# METALS, PESTICIDES, AND SEMIVOLATILE ORGANIC COMPOUNDS IN SEDIMENT IN VALLEY FORGE NATIONAL HISTORICAL PARK, MONTGOMERY COUNTY, PENNSYLVANIA

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 97-4120

*Prepared in cooperation with the*

NATIONAL PARK SERVICE

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*by Andrew G. Reif and Ronald A. Sloto*

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Lemoyne, Pennsylvania
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**U.S. DEPARTMENT OF THE INTERIOR**

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**U.S. GEOLOGICAL SURVEY**

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## CONVERSION FACTORS AND ABBREVIATIONS

| | | |
|---|---|---|
| | Length | |
| inch (in) | 25.4 | millimeter |
| foot (ft) | 0.3048 | meter |
| mile (mi) | 1.609 | kilometer |
| | Area | |
| square mile ($mi^2$) | 2.590 | square kilometer |
| | Discharge | |
| cubic foot per second ($ft^3/s$) | 0.02832 | cubic meter per second |

Temperature

$^oC = (5/9)\ ^oF-32$

Abbreviated water-quality units used in report:

millimeter (mm)
micrograms per gram (µg/g)
micrograms per kilogram (µg/kg)
grams per kilogram (gm/kg)

# METALS, PESTICIDES, AND SEMIVOLATILE ORGANIC COMPOUNDS IN SEDIMENT IN VALLEY FORGE NATIONAL HISTORICAL PARK, MONTGOMERY COUNTY, PENNSYLVANIA

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## ABSTRACT

The Schuylkill River flows through Valley Forge National Historical Park in Lower Providence and West Norriton Townships in Montgomery County, Pa. The concentration of selected metals, pesticides, semivolatile organic compounds, and total carbon in stream-bottom sediments from Valley Forge National Historical Park were determined for samples collected once at 12 sites in and around the Schuylkill River.

Relatively low concentrations of arsenic, chromium, copper, and lead were detected in all samples. The concentrations of these metals are similar to concentrations in other stream-bottom sediment samples collected in the region. The concentrations of iron, manganese, and zinc were elevated in samples from four sites in the Schuylkill River, and the concentration of mercury was elevated in a sample from an impoundment along the river.

The organophosphorus insecticide diazinon was detected in relatively low concentrations in half of the 12 samples analyzed. The organo-chlorine insecticide DDE was detected in all 12 samples analyzed; dieldrin was detected in 10 samples, chlordane, DDD, and DDT were detected in 9 samples, and heptachlor epoxide was detected in one sample. The concentrations of organo-chlorine and organophosphorus insecticides were relatively low and similar to concentrations in samples collected in the region.

Detectable concentrations of 17 semivolatile organic compounds were measured in the 12 samples analyzed. The most commonly detected compounds were fluoranthene, phenanthrene, and pyrene. The maximum concentration detected was 4,800 micrograms per kilogram of phenanthrene. The highest concentrations of compounds were detected in Lamb Run, a small tributary to the Schuylkill River with headwaters in an industrial corporate center. The concentration of compounds in the Schuylkill River below Lamb Run is higher than the Schuylkill River above Lamb Run, indicating that sediment from Lamb Run is increasing the concentration of semivolatile organic compounds in sediment from the Schuylkill River. Concentrations of semivolatile organic compounds are lower in sediment from the Schuylkill River below Myer's Run than above Myer's Run because of the addition of relatively clean sediment from Myer's Run. Samples collected from the floodplain, impounding basin, and wetland along the Schuylkill River contained the lowest concen-trations of semivolatile organic compounds.

Detectable concentrations of polychlorinated biphenyls (PCB's) were measured in 11 of the 12 samples analyzed. The maximum PCB concentration was 37 micrograms per kilogram. Sediment samples from Lamb Run contained the highest concentrations of semivolatile organic compounds and PCB's.

## INTRODUCTION

Valley Forge National Historical Park is a very popular and heavily used recreational area for the large Philadelphia metropolitan area population. Its significance as an important site during the Revolutionary War attracts many visitors from all over the Nation. The park is used by hikers, bikers, picnickers, boaters, and fishermen.

The Schuylkill River and several tributaries, including Myer's Run and Lamb Run, flow through the park and are accessible to the public from boat ramps, picnic areas, and trails. The Schuylkill River flows from its headwaters in east-central Pennsylvania through the city of Reading and Boroughs of Pottstown and Phoenixville to the Delaware River. It receives sediment from industrial, residential, and agricultural sources that may contain contaminants, including metals, pesticides, and semivolatile organic compounds. Lamb Run drains the Valley Forge Corporate Center, which includes the Commodore Semiconductor Group National Priorities List

(Superfund) Site that is contaminated by volatile organic compounds (Roy F. Weston, Inc., 1992). Information on the concentration and distribution of contaminants in stream-bottom sediments in publicly accessible areas is needed by the National Park Service (NPS) for management of Valley Forge National Historical Park.

This report presents the results of chemical analyses of sediment samples from 12 sites in Valley Forge National Historical Park. Each site was sampled once, and samples were analyzed for selected metals, pesticides, total polychlorinated biphenyls (PCB's), total carbon, and semivolatile organic compounds including total polychlorinated napthalenes (PCN's) by the U.S. Geological Survey (USGS) National Water Quality Laboratory in Arvada, Colo. This study was conducted from June 1994 to May 1995 by the USGS in cooperation with the NPS.

Samples were collected as a reconnaissance of bottom-sediment conditions along the Schuylkill River and selected tributaries and floodplains in Valley Forge National Historical Park. Some compounds may not have been detected because of high detection limits and the limited number of compounds analyzed. Further sampling would be needed to determine the extent of the sediment contamination.

### Description of Study Area

The study area is in southeastern Pennsylvania northwest of Philadelphia and includes the part of Valley Forge National Historical Park in Lower Providence and West Norriton Townships in Montgomery County, Pa. (fig. 1). The Schuylkill River flows through the park at river mile 35. The topography of the area is flat to rolling. The area contains an impounding basin that consists of six ponds. Many floodplains along the river contain dredged materials from the Schuylkill River. This 7.5-$mi^2$ part of the park is drained by Myer's Run and Lamb Run, which are small tributaries to the Schuylkill River. These are the only tributaries in the study area. Both tributaries have base-flow discharges of approximately 1 $ft^3/s$ or less. Myer's Run has its headwaters in a residential area and flows through wooded and open space before entering the Schuylkill River. Lamb Run has its headwaters in an industrial complex and flows through wooded and open areas before entering the Schuylkill River. Both tributaries flow under U.S. Route 422, a major 4-lane highway.

### Climate

The study area has a humid, modified continental climate characterized by warm summers and moderately cold winters. The normal (1961-90) mean annual temperature at Phoenixville is 51.7°F. The normal (1961-90) mean temperature for January, the coldest month, is 28°F, and the normal mean temperature for July, the warmest month, is 73.8 °F. The normal (1961-90) annual precipitation at Phoenixville is 42.56 in. (Owenby and Ezell, 1992). Precipitation is about evenly distributed throughout the year; slightly more occurs during the warmer months because of localized thunderstorms.

### Acknowledgments

The authors gratefully acknowledge the assistance of Brian Lambert of the NPS and Roy L. Smith and Robert Davis of the U.S. Environmental Protection Agency (USEPA).

## SAMPLING AND ANALYTICAL METHODS

Samples were collected from depositional areas at the edge of the river, stream, or wetland, where the water depth was 1 to 2 ft. River stage was recorded from the USGS streamflow-measurement station on the Schuylkill River at Pottstown, Pa. Samples collected from wetlands without standing water were collected from near the center of the wetland. An effort was made to collect the most fine-grain stream-bottom sediments at each site because trace contaminants are concentrated in areas high in carbon. Samples were collected by hand from the top 6 to 12 in. of stream-bottom sediment with a polyethylene scoop and sieved through a 2-mm polyethylene sieve to remove gravel. Sand, silt, and clay-size particles that passed through the sieve were collected in a polyethylene collection basin. Stream-bottom sediment was washed through the sieve with native water. Sediment from wetlands without standing water was washed through the sieve with deionized water. The sample was homogenized by mixing and then transferred to clean glass or polyethylene containers and placed on ice for shipment to the USGS laboratory. Between each sample, the equipment was (1) washed with soap, (2) rinsed with deionized water, (3) rinsed with 5 percent hydrochloric acid, (4) rinsed with deionized water, (5) rinsed with methanol, and (6) rinsed with deionized water.

