WORK PLAN FOR THE SCHUYLKILL RIVER BASIN, PENNSYLVANIA: ASSESSMENT OF RIVER QUALITY AS RELATED TO THE DISTRIBUTION AND TRANSPORT OF TRACE METALS AND ORGANIC SUBSTANCES

U.S. GEOLOGICAL SURVEY

Open-File Report 80-566

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TO INTERNATIONAL SYSTEM UNITS (SI)

Multiply inch-pound unit	By	To obtain SI unit
foot (ft)	3.048×10^{-1}	meter (m)
cubic foot per second (ft^3/s)	2.832×10^{-2}	meter per second (m^3/s)
inch (in.)	2.540	centimeter (cm)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
ton (short, 2000 pounds)	9.072×10^{-1}	metric ton (t)
tons per square mile per year (ton/mi^2)/yr	3.503×10^{-1}	kilometer per year (t/km^2)/yr

Work Plan for the Schuylkill River Basin, Pennsylvania: Assessment of River Quality as Related to the Distribution and Transport of Trace Metals and Organic Substances

By G. L. Pederson, T. H. Yorke, and J. K. Stamer

ABSTRACT

The U.S. Geological Survey is making a river-quality assessment of the Schuylkill River basin in Pennsylvania from October 1978 to March 1981. It is part of a continuing program designed to demonstrate the effectiveness of river-quality studies for basin planning and water-resource management. Study objectives include determining (1) presence of selected trace metals and organic substances in the water and sediments of the Schuylkill River between Berne and Philadelphia; (2) source, distribution, and transport of selected trace metals and organic substances in the river from Berne to Philadelphia; (3) frequency of occurrence of selected trace metals and organic substances in the river at Pottstown and Manayunk; (4) effects of low dams on the distribution and transport of selected trace metals and organic substances in the river between Pottstown and Philadelphia.

INTRODUCTION

The U.S. Geological Survey is assessing the river quality of the Schuylkill River basin in southeastern Pennsylvania. The assessment began October 1, 1978, and is to be completed by March 31, 1981. This document is the work plan for the project and includes a discussion of factors affecting water quality, major water-quality problems, and individual plans for addressing the management of selected problems.

The project is part of a continuing program of the U.S. Geological Survey designed to demonstrate the effectiveness of river-quality studies for basin planning and water-resource management. Assessments have been completed for the Willamette River basin in Oregon, the Chattahoochee River basin in Georgia, and the Yampa River basin in Colorado and Wyoming. Other areas are being assessed--the Apalachicola River basin in Florida and the Carson and Truckee River basins in Nevada and California. Objectives of the assessments are (1) to define the types and amounts of data required to assess various river-quality problems and (2) to develop and document methods for assessing planning alternatives in terms of potential impacts on river quality.

Background

The assessments are a result of recommendations from the Advisory Committee on Water Data for Public Use. This Committee was established to help implement the Office of Management and Budget Circular A-67, which designated the Department of Interior responsible for coordinating Federal water-data acquisition and the Geological Survey responsible for acquiring the data. The main function of the Committee is to advise the Geological Survey on the needs for water data.

In 1971, the Advisory Committee was concerned because of a lack of suitable information for river-basin planning and for water-quality management of major rivers. The concern resulted from the inadequacy of available water data to address problems that demanded legislative action. Major problems included: (1) definition of water quality of the Nation's rivers, (2) analysis of water-quality trends, especially the effectiveness of pollution-control programs in improving water quality, (3) determination of whether advanced waste treatment was desirable or necessary on a National, State, or river-basin basis, and (4) definition of the interrelation of land use to water quality. The Committee recommended that the Geological Survey assess these problems. The assessment of the Willamette River basin in Oregon was the pilot study.

Purpose and Scope

The purpose of this project is to study water quality of selected reaches of the Schuylkill River intensively and to develop methods for evaluating planning and management alternatives for improving water quality. As all the water-quality problems in the basin cannot be addressed immediately, available water data and reports were reviewed to define major problems and to delineate specific work elements. The staff was assisted in delineating work elements by a committee composed of representatives of county, State, regional, and Federal organizations. The source, transport, and distribution of trace metals and organic substances were determined to cause the most significant water-quality problems, and the following work elements were delineated for intensive study.

1. Presence of selected trace metals and organic substances in the water and sediments of the Schuylkill River between Berne and Philadelphia.

2. Transport of selected trace metals and organic substances in the river between Berne and Philadelphia.

3. Frequency of occurrence of trace metals and organic substances in the main stem at Pottstown and Manayunk.

4. Effects of low dams on the distribution and transport of trace metals and organic substances in the river between Pottstown and Philadelphia.

DESCRIPTION OF THE SCHUYLKILL RIVER BASIN

The Schuylkill River lies entirely in southeastern Pennsylvania. Principal streams in the basin are shown on figure 1, and the corresponding map-reference numbers and stream names are given in table 1. The headwaters begin at Locust Mountain near Tuscarora in Schuylkill County, and the river flows for 131 miles southeastward to its confluence with the Delaware River in Philadelphia. The drainage area upstream from Fairmount Dam in Philadelphia, which is the downstream end of the study area, is 1,893 mi^2 (square miles). The largest tributaries are Perkiomen Creek, which drains 362 mi^2, Tulpehocken Creek, which drains 219 mi^2, and Maiden Creek, which drains 216 mi^2. Cumulatively, these three tributaries drain 42 percent of the basin. Principal municipalities, in downstream order, are: Pottsville, Reading, Pottstown, Phoenixville, Norristown, Conshohocken, and Philadelphia. As of 1970, the population of the seven largest municipalities together was 2,144,509 (U.S. Department of Commerce, 1971), 91 percent in Philadelphia. The river drains large areas of Schuylkill, Berks, Montgomery, Chester, and Philadelphia Counties and small areas of Carbon, Lehigh, Lebanon, Lancaster, Bucks, and Delaware Counties.

General Hydrology

Climate

Average air temperature in the Schuylkill River basin is 11°C (degrees Celsius); it ranges from 12.5°C in the relatively flat coastal plain to 9.6°C in the mountainous headwaters. The coldest months are January and February; the warmest are July and August.

