PREIMPOUNDMENT HYDROLOGIC CONDITIONS IN THE SWATARA CREEK (1981-84) AND ESTIMATED POSTIMPOUNDMENT WATER QUALITY IN AND DOWNSTREAM FROM THE PLANNED SWATARA STATE PARK RESERVOIR, LEBANON AND SCHUYLKILL COUNTIES, PENNSYLVANIA

By David K. Fishel

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CONVERSION FACTORS AND ABBREVIATIONS

For the convenience of readers who may prefer metric (International system) units rather than inch-pound units used in this report, values may be converted by using the following factors:

Multiply Inch-Pound Unit	By	To Obtain Metric Unit
	Length	
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	4.047	square kilometer (km^2)
square mile (mi^2)	2.590	square kilometer (km^2)
	Flow	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)
	Volume	
gallon (gal)	3.785	liter (L)
	3,785	milliliter (mL)
acre-foot (acre-ft)	1,233	cubic meter (m^3)
	0.001233	cubic hectometer (hm^3)
cubic feet per second-days (cfs-days)	2.447	cubic kilometers (km^3)
	Mass	
pound per day (lb/d)	80.45	kilogram per day (Kg/d)
ton per day, (ton/d) short	0.9072	megagram per day (Mg/d)
ton per square mile per year [(ton/mi^2)/yr]	0.3503	metric ton per square kilometer per year [(t/km^2)/annum]
	Temperature	
degree Fahrenheit (°F)	°C=5/9 (°F-32)	degree Celsius (°C)
	Density	
pound per cubic feet (lb/ft^3)	16.05	kilogram per cubic meter (Kg/m^3)

Sea Level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "Sea Level Datum of 1929".

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ABSTRACT

The hydrology and water quality of Swatara Creek were studied by the U.S. Geological Survey in cooperation with the Pennsylvania Department of Environmental Resources, Bureau of State Parks, from July 1981 through September 1984. The purpose of the study was to determine the effects of anthracite-coal mining and other point and nonpoint sources on the water quality of a planned 10,500 acre-foot reservoir. The Swatara State Park Reservoir is planned to be used for recreation and drinking-water supply for the city of Lebanon and surrounding communities.

Annual precipitation during 1982, 1983, and 1984 was about 8 percent below, near normal, and 29 percent above the long-term average, respectively. The average annual precipitation during a year with near-normal precipitation, the 1983 water year, was 47 inches at Pine Grove. Mean streamflows during 1982, 1983, and 1984 were about 15 percent below, 4 percent above, and 50 percent above the long-term average, respectively. The average streamflow to the planned reservoir area during the 1983 water year was about 220 cubic feet per second.

Inflows to, and downstream discharge from, the planned reservoir were poorly buffered. Median alkalinity ranged from 4 to 7 mg/L (milligrams per liter) and median acidity ranged from 2 to 5 mg/L at the three sampling locations. Maximum total-recoverable iron, aluminum, and manganese concentrations were 100,000, 66,000, and 2,300 μg/L (micrograms per liter), respectively. During 1983 the annual discharges of total-recoverable iron, aluminum, and manganese to the planned reservoir area were estimated to be 692, 300, and 95 tons, respectively. About 87 percent of the total-recoverable iron and 91 percent of the total-recoverable aluminum measured was in the suspended phase. The data indicated that mine drainage affects the quality of Swatara Creek and will affect the quality of the planned reservoir.

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In addition to mine drainage, point-source nutrient and metal discharges will probably affect the planned reservoir. For example, in September 1983, Swatara Creek was sampled downstream from a point source. A dissolved-phosphorus concentration of 14 mg/L and a total ammonia plus organic nitrogen concentration of 8.2 mg/L were measured. At the same location, concentrations of total-recoverable aluminum, chromium, copper, iron, and lead were 35, 300, 110, 1,300, and 32 μg/L, respectively.

Inflows to the planned Swatara State Park Reservoir are estimated to be acidic and rich in nutrients and select metals. Unless an effort is made to improve the quality of water from point and nonpoint sources, these conditions may impair the planned uses for the reservoir. Conservation releases from the reservoir need to be carefully controlled or these conditions also may degrade the water quality downstream.

INTRODUCTION

Background

Plans for the Swatara State Park Reservoir began in July 1968 when $2.7 million was authorized by the Pennsylvania General Assembly in Act 220 for dam and reservoir construction by the Pennsylvania Department of General Services. In December 1980, an additional $7.8 million was authorized in Act 228. The multipurpose reservoir would be used for recreational activities, such as fishing, swimming, and boating, and as a water supply for Lebanon and downstream communities.

The proposed reservoir is to be built downstream from areas extensively mined for anthracite during the past two centuries. As a result of the mining activities, numerous culm[1/] piles exist over a substantial part of the surface of the study area.

A U.S. Geological Survey report by Stuart, Schneider, and Crooks (1967, p. 63) gave an indication of the expected water quality in the planned reservoir in the following statement: "At Inwood the water probably will be slightly acidic (pH below 7.0) most of the time, culm will form a considerable amount of the sediment that deposits in the reservoir, and iron and manganese residues of mine wastes and coal washings will probably be above desirable limits for many types of uses." The report pointed out the need for abatement of acid mine drainage prior to construction of the reservoir, if the reservoir were built at Inwood. Several alternative sites for the reservoir also were studied during this investigation.

1/ Residue from coal-separation procedures.

As part of Operation Scarlift--administered by the Department of Environmental Resources--Berger Associates Inc. (1972); Gannett, Fleming, Corrdry and Carpenter, Inc.; and Anthracite Research and Development Company, Inc., determined sources and amounts of mine drainage entering the Swatara Creek headwaters. Their studies identified five abandoned deep-mine pool overflows--Middle Creek, Indian Head, Colket, Good Spring No. 3, and Good Spring No. 1--as the primary sources of acid mine drainage in a 14.9-mi^2 (square mile) area in the Swatara Creek headwaters. Refuse piles and strip mines were identified as the second and third largest sources of acid. Study results also included recommendations and costs for abatement of acid mine drainage in the upper Swatara Creek watershed.

In June 1981, the U.S. Geological Survey, in cooperation with the Pennsylvania Department of Environmental Resources (PaDER), Bureau of State Parks, began the water-quality phase of the preimpoundment investigation. This investigation (preconstruction in content) was to characterize the water quality and sediment of inflows to, and discharge downstream from the planned reservoir and to estimate the effect of the reservoir on downstream water quality. As a result of findings presented in the preliminary report by Fishel and Richardson (1986), construction of the reservoir was temporarily suspended.

A task force of Federal, State, and local officials and scientists was then formed and chaired by Senator David J. Brightbill in June 1984, to advise PaDER on future plans for the reservoir and to identify the sources of pollution in the Swatara Creek watershed.

Purpose and Scope

This report updates results of water-quality analyses presented in the preliminary report by Fishel and Richardson (1986) and lists the average annual loads of suspended sediment and those metals and nutrients for which sufficient data have been collected. The scope of the study includes (a) the measurement of concentrations of suspended sediment, nutrients (nitrogen and phosphorus) and other constituents common to acid mine drainage (iron, aluminum, manganese, sulfate, and acidity) in surface-water inflows and in the discharge downstream from the planned reservoir, (b) the calculation of loads for the same constituents transported to the planned reservoir during a year with near-normal streamflow, the 1983 water year[2/], (c) the measurement of nutrient and metals concentrations in the bottom material of Swatara Creek and in the soils in the area of the planned reservoir, and (d) a projection of future quality of water in and downstream from the planned reservoir.

2/ The water year is the 12-month period beginning on October 1 and ending on September 30; it is designated by the calendar year in which it ends.

Approach

In order to characterize the water and sediment in the planned reservoir area, three sites were selected at which streamflow and water-quality data were collected for 3 years. Streamflow was measured continuously at two sites upstream from the planned reservoir that represent the major inflows to the reservoir from two subbasins with differing land uses; one is a 72.6-mi^2 area of predominantly anthracite mining (mined site) and the other is a 34.3-mi^2 area of forest and agricultural land (forested and agricultural site). The third site was a partial-record station downstream from the planned dam (downstream site). Data collected at the downstream site were used to determine the effects of mixing of the two upstream inflows and to represent the water quality in the 167-mi^2 Swatara Creek basin.

Streamflow data were compared to the 65 years of record from Swatara Creek at Harper Tavern--a site 15.9 mi downstream from the study area--to characterize streamflows during the study. Streamflow hydrographs for the 3-year study were separated to determine the ground water (base flow) and overland-runoff (stormflow) contributions to the planned reservoir. Streamflow durations were calculated to determine the expected frequency of occurrence of a particular flow.

Annual chemical constituent loads to the planned reservoir were estimated for a year with near-normal streamflow (the 1983 water year) by using the subdivided-day method discussed by Porterfield (1972). In addition, relations between chemical constituent concentrations and discharges and suspended-sediment concentrations and streamflow were developed. Regression statistics for these relations were calculated, and the least-squares method was used to fit regression lines to the data. Relations among instantaneous total-metals and phosphorous concentrations and instantaneous suspended-sediment concentration for storms were used to estimate missing concentration data during selected storms. This information is needed to construct daily storm concentration hydrographs required for the subdivided-day method.

In order to estimate the frequency of occurrence for a particular chemical discharge, streamflow durations were calculated for base flows and stormflows as outlined by Miller (1951). The calculated base-flow durations were then combined with the results of the regression between streamflow and instantaneous base flow chemical discharges to develop the chemical-discharge durations (listed in table 18). The same procedure was used to develop chemical-discharge durations for stormflows. An estimated mean base-flow discharge was calculated as the average of the 5-percent increments of the duration tables using the techniques described by Miller (1951).

Relations between air and water temperatures measured in Pine Grove were developed to show that trends in water temperatures can be predicted by mean air temperatures and may help to predict the onset of thermal stratification and spring and autumn overturn in the planned reservoir.

Streambed and soil samples were collected in and upstream from the planned reservoir to determine the chemical composition of the soils that will be inundated. Particle-size analysis and normalization of chemical data from streambed samples were used to attempt to identify sources of selected metals. Chemical data from streambed samples were normalized to coal concentrations.

Data from other reservoirs with similar morphometric and water-quality characteristics as those expected at the planned Swatara State Park Reservoir were reviewed to estimate the future water quality in and downstream from the planned reservoir.

Description of Study Area, Sampling Sites, and Planned Reservoir

The 167-mi^2 study area lies in Schuylkill and Lebanon Counties in south-central Pennsylvania (fig. 1). The headwaters originate in Broad Mountain and flow southwestward about 29 mi before reaching Inwood, just below the proposed dam. The entire basin lies in the Valley and Ridge physiographic province and has steep rugged ridges and a valley terrain running northeasterly above Inwood. The Swatara Creek descends rapidly at a gradient of 78 ft/mi (feet per mile) between the headwaters and Pine Grove. From Pine Grove to Inwood, the gradient flattens to about 6 ft/mi, causing slower stream velocities and increased sediment deposition.

Both the geology and soils in the headwaters differ from those downstream and greatly influence the water quality of Swatara Creek. In the headwaters near Tremont, bedrock consists of shale, sandstone, conglomerate, and anthracite. Numerous culm piles and seeps from idle mines are scattered throughout the headwaters. Soluble materials in the sedimentary rocks and soils include magnesium, carbonate, sulfate, aluminum, iron, manganese, copper, and phosphate. The presence of the magnesium, carbonate, and sulfate is reflected by the elevated dissolved-solids concentrations, and the presence of anthracite is reflected by low pH and elevated acidity and sulfate concentrations in the Swatara Creek headwaters. Downstream, between Tremont and Inwood, alternating layers of sandstone, shale, and conglomerate form steep ridges and narrow valleys. Soils are composed of residue from weathered sandstone and siltstone. Tributaries from these areas often have dissolved-solids concentrations less than 50 mg/L. Dilution of acid mine drainage begins in this reach of Swatara Creek.

Population density differs significantly throughout the watershed. In the northern part of the basin, in Schuylkill County, much of the basin is rural and sparsely populated. South and west of the study area, in Lebanon County, the basin is more urban, largely because of the communities of Lebanon, Hershey, and Middletown, which depend on the Swatara Creek for water supply. Population density for the entire Swatara Creek basin has surpassed the 60-percent increase predicted by Stuart, Schneider, and Crooks (1967, p. 4) for the period 1960-80. Analysis of census data from 1980, tabulated by the Susquehanna River Basin Commission, showed a 63 percent increase in population during that period (Fishel and Richardson, 1986).

The locations of the sampling sites at which continuous streamflow, water-quality, streambed, and soil samples were collected are shown in figure 1.

The most upstream site at which water-quality samples were collected is Swatara Creek above Highway 895 at Pine Grove-0157[illegible]19 (the mined site), (latitude 40°32'43", longitude 76°2[illegible]'51"), in Schuylkill County. This site has a drainage area of 72.6 mi^2. The water quality is predominantly influenced by drainage from anthracite mines; however, point-source discharges from industries

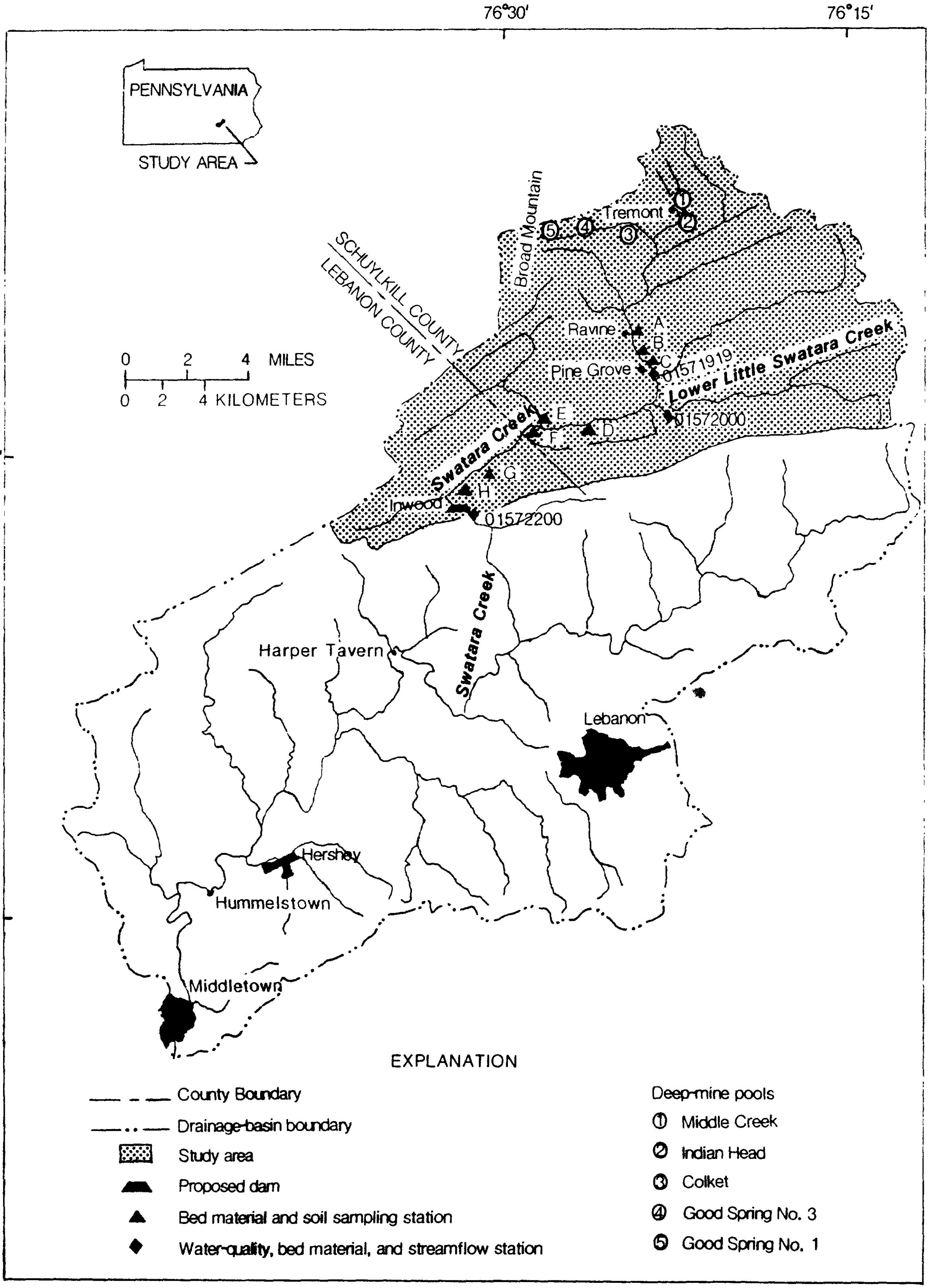

Figure 1.--Swatara Creek basin.

and sewers also are present. The gaging station, equipped with an analog to digital stage recorder, a graphic stage recorder, and an automatic pumping sampler, is on the right bank, 0.3 mi upstream from the bridge on State Highway 895 and 0.7 mi upstream from Lower Little Swatara Creek. The material in the streambed at this site is primarily sand and gravel. During low flows, black silt deposits along the stream banks, and "yellow boy" (precipitates of iron commonly associated with acid mine drainage) covers the rocks. The low-flow channel at this site is bordered by steep banks. The left bank is heavily forested, and the right bank is primarily open land and some trees. The abandoned Feeder Branch of the Union Canal is about 300 ft from the right bank. At stages above 4.50 ft, water samples were collected from the Mill Street bridge about 900 ft upstream from the gage. Storm runoff from the town of Pine Grove enters Swatara Creek from a storm sewer pipe on the right bank immediately upstream from the bridge. The low and medium stage control, below 4.50 ft, is a bedrock outcrop about 150 ft downstream from the gage. The bridge at State Route 895 is the control at high stages. Ice jams occasionally occur at this bridge, and snow removed from Pine Grove is dumped along the right bank.

The second water-quality sampling site is Lower Little Swatara Creek at Pine Grove-01572000 (the forested and agricultural site), (latitude 40°32'15", longitude 76°22'40"), in Schuylkill County. The drainage area for this site is 34.3 mi^2, and the land use is primarily forested and agricultural. This gaging station also is upstream from the planned reservoir and equipped with the same instruments as the mined site. The gage is on the right bank, downstream from the bridge on State Route 501, 0.2 mi south of State Route 895, 0.7 mi upstream from its mouth, and 0.8 mi southeast of Pine Grove. The streambed at this site is primarily sand and gravel with a few rock outcrops. Deciduous trees and cornfields line both banks upstream and downstream from the bridge. The low and medium stage control is about 200 ft downstream of the bridge at a bedrock outcrop. The State Route 645 bridge, 0.65 mi downstream on the Swatara Creek, becomes the control at high flows. Ice jams in the winter at the State Route 501 bridge are frequent.

The third water-quality sampling site is Swatara Creek at Inwood-01572200 (the downstream site), (latitude 40°28'38", longitude 76°31'26"), in Lebanon County. The drainage area for this site is 167 mi^2; the basin is comprised of a combination of mined, forested, and agricultural areas. The site is about 0.8 mi downstream from the planned reservoir on a single-lane steel truss bridge, which carries Township Road 475 over the Swatara Creek 100 ft east of Legislative Route 140 (Old PA 72), 1.9 mi north of Lickdale at Inwood. A wire-weight gage is mounted on the upstream side of the bridge. The streambed at this site is primarily bedrock and some sand and gravel. The low- and medium-stage control is about 300 ft downstream from the bridge at a bedrock outcrop. Ice jams occasionally occur at four bridges in a 5.0 mi reach downstream from the site.

In addition to the samples collected at the three water-quality sites, bed material and soil samples were collected once a year during low flow at eight other sites shown in figure 1.

The general configuration of the planned reservoir will be long and narrow, (fig. 2) which is expected to enhance shoreline development. The drainage area above the planned reservoir is about 167 mi^2; the area of the lake is 775 acres.

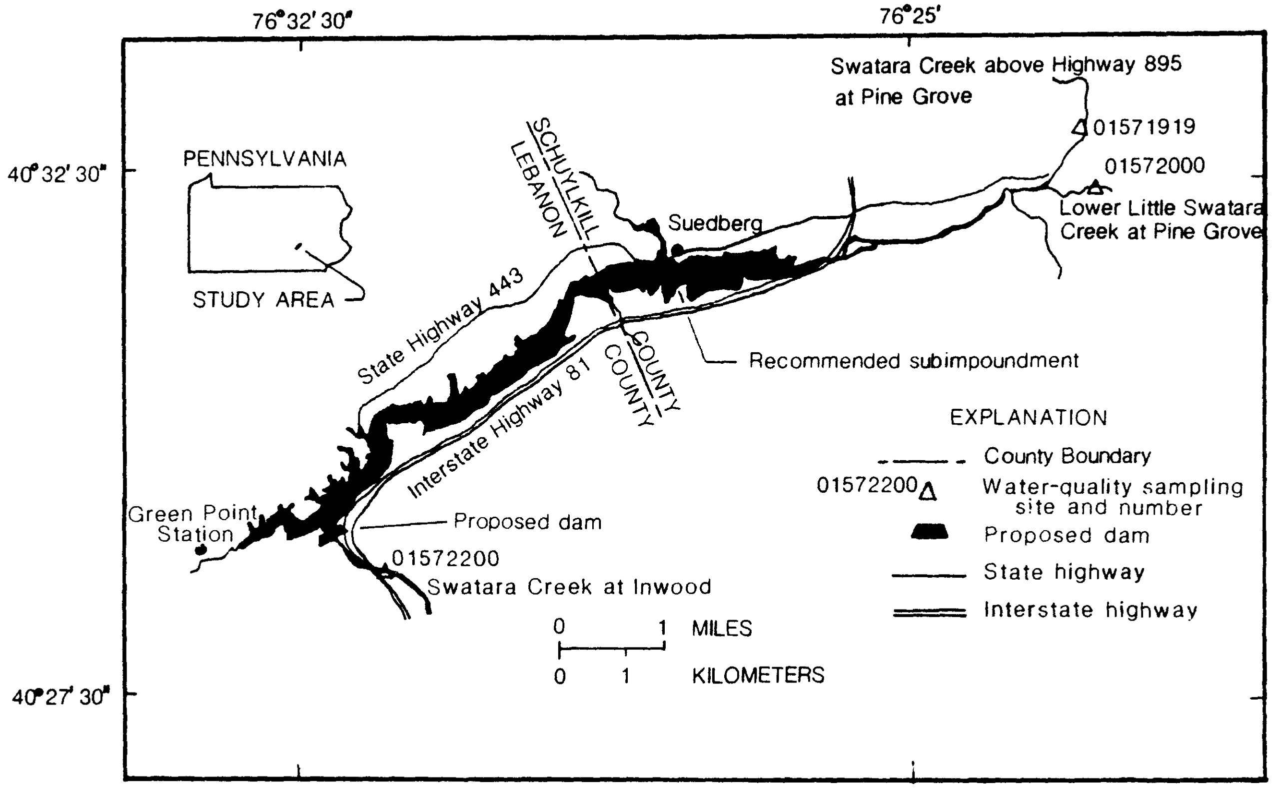

Figure 2.--Configuration of *planned* reservoir and location of water-quality sampling sites.

Table 1.--Basin and lake characteristics for the *planned* Swatara State Park Reservoir.

Major drainage basin: Susquehanna River

Minor drainage basin: Swatara Creek

Location: Swatara Creek State Park

Latitude: 40°28' 59" Longitude: 76°32' 07"

Physical Characteristics:

Altitude at normal pool: 473 ft (144.2 m)

Drainage area: 167 mi2 (432 km2)

Surface area at normal pool 775 acres (3.14 km2)

Shoreline at normal pool: 20.2 mi (32.5 km)

Volume at normal pool: 10,500 acre-ft (12.9 km3)

Mean depth: 13.5 ft (4.11 m)

Maximum depth: 40 ft (12.2 m)

Mean width: 1,200 ft (365.8 m)

Mean flow-through time: 24 days at 221.6 ft3/s (6.28 m3/s)

Lake use: Recreation (including fishing, boating, and swimming), water supply for the city of Lebanon, Pa. and surrounding communities

The basin and lake characteristics for the planned reservoir listed in table 1 indicate that the lake will have a mean depth of about 13.5 ft and a shoreline of about 20.2 mi. The mean flow-through time for an average discharge of 221.6 ft^3/s (cubic feet per second) will be about 24 days or a flushing rate of about 15 times per year. The depth and volume capacity profile in figure 3 indicates that sufficient depths will be present for thermal and chemical stratification; depths exceed 10 ft as far as 6.0 mi upstream from the dam. Chemical and thermal stratification as well as anoxic conditions were found in Blue Marsh Lake at depths as shallow as 10.0 ft on July 24, and August 8, 1979 (Barker, U.S. Geological Survey, Harrisburg District Office, written commun., 1979). Morphometric characteristics of the Blue Marsh Lake are similar to those of the planned reservoir on Swatara Creek. Thus, about 43 percent of the planned reservoir, that volume below a depth of 10 ft of water, may be susceptible to depletion of dissolved oxygen and re-solution of metals. These conditions will be intensified when little mixing and reaeration occurs from inflows and wind action.

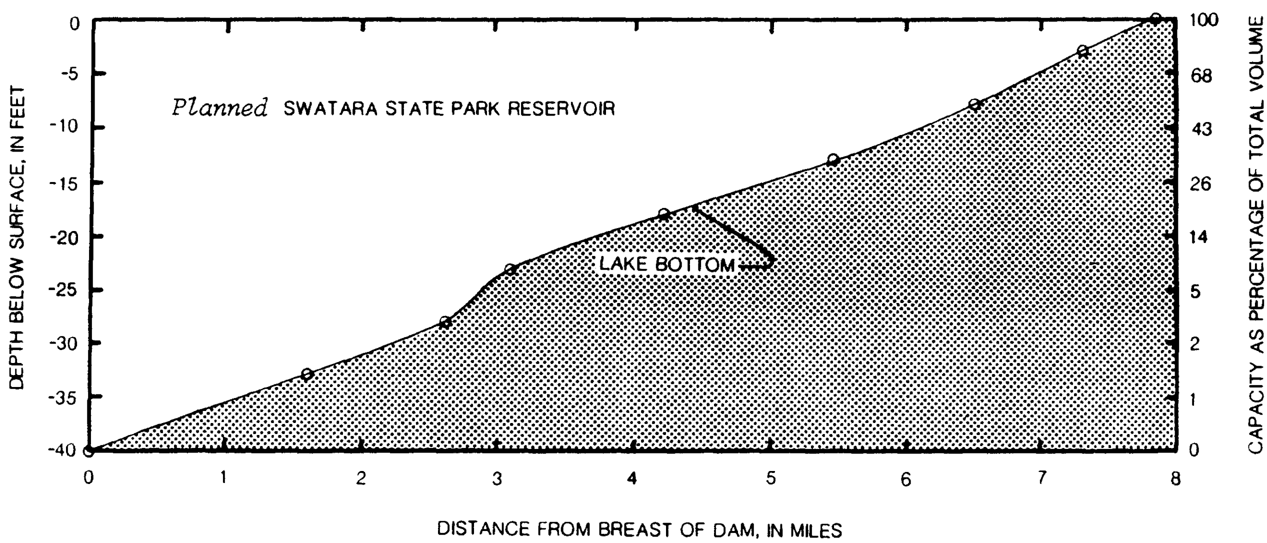

Figure 3.—Depth and capacity profile for *planned* Swatara State Park Reservoir. (Water surface elevation at 473 feet above sea level).

The recommended location of the dam shown in figure 2 is at latitude 40°28'59" and longitude 76°32'07", approximately 0.6 mi upstream from Interstate Highway 81. The site is near the village of Green Point Station in Lebanon County.

The dam will be a concrete gravity type with a 445-foot nongated spillway (Terraqua Resources Corporation, 1982). The spillway crest, at an elevation of 473.0 feet above sea level, will impound 10,500 acre-ft (acre-feet) of water and create a lake area of 775 acres. About 7,000 acre-ft of water in the reservoir, below elevation 468 ft, will be allocated for sediment deposition, recreation, and fish and wildlife. Another 3,500 acre-ft, from elevation 468 to 473 ft, will be designated for a 10 Mgal/d (million gallons per day) water supply for Lebanon, low-flow releases to Swatara Creek, and evaporation. Water may be released from the surface, from two intermediate levels, or from the bottom of the reservoir to enhance downstream water quality. The approximate reservoir depth at the dam will be 40 ft, and the reservoir length will be about 6.8 mi.

A subimpoundment was recommended by the Pennsylvania Fish Commission to reduce the suspended-sediment load to the reservoir (Hoopes, 1981). This structure, with total drawdown capability, could be located near township road 390 at Suedberg. The subimpoundment could retard bedload transport and reduce the amount of suspended metals and nutrients transported to and trapped in the reservoir.

Results of Preliminary Report

The report on the preliminary phase (1981-82) of the study (Fishel and Richardson, 1986) showed that in the 1982 water year precipitation was about 8 percent below normal and streamflow was about 15 percent below the average annual flow. Significant portions of the annual suspended-sediment load of Swatara Creek were transported in a relatively short time. In 1982, 46 percent of the annual suspended-sediment load was transported in 3 days of high flow. Measured alkalinity and acidity indicated that the inflows to and discharge downstream from the planned reservoir are poorly buffered; therefore, acid mine discharges may have a large effect on water quality in the planned reservoir.

Elevated metal concentrations, along with decreases in pH and increases in acidity, confirmed that acid mine drainage has continued to degrade the water quality of Swatara Creek. Iron, lead, copper, and zinc concentrations measured during storms exceeded the U.S. Environmental Protection Agency (USEPA) (1976) criteria for freshwater aquatic life, and concentrations of manganese and lead also exceeded the USEPA criteria for domestic water and human health, respectively.

Acknowledgments

Appreciation is extended to the following persons and their respective agencies for the assistance they provided during the study:

1. Donald Melnicove was the observer at the stream-gaging stations and collected daily suspended-sediment samples and water-temperature data.

2. James Barr, the Swatara State Park superintendant, assisted in water-quality sampling and data collection.

3. Charles Takita of the Susquehanna River Basin Commission provided a compilation of census and land-use data.

4. David Wolfgang from the Pine Grove sewage treatment plant provided a tabulation of daily precipitation data.

5. W. G. Zimmerman provided daily maximum and minimum air-temperature data from Pine Grove.

DATA COLLECTION AND METHODOLOGY

Constituents measured, frequency of data collection, and methods used to collect and analyze the data during the 3-year study are discussed in detail in the following sections.

Data collected during the study are reported in the annual U.S. Geological Survey report, "Water Resources Data for Pennsylvania," Vol. 2, water years 1982-84.

Air-Temperature and Precipitation Data

Time-series plots of Pine Grove's daily air temperatures were compared with plots of daily water temperatures from the mined site and the forested and agricultural site. The plots were used to characterize seasonal variations, to identify point-source discharges, and to identify periods when the onset of thermal stratification and spring and fall overturn may occur in the planned reservoir. Air-temperature data were obtained from a fuel oil dealer in Pine Grove who has maintained daily records for over 30 years. Although analysis of long-term, air-temperature data was beyond the scope of this project, these data may be valuable in estimating long-term, air- and water-temperature frequency distributions and aid in the management of the planned reservoir.

Precipitation data were used to document wet and dry periods, to estimate the frequency of occurrence of a selected precipitation event, and to define the relations among rainfall, runoff, and water quality in the basin.

Streamflow Data

Streamflow data were collected at the three sites shown in figure 2. Continuous streamflow data were collected beginning July 1981 at the forested and agricultural site and October 1981 at the mined site. A partial-record station was established at the downstream site in November 1981. The streamflow gaging stations were discontinued in September 1984.

Stage-discharge relations were defined at each site by measuring streamflow over a wide range of stream stages including base flow and storm conditions using a current meter. Stage-discharge relations were used to determine instantaneous streamflows when water-quality samples were collected. These streamflows were then used to compute chemical-constituent discharges.

Streamflow records for Swatara Creek at Harper Tavern were examined to determine flow conditions during the study, inasmuch as the stations in the study area did not have long-term records. Streamflow records for Swatara Creek at Harper Tavern have been collected for 65 years.

Streamflow hydrographs were separated using the fixed-interval, the sliding-interval, and the local-minima techniques (Pettyjohn and Henning, 1979) for the mined site and for the forested and agricultural site to determine the contribution of base flow and stormflow to the total annual flow. Long-term, mean-daily streamflows for the mined site and for the forested and agricultural site were calculated as the average of the 5 percent increments of the long-term flow durations (see table 5, p. 24).

Base flow and stormflow durations for the mined site and the forested and agricultural site were obtained using the streamflows determined from the fixed-interval hydrograph separation.

Water-Quality Data

Suspended-sediment data collection began in July 1981 at the forested and agricultural site, and in October 1981 at the mined site. Daily suspended-sediment samples were collected manually at these sites during base-flow conditions. During storms, samples were collected more frequently with a U.S. Geological Survey PS-69 automatic pumping sampler. Suspended-sediment samples were collected manually each month and during storms at the downstream site at Inwood. During storms at each site, additional samples were collected manually for analysis of percentages of sand and fine particles or for complete particle-size analysis.