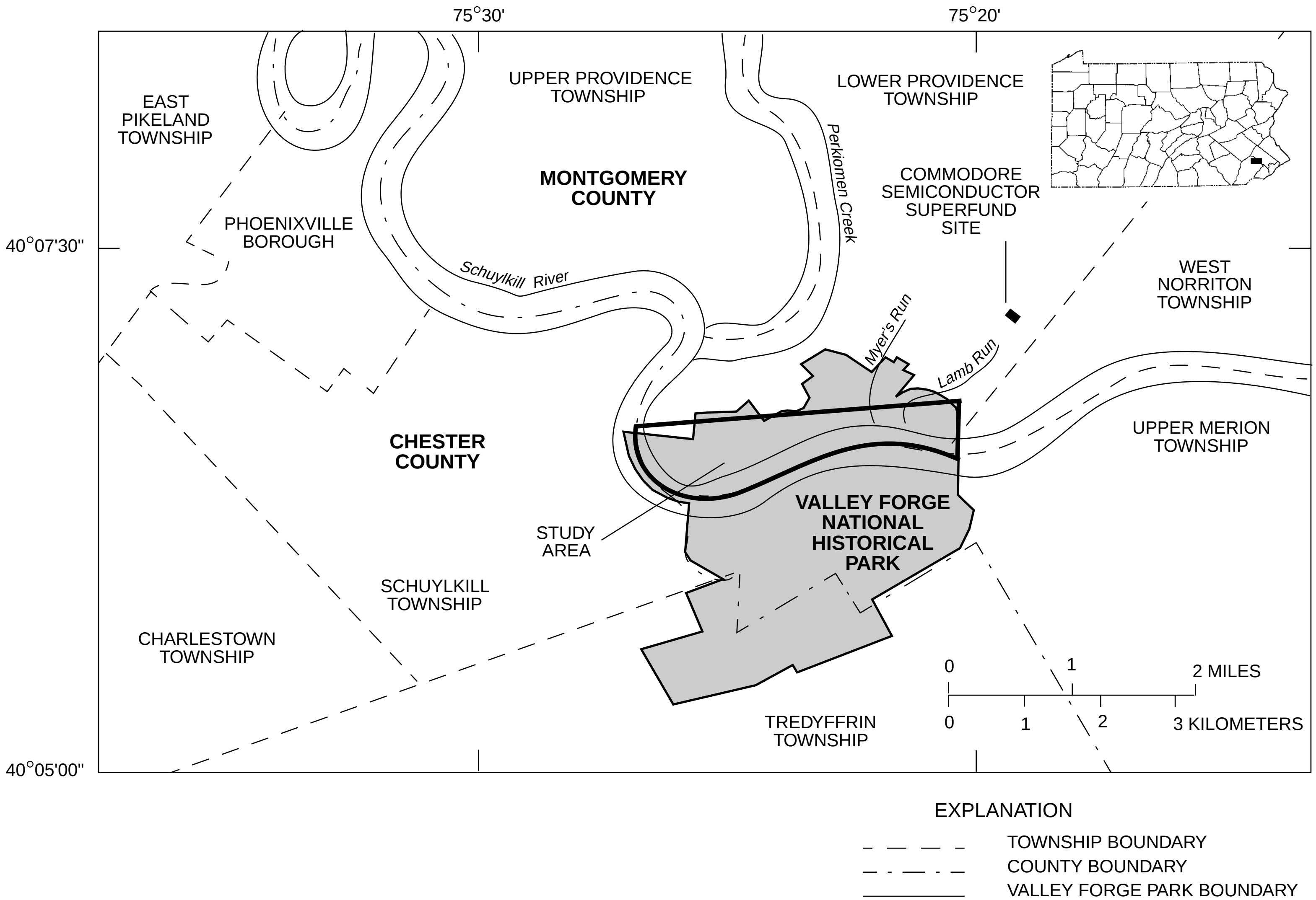



**Figure 1.** Location of study area.

Samples were analyzed for selected metals, pesticides, and semivolatile organic compounds. Selected metals analyzed and reported are arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, and zinc. Metal concen-trations were determined by atomic absorption spectrometry (Fishman and Friedman, 1989). Analyses for organochlorine insecticides included aldrin, chlordane, DDD, DDE, DDT, dieldrin, endosulfan, endrin, heptachlor, heptachlor epoxide, lindane, methoxychlor, mirex, perthane, and toxaphene. Analyses for organophosphorus insecticides included diazinon, ethion, malathion, methyl parathion, parathion, and trithion. Concentrations of organochlorine and organophosphorus pesticides were determined by gas chromatography using a flame photometric detector (Wershaw and others, 1987). Semivolatile organic compounds analyzed are listed in table 1. Concentrations of semivolatile organic compounds were determined by gas chromatography using a mass spectrometric detector (Wershaw and others, 1987). Total PCB's are the sum of penta-, hexa-, hepta-, and octachlorinated biphenyl homologs. Total carbon concentration was determined by the induction furnace method (Wershaw and others, 1987).

***Table 1.*** *Polychlorinated biphenyls, polychlorinated napthalenes, and semivolatile organic compounds analyzed and detection limits in samples of stream-bottom sediment from Valley Forge National Historical Park, Montgomery County, Pennsylvania, June 1994 through May 1995*

[All values are total concentrations in micrograms per kilogram]

| Compound | Detection limit | Compound | Detection limit |
|---|---|---|---|
| Acenaphthene | 200 | Acenaphthylene | 200 |
| Anthracene | 200 | Benzo[a]anthracene | 400 |
| Benzo[b]fluoranthene | 400 | Benzo[k]fluoranthene | 400 |
| Benzo[a]pyrene | 400 | Benzo[g,h,i] perylene | 400 |
| n-Butyl benzyl phthalate | 200 | Bis(2-chloroethoxy)methane | 200 |
| Bis(2-chloroethyl)ether | 200 | Bis(2-chloroisopropyl)ether | 200 |
| 4-Bromophenyl phenyl ether | 200 | Parachlorometa cresol | 600 |
| 2-Chlorophenol | 200 | 2-Chloronaphthalene | 200 |
| 4-Chlorophenyl phenyl ether | 200 | Chrysene | 400 |
| 1,2,5,6-Dibenzanthracene | 400 | Di-n-butyl phthalate | 200 |
| 2,4-Di-chlorophenol | 200 | 2,4-DP | 200 |
| 4, 6-Dinitro-ortho cresol | 600 | 2, 4-Dinitrophenol | 600 |
| 1,2-Dichlorobenzene | 200 | 1,3-Dichlorobenzene | 200 |
| 1,4-Dichlorobenzene | 200 | Diethyl phthalate | 200 |
| Dimethyl phthalate | 200 | 2,4-Dinitrotoluene | 200 |
| 2,6-Dinitrotoluene | 200 | Bis(2-ethyl hexyl)phthalate | 200 |
| Fluorene | 200 | Fluoranthene | 200 |
| Hexachlorobenzene | 200 | Hexachlorobutadiene | 200 |
| Hexachlorocyclopentadiene | 200 | Hexachloroethane | 200 |
| Indeno(1,2,3-cd)pyrene | 400 | Isophorone | 200 |
| Naphthalene | 200 | Nitrobenzene | 200 |
| n-Nitrosodimethylamine | 200 | n-Nitrosodiphenylamine | 200 |
| n-Nitrosodi-n-propylamine | 200 | 2-Nitrophenol | 200 |
| 4-Nitrophenol | 600 | Phenanthrene | 200 |
| Pyrene | 200 | Pentachlorophenol | 600 |
| Phenol | 200 | Di-n-octyl phthalate | 400 |
| 1,2,4-Trichlorobenzene | 200 | 2,4,6-Trichlorophenol | 600 |
| Polychlorinated biphenyls | 1 | Polychlorinated napthalenes | .1 |

Detection limits for some compounds vary because they are set on the basis of quality-assurance testing. All results are reported as dry weights.

## SAMPLING SITES

The 12 sampling sites (fig. 2) were chosen in areas of concern to the NPS. These areas are in parts of the park that are publicly accessible although access to some is difficult. All references to edge of water were determined looking in a downstream direction.

The sample from the Schuylkill River at Betzwood boat ramp (site 1) (latitude 40°06'30", longitude 75°25'23") was collected from the stream bottom 10 ft upstream of the boat ramp and 5 ft from the left edge of the water in 2 ft of water. The river stage of the Schuylkill River at Pottstown during sample collection was 2.77 ft. The area adjacent to the sampling site contains picnic tables and a parking lot and provides easy access to the river.

The sample from the Schuylkill River at Betzwood upstream of boat ramp (site 2) (latitude 40°06'30", longitude 75°25'23") was collected from the stream bottom 300 ft upstream of the boat ramp and 7 ft from the left edge of the water in 2 ft of water. The river stage of the Schuylkill River at Pottstown during sample collection was 2.77 ft. The sampling location is adjacent to the end of the picnic tables and parking lot. Access to the river is limited by a 10 ft dropoff to the river.

The sample from the Schuylkill River below Lamb Run (site 3) (latitude 40°06'36", longitude 75°25'42") was collected from the stream bottom 100 ft downstream of Lamb Run and 2 ft from the left edge of the water in 2 ft of water. The river stage of the Schuylkill River at Pottstown during sample collection was 2.70 ft. The sampling site is adjacent to an old stone house and the hiking trail that runs along the river. Access to the river from the trail at this site is limited to a rocky area at the confluence of Lamb Run.

The sample from Lamb Run at Valley Forge (site 4) (latitude 40°06'42", longitude 75°25'43") was collected from the stream bottom 0.25 mi upstream of the Schuylkill River and 1 ft from the right edge of the water in 2 ft of water. The sample was collected in a depositional area behind a fallen tree. The site is not in a heavily used part of the park, but it is easily accessible from park roads.

