

[1] Concentration was blank eliminated using a factor of 5 times the concentration in field or method blank.

[2] Suspended-sediment concentration was calculated as the difference between total and dissolved concentration. Because dissolved concentration was blank eliminated (footnote 1), suspended-sediment concentration represents total metal concentration, and may be an overestimation of actual sediment concentration.

Table 6. Concentrations of polychlorinated biphenyl (PCB) homologs in water and suspended-sediment samples from selected rivers in New Jersey, 2003-04.

[ng/g, nanograms per gram; pg/L, picograms per liter; <, less than; NA, not applicable]

	Sample identifier											
	Main stem Elizabeth River EBEL073103		West Branch Elizabeth River WBEL080703		Second River SECDR102203				Third River THRD102303			
	Suspended sediment		Suspended sediment		Suspended sediment		Dissolved		Suspended sediment		Dissolved	
Homolog group	**ng/g**	**Percent**	**ng/g**	**Percent**	**ng/g**	**Percent**	**pg/L**	**Percent**	**ng/g**	**Percent**	**pg/L**	**Percent**
Mono + di	5.8	0.71	5.8	0.19	10	5.2	100	19	1.8	0.32	190	7.5
Tri	36	4.5	55	1.8	4.9	2.5	190	34	20	3.5	580	23
Tetra	83	10	380	12	19	9.7	150	26	170	30	1,270	51
Penta	200	25	860	28	59	30	90	16	190	33	430	17
Hexa	252	31	1,090	35	65	33	24	4.2	100	18	46	1.9
Hepta	175	22	570	18	30	16	4.5	.80	59	10	[1].00	.00
Octa	47	5.8	120	3.8	6.2	3.2	[1].00	.00	25	4.3	[1].00	.00
Nona	6.0	.74	8.4	.27	[1].00	.00	[1].00	.00	5.7	.99	[1].00	.00
Deca	2.0	.25	1.6	.05	[1].00	.00	[1].00	.00	2.5	.44	[1].00	.00
Total PCBs	806	100	3,100	100	194	100	563	100	570	100	2,510	100

[1] All concentrations within homolog group either were less than the estimated detection level or were removed in the blank elimination procedure.

[2] Elizabeth River head-of-tide average represents average concentration in Elizabeth River samples collected at Hillside, N.J., during Phase I.

[3] Passaic River head-of-tide represents average concentration in Passaic River samples collected at Little Falls, N.J., during Phase I.

Table 6. Concentrations of polychlorinated biphenyl (PCB) homologs in water and suspended-sediment samples from selected rivers in New Jersey, 2003-04.—Continued

[ng/g, nanograms per gram; pg/L, picograms per liter; <, less than; NA, not applicable]

	Sample identifier											
	Saddle River SADD021004				Pompton River POMP120903				Passaic River above confluence PASS111803			
	Suspended sediment		Dissolved		Suspended sediment		Dissolved		Suspended sediment		Dissolved	
Homolog group	ng/g	Percent	pg/L	Percent	ng/g	Percent	pg/L	Percent	ng/g	Percent	pg/L	Percent
Mono + di	36	1.6	630	28	5.7	2.8	200	25	3.3	3.8	240	24
Tri	490	21	1,080	48	17	8.7	240	31	9.3	11	290	29
Tetra	770	33	450	20	60	30	260	33	12	13	330	33
Penta	510	22	93	4.1	65	32	72	9.2	23	26	100	10
Hexa	320	14	18	.78	35	17	13	1.7	22	26	36	3.6
Hepta	130	5.8	[1].00	.00	12	6.1	[1].00	.00	11	13	3.9	.39
Octa	43	1.9	[1].00	.00	4.3	2.2	[1].00	.00	4.2	4.9	[1].00	.00
Nona	10	.43	[1].00	.00	1.1	.57	[1].00	.00	1.6	1.9	[1].00	.00
Deca	5.4	.23	[1].00	.00	.75	.37	[1].00	.00	1.2	1.4	[1].00	.00
Total PCBs	2,310	100	2,270	100	200	100	790	100	88	100	1,000	100

[1] All concentrations within homolog group either were less than the estimated detection level or were removed in the blank elimination procedure.

[2] Elizabeth River head-of-tide average represents average concentration in Elizabeth River samples collected at Hillside, N.J., during Phase I.

[3] Passaic River head-of-tide represents average concentration in Passaic River samples collected at Little Falls, N.J., during Phase I.

Table 6. Concentrations of polychlorinated biphenyl (PCB) homologs in water and suspended-sediment samples from selected rivers in New Jersey, 2003-04.—Continued

[ng/g, nanograms per gram; pg/L, picograms per liter; <, less than; NA, not applicable]

Homolog group	[2]Elizabeth River - Phase I average				[3]Passaic River– Phase I average			
	Suspended sediment		Dissolved		Suspended sediment		Dissolved	
	ng/g	Percent	pg/L	Percent	ng/g	Percent	pg/L	Percent
Mono + di	35	1.4	1,600	34	4.2	1.7	180	11
Tri	170	6.9	1,600	33	25	10	620	36
Tetra	300	12	760	16	64	26	610	36
Penta	420	17	320	6.8	79	32	210	13
Hexa	770	31	320	6.6	45	18	59	3.5
Hepta	600	24	130	2.7	18	7.4	12	.71
Octa	150	6.2	25	.52	6.3	2.6	3.0	.19
Nona	25	1.0	6.0	.12	2.0	.81	1.5	.09
Deca	11	.44	1.0	.02	1.3	.51	.31	.02
Total PCBs	2,480	100	4,760	100	245	100	1,700	100

[1] All concentrations within homolog group either were less than the estimated detection level or were removed in the blank elimination procedure.

[2] Elizabeth River head-of-tide average represents average concentration in Elizabeth River samples collected at Hillside, N.J., during Phase I.

[3] Passaic River head-of-tide represents average concentration in Passaic River samples collected at Little Falls, N.J., during Phase I.

Table 7. Concentrations and toxic equivalent quotients for selected polychlorinated biphenyls in samples of suspended sediment from selected rivers in New Jersey, 2003-04.

[CON, concentration; TEF, toxic equivalence factor; TEQ, toxic equivalency; all values in picograms per gram; PCB, polychlorinated biphenyl; --, not applicable; BE, blank eliminated]

		Main stem Elizabeth River		West Branch Elizabeth River		Second River		Third River		Saddle River		Pompton River		Passaic River above confluence		Elizabeth River head-of-tide Phase I average[2]		Passaic River head-of-tide Phase I average[2]	
Sample identifier		EBEL073103		WBEL080703		SECDR102203		THRD102303		SADD021004		POMP120903		PASS111803					
PCB number	TEF	CON	TEQ[1]	CON	TEQ[1]	CON	TEQ[1]	CON	TEQ[1]	CON	TEQ[1]	CON	TEQ[1]	CON	TEQ[1]	CON	TEQ[1]	CON	TEQ[1]
11	NA	1,120	0.00	1,250	0.00	1,450	0.00	[3]705	0.00	3,830	0.00	2,220	0.00	1,220	0.00	2,800	--	1,300	--
77	0.0005	1,080	.54	1,860	.93	[3]309	[3].00	1,760	.88	4,030	2.0	1,170	.59	359	.18	4,600	2.28	1,050	0.633
81	.0001	[3]72.5	[3].00	[3]86	[3].00	[3]320	[3].00	[3]230	[3].00	[3]218	[3].00	[3]59	[3].00	[3]33	[3].00	160	.016	40	.004
105	.0001	8,300	.83	29,400	2.9	1,950	.20	10,800	1.1	21,600	2.2	3,800	.38	1,840	.18	15,000	1.48	4,600	.457
[4]114	.0005	516	.26	2,200	1.1	[3]392	[3].00	828	.41	1,220	.61	255	.13	128	.06	1,100	.562	420	.208
118	.0001	23,200	2.3	88,800	8.9	6,140	.61	19,200	1.9	56,300	5.6	8,940	.89	4,870	.49	32,000	3.19	9,300	.927
123	.0001	364	.04	1,210	.12	[3]486	[3].00	581	.06	823	.08	163	.02	84	.01	700	.070	210	.021
126	.1	108	11	372	37	[3]369	[3].00	[3]232	[3].00	203	20	[3]66	[3].00	[3]22	[3].00	440	44.1	70	7.00
[4]156/157	.0005	4,470	2.2	18,200	9.1	1,650	.83	2,240	1.1	8,570	4.3	1,240	.62	745	.37	9,200	4.6	1,370	.70
167	.00001	1,960	.02	7,040	.07	[3]373	[3].00	984	.01	3,430	.03	384	.00	286	.00	4,200	.042	490	.005
[4]169	.01	[3]95.4	[3].00	321	3.2	[3]538	[3].00	[3]288	[3].00	[3]218	[3].00	[3]64	[3].00	[3]23	[3].00	350	3.46	85	.845
170	.0001	17,400	1.7	60,100	6.0	3,270	.33	6,160	.62	13,900	1.4	1,390	.14	1,250	.12	49,000	4.95	1,900	.193
180	.00001	48,900	.49	153,000	1.5	9,190	.09	16,500	.16	36,900	.37	3,380	.03	3,620	.04	140,000	1.44	4,800	.048
189	.0001	695	.07	2,300	.23	[3]398	[3].00	[3]207	[3].00	749	.07	96	.01	43	[3].00	1,900	.189	93	.009
Total TEQ from PCBs	--	--	**19**	--	**71**	--	**2.1**	--	**6.2**	--	**37**	--	**2.8**	--	**1.5**	**259,000**	**66**	**25,000**	**11**

[1] Values of TEQ are in units of pg/g as 2,3,7,8-TCDD.

[2] Average values for head-of-tide low-flow samples collected from the Elizabeth River at Ursino Lake, N.J., and from the Passaic River at Little Falls, N.J., during Phase I.

[3] Congener not detected. Value reported is estimated detection level (EDL). The concentration of non-detected congeners was set to 0 when calculating TEQ.

[4] These congeners coeluted with other PCB congeners in analysis of Phase II samples.

Table 8. Concentrations and toxic equivalent quotients for polychlorinated dibenzo-p-dioxins (CDD) and difuran (CDF) congeners in samples of suspended sediment from selected rivers in New Jersey, 2003-04.

[CON, concentration; TEQ, toxic equivalency quotient; TEF, toxic equivalence factor; all values in picograms per gram; -- not determined; BE, blank eliminated; <, less than]

		Sample identifier									
		Main stem Elizabeth River		West Branch Elizabeth River		Second River		Third River		Saddle River	
		EBEL073103		WBEL080703		SECDR102203		THRD102303		SADD021004	
Organic compound	**^{1}TEF**	**CON**	**TEQ**	**CON**	**TEQ**	**CON**	**TEQ**	**CON**	**TEQ**	**CON**	**TEQ**
2,3,7,8-TCDD	1	^{2}<8.0	0.00	^{2}<9.8	0.00	^{2}<56	0.00	^{2}<22	0.00	^{2}<26	0.00
1,2,3,7,8-PeCDD	1	8.9	8.85	^{2}<6.5	.00	^{2}<31	.00	^{2}<13	.00	24	24
1,2,3,7,8,9-HxCDD	.1	BE	0.0	BE	.00	^{2}<41	.00	BE	0.0	BE	.00
1,2,3,4,7,8-HxCDD	.1	13	1.3	11	1.1	^{2}<41	.00	^{2}<16	.00	74	7.4
1,2,3,6,7,8-HxCDD	.1	BE	0.0	BE	0.0	^{2}<45	.00	BE	.00	137	14
1,2,3,4,6,7,8-HpCDD	.01	550	5.5	813	8.1	BE	.00	940	9.4	3,170	32
OCDD	.0001	6,110	.61	8,040	.80	6,000	.60	10,100	1.0	30,900	3.1
2,3,7,8-TCDF	.1	37	3.7	25	2.5	^{2}<53	.00	60	6.0	51	5.1
1,2,3,7,8-PeCDF	.05	11	.53	10	.50	^{2}<27	.00	^{2}<12	.00	19	.97
2,3,4,7,8-PeCDF	.5	BE	.00	BE	.00	^{2}<26	.00	BE	.00	BE	.00
1,2,3,4,7,8-HxCDF	.1	BE	.00	38	3.8	^{2}<25	.00	BE	.00	BE	.00
2,3,4,6,7,8-HxCDF	.1	BE	.00	BE	.00	^{2}<29	.00	BE	.00	BE	.00
1,2,3,6,7,8-HxCDF	.1	BE	.00	BE	.00	BE	.00	BE	.00	BE	.00
1,2,3,7,8,9-HxCDF	.1	^{2}<4.6	.00	^{2}<5.8	.00	^{2}<37	.00	^{2}<12	.00	^{2}<17	.00
1,2,3,4,6,7,8-HpCDF	.01	180	1.8	304	3.1	BE	.00	265	2.7	860	8.6
1,2,3,4,7,8,9-HpCDF	.01	BE	.00	BE	.00	^{2}<44	.00	BE	.00	BE	.00
OCDF	.0001	362	.04	643	.06	BE	.00	BE	.00	2530	.25
Total CDD	--	**6,680**	**16**	**8,860**	**10**	**6,000**	**.60**	**11,000**	**10.4**	**34,300**	**80.5**
Total CDF	--	**590**	**6.1**	**1,020**	**9.9**	**.00**	**.00**	**325**	**8.6**	**3,460**	**14.9**
Total	--	**7,270**	**22**	**9,880**	**20**	**6,000**	**.60**	**11,300**	**19**	**37,800**	**95**