Analyses for suspended sediment were done in the U.S. Geological Survey's sediment laboratory in Harrisburg, Pa. by methods described by Guy (1969). Daily values for suspended-sediment concentration and discharge were computed using the subdivided-day method described by Porterfield (1972).

Streambed samples were sieved in the field using a 2-mm plastic sieve. Samples were sent to the U.S. Geological Survey laboratory in Denver, Colorado and analyzed using techniques described by Skougstad and others (1979).

Chemical-quality samples were analyzed or preserved for analysis immediately after collection at the sampling location. Field analyses included measurements of water temperature, pH, alkalinity, acidity, specific conductance, dissolved oxygen, fecal coliform, and fecal streptococcal bacteria. Samples analyzed for dissolved constituents were filtered in the field through a 0.45-micrometer membrane filter using a Plexiglas[3/] filter assembly and peristaltic pump. Samples for dissolved organic carbon were filtered through a 0.45-micrometer silver filter using a stainless-steel pressurized nitrogen filtration unit. Bacteriological analyses were done during base flow in the field by techniques described by Greeson and others (1977). Bacteriological samples collected during base flow and storms also were packed in ice and delivered to PaDER, Bureau of Laboratories in Harrisburg, Pennsylvania for analysis within 24 hours of sample collection. Table 2 lists the physical, chemical, and bacteriological analyses performed on water-quality samples.

Chemical-quality data collection began in December 1981 at each of the three sites. Samples were collected monthly during base-flow conditions and at selected stages during seven storms to develop transport curves (relations between constituent concentrations or discharges and streamflow). Storms were selected so that the water quality at each site could be related to different phases of the growing season. Chemical-quality samples were collected using depth-integrating samplers and the equal-transit rate procedure (also referred to as the equal-width increment procedure) (Guy and Norman, 1970). Bacteriological and dissolved oxygen samples were collected, and water temperature measurements were made, at the centroid of flow at each site.

Statistical analysis of water-quality data was performed using the computer package "Statistical Analysis System" (Helwig, 1978). Basic univariate statistics for water-quality characteristics were calculated, including maximum, minimum, and median concentrations and maximum and minimum instantaneous discharges. Regression techniques were used to develop relations (concentration as a function of streamflow) for those constituents for which sufficient data were available; a minimum of 17 data pairs were used. The relations were considered good if the r^2 (coefficient of determination) equaled or exceeded 0.60. Regression lines for constituent concentrations and discharges were fitted analytically using the least-squares method. Attempts using the line of organic correlation as suggested by Hirsch and Gilroy (1984) to fit regression lines for constituent discharges gave poor results, probably because the mean of the streamflows for the values used to establish the regression was much higher than the long-term mean streamflow.

[3/] The use of trade, product, industry, or firm names in this report is for identification or location purposes only, and does not constitute endorsement of products by the U.S. Geological Survey, nor impute responsibility for any present or potential effects on the natural resources.

Table 2.-- Physical, chemical, and bacteriological analyses performed on water-quality samples

[μg/L, micrograms per liter; μS/cm, microsiemens per centimeter; NTU, nephlometric turbidity units; mg/L, milligrams per liter]

Physical and other related analyses

Acidity (mg/L as $CaCO_3$)
Alkalinity (mg/L as $CaCO_3$)
Oxygen, dissolved (mg/L)
pH (units)
Specific conductance (μS/cm at 25 °C)
Water temperature (°C)
Chemical oxygen demand (mg/L)
Turbidity (NTU)

Chemical Analyses

Nutrients (mg/L)

Nitrogen, nitrite dissolved
Nitrogen, nitrite total
Nitrogen, nitrate dissolved
Nitrogen, nitrate total
Nitrogen, ammonia dissolved
Nitrogen, ammonia total
Nitrogen, Kjeldahl dissolved
Nitrogen, Kjeldahl total
Phosphorus, orthophosphate dissolved
Phosphorus, orthophosphate total
Phosphorus, dissolved
Phosphorus, total
Carbon, organic dissolved
Carbon, organic total

Dissolved ions (mg/L)

Calcium
Chloride
Magnesium
Silica
Sodium
Sulfate
Potassium

Metals (μg/L)

Aluminum, dissolved
Aluminum, total-recoverable
Chromium, total-recoverable
Copper, total-recoverable
Iron, dissolved
Iron, total-recoverable
*Lead, total-recoverable
Manganese, dissolved
Manganese, total-recoverable
Mercury, total-recoverable
Zinc, total-recoverable

Bacteriological Analyses

Fecal coliform (colonies/100 mL)
Fecal streptococci (colonies/100 mL)

Regressions developed for base flow and storm runoff included the log of constituent concentration as a function of log of streamflow, log of constituent concentration as a function of the log of suspended-sediment concentration, log of constituent concentration as a function of the log of specific conductance, and log of constituent discharge as a function of the log of streamflow.

Techniques described by Miller (1951) to calculate flow-durations were used to estimate average annual and mean daily base-flow discharges for constituents that were directly correlated with streamflow (r^2 greater than 0.60). The base flow-duration tables were developed from base-flow data obtained from the hydrograph separations. An estimated storm load for a year with nearly normal streamflow (1983 water year) was calculated for constituents that showed good relations with suspended-sediment concentrations. The subdivided-day method was used to estimate the annual storm load for 1983, inasmuch as the flow-duration technique underestimates the annual storm load for stations where few storms of short duration contribute most of the annual load. For example, the 1983 suspended-sediment storm load for the mined site that was estimated using the flow-duration method was 51 percent less than the measured suspended-sediment load. Missing constituent concentrations needed to construct daily hydrographs of constituent concentrations required for the subdivisions were estimated using the relations developed between instantaneous constituent concentrations and suspended-sediment concentrations. The average annual total loads for selected constituents were determined as the sum of the base-flow and stormflow loads.

Storm loads and therefore average annual loads for the downstream site at Inwood could not be calculated from the limited data.

PREIMPOUNDMENT HYDROLOGIC CONDITIONS IN THE SWATARA CREEK

Temperature and Precipitation

Seasonal changes in air temperature commonly are reflected by changes in water temperature and may be used to estimate the occurrence of the maximum change in water temperature. Plotting air and water temperatures over time can then be used to predict the onset of thermal stratification and, possibly, fall and spring overturn in the planned lake. Seasonal changes and the relation between air and water temperature at Pine Grove can be seen in figures 4 and 5. A simple regression, which can be used to estimate the water temperature from air-temperature data collected at Pine Grove, is expressed in equations 1 and 2.

For the mined site,

$$\text{Water temperature, in degrees Celsius} = 0.7042\,(T_{PG}) + 5.7221 \qquad (1)$$

The standard error of estimate = 2.7 °C.

For the forested and agricultural site,

$$\text{Water temperature, in degrees Celsius} = 0.7147\,(T_{PG}) + 4.5739 \qquad (2)$$

The standard error of estimate = 2.7 °C.

where T_{PG} is the daily mean air temperature at Pine Grove, in °C.

Figure 5 also shows the similarities in water temperature patterns for the mined site and the forested and agricultural site. Peak water temperatures for the mined site were usually slightly higher than those for the forested and agricultural site, especially from January through March.

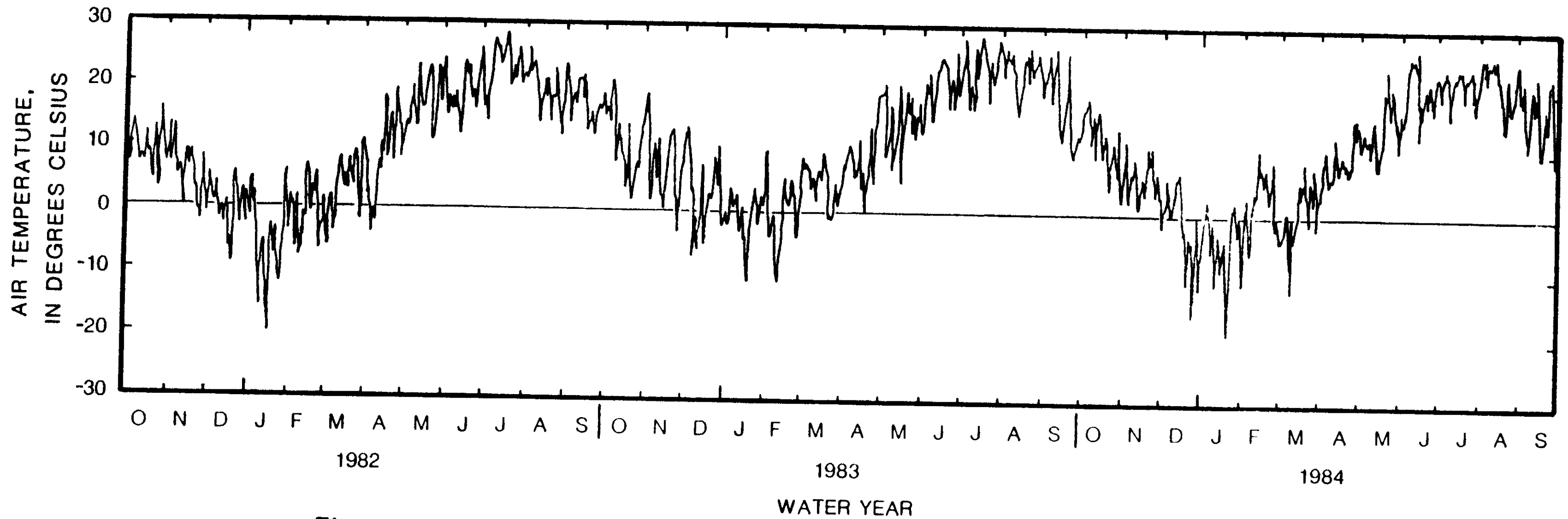

Figure 4.--Daily mean air temperature at Pine Grove, 1982-84 water years.

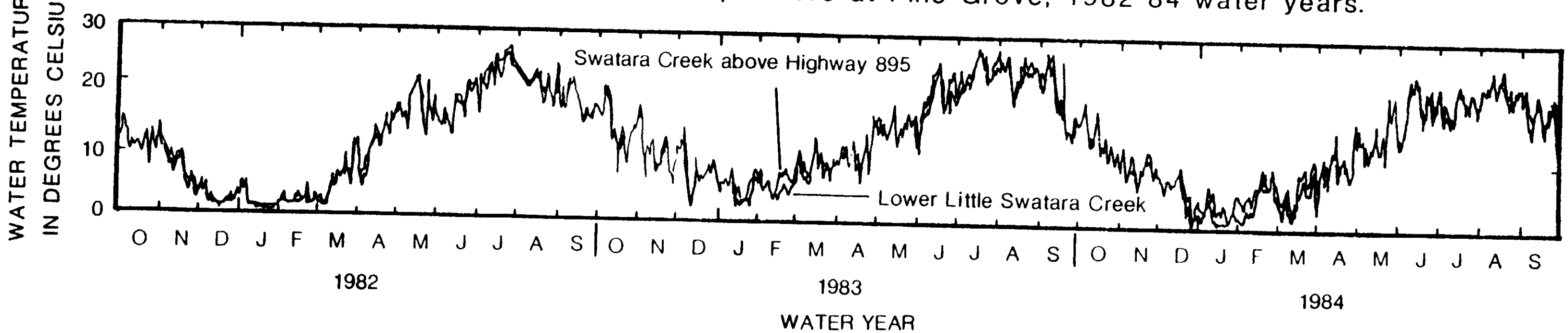

Figure 5.--Daily water temperature for Swatara Creek above Highway 895 (mined site) and Lower Little Swatara Creek at Pine Grove (forested and agricultural site), 1982-84 water years.

Collins (1925) reported that the temperature of surface water approximates the mean monthly temperature of air, and, consequently, surface water is cold in winter but warm in summer. Lohman (1957) states "...on the contrary, the temperature of ground water approximates the mean annual temperature which is generally less then 10 °C".

Thus, ground water released to streams as base flow should have a relatively constant temperature of about 10 °C near its source. However, point-source discharges and the effects of air temperature between the source of base flow and the measuring point can mask the natural water temperatures of base flow. Because the volume of base flow at the mined site is greater than the base flow at the forested and agricultural site, water temperatures at the mined site may be expected to more closely reflect natural base-flow temperatures. This was evident from January through March when air temperatures were cold; yet water temperatures at the mined site were higher than those at the forested and agricultural site. The warmer temperatures at the mined site were probably the result of the ground-water discharges from springs and deep mine tunnels in the headwaters. During the warmer months--June through August--peak water temperatures were often higher at the mined site than at the forested and agricultural site, perhaps as the result of pumping from active mine operations or other point sources.

Daily precipitation measured at Pine Grove during the 1982-84 water years is shown in figure 6. Precipitation in Swatara Creek basin was generally highest from April through August and lowest from September through December. Significant surface runoff in the basin is produced from storms with 1 inch or more of precipitation; such storms occur throughout the year. The largest storm during the study occurred on August 8, 1982, and produced 6.5 in. of precipitation in 12 hours, resulting in substantial flooding to residential and commercial establishments in Pine Grove.

Table 3 shows that about 13 percent or 45 of the 338 precipitation events during the 3-year study were greater than 1.0 in. Therefore, on the average, more than one event with significant surface runoff occurred each month of the study.

Table 3.--Magnitude and number of precipitation events in Pine Grove, October 1, 1981 to September 30, 1984

Precipitation (inches)	Number of events	Percentage of events greater than indicated range of precipitation
0.00 - 0.25	182	46
.26 - .50	62	28
.51 - .75	29	19
.76 - 1.00	20	13
1.01 - 1.50	23	7
1.51 - 1.75	8	4
1.76 - 2.00	4	3
2.01 - 2.50	5	1
2.51 - 3.00	2	1
3.01 - above	3	0
Total	338	

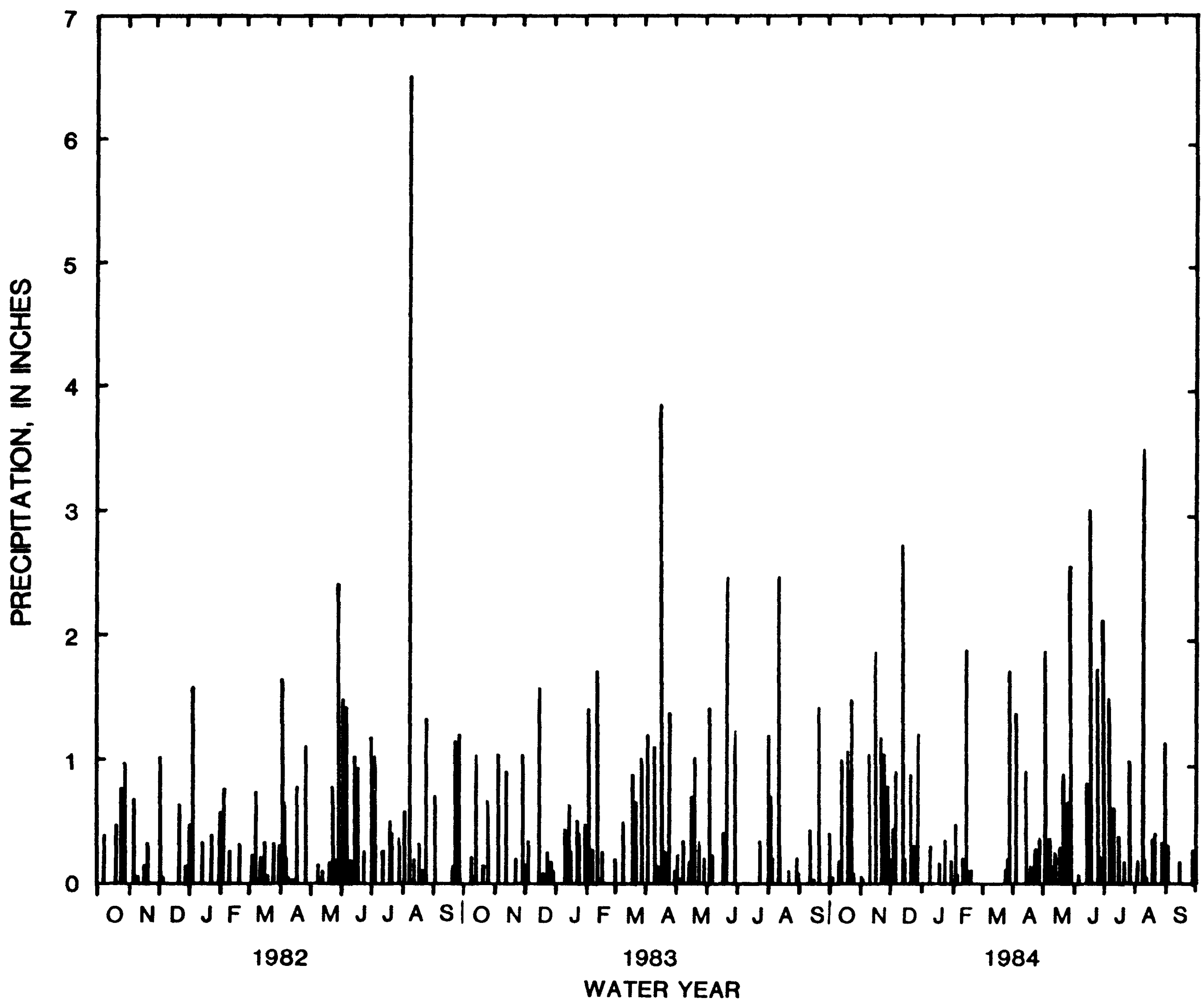

Figure 6.--Daily precipitation at Pine Grove, 1982-84 water years.

There is considerable variation in precipitation within the Swatara Creek basin and much of the variation is caused by local thunderstorms and the orographic effects of the Appalachian Mountains. The difference in precipitation between Lebanon and Pine Grove in table 4 indicates that records collected at Lebanon are not representative of the upper Swatara Creek basin. Therefore, records from Lebanon are not suitable for estimating precipitation or runoff to the planned Swatara State Park Reservoir.

Table 4.--Annual summary of precipitation recorded at Lebanon and Pine Grove October 1, 1981 to September 30, 1984

Water year	Precipitation, in inches				
	Lebanon	Lebanon normal 1931-60	Lebanon variation from normal (percent)	Pine Grove	Pine Grove variation from Lebanon
1982	40.26	43.99	- 8	52.38	+ 12.12
1983	36.45[a]	43.99	-17	47.15	+ 10.70
1984	56.83	43.99	+29	66.37	+ 9.54
Totals	133.54	131.97	+ 1	165.90	+ 32.36

[a] Some days of missing data in 1983.

Because long-term records are not available for Pine Grove, the variations from normal precipitation at the Lebanon station were used to characterize the study period. About 32 in. more precipitation fell at Pine Grove during the study than at Lebanon. A total of 165.9 in. of precipitation fell at Pine Grove during the 3-year study for an annual average of 55.3 in. Precipitation was 8 percent below normal in 1982 and 29 percent above normal in 1984 at Lebanon. Precipitation data for the Lebanon station were missing for January 15 and 16 and February 11 and 12, 1983; however, 2.41 in. of precipitation was recorded at the Myerstown National Oceanic and Atmospheric Administration (NOAA) station east of Lebanon and 2.58 in. was measured in Pine Grove. Therefore, the total precipitation at Lebanon for 1983 may have been higher than that indicated and was probably near normal. Long-term streamflow records for Swatara Creek at Harper Tavern verify that the 1983 precipitation was near normal.

In summary, water temperatures at the mined site and the forested and agricultural site are closely associated with air temperatures at Pine Grove, but water temperatures at the mined site are probably affected by upstream point-source discharges. Total precipitation during the study was significantly different each year; 1982 was drier than normal, 1983 was near normal, and 1984 was wetter than normal.

Streamflow

Streamflow conditions during the period of study are illustrated by the hydrograph separations in figure 7. These hydrographs illustrate the temporal variation of streamflow and show the large contribution of base flow to annual streamflow. Results from the three techniques used for hydrograph separations were within 9 percent of each other; therefore, the average of the three methods was used to calculate annual base flow and stormflow. Base flow and stormflow were 65 and 35 percent, respectively, of the total streamflow from the mined site during the 3-year study. In contrast, 55 and 45 percent of the total streamflow from the forested and agricultural site came from base flow and stormflow, respectively. Surface mining probably contributes to the higher percentage of base flow from the mined site inasmuch as the disturbed soils and reduced slopes from surface mining reduces surface runoff and increases infiltration. Continuous seepage from deep mines in the headwaters also contributes to the higher base flow at the mined site.

The variation in the percentage of base flow contributing to streamflow during a wet year and a dry year can also be seen in figure 7. Base flow comprised almost 69 percent of the streamflow in 1982--a year 8 percent drier than normal--but only about 57 percent in 1984--a year 29 percent wetter than normal--at the mined site.

Monthly bar charts of runoff in figure 8 indicate dry periods when retention will be greatest in the planned reservoir. The 1.13 in. of monthly runoff for a complete water exchange in the planned reservoir was not met for 10 of the 36 months of the study. Critical periods of low runoff were primarily from July through October. During these periods, discharge from the reservoir will be reduced so that a recreational pool level of 473.0 ft (Terraqua Resources Corporation, 1982) may be maintained.

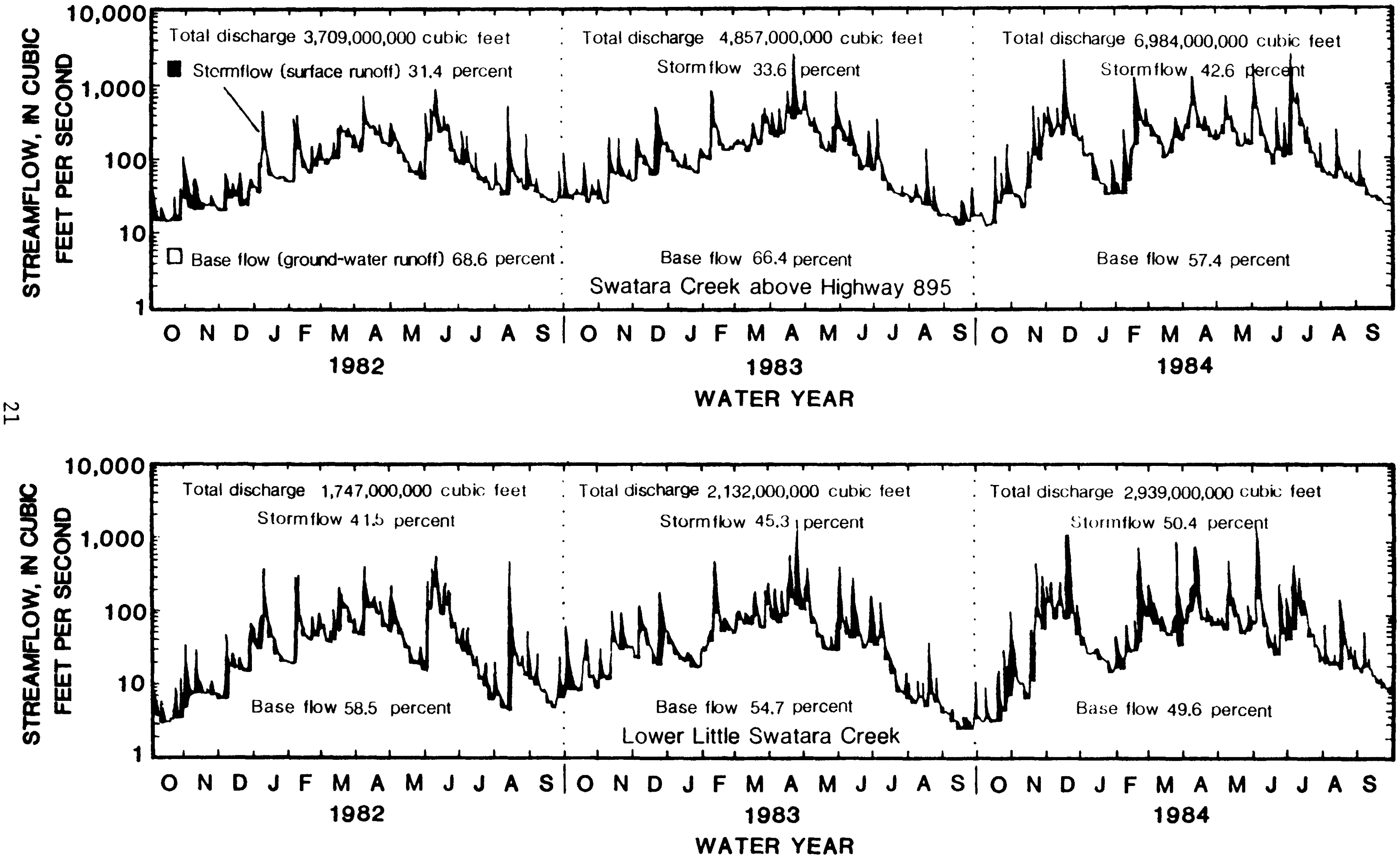

Figure 7.--Hydrograph separations for Swatara Creek above Highway 895 (mined site) and Lower Little Swatara Creek at Pine Grove (forested and agricultural site), 1982-84 water years.

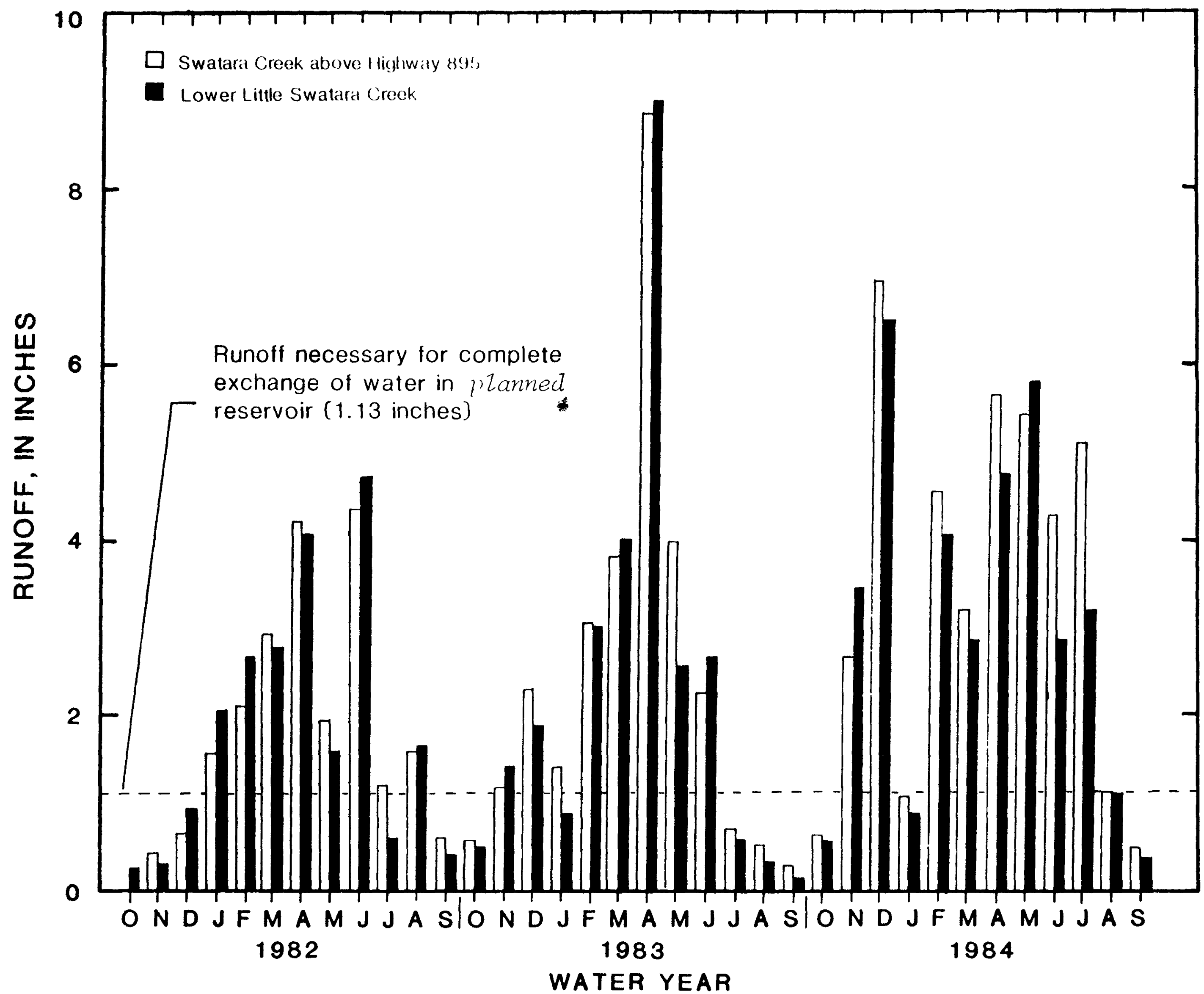

Figure 8.--Monthly runoff for Swatara Creek above Highway 895 (mined site) and Lower Little Swatara Creek at Pine Grove (forested and agricultural site), 1982-84 water years.

Long-term streamflow durations were estimated for the mined site and the forested and agricultural site to determine long-term mean streamflows for each site. Because long-term record is not available for the mined site and the forested and agricultural site, relations were developed between the mean daily streamflows at the mined site and the forested and agricultural site, and the mean daily streamflows at Harper Tavern for the 3-year study. These relations are shown in equations 3 and 4.

For the mined site:

$$\log Q_M = 0.8806 (\log Q_{HT}) - 0.2594 \qquad (3)$$

where Q_M = the daily mean streamflow for the mined site,

Q_{HT} = the daily mean streamflow for Swatara Creek at Harper Tavern,

the r^2 = 0.91, and the standard error = 0.13 log units or + 34 percent and - 25 percent.

For the forested and agricultural site:

$$\log Q_{FA} = 1.0151 (\log Q_{HT}) - 1.0292 \qquad (4)$$

where Q_{FA} = the daily mean streamflow for the forested and agricultural site,

the r^2 = 0.91, and the standard error = 0.16 log units or + 44 percent and - 30 percent.

Equations 3 and 4 were then used to calculate long-term streamflow durations for the 2 sites based on the durations for the 65 years of record for Swatara Creek at Harper Tavern (table 5).

Long-term mean daily streamflows for the downstream site at Inwood were estimated using the relation between instantaneous streamflows at the mined site (designated Q_{895}) and the instantaneous streamflows at the downstream site at Inwood developed in the preliminary report (Fishel and Richardson, 1986):

$$\log Q_I = 1.1756 (Q_{895}) - 0.0286$$

where Q_I = the instantaneous streamflow at the downstream site at Inwood,

Q_{895} = the instantaneous streamflow at the mined site,

the r^2 = 0.95 and the standard error = 0.13 log units or + 34 percent and - 25 percent.

Table 5.--Streamflow durations for study period (1982-84 water years) and estimated long-term durations (1920-84) for the mined site, the forested and agricultural site, and the downstream site

Percentage of time streamflow equaled or exceeded	Streamflow, in cubic feet per second				
	Study period		Estimated long-term		
	Mined site	Forested and agricultural site	Mined site	Forested and agricultural site	Downstream site
95	17.9	4.6	15.2	4.3	23
90	25.8	7	21.3	6.3	34.1
85	31.1	8.3	27	8.3	45.1
80	35.7	11.4	33.4	10.6	57.9
75	45.7	15.4	40.3	13.2	72.2
70	55.8	19.1	47.5	16	87.6
65	67.6	23	55.6	19.1	105
60	83	27.2	65.6	23.1	128
55	102	31.8	76.4	27.6	153
50	120	39.4	88	32.4	181
45	137	46.7	101	38.2	213
40	157	54.2	115	44.4	248
35	176	63.3	132	51.8	291
30	201	73.9	151	60.4	341
25	235	85.5	172	70.5	398
20	274	101	204	85.6	486
15	323	123	245	106	603
10	398	156	308	138	789
5	542	236	430	202	1,100

Estimated long-term mean streamflows for each site are listed in table 6 along with the ranges of streamflow recorded during the study. Long-term mean streamflows were calculated as the average of the 5 percent increments of the streamflow durations in table 5.

Streamflow duration curves (fig. 9) for Swatara Creek at Harper Tavern were used to characterize streamflow conditions during the study and show that higher base flows occurred during the study than during the long-term period of record. Mean streamflows for Swatara Creek at Harper Tavern, located 15.9 mi downstream from the study area, were 15 percent below, 4 percent above, and 50 percent above the long-term average during the 1982, 1983, and 1984 water years, respectively. The duration curves show that the streamflow durations during the study were usually within 7 percent of the long-term record except at flows below 80 ft^3/s. A flow of this magnitude, which would be equaled or exceeded about 95 percent of the time, is equal to a streamflow of about 26 ft^3/s at the mined site.