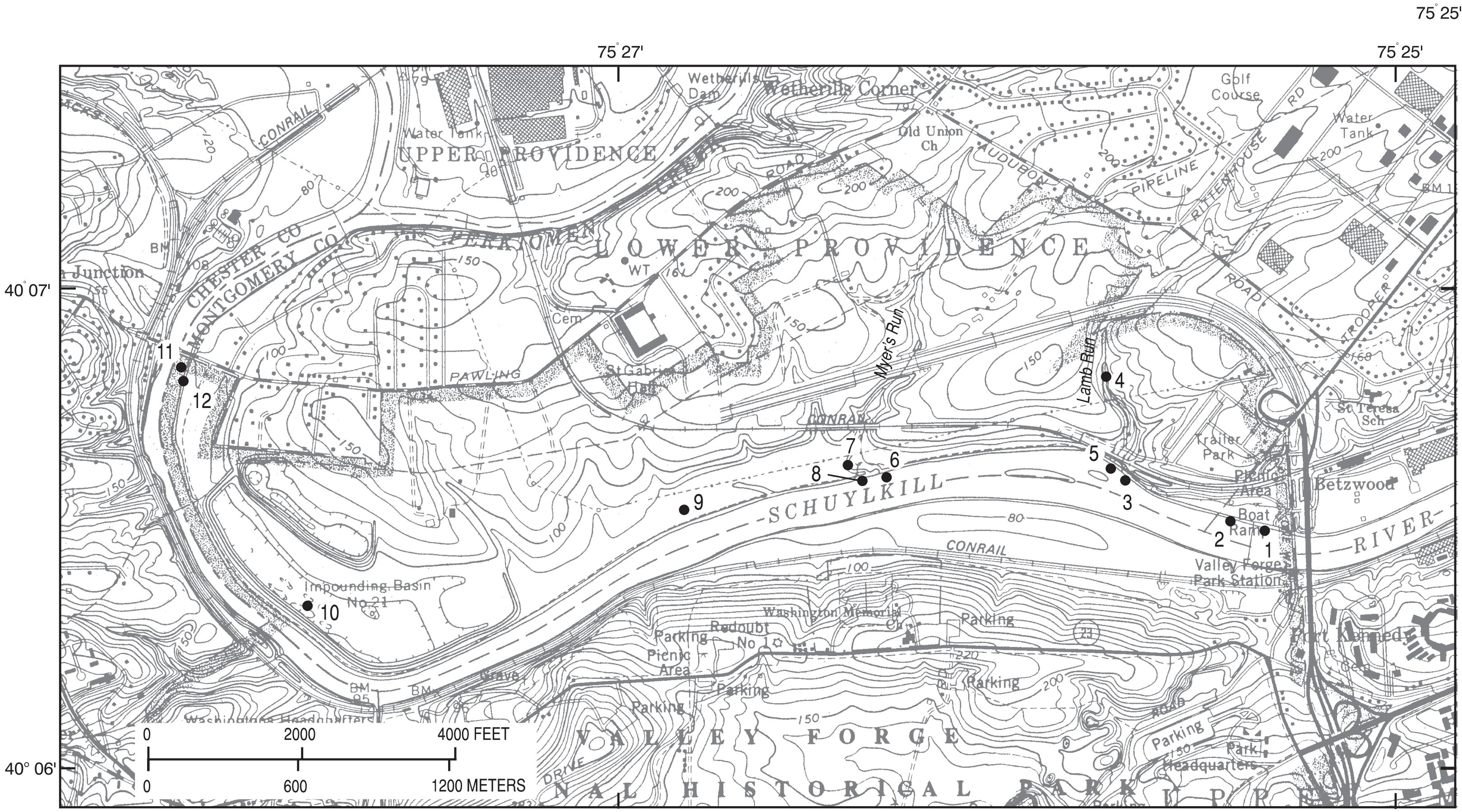
The sample from the Schuylkill River above Lamb Run (site 5) (latitude 40°06'38", longitude 75°25'44") was collected from the stream bottom 100 ft upstream of Lamb Run and 2 ft from the left edge of the water in 2 ft of water. The river stage of the Schuylkill River at Pottstown during sample collection was 2.70 ft. The sampling site is adjacent to the hiking trail that runs along the river. Access to the river from the trail at this site is limited to a rocky area at the confluence of Lamb Run.

The sample from the Schuylkill River below Myer’s Run (site 6) (latitude 40°06'37", longitude 75°26'21") was collected from the stream bottom 60 ft downstream of Myer’s Run and 2 ft from the left edge of the water in 2 ft of water. The river stage of the Schuylkill River at Pottstown during sample collection was 1.73 ft. The sampling site is adjacent to the hiking trail that runs along the river. Access to the river from the trail at this site is limited by steep banks along the Schuylkill River.

The sample from Myer’s Run at Valley Forge (site 7) (latitude 40°06'37", longitude 75°26'24") was collected from the stream bottom 300 ft upstream of the Schuylkill River and from the center of the stream in 1 ft of water. The site is 50 ft upstream of the hiking trail and easily accessible from the hiking trail.

The sample from the Schuylkill River above Myer’s Run (site 8) (latitude 40°06'36", longitude 75°26'24") was collected from the stream bottom 75 ft upstream of Myer’s Run and 2 ft from the left edge of the water in 2 ft of water. The river stage of the Schuylkill River at Pottstown during sample collection was 1.73 ft. The sampling site is adjacent to the hiking trail that runs along the river. Access to the river from the trail at this site is limited by steep banks along the Schuylkill River.

The sample from the wetland below St. Gabriel’s School (site 9) (latitude 40°06'33", longitude 75°26'56") was collected from soil where an intermittent stream enters the wetland. The intermittent stream flows 0.3 mi from St. Gabriel’s School to the wetland, which is 500 ft above the Schuylkill River. The wetland had no standing water during sampling, making it necessary to wash the sediment through the sieve with deioized water.




Base from US Geological Survey Valley Forge 1:24,000 1981

**EXPLANATION**

**SEDIMENT SAMPLING LOCATIONS**

1 Schuylkill River at Betzwood boat ramp
2 Schuylkill River upstream of Betzwood boat ramp
3 Schuylkill River below Lamb Run
4 Lamb Run at Valley Forge
5 Schuylkill River above Lamb Run
6 Schuylkill River below Myer's Run
7 Myer's Run at Valley Forge
8 Schuylkill River above Myer's Run
9 Wetland below St. Gabriel's School
10 Schuylkill Impounding Basin No. 21
11 Schuylkill River at Pawling Road
12 Schuylkill River floodplain at Pawling Road

**Figure 2.** Sediment sampling locations, June 22, 1994 - May 9, 1995, Valley Forge National Historical Park, Montgomery County, Pennsylvania.

The hiking trail is located between the Schuylkill River and the wetland and provides easy access to the wetland.

The sample from Impounding Basin No. 21 (site 10) (latitude 40°06'20", longitude 75°27'57") was collected from bottom sediment 5 ft from the edge of the basin in 2 ft of water. The Impounding Basin is 500 ft from the Schuylkill River and the hiking trail that runs along the river. Access to the impounding basin from the hiking trail is limited by a steep hill. The site is accessible from a small parking area north of the Impounding Basin, but the area is not heavily used.

The sample from the Schuylkill River at Pawling Road (site 11) (latitude 40°06'52", longitude 75°28'14") was a composite sample collected from the stream bottom between 75 and 150 ft downstream of the Pawling Road Bridge and 2 ft from the left edge of the water in 2 ft of water. The river stage of the Schuylkill River at Pottstown during sample collection was 2.44 ft. This site is located adjacent to a parking lot that is at the end of the hiking trail. A floodplain along the river is used for fishing and walking and provides easy access to the river from the parking lot.

The sample from the Schuylkill River floodplain at Pawling Road (site 12) (latitude 40°06'52", longitude 75°28'14") was collected from wet soil 75 ft downstream of the Pawling Road Bridge and 15 ft from the left edge of the river. The floodplain had no standing water during sampling, making it necessary to wash the sediment through the sieve with deioized water. This site is located adjacent to a parking lot that is at the end of the hiking trail. The floodplain is used for fishing and walking and provides easy access to the river from the parking lot.

## SEDIMENT QUALITY

Samples were collected once from 12 sites in Valley Forge National Historical Park (fig. 2). All samples were analyzed for selected metals, pesticides, semivolatile organic compounds, and total carbon. Trace elements will adsorb or chemically bond to organic compounds. Sediments that contain high concentrations of carbon typically will have concentrated levels of trace elements (Horowitz, 1991). Sampling sites were selected in areas that were believed to be rich in organic substances. The concentration of total carbon ranged from 22 to 280 gm/kg (table 2).

### Selected Metals

Metals in stream-bottom sediments come from natural as well as artificial sources. Naturally occurring metals come from rock weathering, soil erosion, and the dissolution of salts. Artificial sources of metals include urban wastewater, industrial activities, mining, and agriculture. Some metals, such as cadmium, chromium, copper, lead, mercury, and zinc, are highly toxic at relatively low concentrations (Meade, 1995).