Table 8. Concentrations and toxic equivalent quotients of polychlorinated dibenzo-p-dioxins and difuran congeners in samples of suspended sediment from selected rivers in New Jersey, 2003-04.—Continued

[CON, concentration; TEQ, toxic equivalence quotient; TEF, toxic equivalence factor; all values in picograms per gram; -- not determined; BE, blank eliminated; <, less than]

		Sample identifier							
		Pompton River		Passaic River above confluence		Elizabeth River head-of-tide[3]		Passaic River head-of-tide[3]	
		POMP120903		PASS111803		Average		Average	
Organic compound	**[1]TEF**	**CON**	**TEQ**	**CON**	**TEQ**	**CON**	**TEQ**	**CON**	**TEQ**
2,3,7,8-TCDD	1	[2]<8.0	0.00	[2]<3.7	0.00	5.1	5.1	3.2	3.2
1,2,3,7,8-PeCDD	1	7.0	7.0	4.3	4.3	24	24	3.3	3.3
1,2,3,7,8,9-HxCDD	.1	BE	.00	BE	.00	93	9.3	16.3	1.6
1,2,3,4,7,8-HxCDD	.1	16	1.6	6.1	.61	32	3.2	7.6	.76
1,2,3,6,7,8-HxCDD	.1	35	3.5	BE	.00	84	8.4	20	2.0
1,2,3,4,6,7,8-HpCDD	.01	695	7.0	372	3.7	1,700	17	510	5.1
OCDD	.0001	5,740	.57	8,960	.90	19,500	2.0	10,400	1.0
2,3,7,8-TCDF	.1	17	1.7	[2]<3.9	.00	77	7.7	16	1.6
1,2,3,7,8-PeCDF	.05	7.1	.36	[2]<2.1	.00	20	.99	3.9	.19
2,3,4,7,8-PeCDF	.5	BE	.00	BE	.00	49	24	8.4	4.2
1,2,3,4,7,8-HxCDF	.1	BE	.00	BE	.00	110	11	14	1.4
2,3,4,6,7,8-HxCDF	.1	BE	.00	BE	.00	45	4.5	7.5	.75
1,2,3,6,7,8-HxCDF	0.1	BE	.00	14.2	1.4	170	17	17	1.7
1,2,3,7,8,9-HxCDF	0.1	[2]<5.4	.00	[2]<2.0	.00	2.1	.21	1.3	.13
1,2,3,4,6,7,8-HpCDF	0.01	177	1.8	91	.91	610	6.1	140	1.4
1,2,3,4,7,8,9-HpCDF	0.01	BE	.00	BE	.00	41	.41	9.2	.092
OCDF	0.0001	441	.04	195	.02	1,150	.12	460	.046
Total CDD	**--**	**6,490**	**19.6**	**9,340**	**9.5**	**21,400**	**69**	**10,950**	**17**
Total CDF	**--**	**642**	**3.9**	**300**	**2.3**	**2,270**	**72**	**670**	**12**
Total	**--**	**7,130**	**24**	**9,640**	**12**	**23,700**	**141**	**11,600**	**29**

[1] TEF values from van Leeuwen, 1997.

[2] Value is the reported estimated detection level; actual concentration would be less than this value. TEQ set to 0.0 for non-detected congeners.

[3] Average values for head-of-tide low-flow samples collected from the Elizabeth River at Ursino Lake, N.J., and from the Passaic River at Little Falls, N.J., during Phase I.

from the main stem of the Elizabeth River and the Pompton and Saddle Rivers; neither was present in the Second River. EDLs for 2,3,7,8-TCDD ranged from 3.7 pg/g for the Passaic River to 56 pg/g for the Second River. The high EDL for the Second River sample resulted from the low mass of suspended sediment that was ultimately collected from this river. The congener 2,3,7,8-TCDF was present in all samples except those from the Second and upper Passaic Rivers. Concentrations of 2,3,7,8-TCDF ranged from 17 pg/g for the Pompton River to 60 pg/g for the Third River.

Toxic equivalencies (TEQs) from PCDD/PCDFs were calculated using the TEFs from VanLeeuwen (1997), expressed in picograms per gram as 2,3,7,8-TCDD, ranged from 0.6 pg/g in the sample from the Second River to 95 pg/g in the sample from the Saddle River. This range of values is larger than that found in Phase I Passaic River head-of-tide samples. Another noteworthy result was the nearly identical dioxin/difuran TEQs (20 and 22 pg/g as 2,3,7,8-TCDD, from PCDD/PCDFs only) calculated for both branches of the Elizabeth River (table 4).

As was found in the Phase I work, the coplanar PCBs contribute significantly to the total TEQs for all rivers, especially the West Branch of the Elizabeth River. TEQs for the coplanar PCBs in the samples (table 4) ranged from 1.5 pg/g in samples from the upper Passaic River to 71 pg/g in those from the West Branch of the Elizabeth River. Summing the TEQs from the PCDD/PCDFs and PCBs results in total toxic equivalencies that ranged from 2.7 pg/g for the Second River to 132 pg/g for the Saddle River (table 4).

Mercury, methylmercury, lead, and cadmium

The trace elements mercury, methylmercury, lead, and cadmium were measured in grab samples collected approximately midway through the sampling period at each site. Two samples were collected at each location—one unfiltered sample for analysis for “total” (whole-water) trace elements, and a second filtered sample for analysis for “dissolved” trace elements. The concentration of trace elements associated with the suspended sediment was assumed to be the difference between the two measured concentrations divided by the concentration of suspended sediment. For example, the calculation for lead concentration is

$$\frac{[(\text{Total Pb (ng/L)} - \text{Dissolved Pb (ng/L)}]}{\text{Suspended sediment (g/L)}} = \text{Particulate Pb (ng/g)}.$$

The measured concentrations of total (whole-water) and dissolved trace elements and the calculated concentrations of trace elements in the suspended sediment are listed in table 5. Total Hg concentrations ranged from 3.12 ng/L for the Third River to 12.2 ng/L for the West Branch of the Elizabeth River. Concentrations of total MeHg ranged from non-detectable (<0.025 ng/L) for the main stem of the Elizabeth River and the Second River to 0.172 ng/L for the upper Passaic River. Total Pb concentrations ranged from 295 ng/L for the Second River to 2,820 ng/L for the West Branch of the Elizabeth River, and total Cd concentrations ranged from 18 ng/L for the Pompton River to 133 ng/L for the main stem of the Elizabeth River. Several of the samples had measurable dissolved concentrations, but these were removed by the blank elimination procedure (using a factor of 5 times the field blank). For these samples, the suspended sediment-bound concentrations were determined using only the total metal concentration and the SS concentrations, and therefore are likely to overestimate the sediment-bound concentrations.

As discussed in the Phase I report, the concentration of total trace elements is related to the amount of suspended material that is captured in a sample, especially in systems where the suspended sediment has a high content of trace elements (Wilson and Bonin, 2007). For the most part, the concentrations of trace elements calculated in the suspended sediment of these rivers are very similar to the concentrations measured in Phase I (Wilson and Bonin, 2007), but only a weak correlation was observed between the concentration of SS or POC and these trace-element concentrations. Although the “whole-water” or total trace-element concentrations in these tributaries may be a function of the amount of SS captured, further sampling would be needed to verify this.

Suspended Sediment and Constituent Loads

The loads of suspended sediment and constituents were calculated for each tributary using the available USGS discharge data and the constituent concentrations in the samples collected in this work. River discharge and suspended sediment are key pieces of information needed to construct suspended-sediment rating curves, which show the relation between daily discharge and daily suspended-sediment load. Historic discharge and suspended-sediment data were available for only a few of the rivers studied here. Because the Second and Third Rivers and the two branches of the Elizabeth River have not been routinely gaged or sampled by the USGS for discharge and sediment, the SS-discharge relation based on the 25 years of data from the main stem of the Elizabeth River at Ursino Lake, N.J., was substituted for these rivers where needed. All of these river basins are in close proximity and have comparable land areas and land cover, so this substitution is considered acceptable. Some historic discharge data are available for the Second River (at Bellville, N.J.) and Third River (at Passaic, N.J.), but the data do not cover the entire 25-year period from 1975 to 2000 used to generate loads in Phase I (Wilson and Bonin, 2007). Historical data on discharge, suspended sediment, and POC were not available for the two branches of the Elizabeth River, so loads were estimated using the relations developed in Phase I for the main stem of the Elizabeth River with the discharge proportioned between the two branches. According to the discharge measured in each branch at the time it was sampled, approximately 88 percent of the combined discharge is supplied by the West Branch, and 12 percent is supplied by the main stem (above the confluence).

Rating curves for suspended sediment and POC in the Saddle, Pompton, and upper Passaic Rivers were prepared using the historic SS and POC concentration data available from the USGS National Water Information System database, following the procedures detailed in Wilson and Bonin (2007). The resulting logarithmic rating curves (table 9) and the mean discharge for each day of the available discharge record then were used to estimate daily and average annual suspended sediment or POC loads (table 9), as discussed farther on. Adjustment for bias introduced during the transformation back to non-log load values was made using the Quasi Maximum Likelihood Estimator described by Ferguson (1986). The more complicated Maximum Variance Unbiased Estimator of Cohn and others (1989), which was used by Wilson and Bonin (2007), was not used here because the approximations made with these calculations made its use unlikely to improve the accuracy of the estimates. The daily SS and POC loads were averaged over the period of record, and then multiplied by 365 to obtain the average annual SS or POC load. The suspended-sediment loads then were multiplied by the value for the total PCB or PCDD/PCDF concentrations, or the sediment-bound concentrations of the individual trace elements, to obtain respective constituent loads. The average annual discharge in each river was multiplied by the total dissolved constituent concentrations to obtain yearly average dissolved loads for the constituents of interest.

The average annual suspended-sediment loads, calculated using available discharge and suspended-sediment data for the water years 1975 to 2003 (where discharge data were available; see table 9) are presented in table 10, along with the average annual suspended-sediment loads estimated at the heads-of-tide of the Passaic and Elizabeth Rivers by Wilson and Bonin (2007). The upper Passaic River has the largest load of sediment, 7.4 Mkg/yr, which is about 4 times more than the load calculated for the Pompton River (1.76 Mkg/yr). Suspended-sediment loads for the tributaries emptying into the tidal Passaic River ranged from 0.19 Mkg/yr for the Second River to 1.0 Mkg/yr for the Saddle River. These loads are comparable to less than 1 percent to 4 percent of the annual suspended-sediment load (23 Mkg/yr) estimated in Phase I for the Passaic River at Little Falls, N.J. (table 11).

The discharge and suspended-sediment loads calculated during this study indicate that, of the three lower Passaic River tributaries (the Second, Third, and Saddle Rivers), the Saddle River clearly contributes the largest loads of dissolved (212 g/yr) and suspended sediment-bound PCBs (2,320 g/yr), suspended sediment-bound PCDD/PCDFs (38 g/yr), total TEQs (130 mg/yr, suspended sediment-bound), and loads of total metal. In fact, the total toxicity (TEQ) load from PCDD/PCDFs in the Saddle River (130 mg/yr) is 30 percent greater than the load in the upper Passaic River (100 mg/yr), a river that has more than 6 times the average annual discharge of the Saddle River.

The loads of constituents in the three lower tributaries can be compared to the load crossing the Passaic River head-of-tide station at Little Falls, N.J., to show their relative contributions to the tidal Passaic River (table 11). The Saddle River adds a mass equivalent of 13 percent of the load that was estimated for the Passaic River head-of-tide for dissolved PCBs, 41 percent for suspended sediment-bound PCBs, 15 percent for suspended sediment-bound PCDD/PCDFs, and 15 percent for total TEQ. The Second and Third Rivers each contribute from less than 1 to 2.9 percent of these constituents to the loads at the Passaic River head-of-tide.

Loads in the upper Passaic and Pompton Rivers combine at Two Bridges to form the load that ultimately reaches Little Falls, N.J. The contributions of the Pompton River and the upper Passaic River can be demonstrated by calculating the relative contribution factors between the tributaries. Contribution factors are defined here as the constituent load in the upper Passaic River divided by the corresponding value for the Pompton River. The discharge in the upper Passaic River (145,000 Mgal/yr) is 20 percent greater than the discharge of the Pompton River (117,000 Mgal/yr). The contribution factor, however, is 4.2 for suspended sediment, 1.7 for POC, 1.6 for dissolved PCBs, 2.0 for suspended sediment-bound PCBs, 5.5 for suspended sediment-bound PCDD/PCDFs, 2.0 for TEQ from PCDD/PCDFs, 2.0 for TEQ from coplanar PCBs, and 2.4 for total TEQ. The factor for suspended sediment-bound PCDD/PCDFs more closely matched the ratio for suspended sediment, whereas the ratios for suspended sediment-bound PCBs, total TEQ, and PCDF TEQ are close to the ratio for POC. This may indicate that PCDD/PCDFs are being delivered and transported by suspended sediment, whereas the PCBs are transported mainly by POC. When the corresponding concentration ratios (upper Passaic River /Pompton River) are calculated using data from table 4, the ratio for total PCB concentration in suspended sediment is 0.44, the ratio for dissolved PCB concentration is 1.3, the ratio for suspended sediment-bound total PCDD/PCDF is 1.4, and the ratio for total TEQ is 0.5. These calculations show that although the concentration of suspended sediment-bound PCBs in the upper Passaic River is about 45 percent that in the Pompton River, because the sediment load in the upper Passaic River is about 4 times that in the Pompton River, the upper Passaic River supplies about twice the suspended sediment-bound PCB load and about twice the toxicity load (expressed as total TEQ) supplied by the Pompton River.