Average precipitation is 42 in. and ranges from 40 in. in the coastal plain to 49 in. in the headwaters. Precipitation is greatest in July and August and least in January and February, although it is fairly evenly distributed throughout the year.

Surface Water

The areal variation in average annual flow of the Schuylkill River depends on the amount of precipitation, geologic terrane, and topography. Flow per unit area is maximum in the mountains, where precipitation and altitudes are greatest, and minimum in the Philadelphia area, where precipitation and altitudes are least (table 2). Monthly streamflow is higher as a result of antecedent conditions, which include saturated soils, near maximum ground-water storage, and periodic snow melts. During the warmer months, streamflow decreases in response to higher rates of evaporation and transpiration.

Water Use

The waters of the Schuylkill River and its tributaries are used extensively for municipal and industrial water supply, recreation, and waste assimilation.

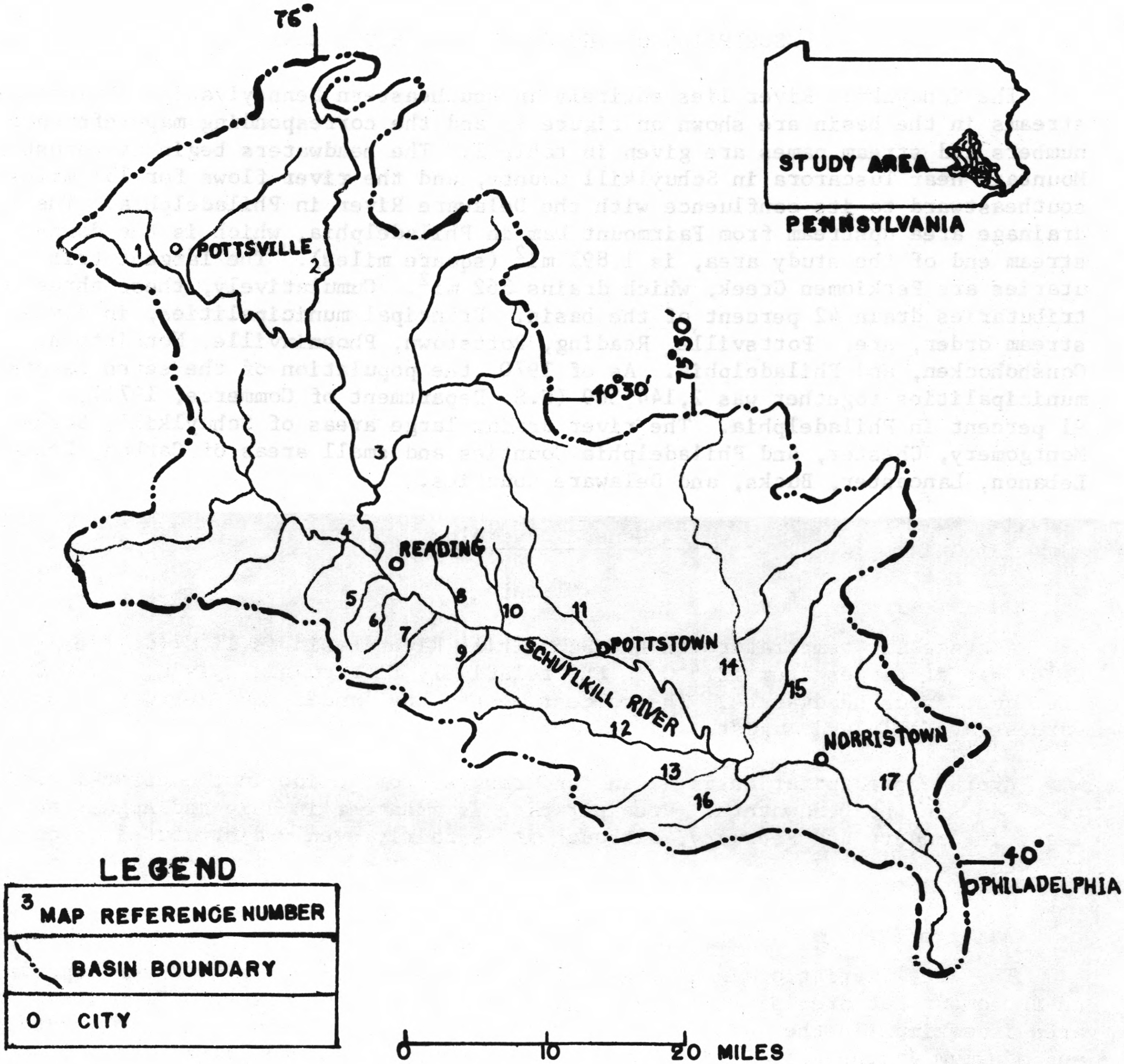

Figure 1.--Principal streams in the Schuylkill River Basin.

Table 1.--Map-reference number and stream name, Schuylkill River basin

Map reference no.	Stream name
1	West Branch Schuylkill River
2	Little Schuylkill River
3	Maiden Creek
4	Tulpehocken Creek
5	Wyomissing Creek
6	Angelica Creek
7	Allegheny Creek
8	Antietam Creek
9	Hay Creek
10	Monocacy Creek
11	Manatawny Creek
12	French Creek
13	Pickering Creek
14	Perkiomen Creek
15	Skippack Creek
16	Valley Creek
17	Wissahickon Creek

Table 2.--Streamflow characteristics at selected stations in the Schuylkill River basin