The concentration of metals detected in samples of stream-bottom sediment varied from site to site. Cadmium was not detected in any sample. Relatively low, 60 µg/g or less, concen-trations of arsenic, chromium, copper, and lead were detected in all samples of stream-bottom sediment (table 2). The concentrations of these metals are similar to those for samples of stream-bottom sediment collected recently by the USGS (Durlin, 1995) and by the U.S. Fish and Wildlife Service (FWS) (Rice, 1993) in Chester County, Pa. (fig. 1). Sampling methods used in the collection of the USGS samples of stream-bottom sediment collected in Chester County were identical to the sampling methods used in this study. Sampling methods used in the collection of the FWS samples of stream-bottom sediment collected in Chester County were similar to the sampling methods used in this study. The physical setting of Chester County is similar to Montgomery County. The concentration of mercury in stream-bottom sediment from the Schuylkill Impounding Basin No. 21 is higher than concentrations in samples of stream-bottom sediment recently collected in Chester County. Mercury concentrations were relatively low in stream-bottom sediment from all other sites sampled. The concentrations of iron, manganese, and zinc in samples of stream-bottom sediment from Schuylkill River at Betzwood boat ramp, Schuylkill River at Betzwood upstream of boat ramp, Schuylkill River below Lamb Run, and Schuylkill River above Lamb Run are higher than concentrations in other samples of stream-bottom sediment collected recently in Chester County. The concentrations of iron, manganese, and zinc in samples of stream-bottom sediment from all other

***Table 2.*** *Results of chemical analyses for selected metals and carbon in stream-bottom sediment, Valley Forge National Historical Park, Montgomery County, Pennsylvania, June 1994 through May 1995*

[µg/g, microgram per gram; gm/kg, gram per kilogram; <, less than]

| Site name | Date | Arsenic, total (µg/g as As) | Cadmium, recoverable (µg/g as Cd) | Chromium, recoverable (µg/g as Cr) | Copper, recoverable (µg/g as Cu) | Iron, recoverable (µg/g as Fe) | Lead, recoverable (µg/g as Pb) | Manganese, recoverable (µg/g as Mn) | Mercury, recoverable (µg/g as Hg) | Zinc, recoverable (µg/g as Zn) | Carbon, total (gm/kg as C) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Schuylkill River at Betzwood | | | | | | | | | | | |
| at boat ramp | 01-31-95 | 3 | <1 | 10 | 30 | 430,000 | 40 | 34,000 | 0.10 | 5,400 | 63 |
| upstream of boat ramp | 01-31-95 | 2 | <1 | 20 | 30 | 330,000 | 40 | 20,000 | .08 | 4,600 | 110 |
| Schuylkill River below Lamb Run | 02-01-95 | 2 | <1 | 10 | 20 | 310,000 | 30 | 17,000 | .06 | 4,000 | 52 |
| Lamb Run at Valley Forge | 06-22-94 | 2 | <1 | 50 | 20 | 13,000 | 30 | 540 | .06 | 120 | 22 |
| Schuylkill River above Lamb Run | 02-01-95 | 3 | <1 | 30 | 50 | 420,000 | 60 | 23,000 | .12 | 6,000 | 74 |
| Schuylkill River below Myer's Run | 05-08-95 | 4 | <1 | 10 | 40 | 12,000 | 40 | 520 | .06 | 140 | 70 |
| Myer's Run at Valley Forge | 05-09-95 | 5 | <1 | 20 | 30 | 15,000 | 40 | 1,200 | .08 | 80 | 34 |
| Schuylkill River above Myer's Run | 05-08-95 | 3 | <1 | 20 | 30 | 11,000 | 50 | 720 | .06 | 160 | 86 |
| Wetland below St. Gabriel's School[1] | 06-22-94 | 2 | <1 | 20 | 10 | 17,000 | 20 | 740 | .05 | 120 | 27 |
| Schuylkill Impounding Basin No. 21 | 06-23-94 | 3 | <1 | 20 | 40 | 23,000 | 60 | 800 | .33 | 250 | 280 |
| Schuylkill River at Pawling Road | | | | | | | | | | | |
| river sample | 04-17-95 | 5 | <1 | 30 | 20 | 12,000 | 40 | 430 | .04 | 110 | 28 |
| floodplain sample[1] | 04-17-95 | 3 | <1 | 30 | 30 | 16,000 | 40 | 1,100 | .08 | 130 | 41 |

[1] Sample was rinsed through sieve with deionized water.

sites are similar to concentrations in samples of stream-bottom sediment collected recently in Chester County.

Stamer and others (1985) reported on the distribution of trace elements, including selected metals, in Schuylkill River bottom sediment from Berne, river mile 95.5, to Philadelphia, river mile 10.2, between 1979 and 1981. The concentration of chromium, copper, and lead in the 12 samples collected from Valley Forge National Historical Park in 1994-95 are lower than the median concentrations reported for the Schuylkill River from Berne to Philadelphia in 1979-81. Concen-trations of arsenic are higher than the median concentrations from 1979 to 1981; concentrations of mercury are similar. Samples of stream-bottom sediment from the Schuylkill River at Betzwood boat ramp, Schuylkill River at Betzwood upstream of boat ramp, Schuylkill River below Lamb Run, and Schuylkill River above Lamb Run have zinc concentrations that exceed the median concen-trations reported from 1979 to 1981. All other samples had zinc concentrations below the median concentrations reported from 1979 to 1981. Cadmium, iron, and manganese were not analyzed by Stamer and others (1985).

Informal sediment-quality guidelines have been developed to identify locations that pose a threat to living resources. The guidelines were developed by compiling data from various sources to determine chemical concentrations that are rarely, sometimes, and usually associated with toxicity (Long and Morgan, 1990). The guideline values, Effects Range-Low (ERL) and Effects Range-Medium (ERM), create three concentration ranges for each chemical. Concentrations below the ERL are associated with minimal toxic effects. Concentrations between the ERL and the ERM are associated with possible toxic effects, and concentrations above the ERM are associated with probable toxic effects (Long and Morgan, 1990). ERL and ERM concentrations for metals are presented in table 3.

Concentrations of arsenic and chromium were below the ERL for all samples (table 3). The concentration of copper was below the ERL in 75 percent of the samples and between the ERL and ERM in 25 percent of the samples (table 3). The concentration of lead was below the ERL in 25 percent of the samples and between the ERL and ERM in 75 percent of the samples (table 3). The concentration of mercury was below the ERL in 92 percent of the samples and between the ERL and ERM in 8 percent of the samples (table 3). The

***Table 3.*** *Effects Range-Low (ERL) and Effects Range-Medium (ERM) guidelines for trace metals*

[From Long and Morgan, 1990; concentrations are in micrograms]

| Compound | Maximum concentration | ERL | ERM |
|---|---|---|---|
| Arsenic | 5 | 33 | 85 |
| Chromium | 50 | 80 | 145 |
| Copper | 50 | 70 | 390 |
| Lead | 60 | 35 | 110 |
| Mercury | .33 | .15 | 1.3 |
| Zinc | 6,000 | 120 | 270 |

concentration of zinc was at or below the ERL in 33.3 percent of the samples, between the ERL and ERM in 33.3 percent of the samples, and above the ERM in 33.3 percent of the samples (table 3). Sediment quality guidelines were not available for iron and manganese. Based on the sediment-quality guidelines, the high levels of zinc pose the greatest threat to living resources.

## Pesticides

Pesticides are widely used in both rural and urban areas of Montgomery County. Pesticides are divided into insecticides, herbicides, and fungicides on the basis of their use. Only insecticides and herbicides were examined in this study. Insecticides are used in agricultural and urban areas to control insects. Herbicides are used to control weeds that compete with crops in agricultural areas and home gardens, to control broad-leaf weeds on lawns and turf, and to defoliate utility, railroad, and highway rights-of-way.

### Organochlorine Insecticides

Organochlorine insecticides have low solubility in water, are persistent in the environment, and are strongly bioaccumulated by many organisms. The use of many organochlorine insecticides has been prohibited or restricted to limited uses by the USEPA. Of the 15 organochlorine insecticides analyzed, 5 were detected (table 4). DDE was detected in all 12 samples. Chlordane, DDD, and DDT were detected in 75 percent of the samples, and dieldrin was detected in 83 percent of the samples. Concentrations of organochlorine insecticides detected ranged from 0.2 µg/kg for DDD to 11 µg/kg for chlordane. Aldrin, endosulfan,

***Table 4.*** *Results of chemical analyses for organochlorine pesticides in stream-bottom sediment, Valley Forge National Historical Park, Montgomery County, Pennsylvania, June 1994 through May 1995*