The sum of the loads of constituents in the upper Passaic and Pompton Rivers also can be compared with the loads estimated for the Passaic River head-of-tide, which are listed in table 10. The head-of-tide loads (Wilson and Bonin, 2007) were calculated using the 25-year average discharge and sediment loads, and present-day concentrations in samples collected during both low-flow and storm discharges. The combined suspended-sediment load for the Pompton and upper Passaic Rivers totals about 9.2 x10^6 kg/yr, which is

Table 9. Rating curves for suspended sediment and particulate organic carbon in the Pompton, upper Passaic, and Saddle Rivers in New Jersey.

[kg/d, kilograms per day; Q, discharge; Mgal/d, million gallons per day; kg, kilograms; ln, natural logarithm; r^2, correlation coefficient]

River	Period of discharge data used	Length of discharge record, in years	Suspended sediment rating curve (SS= suspended-sediment load in kg/d; Q = mean daily discharge, in Mgal/d)	Particulate organic carbon rating curve (POC = Particulate organic carbon load, in kg/d; Q = mean daily discharge, in Mgal/d)
Pompton	Dec. 30, 1988–Jan. 1, 2003	14	$\ln(SS) = 0.7806 * \ln(Q) + 4.0892$ $r^2 = 0.54$	$\ln(POC) = 0.7337 * \ln(Q) + 2.1803$ $r^2 = 0.53$
Upper Passaic	Oct. 1, 1979–Jan. 1, 2003	23	$\ln(SS) = 0.8592 * \ln(Q) + 4.8345$ $r^2 = 0.59$	$\ln(POC) = 0.8196 * \ln(Q) + 2.0014$ $r^2 = 0.58$
Saddle	Jan. 1, 1975–Oct. 30, 2003	29	$\ln(SS) = 1.1126 * \ln(Q) + 3.1766$ $r^2 = 0.38$	$\ln(POC) = 1.1673 * \ln(Q) + 0.2854$ $r^2 = 0.63$
Second, Third, West Branch and main stem of Elizabeth River	Oct 1, 1975–Sept. 30, 2000	25	[1]$\ln(SS) = 1.557 * \ln(Q) + 1.848$ $r^2 = 0.70$	[1]$\ln(POC) = 1.218 * \ln(Q) - 0.015$ $r^2 = 0.56$
[2]Passaic River at Little Falls, N.J.	Aug. 1975–Sept. 2000	25	[1]$\ln(SS) = 1.209 * \ln(Q) + 3.037$ $r^2 = 0.75$	[1]$\ln(POC) = 1.000 * \ln(Q) + 2.861$ $r^2 = 0.94$

[1] Equation from samples collected on the main stem of the Elizabeth River at Ursino Lake, N.J. (From Wilson and Bonin, 2007)

[2] From Wilson and Bonin, 2007.

Table 10. Estimated loads of suspended sediment, particulate organic carbon, organic compounds, and trace elements in selected rivers in New Jersey.

[Mgal/yr, million gallons per year; kg/yr, kilograms per year; g/yr, grams per year; mg/yr, milligrams per year; PCBs, polychlorinated biphenyls; PCDD/PCDFs, polychlorinated dibenzo-p-dioxins and difurans; TEQ, toxic equivalency; yr, year; NA, not analyzed or not calculated; --, concentration below detection level; BE, blank eliminated]

River	Dates of available discharge data	Mean annual discharge (Mgal/yr)	Suspended sediment load (millions of kg/yr)	Particulate organic carbon load (kg/yr)	Dissolved PCB load (g/yr)	Suspended sediment-bound PCB load (g/yr)	Suspended sediment-bound PCDD/PCDF load (g/yr)	TEQ load from PCDD/PCDF (mg/yr)	TEQ load from PCBs (mg/yr)	Total TEQ load (mg/yr)
Pompton	Dec. 30, 1988 – Jan. 1, 2003	117,000	1.76	196,000	349	352	13	41	4.9	46
Upper Passaic	Oct. 1, 1979 – Jan. 1, 2003	145,000	7.40	340,000	549	644	71	88	11	100
Saddle	Jan. 1, 1975 – Oct. 30, 2003	23,500	1.00	72,800	212	2,320	38	95	37	130
Second (discharge at Bellville, N.J.)	May 26, 1937 – Sept. 30, 1964	4,300	.19	8,600	9.2	37	1.1	.11	.40	.51
Third (discharge at Passaic, N.J.)	May 18, 1977 – Sept. 30, 1997	4,900	.23	10,000	47	132	2.6	4.4	1.4	5.8
[1]Passaic head-of-tide at Little Falls, N.J.	Oct. 1, 1975 – Sept. 30, 2000	251,000	23	589,000	1,600	5,600	260	622	250	870
Main stem Elizabeth (above confluence)	NA	746 [2](12 percent)	.05 [2](12 percent)	1,730 [2](12 percent)	NA	40	.36	1.1	.95	2.1
West Branch Elizabeth	NA	5,474 [2](88 percent)	.37 [2](88 percent)	12,700 [2](88 percent)	NA	1,150	3.7	7.4	26	34
[1]Elizabeth at head-of-tide, Hillside N.J.	Feb. 27, 1978 – Aug. 1, 1994	6,220	.42	14,400	110	1,000	12	56	28	84

Table 10. Estimated loads of suspended sediment, particulate organic carbon, organic compounds, and trace elements in selected rivers in New Jersey.—Continued

[Mgal/yr, million gallons per year; kg/yr, kilograms per year; g/yr, grams per year; mg/yr, milligrams per year; PCBs, polychlorinated biphenyls; PCDD/PCDFs, polychlorinated dibenzo-p-dioxins and difurans; TEQ, toxic equivalency; yr, year; NA, not analyzed or not calculated; --, concentration below detection level; BE, blank eliminated]

River	Dissolved mercury load (g/yr)	Suspended sediment mercury load (g/yr)	Dissolved methylmercury load (g/yr)	Suspended sediment methylmercury load (g/yr)	Dissolved lead load (kg/yr)	Suspended sediment lead load (kg/yr)	Dissolved cadmium load (kg/yr)	Suspended sediment cadmium load (kg/yr)
Pompton	[3]BE	[4]3,400	16	19	[3]BE	[4]310	[4]16	[4]6.1
Upper Passaic	[3]BE	[4]6,500	90	13	[3]BE	[4]1,040	18	11
Saddle	120	4,200	--	--	[3]BE	[4]1,140	[4]60	[4]13
Second (discharge at Bellville, N.J.)	[3]BE	[4]1,200	--	--	2.1	56	1.3	1.0
Third (discharge at Passaic, N.J.)	46	130	.5	.6	2.8	89	.35	.59
[1]Passaic head-of-tide at Little Falls, N.J.	1,030	15,000	--	--	320	2,700	45	23
Main stem Elizabeth (above confluence)	6.9	27	--	--	[3]BE	28	.30	.72
West Branch Elizabeth	160	400	1.6	1.7	[3]BE	[4]117	.56	1.2
[1]Elizabeth at head-of-tide, Hillside N.J.	170	1,100	--	--	43	390	2.8	5.4

[1] Loads calculated using grab samples (From Wilson and Bonin, 2007).

[2] Reported value represents the estimated percentage of the mean annual discharge in the main stem Elizabeth River.

[3] Dissolved concentration was removed by blank elimination (table 5).

[4] Sediment-bound concentration was assumed equal to total metal concentration (footnote 3 and table 5). Therefore, sediment-bound load is an overestimation.

about 40 percent of the average annual load estimated for the Passaic River head-of-tide. The combined POC load for the upper Passaic and Pompton Rivers (536,000 kg/yr) totals 91 percent of the load estimated for the head-of-tide. This may indicate that suspended sediment is trapped somewhere downstream from the confluence, but POC, which would tend to be finer grained, is trapped to a much lesser degree. The larger percentage of POC in the upper Passaic River (58 percent) may reflect the presence of the large wetland area upstream from the confluence (fig. 2). The combined load of dissolved total PCB from the two tributaries is 898 g/yr, or 56 percent of the load crossing the head-of-tide station; the suspended sediment-bound PCB load is 996 g/yr, or 18 percent. The load of suspended sediment-bound PCDD/PCDFs is 84 g/yr, or 32 percent; the TEQ from PCDD/PCDFs is 129 mg/yr, or 21 percent. The TEQ from coplanar (suspended sediment-bound) PCBs is 16 mg/yr, or 6 percent, and the total TEQ load is 146 mg/yr, or 17 percent of the load crossing the head-of-tide. The difference between the summed contaminant loads for the tributaries and those for the head-of-tide reflects the effects of (1) the uncertainty caused by the limited number of samples available to characterize the variation in the tributary loads; (2) the error in the estimation procedures, including the rating curves; (3) processes that could alter the concentrations of dissolved and suspended sediment-bound contaminant species below the confluence, including the presence of unknown sources in this area; (4) possible differences between actual concentrations during storms and those measured in this study during low flow.

The lack of historic discharge and suspended-sediment data makes it difficult to reliably estimate the loads for the West Branch and main stem of the Elizabeth River, the two tributaries that eventually combine and flow past the Elizabeth River head-of-tide (tables 10 and 11). A noteworthy result is that the combined load of suspended sediment-bound PCBs estimated for the two branches (1,190 g/yr) slightly exceeds the total load estimated for the Elizabeth River at the head-of-tide (1,000 g/yr). This difference could be the result of analytic uncertainty, or the assumed contribution of discharge and suspended sediment assigned to each tributary. Alternatively, the concentrations measured during this study may not accurately represent the range of values in the tributaries, the values for discharge or suspended-sediment load may have been greatly overestimated, or suspended sediment-bound PCBs may have been removed somewhere between the confluence and the Phase I sampling site at Hillside, N.J. It is possible that suspended sediment-bound PCBs are being buried or lost (by degradation or volatilization) behind the small dam located on the main stem of the Elizabeth River just upstream from the Hillside sampling site (fig. 5). Because the proportion of the discharge attributed to each branch was assumed, the proportion supplied by each branch and the enrichment factors for the loads are considered to be only rough estimates (table 11). A more complete discharge/suspended-sediment record is needed to improve the estimates of loads. On the basis of the concentration data, however, the West Branch of the Elizabeth River appears to be the more important contributor of PCBs. Although the dioxin/furan concentrations are just slightly greater in the West Branch, the higher concentrations of coplanar PCBs result in greater toxicity (as measured by the TEQ) in the West Branch.

The suspended sediment-bound loads of the selected trace elements were calculated and are also presented in table 10. Loads of sediment-bound Hg range from 130 g/yr in the Third River to 6,500 g/yr in the upper Passaic River. The load of sediment-bound Hg in the upper Passaic River is 6,500 g/yr which is (1.9 times) greater than the average annual load estimated for the Pompton River. The largest loads of sediment-bound Pb (1,140 kg/yr) and Cd (60 kg/yr) were also calculated for the Saddle River. Contribution factors (upper Passaic River load/ Pompton River load) show that the upper Passaic River delivers about 1.9 times more sediment-bound Hg, 0.7 times more MeHg, 3.4 times the Pb, and 1.8 times the sediment-bound Cd than does the Pompton River.

The Second River delivers 8.0 percent of the sediment-bound Hg load, 2.1 percent of the sediment-bound Pb load, and 4.3 percent of the sediment-bound Cd load that was estimated for these trace elements at the Passaic River head-of-tide at Little Falls, N.J. For the lower Passaic River tributaries, the Third River contributes 0.9 percent of the sediment-bound Hg, 3.3 percent of the sediment-bound Pb, and 2.6 percent of the sediment-bound Cd to the sediment-bound load estimated to cross at the head-of-tide. The Saddle River delivers significantly higher loads: 28 percent of the Hg, 42 percent of the Pb, and 57 percent of the Cd (sediment-bound) measured at the head-of-tide. (The high percentage for Cd is likely due to the blank correction affecting the dissolved Cd concentration.) The conclusion is similar to that reached for the organic compounds: the Saddle River contributed a substantially greater sediment-bound trace-element load than the other tributaries to the lower Passaic River.

Table 11. Constituent loads expressed as percentage of the average annual suspended-sediment load for the tributaries to, and the heads-of-tide of, the Elizabeth and Passaic Rivers, New Jersey, 2003-04.

[POC, particulate organic carbon; PCBs, polychlorinated biphenyls; PCDD/PCDFs, polychlorinated dibenzo-p-dioxin and difurans; TEQ, toxic equivalency; --, not determined; <, less than; >, greater than]

River	Percent of discharge	Suspended sediment	POC	Dissolved PCBs	Suspended sediment-bound PCBs	Suspended sediment PCDD/PCDFs	TEQ from PCDD/PCDFs	TEQ from PCBs	Total TEQ
Percent of total load estimated for the Passaic River at Little Falls, N.J.									
Pompton	47	7.7	33	22	6	5	7	2	5
Upper Passaic head-of-tide	58	32	58	34	12	27	14	4	12
Saddle	10	4.3	12	13	41	15	15	15	15
Second	1.7	0.8	1.5	<1	<1	<1	<1	<1	<1
Third	2.0	1.0	1.7	2.9	2	1	<1	<1	>1
Percent of total load estimated for the Elizabeth River at Hillside, N.J.									
Main stem Elizabeth	[1]12	[1]12	[1]12	--	4	3	2	3	3
West Branch Elizabeth	[1]88	[1]88	[1]88	--	[1]15	31	13	93	40

[1] Loads based on estimated discharge.