Station name	Drainage area (mi^2)	Average water discharge (ft^3/s)	Average water discharge (in./yr)	7-day 10-year minimum flow (ft^3/s)	Period of record (years)	Average water yield (ft^3/s)/mi^2
Schuylkill River at Landingville	133	285	29.10	28	11	2.14
Little Schuylkill River at Tamaqua	42.9	92.6	29.31	5	58	2.16
Schuylkill River at Berne	355	702	26.85	80	30	1.98
Maiden Creek Tributary at Lenhartsville	7.46	12.1	22.03	0.07	12	1.62
Tulpehocken Creek at Blue Marsh Damsite near Reading	175	272	21.10	34	12	1.55
Tulpehocken Creek near Reading	211	307	19.76	45	27	1.45
Schuylkill River at Reading	880	1,490		160	12	1.69
Schuylkill River at Pottstown	1,147	1,878	22.24	250	51	1.64
French Creek near Phoenixville	59.1	89.4	20.53	11	9	1.51
Pickering Creek near Chester Springs	5.98	9.91	22.51	1.5	10	1.66
Perkiomen Creek at Graterford	279	381	18.54	18	63	1.37
Skippack Creek near Collegeville	53.7	77.3	19.55	.6	11	1.44
Wissahickon Creek at Bell Mills Road, Philadelphia	53.6	67.5	17.09	7.5	8	1.26
Wissahickon Creek at mouth, Philadelphia	64.0	84.4	17.91	7.3	9	1.32
Schuylkill River at Philadelphia	1,893	2,910	20.87	69[1/]	46	1.54

[1/] Does not include diversion by City of Philadelphia

Water Supply

The Schuylkill River and its tributaries are the primary source of public water supply in the basin; an average of 700 ft^3/s (cubic feet per second) is withdrawn. The largest withdrawal is by the city of Philadelphia -- an average of 290 ft^3/s. Other major withdrawers for municipal water supply include: Philadelphia Suburban Water Company, from Pickering Creek, Perkiomen Creek, and the Schuylkill River; and Norristown Water Company, Pottstown Water Authority, and the Borough of Phoenixville, all exclusively from the Schuylkill River. The Reading Bureau of Water withdraws water from Maiden Creek. The Schuylkill County Municipal Authority, the Tamaqua Borough Water Department, and other communities in the headwaters withdraw water from numerous impoundments on small tributaries.

Industry is the biggest water user in the basin, about 1,000 ft^3/s of water in 1977. The major use of industrial water is for cooling condensers of thermoelectric powerplants. About 950 ft^3/s of water was used by the three powerplants on the river at Reading, Phoenixville, and Norristown. Other significant industrial water users include steel, coal, rubber, and paper products.

Recreation

The Schuylkill River and its tributaries are used for boating, water skiing, and fishing. Interest in water-oriented recreation has been increasing steadily since the Schuylkill River Restoration project of the 1950's. The former navigational pools of the Schuylkill, formed by low dams such as Fairmount Dam in Philadelphia, Norristown Dam, Black Rock Dam near Phoenixville, and Felix Dam near Reading, are boating and water skiing centers.

In May 1978, construction was completed on a 226-foot fish ladder at the Fairmount Dam to allow alewife, blueback herring, and shad to spawn upriver. The Pennsylvania Fish Commission hopes that fish ladders will eventually be built at the other four low dams in the reach from Philadelphia to Reading, so that an anadromous fishery can be restored.

Recreation on the Schuylkill was given increased emphasis as a result of recent legislation that designated selected reaches as the first segment in Pennsylvania's Scenic Rivers System.

Waste Assimilation

Most municipal wastewater discharges are in the lower third of the basin. Communities such as Pottsville, Cressona, and Schuylkill Haven in the upper basin, discharge a total of 9.8 ft^3/s, or about 4 percent of the total municipal wastewater. The middle reach, between Leesport and Valley Forge, receives 67 ft^3/s, or 28 percent of the total wastewater discharge. The remaining 68 percent is discharged within the lower third of the basin, downstream from Norristown.

Most industrial discharges are downstream from Reading. The volume of these discharges are small compared to the municipal sources, except for industries that use water for cooling, such as Phoenix Steel at Phoenixville, which discharges about 21 ft^3/s.

WATER QUALITY PROBLEMS

Most water-quality problems of the Schuylkill River are related to acid mine drainage, agriculture, and urbanization. Acid mine drainage has damaged the headwaters, agriculture and urbanization the mid-reach, and urbanization the lower reach.

Upper Reach

The headwaters lie mostly within Schuylkill County. The anthracite coal fields have been mined for more than 100 years. Drainage from underground mines, runoff from strip mines, and seepage from the refuse of past mining contribute waters having high concentrations of sediment. In addition, high concentrations of iron, sulfate, and acidity result from the weathering of iron sulfides associated with coal beds. The waters receiving acid mine drainage generally cannot support aquatic life nor can they be used for public water supply.

Although anthracite production in Schuylkill County is decreasing, data indicate the persistence of acid mine drainage. Biesecker and others (1968) developed a doublemass curve relating sulfate concentration to discharge the river at Berne during 1947-65. The constant slope of the curve suggests that water quality did not change because of changes in mine drainage between 1947 and 1965.

Data for October 1976 to September 1977 (U.S. Geological Survey, 1978) for the Schuylkill at Pottsville show that sulfate concentrations ranged from 122 to 440 mg/L (milligrams per liter), pH ranged from 4.8 to 6.2, and total iron ranged from 1,460 to 4,620 µg/L (micrograms per liter). For the West Branch Schuylkill River at Cressona, sulfate concentrations ranged from 170 to 445 mg/L, pH ranged from 4.3 to 7.5, and total iron ranged from 1,390 to 12,500 µg/L. For the Little Schuylkill River near Tamaqua, sulfate concentrations ranged from 140 to 600 mg/L, pH ranged from 5.1 to 7.2, and total iron ranged from 2,520 to 12,100 µg/L. These data indicate that acid mine drainage into the headwater streams persists and that water quality of the three headwater streams differs but little.

In December 1978, the Geological Survey reconnoitered for trace metals and selected organic compounds. A summary of analyses of bed material in the upper reach is shown in table 3. These data indicate that trace metals and organic substances are not significant in the area affected by acid mine drainage. The high lead concentrations at Berne may represent residuals from a battery manufacturing plant. The concentration of other constituents probably represents background or near background levels.