[All values are total concentrations in micrograms per kilogram; <, less than]

| Site name | Date | Aldrin | Chlordane | DDD | DDE | DDT | Dieldrin | Endosulfan | Endrin |
|---|---|---|---|---|---|---|---|---|---|
| Schuylkill River at Betzwood | | | | | | | | | |
| at boat ramp | 01-31-95 | <0.01 | 11 | <2.0 | 2.7 | <2.0 | 1.2 | <0.1 | <0.3 |
| upstream of boat ramp | 01-31-95 | <.01 | 9.0 | 1.3 | 1.3 | .7 | .7 | <.1 | <.1 |
| Schuylkill River below Lamb Run | 02-01-95 | <.01 | 10 | <2.0 | 1.8 | <2.0 | .6 | <.1 | <.2 |
| Lamb Run at Valley Forge | 06-22-94 | <.01 | <1.0 | .8 | 1.0 | .5 | .9 | <.4 | <.1 |
| Schuylkill River above Lamb Run | 02-01-95 | <.01 | 22 | <3.0 | 3.2 | <1.0 | 1.2 | <.1 | <.6 |
| Schuylkill River below Myer's Run | 05-08-95 | <.01 | 5.0 | 1.1 | 1.1 | .4 | <.4 | <.1 | <.1 |
| Myer's Run at Valley Forge | 05-09-95 | <.01 | 1.0 | .3 | .6 | .3 | <.4 | <.1 | <.1 |
| Schuylkill River above Myer's Run | 05-08-95 | <.01 | 5.0 | 1.5 | 1.4 | .9 | 1.0 | <.1 | <.1 |
| Wetland below St. Gabriel's School[1] | 06-22-94 | <.01 | <1.0 | .2 | .5 | .3 | .3 | <.1 | <.7 |
| Schuylkill Impounding Basin No. 21 | 06-23-94 | <.01 | <1.0 | .4 | 1.6 | .4 | .6 | <.1 | <.1 |
| Schuylkill River at Pawling Road | | | | | | | | | |
| river sample | 04-17-95 | <.01 | 8.0 | 2.2 | 1.6 | .8 | 2.2 | <.1 | <.1 |
| floodplain sample[1] | 04-17-95 | <.01 | 5.0 | 1.2 | 1.0 | .8 | 2.3 | <.1 | <.1 |

| Site name | Date | Heptachlor | Heptachlor epoxide | Lindane | Methoxychlor | Mirex | Perthane | Toxaphene |
|---|---|---|---|---|---|---|---|---|
| Schuylkill River at Betzwood | | | | | | | | |
| at boat ramp | 01-31-95 | <0.1 | <0.1 | <0.1 | <0.4 | <0.1 | <1 | <10 |
| upstream of boat ramp | 01-31-95 | <.1 | <.1 | <.1 | <.4 | <.1 | <1 | <10 |
| Schuylkill River below Lamb Run | 02-01-95 | <.1 | <.1 | <.1 | <.4 | <.1 | <1 | <10 |
| Lamb Run at Valley Forge | 06-22-94 | <.1 | <.1 | <.1 | <.3 | <.1 | <1 | <10 |
| Schuylkill River above Lamb Run | 02-01-95 | <.1 | <.1 | <.1 | <.4 | <.1 | <1 | <10 |
| Schuylkill River below Myer's Run | 05-08-95 | <.1 | <.1 | <.1 | <.4 | <.1 | <1 | <10 |
| Myer's Run at Valley Forge | 05-09-95 | <.1 | <.1 | <.1 | <.4 | <.1 | <1 | <10 |
| Schuylkill River above Myer's Run | 05-08-95 | <.1 | <.1 | <.1 | <.4 | <.1 | <1 | <10 |
| Wetland below St. Gabriel's School[1] | 06-22-94 | <.1 | <.1 | <.1 | <.2 | <.1 | <1 | <10 |
| Schuylkill Impounding Basin No. 21 | 06-23-94 | <.1 | <.1 | <.1 | <.2 | <.1 | <1 | <10 |
| Schuylkill River at Pawling Road | | | | | | | | |
| river sample | 04-17-95 | <.1 | <.1 | <.1 | <.8 | <.1 | <1 | <10 |
| floodplain sample[1] | 04-17-95 | <.1 | <.1 | <.1 | <.4 | <.1 | <1 | <10 |

[1] Sample was rinsed through sieve with deionized water.

endrin, heptachlor, heptachlor epoxide, lindane, methoxychlor, mirex, perthane, and toxaphene were not detected in any sample.

Chlordane is a nonsystematic, broad-spectrum insecticide that was used for termite control in homes and gardens and for soil insects for crop protection. The use of chlordane was restricted by the USEPA in 1980 to commercial termite control; it is no longer available to the general public.

Endrin is used as an insect control on grain crops, as a grasshopper control on crop lands, and as a rodenticide in orchards. Dieldrin is an isomer of endrin. It has been used as a contact insecticide to control corn pests, soil pests, termites, and many other pests. All uses of dieldrin were prohibited by the USEPA in 1973, and it is no longer manufactured in the United States.

DDD, also known as TDE, was formerly manufactured as an insecticide. All uses of DDD were prohibited by the USEPA in 1973, and it is no longer manufactured in the United States. DDD also is a breakdown product of DDT formed by reductive dehalogenation.

DDT is the common name for a mixture of compounds in which the main component is 1,1,1-trichloro-2,2-bis (p-chlorophenyl) ethane. DDT is the best known, as well as the first, of the organochlorine insecticides introduced to agriculture. All uses of DDT were prohibited by the USEPA in 1973. DDE is not produced as a pesticide but is formed by the breakdown of DDT under alkaline conditions. Methoxychlor is an analog of DDT. Methoxychlor is registered for use on 87 crops and is widely used in agriculture, homes, and gardens.

Heptachlor oxidizes to heptachlor epoxide in the soil. The use of heptachlor was restricted by the USEPA in 1983 to subsurface termite control. It is injected into the subsurface outside of dwellings and other buildings.

The concentrations of chlordane, DDD, DDE, DDT, dieldrin, and heptachlor epoxide are relatively low and are similar to concentrations in samples of stream-bottom sediment recently collected in Chester County (Kolva and others, 1989; Durlin, 1995; Rice, 1993). Low concentrations of these compounds are prevalent in the stream-bottom sediments throughout the entire region.

## Organophosphorus Insecticides

Organophosphorus insecticides have been used as substitutes for the banned organochlorine insecticides because they are less persistent in the environment and more selective in their targets.

Detectable concentrations of diazinon were measured in stream-bottom sediment collected from 50 percent of the 12 samples (table 5). Concentrations of diazinon detected ranged from 0.2 to 0.9 µg/kg. Diazinon is widely used in agriculture, homes, and gardens for insect control. It is used to control soil, fruit, and vegetable insects, household pests, and livestock pests. Ethion, malathion, methyl parathion, parathion, and trithion were not detected in any sample.

## Semivolatile Organic Compounds

Semivolatile organic compounds are products of various human activities. Organic molecules are adsorbed onto sediment and deposited in stream-bottom materials. Of the 54 compounds analyzed (table 1), 18 were detected (table 6). Fluoranthene, phenanthrene, pyrene, and PCB's were the most commonly detected compounds, detected in 11 of the 12 samples analyzed. Concentrations of compounds detected ranged from 210 µg/kg for naphthalene to 4,800 µg/kg for phenanthrene. The presence of semivolatile organic compounds in

***Table 5.*** *Results of chemical analyses for organophosphorus insecticides in stream-bottom sediment, Valley Forge National Historical Park, Montgomery County, Pennsylvania, June 1994 through May 1995*

[All values are total concentrations in micrograms per kilogram; <, less than]

| Site name | Date | Diazinon | Ethion | Malathion | Methyl parathion | Parathion | Trithion |
|---|---|---|---|---|---|---|---|
| Schuylkill River at Betzwood | | | | | | | |
| at boat ramp | 01-31-95 | 0.9 | <0.2 | <0.2 | <0.2 | <0.2 | <0.2 |
| upstream of boat ramp | 01-31-95 | .9 | <.2 | <.2 | <.2 | <.2 | <.2 |
| Schuylkill River below Lamb Run | 02-01-95 | .4 | <.2 | <.2 | <.2 | <.2 | <.2 |
| Lamb Run at Valley Forge | 06-22-94 | <.2 | <.2 | <.2 | <.2 | <.2 | <.2 |
| Schuylkill River above Lamb Run | 02-01-95 | .7 | <.2 | <.2 | <.2 | <.2 | <.2 |
| Schuylkill River below Myer's Run | 05-08-95 | .2 | <.2 | <.2 | <.2 | <.2 | <.2 |
| Myer's Run at Valley Forge | 05-09-95 | <.2 | <.2 | <.2 | <.2 | <.2 | <.2 |
| Schuylkill River above Myer's Run | 05-08-95 | .4 | <.2 | <.2 | <.2 | <.2 | <.2 |
| Wetland below St. Gabriel's School[1] | 06-22-94 | <.2 | <.2 | <.2 | <.2 | <.2 | <.2 |
| Schuylkill Impounding Basin No. 21 | 06-23-94 | <.2 | <.2 | <.2 | <.2 | <.2 | <.2 |
| Schuylkill River at Pawling Road | | | | | | | |
| river sample | 04-17-95 | <.2 | <.2 | <.2 | <.2 | <.2 | <.2 |
| floodplain sample[1] | 04-17-95 | <.2 | <.2 | <.2 | <.2 | <.2 | <.2 |

[1] Sample was rinsed through sieve with deionized water.