Chemical characteristics and loads of suspended sediment and constituents by tributary

The characteristics of the PCB and other constituent chemistries and the estimated loads of constituents and sediment were evaluated to determine whether unique characteristics existed that may help identify these tributary sources.

Elizabeth River Tributaries

Summaries of selected values for the Phase II samples, along with corresponding values (means for low-flow samples) for the Phase I samples from the head-of-tide of the Elizabeth River, are presented in table 12. Results of sampling and analysis for Phase I conducted during 2000-03 showed that concentrations of total suspended sediment-bound PCBs in the main stem (head-of-tide) of the Elizabeth River ranged from 725 ng/g to 3,750 ng/g (average of 2,460 ng/g) (Wilson and Bonin, 2007). The two highest concentrations (2,320 and 3,050 ng/g, averaging 2,690 ng/g) measured were in samples collected during low-flow discharge; these samples are the most comparable to the Phase II samples. Total dioxins plus furans in the low-flow discharge samples (Phase I) ranged from 10,300 pg/g to 57,840 pg/g, averaging 23,700 pg/g for the two low-flow samples collected (table 12). Total TEQ values for the two head-of-tide low-flow samples average 209 pg/g.

As a result of the elevated concentrations measured in the main stem, the sampling described in this report was undertaken in the two branches upstream from the head-of-tide with the goals of determining (1) the contribution of suspended sediment and contaminants from these two branches (upstream from the confluence) and (2) whether distinctive characteristics exist in the contaminant chemistry that could serve as a marker for identifying the suspended sediment from each tributary. As previously mentioned, long-term discharge data are not available for either of these branches, so the discharge that was crudely measured at the time the rivers were sampled was used to proportion the flow between the two streams (table 1). It was estimated that the West Branch may supply 80 to 90 percent of the low-flow discharge below the confluence. A greater contribution by the West Branch is consistent with the flows observed at the time the tributaries were sampled.

The concentration of suspended sediment in the West Branch sample was more than 2 times that in the main-stem sample at the time that the samples were collected (4.22 mg/L and 1.81 mg/L, respectively), whereas POC and DOC concentrations in the West Branch (1.44 mg/L and 8.70 mg/L, respectively) were roughly 4 times that in the main stem (0.31 mg/L and 2.24 mg/L, respectively) (table 12). The concentration of suspended sediment-bound total PCBs in the West Branch (3,100 ng/g) was also approximately 4 times that in the main stem (806 ng/g, table 12). The concentration of suspended sediment-bound PCBs in the main stem at the head-of-tide at low flow (average of 2,730 ng/g) is between the two tributary values, but is more similar to the concentration measured in the West Branch (3,100 ng/g). The concentration of suspended sediment-bound total PCDD/PCDFs in the West Branch (9,880 pg/g) was approximately 1.4 times that in the main stem (7,270 pg/g), and both of these concentrations are much lower than those measured downstream at the head-of-tide site during the Phase I sampling (low-flow average 23,700 pg/g). The TEQ values calculated for the PCDD/PCDFs were very similar between the two (20 and 22 pg/g, respectively (table 4)), but the TEQ for the coplanar PCBs in the West Branch (71 pg/g) was more than 3.5 times that in the main stem (19 pg/g (table 4)), causing the total TEQ in the West Branch (91 pg/g) to be about 2 times that in the main stem (41 pg/g (table 12)).

As discussed earlier, these concentrations produce a TEQ load from suspended sediment-bound PCBs and PCDD/PCDFs in the West Branch that is about 16 times that in the main stem (table 10). The estimates show that the average annual sediment-bound toxicity load measured at the head-of-tide (average of 84 mg/yr for both storm and low-flow samples) cannot be attributed to the sum of the loads (36 mg/yr) in the main stem and West Branch (table 12). Although this may indicate the presence of another source of TEQ (and PCDD/PCDFs) between the head-of-tide and where the tributaries converge, additional work would be needed to verify this. On the basis of these results (and assumptions made regarding discharge), however, the West Branch is the likely major contributor of PCBs, PCDD/PCDFs, and toxicity (measured by TEQ) to the main stem at the head-of-tide of the Elizabeth River.

Another goal of this work was to determine whether a distinct chemical signature exists that can be used to identify suspended sediment from either branch. The relative concentrations (percent of total contributed by each congener group) for PCB homologs in the suspended sediment (table 6) were generally the same in both tributaries. The most notable difference observed was that the suspended sediment in the West Branch contained a slightly higher percentage of the tetra- and penta-chlorinated homologs, but these differences are minor. When compared with the average low-flow concentrations measured in Phase I work (table 6), the Phase II samples from the main stem and West Branch contained higher percentages of hexa- to deca-homologs, and lower percentages of mono- to penta-homologs. In other words, there appears to be a shift toward less chlorinated homologs in the sediment collected downstream at the head-of-tide. Of the coplanar congeners that were measurable in the Phase II samples (tables 7 and 13), all coplanar PCBs were present in higher concentrations in the West Branch than in the main stem, although the relative percentages of these congeners were approximately the same in the two samples.

A few PCB congeners were found to be unique to the West Branch. Of the entire suite of congeners that was mea-

Table 12. Concentrations of organic compounds and other selected constituents in samples from tributaries to the main stem of the Elizabeth, Pompton, and Passaic Rivers in New Jersey, 2003-04.

[ft^3/s, cubic feet per second, mg/L, milligrams per liter; pg/L, picograms per liter; ng/g, nanograms per gram; pg/g, picograms per gram; PCBs, polychlorinated biphenyls; PCDD/PCDFs, polychlorinated dibenzo-p-dioxins and difurans; --, not applicable]

Characteristic or constituent	Date	Main stem Elizabeth River	West Branch Elizabeth River	Elizabeth River head-of-tide[1]	Date	Pompton River	Passaic River above confluence	Passaic River head-of-tide[1]
Mean daily discharge, in ft^3/s	Aug. 7, 2003	--	17.6	8.5	Dec. 9, 2003	581	713	1,360
	July 31, 2003	12	--	9.3	Nov. 18, 2003	303	400	700
	April 25, 2001	--	--	10.3	Oct. 17, 2001	59	133	171
Date sampled	--	July 31, 2003	Aug. 7, 2003	--	--	Dec. 9, 2003	Nov. 18, 2003	--
Identifier	--	EBEL073103	WBEL080703	[1]Average	--	POMP120903	PASS111803	[1]Average
Suspended sediment, in mg/L	--	1.81	4.22	3.9	--	2.04	4.79	12.6
Particulate organic carbon, in mg/L	--	.31	1.44	.59	--	.399	.445	.78
Dissolved organic carbon, in mg/L	--	2.24	8.70	3.78	--	2.55	4.94	4.30
Total dissolved PCBs, in pg/L	--	--	--	7,210	--	788	1,000	1,900
Total suspended sediment-bound PCBs, in ng/g	--	806	3,100	2,690	--	200	87	253
Total suspended sediment-bound PCBs, in ng/g of carbon	--	4,570	8,970	26,000	--	847	810	4,200
Total suspended sediment-bound PCDD/PCDFs, in pg/g	--	7,270	9,880	23,700	--	7,140	9,640	11,700
Total TEQ, in pg/g as 2,3,7,8-TCDD (from PCDD, PCDF, and PCBs)	--	41	91	209	--	26	14	37
Total PCB load, in g/yr	--	40	1,150	1,150	--	352	644	7,200
Total PCDD/PCDF load, in g/yr	--	.36	3.7	12	--	13	71	260
Total TEQ load, in mg/yr as 2,3,7,8-TCDD	--	2.1	34	[2]84	--	46	100	[2]870

[1] Concentrations for Phase I samples at head-of-tide are the averages for samples collected on June 9, 2000, and April 25, 2001, for the Elizabeth River at Hillside N.J.; and June 22, 2000, and October 17, 2001, for the Passaic River at Little Falls, N.J.

[2] Total TEQ load from PCDD, PCDF, and PCBs is 25-year average calculated including storm and low-flow discharge loads.

Table 13. Concentrations and toxic equivalencies of selected polychlorinated biphenyls in samples of suspended sediment from the Elizabeth, Pompton, and Passaic Rivers in New Jersey, 2003-04.

[PCB, polychlorinated biphenyl; TEF, toxic equivalence factor; TEQ, toxic equivalency; all concentrations in picograms per gram; CON, concentration; --, not applicable; ND, not detected]

Sample identifier		Main stem Elizabeth River		West Branch Elizabeth River		Elizabeth River head-of-tide[1]		Pompton River		Passaic River above confluence		Passaic River head-of-tide[1]	
		EBEL073103		WBEL080703		Average		POMP120903		PASS111803		Average	
PCB number	**TEF**	**CON**	**TEQ**	**CON**	**TEQ**	**CON**	**TEQ**	**CON**	**TEQ**	**CON**	**TEQ**	**CON**	**TEQ**
11	--	1,120	--	1,250	--	2,950	--	2,220	--	1,200	--	1,580	--
77	0.0005	1,080	0.54	1,860	0.93	6,350	3.2	1,170	0.59	359	0.18	1,050	0.53
81	.0001	ND	.00	ND	.00	184	.018	ND	.00	ND	.00	30	.003
105	.0001	8,300	.83	29,400	2.9	17,000	1.7	3,800	.38	1,800	.18	4,150	.42
114	.0005	516	.26	2,200	1.10	1,450	.73	255	.13	128	.06	360	.18
118	.0001	23,200	2.3	88,800	8.9	34,000	3.4	8,940	.89	4,870	.49	9,100	.91
123	.0001	364	.04	1,210	.12	925	.093	163	.02	84	.01	210	.021
126	.1	108	11	372	37	435	44	ND	.00	ND	.00	54	5.4
156	.0005	4,470	2.2	18,200	9.1	7,900	4.0	1,240	.62	745	0.37	1,150	.58
157	.0005	[2]--	--	[2]--	--	1,650	.83	[2]--	--	[2]--	--	275	.14
167	.00001	1,960	.02	7,040	.07	4,750	.048	384	.00	286	.00	515	.0052
169	.01	ND	.00	321	3.2	405	4.04	ND	.00	ND	.00	54	.54
170	.0001	17,400	1.7	60,200	6.0	61,500	6.15	1,390	.14	1,250	.12	2,050	.21
180	.00001	48,900	.49	153,000	1.5	180,000	1.8	3,380	.03	3,620	.04	4,850	.049
189	.0001	695	.07	2,300	.23	2,300	.23	96	.01	43	.00	92	.0092
Total TEQ	--	--	19	--	71	--	70	--	2.8	--	1.5	--	8.9

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[1] Concentrations for Phase I samples at head-of-tide are the average values for samples collected on June 9, 2000, and April 25, 2001, for the Elizabeth River at Hillside N.J.; and June 22, 2000, and October 17, 2001, for the Passaic River at Little Falls, N.J.

[2] PCB 157 co-eluted with PCB 156 in these samples.

sured, PCBs 5, 10, and 169 were present only in the samples from the West Branch, whereas no congener was unique to the main stem.

PCB 11 was shown in the Phase I sampling to be a potentially useful marker of PCB sources and has been attributed to pigment production and associated waste streams (Litton and others, 2002). The concentrations of PCB 11 were nearly equal in sediment samples from the main and West Branches (1,120 pg/g and 1,250 pg/g, respectively) (table 13). These values are less than the average low-flow value at the head-of-tide station (2,950 pg/g, table 13), but are nearly equal to the value in one of the Phase I low-flow samples (1,000 pg/g in the June 2000 sample). Thus, PCB 11 does not appear to be useful in distinguishing suspended sediment between the two branches. Further investigation of the sources of PCB 11 could facilitate the identification of the sources of PCBs in the two branches.

Although the concentrations of total PCDD/PCDFs are slightly greater in the West Branch (9,880 pg/g) than in the main stem (7,270 pg/g) (table 4), the concentrations are sufficiently similar to preclude their use in identifying the tributary source to the main stem. The concentrations of PCDD/PCDFs in both tributaries are 32 to 40 percent of the average value measured in the low-flow samples from Phase I (23,700 pg/g, table 12). It appears, therefore, that additional source(s) are present downstream from the confluence of these branches. Similarly, the suite of measurable PCDD/PCDFs and their relative concentrations are essentially identical in the two branches and at the head-of-tide, which limits their usefulness for distinguishing the tributaries as sources.

The concentration of sediment-bound Hg was greater in the West Branch of the Elizabeth River, whereas sediment-bound Pb and Cd concentrations were greater in the main stem of the Elizabeth River (table 5). Concentrations of dissolved Hg and Pb were greater in the sample collected from the West Branch of the Elizabeth River, but the concentration of dissolved Cd was greater in the main stem of the Elizabeth River. Methylmercury was detected only in the sample collected from the main stem of the Elizabeth River.