Table 3.--Results of trace-metal and organic analyses of river-bed sediments, headwaters to Berne, December 1978

	Cadmium (µg/g)	Chromium (µg/g)	Copper (µg/g)	Lead (µg/g)	Zinc (µg/g)	PCBs (µg/kg)	DDT DDE DDD (µg/kg)	Chlordane (µg/kg)
Schuylkill River at Port Carbon	<10	<10	20	40	50			
West Branch Schuylkill River at Minersville	<10	10	30	30	70			
West Branch Schuylkill River at Cressona	<10	10	40	40	190			
Schuylkill River at Landingville	<10	10	30	30	100	53	0.0	0
Schuylkill River at Auburn	<10	10	20	20	70			
Little Schuylkill River at New Ringgold	<10	10	30	40	70			
Little Schuylkill River at Drehersville	<10	10	30	20	90			
Little Schuylkill River at Port Clinton	<10	10	30	70	80			
Schuylkill River at Berne	<10	10	20	180	100	19	4.0	4

Middle Reach

In the midreach of the Schuylkill, from Leesport to Phoenixville, urbanization and agriculture adversely impact the river and its tributaries. In this reach are the urban centers of Reading, Pottstown, and Phoenixville. Urbanization has created demands on the river and its tributaries for water supply, power generation, and transport and assimilation of waste. Water withdrawals for municipal supply average about 50 ft^3/s. Two thermoelectric power plants, Metropolitan Edison's Titus Station and Philadelphia Electric's Cromby Station, withdraw and subsequently discharge about 700 ft^3/s of heated water. Municipal wastewater treatment facilities discharge about 50 ft^3/s into the river, and industries discharge about 30 ft^3/s of waste water. The impacts of urbanization in this reach are depressed DO (dissolved oxygen) concentrations during median to low flows and significant concentrations of trace metals and organic substances in the water column, river-bed sediments, and fish.

During the 1973 water-quality survey by DER (Pennsylvania Department of Environmental Resources) and EPA (U.S. Environmental Protection Agency), lead concentrations in river-bed sediments and fish were high (Brezina and others, 1974). Concentrations of PCBs in fish collected from the Reading to Pottstown reach were the highest found in Pennsylvania during a 1976 DER survey (Brezina and Arnold, 1976). High concentrations of phenols were observed in the entire reach from Reading to Pottstown during the August 1976 COWAMP/208 (Comprehensive Water Quality Management Plan) survey (DVRPC, 1978).

Data from the Survey's December 1978 reconnaissance confirm high concentrations of lead and other trace elements in the river-bed sediments (table 4). Concentrations of lead exceeded 250 μg/g at six to eight main stem stations. Cacoosing Creek (370 μg/g) and Bernhart Run (1600 μg/g) also had high concentrations of lead in the bed sediments. Copper concentrations exceeded 100 μg/g at five of eight main stem stations. The only tributary where copper in the river-bed sediments exceeded 100 μg/g was Cacoosing Creek (180 μg/g). Only three of eight main stem stations had chromium concentrations greater than 100 μg/g. No tributary site had a chromium concentration greater than 20 μg/g. Concentrations of cadmium in river-bed sediments were low throughout the basin. Concentrations of zinc exceeded 500 μg/g at four of eight main stem stations. Zinc concentrations were low at all tributary stations.

High concentrations of organic compounds were also found in the river-bed sediments in the middle reach. Most notable were PCB concentrations of 310, 950, and 310 μg/kg (micrograms per kilogram) at Reading, Lorane, and Birdsboro. Wyomissing Creek and Angelica Creek, tributaries draining the Reading area, had high concentrations of PCBs (400 and 780 μg/kg) in the bed sediments. Chlordane and DDT residues were also high at several main stem and tributary sites. Wyomissing Creek and the highest concentrations of chlordane and total DDT in the basin.

Table 4.--Results of trace-metal and organic analyses of stream-bed sediments, Leesport to Phoenixville, December 1978.

	Cadmium (µg/g)	Chromium (µg/g)	Copper (µg/g)	Lead (µg/g)	Zinc (µg/g)	PCBs (µg/kg)	DDT DDE DDD (µg/kg)	Chlordane (µg/kg)
Maiden Creek near Leesport	<10	10	20	50	60	76	1.3	0
Schuylkill River at Felix Dam near Reading	<10	10	30	90	130			
Laurel Run at mouth near Reading	<10	10	20	80	30			
Bernhart Run at Reading	<10	20	30	1,600	100	30	0.8	2
Schuylkill River above Tulpehocken Creek at Reading	<10	140	110	500	480	310	25	10
Cacoosing Creek near Reading	<10	20	180	370	120			
Tulpehocken Creek at Reading	<10	20	30	40	120			
Wyomissing Creek at West Reading	<10	10	20	230	100	400	118	57
Schuylkill River at Ridgewood near Reading	<10	10	30	300	80	76	14.7	18
Angelica Creek near Reading	<10	10	10	20	30	780	1.6	7
Schuylkill River near Lorane	<10	120	320	330	820	950	0.0	0
Antietam Creek at Lorane	<10	10	20	40	60	12	1.3	14
Hay Creek at Birdsboro	<10	<10	<10	120	30	0	1.4	2

Table 4.--Results of trace-metal and organic analyses of stream-bed sediments, Leesport to Phoenixville, December 1978--Continued.

	Cadmium (µg/g)	Chromium (µg/g)	Copper (µg/g)	Lead (µg/g)	Zinc (µg/g)	PCBs (µg/kg)	DDT DDE DDD (µg/kg)	Chlordane (µg/kg)
Schuylkill River at Monocacy Station near Birdsboro	<10	50	330	260	700	310	14	28
Monocacy Creek near Monocacy	<10	10	10	40	50	4	0.0	0
Manatawny Creek at Pottstown	<10	20	20	60	1,300	120	6.6	12
Schuylkill River at Pottstown	<10	30	80	100	290			
Schuylkill River at Linfield	<10	50	100	300	380			
Schuylkill River at Black Rock Pool near Phoenixville	30	130	190	250	1,000	120	3.8	41
French Creek near Phoenixville	<10	10	<10	20	30	0	0.0	0

The impact of urbanization of the DO regime in the midreach was observed during the August 1976 COWAMP/208 survey. Concentrations of DO were depressed in the reach between Reading and Pottstown. They decreased from an average of 8.1 mg/L at Reading to less than 5 mg/L at Pottstown. The low DO concentrations during warm weather, low-flow periods are probably owing to oxidation of organic material in municipal wastewater. The organic load is increased in the Reading area and downstream because of waste discharges from Reading, Wyomissing, and Birdsboro. In addition to the municipal wastewater discharges, a powerplant discharges (recirculates) about 250 ft^3/s of heated effluent just downstream from Reading.