***Table 6.*** *Results of chemical analyses for semivolatile organic compounds detected and PCB's in stream-bottom sediments, Valley Forge National Historical Park, Montgomery County, Pennsylvania, June 1994 through May 1995*

[All values are in micrograms per kilogram; PCB, polychlorinated biphenyls; <, less than]

| Site name | Date | Anthracene | Benzo[a]-anthracene | Benzo[b]-fluoranthene | Benzo[k]-fluoranthene | Benzo[a]-pyrene | Benzo-[g,h,i,]-perylene | n-Butyl-benzyl phthalate | Chrysene | 1, 2, 5, 6-Dibenz-anthracene |
|---|---|---|---|---|---|---|---|---|---|---|
| Schuylkill River at Betzwood | | | | | | | | | | |
| at boat ramp | 01-31-95 | <200 | <400 | 430 | <400 | <400 | <400 | <200 | <400 | <400 |
| upstream of boat ramp | 01-31-95 | <200 | 650 | 750 | 650 | 670 | <400 | 390 | 690 | <400 |
| Schuylkill River below Lamb Run | 02-01-95 | 430 | 1,400 | 1,500 | 1,200 | 1,300 | <400 | <200 | 1,600 | 540 |
| Lamb Run at Valley Forge | 06-22-94 | 510 | 2,800 | 4,700 | 3,100 | 3,000 | 1,200 | <200 | 4,000 | 740 |
| Schuylkill River above Lamb Run | 02-01-95 | <200 | 430 | 510 | <400 | 470 | <400 | <200 | 460 | <400 |
| Schuylkill River below Myer's Run | 05-08-95 | 260 | 500 | 580 | 480 | 570 | 410 | <200 | 560 | <400 |
| Myer's Run at Valley Forge | 05-09-95 | <200 | <400 | <400 | <400 | <400 | <400 | <200 | <400 | <400 |
| Schuylkill River above Myer's Run | 05-08-95 | 300 | 720 | 890 | 560 | 800 | <400 | <200 | 660 | <400 |
| Wetland below St. Gabriel's School[1] | 06-22-94 | <200 | <400 | <400 | <400 | <400 | <400 | <200 | <400 | <400 |
| Schuylkill Impounding Basin No. 21 | 06-23-94 | <200 | <400 | <400 | <400 | <400 | <400 | <200 | <400 | <400 |
| Schuylkill River at Pawling Road | | | | | | | | | | |
| river sample | 04-17-95 | 300 | 900 | 900 | 780 | <400 | 570 | <200 | 960 | <400 |
| floodplain sample[1] | 04-17-95 | <200 | <400 | 400 | <400 | <400 | <400 | 200 | <400 | <400 |

| Site name | Date | Diethyl phthalate | Bis (2-ethyl hexyl) phthalate | Fluorene | Fluoranthene | Indeno-(1, 2, 3-cd) pyrene | Naphthalene | Phenanthrene | Pyrene | PCB's |
|---|---|---|---|---|---|---|---|---|---|---|
| Schuylkill River at Betzwood | | | | | | | | | | |
| at boat ramp | 01-31-95 | <200 | 500 | <200 | 510 | <400 | <200 | 360 | 480 | 10 |
| upstream of boat ramp | 01-31-95 | <200 | 700 | <200 | 1,100 | <400 | <200 | 660 | 860 | 11 |
| Schuylkill River below Lamb Run | 02-01-95 | <200 | 910 | 230 | 2,700 | 540 | <200 | 2,000 | 2,000 | 10 |
| Lamb Run at Valley Forge | 06-22-94 | <200 | 1,100 | 210 | 570 | 1,300 | <200 | 4,800 | 350 | 37 |
| Schuylkill River above Lamb Run | 02-01-95 | <200 | 430 | <200 | 770 | <400 | <200 | 500 | 730 | 8 |
| Schuylkill River below Myer's Run | 05-08-95 | <200 | 560 | <200 | 680 | 440 | <200 | 660 | 570 | 16 |
| Myer's Run at Valley Forge | 05-09-95 | <200 | 210 | <200 | 310 | <400 | <200 | 270 | 260 | 6 |
| Schuylkill River above Myer's Run | 05-08-95 | 660 | 650 | <200 | 950 | <400 | 210 | 840 | 860 | 30 |
| Wetland below St. Gabriel's School[1] | 06-22-94 | <200 | <200 | <200 | <200 | <400 | <200 | <200 | <200 | 13 |
| Schuylkill Impounding Basin No. 21 | 06-23-94 | <200 | <200 | <200 | 240 | <400 | <200 | 200 | 200 | 7 |
| Schuylkill River at Pawling Road | | | | | | | | | | |
| river sample | 04-17-95 | <200 | 450 | <200 | 1,300 | 590 | <200 | 1,200 | 1,100 | <1 |
| floodplain sample[1] | 04-17-95 | <200 | 390 | <200 | 310 | <400 | <200 | 230 | 280 | 14 |

[1] Sample was rinsed through sieve with deionized water.

Schuylkill River sediments is due to years of industrial activities along the river. Coal mining and transportation, along with related industries, during the past 100 years have contributed to the current conditions.

Stream-bottom sediment from Lamb Run at Valley Forge contained the highest number of compounds detected and the highest concentrations of those compounds (table 6). Stream-bottom sediment from Lamb Run at Valley Forge also contained the lowest concentration of carbon (table 2). Because sediments rich in carbon tend to concentrate contaminants, parts of Lamb Run that are rich in carbon may contain higher concentrations of semivolatile organic compounds. Stream-bottom sediment from the Schuylkill River below Lamb Run contained higher concentrations of semivolatile organic compounds than the stream-bottom sediment from the Schuylkill River above Lamb Run indicating that the semivolatile organic compounds in Lamb Run are being washed into the

Schuylkill River. The sample of stream-bottom sediment from Myer's Run at Valley Forge contained four detectable semivolatile organic compounds. The maximum concentration measured was 310 µg/kg for fluoranthene. Both Lamb Run and Myer's Run flow through similar physical settings although the headwaters of Lamb Run are in a more industrial area. This industrialized area is the most probable source of semivolatile organic compounds in Lamb Run.

Samples collected from the floodplain, wetland, and impounding basin contained few detected compounds and low concentrations of these compounds. The wetland sediment contained no detectable compounds. The floodplain sample contained six detectable compounds; the maximum concentration was 400 µg/kg for benzo[b]-flouranthene. The sample from the impounding basin contained the highest concentration of carbon, but only three semivolatile organic compounds were detected. The maximum concentration measured was 240 µg/kg for fluoranthene.

The Schuylkill River was used to barge coal since the 1820's, and the river has received large quantities of coal fines from the mining and processing of coal. Anthracene, benzo[a]anthracene, benzo[a]pyrene, chrysene, 1,2,5,6-dibenz-anthracene, fluoranthene, phenanthrene, napthalene, and pyrene are found in coal tar and were detected in several of the samples of stream-bottom sediment collected.

An apparent effects threshold (AET) is the sediment concentration of a compound above which statistically significant biological effects (usually changes in composition in benthic invertebrate communities) are always expected (Barrick and Beller, 1988). AET values are determined using a combination of sediment bioassays and evaluation of the indigenous macroinvertebrate communities. In sediment bioassays, a test organism is exposed to sediment that contains a known concentration of a compound for a fixed period of time. The evaluation of indigenous macroinvertebrate communities involves measuring the abundance of macroinvertebrates at field sites. The macro-invertebrate abundances are then compared to concentrations of a compound in the sediment to determine the concentration above which statistically significant biological effects are noticed. The AET determined by bioassay is verified by comparison with the observed field levels before the final AET is set. A series of AET values, specific to each test organism, are generated for each compound. The AET values used in this report for amphipods and benthic macroinvertebrates (table 7) were developed from data collected for various projects from Puget Sound, Wash. (Barrick and Beller, 1988).

Risk-based concentrations (RBC) for a lifetime cancer risk of $10^{(-6)}$ were provided by the USEPA (Roy L. Smith, U.S. Environmental Protection Agency, written commun., 1994). The RBC is not a regulatory limit. RBC's are calculated using toxicity constants that are combined with standard exposure scenarios. The toxicity constants come from carcinogenic potency slopes obtained from various USEPA sources. Differences between RBC values for residential versus industrial soil are because of different exposure scenarios. RBC calculations have several important limitations. Excluded from consideration are the transfers from soil to air and water and cumulative risk from multiple contaminants. The RBC's also assume that the exposure scenarios used are appropriate for the site. With these limitations, the RBC is a screening tool and not a substitute for a site-specific risk assessment (Roy L. Smith, written commun., 1994). RBC's are presented in this report on table 7 to identify the detected compounds that present the greatest health risks.

Anthracene was detected in 41 percent of samples collected; concentrations ranged from 260 to 510 µg/kg (table 6). All concentrations detected lie between the ERL and ERM (table 8). Anthracene is used in the manufacture of dyes (Windholz and others, 1976, p. 93).

Benzo[a]anthracene was detected in 58 percent of samples collected; concentrations ranged from 430 to 2,800 µg/kg (table 6). The concentration of benzo[a]anthracene exceeded the RBC of 880 µg/kg for residential soil in three samples (table 6). The concentration of benzo[a]anthracene was between the ERL and the ERM in six samples and exceeded the ERM in one sample (table 8). Benzo[a]anth-racene (also called 1,2-benzanthracene) is a contaminant with no reported commercial use or application. It is found in gasoline, crude oil, wood preservative sludge, oil, and waxes. It is a confirmed human carcinogen and irritant (Lucius and others, 1992, p. 113-114).