Second, Third, and Saddle Rivers

The Second, Third, and Saddle Rivers are the principal tributaries that empty into the tidal Passaic River downstream from Little Falls, N.J. (the head-of-tide). These three tributaries drain basins of roughly similar size and land use. Although these tributaries receive ground water, for the most part they serve as conduits for stormwater from roads, catch basins, parking lots, and other areas, and thus show rapid response and large fluctuations in discharge during storms. The water transported during low-discharge conditions is precipitation that has infiltrated the uncovered areas of the basin, and would contain a variety of compounds that were spilled onto urban and industrial soils. In contrast, stormwater would contain compounds washed off roads and other paved areas, to some extent diluted directly by precipitation. Thus, the dissolved composition during low-discharge conditions may not be representative of the average yearly dissolved composition of water carried by these streams. In contrast, the suspended sediment transported in these streams during low discharge would be the finest sized particles. These particles are continuously carried by streams during both low- and high-precipitation-driven flow, and therefore would be representative of the composition of the suspended sediment carried in the river annually.

Discharge in the Saddle River has been measured by the USGS at Lodi, N.J., since 1923; the annual average discharge from 1923 to 2005 was 23,500 Mgal/yr (table 1). The Third River was gaged from May 18, 1977, through August 30, 1997; for this period the average daily discharge was 4,900 Mgal/yr. At present (2007) the Second River is not gaged by the USGS but was gaged from 1937 through 1964. During this period, discharge averaged 11,786 Mgal/d, or 4,300 Mgal/yr. It is not known whether the present-day discharge differs significantly from this historic value, as the basin land coverage may or may not have changed substantially over this period; however, these average discharge values are assumed to represent the present-day discharge in the Second River. For comparison, the Saddle River carries about 11 times, the Third River 3.6 times, and the Second River roughly 2 times the water discharged by the main stem of the Elizabeth River. The Elizabeth River Basin has an area and basin characteristics that are very similar to those of the Second and Third River Basins. The Saddle River volume is comparable to about 10 percent of the average annual discharge (251,000 Mgal/yr) of the Passaic River at Little Falls (the head-of-tide gaging station), whereas the Second and Third Rivers are comparable to less than 2 percent.

Considering the similar land use and cover in these river basins, the concentrations of PCBs and dioxin/furans were expected to be similar amongst these rivers. Results of the sampling showed that suspended-sediment concentrations (within a factor of 2) were similar in the Second, Third, and Saddle Rivers, but the carbon (POC and DOC) content of the Saddle River was about 2.5 times the levels in the other two rivers during low-flow conditions (table 2). PCB concentrations, however, differed among the tributaries. The total dissolved PCB concentrations were similar for the Saddle and Third Rivers (2,270 and 2,510 pg/L, respectively), and both were much greater than the total dissolved concentration for the Second River (563 pg/L) (table 4). The concentration of suspended sediment-bound PCBs (2,320 ng/g) was highest in the Saddle River, where it was 4 and 12 times greater than for the Third River (575 ng/g) and Second River (194 ng/g). The concentration of suspended sediment-bound total PCBs was about 9 times that measured in the Passaic River head-of-tide Phase I samples (254 ng/g).

Suspended sediment-bound loads from the Saddle River (2,320 g/yr) were about 40 percent of the average annual load estimated for the Passaic River head-of-tide (5,600 g/yr). PCB

Table 14. Concentrations and toxic equivalent quotients of polychlorinated dibenzo-p-dioxins and difuran congeners in samples of suspended sediment from the Elizabeth, Pompton, and Passaic Rivers in New Jersey, 2003-04.

[TEQ, toxic equivalency; PCBs, polychlorinated biphenyls; all values in picograms per gram; CON, concentration; --, not appplicable; BE, blank eliminated; <, less than]

Sample identifier	Main stem Elizabeth River		West Branch Elizabeth River		Elizabeth River head-of-tide[1]		Pompton River		Passaic River above confluence		Passaic River head-of-tide[1]	
	EBEL073103		WBEL080703		Average		POMP120903		PASS111803		Average	
Compound	CON	TEQ	CON	TEQ	CON	TEQ	CON	TEQ	CON	TEQ	CON	TEQ
2,3,7,8-TCDD	[2]<8.0	0.00	[2]<9.8	0.00	5.1	5.1	[2]<8.0	0.00	[2]<3.7	0.00	3.2	3.2
1,2,3,7,8-PeCDD	8.9	8.85	[2]<6.5	.00	24	24	7.0	7.0	4.3	4.3	3.3	3.3
1,2,3,7,8,9-HxCDD	BE	0.0	BE	.00	93	9.3	BE	.00	BE	.00	16.3	1.6
1,2,3,4,7,8-HxCDD	13	1.3	11	1.1	32	3.2	16	1.6	6.1	.61	7.6	.76
1,2,3,6,7,8-HxCDD	BE	0.0	BE	0.0	84	8.4	35	3.5	BE	.00	19.6	2.0
1,2,3,4,6,7,8-HpCDD	550	5.5	813	8.1	1700	17	695	7.0	372	3.7	512	5.1
OCDD	6,110	.61	8,040	.80	19,500	1.9	5,740	.57	8,960	.90	10,400	1.0
2,3,7,8-TCDF	37	3.7	25	2.5	77	7.7	17	1.7	<3.9	.00	15.8	1.6
1,2,3,7,8-PeCDF	11	.53	10	.50	20	.99	7.1	.36	<2.1	.00	3.9	.19
2,3,4,7,8-PeCDF	BE	.00	BE	.00	49	24	BE	.00	BE	.00	8.4	4.2
1,2,3,4,7,8-HxCDF	BE	.00	38	3.8	110	11	BE	.00	BE	.00	14.3	1.4
2,3,4,6,7,8-HxCDF	BE	.00	BE	.00	45	4.5	BE	.00	BE	.00	7.5	.75
1,2,3,6,7,8-HxCDF	BE	.00	BE	.00	170	17	BE	.00	14.2	1.4	16.9	1.7
1,2,3,7,8,9-HxCDF	[2]<4.6	.00	<5.8	.00	2.1	.21	<5.4	.00	<2.0	.00	1.3	.13
1,2,3,4,6,7,8-HpCDF	180	1.8	304	3.1	610	6.1	177	1.8	91	.91	138	1.4
1,2,3,4,7,8,9-HpCDF	BE	.00	BE	.00	41	.41	BE	.00	BE	.00	9.2	.092
OCDF	362	.04	643	.06	1,150	.12	441	.04	195	.02	460	.046
Total CDD	6,680	16	8,860	10	21,400	69	6,490	19.6	9,340	9.5	11,000	17
Total CDF	590	6.1	1,020	9.9	2,270	72	642	3.9	300	2.4	671	11
Total	**7,270**	**22**	**9,880**	**20**	**23,700**	**140**	**7,130**	**24**	**9,640**	**11.8**	**11,600**	**28**
Total TEQ from PCBs	**--**	**19**	**--**	**71**	**--**	**70**	**--**	**2.8**	**--**	**1.5**	**--**	**8.9**
Total TEQ	**--**	**41**	**--**	**91**	**--**	**210**	**--**	**27**	**--**	**13**	**--**	**37**

[1] Concentrations for Phase I samples at head-of-tide are the average values for samples collected on June 9, 2000, and April 25, 2001, for the Elizabeth River at Hillside N.J.; and June 22, 2000, and October 17, 2001, for the Passaic River at Little Falls, N.J.

[2] Value is the reported estimated detection level; actual concentration would be less than this value. Value not included in TEQ total.

loads from the Second and Third Rivers are estimated to be only a minor percentage of the head-of-tide load.

The PCDD/PCDF content also varied among the tributaries; the concentration of total PCDD/PCDFs in the Saddle River (37,700 pg/g) was about 3 times that in the Third River (11,300 pg/g) and about 6 times that in the Second River (6,000 pg/g) (table 4). In fact, the suspended sediment-bound total PCDD/PCDF concentration in the sample from the Saddle River was second only to that in a sample collected from the Elizabeth River, which had the highest total dioxin-furan concentration (57,500 pg/g, collected June 4, 2003) measured in the Phase I head-of-tide sampling. The total PCDD/PCDF concentrations in the Phase I head-of-tide samples ranged from 10,000 pg/g to 12,800 pg/g of sediment. Thus, although the concentrations in the Second and Third Rivers are similar to that at the head-of-tide, the concentration in the Saddle River is about 3 times greater. Although a number of congeners either were not detected or were removed from each sample by blank elimination (especially for the Second River sample), the PCDD/PCDF concentrations in these three rivers were similar to that in the Passaic River (at the head-of-tide).

As was the case with the Passaic River, OCDD and OCDF (only in the Saddle River) were the dominant congeners in the suspended sediment in all samples. The total TEQ values (sum of PCDD/PCDFs and coplanar PCBs) for these three rivers were 2.7 pg/g (as 2,3,7,8-TCDD) for the Second River, 25 pg/g for the Third River, and 132 pg/g for the Saddle River. For comparison, the average total TEQ (sum of PCDD, PCDF, and coplanar PCBs) for the Passaic River head-of-tide (low-flow average) was 37 pg/g. Thus, the concentration of total PCDD/PCDF and the TEQ from the PCDD/PCDFs and PCBs in suspended sediment from the Saddle River are about 3 times the averages in the suspended sediment collected from the Passaic River at the head-of-tide. These elevated concentrations, combined with the higher average discharges and estimated sediment loads, result in the Saddle River supplying the largest tributary load of total PCDD/PCDF (38 g/yr), TEQ from coplanar PCBs (37 mg/yr), and total TEQ (130 mg/yr) to the tidal Passaic River. Additionally, the Saddle and Third Rivers sediments have a high percentage (more than 70 percent) of toxicity from PCDD/PCDFs—in the Second River the majority of toxicity is from the coplanar PCBs.

The relative concentrations of the PCDD/PCDFs are nearly indistinguishable among these three tributaries; however, because the concentrations of many of the congeners were less than detection levels, especially in the Second River, this similarity represents the similar analytical capabilities and EDLs that were achieved and not actual concentrations.

When only congeners with measurable values are plotted (fig. 7), it is evident that the principal congeners in the Third and Saddle Rivers are the octa- and hepta- congeners (OCDD, 1,2,3,4,6,7,8-HpCDD, OCDF, and 1,2,3,4,6,7,8-HpCDF). The profiles of congeners in suspended sediment from the Saddle and Third Rivers are very similar to those of the congeners in suspended sediment collected during the Phase I low-flow sampling at the Passaic River head-of-tide at Little Falls, N.J. Because the relative concentrations are so similar, the PCDD/PCDFs are likely not useful for identifying the tributary sources.

Only minor differences are apparent between the PCB congener makeup of the suspended sediment from the Saddle and Third Rivers and that from the main stem of the Passaic River (Phase I samples collected during low-flow conditions at the head-of-tide station at Little Falls, N.J.) (fig. 8). The tetra-chlorinated homolog is the principal PCB group in the Saddle River (33 percent), whereas the tetra- and penta-chlorinated homolog dominates in the Third River suspended sediment (fig. 8, table 6). The suspended sediment from the main stem of the Passaic River (Phase I samples) had a slightly higher percentage of the penta-, hexa- and hepta-chlorinated homologs (table 6), and a slightly lower percentage of the tetra-homologs than the sediment from the Saddle River. The Second River has only two dominant homologs, the mono+di and the hexa groups, and to a lesser extent the hepta-, but this distribution may be the result of the many "less-than" values reported for the congeners (due to the small sample mass that was collected).

An inspection of the subset of coplanar PCBs plus PCB 11 revealed slight differences in the makeup of suspended sediment from the Third, Saddle, and main stem of the Passaic Rivers (Phase I Passaic River head-of-tide samples) (table 7). Concentrations of many of the PCBs in the Second River sediment were below the detection levels, including many of the coplanar PCBS, so only a limited comparison can be made with the other tributaries. PCB 11 was present at similar absolute and relative (percent by weight) concentrations in the Second River (1,450 pg/g, 0.75 percent), the upper Passaic River (1,220 pg/g, 1.4 percent), the Pompton River (2,220 pg/g, 1.1 percent) and the Phase I Passaic River head-of-tide (1,560 pg/g, 0.62 percent for low-flow) samples. A higher concentration and lower percentage was found in the sediment from the Saddle River (3,830 pg/g, 0.17 percent), indicating that PCB 11 may be a possible indicator for distinguishing Saddle River sediments.

PCB congener 126 was found at a moderate concentration (203 pg/g) in the Saddle River, but was not present at measurable concentrations in the sediment from the two other tributaries. This congener was found only occasionally in the head-of-tide sampling (Phase I), and only at low concentrations. The concentrations of the other coplanar PCBs 77, 105, 114, and 123 in the various rivers differ by less than a factor of two, and therefore, may not provide useful indicators for distinguishing sediment from these rivers. Concentrations of PCB 118, 156/157, 167, 170, and 180 differ by at least a factor of three, so these compounds may have utility in distinguishing between rivers. These observations particularly apply to the Saddle River sediment, which had the highest concentrations of coplanar PCBS of the three tributaries.