The impact of agriculture on water quality in the midreach is indicated by the trophic status of Lake Ontelaunee, which was formed by impounding Maiden Creek. The 1973 National Lake Eutrophication Survey by EPA ranked Lake Ontelaunee the third most eutrophic lake of the 17 surveyed in Pennsylvania. The lake exhibits large diel DO fluctuations, high pH at the surface, and low light penetration during algal blooms. Water-quality data (October 1976 - September 1977) collected from Maiden Creek downstream from the lake indicate significant concentrations of nitrate (as nitrogen) and total phosphorus, which ranged from 1.4 to 5.6 mg/L and 0.04 to 0.79 mg/L, respectively (U.S. Geological Survey, 1978).

Tulpehocken Creek which flows into the Schuylkill River from the west also drains a predominantly agricultural area. Water-quality data collected from the stream at the site of the Blue Marsh Dam show high nutrient concentrations (U.S. Geological Survey, 1978). Nitrate concentrations ranged from 2.4 to 4.8 mg/L and averaged 3.8 mg/L; total phosphorus concentrations ranged from 0.03 to 0.39 mg/L and averaged 0.14 mg/L during October 1976 to September 1977. The influence of the nutrient inflows from Tulpehocken and Maiden Creeks at Reading is shown by the average nitrate (3.0 mg/L) and total phosphorus (0.22 mg/L) concentrations during October 1976 to September 1977. Nutrient concentrations in the river remained high during this period at Pottstown, which is 28 miles downstream from Reading.

Lower Reach

The lower reach of the Schuylkill, from Phoenixville to Fairmount Dam, is affected by municipal and industrial wastewater discharges. River-bed sediments contain high concentrations of trace metals such as lead, copper, zinc, and cadmium and high concentrations of organic substances such as PCBs and other chlorinated hydrocarbons. The water periodically contains high concentrations of phenols and dissolved trace metals. Fish collected in this reach have contained high concentrations of trace metals and organic substances.

Data from the December 1978 reconnaissance indicate that sediment in the main stem at Black Rock Pool near Phoenixville, at Norristown, and at Philadelphia, contains high concentrations of trace metals and organic substances (table 5). The only insecticides detected in the sediment were those listed in table 5. PCBs and insecticides were not detected in the water column at these sites. Dissolved concentrations of most trace metals were not exceptionally high at any of the sites. Trace metal and organic data for tributaries in the Phoenixville to Fairmount reach indicated that the tributaries sampled are not the primary source of the trace substances. However, concentrations of PCBs in the sediment of Perkiomen Creek at Oaks and Wissahickon Creek at Philadelphia were appreciable (150 and 93 μg/kg).

Concentrations of PCBs of 1.64 μg/g were determined in smallmouth bass, and green, bluegill, and pumpkinseed sunfish collected by DER in 1976 just downstream from Plymouth Dam, and concentrations of PCBs of 3.69 μg/g were determined in carp collected just upstream from Flat Rock Dam (Brezina and Arnold, 1976). These fish also contained small concentrations of DDT in the edible tissue.

High concentrations of phenolic compounds were found in the water during the August 1976 COWAMP/208 survey. The 25-day mean concentration of phenol at Flat Rock Pool was 0.028 mg/L, considerably higher than DER's proposed maximum criterion of 0.005 mg/L. Although small concentrations of phenols are not toxic to humans, phenols impart taste and odor to drinking water.

Another impact of urbanization in the lower reach is on the DO regime. DO, in the 15-mile Norristown-to-Fairmount Dam reach, is depressed during warm-weather low-flow periods. Several factors contribute to the low DO during these periods. (1) The large volume of wastewater discharged into the river from municipal and industrial sources totals about 150 ft^3/s. The 7-day, 10-year minimum streamflow at Philadelphia is about 350 ft^3/s, which includes the diversion by the city of Philadelphia for municipal water supply. Thus, during a critical low-flow period, 43 percent of the flow at Philadelphia is wastewater discharged downstream from Norristown. (2) Thermal discharges from powerplants decrease the waste assimilative capacity of a stream and increase the rate of oxidation of organic wasteloads. A powerplant just upstream from the Norristown Dam discharges about 190 ft^3/s of heated effluent into the river. (3) The three dams downstream from Norristown (Plymouth, Flat Rock, and Fairmount) create pools and reduce the velocity of the river and, consequently, reduce the ability of the river to reaerate itself.

Table 5.--Results of trace-metal and organic analyses in the reach of the Schuylkill River from Phoenixville to Fairmount Dam, December 1978

	River-bed Sediment								Dissolved in Water Column		
	Cadmium (µg/g)	Chromium (µg/g)	Copper (µg/g)	Lead (µg/g)	Zinc (µg/g)	PCBs (µg/kg)	DDT DDE DDD (µg/kg)	Chlordane (µg/kg)	Chromium (µg/L)	Copper (µg/L)	Zinc (µg/L)
Schuylkill River at Black Rock Pool near Phoenixville	30	130	190	250	1,000	120	15.8	41	1	5	80
Schuylkill River at Norristown	<10	30	70	400	1,000	2,400	8.3	64	0	7	120
Schuylkill River at Philadelphia	<10	50	80	180	170	240	19.4	74	0	4	0

The effect of urbanization on the tributaries near Philadelphia has also caused a sedimentation problem in the lower pools of the river. Sediment yields of the various sub-basins of the Schuylkill generally increase downstream. The average annual sediment yield of the river at Berne is about 40 tons/mi^2. The yields of Tulpehocken and Perkiomen Creeks are 130 and 210 tons/mi^2, respectively. Wissahickon Creek, which drains urbanizing areas of Montogmery County, has an average annual sediment yield of about 800 tons/mi^2 (Biesecker and others, 1968). Other smaller streams that drain into the lower pools of the Schuylkill, such as Valley, Trout, Stony, and Plymouth Creeks, probably discharge sediment loads comparable to the load of Wissahickon Creek.