***Table 7.*** *Semivolatile organic compounds detected and PCB's in stream-bottom sediments, Valley Forge National Historical Park, Montgomery County, Pennsylvania, June 1994 through May 1995, and risk-based concentration and apparent effects thresholds*

[All values are in micrograms per kilogram; RBC, risk-based concentration; --, no risk-based concentration or apparent effects threshold; PCB's, polychlorinated biphenyls]

| Compound | Number of sites detected | Maximum concentration | RBC, residential soil | RBC, industrial soil | Amphipod apparent effects threshold (AET) | Benthic macroinvertebrate, apparent effects threshold (AET) |
|---|---|---|---|---|---|---|
| Anthracene | 5 | 510 | 23,000,000 | 310,000,000 | 13,000 | 4,400 |
| Benzo[a]anthracene | 7 | 2,800 | 880 | 3,900 | 5,100 | 5,100 |
| Benzo[b]fluoranthene | 9 | 4,700 | 880 | 3,900 | 7,800 | 9,900 |
| Benzo[k]fluoranthene | 6 | 3,100 | 8,800 | 39,000 | 7,800 | 9,900 |
| Benzo[a]pyrene | 6 | 3,000 | 88 | 390 | 3,000 | 3,600 |
| Benzo[g,h,i] perylene | 3 | 1,200 | -- | -- | 1,400 | 2,600 |
| n-Butyl benzyl phthalate | 2 | 390 | 1,600,000 | 200,000,000 | 900 | 900 |
| Chrysene | 7 | 4,000 | 88,000 | 390,000 | 9,200 | 9,200 |
| 1,2,5,6-Dibenzanthracene | 2 | 740 | 88 | 390 | 540 | 970 |
| Diethyl phthalate | 1 | 660 | 63,000,000 | 820,000,000 | -- | 200 |
| Bis(2-ethyl hexyl)phthalate | 10 | 1,100 | 46,000 | 200,000 | -- | 1,300 |
| Fluorene | 2 | 230 | 3,100,000 | 41,000,000 | 3,600 | 1,000 |
| Fluoranthene | 11 | 2,700 | 3,100,000 | 41,000,000 | 30,000 | 24,000 |
| Indeno(1,2,3-cd)pyrene | 4 | 1,300 | 880 | 3,900 | 1,800 | 2,600 |
| Naphthalene | 1 | 210 | 3,100,000 | 41,000,000 | 2,400 | 2,700 |
| Phenanthrene | 11 | 4,800 | -- | -- | 6,900 | 5,400 |
| Pyrene | 11 | 2,000 | 2,300,000 | 31,000,000 | 16,000 | 16,000 |
| PCB's | 11 | 37 | 83 | 370 | 190 | 65 |

***Table 8.*** *Effects Range-Low and Effects Range-Medium guidelines for semivolatile organic compounds and PCB's*

[From Long and Morgan, 1990; concentrations are in milligrams]

| Compound | Maximum concentration | Effects Range-Low | Effects Range-Medium |
|---|---|---|---|
| Anthracene | 510 | 85 | 960 |
| Benzo[a]anthracene | 2,800 | 230 | 1,600 |
| Benzo[a]pyrene | 3,000 | 400 | 2,500 |
| Chrysene | 4,000 | 400 | 2,800 |
| 1,2,5,6-Dibenzanthracene | 740 | 60 | 260 |
| Fluorene | 230 | 35 | 640 |
| Fluoranthene | 2,700 | 600 | 3,600 |
| Naphthalene | 210 | 340 | 2,100 |
| Phenanthrene | 4,800 | 225 | 1,380 |
| Pyrene | 2,000 | 350 | 2,200 |
| Polychlorinated biphenyls (PCB) | 37 | 50 | 400 |

Benzo[b]fluoranthene was detected in 75 percent of samples collected; concentrations ranged from 430 to 4,700 µg/kg (table 6). The concentration of benzo[b]fluoranthene exceeded the RBC of 880 µg/kg for residential soil in three samples and exceeded the RBC of 3,900 µg/kg for industrial soil in one sample (table 6). Benzo[b]fluoranthene (also called benz(e)acephenanthrylene) is present in crude oil, lubricating oil, sewage sludge, and effluent. It is an irritant and potential human carcinogen (Lucius and others, 1992, p. 110).

Benzo[a]pyrene was detected in 50 percent of samples collected; concentrations ranged from 470 to 3,000 µg/kg (table 6). The concentration of benzo[a]pyrene exceeded the RBC of 390 µg/kg for industrial soil in six samples and equalled the amphipod AET of 3,000 µg/kg in one sample (table 6). The concentration of benzo[a]pyrene was between the ERL and the ERM in five samples and exceeded the ERM in one sample (table 8).

Benzo[a]pyrene is a by-product of combustion and is present in coal tar and asphalt tarring operations. It is a suspected human carcinogen (Lucius and others, 1992, p. 128-129).

Chrysene was detected in 58 percent of samples collected; concentrations ranged from 460 to 4,000 µg/kg (table 6). The concentration of chrysene was between the ERL and the ERM in six samples and exceeded the ERM in one sample (table 8). Chrysene is formed in the hydrocarbon combustion process and may be released from oil spills. It is a constituent of gasoline, motor oil, and crude oil. It is a suspected human carcinogen (Lucius and others, 1992, p. 204-205).

1,2,5,6-dibenzanthracene was detected in 16 percent of samples collected; concentrations ranged from 540 to 740 µg/kg (table 6). The concentration of 1,2,5,6-dibenzanthracene detected in two samples exceeded the RBC of 390 µg/kg for industrial soil, exceeded the amphipod AET of 540 µg/kg in one sample, and was equal to it in another (table 6). The concentration of benzo[a]anthracene exceeded the ERM in two samples (table 8). 1,2,5,6-dibenzanthracene (also known as dibenz[a,h]anthracene) is a contaminant or by-product of wood preservative sludge and high-octane gasoline. It is an irritant and a confirmed human carcinogen and mutagen (Lucius and others, 1992, p. 223-224).

Diethyl phthalate was detected in 8 percent of samples collected; the concentration was 660 µg/kg (table 6). The concentration of diethyl phthalate exceeded the benthic AET of 200 µg/kg in one sample (table 6). Diethyl phthalate is used in insecticidal sprays, plastics manufacture and processing, and solid rocket propellants. It is a mild irritant (Lucius and others, 1992, p. 284-226).

Bis(2-ethylhexyl)phthalate was detected in 83 percent of samples collected; concentrations ranged from 210 to 1,100 µg/kg (table 6). Bis(2-ethylhexyl)phthalate [also known as 1,2-benzenedicarboxylic acid bis(2-ethylhexyl) ester and DEHP] is used as a plasticizer for many resins and elastomers and in plastics manufacturing and processing. It is a mild irritant and a possible human carcinogen and mutagen (Lucius and others, 1992, p. 142-143).

Fluorene was detected in 16 percent of samples collected; concentrations ranged from 210 to 230 µg/kg (table 6). The concentration of fluorene was between the ERL and the ERM in two samples (table 8). Fluorene is found in coke oven tar (Windholz and others, 1976, p. 537).

Fluoranthene was detected in 91 percent of samples collected; concentrations ranged from 240 to 2,700 µg/kg (table 6). The concentration of fluoranthene was below the ERL in five samples and between the ERL and the ERM in six samples (table 8). Fluoranthene is produced by the pyrolytic processing of raw materials, such as coal and petroleum, at high temperatures. It also is found in gasoline and coal tar pitch. It is an irritant and potential carcinogen (Lucius and others, 1992, p. 333-334).

Indeno(1,2,3-cd)pyrene was detected in 33 percent of samples collected; concentrations ranged from 440 to 1,300 µg/kg (table 6). The concentration of indeno(1,2,3-cd)pyrene exceeded the RBC of 880 µg/kg for residential soil in one sample (table 6).

Napthalene was detected in 8 percent of samples collected; the concentration was 210 µg/kg (table 6). The concentration of napthalene lies below the ERL (table 8). Napthalene is used in dyes, solvents, lubricants, motor fuels, preservatives, and fungicides. It is an irritant and a possible carcinogen (Lucius and others, 1992, p. 380-381).

Phenanthrene was detected in 91 percent of samples collected; concentrations ranged from 200 to 4,800 µg/kg (table 6). The concentration of phenanthrene was below the ERL in one sample, between the ERL and the ERM in eight samples, and exceeded the ERM in two samples (table 8). Phenanthrene is used in dyes, explosives, drug synthesis, and biochemical research. It is found in gasoline and may be released from oil spills. It is an irritant and possible human carcinogen (Lucius and others, 1992, p. 399-400).

Pyrene was detected in 91 percent of samples collected; concentrations ranged from 200 to 2,000 µg/kg (table 6). The concentration of pyrene was equal to or below the ERL in four samples and between the ERL and the ERM in seven samples (table 8). Pyrene occurs in coal tar and is formed by the destructive hydrogenation of hard coal (Windholz and others, 1976, p. 537).

PCB's were detected in 91 percent of samples collected; concentrations ranged from 6 to 37 µg/kg (table 6). The concentrations of PCB's were below the ERL in all samples (table 8). PCB's were used in electrical capacitors, electrical transformers, hydraulic fluids, cutting oils, and high pressure lubricants. PCB's have been banned in the United States, but because of their high stability, they still persist in the environment. They are highly toxic and suspected carcinogens (Lucius and others, 1992, p. 104-105).