Table 6.--Yearly minimum and maximum daily streamflow (1982-84 water years) and the estimated long-term mean streamflow for three stations in the study area

	Streamflow, in cubic feet per second (Minimum - Maximum)		
	Mined site (01571919)	Forested and agricultural site (01572000)	Downstream site (01572200)
1982 water year	17.0 - 2,330	2.8 - 1,370	26.2 - *
1983 water year	13.0 - 3,200	2.5 - 2,720	19.1 - *
1984 water year	11.9 - 4,050	3.5 - 2,230	17.2 - *
Estimated long-term mean	122.5	50.4	

Minimum values for the downstream site are estimates based on equation 5.

* Maximum streamflows for downstream site were not estimated because maximum streamflows at the mined site were much higher than those streamflows used to develop the relation with the downstream site.

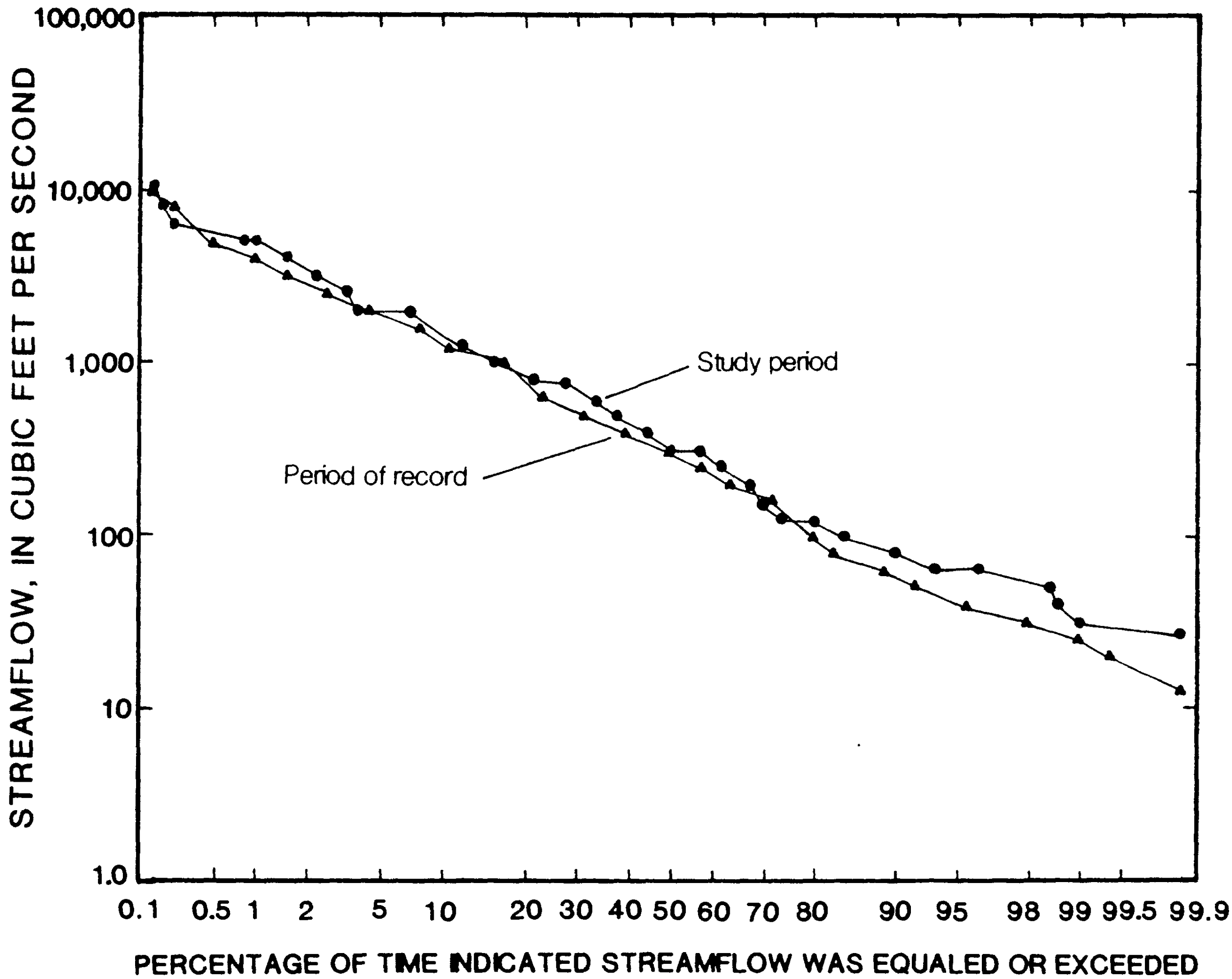

Figure 9.--Streamflow-duration curves for Swatara Creek at Harper Tavern for the study period (1982-84 water years), and the period of record (1920-84).

Higher base flow during the study period may be indicative of land use changes and/or other natural and climatic variables. Extensive strip mining occurred in the basin mainly during the Second World War and directly thereafter (Berger Associates, Inc., 1972, p. 93). Since that time surface reclamation activities such as regrading and hydroseeding have been encouraged to reduce erosion of refuse banks. Consequently, the surface reclamation activities facilitate infiltration and subsequent discharge of ground water to streams as base flow. If the recommended reclamation activities continue to be implemented on a wide scale, then the percent of streamflow discharged as base flow can be expected to increase in the future.

As a consequence of the changing land use and(or) other natural variations, the long-term duration curve is of little value in predicting the frequency of occurrence of future base flows. Therefore, base-flow and stormflow durations for the 3-year study period (table 18, p. 92) were calculated using streamflows from the hydrograph separations of the 3 years of data. Durations were developed for both base flow and stormflows to indicate the chemical loads contributed by both base flow and storms. The annual average base flow for both the mined site and the forested and agricultural site is significantly higher than the average annual stormflow even though the maximum stormflows at the sites were 4 and 6 times greater, respectively, than the corresponding maximum base flows. These results reflect the extended durations of high base flows as compared to the very short storm durations, but the durations may change depending on the effects of land-use which are unknown at this time.

Since base flows increased during the study period and more than 55 percent of the total flow to the planned reservoir will be base flow, an estimate of the detention time or time of travel for water to flow through the reservoir during mean streamflows was based on the measured streamflows for a normal year (1983 water year). Detention in the reservoir will be influenced by the design and operation of the release gates, however, based on the sum of the mean streamflows (221.6 ft^3/s) measured for the mined site and the forested and agricultural site during the 1983 water year, and a reservoir capacity of 10,500 acre-ft the average detention time would be approximately 24 days.

In conclusion, base flow has a large impact on the Swatara Creek. Even during the 1984 water year when precipitation was 29 percent higher than normal, base flow comprised 57 percent of the total streamflow at the mined site and 50 percent of the total streamflow at the forested and agricultural site. Low flows often occur from July through October, because vegetative cover increases evapotranspiration, which decreases the available water for base flow. Base-flow and storm-flow durations indicate that Swatara Creek contains both base and stormflow 75 percent of the time. The contribution of base flow to total flow in Swatara Creek equals or exceeds the contribution of stormflow 95 percent of the time; however, the effects of the stormflow are relatively sudden and permit little time for aquatic life to adjust.

Water Quality

Several investigators have attempted to determine the effects of reservoirs on water quality with little preconstruction data. Few have been able to document existing water quality prior to reservoir construction, to estimate the future water quality of the planned reservoir using current data, and then to predict the effects of the reservoir on downstream water quality. This study attempts to do each of the above for a planned reservoir that is expected to have a low-buffering capacity, and the primary inflow coming from an area extensively mined for anthracite.

Preimpoundment Water Quality

The preliminary report by Fishel and Richardson (1986) describes the water quality of the Swatara Creek in the vicinity of the planned reservoir for the 1982 water year. Table 7 updates that information by listing ranges and medians for measured concentrations and discharges during the entire 3-year study.

Correlations among base-flow concentrations of constituents with streamflow, suspended-sediment concentration, and specific conductance were poor (r^2 less than 0.60). The poor correlations are probably caused, in part, by the numerous point-source discharges from active and inactive mines, industries, and sewers in the Swatara Creek headwaters.

The effect of a point discharge on downstream water quality can be seen in the following example. Samples were collected during base flow on September 7, 1983, when a milky discharge that discolored the entire channel was observed at the mined site. Water-quality and bottom material samples were collected at the State Highway 443 bridge upstream from the gage located above Highway 895. No discoloration of the stream was found during reconnaissance of the stream at the next upstream bridge, 0.9 mi upstream from State Highway 443.

A comparison of water-quality concentrations measured at three sites during the occurrence of an industrial point discharge are given in table 8 (p. 34). The first sampling site was immediately downstream from the point discharge at Swatara Creek at Highway 443 at Pine Grove. The second sampling site was 0.65 mi downstream from Highway 443 at the mined site, and the third site was 12.45 mi downstream from Highway 443 at the downstream site. The table shows that elevated metal and nutrient concentrations were present in Swatara Creek because of the point-source discharge. Generally this discharge does not significantly increase the streamflow but strongly affects the water-quality of Swatara Creek.

The effect of the point-discharge on water quality on September 7, 1983, was greatest just below the discharge point. Metal and phosphorus concentrations were significantly lower at the mined site than upstream at the Highway 443 site. Bottom-material data presented later in this report indicate that some of the metals and phosphorus precipitate and coat the streambed in the short stream reach from the discharge point to the mined site.

Regression of concentrations of selected metals, nutrients and dissolved ions with suspended sediment and specific conductance in storm runoff were good (r^2 greater than 0.60) and are listed in table 9 (p. 35-37). Regression of base-flow and stormflow constituent discharges with streamflow (table 10, p. 38-45) were also good, and were used to calculate durations of chemical constituent discharges.

Table 7.--Ranges and medians of water-quality characteristics, constituent concentrations, and instantaneous constituent discharges, 1982-84 water years
[Min, minimum; max, maximum; µS/cm, microsiemens per centimeter at 25 °Celsius; °C, degrees Celsius]

[Concentration in milligrams per liter and discharge in tons per day except as noted]

Characteristic or constituent	Statistic	Location: Mined site (01571919)		Forested and agricultural site (01572000)		Downstream site (01572200)	
Acidity as $CaCO_3$	Median concentration	5.0		2.0		4.0	
	Number of samples	57		59		53	
	Min - max concentration	.0	- 21.0	.0	- 10.0	0.0	- 14.0
	Min - max discharge	.00	- 49.41	.00	- 17.98	0.00	- 57.13
Alkalinity as $CaCO_3$	Median concentration	4.0		7.0		5.0	
	Number of samples	59		59		53	
	Min - max concentration	.0	- 12.0	.0	- 40	0.0	- 11.0
	Min - max discharge	0	- 29.97	.15	- 17.28	.46	- 99.98
pH	Median	6.4		6.9		6.5	
	Number of samples	60		59		53	
	Minimum - maximum	5.4	- 7.2	5.8	- 8.4	5.9	- 7.5
Specific conductance (µS/cm)	Median	180		68		129	
	Number of samples	60		59		53	
	Minimum - maximum	102	- 380	54	- 88	72	- 268
Water temperature (°C)	Median	9.5		10		9.0	
	Number of samples	63		61		53	
	Minimum - maximum	.0	- 23.0	.0	- 23.5	.0	- 25.5
Dissolved oxygen	Median	11.3		10.8		10.9	
	Number of samples	60		59		52	
	Minimum - Maximum	5.6	- 13.8	7	- 14.6	7.2	- 14.0
Chemical oxygen demand	Median concentration	22		12		17	
	Number of samples	54		53		49	
	Min - max concentration	<10	- 2,140	<10	- 160	<10	- 600
	Min - max discharge	.65	7,050	.06	- 111	0.86	- 3,110
Turbidity (NTU)	Median	12		6		7.3	
	Number of samples	58		57		52	
	Minimum - maximum	2.0	- 940	1.5	- 265	.65	- 280
Sediment, suspended [1/]	Median concentration	22		11		13	
	Number of samples	61		61		53	
	Min - max concentration	1	- 5,270	1	- 1,360	1	- 945
	Min - max discharge	.10	- 17,400	.02	- 3,030	.10	- 9,240
Streamflow (ft^3/s) [1/]	Median	166		64		274	
	Number of samples	59		59		53	
	Minimum - maximum	15.0	- 1,850	2.00	- 860	32	- 5,290

1/ Values for these constituents were determined from samples which had a complete chemical analysis.

Table 7.--Ranges and medians of water-quality characteristics, constituent concentrations, and instantaneous constituent discharges, 1982-84 water years--Continued

[Min, minimum; max, maximum; µS/cm, microsiemens per centimeter at 25 °Celsius; °C, degrees Celsius]

[Concentration in milligrams per liter and discharge in tons per day except as noted]

Characteristic or constituent	Statistic	Location: Mined site (01571919)	Location: Forested and agricultural site (01572000)	Location: Downstream site (01572200)
Nitrate,	Median concentration	0.79	1.4	0.90
dissolved	Number of samples	49	50	40
as N	Min - max concentration	.19 - 1.80	.33 - 3.3	.47 - 1.70
	Min - max discharge	.01 - 3.82	<.01 - 4.41	.05 - 8.00
	Median concentration	.81	1.4	.95
Nitrate,	Number of samples	48	49	40
total	Min - max concentration	.19 - 1.80	.33 - 3.3	.47 - 2.0
as N	Min - max discharge	.01 - 3.82	<.01 - 4.41	.08 - 8.00
	Median concentration	.01	.01	.01
Nitrite,	Number of samples	59	58	53
dissolved	Min - max concentration	< .01 - .12	< .01 - .02	< .01 - .01
as N	Min - max discharge	< .01 - .05	< .01 - .02	< .01 - .14
	Median concentration	.01	.01	.01
Nitrite,	Number of samples	59	59	53
total	Min - max	< .01 - .13	< .01 - .03	< .01 - .04
as N	Min - max discharge	< .01 - .05	< .01 - .05	< .01 - .21
	Median concentration	.15	.05	.09
Ammonia,	Number of samples	59	58	53
dissolved	Min - max concentration	.05 - 2.95	.01 - .73	.01 - 1.5
as N	Min - max discharge	.01 - 1.25	< .01 - .47	< .01 - 2.29
	Median concentration	0.16	0.06	0.09
Ammonia,	Number of samples	59	58	53
total	Min - max concentration	.07 - 2.95	.01 - .73	.01 - .29
as N	Min - max discharge	.01 - 1.30	< .01 - .54	< .01 - 2.43
Organic	Median concentration	.52	.47	.50
nitrogen,	Number of samples	56	52	48
dissolved	Min - max concentration	.01 - 1.20	.01 - 2.1	.01 - 1.1
as N	Min - max discharge	.03 - 5.99	<.01 - 1.58	.03 - 14.3
Organic	Median concentration	.70	.62	.60
nitrogen,	Number of samples	58	54	48
total	Min - max concentration	.01 - 4.10	.16 - 2.2	.03 - 6.6
as N	Min - max discharge	<.01 - 20.48	.01 - 1.81	.02 - 94.3
Ammonia +	Median concentration	.74	.60	.60
organic	Number of samples	57	58	52
nitrogen,	Min - max concentration	.16 - 1.80	.12 - 2.2	.08 - 1.20
dissolved	Min - max discharge	.04 - 6.99	.01 - 1.66	.04 - 17.1
as N				
Ammonia +	Median concentration	.92	.70	.78
organic	Number of samples	59	58	51
nitrogen,	Min - max concentration	.18 - 4.40	.21 - 2.4	.09 - 6.8
total	Min - max discharge	.04 - 21.98	.01 - 2.09	.05 - 97.1
as N				

Table 7.--Ranges and medians of water-quality characteristics, constituent concentrations, and instantaneous constituent discharges, 1982-84 water years--Continued
[Min, minimum; max, maximum; µS/cm, microsiemens per centimeter at 25 °Celsius; °C, degrees Celsius]

[Concentration in milligrams per liter and discharge in tons per day except as noted]

Characteristic or constituent	Statistic	Location: Mined site (01571919)	Location: Forested and agricultural site (01572000)	Location: Downstream site (01572200)
	Median	1.9	2.3	1.8
Nitrogen,	Number of samples	56	53	40
total	Min - max concentration	.81 - 5.0	.69 - 3.8	.69 - 7.4
as N	Min - max discharge	.08 - 24.98	.02 - 6.50	.11 - 106
Ortho-	Median concentration	<.01	.01	<.01
phosphate,	Number of samples	58	58	52
dissolved	Min - max concentration	<.01 - .01	<.01 - .04	<.01 - .01
as P	Min - max discharge	<.01 - .05	<.01 - .05	<.01 - .14
Ortho-	Median concentration	<.01	.01	<.01
phosphate,	Number of samples	58	56	52
total	Min - max concentration	<.01 - .16	<.01 - .06	<.01 - .11
as P	Min - max discharge	<.01 - .43	<.01 - .09	<.01 - .86
	Median concentration	0.02	0.03	0.02
Phosphorus,	Number of samples	59	59	53
dissolved	Min - max concentration	.01 - .06	<.01 - .10	.01 - .05
as P	Min - max discharge	<.01 - .15	<.01 - .18	<.01 - .43
	Median concentration	.06	.05	.04
Phosphorus,	Number of samples	59	59	53
total	Min - max concentration	.01 - 2.20	.01 - .54	.01 - .61
as P	Min - max discharge	<.01 - .95	<.01 - .56	<.01 - 3.52
	Median concentration	2.2	2.6	2.1
Organic	Number of samples	50	54	47
carbon,	Min - max concentration	<1.0 - 7.8	<1.0 - 7.0	1.0 - 4.9
dissolved	Min - max discharge	.14 - 8.23	.02 - 12.6	.16 - 70.0
	Median concentration	3.1	2.8	2.1
Organic	Number of samples	51	52	47
carbon,	Min - max concentration	<1.0 - 90.0	<1.0 - 8.8	<1.0 - 8.9
total	Min - max discharge	.10 - 31.10	.02 - 15.82	.16 - 81.4

Table 7.--Ranges and medians of water-quality characteristics, constituent concentrations, and instantaneous constituent discharges, 1982-84 water years--Continued
[Min, minimum; max, maximum; µS/cm, microsiemens per centimeter at 25 °Celsius; °C, degrees Celsius]

[Concentration in micrograms per liter and discharge in tons per day except as noted]

Characteristic or constituent	Statistic	Location: Mined site (01571919)	Location: Forested and agricultural site (01572000)	Location: Downstream site (01572200)
Aluminum, dissolved	Median concentration	100	90	100
	Number of samples	58	57	53
	Min - max concentration	20 - 500	<10 330	<10 - 560
	Min - max dischage	< .01- .96	< .01 - .21	.01 - 2.57
Aluminum, total	Median concentration	795	380	480
	Number of samples	59	59	53
	Min - max concentration	200 - 66,000	50 - 11,000	80 - 15,000
	min - max discharge	.02 - 175	< .01 - 8.82	.01 - 147
Chromium, total	Median concentration	20	10	15
	Number of samples	27	25	20
	Min - max concentration	<10 - 70	<10 - 70	<10 - 70
	Min - max discharge	< .01 - .35	< .01 - .12	< .01 - 1.00
Copper, total	Median concentration	20	25	25
	Number of samples	27	26	20
	Min - max cncentration	<10 - 230	<10 - 80	<10 - 100
	Min - max discharge	<.01 - .76	< .01 - .12	<.01 - 1.14
Iron, dissolved	Median concentration	420	85	90
	Number of samples	59	58	53
	Min - max concentration	40 - 1,800	<10 - 210	10 - 770
	Min - max discharge	.01 - 1.33	< [illegible] - .18	<.01 - 1.43
Iron, total	Median concentration	1,700	400	740
	Number of samples	59	59	53
	Min - max concentration	200 - 100,000	100 - 19,000	70 - 30,000
	Min - max discharge	.02 - 306	< .01 - 16.2	.01 - 195
Lead, total	Median concentration	22	6.5	6.7
	Number of samples	30	29	23
	Min - max concentration	4 - 172	< 5 - 34	4.5 - 96
	Min - max discharge	< .01 - .49	< .01 - .07	< .01 - 1.37
Manganese, dissolved	Median concentration	720	30	310
	Number of samples	59	58	53
	Min - max concentration	270 - 2,000	10 - 200	30 - 830
	Min - max discharge	.05 - 2.05	< .10 - .27	.01 - 3.29
Manganese, total	Median concentration	800	50	350
	Number of samples	59	59	53
	Min - max concentration	410 - 2,300	10 - 670	40 - 1400
	Min - max discharge	.06 - 6.92	< .01 - .74	.01 - 7.86
Mercury, total	Median concentration	< 2.0	< 2.0	< 2.0
	Number of samples	27	26	20
	Min - max concentration	< 2.0 - 2.0	< 2.0 - < 2.0	< 2.0 - < 2.0
	Min - max discharge	< .01 - < .01	< .01 - < .01	< .01 - .03
Zinc, total	Median concentration	90	30	70
	Number of samples	27	25	20
	Min - max concentration	<10 - 320	<10 - 110	<10 - 170
	Min - max discharge	<.01 - 1.05	< .01 - .12	.01 - 1.37

Table 7.--Ranges and medians of water-quality characteristics, constituent concentrations, and instantaneous constituent discharges, 1982-84 water years--Continued
[Min, minimum; max, maximum; µS/cm, microsiemens per centimeter at 25 °Celsius; °C, degrees Celsius]

[Concentration in milligrams per liter and discharge in tons per day except as noted]

Characteristic or constituent	Statistic	Location: Mined site (01571919)		Location: Forested and agricultural site (01572000)		Location: Downstream site (01572200)	
Calcium, dissolved	Median concentration	12		4.5		8.0	
	Number of samples	58		57		53	
	Min - max concentration	2.7 -	24	1.9 -	6.6	1.9 -	18
	Min - max discharge	0.90 -	19.2	.04 -	9.75	.85 -	36.8
Chloride, dissolved	Median concentration	7		6.0		6.0	
	Number of samples	59		59		52	
	Min - max concentration	4.0 -	32	2.0 -	8.0	4.0 -	12
	Min - max discharge	.40 -	105	.03 -	12.59	.69 -	100
Magnesium, dissolved	Median concentration	7.7		2.1		4.8	
	Number of samples	59		57		53	
	Min - max concentration	2.9 -	18	1.6 -	5.1	1.9 -	12
	Min - max discharge	.63 -	14.5	.02 -	4.41	.37 -	27.1
Potassium, dissolved	Median concentration	1.2		1.0		1.1	
	Number of samples	58		58		53	
	Min - max concentration	.70 -	3.4	.48 -	3.8	.60 -	2.8
	Min - max discharge	.06 -	6.99	.01 -	6.83	.09 -	15.7
Silica, dissolved	Median concentration	5.9		4.6		5.6	
	Number of samples	57		55		50	
	Min - max concentration	1.1 -	9.5	.50 -	8.2	1.1 -	7.0
	Min - max discharge	.23 -	13.4	.03 -	7.66	.39 -	29.1
Sodium, dissolved	Median concentration	5.3		2.7		4.2	
	Number of samples	59		54		53	
	Min - max concentration	1.5 -	20	1.8 -	4.7	1.8 -	12.0
	Min - max discharge	.60 -	17.1	.02 -	6.83	.49 -	21.5
Sulfate, dissolved	Median	55		10		34	
	Number of samples	59		59		53	
	Min - max concentration	5 -	130	< 5 -	55	10 -	90
	Min - max discharge	4.45 -	170	.08 -	24.9	1.38 -	357
Hardness, dissolved	Median	61		20		40	
	Number of samples	59		21		53	
	Min - max concentration	19 -	130	12 -	43	13 -	86
Fecal Coliform (colonies/ 100 mL)	Median concentration	23		120		20	
	Number of samples	34		34		33	
	Min - max concentration	<1 -	>1,200	K3 -	3,500	K1 -	1,200
Fecal Streptococci (colonies/ 100 mL)	Median concentration	100		200		32	
	Number of samples	34		34		34	
	Min - max concentration	K3 -	5,900	K1 -	24,000	K3 -	1,700

K = Value based on non-ideal colony count

Table 8.--Comparison of concentrations of selected constituents at three sites in Swatara Creek during a point-source discharge, September 7, 1983

[mg/L, milligrams per liter; a dash indicates sample not analyzed for that constituent]

Constituent (in mg/L, except as noted)	Swatara Creek at Hwy 443 at Pine Grove	Mined site	Downstream site
pH	5.8	6.5	7.5
Chemical oxygen demand	290	28	12
Acidity, as $CaCO_3$	50	0	0
Alkalinity, as $CaCO_3$	5	8	10
Silica, dissolved	9.8	7.1	5.8
Dissolved solids residue	268	234	80
Ammonia, total as N	2.8	.79	.02
Ammonia, dissolved as N	1.8	.79	.01
Ammonia + organic total as N	8.2	2.2	.60
Phosphorus, total as P	19	.45	.08
Phosphorus, dissolved as P	14	.01	.01
Aluminum, total-recoverable[1/]	35,300	1,600	150
Chromium, total-recoverable[1/]	110	--	--
Copper, total-recoverable[1/]	110	--	--
Iron, total-recoverable[1/]	1,300	410	190
Lead, total-recoverable[1/]	32	< 5	< 5
Manganese, total-recoverable[1/]	10	1,600	130
Zinc, total-recoverable[1/]	210	--	--
Carbon, organic, total	31	5.6	1.8

[1/]Units for these constituents are micrograms per liter.

Table 9.--Regression statistics for constituent concentrations as a function of suspended-sediment concentration and specific conductance in storm runoff

[n, number of observations; r^2, coefficient of determination]

$y = ax + b$

Mined site

(01571919 Swatara Creek above Highway 895)

(y) Dependent variable (log of constituent)	(x) Independent variable (log of constituent)	n	r^2	(b) Intercept	(a) Slope	Standard error of estimate (log units)	Standard error of estimate (in percent) plus	Standard error of estimate (in percent) minus
Aluminum, suspended	suspended sediment	24	0.85	1.5412	0.8401	0.2685	86	46
Aluminum, total recoverable	suspended sediment	25	.89	1.7585	.7720	.1967	57	36
Iron, suspended	suspended sediment	25	.97	1.8019	.8699	.1140	30	23
Iron, total recoverable	suspended sediment	25	.96	2.0392	.7916	.1187	31	24
Manganese, suspended	suspended sediment	22	.63	.6961	.6405	.3825	141	59
Manganese, dissolved	specific conductance	25	.88	.1791	1.1631	.0583	14	13
Magnesium, dissolved	specific conductance	25	.87	-1.7794	1.1536	.0608	15	13
Sulfate, dissolved	specific conductance	25	.79	-1.1448	1.2479	.0866	22	18

Dissolved iron, total copper and lead concentrations also showed a direct relation to suspended sediment but the r^2 values were slightly lower than 0.60.

Table 9.--Regression statistics for constituent concentrations as a function of suspended-sediment concentration and specific conductance in storm runoff--Continued

[n, number of observations; r^2, coefficient of determination]

$y = ax + b$

Forested and agricultural site

(01572000 Lower Little Swatara Creek at Pine Grove)

(y) Dependent variable (log of constituent)	(x) Independent variable (log of constituent)	n	r^2	(b) Intercept	(a) Slope	Standard error of estimate (log units)	Standard error of estimate (in percent) plus	Standard error of estimate (in percent) minus
Aluminum, suspended	suspended sediment	24	0.69	1.6033	0.7949	0.3098	104	51
Aluminum, total recoverable	suspended sediment	25	.69	1.8547	.7007	.2743	88	47
Iron, suspended	suspended sediment	25	.74	1.6300	.8590	.2972	98	50
Iron, total recoverable	suspended sediment	25	.72	1.7621	.8068	.2905	95	49
Manganese, suspended	suspended sediment	23	.62	.6844	.6065	.2698	86	46
Phosphorus, orthophosphate	suspended sediment	24	.67	-2.5400	.4400	.1797	51	34
Phosphorus, suspended	suspended sediment	25	.72	-5.7060	1.5935	.5648	267	73
Phosphorus, total	suspended sediment	25	.79	-1.8769	.4940	.1456	40	28

Total manganese also showed a direct relation to suspended sediment but the r^2 value was slightly lower than 0.60.

Table 9.--Regression statistics for constituent concentrations as a function of suspended-sediment concentration and specific conductance in storm runoff--Continued

[n, number of observations; r^2, coefficient of determination]

$y = ax + b$

Downstream site

(01572200 Swatara Creek at Inwood)

(y) Dependent variable (log of constituent)	(x) Independent variable (log of constituent)	n	r^2	(b) Intercept	(a) Slope	Standard error of estimate (log units)	(in percent) plus	minus
Aluminum, suspended	suspended sediment	19	0.91	1.2812	0.9665	0.2135	63	39
Aluminum, total recoverable	suspended sediment	19	.92	1.6404	.8294	.1649	46	32
Chemical oxygen demand	suspended sediment	17	.68	.4923	.6414	.3155	107	52
Iron, suspended	suspended sediment	29	.85	1.5071	.9832	.2855	93	48
Iron, total recoverable	suspended sediment	19	.90	1.6603	.9251	.2113	63	39
Manganese, suspended	suspended sediment	18	.62	.7059	.6742	.3720	136	58
Phosphorus, suspended	suspended sediment	18	.66	-5.3281	1.4396	.7141	418	81
Phosphorus, total	suspended sediment	19	.71	-2.0008	.5262	.2311	70	41
Magnesium, dissolved	specific conductance	19	.63	-1,3814	.9497	.1212	32	24

Total lead and orthophosphate phosphorus concentrations also showed a direct relation to suspended sediment but the r^2 values were slightly lower than 0.60.