Problems caused by the excessive sediment load from the lower basin are compounded by the lack of spoil-disposal areas in the lower pools. The Flat Rock and Fairmount pools have no desilting basins. Spoil dredged from the pools must be barged or trucked to remote sites. The potential for contaminating water supplies with trace substances in river sediments limits the practicability of spoil sites in the Philadelphia area.

BASIC STUDY DESIGN

This study will address the source, transport, and distribution of trace metals and organic substqnces in the Schuylkill River basin. Results of the study should provide planners with information for managing these trace substances. Potential management tools include controlling or eliminating sources, predicting when water-quality criteria are not met at municipal intakes on the river, and controlling the distirbution in the river-bed sediments. Some questions that will be addressed include:

1. What trace metals and organic substances are present in the Schuylkill River?

2. Where are the source areas of the trace metals and organic substances?

3. What is the relative contribution of selected tributaries and main stem reaches to the trace metal and organic substance load of the river?

4. What are the principal transport mechanisms of trace metals and organic substances in the river?

5. Where, when, and how often do concentrations of trace metals and organic substances exceed water-quality criteria?

6. How do the low dams on the lower river affect the distribution of trace metals and organic substances?

The study will have four elements intended to address the problems of trace metals and organic substances in the Schuylkill River basin. The first is the Presence of Trace Metals and Organic Substances. This element will determine what trace metals and organic substances are present in the basin. Analyses will include trace metals, pesticides, PCBs, purgeable organic substances, and base/neutral and acid extractable organic substances.

The second, Transport of Trace Metals and Organic Substances, will identify the source areas and quantify the movement of the substances selected for detailed study. This element will focus on transport on discrete reaches of the river and selected tributaries.

The third, Frequency of Occurrence of Trace Metals and Organic Substances, will evaluate the temporal distribution and methods of transport at two sites on the main stem.

The fourth, Effects of Low Dams on the Distribution of Trace Metals and Organic Substances, will address the inflow and outflow of suspended sediment and selected trace metals and organic substances in the numerous pools on the Schuylkill. Samples will be collected at the inflow and outflow of several pools during storms to document timing, magnitude, and transport through the pools. Surface bed-material samples and core samples will be analyzed to determine the short-term and long-term accumulation in Fairmount Pool.

The objectives and specific methods of each study element are presented in the following sections.

Presence of Trace Substances

Objectives

1. To determine the presence of trace metals and organic substances, as set forth in EPA's list of 129 priority pollutants, in the water and sediments of the Schuylkill from Berne (river mile 95) to Philadelphia (river mile 9).

2. To determine the relation of concentrations of trace metals and organic substances to particle size in the river-bed sediments.

Methods

As indicated earlier in the work plan, river-bed sediments were collected at many sites on the main stem and most of its major tributaries. The samples were analyzed for selected trace metals and (or) organic substances and particle-size distribution. Discrete samples of water suspended-sediment mixtures were collected near municipal water supply intakes and analyzed for metals, pesticides and PCBs. Suspended-sediment/water mixtures have been collected from the river at Reading, Pottstown, and Manayunk; and river-bed sediments have been collected at Lorane, in the Vincent Pool, and in the Fairmount Pool to determine the presence of priority pollutants.

The three main stem sites, Reading, Pottstown, and Manayunk, were selected for this initial screening because (1) all three sites are Survey gaging stations, (2) Pottstown and Manayunk are sites just upstream from major diversions for municipal water supply, and (3) all three sites are downstream from numerous industrial and municipal wastewater discharges.

Water samples were collected during base-flow and storm conditions, and bed sediments were collected during base flow. The samples were analyzed for 31 purgeable organic substances, which include benzene and chloroform; 46 base-netural extractable compounds, which include chlorinated benzene compounds, phthalate esters, and polynuclear aromatic hydrocarbons; 11 acid extractable organic substances which include phenols and chlorinated phenols; 26 PCBs and pesticides, which include DDT, chlordane and toxaphene; and 13 metals, which include arsenic, lead, and mercury. Sediment concentration and particle-size distribution (storm samples only) will also be determined. The river-bed sediments will be analyzed for the base-neutral extractable organic compounds, pesticides, PCBs, metals, and particle-size distribution.

To date, we have received data on the bed-material and water samples collected during the base-flow period. The data indicate significant concentrations of some metals such as lead and zinc, DDT and its degradation products, base-neutral extractable organic substances, and PCBs in the bed-material and no significant concentrations of constituents in the water samples. The absence of purgeable and acid extractable organic substances (detection limit is about 1 μg/L), may indicate that (1) these substances are not discharged into the river continuously or (2), if they are discharged continuously, they are present in concentrations lower than the present limits of detection. Therefore, about 10 water samples for determinations of purgeable and acid extractable organic substances will be collected randomly for about a year on the river near Lorane (just downstream from the Reading area) and at Pottstown and Manayunk.

The second objective of this element involves collecting composite bed-material samples from each of the six pools from Pottstown to Fairmount Dam. The pools, in downstream order, are Vincent, Black Rock, Norristown, Plymouth, Flat Rock, and Fairmount. The bed-material samples will be split into five particle-size fractions: 0.25 to 2 mm (millimeters), 0.062 to .25 mm, finer than 0.062 mm, finer than 0.016 mm, and finer than 0.004 mm. Each fraction from each of the six pools will then by analyzed for PCBs and lead, which can serve as indicators for the sorption of organic substances and metals. PCBs and lead were selected for study because of their significant concentrations during the December 1978 reconnaissance. The results of size-fraction work will determine (1) which particle-size fraction of sediment is associated with the largest concentrations of organic substances and metals sorbed onto the sediments (2) which particle-size fraction of bed-sediments should be analyzed for trace substances during a possible intensive bed-material study (see addendum), and (3) the mechanism by which relatively insoluble trace metals and organic substances are transported in the stream, reach by reach.

The results of the initial screening of the water/suspended-sediment mixture and the bed sediments will be evaluated and compared with previous studies of trace metals and organic substances to determine what trace substances are present and where.

Transport of Trace Metals and Organic Substances

Objectives

1. To determine the major source areas of selected trace substances in the Schuylkill River basin.

2. To determine the relative contribution of each source area to the average-annual load of selected trace substances transported in the river Berne and Philadelphia.