In 70 percent of the samples that had detections of semivolatile organic compounds and PCB's, the concentrations were between the ERL and the ERM. In 9 percent of these samples, the concentrations exceeded the ERM. Concentrations above the ERL indicate that these compounds pose possible toxic effects, and concentrations above the ERM pose probable toxic effects to the living resources in the area. All samples that exceeded the ERM level were collected from Lamb Run at Valley Forge and from the Schuylkill River below Lamb Run. This is the area that is the greatest threat to living resources.

The samples of stream-bottom sediment collected contain a complex mixture of organic compounds that tend to be carcinogenic. Many compounds detected in the samples of stream-bottom sediment also are phototoxic. Phototoxic compounds show greatly increased toxicity when exposed to solar radiation. The RBC and AET concentrations do not account for phototoxicity and may be underestimates of actual toxicity. The compounds detected in stream-bottom sediment samples that have been documented as phototoxic are anthracene, benzo[a]anthracene, benzo[k]fluoranthene, benzo[a]pyrene, benzo[g,h,i]perylene, chrysene, fluoranthene, and pyrene (Newstead and Geisy, 1987).

## SUMMARY AND CONCLUSIONS

Samples of stream-bottom sediment were collected once from 12 sites in and around the Schuylkill River including floodplains and wetlands along the river and from tributaries to the Schuylkill River in Valley Forge National Historical Park from June 1994 through May 1995. The stream-bottom sediment was analyzed for selected metals, pesticides, semivolatile organic compounds, and total carbon.

Concentrations of arsenic, chromium, copper, and lead are relatively low and similar to concentrations in samples of stream-bottom sediment recently collected in Chester County. The concentration of mercury in stream-bottom sediment from Schuylkill Impounding Basin No. 21 is higher than concentrations in stream-bottom sediment from the other 11 sites and higher than samples of stream-bottom sediment recently collected in Chester County. The concentrations of iron, manganese, and zinc in stream-bottom sediment from Schuylkill River at Betzwood boat ramp, Schuylkill River at Betzwood upstream of boat ramp, Schuylkill River below Lamb Run, and Schuylkill River above Lamb Run are elevated compared to the stream-bottom sediment from other sites sampled. The source of the elevated metal concentrations is unknown, but it begins upstream of Lamb Run and continues to at least the Betzwood Boat Ramp and possibly further downstream.

Detectable concentrations of the organochlorine insecticide DDE were measured in all 12 samples analyzed. Dieldrin was detected in 10 samples; chlordane, DDD, and DDT were detected in 9 samples; and heptachlor epoxide was detected in 1 sample. The organophosphorus insecticide diazinon was detected in relatively low concentrations in half of the 12 samples analyzed. The concentrations of organochlorine and organophosphorus insecticides are relatively low and similar to samples recently collected in Chester County. Low concentrations of these compounds are prevalent in the stream-bottom sediments throughout the entire region.

Detectable concentrations of the semivolatile organic compounds fluoranthene, phenanthrene, and pyrene were detected in 11 of the 12 samples analyzed. Bis(2-ethyl hexyl)phthalate was detected in 10 samples; benzo[b]fluoranthene was detected in 9 samples; benzo[a]anthracene and chrysene were detected in 7 samples; benzo[k]fluoranthene and benzo[a]pyrene were detected in 6 samples; anthracene was detected in 5 samples; indeno(1,2,3-cd)pyrene was detected in 4 samples; benzo[g,h,i]-perylene was detected in 3 samples; n-butyl benzyl phthalate, 1,2,5,6-dibenzanthracene, and fluorene were detected in 2 samples; and diethyl phthalate and naphthalene were detected in 1 sample. Detectable concentrations of PCB's were measured in 11 of the 12 samples analyzed.

The highest concentration of semivolatile organic compounds, including PCB's, was detected in stream-bottom sediment from Lamb Run at Valley Forge, a small tributary to the Schuylkill River with headwaters in an industrial corporate center. This industrial corporate center is the most probable source of semivolatile organic compounds in stream-bottom sediment from Lamb Run. The concentration of semivolatile organic compounds in stream-bottom sediment from the Schuylkill River below Lamb Run is higher than stream-bottom sediment from the Schuylkill River above Lamb Run, indicating that sediment from Lamb Run is increasing the concentrations of semivolatile organic compounds in the Schuylkill River. Concentrations of semivolatile organic compounds are lower in the stream-bottom sediment from the Schuylkill River below Myer's Run than in the stream-bottom sediment from above Myer's Run because of the addition of relatively clean stream-bottom sediment from Myer's Run. The highest concentration of PCB's in the Schuylkill River was detected in the stream-bottom sediment from above Myer's Run. Samples collected from the floodplain, impounding basin, and wetland along the Schuylkill River contained the lowest concentrations of semivolatile organic compounds.

Analysis of 12 samples of stream-bottom sediment collected in and around the Schuylkill River including floodplains and wetlands along the river and from tributaries to the Schuylkill River in Valley Forge National Historical Park indicate elevated metal concentrations at four sites and low-level, wide-spread pesticide contamination at all sites. Semivolatile organic compounds were detected in all samples and PCB's were detected in 11 of 12 samples. Samples of stream-bottom sediment from Lamb Run at Valley Forge contained the highest concentrations of semivolatile organic compounds. Because Lamb Run also contained the lowest concentration of carbon, the concentration of semivolatile organic compounds may be higher in organic rich sediments. Such areas may contain high concentrations of many organic compounds.

Sediment-quality guidelines have been developed for specific compounds by the USEPA and others to screen results for potential toxic concentrations. When results are compared to these guidelines, the concentrations of metals, pesticides semivolatile organic compounds and PCB's are high enough to cause possible toxic effects to living resources. The high levels of zinc in the Schuylkill River along with the high levels of semivolatile organic compounds in Lamb Run and the Schuylkill River below Lamb Run indicate a potential toxic effect to living resources.

## REFERENCES CITED


Barrick, R., and Beller, H., 1988, The apparent effects threshold approach—Briefing report to the EPA Science Advisory Board: United States Environmental Protection Agency Report 910/9-89-013, 57 p.

Durlin, R.R., 1995, Water resources data for Pennsylvania, 1994—volume 1: U.S. Geological Survey Water-Data Report PA-94-1, 297 p.

Fishman, M.J., and Friedman, L.C., eds; 1989, Methods for determination of inorganic substances in water and fluvial sediments: U.S. Geological Survey Techniques of Water-Resources Investigation, book 5, chap. A1, 545 p.

Horowitz, A. J., 1991, A primer on sediment-trace element chemistry: Chelsea, Mich., Lewis Publishers Inc., 136 p.

Kolva, J.R., White, T.E., Druther, R.L., and Moleski, Paul, 1989, Water resources data for Pennsylvania, 1987—volume 1: U.S. Geological Survey Water-Data Report PA-87-1, 290 p.

Long, E.R., and Morgan, L.G., 1990, The potential for biological effects of sediment-sorbed contaminants tested in the National Status and Trends Program: Seattle, Wash., National Oceanic and Atmospheric Administration, NOAA Technical Memorandum NOS OMA 62, 175 p.

Lucius, J.E., Olhoeft, G.R., Hill, P.L., and Duke, S.K., 1992, Properties and hazards of 108 selected toxic substances - 1992 edition: U.S. Geological Survey Open-File Report 92-527, 554 p.

Meade, R.H., ed., 1995, Contaminants in the Mississippi River, 1987-92: U.S. Geological Survey Circular 1133, 140 p.

Newstead, J.L., and Geisy, J.P., 1987, Predictive models for photoinduced acute toxicity of polycyclic aromatic hydrocarbons to *Daphnia magna*: Environmental Toxicology and Chemistry, vol. 6, p. 445-461.

Owenby, J.R., and Ezell, D.S., 1992, Monthly station normals of temperature, precipitation, and heating and cooling degree days, 1961-1990, Pennsylvania: National Oceanic and Atmospheric Administration Climatography of the United States No. 81, 25 p.

Rice, C.L., 1993, Environmental contaminants in soils and sediments from the Red Clay Creek Watershed, Pennsylvania and Delaware: U.S. Fish and Wildlife Service, Pennsylvania Field Office Special Project Report 93-7, 67 p.

Roy F. Weston, Inc., 1992, Remedial investigation and feasibilty study of the CSG facility: Norristown, Pa., p. 1-21.

Stamer, J.K., Yorke, T.H., and Pederson, G.L., 1985, Distribution and transport of trace substances in the Schuylkill River Basin from Berne to Philadelphia, Pennsylvania: U.S. Geological Survey Water -Supply Paper 2256A, 45 p.

Wershaw, R.L., Fishman, M.J., Grabbe, R.R., and Lowe, L.E., eds., 1987, Methods for determination of organic substances in water and fluvial sediments: U.S. Geological Survey Techniques of Water-Resources Investigation, book 5, chap. A3, 80 p.

Windholz, Martha, Budavari, Susan, Stroumtsos, L.Y., and Fertig, M.N., eds., 1976, The Merck index: Rahway, N.J., Merck and Company, 1,606 p.