Table 10.—Regression statistics for constituent loads as a function of base flow or stormflow

[constituent loads, in tons per day; flow, in cubic feet per second]
$y = ax + b$

Mined site

(01571919 Swatara Creek above Highway 895)

(x) Independent variable (log of streamflow)	(y) Dependent variable (log of constituent load)	(b) Intercept	(a) Slope	Coefficient of determination (r^2)	Standard error of estimate (log units)	Standard error of estimate (in percent) plus	Standard error of estimate (in percent) minus
Base flow	Acidity, as $CaCO_3$ (load +1)	-0.6172	0.4881	0.63	0.145	40	28
Stormflow	Acidity, as $CaCO_3$ (load +1)	-1.0098	.7231	.76	.192	56	36
Stormflow	Alkalinity, as $CaCO_3$ (load +1)	- .8283	.6051	.62	.223	67	40
Base flow	Aluminum, dissolved	-3.8682	1.1217	.73	.251	78	44
Stormflow	Aluminum, dissolved	-4.0415	1.2477	.85	.251	78	44
Base flow	Aluminum, total recoverable	-2.6526	.9599	.86	.145	40	28
Base flow	Calcium, dissolved	- .8949	.7256	.96	.054	13	12
Stormflow	Calcium, dissolved	- .6903	.6220	.85	.121	32	24
Base flow	Carbon, dissolved organic	-1.6485	.6764	.69	.159	44	31
Stormflow	Carbon, dissolved organic	-1.9000	.9071	.75	.209	62	38
Base flow	Carbon, total organic	-1.6837	.7153	.68	.179	51	34
Stormflow	Carbon, total organic	-1.4356	.8101	.61	.348	123	55
Base flow	Chemical oxygen demand	-1.1392	.8813	.64	.248	77	44
Base flow	Chloride, dissolved	-1.3299	.8085	.92	.087	22	18
Stormflow	Chloride, dissolved	-1.7730	1.0424	.86	.195	57	36
Stormflow	Chromium, total recoverable	-4.9278	1.2946	.76	.337	117	54
Stormflow	Copper, total recoverable	-4.4414	1.1576	.62	.423	165	62
Base flow	Iron, dissolved	-4.2895	1.6650	.74	.372	136	58
Base flow	Iron, total recoverable	-3.0488	1.2744	.76	.264	84	46
Stormflow	Iron, total recoverable	-3.1164	1.4890	.62	.547	252	72
Stormflow	Lead, total recoverable	-5.3930	1.4503	.70	.446	179	64
Base flow	Magnesium, dissolved	-1.0574	.7390	.93	.075	19	16
Stormflow	Magnesium, dissolved	-.9919	.6670	.95	.070	17	15

Table 10.--Regression statistics for constituent loads as a function of base flow or stormflow--Continued

[constituent loads, in tons per day; flow, in cubic feet per second]
$y = ax + b$

Mined site

(01571919 Swatara Creek above Highway 895)

(x) Independent variable (log of streamflow)	(y) Dependent variable (log of constituent load)	(b) Intercept	(a) Slope	Coefficient of determination (r^2)	Standard error of estimate (log units)	Standard error of estimate (in percent) plus	Standard error of estimate (in percent) minus
Base flow	Manganese, dissolved	-2.0363	0.7084	0.89	0.093	24	19
Stormflow	Manganese, dissolved	-2.0923	.7005	.93	.092	24	19
Base flow	Manganese, total recoverable	-2.0303	.7213	.89	.093	24	19
Stormflow	Manganese, total recoverable	-2.2549	.8145	.78	.201	59	37
Base flow	Nitrogen, ammonia + organic dissolved as N	-2.3953	.8290	.64	.233	71	42
Stormflow	Nitrogen, ammonia + organic dissolved as N	-2.3666	.8559	.63	.254	79	44
Base flow	Nitrogen, ammonia + organic total as N	-2.1082	.7334	.60	.225	68	40
Base flow	Nitrogen, nitrate dissolved as N	-3.3513	1.3219	.86	.185	53	35
Stormflow	Nitrogen, nitrate dissolved as N	-3.2440	1.2273	.83	.223	67	40
Base flow	Nitrogen, total as N	-2.1679	.9096	.87	.136	37	27
Stormflow	Nitrogen, total aa N	-2.1687	.9735	.90	.151	42	29
Base flow	Phosphorus, dissolved as P	-4.2374	.9439	.72	.217	65	39
Stormflow	Phosphorus, dissolved as P	-4.4020	1.0538	.85	.206	61	38
Base flow	Potassium, dissolved	-1.9382	.7037	.83	.121	32	24
Stormflow	Potassium, dissolved	-2.3456	.9582	.87	.171	48	33
Base flow	Sediment, suspended	-2.9533	1.7605	.73	.453	184	65
Stormflow	Sediment, suspended	-2.3854	1.7611	.62	.638	334	77
Base flow	Silica, dissolved	-1.8004	1.0087	.92	.109	29	22
Stormflow	Silica, dissolved	-1.4050	.7979	.81	.182	52	34
Base flow	Sodium, dissolved	- .9095	.5597	.86	.085	22	18
Stormflow	Sodium, dissolved	-1.0229	.6517	.77	.167	47	32
Stormflow	Sulfate, dissolved	- .1864	.6820	.88	.121	32	24
Stormflow	Zinc, total recoverable	-3.3318	.9011	.68	.288	94	48

Table 10.--Regression statistics for constituent loads as a function of base flow or stormflow--Continued

[constituent loads, in tons per day; flow, in cubic feet per second]

$y = ax + b$

Forested and agricultural site

(01572000 Lower Little Swatara Creek at Pine Grove)

(x) Independent variable (log of streamflow)	(y) Dependent variable (log of constituent load)	(b) Intercept	(a) Slope	Coefficient of determination (r^2)	Standard error of estimate (log units)	Standard error of estimate (in percent) plus	Standard error of estimate (in percent) minus
Stormflow	Acidity, as $CaCO_3$ (load +1)	-0.4977	0.4235	0.60	0.229	69	41
Base flow	Aluminum, dissolved	-3.5726	.9230	.61	.339	118	54
Stormflow	Aluminum, dissolved	-3.5062	.9723	.84	.283	92	48
Base flow	Aluminum, total recoverable	-3.3301	1.0063	.68	.315	107	52
Stormflow	Aluminum, total recoverable	-3.1766	1.3294	.80	.438	174	64
Base flow	Calcium, dissolved	-1.8434	.9511	.96	.086	22	18
Stormflow	Calcium, dissolved	-1.8491	.9513	.93	.144	39	28
Base flow	Carbon, dissolved organic	-2.3351	1.0479	.87	.186	53	35
Stormflow	Carbon, dissolved organic	-2.3423	1.1440	.95	.166	47	32
Base flow	Carbon, total organic	-2.3179	1.0373	.84	.211	63	38
Stormflow	Carbon, total organic	-2.2054	1.0990	.95	.172	49	33
Base flow	Chemical oxygen demand	-1.5157	1.0745	.76	.285	93	48
Stormflow	Chemical oxygen demand	-1.5922	1.1860	.91	.272	87	47
Base flow	Chloride, dissolved	-1.7460	.9391	.96	.087	22	18
Stormflow	Chloride, dissolved	-1.7418	.9438	.82	.291	95	49
Stormflow	Chromium, total recoverable	-4.8489	1.2912	.89	.309	104	51
Stormflow	Copper, total recoverable	-4.4190	1.1272	.88	.281	91	48
Base flow	Iron, dissolved	-3.5182	.9006	.82	.196	57	36
Stormflow	Iron, dissolved	-3.3655	.8225	.72	.342	120	54
Base flow	Iron, total recoverable	-3.4712	1.1695	.79	.277	89	47
Stormflow	Iron, total recoverable	-3.2089	1.3895	.78	.485	205	67
Stormflow	Lead, total recoverable	-5.2280	1.3433	.90	.298	99	50

Table 10.—Regression statistics for constituent loads as a function of base flow or stormflow—Continued

[constituent loads, in tons per day; flow, in cubic feet per second]
$y = ax + b$

Forested and agricultural site

(01572000 Lower Little Swatara Creek at Pine Grove)

(x) Independent variable (log of streamflow)	(y) Dependent variable (log of constituent load)	(b) Intercept	(a) Slope	Coefficient of determination (r^2)	Standard error of estimate (log units)	Standard error of estimate (in percent) plus	Standard error of estimate (in percent) minus
Base flow	Magnesium, dissolved	-2.1554	0.9628	0.96	0.094	24	19
Stormflow	Magnesium, dissolved	-2.1994	.9763	.98	.081	20	17
Base flow	Manganese, dissolved	-4.2551	1.0339	.76	.268	85	46
Stormflow	Manganese, dissolved	-4.1797	1.1173	.78	.391	146	59
Base flow	Manganese, total recoverable	-4.1916	1.1366	.74	.318	108	52
Stormflow	Manganese, total recoverable	-3.9903	1.2144	.85	.334	116	54
Base flow	Nitrogen, ammonia dissolved as N	-4.2940	1.1605	.75	.302	100	50
Stormflow	Nitrogen, ammonia dissolved as N	-3.7490	1.0501	.71	.438	174	64
Base flow	Nitrogen, ammonia total as N	-4.4043	1.2863	.79	.298	99	50
Stormflow	Nitrogen, ammonia total as N	-3.6367	1.0327	.76	.377	138	58
Base flow	Nitrogen, ammonia + organic dissolved as N	-2.8269	.9529	.75	.251	78	44
Stormflow	Nitrogen, ammonia + organic dissolved as N	-2.4672	.8716	.88	.211	63	38
Base flow	Nitrogen, ammonia + organic total as N	-2.9180	1.0507	.83	.225	68	40
Stormflow	Nitrogen, ammonia + organic total as N	-2.5370	.9503	.91	.202	59	37
Base flow	Nitrogen, nitrate dissolved as N	-3.0655	1.4113	.92	.187	54	35
Stormflow	Nitrogen, nitrate dissolved as N	-2.8354	1.2006	.96	.163	46	31
Base flow	Nitrogen, organic dissolved as N	-2.9929	1.0193	.72	.269	86	46
Base flow	Nitrogen, organic total as N	-2.9129	1.0155	.77	.254	79	44
Stormflow	Nitrogen, organic total as N	-2.4374	.8734	.71	.246	76	43

Table 10.--Regression statistics for constituent loads as a function of base flow or stormflow--Continued

[constituent loads, in tons per day; flow, in cubic feet per second]

$$y = ax + b$$

Forested and agricultural site

(01572000 Lower Little Swatara Creek at Pine Grove)

(x) Independent variable (log of streamflow)	(y) Dependent variable (log of constituent load)	(b) Intercept	(a) Slope	Coefficient of determination (r^2)	Standard error of estimate (log units)	Standard error of estimate (in percent) plus	Standard error of estimate (in percent) minus
Base flow	Nitrogen, total as N	-2.6502	1.2433	0.93	0.157	44	30
Stormflow	Nitrogen, total as N	-2.2498	1.0449	.96	.092	24	19
Base flow	Phosphorus, dissolved as P	-4.0832	.8955	.78	.218	65	39
Stormflow	Phosphorus, dissolved as P	-4.4349	1.1931	.96	.169	48	32
Base flow	Phosphorus, total as P	-3.9133	.9177	.78	.223	67	40
Stormflow	Phosphorus, total as P	-4.1793	1.2872	.92	.258	81	45
Base flow	Potassium, dissolved	-2.3492	.8448	.87	.152	42	30
Stormflow	Potassium, dissolved	-2.5198	1.0466	.94	.173	49	33
Base flow	Sediment, suspended	-2.9439	1.7577	.80	.483	204	67
Stormflow	Sediment, suspended	-2.2716	1.7190	.88	.416	161	62
Base flow	Silica, dissolved	-2.0204	1.0749	.86	.201	59	37
Stormflow	Silica, dissolved	-2.1135	1.0549	.87	.206	61	38
Base flow	Sodium, dissolved	-1.9862	.9119	.95	.095	24	20
Stormflow	Sodium, dissolved	-2.1933	1.0269	.97	.108	28	22
Base flow	Sulfate, dissolved	-1.4773	.9681	.67	.312	105	51
Stormflow	Sulfate, dissolved	-1.5095	.9484	.82	.293	96	49
Stormflow	Zinc, total recoverable	-4.1401	1.0142	.86	.278	90	47

Table 10.--Regression statistics for constituent loads as a function of base flow or stormflow--Continued

[constituent loads, in tons per day; flow, in cubic feet per second]

$y = ax + b$

Downstream site

(01572200 Swatara Creek at Inwood)

(x) Independent variable (log of streamflow)	(y) Dependent variable (log of constituent load)	(b) Intercept	(a) Slope	Coefficient of determination (r^2)	Standard error of estimate (log units)	Standard error of estimate (in percent) plus	Standard error of estimate (in percent) minus
Base flow	Acidity, as $CaCO_3$ (load + 1)	-1.0769	0.6882	0.65	0.204	60	37
Stormflow	Acidity, as $CaCO_3$ (load + 1)	-1.3247	.8003	.88	.181	52	34
Stormflow	Alkalinity, as $CaCO_3$ (load + 1)	-1.1692	.7778	.83	.208	61	38
Stormflow	Aluminum, dissolved	-3.6649	1.0680	.81	.309	104	51
Base flow	Aluminum, total recoverable	-3.9882	1.4038	.85	.235	72	42
Stormflow	Aluminum, total recoverable	-4.4772	1.7241	.86	.410	157	61
Base flow	Calcium, dissolved	-1.0211	.7433	.92	.087	22	18
Stormflow	Calcium, dissolved	- .9661	.7085	.86	.171	48	33
Base flow	Carbon, dissolved organic	-2.1536	.9272	.81	.180	51	34
Stormflow	Carbon, dissolved organic	-2.4383	1.0870	.94	.149	41	29
Base flow	Carbon, total organic	-2.3127	1.0023	.84	.175	50	33
Stormflow	Carbon, total organic	-2.5938	1.1830	.93	.202	59	37
Stormflow	Chemical oxygen demand	-2.1996	1.4614	.79	.474	198	66
Base flow	Chloride, dissolved	-1.3495	.8181	.92	.099	26	20
Stormflow	Chloride, dissolved	-1.5467	.9256	.96	.111	29	23
Stormflow	Chromium, total recoverable	-5.3116	1.3832	.88	.308	103	51
Stormflow	Copper, total recoverable	-4.8304	1.2685	.84	.328	113	53
Base flow	Iron, dissolved	-4.3315	1.3408	.64	.406	155	61
Stormflow	Iron, dissolved	-3.6366	.9608	.74	.337	117	54
Base flow	Iron, total recoverable	-4.0541	1.4950	.83	.268	85	46
Stormflow	Iron, total recoverable	-4.7986	1.9070	.89	.398	150	60
Stormflow	Lead, total recoverable	-5.7449	1.4831	.83	.126	34	25

Table 10.--Regression statistics for constituent loads as a function of base flow or stormflow--Continued

[constituent loads, in tons per day; flow, in cubic feet per second]

$y = ax + b$

Downstream site

(01572200 Swatara Creek at Inwood)

(x) Independent variable (log of streamflow)	(y) Dependent variable (log of constituent load)	(b) Intercept	(a) Slope	Coefficient of determination (r^2)	Standard error of estimate (log units)	(in percent) plus	minus
Base flow	Magnesium, dissolved	-1.2447	0.7531	0.92	0.091	23	19
Stormflow	Magnesium, dissolved	-1.3589	.7707	.91	.142	39	28
Stormflow	Manganese, dissolved	-3.2272	1.0151	.83	.274	88	47
Base flow	Manganese, total recoverable	-3.0444	1.0180	.87	.158	44	30
Stormflow	Manganese, total recoverable	-3.5806	1.2082	.87	.283	92	48
Stormflow	Nitrogen, ammonia dissolved as N	-3.9299	1.1389	.78	.364	131	57
Base flow	Nitrogen, ammonia total as N	-3.8568	1.0827	.61	.349	123	55
Stormflow	Nitrogen, ammonia total as N	-3.7907	1.0841	.86	.263	83	45
Base flow	Nitrogen, ammonia + organic dissolved as N	-2.9156	1.0182	.71	.260	82	45
Stormflow	Nitrogen, ammonia + organic dissolved as N	-2.4148	.8816	.88	.189	55	35
Base flow	Nitrogen, ammonia + organic total as N	-2.8166	1.0039	.72	.257	81	45
Stormflow	Nitrogen, ammonia + organic total as N	-2.7147	1.0509	.79	.319	108	52
Base flow	Nitrogen, nitrate dissolved as N	-3.2367	1.2844	.94	.123	33	25
Stormflow	Nitrogen, nitrate dissolved as N	-2.8038	1.0695	.94	.150	41	29
Base flow	Nitrogen, organic dissolved as N	-3.1573	1.0735	.61	.338	118	54
Stormflow	Nitrogen, organic dissolved as N	-2.6239	.9229	.75	.228	69	41
Base flow	Nitrogen, organic total as N	-3.0065	1.0446	.63	.321	109	52
Stormflow	Nitrogen, organic total as N	-2.9168	1.0986	.67	.352	125	56
Base flow	Nitrogen, total as N	-2.6239	1.1053	.91	.137	37	27
Stormflow	Nitrogen, total as N	-2.8760	1.2144	.92	.160	45	31
Base flow	Phosphorus, dissolved as P	-3.9530	.8370	.70	.221	66	40
Stormflow	Phosphorus, dissolved as P	-4.6834	1.1344	.93	.184	53	35

Table 10.--Regression statistics for constituent loads as a function of base flow or stormflow--Continued

[constituent loads, in tons per day; flow, in cubic feet per second]

$y = ax + b$

Downstream site

(01572200 Swatara Creek at Inwood)

(x) Independent variable (log of streamflow)	(y) Dependent variable (log of constituent load)	(b) Intercept	(a) Slope	Coefficient of determination (r^2)	Standard error of estimate (log units)	Standard error of estimate (in percent) plus	Standard error of estimate (in percent) minus
Base flow	Phosphorus, total as P	-3.9055	0.9562	0.70	0.249	77	44
Stormflow	Phosphorus, total as P	-4.9083	1.4560	.87	.334	119	54
Base flow	Potassium, dissolved	-1.9689	.7372	.85	.125	33	25
Stormflow	Potassium, dissolved	-2.4127	.9674	.95	.139	38	27
Base flow	Sediment, suspended	-3.1783	1.6275	.80	.322	110	52
Stormflow	Sediment, suspended	-3.2344	1.8743	.86	.452	183	65
Base flow	Silica, dissolved	-1.8003	.9873	.94	.099	26	20
Stormflow	Silica, dissolved	-1.5674	.8399	.81	.247	77	43
Base flow	Sodium, dissolved	-1.2027	.6886	.89	.095	24	20
Stormflow	Sodium, dissolved	-1.4696	.8055	.87	.180	51	34
Base flow	Sulfate, dissolved	- .6766	.8614	.78	.184	53	35
Stormflow	Sulfate, dissolved	- .7478	.8303	.81	.242	75	43
Stormflow	Zinc, total recoverable	-4.1234	1.1352	.87	.264	84	46

As mentioned earlier, the flow-duration technique underestimates the annual storm load when a few storms contribute most of the annual load. Therefore, an annual storm load and mean daily storm discharge were not calculated. However, the storm-flow durations (table 18) can be used to show general differences between base-flow and storm-flow discharges for a particular streamflow. For example at the mined site, 75 percent of the time the base flow will be equal to or exceed 32 ft^3/s and 30 percent of the time stormflow[4/] also will be equal to or exceed 32 ft^3/s. Corresponding dissolved aluminum discharges for both base flow and stormflow will equal or exceed--0.007 ton/d (tons per day)--but the corresponding total iron discharge during base flow that will be equaled or exceeded--0.074 ton/d--is only about half the total iron stormflow exceeded--0.133 ton/d--that will be equaled or exceeded for the same streamflow of 32 ft^3/s.

Acidity, alkalinity, pH, chemical oxygen demand, turbidity, and specific conductance

The acidic discharge from the mined site to the study area is two times greater than the alkaline discharge from the forested and agricultural site to the study area. Inflows from both sites have a low buffering capacity. The median acidity concentration was 5.0 mg/L (as $CaCO_3$) at the mined site, and 2.0 mg/L as $CaCO_3$ at the forested and agricultural site (see table 7). The mean daily acidity discharge in base flow at the mined site was 1.17 tons/d and will be equaled or exceeded 45 percent of the time (see table 18). The mined site yields about 5.90 $(tons/yr)/mi^2$ of acidity (as $CaCO_3$) in base flow.

Table 18 shows that stormflow acidity discharges are more than three times greater from the mined site than from the forested and agricultural site. Acid discharges from the mined site are slightly greater than the alkaline discharges from the mined site at most stormflows.

The median pH for the streamflow at the mined site was 6.4 and was only slightly higher, 6.5, at the site 10 miles downstream at Inwood (see table 7, p. 29). Streamflow at the forested and agricultural site had a median pH of 6.9.

Chemical oxygen demand in base flow and stormflow from the mined site was much higher than from the forested and agricultural site. The annual chemical oxygen demand load of 1,590 tons in base flow from the mined site was more than two times greater than the annual chemical oxygen demand load of 619 tons in base flow from the forested and agricultural site (see table 18, p. 82). The maximum chemical oxygen demand discharge of 7,050 tons/d which was measured at the mined site during a storm on February 14, 1984, was more than 70 times greater than the maximum at the forested and agricultural site (see table 7, p. 29).

Turbidity also was higher at the mined site than the forested and agricultural site during base flow and stormflow. The median turbidity from the mined site was 12 NTU (nephlometric turbidity units) and the median for the forested and agricultural site was 6 NTU. During storms, extremely turbid water was discharged from the mined site. A turbidity of 940 NTU was recorded during a storm in February 1984 at the mined site.

Plots of specific conductance measured once daily at the mined site and the forested and agricultural site (fig. 10) show that discharges with elevated

4/ Stormflow is referred to as the total streamflow minus base flow.

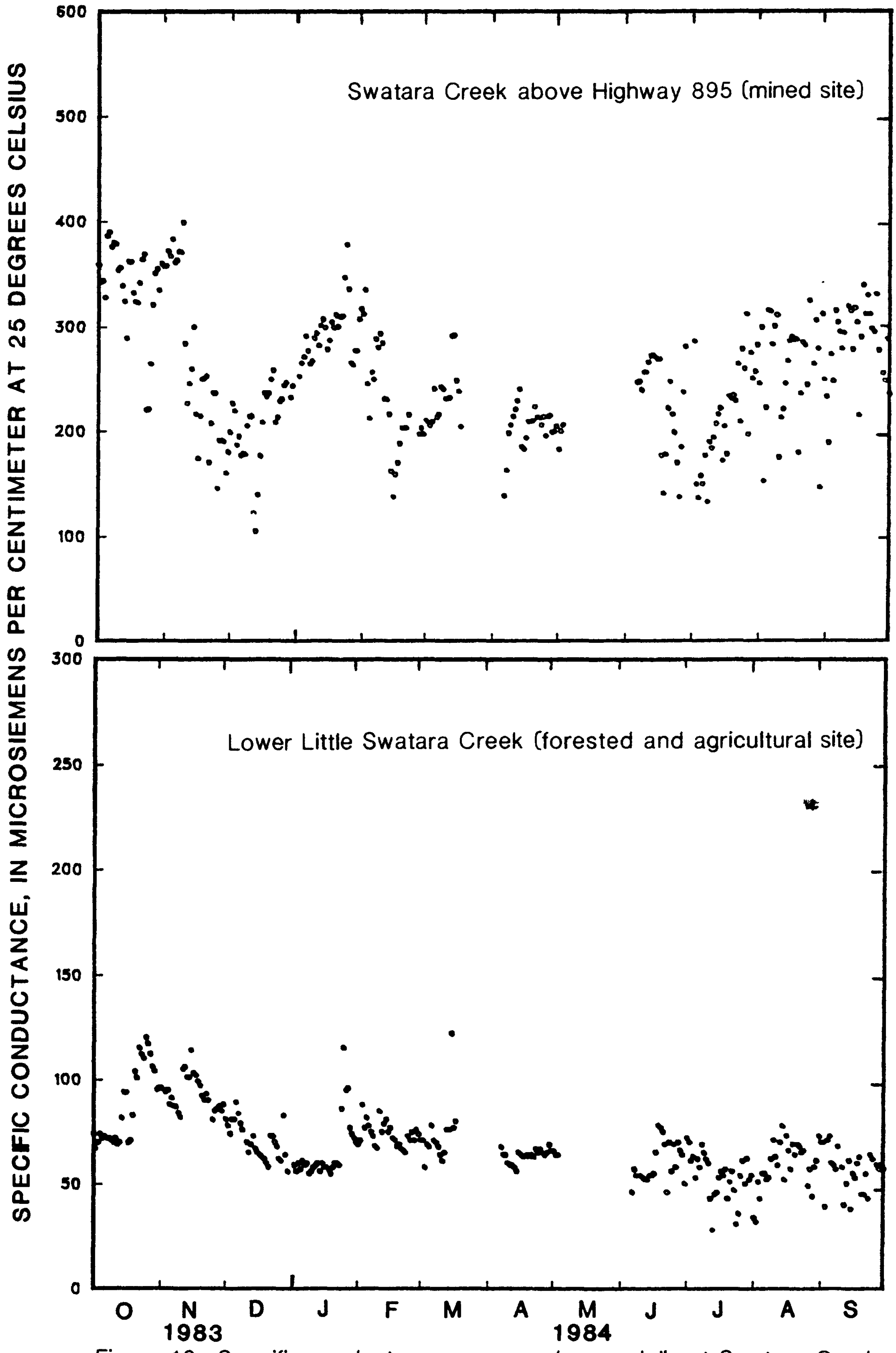

Figure 10.--Specific conductance measured once daily at Swatara Creek above Highway 895 and Lower Little Swatara Creek, October 1983 through September 1984.

specific conductances are more frequent at the mined site, as indicated by the plot peaks. The figure shows more scatter and a greater range in daily values at the mined site than at the forested and agricultural site. Because specific conductance is a measure of the dissolved ions, including iron, aluminum, manganese, and sulfate, the elevated specific conductances may reflect the mining and industrial activities in the Swatara Creek headwaters.

The sources causing peaks in specific conductance could not be identified for either site. Peaks occurred throughout the year, during different days of the week, and during different times of the day. Correlations between specific conductance and dissolved ions were poor (r^2 less than 0.60) except for dissolved magnesium and sulfate storm concentrations at the mined site, and dissolved magnesium at the downstream site at Inwood (see table 9, p. 37). Many of the sudden decreases in specific conductance had a direct correlation with increased precipitation and therefore, surface runoff.

Metals

Constituent concentrations and discharges listed in table 7 on pages 29-33 indicate the differences in metal concentrations between the mined site, the forested and agricultural site, and the downstream site. Data in the table along with bottom material data discussed later, supports that mine drainage and point-source discharges from the Swatara Creek above Highway 895 affect the water quality of Swatara Creek between Pine Grove and the downstream site at Inwood.

Recommended USEPA criteria (U.S. Environmental Protection Agency, 1976, 1980, 1986) and Pennsylvania water-quality standards (PaDER, 1979) for metals are listed in table 11. Also listed is the percent of samples from the mined site, forested and agricultural site, and the downstream site that exceeded a particular limit. Metal concentrations often exceeded the recommended values at all three sites. However, concentrations at the forested and agricultural site were lower than those at the mined site. A slight reduction in metal concentrations between the mined site and the downstream site probably was due to the discharge from the forested and agricultural site.

Aluminum concentrations in the study area were often highest at the mined site and often exceeded recommended values. At one time, aluminum in water was thought to be harmless because it is the most abundant metal on earth, because it usually occurs as complex aluminum silicates such as feldspar, and because suspended forms of aluminum can be readily removed from water using treatment processes. More recently, the criterion suggested for aluminum by USEPA (Office of Research and Development, Environmental Research Laboratory, Duluth, Minnesota, written commun., 1986) and discussed by Stephan and others (1985), indicates "...freshwater aquatic organisms and their uses should not be affected unacceptably, when the pH is between 6.5 and 9.0, if the 4-day average concentration of aluminum does not exceed 150 µg/L more than once every 3 years on the average, and if the 1-hour average concentration does not exceed 950 µg/L more than once every 3 years on the average." The range of pH from 6.5 to 9.0 was selected to adequately protect freshwater fishes, and bottom dwelling invertebrate fish-food organisms. The Pennsylvania water-quality standard states that the aluminum concentration should not be greater than 10 percent of the 96-hour

Table 11.--Water-quality criteria and standards for selected metals and the percent of samples from the mined site, forested and agricultural site, and the downstream site that exceeded the criteria or standards

[M, mined site; FA, forested and agricultural site; D, downstream site; mg/L, milligrams per liter; μg/L, micrograms per liter]

Constituent	USEPA criteria	Reference	Percent of samples exceeding criteria			PaDER standard	Reference	Percent of samples exceeding standard		
			M	FA	D			M	FA	D
Aluminum	950 μg/L	(1)	43	23	19	500 μg/L	(2)	90	37	26
Iron	.3 mg/L	(3)	98	55	70	1.5 mg/L	(5)	58	17	21
	1 mg/L	(4)	77	23	28	.3 mg/L	(6)	57	55	4
Manganese	50 μg/L	(7)	100	37	98	1.0 mg/L	(8)	33	0	2
Lead*	3.8 μg/L	(9)	76	59	65	50 μg/L	(11)	17	4	20
	50 μg/L	(10)	17	4	20					
Copper*	22 μg/L	(11)	41	35	25					
Zinc*	47 μg/L	(12)	96	24	17					

(1) Criterion suggested by U.S. Environmental Protection Agency, (USEPA), Office of Research and Development, Environmental Research Laboratory, Duluth Minnesota, written commun., 1986, 1-hour average concentration should not be exceeded once every 3 years.

(2) Ulanowski, J., Pennsylvania Department of Environmental Resources (PaDER), Bureau of Water Quality Management, oral commun., 1986, 96-hr LC 50 has not been determined for many fish species, a value of 500 μg/L is generally felt safe for Pennsylvania streams.

(3) USEPA, 1976, 1980 for domestic water supplies.

(4) USEPA, 1976, 1980 for freshwater aquatic life.

(5) PaDER, 1979, for total iron concentrations.

(6) PaDER, 1979, for dissolved iron concentrations.

(7) USEPA, 1976, for domestic water supplies.

(8) PaDER, 1979, to reduce aesthetic damage and prevent objectional tastes.

(9) USEPA, 1980, for freshwater aquatic life in water with a hardness of 100 mg/L as $CaCO_3$.

(10) USEPA, 1980, human health criterion.

(11) USEPA, 1980, for freshwater aquatic life in water with a hardness of 100 mg/L as $CaCO_3$.

(12) USEPA, 1980, for freshwater aquatic life in water with a hardness of 100 mg/L as $CaCO_3$.

*Lead, copper, and zinc were only measured during storms.

LC 50 (lethal concentration for 50 percent of the specific species maintained for 96 hours for representative important species). Pennsylvania water-quality standards for Swatara Creek are based on the cold-water fishery classification given to Swatara Creek from its source to the planned reservoir, but the 96-hr LC 50 value for aluminum and other metal concentrations has not been determined for many fish species and may be quite different depending on other characteristics of the native water, such as pH. An aluminum concentration generally felt safe for Pennsylvania streams is about 500 μg/L (Ulanowski, J., PaDER, Bureau of Water Quality Management, oral commun., 1986), inasmuch as ambient conditions may be different for each stream.

At the mined site the median total-recoverable[5/] aluminum concentration was 795 μg/L and the median pH was 6.4 based on 60 samples. The maximum total-recoverable aluminum concentration measured at the mined site was 66,000 μg/L, and at the downstream site the maxiumum total-recoverable aluminum concentration was 15,000 μg/L (table 7, p. 32). Based on these data and data in table 11 on page 49, aluminum concentrations in the Swatara Creek near the Swatara State Park Reservoir are not acceptable for freshwater aquatic organisms and their uses.

Total-recoverable iron, manganese, lead, copper, and zinc concentrations also exceeded USEPA and PaDER limits as indicated in table 11. These metals like aluminum are of concern because they may be sorbed to clay particles and accumulate in areas of the planned reservoir making those areas unsuitable for aquatic organisms. In addition, removal of these metals from water to be used for domestic purposes will require special treatment such as pH adjustment, aeration, superchlorination, or chemical precipitation.

Figure 11 shows the relation between suspended-aluminum, iron, and manganese concentrations and suspended-sediment concentrations. Figure 12 shows relations between discharges of selected metals and streamflow. Regression statistics for these relations are given in tables 9 and 10.

[5/] Total-recoverable as used in this report is defined as the amount of a given constituent that is in solution after a representative water-suspended sediment sample has been digested by a method (usually using a dilute acid solution) that results in dissolution of only readily soluble substances. Complete dissolution of all particulate matter is not achieved by the digestion treatment, and thus the determination represents something less than the "total" amount (that is, less than 95 percent) of the constituent present in the dissolved and suspended phases of the sample. To achieve comparability of analytical data, equivalent digestion procedures would be required of all laboratories performing such analyses because different digestion procedures are likely to produce different analytical results.

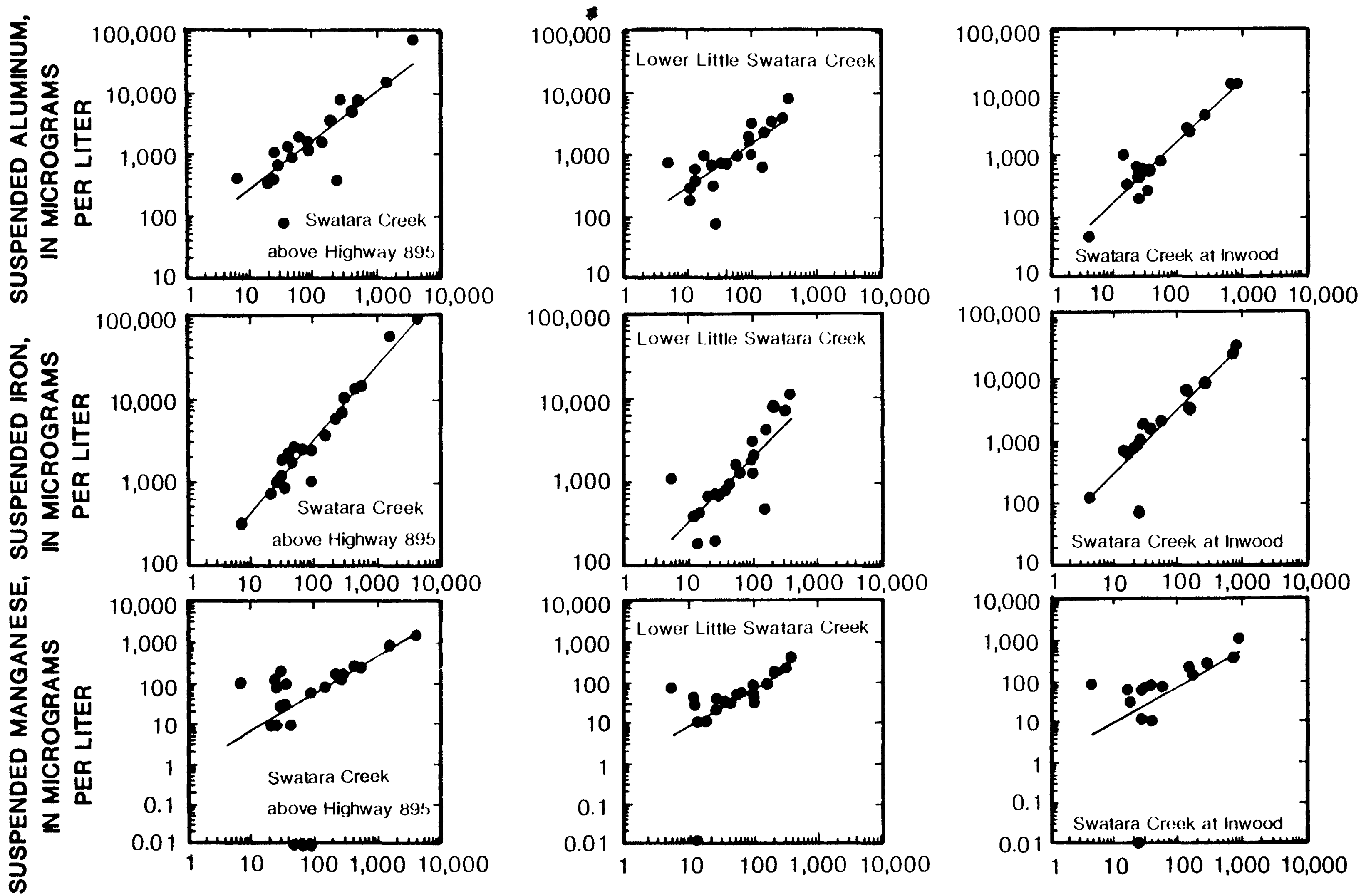

Figure 11.--Regressions of suspended-aluminum, iron, and manganese concentrations as functions of suspended-sediment concentration.