Methods

On the basis of previous data collected by DER and the Geological Survey, 5 sites on the main stem and sites on 13 tributaries have been selected to collect data to develop average-annual transport curves of selected trace substances. The list of stream stations, constituents, and anticipated number of samples is shown in table 6.

Samples of suspended-sediment/water mixtures will be collected at each of the 18 stream sites over a wide range of hydrologic and seasonal conditions. Sample collection will be well distributed throughout the range of streamflow during the study.

Flow-duration and sediment-transplant curves will be used to determine, on an average annual basis, the major source areas of selected trace substances and the relative contributions of trace substances from each of the major tributaries. The source areas to be studied are from Berne to Reading, Reading to Pottstown, Pottstown to Port Kennedy, and Port Kennedy to Manayunk.

By determining the average annual loads of selected trace substances, by reach, some indication of the role of the pools in trapping trace metals and organic substances can be evaluated. For example, a decrease in the average annual load of some constituent from Port Kennedy to Manayunk would indicate that the Norristown, Plymouth, and Flat Rock Pools serve as repositories for that constituent.

Transport curves cannot be developed from groups of some substances, which include the purgeable and acid extractable organic substances, because the constituents within these groups are not usually present in the river at the current limits of analytical detection.

Frequency of Occurrence of Trace Metals and Organic Substances

This element will determine the percentage of time that water-quality criteria may be violated, as applied to aquatic life and public water supplies, and the mechanism by which the material is being transported by the river.

Table 6.--List of stream stations to be used for determining transport and the anticipated number of samples of each constituent or group of constituents

Station Name	Metals	PCBs and Insecticides	Base-neutral Organic Compounds	Suspended-sediment Concentration and Particle-size Distribution
Schuylkill River at Berne	20	20	20	20
Maiden Cr. at mouth near Temple	20	20	3-20	20
Bernhart Run at Reading	20			20
Tulpehocken Cr. near Reading	20	20	3-20	20
Schuylkill R. at Reading	20	20	20	20
Wyomissing Cr. at West Reading	20	20	3-20	20
Angelica Cr. near Reading		20		20
Manatawny Cr. at Pottstown	20	20	3-20	20
Schuylkill R. at Pottstown	20	20	20	20
French Cr. at Phoenixville	20			20
Perkiomen Cr. at Graterford	20	20	3-20	20
Skippack Cr. near Collegeville	20			20
Valley Cr. at Valley Forge	20	20	3-20	20
Schuylkill R. at Port Kennedy	20	20	20	20
Stone Cr. at Norristown	20	20	3-20	20
Plymouth Cr. at Conshohocken	20	20	3-20	20
Schuylkill R. at Manayunk, Philadelphia	20	20	20	20
Wissahickon Cr. at mouth at Philadelphia	20	20	3-20	20

Objectives

1. To determine the frequency of occurrence and timing of high concentrations of trace metals and organic substances at selected sites.

2. To define the transport mechanism of trace metals and organic substances at selected sites between Reading and Fairmount Dam.

Methods

Two sites on the main stem, Pottstown and Manayunk, have been selected to study the frequency of occurrence and transport mechanism of selected trace substances. These sites were selected because of their proximity to major water intakes, their location downstream from highly industrial areas in Reading and Norristown, and the availability of long-term water discharge data.

Approximately 20 samples will be collected at each site to define variations in concentrations of trace substances. The sampling schedule for heavy metals and organic compounds that are normally associated with particulate material, such as PCBs, chlorinated insecticides, and some industrial organic compounds will be based on the flow regime of the river. Samples will be collected throughout the range of discharge during the study.

All water samples will be collected as discrete samples, representative of a specific time and water discharge. A depth-integrating sediment sampler will be used to collect samples. A single vertical in the river section will be used if suspended-sediment concentration and specific conductance are uniform across the section. Otherwise, discharge-weighted or width integrated samples will be collected.

Transport curves will be developed for the constituents that are normally associated with suspended sediment or are discharge dependent. These curves will relate the concentration of each constituent (total concentration for the organic substances and total and dissolved concentrations for the metals) to discharge, suspended-sediment concentration, or the concentration of the silt and clay fraction of sediment. The transport curves will be used with long-term streamflow and sediment characteristics to determine concentration-frequency relations of selected trace substances at Pottstown and Manayunk. The total load of each selected trace substance transported by the river at Pottstown and Manayunk will also be computed.

Effect of Low Dams on the Distribution of Trace Metals and Organic Substances

This effort will concentrate on the transport of suspended sediment and those trace substances sorbed onto the sediments into the old navigation pools on the lower Schuylkill and their distribution within the pools. The basic purpose of this phase is to determine how the pools affect the movement of sediment and trace substances and to determine whether the pools can be used to control the distribution of trace substances.

Objectives

1. To determine the flow characteristics that affect the transport of suspended sediment and trace substances sorbed onto the sediments through the pools.

2. To determine current and long-term rates of sediment deposition and the trap efficiency of the pools on the lower Schuylkill.

3. To determine the amount of trace substances deposited in the pools and the timing of the deposition.

Methods

The current rates of deposition within the pools and factors affecting the transport of trace substances through the pools will be determined by multiple intensive sampling of inflow and outflow of Vincent Pool and the Norristown, Plymouth, and Flat Rock Pools. The Vincent Pool was selected because it is the first pool downstream from the highly industrialized Reading area and because no major tributaries flow directly into the pool. The study of the Norristown, Plymouth, and Flat Rock Pools will provide an evaluation of the effectiveness of a series of pools on the lower river.

Inflow and outflow of the pools will be sampled during about five storms, including two intense summer storms and one large spring storm. Approximately 10 samples will be collected during each storm to define the temporal variation of suspended-sediment concentration, particle-size distribution, and concentration of selected trace substances. A representative metal and organic compound, probably lead and PCBs, will be analyzed to define the transport of trace substances through the pool. By sampling the rise, peak, and recession of several storms, it will be possible to determine how much sediment and trace material is transported into and out of the pools during different flow conditions. Specifically, the data will help determine the flow conditions that induce deposition or scour in the pools.