Concentrations of metals varied among the tributaries. Sediment-bound Pb and Cd were highest in the Saddle River (1,140,000 ng/g for Pb, and 60,200 ng/g for Cd), whereas Hg was highest in the Second River (6,210 ng/g). Dissolved Pb

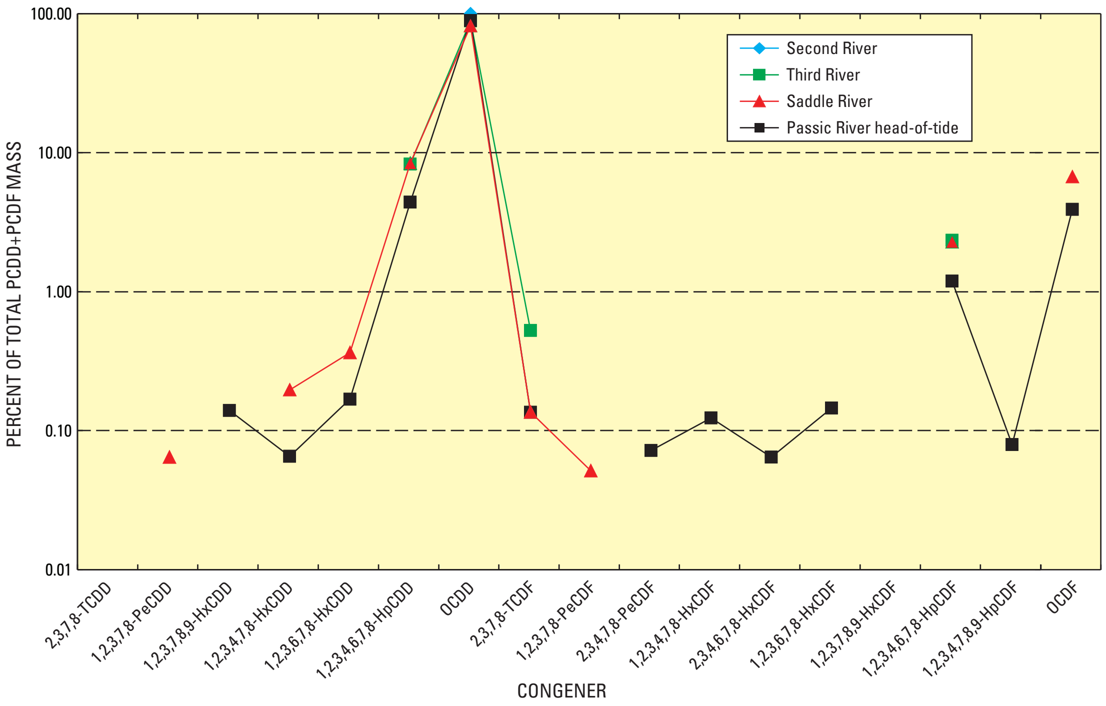


Figure 7. Percentage of polychlorinated dibenzo-p-dioxin and polychlorinated dibenzo-p-difuran congeners, in percent of total dioxins and difurans, in samples of suspended sediment from the Second, Third, Saddle, and Passaic Rivers in New Jersey, 2003-04.

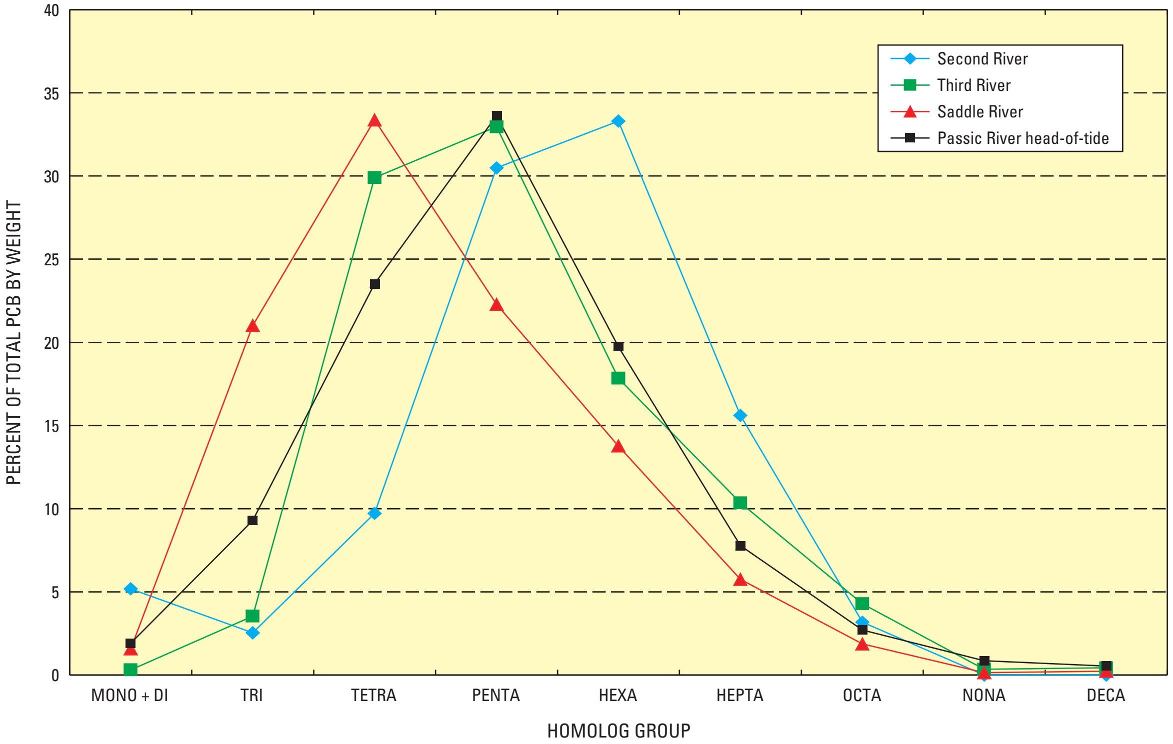


Figure 8. Percentage of polychlorinated biphenyl (PCB) homolog groups in samples of suspended sediment from the Second, Third, Saddle, and Passaic Rivers in New Jersey, 2003-04.

and Hg were highest in the Third River (148 ng/L and 2.46 ng/L, respectively), and dissolved Cd was highest in the Second River (79 ng/L).

Pompton River and upper Passaic River

The Pompton and upper Passaic Rivers converge roughly 3.9 miles upstream from Little Falls, N.J., the site of the Phase I head-of-tide sampling station (figs. 1 and 2). The discharge in the Pompton River is gaged at Pompton Plains, N.J., located approximately 5 miles upstream from the confluence, whereas discharge in the upper Passaic River is gaged approximately 12 river miles upstream from the confluence at Pine Brook, N.J. The average annual discharge (from Oct. 1, 1979, to Oct. 1, 2002) of the upper Passaic River was calculated to be 395.74 Mgal/d, which is 58 percent of the average annual discharge measured at Little Falls during that same period. The difference between the discharge at Little Falls and that at Pine Brook (table 1) can be assumed to be the discharge of the Pompton River that reaches the confluence, and was calculated to be 291 Mgal/d, or 42 percent of the total measured at Little Falls. Generally, the percent contribution of the upper Passaic River to the annual flow measured at Little Falls ranges from 40 to 60 percent, and these long-term values (58 and 42 percent, respectively) may not accurately represent the contribution of the two tributaries for any specific year. The contribution of the upper tributaries varies for a number of reasons. First, water is withdrawn from the Pompton River just upstream from the confluence for public water supply, and the volume of withdrawal can be highly variable depending upon seasonal or other unrelated factors. Second, a sewage-treatment plant is present on Singac Brook, located upstream from the confluence on the Pompton River. The discharge from this plant can vary considerably and can represent a large proportion of Pompton River flow. And finally, a considerable amount of input and loss probably occurs between the streamflow-gaging stations (especially for the upper Passaic River), the confluence, and the station at Little Falls. Thus, at any given time, the actual contributions from the two tributaries could differ from the discharge used in this report to estimate suspended-sediment and constituent loads.

At the time the samples were collected for this study, the mean concentrations of suspended sediment in the Pompton and upper Passaic Rivers were 2 and 4.8 mg/L, respectively, whereas the concentrations of POC were about the same (0.4 mg/L) in both rivers (table 2). These values are typical of conditions during low flow in New Jersey rivers. However, the concentration of total dissolved PCBs in the upper Passaic River (1,000 pg/L) was 1.3 times the concentration of total dissolved PCBs in the Pompton River (788 pg/L), whereas the concentration of total suspended sediment-bound PCBs in the upper Passaic River (87 ng/g) was slightly less than one-half the concentration in the Pompton River (200 ng/g) (table 4). Thus, substantial differences exist in the phase concentrations in the two tributaries. These concentrations in the two tributaries are lower than those measured for the Passaic River head-of-tide during low discharge (average of 1,890 pg/L and 253 pg/g for June 2000 and October 2001, respectively, table 12) or the average concentrations for all sampling events during the Phase I samples (1,700 pg/L and 248 ng/g for storm and low-flow concentrations combined) (Bonin and Wilson, 2006).

The difference in the PCB concentrations between samples from the tributaries and from the main stem of the Passaic River are larger than can be explained by the accuracy of the analytical methods (approximately 10 to 12 percent; Bonin and Wilson, 2006). Although based on only a few samples, the concentrations measured for the Passaic River head-of-tide apparently cannot be explained solely by the water and suspended sediment supplied by these two tributaries. Either the variability in the composition of water and suspended sediment in these two tributaries is much larger than is known from the available data, or an unknown source of PCBs (dissolved and sediment-bound) is present downstream from the confluence of the Pompton and upper Passaic River.

The relative concentrations for the PCB homologs in the suspended sediment (table 6; fig. 9) indicate that the suspended sediment at the head-of-tide exhibits characteristics consistent with a mixture of suspended sediment from just the two upstream tributaries. The congener profile (the percent of total PCBs accounted for by each homolog group) of the suspended sediment from the Passaic River head-of-tide does not fully match the congener profiles in the suspended sediment of either tributary, although it is most similar to that from the Pompton River. The suspended sediment collected at the head-of-tide station had a percent composition of all PCB homologs—except for the mono+di, tri, and penta-PCBs—that was intermediate between the compositions in the Pompton and upper Passaic Rivers. This finding is consistent with the Passaic River head-of-tide samples containing a mixture of suspended sediment from the two tributaries. The closer agreement between the profile for the Pompton River and the head-of-tide sediment supports the hypothesis that the Pompton is the more important tributary source of the PCBs. Further insight into possible source(s) of high total PCBs might be found in the chemistry of sediment buried behind the small dam at Little Falls, located immediately upstream from the head-of-tide sampling site.

The relative composition of dissolved PCB homologs (fig. 10) shows the homolog composition in the Pompton and upper Passaic Rivers and the main stem are very similar, especially for the tetra-, penta-, and hexa homologs. The mono+di and tri-homolog composition of the water at the head-of-tide is problematic, and does not seem to be explained by a mixture of the two tributaries. Specifically, the percentage of the mono+di homologs at the head-of-tide is too low, and that of the tri-homolog is too high, to be explained by simple mixing of the Pompton and upper Passaic River waters. These differences might be explained by analytic difficulties, or by the higher volatility of these homolog groups and the temperature differences between the dates when sampling was

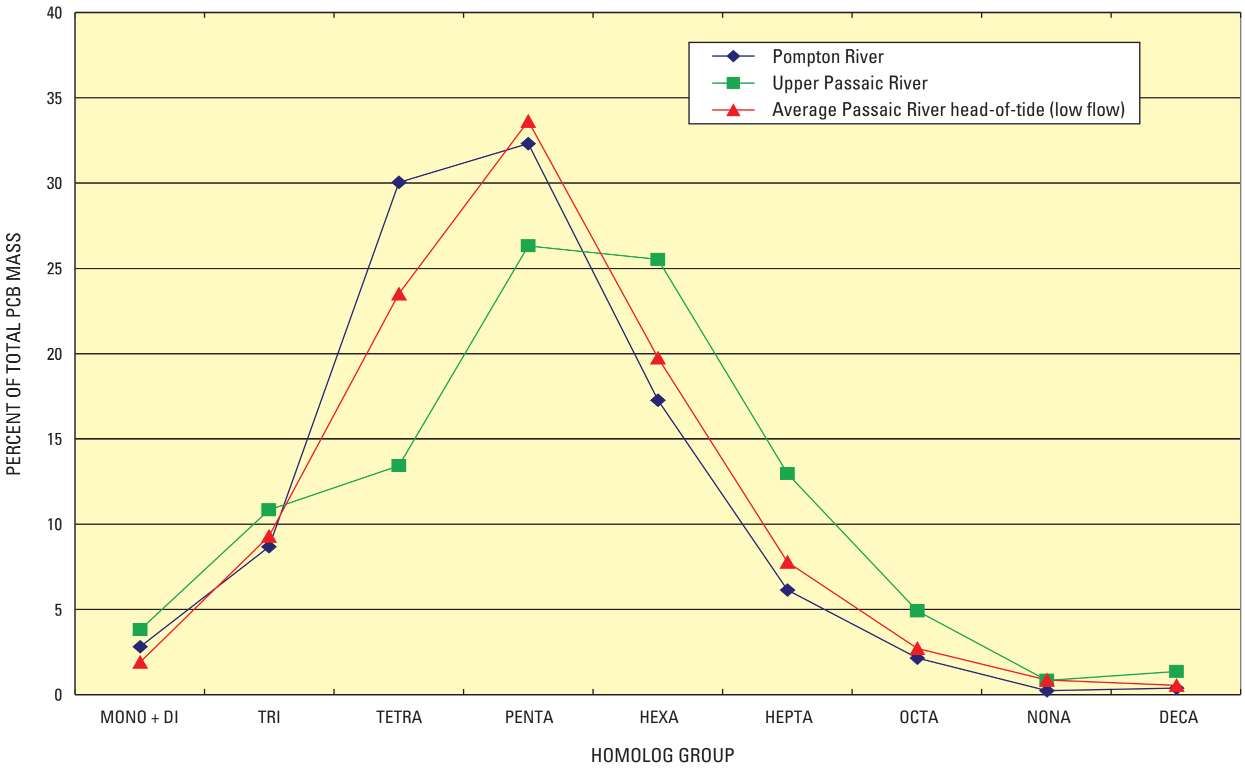


Figure 9. Polychlorinated biphenyl (PCB) homolog distribution, in percent of total mass, in samples of suspended sediment from the Pompton and Passaic Rivers and the Passaic River head-of-tide in New Jersey, 2003-04.