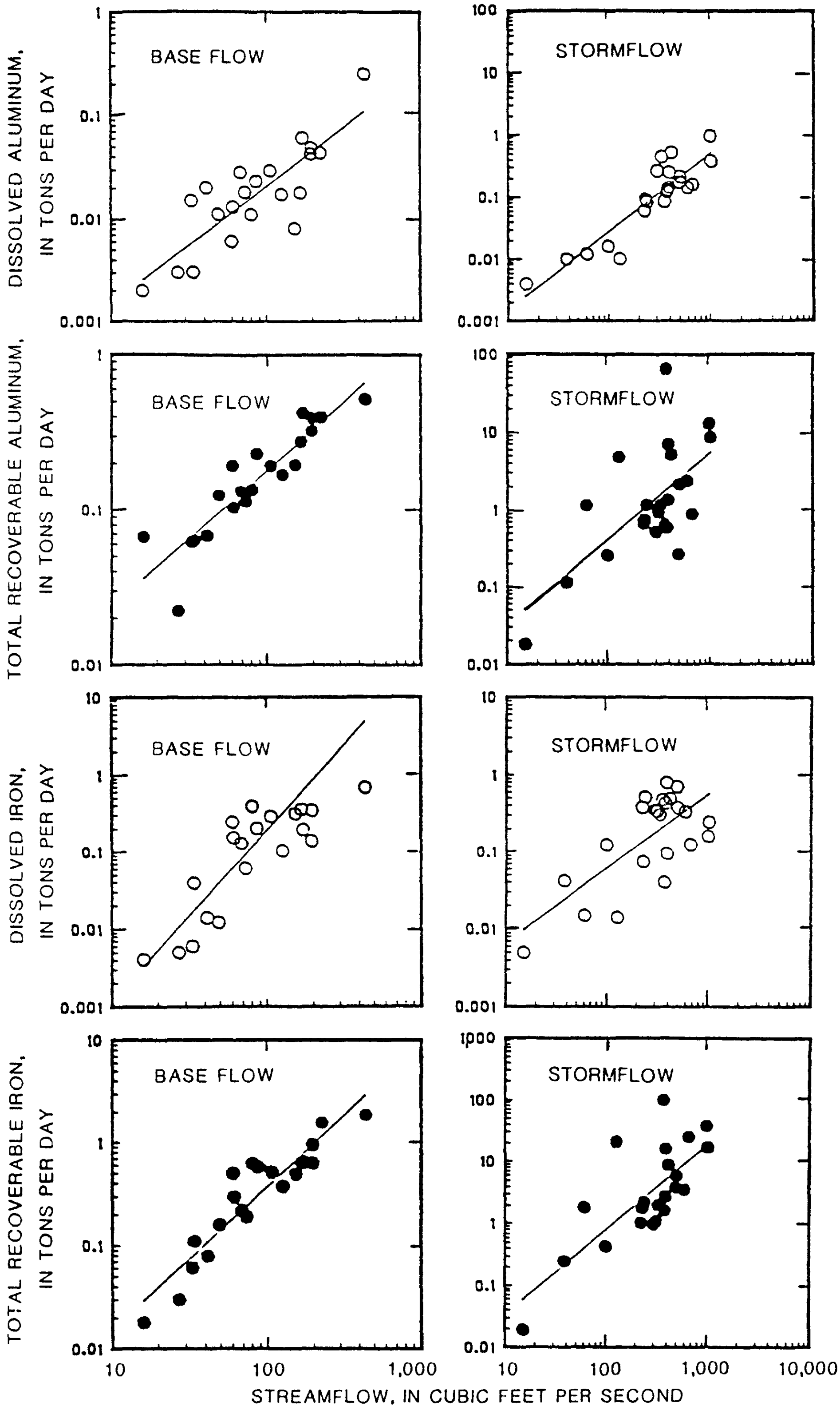

Figure 12.--Regressions of base-flow and stormflow total-recoverable and dissolved-aluminum and iron discharges as functions of streamflow for Swatara Creek above Highway 895.

Most of the trace metals transported to the planned Swatara State Park Reservoir area are adsorbed on suspended sediment, and more than 1,000 tons of various trace metals are transported during years with near-normal streamflow. An average of about 692 tons of total-recoverable iron, 300 tons of total-recoverable aluminum and more than 95 tons of total-recoverable manganese are transported annually to the study area (fig. 13) (table 12). About 91 and 87 percent of the total-recoverable aluminum and iron, is transported in suspension respectively. More than 18 tons of suspended manganese was transported to the study area from the mined site and the forested and agricultural site, respectively, during the 1983 water year.

An average of about 36 percent of the total-recoverable iron load and 27 percent of the total-recoverable aluminum load, respecively, is transported annually in base flow from the two inflows. About 80, 248, and 95 tons of total-recoverable aluminum, iron, and manganese respectively, were transported from these sites in base flow during the 1983 water year. In base flow, approximately 28 percent of the iron, 92 percent of the manganese, and 14 percent of the aluminum was transported in a dissolved phase. During base flow, the mined site, which has an area that is twice the forested and agricultural area, contributes 91 and 98 percent of the total-recoverable aluminum and manganese, respectively, but only 59 percent of the total-recoverable iron. Total-recoverable aluminum annual yields during base flow were 5 times higher at the mined site--1.00 ton/mi^2--than at the forested and agricultural site--0.21 ton/mi^2. Total-recoverable iron annual yields during base flow were higher at the forested and agricultural site--2.97 tons/mi^2--than at the mined site--2.0 tons/mi^2.

Concentrations of metals dissolved in base flows were different during various hydrologic conditions at Swatara Creek above Highway 895; the variations within a year were greater than the variations between years, even when annual flows differed significantly (fig. 14). For example, even though the water year 1982 was dry, 1983 normal, and 1984 wet, the ranges of dissolved-metal concentrations did not vary much during the 3 years. However, dissolved-iron concentrations showed a strong seasonal trend; maximums occurred each year between January and March when there was little surface runoff and water temperatures were low. The highest base-flow concentrations of dissolved iron, aluminum, and manganese measured during the study were 1,800 μg/L, 200 μg/L, and 2,000 μg/L, respectively, and all were measured at the mined site. Dissolved-aluminum concentrations varied the least, but increased with higher base flows and lower pH during the wetter 1984 water year. Dissolved-manganese concentrations were highest from July through November when flows were low and water temperature and pH were highest.

Storms contributed an average of about 220 and 444 tons/yr of total-recoverable aluminum and iron, respectively, to the reservoir area from the mined site and the forested and agricultural site (table 12). The mined site, contributed 75 and 82 percent of the total-recoverable aluminum and iron, respectively, during storms. Most of the iron and aluminum discharge occurred in about 4 to 5 days each year. The timing of these discharges is highly variable and difficult to predict. The largest metals discharges from the mined site for 1982, 1983, and 1984, occurred in August, April, and February, respectively. Thus, maximum metals discharges from the mined site appear to be independent of season and precipitation. However, the storm discharges at the forested and

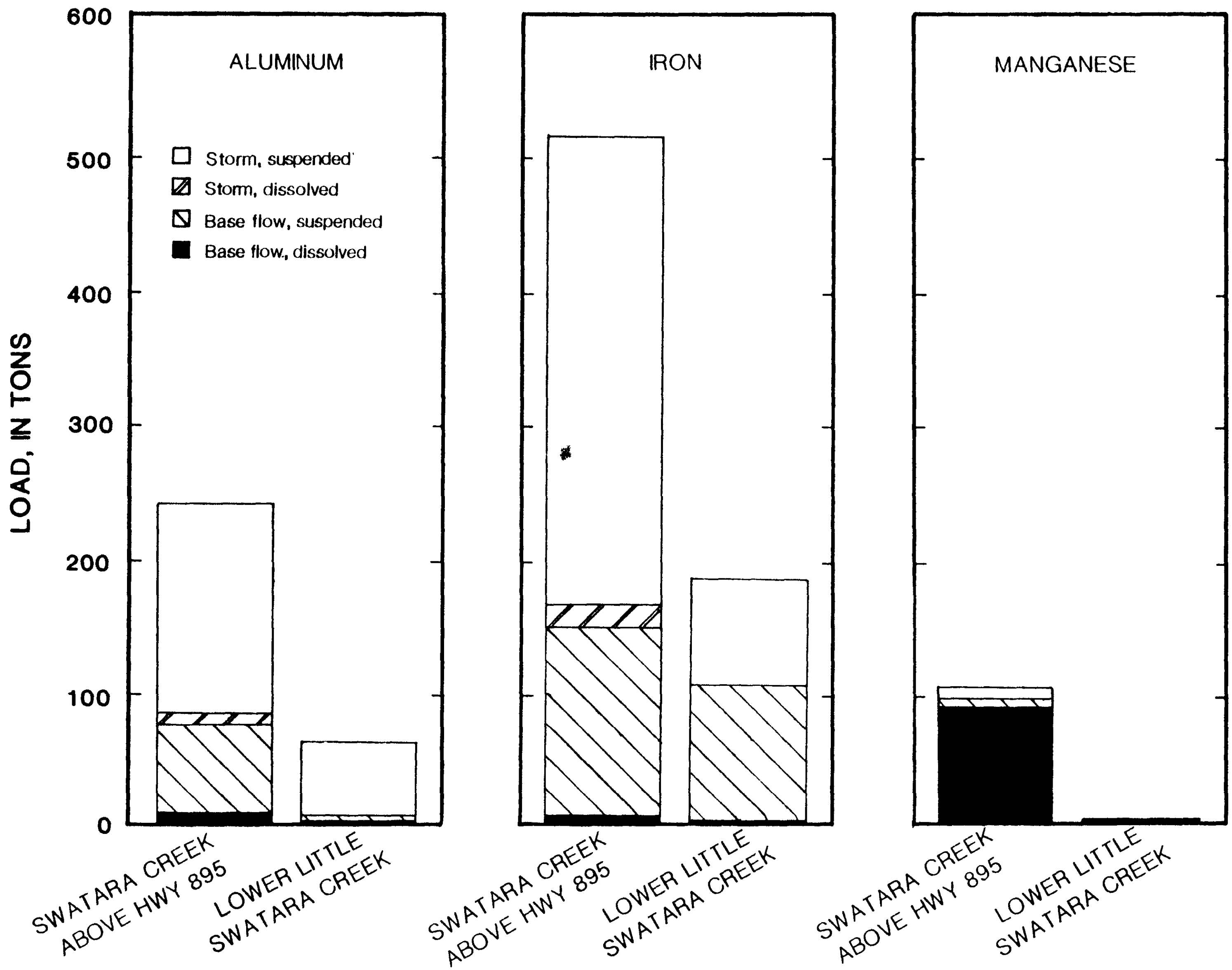

Figure 13.--Estimated annual loads of dissolved and suspended aluminum, iron, and manganese in Swatara State Park Reservoir study area.

Table 12.-- Estimated average annual aluminum, iron, and manganese loads for Swatara State Park Reservoir study area

[loads, in tons; a dash indicates a poor fit in the regression and therefore a poor estimate of load]

	Mined site			Forested and agricultural site		
	Base flow	Stormflow	Total	Base flow	Stormflow	Total
Aluminum, dissolved	9.86	10.5	20.36	2.92	2.46	5.38
Auminumn, suspended	62.7	156	219	4.38	51.2	55.6
Aluminum, total	72.56	166.5	239.06	7.30	53.66	60.98
Iron, dissolved	66.4	18	84.4	2.92	1.28	4.20
Iron, suspended	79.2	346	425.2	99.1	78.9	178
Iron, total	145.6	364	509.6	102	80.18	182.18
Manganese, dissolved	86.1	--	--	1.10	--	--
Manganese, suspended	7.0	8.28	15.28	0.73	2.11	2.83
Manganese, total	93.1	--	--	1.83	--	--

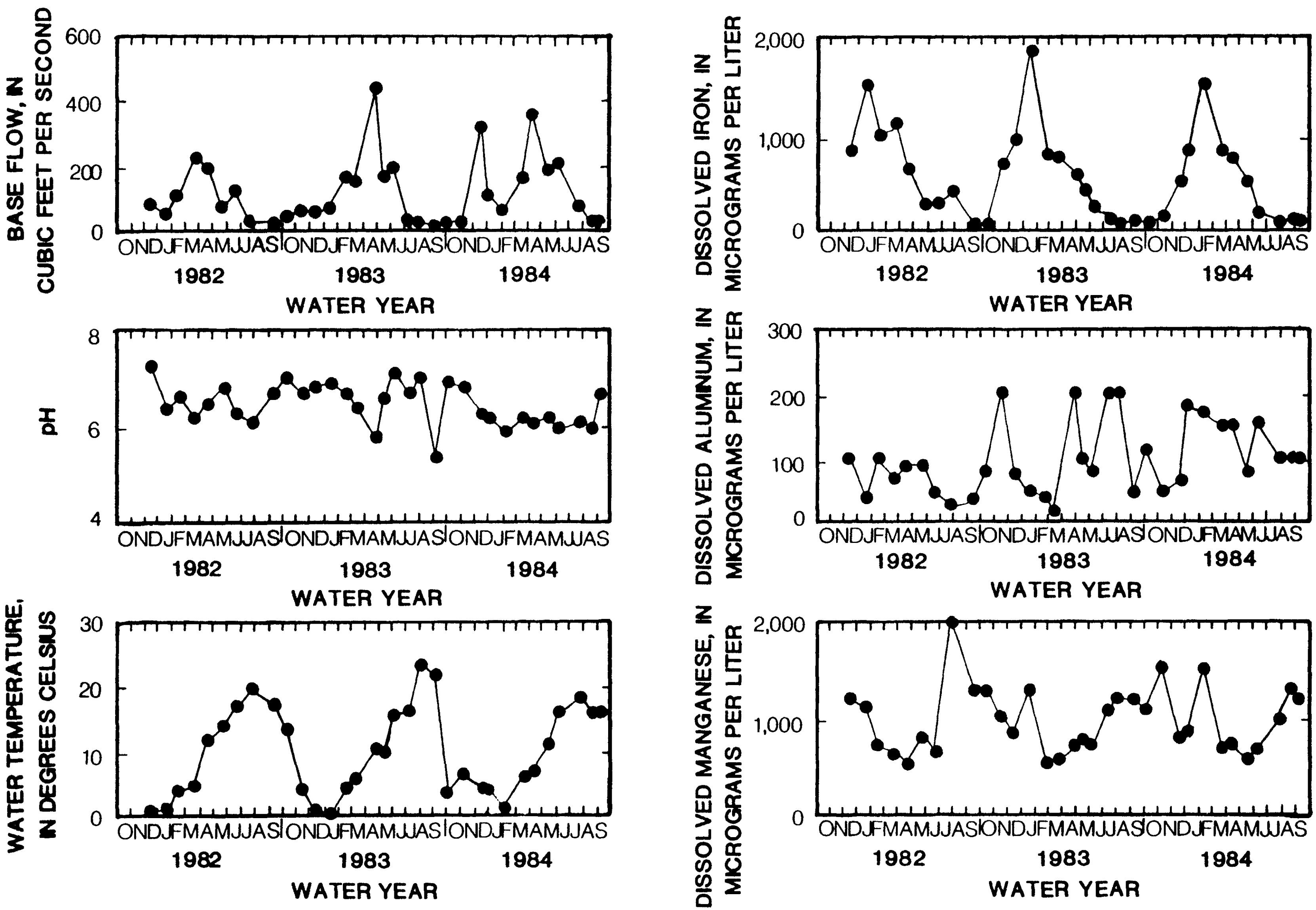

Figure 14.--Base flow, pH, water temperature, and dissolved-iron, aluminum, and manganese concentrations at Swatara Creek above Highway 895, 1982-84 water years.

agricultural site are dependent on both precipitation and season inasmuch as metals discharges consistently were higher in the winter when little vegetation was present. More than 94 percent of the aluminum and iron discharged during storms to the study area was suspended (fig. 13).

Regressions of manganese storm discharges on streamflow and suspended-sediment concentration were low (r^2 less than 0.60), so that estimates of average annual storm discharges for manganese were not made.

Annual storm yields of total-recoverable aluminum and iron were higher at the mined site--2.29 tons/mi^2 and 5.01 tons/mi^2, respectively--than at the forested and agricultural site--1.56 tons/mi^2 and 2.34 tons/mi^2, respectively.

Concentrations of metals in the streambed and near the base of a culm pile in the vicinity of the planned Swatara State Park Reservoir were determined from samples collected each year during low flows. After reviewing bottom-material and storm-water-quality data for the 1982 water year, additional sampling sites and metals were selected to improve the characterization of sediments in the study area and to attempt an identification of sources of metals that may affect water quality in the planned reservoir.

Table 13 lists the concentrations of coal and metals in the bottom material and near a culm pile at Suedberg for sites in the 14.5-mi stream reach from Swatara Creek at Ravine to Swatara Creek at Inwood shown in figure 1. Bed-material samples collected from Swatara Creek at Ravine--the most upstream site--contained 63 percent coal. Concentrations of coal generally declined downstream.

Metals concentrations commonly associated with coal, especially aluminum, iron, and manganese, were higher in the main stem of the Swatara Creek than in Lower Little Swatara Creek (table 13). Concentrations of aluminum, iron, lead, copper, and zinc reached a maximum at the site 1.9-mi downstream from Ravine (at Route 443), which is immediately downstream from a point-source discharge. Mercury and selenium concentrations as high as 1.9 μg/g and 7.0 μg/g, respectively, were measured in the 14.5-mi stream reach affected by mine drainage. No detectable selenium and little mercury was found at the forested and agricultural site. Aluminum and iron concentrations were much lower at the forested and agricultural site than at the mined site.

The sample collected at the base of the culm pile at Suedberg was enriched with aluminum, iron, and selenium.

Bottom-material data collected on September 6, 1984, were used to identify sources of particular trace metals. The data were normalized using coal as a diluent and then plotted (fig. 15) to show the distribution of metals from their sources. This normalizing technique described by Horowitz (1984, p. 62) was used so that a dilution factor could be multiplied by the chemical concentration of the selected constituent to minimize the influence of the coal mining. The dilution factor was calculated by dividing the percent of the size fraction that was less than 20 micrometers of coal into 100. Particle-size analyses of bottom-material samples were compared to determine whether the metals were associated with a particular size fraction and whether the fine sediments were evenly distributed in the stream reach. Normalized concentrations of aluminum,

Table 13.--Concentrations of coal and metals in bottom material in the vicinity of the planned Swatara State Park Reservoir
[Concentrations are in micrograms per gram, except coal, which is given in grams per kilogram]

Station	Date	Coal	Aluminum	Arsenic	Cadium	Chromium	Cobalt	Copper	Iron	Lead	Manganese	Mercury	Selenium	Zinc
Swatara Creek at Ravina (A)	9/06/84	630	1,600					12	5,400	<10	270	0.27	7	50
Swatare Craek 1.0 mi below Ravine (B)	9/06/84	240	1,600					18	7,600	20	370	.15		23
Swatare Creek 1.9 mi below Ravine at High-way 443 (C)	9/07/83			<1	2	9	30	60	32,000	80	260	.26		140
	9/06/84	39	7,700					59	19,000	270	260	.33	6	300
Mined eite														
Swatare Creek above Highway 895, 2.5 mi below Ravine (01571919)	9/14/82		5,600						13,000		650			
	9/07/83			<1	1	4	20	20	7,400	20	380	.01		64
	9/06/84	66	2,400					19	6,700	20	270	.05		46
Forested and Agricultural site														
Lower Little Swatara Creek (01572000)	9/14/82		900						2,900		340			
	9/07/83			<1	1	5	10	5	8,200	10	590	<.01		
	9/06/84	<1.0	950					4	4,100	20	250	.05	<1	24
Swatare Creek 7.2 mi below Ravine near Airport (D)	9/06/84	85	960					10	4,200	<10	210	<.01		37
Swatara Creek** 7.9 mi below Ravine at base of culm pile (E)	9/06/84	120	2,300					41	13,000	40	120	.32	12	30
Swatara Creek 7.9 mi below Ravine et Suedberg (F)	9/14/82		580						2,500		220			
Swatare Creek 11.2 mi below Ravine (G)	9/14/82		660						2,800		370			
	9/06/84	46	900					8	3,700	<10	320	.08		45
Swatare Creek 13.0 mi below Ravine (H)	9/14/82		1,700						5,700		1,000			
	9/06/84	62	970					10	4,000	<10	440	.03		52
Downstream site														
Swatara Creek at Inwood 14.5 mi below Ravine (01572200)	9/14/82		900						3,300		720			
	9/07/83			<1	2	5	80	30	9,500	20	3,600	.05		250
	9/06/84	14	1,600					13	6,700	10	790	1.9		91

** Sample collected at base of culm pile not from stream bottom.

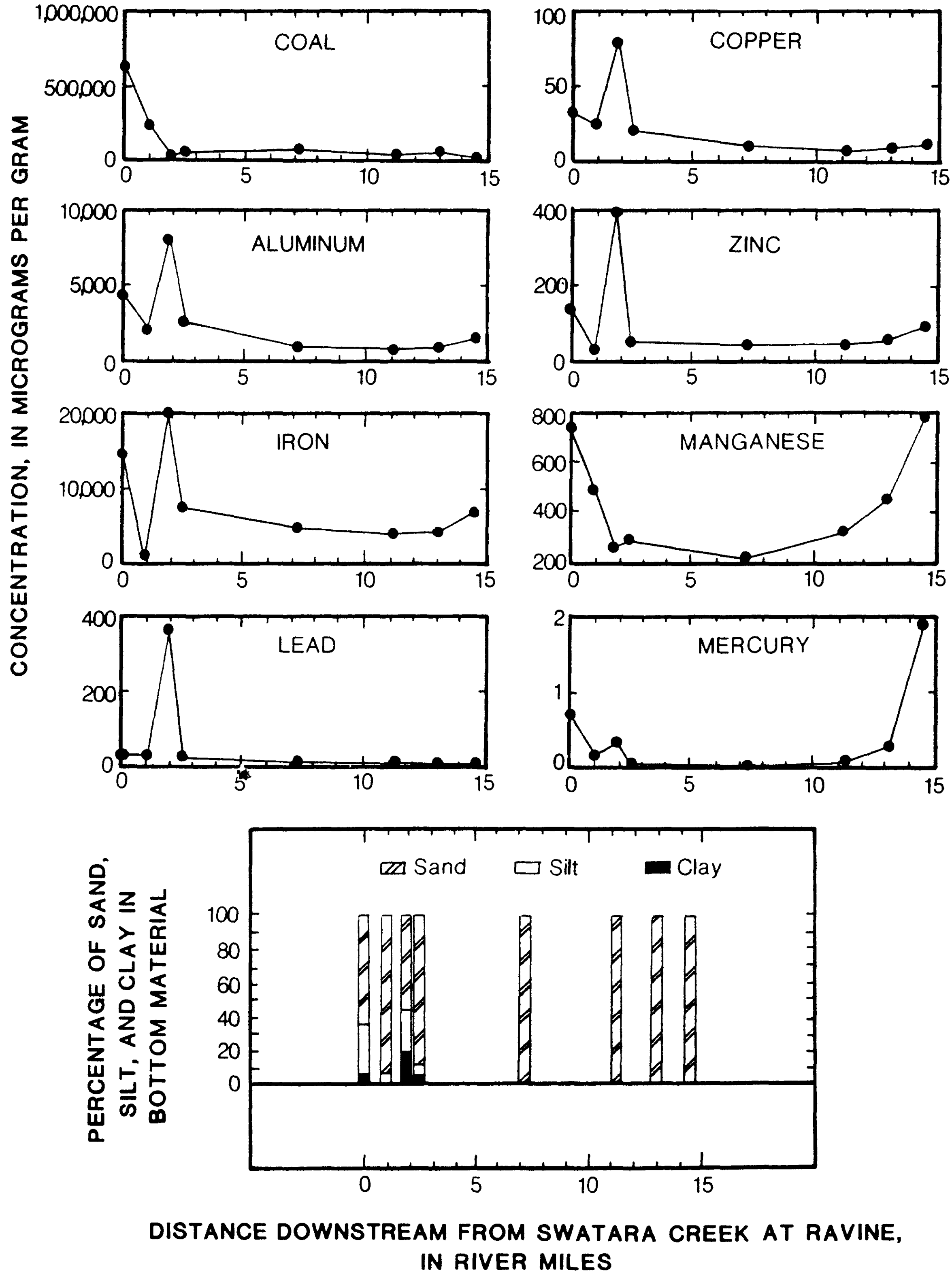

Figure 15.--Coal, normalized total-recoverable metals concentrations, and particle-size distribution of bottom material in the vicinity of the *planned* reservoir.

iron, lead, copper, and zinc reached a maximum 1.9 mi below Ravine. Particle-size data show that the highest percentages of silt and clay in the bed material also were found 1.9 mi below Ravine. The elevated metals concentrations 1.9 mi downstream from Ravine probably derive from a source other than coal, because the concentration of coal is much lower at this site and the bottom material is extremely fine. A possible source of the metals may be the point-source discharge mentioned earlier in this report. The point-source discharge is immediately upstream from the sampling point, and the point-source discharge contained elevated concentrations of aluminum, iron, lead, copper, and zinc, and low concentrations of manganese. The decrease in manganese in the bottom material below the point-source discharge 1.9 mi downstream from Ravine may be associated with the elevated dissolved-manganese concentration measured 2.5 mi downstream from Ravine. Ingols and Wilroy (1962) indicated that manganese may redissolve and move downstream as a result of the influence of a water discharge containing tannic acid. The current site of the point discharge is at a textile-dye plant, and a tannery used to be located at the site.

In summary, metal concentrations measured at the mined site and the forested and agricultural site often exceeded the recommended USEPA criteria and Pennsylvania water-quality standards. During a year with normal streamflow, more than 1,000 tons of metals, most of which are attached to sediment, are transported to the planned reservoir study area from the mined site--Swatara Creek above Highway 895--and the forested and agricultural site--Lower Little Swatara Creek. About 36 percent of the total-recoverable iron and 27 percent of the total-recoverable aluminum is transported during base flow. Swatara Creek also is probably affected by point sources other than mine discharges. The point-source discharge measured during the study probably contributed lead, copper, and zinc in addition to iron and aluminum which also are commonly associated with coal. The point-source discharge also may have been responsible for the resolution of manganese from the bottom material. Unlike iron and aluminum, manganese is being transported primarily in the dissolved phase in the stream reach within the study area. Mercury and selenium concentrations in the Swatara Creek bottom material were higher at the mined site than the forested and agricultural site.

Nutrients

The amount of nutrients transported into a reservoir is important because of the critical role of nutrients in eutrophication. Wetzel (1975) states "the term eutrophication is synonymous with increased growth rates of the biota of lakes," and "the most conspicuous, basic, and accurately measurable criterion of accelerated productivity is increasing rates of photosynthesis by algae and larger plants per given area." The danger in increased photosynthesis or growth rates is that, as the algal bloom increases, it consumes more oxygen than it generates within the reservoir and the demand for oxygen increases in the deeper water as dead algae settles to the bottom and decomposes. Therefore, there is little oxygen available for other aquatic life in the reservoir. If the dischage from the reservoir is not well aerated, then releases of poorly oxygenated water from the reservoir also may cause adverse effects downstream.

Two of the primary nutrients required for algal growth are phosphorus and nitrogen. Commonly, the limiting nutrient for increased algal and plant growth within a reservoir is the amount of phosphorus transported to the reservoir (Vallentyne, 1970).

A conservative estimate of the average annual phosphorus load to the planned Swatara Creek State Park Reservoir was based on limited data because relations between total-phosphorus concentrations and streamflow or suspended-sediment concentrations were low (r^2 less than 0.60). Poor correlations between phosphorus concentrations, streamflow, and suspended sediment probably resulted from the point-source discharge near Highway 443 mentioned earlier, inasmuch as extremely high total- and dissolved-phosphorus concentrations of 19 mg/L and 14 mg/L, respectively, were measured at the site on September 7, 1983, (table 8). Similar elevated phosphorus concentrations were measured during low flows in October 1982 and September, October, and November 1983 at the mined site (fig. 16) that also may be the direct result of the upstream industrial point-source.

Large quantities of phosphorus are transported in Swatara Creek during storms, and much of the phosphorus may originate from the point-source near Swatara Creek above Highway 443. The maximum total-phosphosus concentration that was measured during a storm was 2.2 mg/L. This storm concentation was measured 0.6 mi downstream from the industrial point-source at the mined site, and was eight times higher than any other concentration measured in storm runoff. The maximum storm concentration was measured 2 weeks after a phosphorus concentration of 19 mg/L was measured at the point source on September 7, 1983. The elevated storm concentration probably resulted from the resuspension of phosphorus that had been discharged from the point source, and complexed and precipitated with iron and aluminum.

Base flow from the mined site and the forested and agricultural site transports an average of about 1.83 tons and 0.73 ton, respectively, of dissolved phosphorus annually to the Swatara State Park Reservoir area. An additional 0.73 ton of suspended phosphorus is transported as base flow to the study area from the forested and agricultural site. Because a relation between total-phosphorus discharge and streamflow during base flow at the mined site could not be demonstrated, an average annual total- and suspended-phosphorus discharge for the mined site could not be calculated. However, inasmuch as concentrations in base flow of suspended phosphorus were usually at least two times higher than concentrations of dissolved phosphorus, the suspended-phosphorus discharge during base flow can be estimated to be at least twice the dissolved-phosphorus discharge. Thus, the average annual base flow suspended-phosphorus discharge for the mined site was at least 3.6 tons, and the average annual total-phosphorus discharge to the Swatara State Park Reservoir study area as base flow was at least 6.89 tons. During base flow, at least 63 percent of the total-phosphorus load was suspended, and about 79 percent of the total load came from the mined site.

Average daily base-flow discharges and yields indicate that more phophorus is being discharged from the mined site than from the forested and agricultural site. The average daily dissolved-phosphorus discharge in base flow for the mined site, and the forested and agricultural site were 0.005 ton/d, and 0.002 ton/d, respectively. The average annual base-flow yields of dissolved phosphorus from the mined site--0.03 ton/mi^2--and from the forested and agricultural site--0.02 ton/mi^2--were nearly equal. However, the average annual base-flow yield for suspended phosphorus was more than 2.5 times greater from the mined site than from the forested and agricultural site.

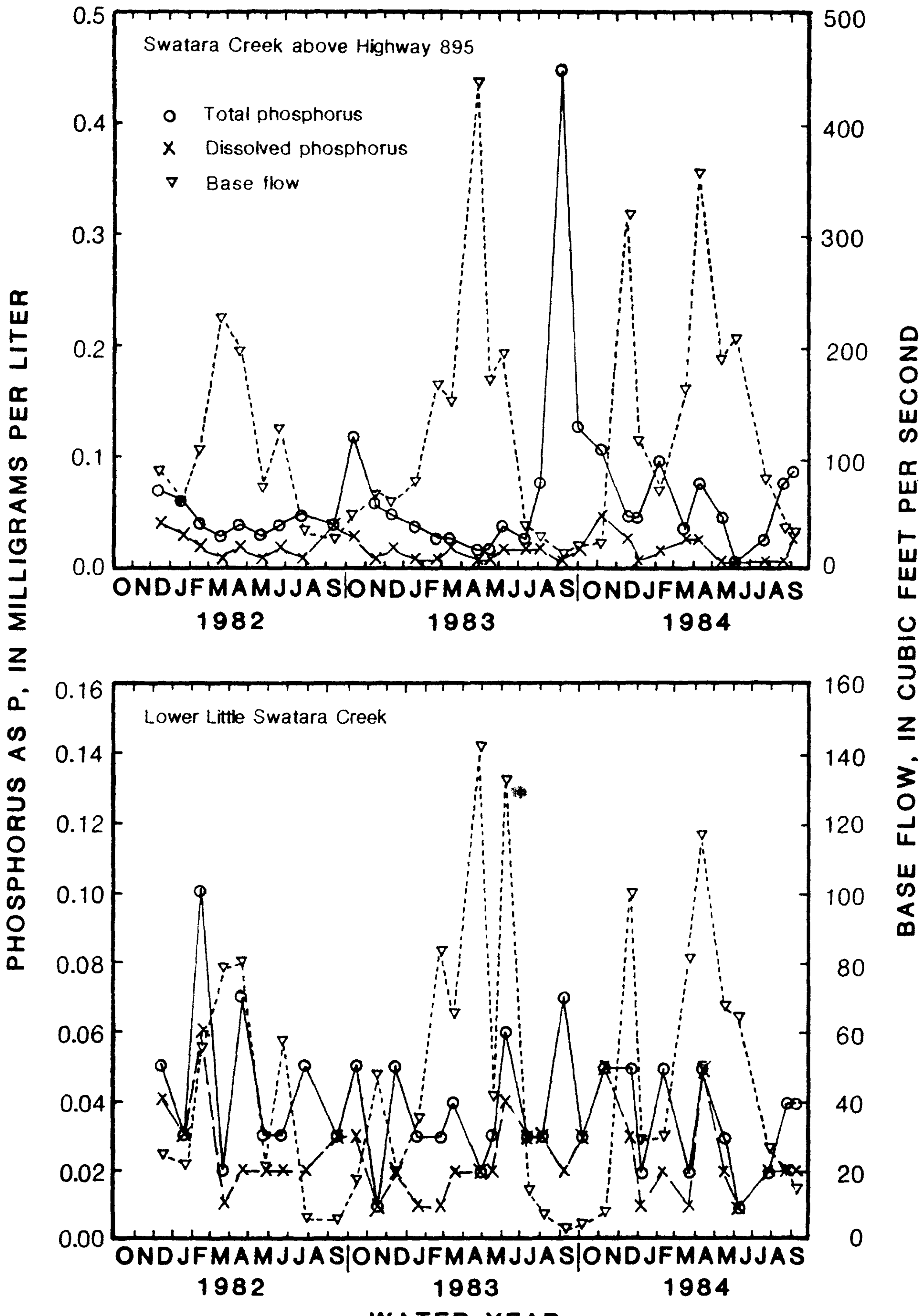

Figure 16.--Total- and dissolved-phosphorus concentrations at Swatara Creek above Highway 895 (mined site) and Lower Little Swatara Creek (forested and agricultural site), and their relation to base flow, 1982-84 water years.