Several storms may also be sampled at intermediate points within the Vincent Pool to define the response of suspended sediment and trace substances to changing hydraulic conditions. Several sets of bed-material samples will be collected to determine the effect of hydraulic conditions, such as mean velocity, cross-sectional area, and depth, on the longitudinal distribution of sediments and sorbed trace substances in the pool.

The long-term rate of sediment and trace substance deposition within the pools and the trap efficiency of the pools will be determined by analyzing streamflow and suspended-sediment data and from sedimentation surveys. Streamflow data are available for several sites upstream and downstream from the low dams and for most of the major tributaries. Suspended-sediment data are also available for selected periods between 1950 and 1976. These data will be used, together with the suspended-sediment data collected during the study, to determine the total inflow of sediment to the lower pools since the Schuylkill River Restoration Project was completed in 1954. Sedimentation surveys in the mid 1950's, 1970, 1973, and 1977-78 will be used to document the total accumulation of sediment in the pools. The more frequent surveys in recent years will help document the effects of large storms such as Hurricane Agnes, which occurred between the 1970 and 1973 surveys.

The total accumulation of selected trace substances in the pools will be evaluated by analyzing several core samples collected in the Fairmount Pool. Cores will be collected near the dam, in the middle of the pool, and at the head of the pool. Sedimentation surveys will be used to locate sampling points in areas of long-term deposition. The cores will be segmented into about 5-year accumulations and analyzed for selected metals, PCBs, pesticides, and base-neutral organic compounds. The results will help to quantify the total distribution of trace substances introduced into the basin since the restoration project in 1954.

The sampling schedule for studying the effects of low dams on the distribution of trace substances is listed in table 7.

Products

The results of the field work will be presented in two reports titled, "Source, distribution, and transport of selected trace metals and organic substances in the Schuylkill River between Berne and Philadelphia, Pennsylvania" and "Effects of low-level dams on the distribution of trace substances in the lower Schuylkill River Pennsylvania." The first report will discuss the presence of trace substances in the river and the source and transport of selected substances between Berne and Philadelphia. Data will be analyzed to determine the average-annual loads of trace substances originating in selected reaches of the main stem and most of the tributaries. Transport mechanisms and the frequency of occurrence of trace metals and organic substances at major water intakes on the river will be discussed.

The second report will present the results of several related studies concerned with the effects of low dams on the distribution of trace substances in the lower river. Long-term sedimentation rates and trap efficiency will be determined for each pool. The accumulation of trace substances will be quantified for the Fairmount Pool. Interaction between the bed sediments and the water column will be defined in terms of deposition and resuspension of sediments and trace substances during storms. The potential for managing the pools to control the transport of trace substances will be evaluated. Also, the potential effects of extremes, such as droughts or floods, on the distribution of trace substances will be evaluated in terms of impacts on water supplies and the aquatic ecosystem.

Table 7.--Samples required for the study of the effects of low dams on the distribution of trace substances.

Parameters	Pottstown	Vincent Pool	Royersford	Port Kennedy	Manayunk	Fairmount Pool
			Sample Sites			
			number of samples			
Water samples						
Lead, total recoverable	40[a]	20	50	40[a]	40[a]	
Lead, dissolved	40[a]	20	50	40[a]	40[a]	
PCB, total recoverable	40[a]	20	50	40[a]	40[a]	
Suspended sediment						
concentration	40[a]	20	50	40[a]	40[a]	
particle size	40[a]	20	50	40[a]	40[a]	
Bed material						
Metals						15
Chlorinated insecticides						15
Base/neutral organic compounds						15
PCBs		12				15
Lead		12				
Particle size		12				15

[a] 10 additional samples will be collected at Pottstown, Port Kennedy, and Manayunk as part of the transport and frequency studies.

Two conceptual papers dealing with present-day methodology and analytical sampling will be prepared during the project. The first paper will summarize the intent and objectives of pertinent Federal legislation concerning trace substances. The types of programs needed to meet the objectives of the Federal laws will be discussed. Examples will be given of the types of data and frequency of collection needed for the programs. The report will include discussions of the priority pollutant list according to analytical category as well as hydrologic response. The first paper will also include a discussion of -- (a) what is known about the impact of the priority pollutants on aquatic life; (b) what we do and do not know about documenting these impacts; and (c) what applicable criteria and standards are pertinent?

The second paper will concern the knowledge, or lack thereof, of how to sample varying hydrologic environments for trace organic substances. The paper will detail present sampling methods, including strengths and weaknesses. Discussion of the various analytical schemes for trace organic substances will be necessary. Different sampling and analytical schemes will be given as examples to show how they vary with the objectives of data collection as well as the hydrologic environment. For example, a sampling scheme to detect priority pollutants would be less involved than one used to determine the frequency of their occurrence.

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ADDENDA

Distribution of Trace Substances

Discrete water samples (grab samples) may miss insoluble toxic substances, which include trace metals, chlorinated insecticides, PCBs, and base-neutral extractable organic compounds. Stream-bed sediments, by contrast, can serve as long-term integrators of stream quality, because of the attraction between sediments and relatively insoluble toxic substances. Therefore, stream-bed sediments in the main stem and selected tributaries will be sampled intensively during the late summer or early fall. The season selected will allow time for sediments to deposit during the late spring and summer, when streamflow is not generally as large as in the winter and early spring. The sites to be selected will be based in part on the spatial distribution of point-source discharges, location of pools formed by low dams, and other areas of suspected deposition. About 50 sites will be selected and stream-bed sediments sampled for trace metals, chlorinated pesticides, base-neutral extractable organic compounds, and PCBs. Particle-size fractions of 63 microns or finer will be analyzed, which minimizes anamalous determinations that arise from differences in particle-size distribution from sample to sample.

Sampling of Municipal Surface-Water Supplies

Water taken from the Schuylkill River by Pottstown, Philadelphia Suburban, and the city of Philadelphia will be sampled as follows: Water samples will be composited for 1 week; this will be done once a month for a year. The samples will be analyzed for all organic compounds that can be identified by gas chromatography/mass spectrometer techniques. The purpose of the sampling and subsequent analysis is to determine what, and to some extent when, organic substances are present at each of the above intakes.