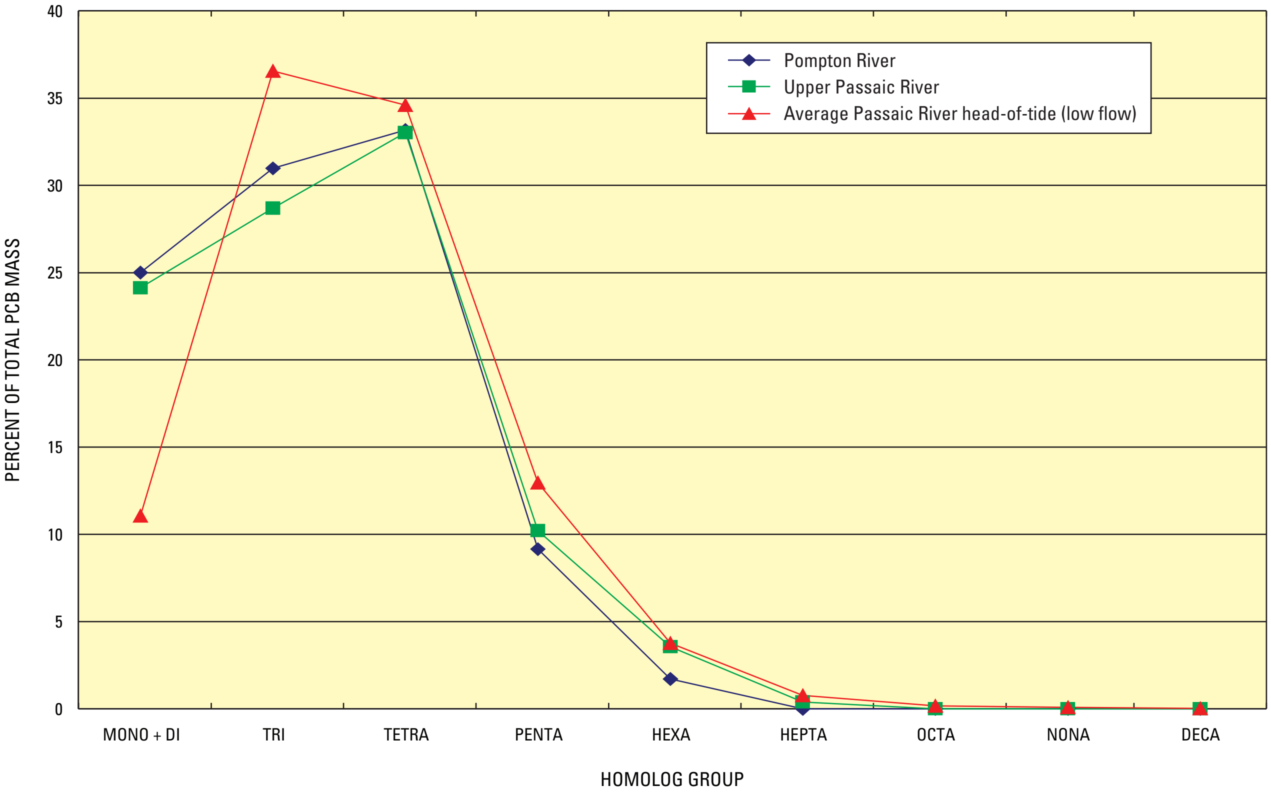
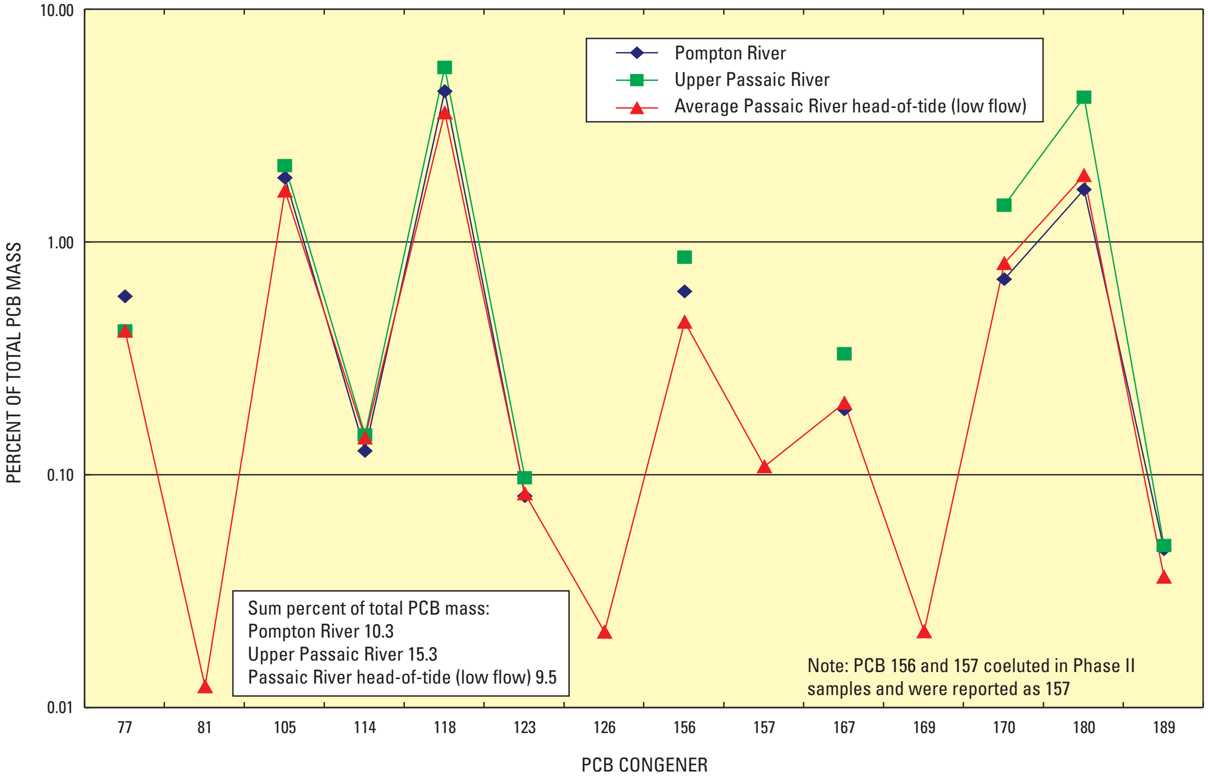


Figure 10. Polychlorinated biphenyl (PCB) homolog distribution, in percent of weight, in samples of water from the Pompton and Passaic Rivers and the Passaic River head-of-tide in New Jersey, 2003-04.

conducted (head-of-tide sampling in the warmer summer and fall months).

On evaluation of the subset of the coplanar PCBs plus PCB 11 (fig. 11) in the suspended sediment, representing the congeners from the penta- and hexa-homolog groups, it was determined that the relative concentrations are similar for most of the individual congeners in the suspended sediment from the Pompton River, upper Passaic River, and Passaic River head-of-tide (Phase I). However, concentrations of several congeners differ greatly among the tributaries. Therefore, it may be possible to use these congeners to discern the amount of suspended sediment from each tributary using individual PCBs such as 11, 77, 105, 118, 156, and 157. For example, the concentration of PCB 11 in the Passaic River at the head-of-tide (1,300 pg/g, average of the low-flow samples) was intermediate between the concentrations in the Pompton River (2,220 pg/g) and those in the upper Passaic River (1,220 pg/g) (table 13). The PCB 11 concentration at the head-of-tide can be explained in terms of mixing of suspended sediment from the tributaries in roughly the same proportions as each tributary contributes water: (0.58 * 1,220 pg/g + 0.42 * 2,220 pg/g) = 1,640 pg/g. This value is nearly equal (within the likely margin of analytical error) to the values measured at the head-of-tide. For this volume-weighted calculation, it was assumed that the suspended-sediment concentration (mass per volume of water) in each tributary was about equal, which was the case for low-flow conditions. However, linear mixing cannot explain the concentrations of all PCBs. For example, the concentration of PCB 77 in the main stem of the Passaic River (low flow) averaged 1,050 pg/g, which was higher than in the upper Passaic River (360 pg/g) and lower than in the Pompton River (1,170 pg/g). Mixing in proportion to discharge results in a concentration of only 700 pg/g (0.58 * 359 pg/g + 0.42 * 1,170 pg/g = 700 pg/g), too low to explain the average value at the head-of-tide. Likewise, for PCB 209 (the most hydrophobic of all PCBs), the concentration was 1,170 pg/g for the upper Passaic River, and 750 pg/g for the Pompton River, but averaged 1,200 pg/g for the Passaic River head-of-tide, which clearly cannot be explained by either tributary source alone, as mixing in proportion to discharge results in an estimated concentration of 994 pg/g (0.58 * 1,170 pg/g + 0.42 * 750 pg/g = 994 pg/g). Thus, any additional source likely contains some congeners at concentrations that are higher than were measured in either tributary—PCB 209, for example; other congeners (77, for example) would have been present at lower concentrations or may have been affected by dilution, volatilization, or degradation in areas downstream from the confluence. However, the fact that a large difference exists between the estimated total PCB load (estimated using the storm plus low-flow concentrations from Phase I sampling and the 25-year average sediment load) at the head-of-tide (7,200 g/yr, table 12) and the sum of the total PCB loads for the Pompton



Sum percent of total PCB mass:
Pompton River 10.3
Upper Passaic River 15.3
Passaic River head-of-tide (low flow) 9.5

Note: PCB 156 and 157 coeluted in Phase II samples and were reported as 157

Figure 11. Polychlorinated biphenyl (PCB) congener distribution, in percent of total mass, in samples of suspended sediment from the Pompton and Passaic Rivers and the Passaic River head-of-tide in New Jersey, 2003-04.

and upper Passaic Rivers (996 g/yr, table 12) shows that a significant source of PCBs may exist downstream from the confluence of these tributaries, or that stormflow concentrations in the Pompton and upper Passaic Rivers may increase substantially from low-flow levels. Further work would be required to verify whether one or both of these hypotheses is correct.

The presence or absence of congeners may be a more useful characteristic for identifying the suspended sediment contributed by the tributaries and, potentially, for identifying additional sources (table 15). Of the entire suite of measured PCBs, it was determined that congeners 4, 10, 16, 17, 19, 27, 43, and 46 were present in suspended sediment only from the Pompton River, whereas PCBs 83, 191, 201, 205, and 207 were present exclusively in the suspended sediment from the upper Passaic River. Only congener 126 was found in the head-of-tide samples but not in the two tributary samples. With the exception of PCB 83 (where detected), the relative concentrations (in weight percentages) of the tributary-unique PCBs generally agree with the percentages measured in the Passaic River head-of-tide suspended sediment (table 15). The PCB 83 value may represent an analytical error in the concentrations or may indicate the presence of a PCB source downstream from the confluence. Likewise, PCB 126 (the PCB congener with the highest toxic equivalency factor (TEF)) was present in the Passaic River head-of-tide suspended sediment (54 pg/g) but was below detection in the suspended sediment from both the upper Passaic and Pompton Rivers (estimated detection levels of 22 and 66 pg/g, respectively). This observation lends support to the presence of other source(s) of PCBs between the confluence and the head-of-tide station.

The concentrations of total sediment-bound PCDD/PCDFs in both of the tributaries (7,140 pg/g in the Pompton River, and 9,640 pg/g in the upper Passaic River) are lower than the average measured in the Passaic River head-of-tide low-flow samples (11,700 pg/g) during Phase I work (table 12). The concentrations of all dioxins and difurans, except 2,3,7,8-TCDD (not present in either sample) and OCDD, were higher in the Pompton River than in the upper Passaic River.

As for the PCBs, a mixture of the two tributaries cannot explain the total PCDD/PCDF concentrations that were measured at the head-of-tide at Little Falls without an additional source of suspended sediment with a high total PCDD/PCDF content. Total concentrations for the PCDD/PCDFs can be misleading, however, because of the dominance of the OCDD and OCDF congeners, which typically are found at concentrations several orders of magnitude greater, and therefore obscure other congener concentrations that may be important. Therefore, evaluation of the individual congeners could be more useful than evaluation of the totals. For example, several of the congeners (1,2,3,4,6,7,8-HpPCDD, 1,2,3,6,7,8-HxCDF, 1,2,3,4,6,7,8-HpCDF, and OCDF, for example) in the Pompton River suspended sediment were present at concentrations simi-

Table 15. Concentrations of selected polychlorinated biphenyl (PCB) congeners in samples of suspended sediment from the Pompton River, upper Passaic River, and main stem of the Passaic River at the head-of-tide, 2003-04.