Maximum base-flow total- and dissolved-phosphorus concentrations were 0.45 mg/L and 0.07 mg/L, respectively, at the mined site, on September 7, 1983, and 0.10 mg/L and 0.06 mg/L, respectively, at the forested and agricultural site on February 16, 1982 (fig. 16). Dissolved-phosphorus concentrations in base flow at the mined site and the forested and agricultural site remained relatively constant throughout the year and varied little between dry, normal, and wet years. Total-phosphorus concentrations in base flow at the mined site varied considerably; the highest concentrations occurred during low flows in September and October. These variations probably reflect the point-source discharge just upstream from Route 443.

Storm loads and base-flow loads from the forested and agricultural site for total phosphorus were 3.06 tons and 1.46 tons, respectively, during the near-normal 1983 water year. About 91 percent of the 3.06 ton storm load was dissolved phosphorus; about 16 percent was orthophosphate.

An average annual storm load from the mined site was estimated to be at least 3.06 tons. This load was estimated because the relation between total-phosphorus concentrations and streamflow was low (r^2 less than 0.60), and the estimation was based on the assumption that the storm loads at the mined site must be at least equal to those at the forested and agricultural site since the concentrations and stormflows were almost always higher at the mined site.

In summary, table 14 shows that, based on a conservative estimate, an average of at least 13.01 tons of phosphorus is transported to the planned reservoir study area during a normal year. At least 65 percent of the phosphorus comes from the mined site and at least 47 percent is transported from both sites by storms.

Table 14.--Conservative estimate of annual phosphorus load, as P, for Swatara State Park Reservoir study area
[load in tons]

Location	Base-flow load			Stormflow load			Annual load	
	Dissolved	Suspended	Total	Dissolved	Suspended	Total	Total	Percentage
Mined site	1.83	3.60[a]	5.43[a]	--	--	3.06[a]	8.49	65
Forested and agricultural site	.73	.73	1.46	2.78	0.28	3.06[a]	4.52	35
Total Phosphorus	2.56	4.33[a]	6.89[a]	--	--	6.12[a]	13.01	100
Percentage	20	33	53	--	--	47	--	100

[a] Conservative estimates based on limited data.

Average annual total-nitrogen discharges were not calculated because of the limited amount of data collected during the 3-year study. Most of the nitrogen transported in the study area was dissolved, so that correlations like those used to estimate metal and phosphorus concentrations in storm runoff based on suspended-sediment concentrations could not be used.

The relation between nitrogen concentrations in base flow and streamflow at the mined site were low (r^2 less than 0.60). Lack of evident correlations probably were the result of the point-source discharge mentioned previously. For example, elevated concentrations of total and dissolved ammonia, and of ammonia plus organic nitrogen, were measured during base flow on September 7, 1983 at the mined site (table 8). The elevated nitrogen concentrations at Swatara Creek at Highway 443 listed in table 8 were measured just upstream from the mined site and were probably the result of the point-source discharge mentioned previously. Similar point discharges also may have been responsible for the elevated base-flow ammonia-nitrogen concentrations measured at the mined site in July and September 1982, July through September 1983, and September and October 1984.

During base flow, an average of at least 175 and 94 tons of nitrogen from the mined site and the forested and agricultural site, respectively, are discharged annually to the planned reservoir study area (table 15). Like phosphorus, 65 percent of the nitrogen during base flow is discharged from the mined site. About 53 percent of the base-flow nitrogen--93.1 tons--from the mined site is discharged as dissolved nitrate, and about 74 percent of the base-flow nitrogen--72.3 tons--from the forested and agricultural site is discharged as dissolved nitrate.

Table 15.--Estimated annual base-flow nitrogen loads, as N, to the Swatara State Park Reservoir study area
[load in tons]

	Ammonia		Ammonia & Organic		Dissolved	Total	Percentage of total
	Dissolved	Total	Dissolved	Total	Nitrate	Nitrogen	nitrogen load
Swatara Creek above Highway 895	--	--	68.3	82.5	93.1	175.6	65
Lower Little Swatara Creek	1.46	1.83	18.2	22.3	72.3	94.6	35
Total	--	--	86.5	104.8	165.4	270.2	100
Percentage	--	--	32	39	61	100	

Average daily base-flow nitrate-nitrogen discharges from the mined site--0.255 ton/d--were higher than those from the forested and agricultural site--0.198 ton/d--but the yield from the forested and agricultural site--2.11 (tons/yr)/mi^2--was higher than from the mined site--1.28 (tons/yr)/mi^2. In contrast to the average annual yields for nitrate-nitrogen discharges in base flow, the average annual yield for total ammonia plus organic nitrogen in base flow was higher from the mined site--1.14 (tons/yr)/mi^2--than from the forested and agricultural site--0.65 (ton/yr)/mi^2. About 82 percent of the yields of total ammonia plus organic nitrogen in base flow from both sites was dissolved.

Maximum total-nitrogen (fig. 17) concentrations in base flow were 3.8 and 3.2 mg/L at the forested and agricultural site and at the mined site, respectively, and occurred December 1982 and February 23, 1983, respectively.

Total-nitrogen concentrations in base flow at the two inflows (fig. 17) decreased during the 3-year study and during the "wet" 1984 water year at both sites. At the forested and agricultural site, concentrations decreased during each year of the study. Similar decreases in nitrogen concentrations are seen at intensively farmed sites in the Conestoga Creek headwaters in Lancaster County and may be related to the uptake of nitrogen by corn during the growing season (U.S. Department of Agriculture, 1985). After the crop is harvested in September, farmers are able to spread nitrogen as manure, which then can infiltrate through the soil and enter the ground-water system, and ultimately discharge to streams in base flow. Although this was originally thought to be a long process, nitrogen concentrations in base flow measured in Lancaster County increase within several days following manure and fertilizer applications and subsequent large precipitation events.

Annual total-nitrogen discharges in storm runoff were higher than discharges in base flow at the mined site and the forested and agricultural site because of increases in suspended organic-nitrogen concentrations. Average annual nitrogen discharges in storm runoff were not calculated, because the relations between nitrate- and ammonia-nitrogen with streamflow were poor (r^2 less than 0.60). Most of the nitrate and ammonia-nitrogen was dissolved and diluted during storms.

Major ions

The ionic strength of water in Swatara Creek changes in the reach between Highway 895 to Inwood. This change results from dilution of the mixed-cation-sulfate type of water from the mined site by the less mineralized mixed-cation-mixed-anion inflow from the forested and agricultural site (Fishel and Richardson, 1986). The median sulfate concentration is more than 5 times higher in the mine drainage than in the agricultural and forested drainage (table 7). Water in the planned Swatara State Park Reservoir area is generally soft, with hardness values less than 70 mg/L as $CaCO_3$ at the mined site and the downstream site at Inwood, and 30 mg/L as $CaCO_3$ at the forested and agricultural site.

Instantaneous and median sulfate concentrations and discharges (table 7) indicate that most sulfate in Swatara Creek originates from mine drainage upstream from Highway 895. Increases in dissolved-calcium, magnesium, carbonate, and sulfate concentrations reflect mining operations where rock has been

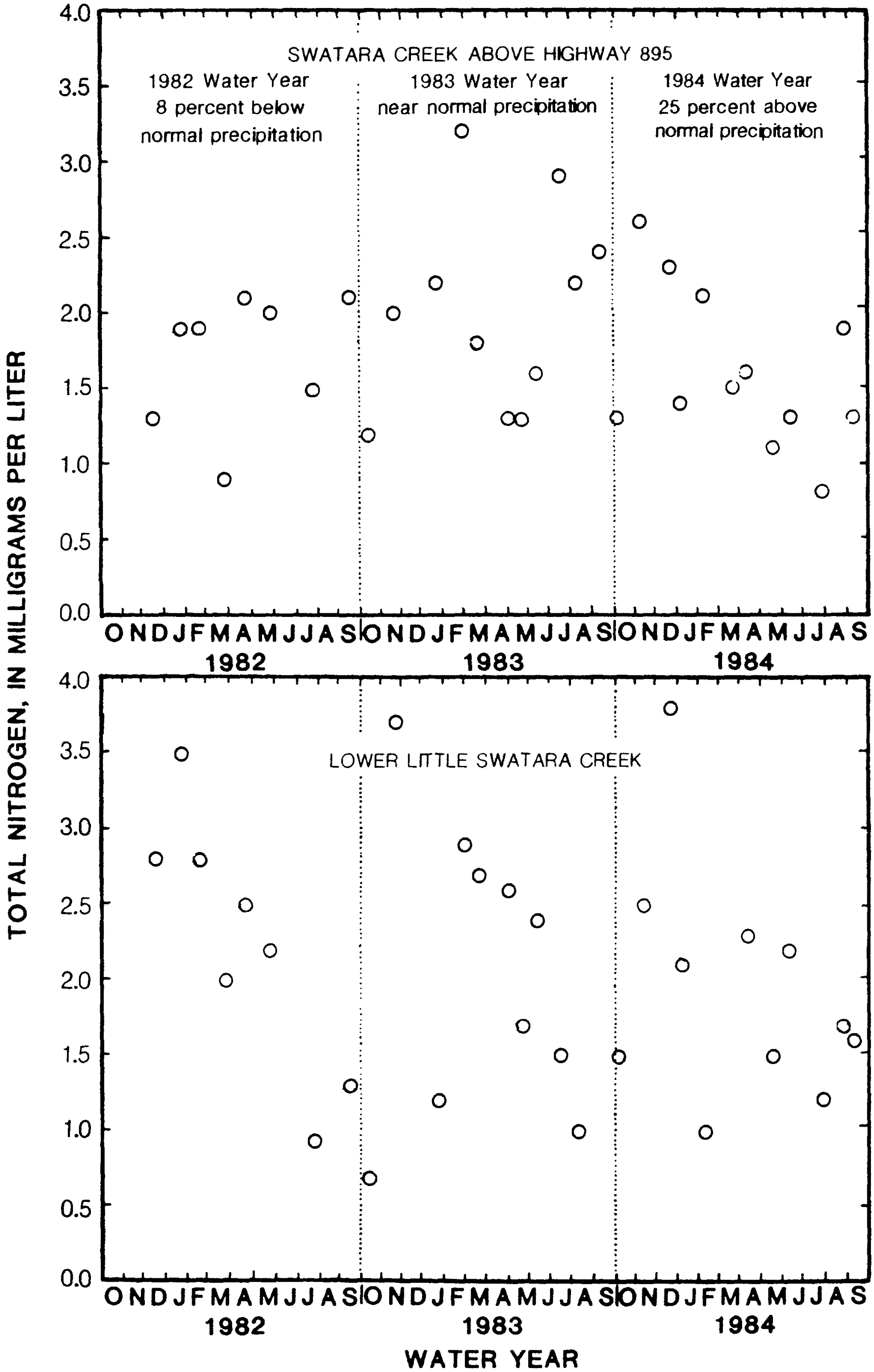

Figure 17.--Total-nitrogen concentrations in base flow at Swatara Creek above Highway 895 (mined site) and Lower Little Swatara Creek (forested and agricultural site), 1982-84 water years.

disturbed and minerals are exposed and available for dissolution. Much of the sulfate anion comes from base flow that originates in both active and inactive mines in the study area. Additional sulfate may come from the continuous drainage of deep mine tunnels in the Swatara Creek headwaters. Slugs of acidic water high in sulfate also come from the culm piles when storm runoff washes the oxidized pyritic material into the streams. Occasionally, some surface runoff may infiltrate into the waste piles and leach acid into the local ground water. Later, this ground water, with its high sulfate concentrations, discharges to streams as base flow.

Discharges of individual ions could not be estimated from the limited data collected because the dissolved-ion concentrations correlated poorly with streamflow. The low correlations during base flow probably resulted from point discharges in the Swatara Creek headwaters. Low correlations between dissolved-ion concentrations and streamflow during storms probably resulted from the interaction between diluted base flow and slugs of storm runoff with elevated acid concentrations. Correlations for the forested and agricultural site were affected by changes in the minimum detection limit set by the analyzing agency in the third year of the study, inasmuch as dissolved-sulfate concentrations were commonly reported to be less than or equal to 5.0 mg/L during 1982 and 1983 but were reported to be less than 25.0 mg/L during 1984. Therefore it was not possible to analyze 1984 water year sulfate data with 1982 and 1983 water year data for the forested and agricultural site.

Daily and annual dissolved-ion loads and yields during base flow were estimated using relations between streamflow and constituent discharges when the relation had a r^2 greater than 0.60 (table 16). The estimate for the sulfate load from base flow for the mined site was made by multiplying the median sulfate concentration (77 mg/L) in base flow by the average daily base flow (109 ft^3/s), inasmuch as the correlation between instantaneous sulfate discharge and instantaneous streamflow was low (r^2 less than 0.60). This method resulted in an annual sulfate load from base flow that was 11 percent higher than the load estimated by the flow-duration method when applied to the forested and agricultural site. The estimate for the annual sulfate load from base flow for the mined site is, therefore, probably slightly higher and not as accurate as estimates for the other dissolved ions.

Table 16.--Estimated annual major ion loads and yields in base flow for Swatara State Park Reservoir study area
[(tons/yr)/mi^2, tons per year per square mile]

	Mined site (01571919)		Forested and agricultural site (01572000)	
	Discharge (tons)	Yield (tons/yr)/mi^2	Discharge (tons)	Yield (tons/yr)/mi^2
Calcium	1,300	17.9	175	5.10
Magnesium	953	13.1	89.4	2.61
Potassium	566	7.8	108	3.15
Sulfate	8,270[a]	114	436	12.7

[a]Estimates for these values are based on the median concentration in base flow and average daily base flow.

As expected, table 16 shows higher loads and yields of major ions from the mined site than from the forested and agricultural site. The estimated annual base-flow dissolved-sulfate load was nearly 20 times higher, and the yield was 10 times higher at the mined site than at the forested and agricultural site. Dissolved-sulfate concentrations were much higher at the mined site than the forested and agricultural site. The maximum sulfate concentration in base flow was 130 mg/L at the mined site. Lower peak concentrations occurred throughout the study at the forested and agricultural site, and the maximum concentration in base flow was 55 mg/L.

The annual increases in sulfate concentrations in base flow at the mined site appear to be due to two factors (fig. 18): First, increased concentrations are evident from July through November when base-flow discharges were not diluted as they were during other parts of the year; second, higher sulfate concentrations occur during wet years, such as the 1984 water year, when discharges

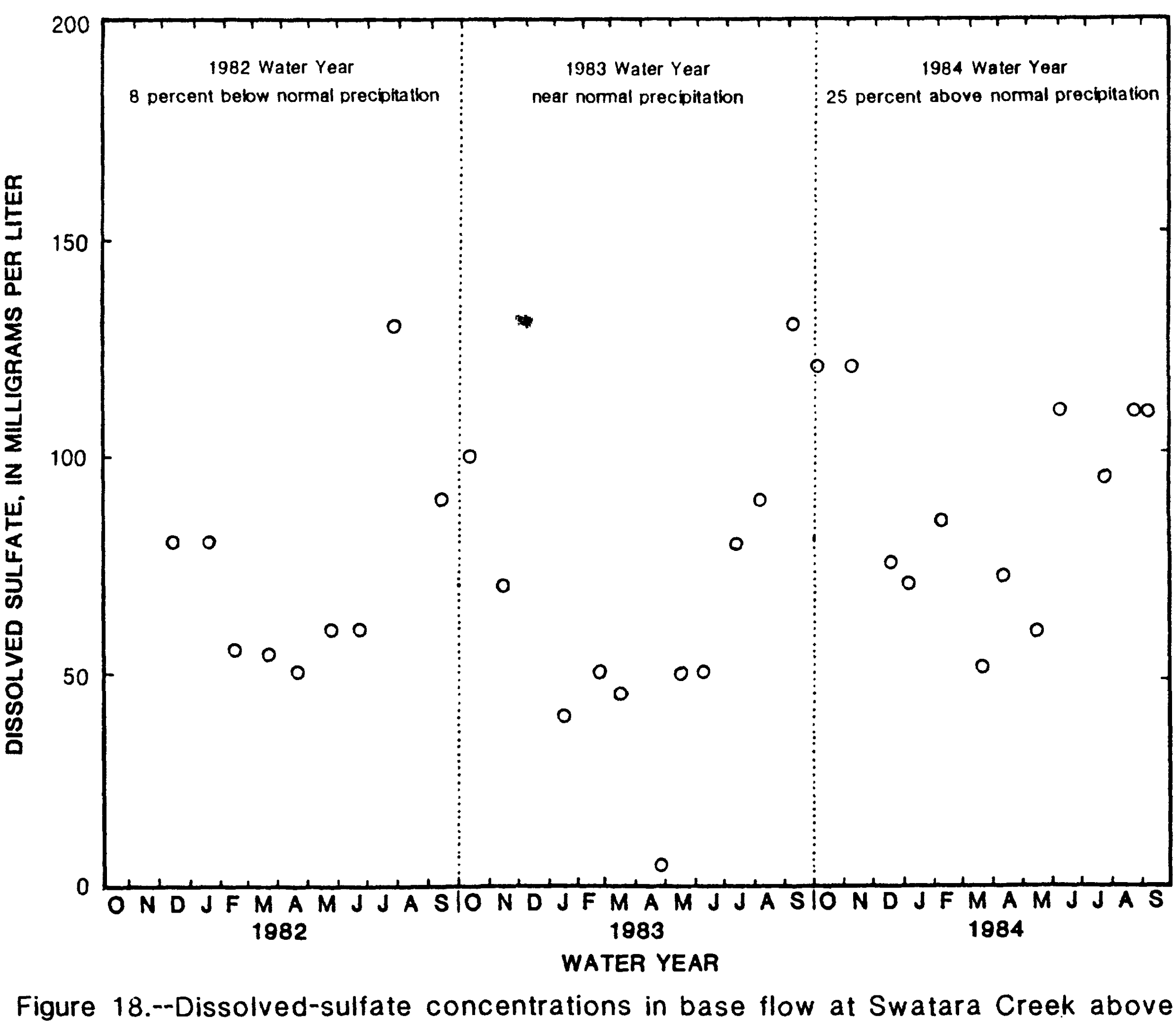

Figure 18.--Dissolved-sulfate concentrations in base flow at Swatara Creek above Highway 895 (mined site), 1982-84 water years.

from the deep mine tunnels increase. Increases in sulfate concentrations in base flow for the 3-year period may have resulted from the above normal precipitation during the third year of the study, however they were not statistically significant.

Annual major ion discharges during storms could not be calculated from the limited data. Unlike suspended nutrients whose concentrations tend to increase during storm flows, concentrations of dissolved substances generally were diluted, especially if they were discharged at a constant rate from a point source. Although a few storms may contribute a substantial part of the annual nutrient load, the same storms may contribute very little to the annual major ion load depending on the amount of runoff and the availability of the ion. Without using the same analytical detection limit throughout a study, and measuring the dilution for each storm, an annual discharge is difficult to estimate. For example, at Swatara Creek above Highway 895, during the storm on February 14, 1984, dissolved sulfate was diluted from 61 mg/L to 34 mg/L at the peak streamflow. Although the sulfate concentration was diluted, the maximum instantaneous sulfate discharge (170 tons/d) for the 3-year study at the mined site was measured at peak streamflow on the storm hydrograph.

Several observations from the instantaneous sulfate concentrations in storm runoff provide information on the expected storm discharges. Sulfate concentrations at the mined site were diluted during all storms, but concentrations returned quickly to high levels before streamflows returned to base flow. This observation suggests that sulfate is transported primarily in ground water and at times may be discharged to the streams from bank storage or leachate from culm piles near the stream as discharges recede. Elevated sulfate concentrations prior to return to base flow, and maximum instantaneous sulfate discharges near streamflow peaks, suggest that the annual load of sulfate from the mined site is probably higher than the estimated 1,830 tons calculated from the average daily stormflow (53 ft^3/s) and median concentration (35 mg/L) during storm runoff. Thus, the total annual load for sulfate from the mined site is probably greater than the sum of the estimated loads of 8,270 tons from base flow and 1,830 tons from storm runoff.

Microorganisms

The USEPA criterion and the Pennsylvania recommended standard for primary contact water (swimming) is less than 200 fecal-coliform colonies per 100 mL of water based on a geometric mean of five consecutive samples (U.S. Environmental Protection Agency, 1976 and Pennsylvania Department of Environmental Resources, 1979). Inasmuch as bacteriological sampling was performed once a month and during storms, rather than daily, it is difficult to compare the data to the standard. However, duplicate samples collected during base flow and analyzed both in the field and by the PaDER laboratory in Harrisburg gave similar results. Bacteriological data indicate 9 and 35 percent of the base-flow samples collected at the mined site and the forested and agricultural site, respectively, had greater than 200 colonies per 100 mL of water. Maximum base-flow fecal-coliform counts as high as 1,200 colonies per 100 mL of water occurred during the period from September through November at the mined site. Fecal-coliform counts as high as 3,500 colonies per 100 mL of water from May through October occurred at the forested and agricultural site.

Fecal-coliform counts in 71 percent of the base-flow samples were two times higher at the forested and agricultural site than at the mined site. The low counts at the mined site may reflect the toxic conditions that reduce the survival rate of bacteria (Hackney and Bissonnette, 1978).

Fecal-streptococci counts during base flow were higher than fecal-coliform counts at both the mined site and the agricultural and forested site. Fecal-streptococci counts were two times higher in over 53 percent of the base-flow samples at the forested and agricultural site than at the mined site. Maximum counts at both sites occurred between June through October.

Sources of bacteria are commonly determined using the ratio of fecal coliform to fecal streptococci, FC/FS. Geldreich and Kenner (1969), reported that fecal-coliform counts are at least four times higher than fecal-streptococci counts in human feces. Conversely, fecal-streptococci counts are 1.4 times higher than fecal-coliform counts in farm animals, dogs, cats, and rodents. Lin and others (1974) suggest the following guides for interpreting FC/FS ratios.

$FC/FS \leq 0.7$	animal waste
$FC/FS \geq 0.7$ and ≤ 1	preponderance animal waste
$FC/FS > 1$ and ≤ 2	difficult to interpret
$FC/FS > 2$ and ≤ 4	preponderance human waste
$FC/FS > 4$	human waste

These correlations are most helpful when bacterial survival rates are not influenced by factors such as mine drainage and if samples are collected within 24 hours of the contact of the bacteria with the receiving water. Because mine drainage affects the survival rate of bacteria at Swatara Creek above Highway 895, the FC/FS ratio may not be helpful in identifying the source of bacteria in this stream. Because Lower Little Swatara Creek is unaffected by mine drainage, and travel times from the headwaters to the sampling point are less than 24 hours, the FC/FS ratio probably is a good method for determining source of bacteria in this stream. About 21 percent of the samples collected from the forested and agricultural site had a FC/FS ratio greater than 2, indicating probable periodic point discharges of human waste at the site.

ESTIMATED POSTIMPOUNDMENT WATER QUALITY IN THE PLANNED RESERVOIR

Estimates of the water quality of the planned Swatara State Park Reservoir are based on numerous chemical and physical characteristics of the planned reservoir and other reservoirs with similar drainage basin characteristics. A comparison of the water quality of reservoirs, and in downstream river reaches, can only be discussed qualitatively, as suggested by Flippo (1970), because no two reservoirs have identical morphological characteristics, sedimentation rates, and inflows with the same streamflow and chemical loads. These factors play an important role in the chemical reactions taking place in a reservoir and will be included in the following discussion.

Thermal Stratification

Thermal stratification in the planned Swatara State Park Reservoir can be expected to occur much like other reservoirs with similar morphological characteristics and geographic locations. Water temperatures in the reservoir will be different from those of the inflows because of the effects of solar radiation on the water surface, increased retention times within the reservoir, and mixing by wind action and streamflows. However, because the discharges from the mined site to the planned reservoir will be about twice that from the forested and agricultural site, mixing of these two discharges will result in an inflow to the reservoir with water temperatures more closely related to those at the mined site.

Because changes in water temperatures in a reservoir are largely the result of increased solar radiation followed by the warming of the water surface, estimating changes in water temperature at the inflows may help to predict the onset of stratification and overturn. Predicting the onset of stratification and overturn will aid managers of the reservoir to determine the timing and the quantity of water to be released to maintain optimum water quality in and downstream from the reservoir. Estimating the timing of rapid changes in water temperature at the inflows will only be helpful, however, if following these changes, the water temperatures are sustained and other conditions, such as wind action, have a minimal effect on water in the reservoir.

For example, in late April and in September water temperatures rapidly increase and decrease, respectively, at the mined site and at the forested and agricultural site. Occasionally the rapid changes are followed by periods of sustained warm or cool water discharges. Time-series plots of air and water temperatures (figs. 4-5), indicate the greatest changes in water temperatures are closely associated with changes in air temperatures measured at Pine Grove. Following these periods of rapid changes, there is a flattening of the curves that represents a period of sustained warmer or cooler temperatures, respectively. Using equations 1 and 2 estimates of these changes can be made.

On April 25, for example, the mean daily air temperature was 5.0 °C and measured water temperatures were 7.5 and 8.0 °C, respectively, at the mined site and the forested and agricultural site. Estimated temperatures from equations 1 and 2 were 9.2 and 8.1 °C, respectively. The next day, the daily mean air temperature rose to 11.0 °C (fig. 4) and measured water temperatures at the mined site and forested and agricultural sites were 11.5 and 11.0 °C, respectively. The increase in air temperature was also reflected by increases in estimated water temperatures. Estimated water temperatures were 13.5 and 12.4 °C for the mined site and the forested and agricultural sites, respectively. The 7-day period following April 25 (April 26-May 2) would have been ideal for the onset of the formation of density layers in the lake especially if the wind were calm. Air temperatures during these 7 days remained significantly higher than those measured on April 25 and would probably have resulted in warmer inflows to the reservoir than those of several days earlier. As solar radiation and air temperatures increase, the upper layer of the reservoir would become warmer and less dense. The warm-water inflows would mix with water with a similar density near the reservoir surface and would flow over the cooler, denser water near the bottom of the reservoir. Thus, the establishment of density layers in the reservoir is predicted to begin as early as late April. Release of water from the bottom of the reservoir from April through September may help reduce the extent of thermal stratification.

The onset of fall overturn likewise may be predicted by determining when the maximum rate of change in water temperature at the inflows occurs and when density layers in the lake are close to the density of the water of the inflows. Such a period occurred in September 1983 and could have been predicted by using the time-series plots and equations 1 and 2. In this particular instance, daily mean air temperature decreased from 26.0 °C on September 20, 1983, to 9.0 °C on September 24. Concurrently, water temperatures dropped from 22.0 and 23.5 °C to 14.5 and 15.0 °C, respectively, at the mined site and the forested and agricultural site. Estimated declines in water temperatures using equations 1 and 2 would have been from 24.0 to 12.1 °C and from 23.5 °C to 11.1 °C, respectively, at the mined site and the forested and agricultural site. These sudden air- and water-temperature changes signal the beginning of when water temperatures and densities from inflows would approach those in the lower part of the reservoir and when mixing of the upper and lower layers of the reservoir might occur. Figures 4 and 5 show that similar patterns can be identified annually; therefore, stratification and fall overturn is predicted to occur about the same time each year.

Productivity in the Reservoir

The water quality of the planned reservoir, in terms of productivity, was estimated using a graphical technique developed by Vollenweider (1975) (fig. 19). Vollenweider developed a method by which conditions in a lake can be predicted using the estimated phosphorus loading required to maintain a steady state of productivity. When these levels are exceeded, rapid eutrophication is likely. Work done by Dillion and Rigler (1974) and Dillion (1975) led to the inclusion of a factor for the retention of phosphorus in a lake termed the hydraulic residence time (tw), which is included in figure 19. Also included in the figure are results from Barker, (U.S. Geological Survey, written commun., 1979) who used this method to classify the productivity of several lakes in Pennsylvania. When this method is applied to the planned Swatara State Park Reservoir which will have an estimated phosphorus loading of over 13 tons during a normal year and a flushing rate of 15.3 times a year, then eutrophication is a possibility for the planned reservoir. The actual rate at which the planned reservoir will become eutrophic will depend on the actual loadings and the volume of inflow. The process of eutrophication may be slowed by eliminating or reducing input from sources of nutrients such as the point source mentioned earlier.

Effects of Base Flow and Runoff

Water quality of the planned reservoir will largely depend on the quality of base flow and runoff. Since 95 percent of the time streamflow to the planned reservoir will consist mostly of base flow, the water quality of the planned reservoir will largely depend on the quality of base flow. Chemical data presented earlier indicate that variations in chemical concentrations in base flow will probably be greater within a year than between years, and that the chemical concentrations of inflows to the planned reservoir during base flow are affected by point sources.

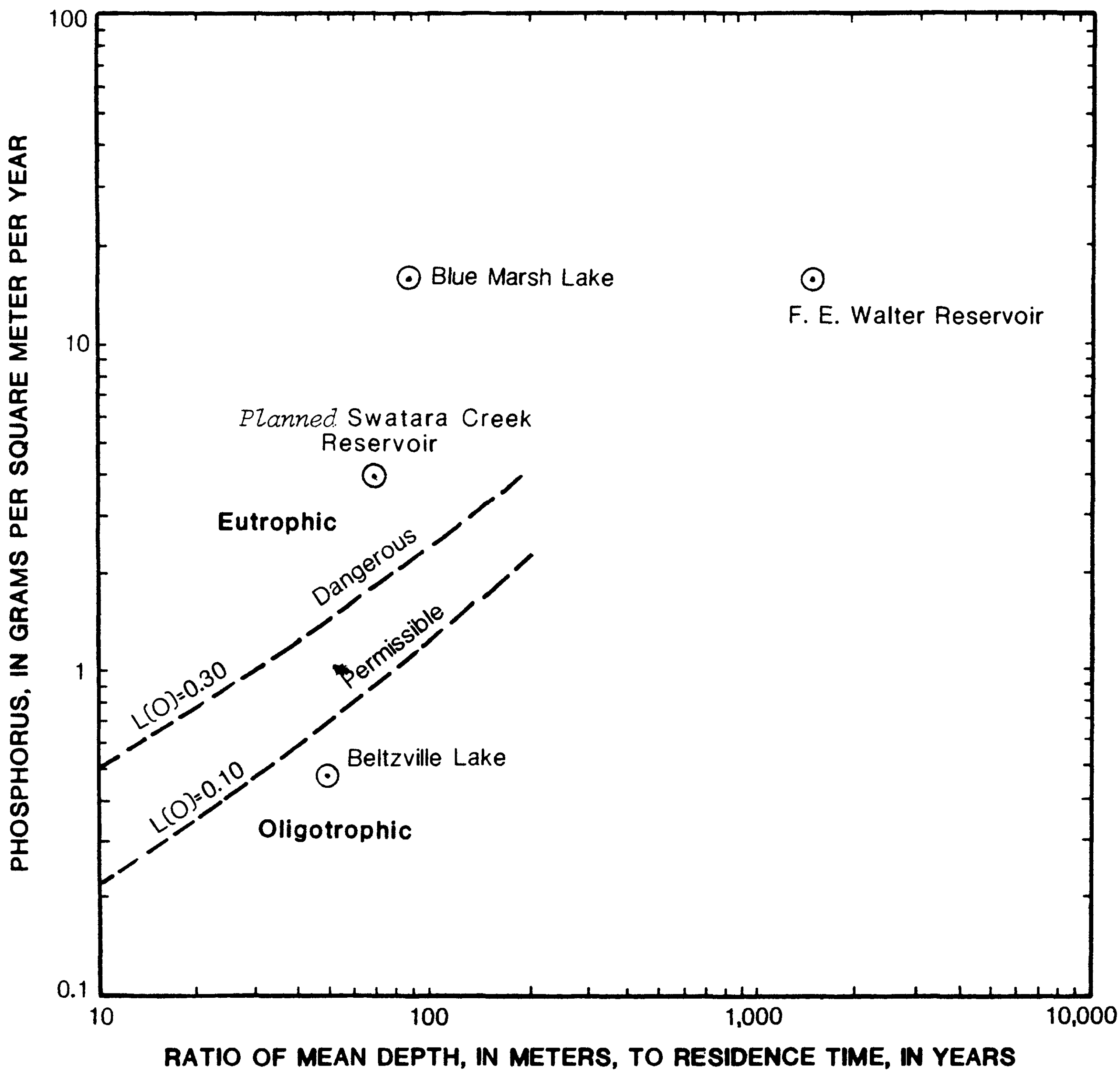

Figure 19.--Eutrophic potential for *planned* Swatara State Park Reservoir based on conservative phosphorus loadings modified (from Vollenweider, 1975).