[pg/g, picograms per gram; ND, congener not detected; value in parentheses is estimated detection level; --, not calculated for ND concentration]

PCB number	Pompton River		Upper Passaic River		Average in the Passaic River head-of-tide[1]	
	Concentration (pg/g)	Percent of weight	Concentration (pg/g)	Percent of weight	Concentration (pg/g)	Percent of weight
4	491	0.24	ND (1500)	--	575	.23
10	149	.07	ND (920)	--	62	.03
16	588	.29	ND (375)	--	830	0.33
17	1,040	.52	ND (304)	--	1,550	.61
19	730	.36	ND (330)	--	650	.26
27	515	.26	ND (215)	--	565	.22
43	270	.13	ND (42)	--	245	.10
46	344	.17	ND (56)	--	490	.19
83	ND (170)	--	107	.12	8,600	3.4
126	ND (66)	--	ND (22)	--	54	.02
191	ND (74)	--	66	0.08	110	.04
201	ND (84)	--	118	.14	285	.11
205	ND (54)	--	39	.04	83	.03
207	ND (81)	--	136	.16	200	.08

[1] Average values for Passaic River head-of-tide were calculated using low-discharge samples collected on June 22, 2000, and October 17, 2001, during the Phase I sampling.

lar to those measured at Little Falls (table 14). If additional sources exist for the PCDD/PCDFs, then the concentrations of these congeners in these additional sources must be similar to the concentrations measured in the Pompton River.

The relative PCDD/PCDF concentration profiles (fig. 12, table 14) generally are similar for the two tributaries, and also generally match the profile for the Passaic River head-of-tide (but note that there are a large number of non-detected and (or) blank censored congeners in all three samples). The Pompton River suspended sediment sample contained about twice the percentage of the hexa-, hepta-, and OCDF congeners as was measured in the suspended sediment from either the upper Passaic River or the head-of-tide of the Passaic River (during Phase I sampling). Several of the penta- and hexa-CDF congeners were absent from the suspended sediment from the two tributaries, whereas measurable concentrations of these compounds were present in the Passaic River head-of-tide suspended sediment. Although it is possible that the true variability in the concentrations of PCDD/PCDFs has not been captured in these few samples, the concentrations also could indicate that an additional source of PCDD/PDCF is present in the area, downstream of the confluence of the Passaic River and the Pompton River.

The concentrations of sediment-bound metals were higher in the Pompton River than in the upper Passaic River (table 5): Pb was 1.2 times higher, Hg was 2.2 times higher, and Cd was 6 times higher in the Pompton River. In contrast, the calculated loads of trace elements (table 10) for these two tributaries show that about 2 times more sediment-bound Hg (6,500 g/yr), 3 times more sediment-bound Pb (1,040 g/yr), and 2 times the sediment-bound Cd load are delivered by the upper Passaic River than by the Pompton River. The combined sediment-bound Hg load from the two tributaries (9,900 g/yr) represents about two-thirds the average annual sediment-bound load estimated in the Phase I work to cross the head-of-tide at Little Falls (15,000 g/yr). The combined load of sediment-bound Pb from the two tributaries (1,350 kg/yr) is about one-half the estimated average annual load at the head-of-tide (2,700 kg/yr); but note that the load for Pb from the two tributaries is likely to be an overestimation (table 10, footnote 4). These results imply that additional sources of Hg and Pb may exist below the confluence of the Pompton and upper Passaic Rivers.

These loads were compared with loads delivered by the Saddle River, the largest tributary below the confluence. The estimates in table 10 show that the Saddle River delivers 40 percent of the sediment-bound Hg, 85 percent of the sediment-bound Pb, and roughly 75 percent of the sediment-bound Cd delivered by the Pompton and upper Passaic Rivers combined—despite the observation that the Saddle River carries only about 10 percent of the total sediment load of the combined Pompton and upper Passaic Rivers.

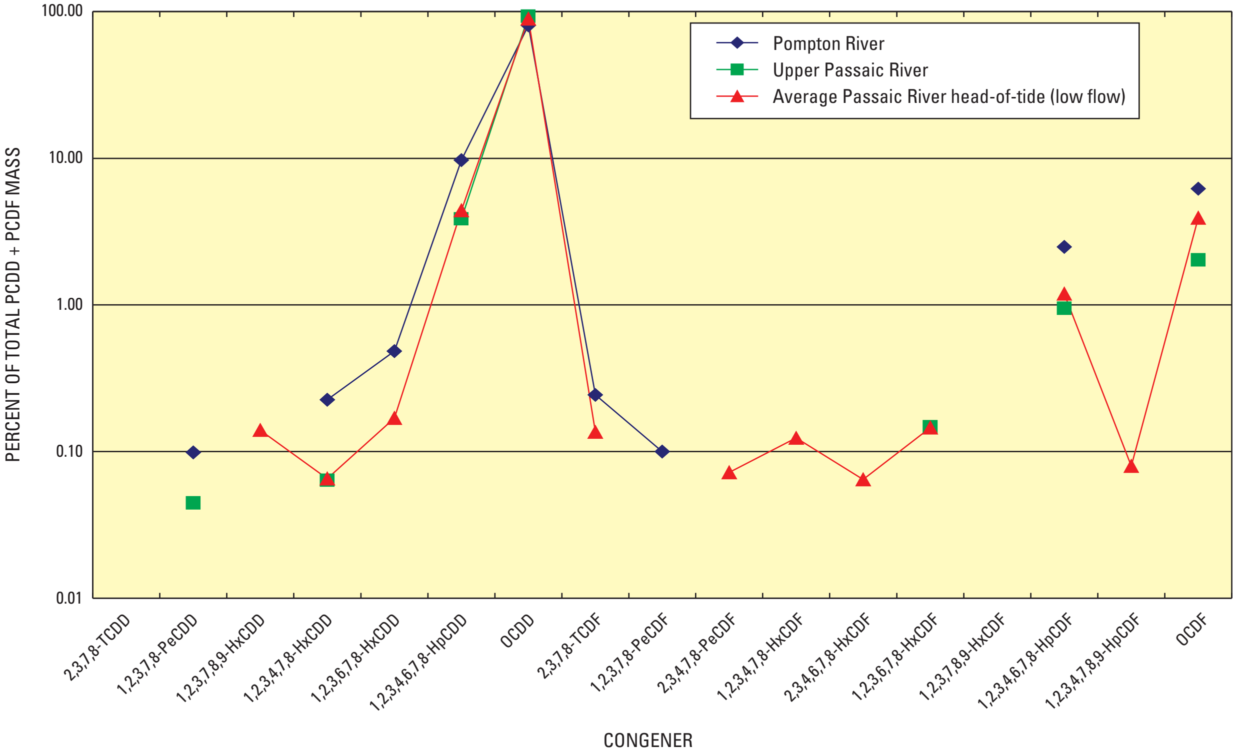


Figure 12. Concentrations of dioxins and difurans, in percent of total mass, in samples of suspended sediment from the Pompton and Passaic Rivers and the Passaic River head-of-tide in New Jersey, 2003-04.

Summary and Conclusions

The N.J. Department of Environmental Protection (NJDEP), as part of its Toxics Reduction Workplan for the New York-New Jersey Harbor (NJTRWP, the New Jersey component of the New York-New Jersey Harbor Estuary Program Contaminant Assessment and Reduction Program, CARP) conducted an extensive Phase I sampling program in cooperation with other agencies to determine the concentrations and loads in the tributaries, estuaries, and kills (streams) associated with Newark and Raritan Bays from 2000 to 2004. As a follow-up to the Phase I work, the U.S. Geological Survey conducted a study from July 2003 to February 2004 to determine the concentrations and loads of organic compounds and trace elements in the upper Passaic, Saddle, and Pompton Rivers, and in the West Branch and main stem of the Elizabeth Rivers.

Samples of suspended sediment and water were collected from July 2003 to February 2004 and analyzed for polychlorinated biphenyls (PCBs), polychlorinated dibenzo-p-dioxins and polychlorinated dibenzo-p-difuran compounds (PCDD/PCDFs), and trace elements in the major tributaries to the tidal Passaic River (the Saddle, Second, and Third Rivers), the two main tributaries to the freshwater Passaic River (the Pompton and upper Passaic Rivers), and the two main tributaries to the freshwater Elizabeth River (the West Branch and the main stem). This sampling was conducted on the basis of results obtained in the Phase I NJTRWP CARP work that was performed at the heads-of-tide and downstream from these rivers. The sampling and analytical methods used in this current work were identical to those of the Phase I work.

Organic chemicals and inorganic trace elements were found in measurable concentrations in water and suspended sediment from each of the rivers sampled. The low suspended-sediment content in the Second River at the time of sampling resulted in poor resolution of the concentrations of the individual PCDD/PCDF congeners for this river.

Pompton and upper Passaic Rivers

Concentrations of suspended sediment-bound PCBs were greater in samples from the Pompton River than in those from the upper Passaic River, whereas concentrations of sediment-bound total PCDD/PCDFs and dissolved PCBs were greater in the upper Passaic River. Total toxic equivalencies (TEQs, the sum of PCDDs, PCDFs, and coplanar PCBs) for suspended sediment were 26 pg/g and 13.5 pg/g for the Pompton River and the upper Passaic River, respectively. Concentrations of sediment-bound Hg, Pb, and Cd were higher in the Pompton River than in the upper Passaic River.

The estimated loads of suspended sediment-bound PCBs (644 g/yr) and PCDD/PCDFs (71 g/yr), total TEQ (100 mg/yr from PCDD/PCDFs and coplanar PCBs), and dissolved PCBs (549 g/yr) were 1.5 to 5.5 times greater in the upper Passaic River than in the Pompton River (352 g/yr, 13 g/yr, 46 mg/yr, and 349 g/yr, respectively). Likewise, sediment-bound Hg, Pb, and Cd loads in the upper Passaic River (6,500 g/yr, 1,040 kg/yr, and 11 kg/yr, respectively) exceeded those calculated for the Pompton River (3,400 g/yr, 310 kg/yr, and 6.1 kg/yr, respectively). Thus, the data indicate that the upper Passaic River was the more important of the two tributaries as a source of these compounds to the head-of-tide station on the Passaic River.

Combined loads of these constituents in the two tributaries were 30 to 80 percent lower than those estimated in the NJTWRP Phase I work for the head-of-tide location on the Passaic River at Little Falls, N.J. This observation indicates that additional sources of these contaminants may exist downriver from the tributary confluence, or that stormflow concentrations may differ greatly from the low-flow concentrations measured here. The PCB homolog composition of the suspended sediment at the head-of-tide suggests mixing from the two upstream tributaries. Thus, any additional sources of PCBs are likely to have a homolog composition similar to that measured in the tributaries. The PCDD/PCDF homolog composition of sediment in the two tributaries also was similar.

Lower Passaic River Tributaries

The Saddle, Second, and Third Rivers drain highly urbanized basins and directly enter the lower estuarine Passaic River. Concentrations of total suspended sediment-bound PCBs and PCDD/PCDFs were greatest in the Saddle River, followed by the Third and Second Rivers. Concentrations of dissolved PCBs were slightly greater in the Third River than in the Saddle River. Concentrations of sediment-bound Hg, Pb, and Cd were also greatest in the Saddle River, followed by the Second River (for Hg and Cd) and Third River (for Pb). Concentrations of dissolved Hg and Pb were greatest in the Third River, and concentrations of dissolved Cd were greatest in the Second River.

Although there is a lack of comprehensive discharge and suspended-sediment data for the Second and Third Rivers, the available data suggest that the Saddle River supplied the largest load of these organic compounds and metals to the Passaic River Estuary. When compared with the loads estimated in Phase I work to cross the head-of-tide, the Saddle River was estimated to contribute an additional 4.4 percent (of the head-of-tide load) to the suspended-sediment load, 13 percent to the dissolved PCB load, 41 percent to the suspended sediment-bound PCB load, 15 percent to the suspended sediment-bound PCDD/PCDF load, and 15 percent to the total load of TEQ toxicity (PCDD/PCDFs plus coplanar PCBs) during an average year to the Passaic River Estuary.

Elizabeth River Tributaries

Concentrations of suspended sediment-bound total PCBs and PCDD/PCDFs, and total TEQs (from PCDDs, PCDFs, and coplanar PCBs) were greater in suspended sediment for the West Branch of the Elizabeth River than the main stem of the river (sampled upstream from the confluence). Concentrations of sediment-bound Hg were greater in the West Branch of the Elizabeth River, but concentrations of sediment-bound Pb and Cd were greater in the main stem. Concentrations of dissolved Hg and Pb were greater in the West Branch, and dissolved Cd was greater in the main stem of the Elizabeth River.

Historic discharge and sediment-concentration data were not available for the main stem and the West Branch of the Elizabeth River, so only rough estimations of loads could be made, using the assumption that 88 percent of the total flow and suspended-sediment load is transported by the West Branch, and 12 percent is transported by the main stem. With these assumptions, the West Branch of the Elizabeth River contributes the larger share of suspended sediment-bound PCBs, PCDD/PCDFs, total TEQs (from PCDDs, PCDFs, and coplanar PCBs), and suspended sediment-bound Hg, Pb, and Cd. The available data suggest that there are additional sources of sediment-bound PCDD/PCDFs, Hg, and Pb between the confluence of the two tributaries and the head-of-tide.

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