Although the water quality of the planned reservoir will often be dominated by base flow, sudden changes in the chemical composition of the reservoir may occur in response to runoff from precipitation events. Table 17 summarizes the precipitation and stream response in terms of total streamflow, surface runoff, and sediment for precipitation events during which water-quality samples were collected. Responses indicated in the table are representative of typical storms, but do not reflect the maximum responses observed during the study. Because precipitation data were collected only once daily at Pine Grove, the following discussion is limited to 24-hour responses in surface runoff and water quality resulting from precipitation. Water quality is indexed to suspended-sediment yields and loads, because most of the metals transported during the study were sorbed to suspended sediment.

Streamflow, runoff, suspended-sediment yields, and suspended-sediment loads during storms varied significantly with variations in magnitude and duration of precipitation events, and with seasons. Water-quality responses represented by the suspended-sediment yields and loads were not always directly related to the amount of precipitation. Responses are probably related to antecedent soil conditions, land use, topography, and geology. For example, on April 10, 1983, (table 16), 1.10 in. of precipitation fell, and streams responded with large increases in surface runoff and suspended-sediment yields of 6.42 and 18.2 (tons/d)/mi^2 at the mined site and the forested and agricultural site, respectively. These responses may have resulted from the saturated conditions of the soils inasmuch as 0.83 in. of precipitation fell the previous day. On September 22, 1983, 1.42 in. of precipitation fell and the response by surface runoff and suspended-sediment yields were much lower than the storm in April. These responses were probably the result of the dry soil which facilitated infiltration of precipitation.

Stream responses also differed significantly at the two sites, indicating that the sources of inflow (base flow and storm runoff) and the effects of the combined inflow on the planned reservoir from a particular storm will be difficult to predict. Storm 2 resulted in similiar yields from both sites. Resultant discharge to the reservoir would be a simple flow-weighted mixture of the two discharges. Storm 3, however, produced a load of 581 tons of suspended sediment from the mined site and a load of 8.03 tons from the agricultural and forested site. In contrast, storm 5 produced a larger suspended-sediment yield from the agricultural and forested site than from the mined site; the loads from each site were comparable (775 tons and 732 tons, respectively). The contrast between the storms may be the result of seasonal and land-use differences. Less vegetation covered the forested and agricultural site during storm 5 (April) than during storm 3 (August). Suspended-sediment yields at the forested and agricultural site also were high during the February and December storms when vegetation cover was minimal.

The effect of storms on the planned reservoir will differ according to the response of upstream basins to the storms. For example, if suspended-sediment yields from the mined site are high, much of the suspended sediment delivered to the reservoir will be enriched with coal. Because coal has a low density, most of it may be transported through the main body of the reservoir and discharged, depending on the density currents and the type of release. In contrast, if suspended-sediment yields from the forested and agricultural site are high, the suspended sediment delivered to the reservoir will have a higher density. This

Table 17.--Summary of amount of precipitation, streamflow, runoff, and suspended-sediment yield and load during selected storms at the mined site (01571919), and the forested and agricultural site (01572000)

[ft^3/s, cubic feet per second; $(tons/d)/mi^2$, tons per day per square mile]

Storm	Total precipitation (inches)	Date	Precipitation (inches)	Streamflow: Total (ft^3/s)	Streamflow: Surface runoff (ft^3/s)	Streamflow: Total (ft^3/s)	Streamflow: Surface runoff (ft^3/s)	Suspended-sediment yield $(tons/d)/mi^2$		Suspended-sediment load (tons)	
				01571919		01572000		01571919	01572000	01571919	01572000
1	1.39	February 2, 1982	0	180	130	140	122	0.32	0.32	23	11
		3	.63	339	299	260	188	2.0	3.67	145	126
		4	.76	424	284	300	228	.73	2.80	53	96
		5	0	239	99	94	22	.22	.32	16	12
2	1.75	April 25, 1982	0	150	0	49	0	.05	.02	150	.66
		26	0	214	64	109	60	.61	.52	214	18
		27	1.10	281	131	145	96	.36	.35	281	12
		28	.65	310	160	208	159	.50	.67	310	23
		29	0	259	82	144	75	.13	.16	259	5.4
3	1.45	August 24, 1982	.09	38	0	12	0	.01	.17	1.0	.19
		25	1.32	233	195	49	37	7.88	1.31	572	7.0
		26	.04	111	73	24	12	.11	.38	8.1	.84
4	1.68	December 14, 1982	0	59	0	20	0	.02	.00	1.3	.16
		15	1.58	60	0	19	0	.02	.01	1.5	.21
		16	.10	485	425	174	155	9.88	2.57	717	88
		17	0	367	307	150	131	.41	.24	30	8.1
5	2.40	April 7, 1983	.05	216	0	89	0	.13	.05	9.3	1.7
		8	.28	325	109	159	70	.83	.85	60	29
		9	.83	395	0	232	67	.44	.70	32	24
		10	1.10	807	412	608	443	6.42	18.2	466	624
		11	.14	700	305	390	225	1.56	2.22	113	76
		12	0	506	111	230	65	.72	.61	52	21
6	1.42	September 20, 1983	0	14	0	2.8	0	.00	.00	.15	.00
		21	0	39	22	4.9	1.0	1.21	.00	88	.11
		22	1.42	36	19	12	8.1	.17	.01	12	.29
		23	0	18	1	4.9	1.0	.01	.00	.39	.09
7	2.02	February 13, 1984	.02	153	0	40	0	.07	.04	5.0	1.3
		14	.03	726	573	289	249	39.26	23.73	2,850	814
		15	1.87	1,310	157	717	677	9.89	13.32	718	457
		16	.10	7,061	553	350	310	1.45	2.01	105	69

sediment may, therefore, be deposited near the head of the reservoir, thereby affecting a much smaller part of the reservoir. Storms of larger magnitude, however may resuspend this sediment and transport it farther into the main body of the reservoir or, if the reservoir is drawn down, this sediment may be exposed and become vulnerable to erosion.

Inputs of suspended constituents such as iron, aluminum, and phosphorus to the reservoir will generally be higher during wet years than dry years. For example, the combined suspended-sediment load to the reservoir from the mined site and the forested and agricultural site was 21,000 tons--5 percent of which was sorbed and particulate iron, aluminum, and manganese--during the 1983 water year when streamflow was near normal. In contrast, the combined suspended-sediment load to the reservoir from the two sites was 59 percent higher in 1984 and 24 percent lower in 1982 when streamflows at Swatara Creek at Harper Tavern were 50 percent above average and 15 percent below average, respectively.

Inputs of constituents that were transported primarily in the dissolved phase to the reservoir may be highest following periods when water infiltrating to the groundwater has had longer contact time with soluble constituents and is released as base flow with little dilution occurring. These constituents include sulfate, nitrate, and manganese.

Accidental Discharges and Land-Use Changes

Accidental discharges and land-use changes upstream from a reservoir may significantly alter the water quality in the planned Swatara State Park Reservoir because the reservoir is expected to have a low buffering capacity. Accidental discharges may reach the main body of the reservoir before being diluted inasmuch as the reservoir will be long, narrow and relatively shallow, and most of the inflow comes from an area extensively mined for anthracite.

Two accidental discharges of fuel from an automobile and truck plaza near Pine Grove just upstream from the head of the planned reservoir occurred during the week of February 8, 1984 (Harrisburg Patriot News, 1984). Both spills would have strongly affected the water quality of the planned reservoir. Water-supply intakes used by Dauphin Consolidated Water Supply Company downstream at Hummelstown (fig. 1) were shut down, and farmers were advised to keep livestock from Swatara Creek. The first spill was visible under the ice that covered nearly 50 percent of the stream channel at Inwood. Prior to dilution of the fuel by stormflow on February 8, 1984, many small fish were found dead along the stream bank at Inwood. The maximum dissolved-organic carbon concentration (4.9 mg/L) at Swatara Creek at Inwood for the 3-year study was measured during the peak streamflow of this storm. The second spill was reported to be larger than the first. Fuel concentrations in Swatara Creek near Hummelstown following the second spill were measured by the water company. Concentrations of dissolved-organic carbon were 0.17 mg/L several days after the spill. The effect of this type of spill may be confined to the reservoir after it is completed.

A common land-use practice in the study area is the placement of culm along streambanks. If this practice is continued, it probably will affect the reservoir. Berger Associates Inc. (1972) identified coal-mine-refuse piles as the second largest source of acidity in the basin. From 1948 through 1982, several large culm piles, totaling approximately 834,000 tons (Trovel, C.P., PaDER, Bureau of State Parks oral commun., 1985) have been placed near the planned reservoir, and it will require an estimated 3 years to remove these piles. The main pile, immediately east of Township Highway 390 (fig. 2) has about 529,000 tons of culm, borders the Swatara Creek near the head of the planned reservoir, and will become a peninsula in the reservoir upon its completion. Runoff and erosion from this pile are expected to contribute slugs of acid and metals. Results of a chemical analysis of a soil sample collected from washings at the base of the pile are given in table 12. The washings contain elevated concentrations of coal, aluminum, iron, copper, lead, mercury and selenium.

Estimating Inflow Water Quality from Duration Tables

Duration tables of mean daily streamflow and constituent discharges have been used by several investigators, (Johnson, 1970, Schornick and Fishel, 1980, and Fishel, 1984) to estimate the water quality of streams in various parts of the country. This method should be used with caution when (1) analyzing short periods of record, (2) major land-use changes have affected the hydrology of the study area, and (3) few precipitation events have a major effect during the study period. Because each of these factors has been shown to be important in estimating the water quality of the planned reservoir, duration tables were developed separately for both base flow and stormflow.

In order to estimate the water quality of inflow for the planned reservoir, the flow that represents the 50-percent flow-duration value, and the relation between streamflow and constituent discharge were used to estimate a base-flow concentration and load for the 50-percent flow-duration value. When this method is used for both inflow streams, a resultant base-flow concentration or load can be calculated for Swatara Creek at the location of the planned reservoir. A similar approach can be used to calculate a mean daily load as the average of the 5-percent increments of the duration tables using techniques described by Miller (1951). Instantaneous chemical-constituent discharges to the planned reservoir however, can not be determined by simply summing the discharges from any two different duration intervals for the two inflows. Table 18 (at back) can be used to estimate the frequency of occurrence of chemical constituent discharges to the reservoir and resultant concentrations if a common duration interval is assumed for the inflows. The table also lists the mean daily base-flow loads and annual base-flow loads.

Table 18. -- Durations of estimated mean daily base flow and stormflow, and constituent base-flow and stormflow discharges, for the mined site (Swatara Creek above Highway 895 - 01571919), and the forested and agricultural site (Lower Little Swatara Creek - 01572000), 1982-84 water years

[Streamflow, in cubic feet per second; constituent discharges, in tons per day]

Percentage of time equaled or exceeded	Streamflow				Acidity, as $CaCO_3$			Alkalinity, as $CaCO_3$
	Base flow		Stormflow		Base flow	Stormflow		Stormflow
	01571919	01572000	01571919	01572000	01571919	01571919	01572000	01571919
98.75	13	0.0	0	0.0	0.0000	0.0000	0.0000	0.0000
95.00	16	3.9	0	.0	.0000	.0000	.0000	.0000
90.00	22	5.4	0	.0	.0915	.0000	.0000	.0000
85.00	26	7.2	0	.0	.1843	.0000	.0000	.0000
80.00	29	8.0	0	.0	.2491	.0000	.0000	.0000
75.00	32	12.0	1	.1	.3106	.0000	.0000	.0000
70.00	36	15.0	2	.7	.3881	.0000	.0000	.0000
65.00	46	18.0	3	1.1	.5646	.0000	.0000	.0000
60.00	52	20.0	5	1.8	.6610	.0000	.0000	.0000
55.00	61	24.0	7	2.9	.7956	.0000	.0000	.0000
50.00	70	29.0	10	4.1	.9204	.0000	.0000	.0000
45.00	90	34.0	13	6.0	1.171	.0000	.0000	.0000
40.00	103	39.0	18	8.1	1.319	.0000	.0000	.0000
35.00	120	46.0	23	12.0	1.498	.0000	.0000	.0000
30.00	138	52.0	32	17.0	1.675	.1983	.0554	.2091
25.00	152	58.0	44	23.0	1.804	.5086	.1995	.4661
20.00	180	68.0	61	30.0	2.045	.9106	.3423	.7865
15.00	209	79.0	#87	44.0	2.275	1.470	.5787	1.215
10.00	252	97.0	126	74.0	2.589	2.228	.9675	1.771
5.00	306	115.0	225	137.0	2.945	3.910	1.554	2.936
1.25	475	174.0	808	410.0	3.890	11.38	3.063	7.530
Mean	109	41	53	28	1.17	--	--	--
Annual total	39,800	15,000	19,300	10,200	428	--	--	--

Table 18. -- Durations of estimated mean daily base flow and stormflow, and constituent base-flow and stormflow discharges, for the mined site (Swatara Creek above Highway 895 - 01571919), and the forested and agricultural site (Lower Little Swatara Creek - 01572000), 1982-84 water years--Continued

[Streamflow, in cubic feet per second; constituent discharges, in tons per day]

Percentage of time equaled or exceeded	Aluminum, dissolved				Aluminum, total recoverable		
	Base flow		Stormflow		Base flow		Stormflow
	01571919	01572000	01571919	01572000	01571919	01572000	01572000
98.75	0.0024	0.0000	0.0000	0.0000	0.0261	0.0000	0.0000
95.00	.0030	.0009	.0000	.0000	.0319	.0018	.0000
90.00	.0043	.0013	.0000	.0000	.0433	.0026	.0000
85.00	.0052	.0017	.0000	.0000	.0508	.0034	.0000
80.00	.0059	.0018	.0000	.0000	.0564	.0038	.0000
75.00	.0066	.0027	.0001	.0000	.0620	.0057	.0000
70.00	.0075	.0033	.0002	.0002	.0694	.0071	.0004
65.00	.0099	.0039	.0004	.0003	.0878	.0086	.0008
60.00	.0114	.0042	.0007	.0006	.0988	.0095	.0014
55.00	.0136	.0050	.0010	.0009	.1151	.0114	.0027
50.00	.0159	.0060	.0016	.0012	.1314	.0139	.0044
45.00	.0211	.0069	.0022	.0018	.1672	.0163	.0072
40.00	.0245	.0079	.0033	.0024	.1903	.0187	.0107
35.00	.0291	.0092	.0045	.0035	.2204	.0220	.0181
30.00	.0340	.0103	.0069	.0049	.2520	.0249	.0288
25.00	.0379	.0114	.0102	.0066	.2765	.0278	.0430
20.00	.0459	.0131	.0153	.0085	.3253	.0327	.0612
15.00	.0542	.0151	.0239	.0124	.3754	.0380	.1019
10.00	.0669	.0182	.0379	.0205	.4493	.0467	.2034
5.00	.0832	.0214	.0782	.0373	.5413	.0554	.4613
1.25	.1362	.0313	.3855	.1082	.8256	.0841	1.981
Mean	.027	.008	--	--	.199	.020	--
Annual total	9.86	2.92	--	--	72.6	7.3	--

Table 18. -- **Durations of estimated mean daily base flow and stormflow, and constituent base-flow and stormflow discharges, for the mined site (Swatara Creek above Highway 895 - 01571919), and the forested and agricultural site (Lower Little Swatara Creek - 01572000), 1982-84 water years--Continued**

[Streamflow, in cubic feet per second; constituent discharges, in tons per day]

Percentage of time equaled or exceeded	Calcium, dissolved			
	Base flow		Stormflow	
	01571919	01572000	01571919	01572000
98.75	0.8192	0.0000	0.0000	0.0000
95.00	.9524	.0523	.0000	.0000
90.00	1.200	.0713	.0000	.0000
85.00	1.355	.0938	.0000	.0000
80.00	1.466	.1036	.0000	.0000
75.00	1.575	.1524	.2040	.0016
70.00	1.715	.1884	.3140	.0101
65.00	2.049	.2241	.4041	.0155
60.00	2.240	.2478	.5552	.0248
55.00	2.515	.2947	.6845	.0390
50.00	2.779	.3528	.8545	.0542
45.00	3.335	.4104	1.006	.0778
40.00	3.678	.4676	1.232	.1036
35.00	4.109	.5471	1.434	.1505
30.00	4.548	.6147	1.762	.2096
25.00	4.878	.6820	2.148	.2794
20.00	5.515	.7934	2.631	.3598
15.00	6.146	.9150	3.282	.5180
10.00	7.040	1.112	4.132	.8494
5.00	8.105	1.308	5.926	1.526
1.25	11.15	1.939	13.12	4.330
Mean	3.56	.480	--	--
Annual total	1,300	175	--	--

Table 18. -- Durations of estimated mean daily base flow and stormflow, and constituent base-flow and stormflow discharges, for the mined site (Swatara Creek above Highway 895 - 01571919), and the forested and agricultural site (Lower Little Swatara Creek - 01572000), 1982-84 water years--Continued

[Streamflow, in cubic feet per second; constituent discharges, in tons per day]

Percentage of time equaled or exceeded	Carbon, organic dissolved				Carbon, organic total		
	Base flow		Stormflow		Base flow	Stormflow	
	01571919	01572000	01571919	01572000	01572000	01571919	01572000
98.75	0.1273	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
95.00	.1465	.0192	.0000	.0000	.0197	.0000	.0000
90.00	.1818	.0271	.0000	.0000	.0277	.0000	.0000
85.00	.2035	.0366	.0000	.0000	.0373	.0000	.0000
80.00	.2191	.0409	.0000	.0000	.0416	.0000	.0000
75.00	.2342	.0625	.0126	.0003	.0633	.0367	.0005
70.00	.2536	.0790	.0236	.0030	.0798	.0643	.0042
65.00	.2994	.0956	.0341	.0050	.0964	.0893	.0069
60.00	.3252	.1067	.0542	.0087	.1076	.1351	.0119
55.00	.3623	.1292	.0736	.0150	.1300	.1774	.0201
50.00	.3977	.1575	.1016	.0223	.1581	.2369	.0294
45.00	.4714	.1861	.1290	.0345	.1865	.2930	.0446
40.00	.5164	.2149	.1732	.0486	.2150	.3813	.0621
35.00	.5726	.2554	.2164	.0763	.2552	.4651	.0956
30.00	.6294	.2905	.2920	.1136	.2898	.6078	.1402
25.00	.6719	.3257	.3897	.1605	.3246	.7866	.1955
20.00	.7533	.3848	.5242	.2175	.3828	1.025	.2618
15.00	.8334	.4502	.7233	.3371	.4472	1.366	.3988
10.00	.9458	.5583	1.012	.6111	.5533	1.845	.7061
5.00	1.079	.6673	1.713	1.236	.6602	2.951	1.390
1.25	1.452	1.030	5.462	4.332	1.014	8.312	4.635
Mean	.494	.230	--	--	.242	--	--
Annual total	180	84	--	--	88	--	--

Table 18. -- Durations of estimated mean daily base flow and stormflow, and constituent base-flow and stormflow discharges, for the mined site (Swatara Creek above Highway 895 - 01571919), and the forested and agricultural site (Lower Little Swatara Creek - 01572000), 1982-84 water years--Continued

[Streamflow, in cubic feet per second; constituent discharges, in tons per day]

Percentage of time equaled or exceeded	Chemical oxygen demand			Chloride, dissolved			
	Base flow		Stormflow	Base flow		Stormflow	
	01571919	01572000	01572000	01571919	01572000	01571919	01572000
98.75	0.6959	0.0000	0.0000	0.3722	0.0000	0.0000	0.00000
95.00	.8356	.1316	.0000	.4402	.0644	.0000	.00000
90.00	1.106	.1868	.0000	.5694	.0875	.0000	.00000
85.00	1.282	.2544	.0000	.6518	.1146	.0000	.00000
80.00	1.411	.2849	.0000	.7120	.1265	.0000	.00000
75.00	1.539	.4404	.0017	.7709	.1851	.0169	.00206
70.00	1.708	.5598	.0168	.8480	.2283	.0347	.01294
65.00	2.119	.6809	.0286	1.034	.2709	.0530	.0198
60.00	2.361	.7625	.0514	1.142	.2991	.0903	.0316
55.00	2.718	.9276	.0904	1.299	.3549	.1282	.0495
50.00	3.068	1.137	.1363	1.452	.4240	.1860	.0686
45.00	3.829	1.349	.2141	1.779	.4923	.2444	.0983
40.00	4.312	1.563	.3057	1.984	.5600	.3432	.1305
35.00	4.934	1.866	.4872	2.244	.6539	.4431	.1891
30.00	5.580	2.129	.7364	2.513	.7337	.6251	.2627
25.00	6.077	2.394	1.054	2.717	.8129	.8712	.3495
20.00	7.053	2.840	1.444	3.115	.9439	1.225	.4491
15.00	8.045	3.337	2.275	3.515	1.087	1.773	.6446
10.00	9.488	4.160	4.214	4.089	1.318	2.609	1.053
5.00	11.26	4.995	8.749	4.784	1.546	4.774	1.883
1.25	16.59	7.794	32.10	6.827	2.281	18.10	5.298
Mean	4.37	1.69	--	1.96	.572	--	--
Annual total	1,590	619	--	715	209	--	--

Table 18. -- Durations of estimated mean daily base flow and stormflow, and constituent base-flow and stormflow discharges, for the mined site (Swatara Creek above Highway 895 - 01571919), and the forested and agricultural site (Lower Little Swatara Creek - 01572000), 1982-84 water years--Continued

[Streamflow, in cubic feet per second; constituent discharges, in tons per day]

Percentage of time equaled or exceeded	Chromium, total recoverable		Copper, total recoverable	
	Stormflow		Stormflow	
	01571919	01572000	01571919	01572000
98.75	0.0000	0.0000	0.0000	0.0000
95.00	.0000	.0000	.0000	.0000
90.00	.0000	.0000	.0000	.0000
85.00	.0000	.0000	.0000	.0000
80.00	.0000	.0000	.0000	.0000
75.00	.0000	.0000	.0000	.0000
70.00	.0000	.0000	.0001	.0000
65.00	.0000	.0000	.0001	.0000
60.00	.0001	.0000	.0002	.0001
55.00	.0001	.0001	.0003	.0001
50.00	.0002	.0001	.0005	.0002
45.00	.0003	.0001	.0007	.0003
40.00	.0005	.0002	.0010	.0004
35.00	.0007	.0004	.0014	.0006
30.00	.0010	.0005	.0020	.0009
25.00	.0016	.0008	.0029	.0013
20.00	.0024	.0011	.0042	.0018
15.00	.0038	.0019	.0064	.0027
10.00	.0062	.0037	.0098	.0049
5.00	.0131	.0081	.0191	.0098
1.25	.0686	.0335	.0840	.0336

Table 18. -- Durations of estimated mean daily base flow and stormflow, and constituent base-flow and stormflow discharges, for the mined site (Swatara Creek above Highway 895 - 01571919), and the forested and agricultural site (Lower Little Swatara Creek - 01572000), 1982-84 water years--Continued

[Streamflow, in cubic feet per second; constituent discharges, in tons per day]

Percentage of time equaled or exceeded	Iron, dissolved			Iron, total recoverable				Lead, total recoverable	
	Base flow		Stormflow	Base flow		Stormflow		Stormflow	
	01571919	01572000	01572000	01571919	01572000	01571919	01572000	01571919	01572000
98.75	0.0037	0.0000	0.0000	0.0235	0.0000	0.0000	0.0000	0.0000	0.0000
95.00	.0052	.0010	.0000	.0306	.0017	.0000	.0000	.0000	.0000
90.00	.0088	.0014	.0000	.0459	.0024	.0000	.0000	.0000	.0000
85.00	.0116	.0018	.0000	.0568	.0034	.0000	.0000	.0000	.0000
80.00	.0140	.0020	.0000	.0653	.0038	.0000	.0000	.0000	.0000
75.00	.0165	.0028	.0000	.0740	.0062	.0008	.0000	.0000	.0000
70.00	.0200	.0035	.0000	.0860	.0080	.0021	.0004	.0000	.0000
65.00	.0301	.0041	.0000	.1176	.0099	.0039	.0007	.0000	.0000
60.00	.0370	.0045	.0000	.1374	.0112	.0084	.0014	.0000	.0000
55.00	.0482	.0053	.0001	.1684	.0139	.0139	.0027	.0001	.0000
50.00	.0606	.0063	.0001	.2007	.0173	.0236	.0044	.0001	.0000
45.00	.0921	.0073	.0001	.2765	.0209	.0349	.0074	.0002	.0001
40.00	.1153	.0082	.0001	.3284	.0245	.0566	.0113	.0003	.0001
35.00	.1487	.0095	.0002	.3989	.0297	.0815	.0195	.0004	.0002
30.00	.1877	.0106	.0002	.4767	.0343	.1333	.0317	.0006	.0003
25.00	.2204	.0117	.0003	.5392	.0390	.2141	.0482	.0010	.0004
20.00	.2921	.0136	.0004	.6688	.0470	.3483	.0698	.0016	.0006
15.00	.3746	.0155	.0005	.8091	.0560	.5909	.1188	.0026	.0010
10.00	.5115	.0187	.0007	1.027	.0712	1.026	.2446	.0045	.0019
5.00	.7067	.0218	.0012	1.315	.0869	2.432	.5755	.0104	.0044
1.25	1.470	.0316	.0015	2.303	.1410	16.321	2.640	.0666	.0191
Mean	.182	.008	--	.399	.279	--	--	--	--
Annual total	66.4	2.92	--	146	102	--	--	--	--

Table 18. -- Durations of estimated mean daily base flow and stormflow, and constituent base-flow and stormflow discharges, for the mined site (Swatara Creek above Highway 895 - 01571919), and the forested and agricultural site (Lower Little Swatara Creek - 01572000), 1982-84 water years--Continued

[Streamflow, in cubic feet per second; constituent discharges, in tons per day]

Percentage of time equalled or exceeded	Magnesium, dissolved				Manganese, dissolved			
	Base flow		Stormflow		Base flow		Stormflow	
	01571919	01572000	01571919	01572000	01571919	01572000	01571919	01572000
98.75	0.5832	0.0000	0.0000	0.0000	0.0566	0.0000	0.0000	0.0000
95.00	.6799	.0259	.0000	.0000	.0656	.0002	.0000	.0000
90.00	.8603	.0355	.0000	.0000	.0822	.0003	.0000	.0000
85.00	.9733	.0468	.0000	.0000	.0925	.0004	.0000	.0000
80.00	1.055	.0518	.0000	.0000	.0999	.0005	.0000	.0000
75.00	1.135	.0765	.1019	.0007	.1071	.0007	.0081	.0000
70.00	1.238	.0948	.1618	.0045	.1165	.0009	.0131	.0000
65.00	1.484	.1130	.2120	.0069	.1385	.0011	.0175	.0001
60.00	1.625	.1251	.2981	.0112	.1511	.0012	.0250	.0001
55.00	1.828	.1491	.3731	.0179	.1692	.0015	.0316	.0002
50.00	2.024	.1789	.4733	.0250	.1865	.0018	.0406	.0003
45.00	2.437	.2085	.5638	.0363	.2229	.0021	.0488	.0005
40.00	2.692	.2380	.7004	.0487	.2452	.0024	.0612	.0007
35.00	3.014	.2789	.8248	.0715	.2733	.0029	.0727	.0011
30.00	3.342	.3139	1.028	.1004	.3017	.0033	.0916	.0016
25.00	3.589	.3487	1.271	.1349	.3231	.0037	.1145	.0022
20.00	4.067	.4064	1.581	.1749	.3642	.0044	.1440	.0030
15.00	4.541	.4695	2.003	.2542	.4049	.0051	.1846	.0045
10.00	5.215	.5721	2.565	.4222	.4622	.0063	.2393	.0081
5.00	6.019	.6740	3.776	.7703	.5304	.0075	.3593	.0161
1.25	8.331	1.004	8.858	2.246	.7242	.0115	.8797	.0549
Mean	2.61	.245	--	--	.236	.003	--	--
Annual total	953	89.4	--	--	86.1	1.10	--	--

Table 18. — Durations of estimated mean daily base flow and stormflow, and constituent base-flow and stormflow discharges, for the mined site (Swatara Creek above Highway 895 - 01571919), and the forested and agricultural site (Lower Little Swatara Creek - 01572000), 1982-84 water years--Continued

[Streamflow, in cubic feet per second; constituent discharges, in tons per day]

Percentage of time equaled o: exceeded	Manganese, total				Ammonia, dissolved as N		Ammonia, total as N	
	Base flow		Stormflow		Base flow	Stormflow	Base flow	Stormflow
	01571919	01572000	01571919	01572000	01572000	01572000	0172000	01572000
98.75	0.0593	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
95.00	.0689	.0003	.0000	.0000	.0002	.0000	.0002	.0000
90.00	.0867	.0004	.0000	.0000	.0004	.0000	.0003	.0000
85.00	.0978	.0006	.0000	.0000	.0005	.0000	.0005	.0000
80.00	.1058	.0007	.0000	.0000	.0006	.0000	.0006	.0000
75.00	.1136	.0011	.0056	.0000	.0009	.0000	.0010	.0000
70.00	.1237	.0014	.0098	.0001	.0012	.0001	.0013	.0002
65.00	.1476	.0017	.0136	.0001	.0015	.0002	.0016	.0003
60.00	.1612	.0019	.0206	.0002	.0016	.0003	.0019	.0004
55.00	.1809	.0024	.0271	.0004	.0020	.0005	.0023	.0007
50.00	.1998	.0030	.0363	.0006	.0025	.0008	.0030	.0010
45.00	.2395	.0035	.0449	.0009	.0030	.0012	.0037	.0015
40.00	.2640	.0041	.0586	.0013	.0036	.0016	.0044	.0020
35.00	.2947	.0050	.0715	.0021	.0043	.0024	.0054	.0030
30.00	.3260	.0057	.0936	.0032	.0050	.0035	.0064	.0043
25.00	.3495	.0065	.1212	.0046	.0057	.0048	.0073	.0059
20.00	.3948	.0078	.1582	.0064	.0068	.0063	.0090	.0077
15.00	.4398	.0092	.2113	.0101	.0081	.0095	.0109	.0115
10.00	.5033	.0117	.2857	.0190	.0103	.0164	.0142	.0197
5.00	.5790	.0141	.4581	.0402	.0125	.0312	.0176	.0371
1.25	.7951	.0226	1.298	.1523	.0202	.0988	.0300	.1152
Mean	.253	.005	--	--	.004	--	.005	--
Annual total	93.1	1.83	--	--	1.46	--	1.83	--

Table 18. -- Durations of estimated mean daily base flow and stormflow, and constituent base-flow and stormflow discharges, for the mined site (Swatara Creek above Highway 895 - 01571919), and the forested and agricultural site (Lower Little Swatara Creek - 01572000), 1982-84 water years--Continued

[Streamflow, in cubic feet per second; constituent discharges, in tons per day]

Percentage of time equaled or exceeded	Ammonia + organic nitrogen, dissolved as N				Ammonia + organic nitrogen, total as N		
	Base flow		Stormflow		Base flow		Stormflow
	01571919	01572000	01571919	01572000	01571919	01572000	01572000
98.75	0.0337	0.0000	0.0000	0.0000	0.0511	0.0000	0.0000
95.00	.0401	.0054	.0000	.0000	.0596	.0050	.0000
90.00	.0522	.0074	.0000	.0000	.0752	.0071	.0000
85.00	.0599	.0098	.0000	.0000	.0850	.0096	.0000
80.00	.0656	.0108	.0000	.0000	.0921	.0107	.0000
75.00	.0712	.0159	.0043	.0005	.0990	.0164	.0003
70.00	.0785	.0197	.0078	.0025	.1079	.0208	.0021
65.00	.0962	.0234	.0110	.0037	.1292	.0252	.0032
60.00	.1065	.0259	.0170	.0057	.1414	.0281	.0051
55.00	.1215	.0308	.0227	.0086	.1589	.0341	.0080
50.00	.1362	.0369	.0308	.0117	.1758	.0415	.0111
45.00	.1678	.0429	.0386	.0163	.2114	.0491	.0159
40.00	.1876	.0489	.0510	.0211	.2334	.0567	.0212
35.00	.2130	.0572	.0629	.0297	.2610	.0675	.0308
30.00	.2391	.0643	.0835	.0403	.2892	.0767	.0429
25.00	.2591	.0714	.1097	.0524	.3104	.0861	.0572
20.00	.2981	.0830	.1450	.0661	.3514	.1017	.0736
15.00	.3374	.0958	.1965	.0923	.3921	.1191	.1059
10.00	.3940	.1165	.2698	.1452	.4498	.1477	.1735
5.00	.4628	.1370	.4432	.2484	.5186	.1767	.3115
1.25	.6663	.2033	1.324	.6458	.7160	.2730	.8829
Mean	.187	.050	--	--	.226	.061	--
Annual total	68.31	18.2	--	--	82.5	22.3	--

Table 18. — Durations of estimated mean daily base flow and stormflow, and constituent base-flow and stormflow discharges, for the mined site (Swatara Creek above Highway 895 - 01571919), and the forested and agricultural site (Lower Little Swatara Creek - 01572000), 1982-84 water years--Continued

[Streamflow, in cubic feet per second; constituent discharges, in tons per day]

Percentage of time equaled or exceeded	Nitrate, dissolved as N				Organic nitrogen, dissolved as N	Organic nitrogen, total as N	
	Base flow		Stormflow		Base flow	Base flow	Stormflow
	01571919	01572000	01571919	01572000	01572000	01572000	01572000
98.75	0.0132	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
95.00	.0174	.0059	.0000	.0000	.0041	.0049	.0000
90.00	.0265	.0093	.0000	.0000	.0057	.0068	.0000
85.00	.0330	.0140	.0000	.0000	.0076	.0091	.0000
80.00	.0382	.0162	.0000	.0000	.0085	.0101	.0000
75.00	.0435	.0287	.0006	.0001	.0128	.0152	.0005
70.00	.0508	.0393	.0013	.0010	.0161	.0191	.0027
65.00	.0703	.0508	.0022	.0016	.0193	.0230	.0040
60.00	.0826	.0590	.0041	.0030	.0215	.0256	.0061
55.00	.1020	.0763	.0062	.0052	.0260	.0308	.0093
50.00	.1224	.0996	.0096	.0080	.0315	.0373	.0125
45.00	.1706	.1247	.0133	.0126	.0370	.0439	.0175
40.00	.2039	.1514	.0198	.0180	.0425	.0504	.0227
35.00	.2496	.1910	.0268	.0289	.0503	.0597	.0320
30.00	.3002	.2271	.0401	.0438	.0570	.0676	.0434
25.00	.3411	.2650	.0593	.0630	.0638	.0755	.0565
20.00	.4265	.3317	.0885	.0867	.0750	.0887	.0712
15.00	.5196	.4098	.1369	.1373	.0874	.1033	.0995
10.00	.6654	.5476	.2157	.2563	.1077	.1273	.1567
5.00	.8602	.6962	.4394	.5370	.1281	.1513	.2684
1.25	1.5382	1.249	2.110	2.002	.1954	.2303	.6992
Mean	.255	.198	--	--	.045	.053	--
Annual total	93.1	72.3	--	--	16.4	19.4	--

Table 18. — Durations of estimated mean daily base flow and stormflow, and constituent base-flow and stormflow discharges, for the mined site (Swatara Creek above Highway 895 - 01571919), and the forested and agricultural site (Lower Little Swatara Creek - 01572000), 1982-84 water years--Continued

[Streamflow, in cubic feet per second; constituent discharges, in tons per day]

Percentage of time equaled or exceeded	Nitrogen, total as N				Phosphorus, dissolved as P			
	Base flow		Stormflow		Base flow		Stormflow	
	01571919	01572000	01571919	01572000	01571919	01572000	01571919	01572000
98.75	0.0700	0.0000	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000
95.00	.0846	.0122	.0000	.0000	.0008	.0003	.0000	.0000
90.00	.1130	.0182	.0000	.0000	.0011	.0004	.0000	.0000
85.00	.1316	.0260	.0000	.0000	.0013	.0005	.0000	.0000
80.00	.1453	.0297	.0000	.0000	.0014	.0005	.0000	.0000
75.00	.1589	.0492	.0068	.0005	.0015	.0008	.0000	.0000
70.00	.1769	.0649	.0133	.0039	.0017	.0009	.0001	.0000
65.00	.2211	.0814	.0198	.0062	.0021	.0011	.0001	.0000
60.00	.2472	.0928	.0325	.0104	.0024	.0012	.0002	.0001
55.00	.2858	.1164	.0451	.0171	.0028	.0014	.0003	.0001
50.00	.3239	.1472	.0638	.0246	.0032	.0017	.0004	.0002
45.00	.4071	.1794	.0824	.0366	.0040	.0019	.0006	.0003
40.00	.4602	.2128	.1131	.0501	.0046	.0022	.0008	.0004
35.00	.5288	.2613	.1435	.0755	.0053	.0025	.0011	.0007
30.00	.6005	.3043	.1980	.1086	.0061	.0028	.0015	.0011
25.00	.6557	.3486	.2699	.1490	.0066	.0031	.0021	.0015
20.00	.7647	.4248	.3710	.1966	.0078	.0036	.0030	.0021
15.00	.8760	.5118	.5241	.2934	.0090	.0041	.0044	.0034
10.00	1.039	.6606	.7516	.5051	.0107	.0050	.0065	.0062
5.00	1.239	.8163	1.322	.9613	.0128	.0058	.0119	.0130
1.25	1.848	1.366	4.588	3.022	.0195	.0084	.0459	.0481
Mean	.471	.252	--	--	.005	.002	--	--
Annual total	172	92.0	--	--	1.83	.73	--	--

Table 18. -- **Durations of estimated mean daily base flow and stormflow, and constituent base-flow and stormflow discharges, for the mined site (Swatara Creek above Highway 895 - 01571919), and the forested and agricultural site (Lower Little Swatara Creek - 01572000), 1982-84 water years--Continued**

[Streamflow, in cubic feet per second; constituent discharges, in tons per day]

Percentage of time equaled or exceeded	Phosphorus, total as P		Potassium, dissolved			
	Base flow	Stormflow	Base flow		Stormflow	
	01572000	01572000	01571919	01572000	01571919	01572000
98.75	0.0000	0.0000	0.0701	0.0000	0.0000	0.0000
95.00	.0004	.0000	.0811	.0141	.0000	.0000
90.00	.0006	.0000	.1015	.0186	.0000	.0000
85.00	.0007	.0000	.1142	.0237	.0000	.0000
80.00	.0008	.0000	.1233	.0259	.0000	.0000
75.00	.0012	.0000	.1321	.0365	.0045	.0003
70.00	.0015	.0000	.1435	.0441	.0088	.0021
65.00	.0017	.0001	.1706	.0514	.0129	.0033
60.00	.0019	.0001	.1859	.0562	.0211	.0056
55.00	.0023	.0003	.2080	.0656	.0291	.0092
50.00	.0027	.0004	.2292	.0770	.0410	.0132
45.00	.0031	.0007	.2735	.0880	.0527	.0197
40.00	.0035	.0010	.3008	.0988	.0720	.0270
35.00	.0041	.0016	.3349	.1136	.0910	.0407
30.00	.0046	.0025	.3695	.1260	.1249	.0586
25.00	.0051	.0037	.3955	.1382	.1695	.0804
20.00	.0059	.0053	.4455	.1581	.2318	.1062
15.00	.0067	.0086	.4949	.1794	.3257	.1586
10.00	.0081	.0169	.5645	.2134	.4645	.2732
5.00	.0095	.0372	.6471	.2464	.8096	.5206
1.25	.0139	.1527	.8818	.3496	2.756	1.640
Mean	.004	--	.290	.098	--	--
Annual total	1.46	--	106	35.8	--	--

Table 18. — Durations of estimated mean daily base flow and stormflow, and constituent base-flow and stormflow discharges, for the mined site (Swatara Creek above Highway 895 - 01571919), and the forested and agricultural site (Lower Little Swatara Creek - 01572000), 1982-84 water years—Continued

[Streamflow, in cubic feet per second; constituent discharges, in tons per day]

Percentage of time equaled or exceeded	Sediment, suspended				Silica, dissolved			
	Base flow		Stormflow		Base flow		Stormflow	
	01571919	01572000	01571919	01572000	01571919	01572000	01571919	01572000
98.75	0.1018	0.0000	0.0000	0.0000	0.2105	0.0000	0.0000	0.0000
95.00	.1467	.0124	.0000	.0000	.2595	.0412	.0000	.0000
90.00	.2571	.0220	.0000	.0000	.3578	.0585	.0000	.0000
85.00	.3450	.0366	.0000	.0000	.4235	.0796	.0000	.0000
80.00	.4181	.0440	.0000	.0000	.4728	.0892	.0000	.0000
75.00	.4972	.0897	.0040	.0000	.5222	.1379	.0394	.0007
70.00	.6117	.1328	.0140	.0030	.5881	.1753	.0684	.0053
65.00	.9419	.1830	.0290	.0060	.7530	.2132	.0946	.0085
60.00	1.169	.2202	.0700	.0150	.8522	.2388	.1421	.0143
55.00	1.548	.3035	.1270	.0330	1.001	.2905	.1859	.0237
50.00	1.972	.4232	.2380	.0610	1.150	.3561	.2471	.0341
45.00	3.070	.5597	.3770	.1160	1.482	.4225	.3047	.0510
40.00	3.893	.7124	.6690	.1950	1.698	.4896	.3950	.0700
35.00	5.094	.9522	1.030	.3830	1.981	.5846	.4803	.1059
30.00	6.516	1.181	1.842	.6970	2.281	.6670	.6251	.1529
25.00	7.724	1.431	3.228	1.173	2.514	.7501	.8060	.2104
20.00	10.40	1.893	5.738	1.852	2.982	.8900	1.046	.2784
15.00	13.53	2.464	10.72	3.577	3.467	1.046	1.388	.4170
10.00	18.81	3.534	20.59	8.742	4.187	1.304	1.866	.7217
5.00	26.47	4.766	57.15	25.20	5.092	1.565	2.964	1.382
1.25	57.41	9.870	543.1	165.9	7.936	2.443	8.219	4.393
Mean	7.66	1.37	--	--	1.91	.564	--	--
Annual total	2,800	501	--	--	699	206	--	--

Table 18. — Durations of estimated mean daily base flow and stormflow, and constituent base-flow and stormflow discharges, for the mined site (Swatara Creek above Highway 895 - 01571919), and the forested and agricultural site (Lower Little Swatara Creek - 01572000), 1982-84 water years--Continued

[Streamflow, in cubic feet per second; constituent discharges, in tons per day]

		Sodium, dissolved			
		Base flow		Stormflow	
	Percentage of time equaled or exceeded	01571919	01572000	01571919	01572000
	98.75	0.5176	0.0000	0.0000	0.0000
	95.00	.5814	.0357	.0000	.0000
	90.00	.6948	.0480	.0000	.0000
	85.00	.7629	.0625	.0000	.0000
	80.00	.8110	.0688	.0000	.0000
	75.00	.8569	.0995	.0949	.0006
	70.00	.9153	.1220	.1490	.0044
	65.00	1.050	.1440	.1941	.0071
	60.00	1.124	.1586	.2708	.0117
	55.00	1.230	.1872	.3372	.0191
	50.00	1.328	.2225	.4254	.0273
	45.00	1.529	.2572	.5047	.0403
	40.00	1.648	.2915	.6240	.0549
	35.00	1.796	.3389	.7320	.0822
	30.00	1.942	.3790	.9078	.1176
	25.00	2.050	.4187	1.117	.1604
	20.00	2.253	.4840	1.382	.2106
	15.00	2.450	.5549	1.742	.3122
	10.00	2.720	.6692	2.218	.5324
	5.00	3.032	.7815	3.236	1.002
	1.25	3.878	1.140	7.445	3.089
Mean	1.55	.295	—	—	—
Annual total	566	108	—	—	—

Table 18. — **Durations of estimated mean daily base flow and stormflow, and constituent base-flow and stormflow discharges, for the mined site (Swatara Creek above Highway 895 - 01571919), and the forested and agricultural site (Lower Little Swatara Creek - 01572000), 1982-84 water years**—Continued

[Streamflow, in cubic feet per second; constituent discharges, in tons per day]

Percentage of time equaled or exceeded	Sulfate, dissolved: Base flow 01572000	Sulfate, dissolved: Stormflow 01571919	Sulfate, dissolved: Stormflow 01572000	Zinc, total recoverable: Stormflow 01571919	Zinc, total recoverable: Stormflow 01572000
98.75	0.0000	0.0000	0.0000	0.0000	0.0000
95.00	.1244	.0000	.0000	.0000	.0000
90.00	.1705	.0000	.0000	.0000	.0000
85.00	.2253	.0000	.0000	.0000	.0000
80.00	.2494	.0000	.0000	.0000	.0000
75.00	.3694	.6510	.0035	.0005	.0000
70.00	.4584	1.044	.0221	.0009	.0001
65.00	.5469	1.377	.0339	.0013	.0001
60.00	.6057	1.951	.0540	.0020	.0001
55.00	.7226	2.454	.0849	.0027	.0002
50.00	.8679	3.130	.1179	.0037	.0003
45.00	1.012	3.744	.1692	.0047	.0004
40.00	1.156	4.674	.2250	.0063	.0006
35.00	1.356	5.525	.3266	.0079	.0009
30.00	1.527	6.920	.4544	.0106	.0013
25.00	1.698	8.599	.6053	.0141	.0017
20.00	1.980	10.74	.7788	.0189	.0023
15.00	2.290	13.69	1.120	.0261	.0034
10.00	2.793	17.62	1.833	.0364	.0057
5.00	3.294	26.17	3.288	.0613	.0106
1.25	4.918	62.58	9.300	.1941	.0323
Mean	1.20	--	--	--	--
Annual total	436	--	--	--	--

Equations 5 and 6 below can be used to determine corresponding constituent concentrations for streamflows and chemical constituent discharges at selected duration intervals, and to compute concentrations in the resultant inflow to the planned reservoir, respectively.

$$C = \frac{D}{Q \times 0.0027} \quad , \qquad (5)$$

where C = the concentration of the inflow, in milligrams per liter;

D = the chemical constituent discharge of the inflow, in tons per day; and

Q = the quantity of the inflow, in cubic feet per second.

$$C_r = \frac{D_1 + D_2}{(Q_1 + Q_2) \times 0.0027} \quad , \qquad (6)$$

where C_r = the resultant concentration, in milligrams per liter;

D_1 = the chemical constituent discharge for the mined site, in tons per day;

D_2 = the chemical constituent discharge for the forested and agricultural site, in tons per day;

Q_1 = the quantity of the inflow from the mined site, in cubic feet per second; and

Q_2 = the quantity of the inflow from the forested and agricultural site, in cubic feet per second.

For example, assuming median streamflows (a duration percentage of 50 in table 18), the corresponding constituent concentrations for total-recoverable aluminum at the mined site, the forested and agricultural site, and the resultant concentration of the inflow to the planned reservoir would be calculated as follows:

$$C_1 = \frac{D_1}{Q_1 \times 0.0027} \quad \text{and} \quad C_2 = \frac{D_2}{Q_2 \times 0.0027}$$

therefore $$C_1 = \frac{0.131}{70 \times 0.0027} \quad \text{and} \quad C_2 = \frac{0.014}{29 \times 0.0027}$$

and $C_1 = 0.69$ milligrams per liter and $C_2 = 0.18$ milligrams per liter.

Thus $$C_r = \frac{D_1 + D_2}{(Q_1 + Q_2) \times 0.0027}$$

therefore $$C_r = \frac{0.131 + 0.014}{(70 + 29) \times 0.0027}$$

and $C_r = 0.54$ milligrams per liter or

540 micrograms per liter.

The assumption of median streamflows occurring at the same time at both stations is based on the close proximity of the stations and the good correlation between instantaneous streamflows at the sites.

This information, along with the value of 500 μg/L for total aluminum generally considered to be the maximum level for freshwater organisms in most Pennsylvania streams, points out that 50 percent of the time the total-recoverable aluminum concentration in the base flow entering the planned reservoir will equal or exceed the safe value for the cold-water fishery classification given to Swatara Creek.

ESTIMATED WATER QUALITY DOWNSTREAM FROM THE PLANNED RESERVOIR

As suggested during the preceeding discussion, the water quality of Swatara Creek in and downstream from the reservoir will need to be monitored closely. Because the reservoir will stratify thermally and chemically in the summer and autumn, releases during this part of the year will have the greatest impact on downstream water quality. Conservation releases need to be carefully controlled from the release gates, so that water from the hypolimnion with decreased dissolved-oxygen levels and elevated dissolved-metal concentrations will not degrade the downstream water-quality and be detrimental to the aquatic community.

The reservoir will act as a sediment trap and, therefore, reduce the concentrations of total phosphorus, iron, aluminum, lead, copper, and zinc discharged immediately downstream from the reservoir. During high flows resuspension and release of the sediment may cause elevated phosphorus and metal concentrations downstream from the reservoir. Because peak flows at Harper Tavern and other points downstream from Inwood probably will be reduced by the reservoir, the frequency of large discharges of nutrients and metals, such as those currently being measured at Inwood, also will be reduced.

When storm discharges are large or when the winter-pool level is to be maintained by releasing water from the hypolimnion, rapid flushing of elevated concentrations of dissolved iron, aluminum, lead, copper, and zinc that may occur could have an adverse effect on the downstream aquatic community.

Acidic conditions similar to those reported by the Pennsylvania Fish Commission for Tioga-Hammond Lakes (Baltimore Corps of Engineers, oral commun., 1984) may also occur in the planned Swatara State Park Reservoir. Mixing in the reservoir may be reduced during winters when severe ice buildup develops and the inflow channel becomes constricted. If during these periods, acidic storm discharges from the mined site are not diluted before they enter the reservoir, the acidic discharges may be trapped in pockets or accumulate near the release structure without mixing with the main body of water in the reservoir. These pockets or accumulations of acid, like those observed at the Tioga-Hammond Lakes, may be detrimental to fish in the reservoir and release of this water may kill fish downstream.

Studies by the U.S. Army Corps of Engineers (1976, 1978, 1980, and 1982) of other Pennsylvania, Maryland, and West Virginia reservoirs with different morphometric characteristics but similar mine-drainage inflows support the results of this study. Figure 20 shows the locations and table 19 lists outflow characteristics of selected reservoirs and their effects on downstream water quality. Water-quality characteristics of Swatara Creek at Inwood were included to show current downstream conditions prior to reservoir construction.

The planned Swatara State Park Reservoir is expected to have morphological and chemical characteristics similar to Crooked Creek Lake. Therefore, water quality downstream from the Swatara State Park Reservoir is expected to be similar to that observed downstream from Crooked Creek Lake, which also receives acid mine drainage. Reports of acidity in the Crooked Creek Lake (U.S. Army Corps of Engineers, 1980, p. 6) stated that it was "so severe that it caused bleaching and rotting effect on the fabric of bathers and water skier's swimming suits."

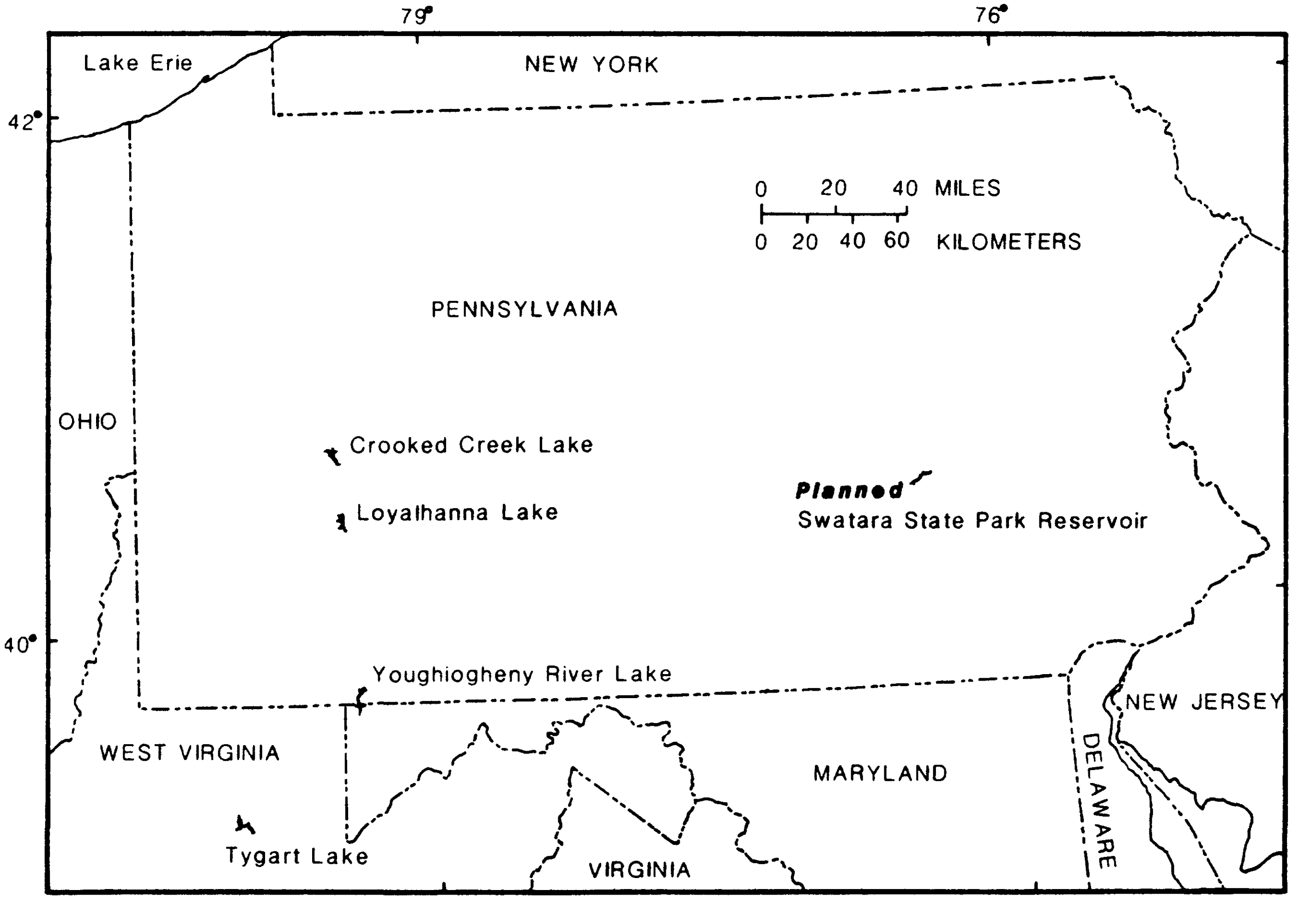

Figure 20.--Locations of seclected reservoirs with mine-drainage inflows similar to the *planned* Swatara State Park Reservoir.

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Data collected downstream from the Crooked Creek Lake may not be representative of typical conditions, inasmuch as excessive precipitation flushed the lake approximately 12 times in 5 months. At the planned Swatara State Park Reservoir, the average flushing rate of about 15.3 times in 12 months is expected to cause greater thermal and chemical stratification than that observed in Crooked Creek Lake. Streamflows during the chemical sampling of the inflows and outflows to the Crooked Creek Lake and other reservoirs were not reported, so an assessment of the conditions expected in the Swatara State Park Reservoir can be made only qualitatively.

The depths of the Tygart Lake and Youghiogheny River Lake provide benefits that will not be present at the planned reservoir. Bottom withdrawals from the hypolimnion of these larger lakes prevent buildup of poorly oxygenated water having elevated dissolved-metals concentrations. These lakes also have the capacity to dilute inflow storm concentrations and greater buffering capacities that can decrease extremes in pH. Unlike inflow to these deeper lakes, inflow to the planned Swatara State Park Reservoir may flow through the entire lake to the outflow structure with little mixing occurring in the density currents, and then be discharged directly downstream.

Alkalinity in the planned Swatara State Park Reservoir will be important in stabilizing the water quality in and downstream from the reservoir. Each of the reservoirs in table 18 has higher buffering capacities than Swatara Creek. Acidic discharges entering the planned Swatara State Park Reservoir may not be diluted as much as they are in the other reservoirs. If dilution of acidity does not occur, and reducing conditions exist in the hypoliminion, then acidic discharges with metal concentrations higher than those observed in the other reservoirs can be expected.

The need for careful monitoring of streamflow and water quality above and below the planned reservoir is shown by data from each of the lakes. Careful management of conservation releases from the reservoir by PaDER, Bureau of Parks will require monitoring data so that water from the hypoliminion with depleted dissolved-oxygen concentrations and elevated dissolved-metals concentrations will not degrade downstream water quality. Monitoring data also will provide information on (1) the location of density currents that could increase acidity near the outlet structure, or (2) discharges from the lake that have low pH and high metal and nutrient concentrations.

SUMMARY AND CONCLUSIONS

1. The planned Swatara State Park Reservoir, 9 mi northwest of Lebanon, Pa., will be long and narrow with a shore line of about 20.2 mi, a mean width of 1,200 ft, a mean depth of 13.5 ft, and a maximum depth of about 40 ft. The length of the reservoir will enhance development of shoreline communities. Depths exceeding 10 ft, where thermal and chemical stratification may occur, will extend as far as 6.0 mi upstream from the dam. About 43 percent of the lake volume will be in this critical area.

2. Daily water temperatures at the inflows to the planned reservoir are expected to increase as early as April 25 and to decrease beginning in September. Simple linear regressions between water temperature at inflows and mean daily air temperatures measured in Pine Grove were good (r^2 greater than 0.60) and can be used to predict periods of maximum change in water temperature of inflows. Release of water from the bottom of the reservoir may help reduce thermal stratification between April and September.

3. Thermal stratification in the planned reservoir can be expected to occur like other reservoirs with similar morphometry and geographic locations.

4. Precipitation for the 1982, 1983, and 1984 water years was 8 percent below normal, near normal, and 25 percent above normal, respectively.

5. Precipitation data collected at the NOAA station in Lebanon is not representative of the study area and probably should not be used to estimate runoff to the planned reservoir.

6. Mean streamflows during the 3-year study were 15 percent below, 4 percent above, and 50 percent above the 65-year average at Swatara Creek at Harper Tavern, 15.9* mi downstream from the study area.

7. Iron, aluminum, and phosphorus discharges to the reservoir are expected to be higher during wet years, while sulfate, nitrate, and manganese may be higher during periods when infiltration has had longer contact times with soluble constitutents.

8. Base flow will have a large effect on water quality in the planned reservoir. During the 3-year study, base flow and stormflow comprised 65 and 35 percent, respectively, of the annual inflow to the reservoir area from the mined site and 55 and 45 percent, respectively, of the annual inflow from the forested and agricultural site. Base flow comprised almost 69 percent of the streamflow in 1982--a dry year--but only about 57 percent in 1984--a wet year--at the mined site.

9. About 1.13 in. of runoff is necessary for complete water exchange in the planned reservoir. This amount was not met during 10 of the 36 months of the study. Critical times were July through October when reduced runoff would have necessitated small releases so that a recreational pool of 473.0 ft could have been maintained. As a result, thermal stratification, oxygen depletion, and increases in dissolved metals, dissolved phosphorus, and hydrogen sulfide concentrations in the hypolimnion can be expected.

10. Inflows to and the discharge downstream from the planned reservoir study area are poorly buffered. Median alkalinity and acidity concentrations were less than 10 and 5 mg/L (as $CaCO_3$), respectively. Therefore, acidic discharges from upstream mines may enter the reservoir rapidly, form density currents with little dilution, increase acidity in the reservoir and at the release structure, or be discharged and adversely affect downstream aquatic communities.

11. Concentrations of aluminum, iron, and manganese at the mined site and at the downstream site at Inwood often exceeded the USEPA criteria for freshwater aquatic organisms and Pennsylvania water-quality standards. Lead, copper, and zinc concentrations during storms also often exceeded the USEPA criteria for freshwater aquatic life. Maximum total-iron, aluminum, and manganese concentrations of 100,000 μg/L, 66,000 μg/L, and 2,300 μg/L, respectively, in storm runoff demonstrate the effect of mine drainage that is discharged into Swatara Creek above the planned reservoir.

12. Concentrations of suspended iron, aluminum, manganese, and phosphorus in storm runoff were directly related to suspended-sediment concentrations (r^2 greater than 0.62). These relations were used to estimate annual storm loads.

13. About 21,000 tons of suspended sediment were transported to the area of the planned reservoir during 1983 when streamflow was near normal. About 5 percent of this suspended-sediment load was sorbed and particulate iron, aluminum, and manganese. The suspended-sediment discharge was 59 percent higher during 1984 when streamflow was 50 percent above normal, and was 24 percent lower during 1982 when streamflow was 15 percent below normal.

14. On the average, more than 692, 300, and 95 tons of total-recoverable iron, aluminum, and manganese, respectively, were discharged annually into the area of the planned reservoir. Most of the annual storm load was discharged in 4 to 5 days. About 91 and 87 percent of the total aluminum and iron discharges were associated with suspended sediment, and storms annually contributed about 444 and 220 tons of total-recoverable iron and aluminum, respectively. The mined site contributed 91 and 98 percent of the total-recoverable aluminum and manganese, respectively, during base flow, but only 59 percent of the total-recoverable iron.

15. Point-source discharges, in addition to mine drainage, are expected to affect water quality in the planned reservoir. Concentrations of total-recoverable aluminum, total-recoverable lead, chemical-oxygen demand, and dissolved phosphorus measured in Swatara Creek just below a point discharge near Swatara Creek above Highway 443 were 35,000 μg/L, 32 μg/L, 290 mg/L, and 14 mg/L, respectively. The point-source discharges are probably partly responsible for the poor correlations between nutrient and metals concentration in base flow and stormflow in Swatara Creek.

16. Concentrations of aluminum, iron, lead, copper, and zinc in bottom-material were greatest near Swatara Creek above Highway 443 just downstream from the point source near Swatara Creek above Highway 443. Reduced manganese concentrations in Swatara Creek bottom-material samples correspond to increases in concentrations in the water, which indicates that manganese is redissolved downstream from the point source. Less than 1 g/k of coal and less than 1 μg/L of selenium was measured in the bottom material from the forested and agricultural site and aluminum and iron concentrations were significantly lower than those at the mined site.

17. A 529,000-ton culm pile within Swatara State Park is expected to require 3 years or more to remove; if not removed, it will become a pennisula in the planned reservoir. Analyses of washings from the base of this pile indicate that the fine coal particles and runoff from the waste pile contain elevated concentrations of aluminum, iron, copper, lead, mercury, and selenium. Washings from this culm pile may cause significant chemical input to the planned reservoir.

18. Measured nutrient concentrations in inflow and estimates of phosphorus loadings indicate that the planned reservoir will be productive and may become eutrophic if discharges of phosphorus are not reduced. Nitrogen concentrations in base flow at the mined site showed an upward trend from October through September during the dry and normal year but a downward trend from November through July during the wet year. The downward trend was probably the result of dilution of the point-source discharge which had elevated ammonia concentrations. Trends in nitrogen concentrations in base flow at the forested and agricultural site were downward each year, perhaps as a result of the seasonal uptake of nitrogen by plants. Similar downward trends have been seen in other agricultural basins in Lancaster County.

19. Dissolved-sulfate concentrations in base flow at the mined site were highest during low flows when much of the streamflow was discharged from deep mines in the Swatara Creek headwaters.

20. Bacteriological data collected during base flow show 9 and 35 percent of the fecal-coliform concentrations at Swatara Creek above Highway 895 and Lower Little Swatara Creek, respectively, were above 200 colonies/100 mL. Seventy-one percent of the fecal-coliform samples during base flow were over two times higher at the forested and agricultural site than at the mined site. About 21 percent of the samples collected from the forested and agricultural site had an FC/FS ratio greater than 2, indicating that discharges of human waste probably are present in the waters at the site.

21. Through use of duration techniques, the safe concentration of total-recoverable aluminum of 500 μg/L in the inflow to the planned reservoir will be equalled or exceeded more than 50 percent of the time.

SUMMARY AND CONCLUSIONS--Continued

22. Data from reservoirs in Pennsylvania, Maryland, and West Virginia with inflow and reservoir characteristics similiar to those of the planned Swatara State Park Reservoir provide examples of the expected water quality in and downstream from the planned reservoir. The formation of density currents in the planned reservoir, such as those observed in the Crooked Creek and Loyalhanna Lakes, is likely. Because the planned reservoir will not have the buffering capacities of the larger and deeper Tygart Lake and Youghiogheny River Lake, extremes in pH may occur and dilution of acidic storm runoff may not be possible at the Swatara State Park Reservoir.

23. Unless conservation releases from the planned Swatara State Park reservoir are carefully controlled, poorly oxygenated water with elevated metals concentrations may degrade the downstream quality and be detrimental to the aquatic community.

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