WATER QUALITY OF THE WEST BRANCH LACKAWAXEN RIVER AND LIMNOLOGY OF PROMPTON LAKE, WAYNE COUNTY, PENNSYLVANIA, OCTOBER 1986 THROUGH SEPTEMBER 1987

by James L. Barker

U.S. Geological Survey

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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 SI units
inch (in.)	25.4	millimeter (mm)
inch (in.)	2.54×10^4	micrometer (μm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
acre	0.405	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
acre-feet (acre-ft)	1.233×10^{-6}	cubic kilometer (km^3)
cubic feet per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
ton, short	0.9072	megagram (Mg)
ton per square mile (ton/mi^2)	0.3503	megagrams per square kilometer (Mg/km^2)
pounds per square foot (lbs/ft^2)	488.3	grams per square meter (g/m^2)
degree Fahrenheit (°F)	°C = 5/9 (°F-32)	degree Celsius (°C)

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 water quality of the West Branch Lackawaxen River and the limnology of Prompton Lake in northeastern Pennsylvania were studied from October 1986 through September 1987 to determine past and present water-quality conditions in the basin, and to determine the possible effects of raising the lake level on the water quality of the lake, of the river downstream, and of ground water.

Past and present water quality of the West Branch Lackawaxen River and Prompton Lake generally meets State standards for high-quality waters that support the maintenance and propagation of cold-water fishes. However, suggested criteria by the U.S. Environmental Protection Agency intended to control excessive algal growth in the lake are exceeded most, if not all, of the time for nitrogen and most of the time for phosphorus.

The average annual total nitrogen load entering the lake is 114 tons. Of this total, 41 tons is inorganic nitrite plus nitrate, 48 tons organic nitrogen, and 25 tons ammonia nitrogen. Estimated annual yields of total nitrogen, inorganic nitrite plus nitrate, organic nitrogen, and ammonia nitrogen are 1.9, 0.7, 0.8, and 0.4 tons/mi^2 (tons per square mile), respectively. The average annual phosphorus load is estimated to be 4.7 tons, which is equivalent to a yield of 0.08 tons/mi^2. About 62 percent, or 2.9 tons, is dissolved phosphorus that is readily available for plant assimilation. The waters of the West Branch Lackawaxen River and Prompton Lake are decidedly phosphorus limited.

The long-term average annual suspended-sediment yield to the lake is about 70 tons/mi^2. Life expectancy of the 774 acre-feet of space allocated for sediment loads in the raised pool is estimated to be about 287 years.

During the 1987 water year, about 51 percent of the annual sediment load was transported during 7 days by storm-water runoff. The maximum sediment discharge during the study period was 400 tons per day.

Lake-profile studies show that thermal and chemical stratification develops in early June and persists through September. Water below a depth of about 20 feet becomes anoxic, or nearly so, by mid-July.

Summer concentrations of chlorophyll are indicative of eutrophic conditions. Although raising of the lake level is expected to increase the efficiency of the lake in trapping nutrients, the increased depth and volume will reduce the concentrations of available nutrients and, thereby, reduce the eutrophication potential of the lake.

The water level in about 30 wells near the lake probably will rise after the lake level is raised, and the well yields probably will increase slightly. Flow of water from the lake to the aquifer as the lake is being raised may temporarily increase mineral content of water in the aquifer. After a new equilibrium is reached, however, water will again flow from the aquifer to the lake, thereby restoring the aquifer's water quality.

INTRODUCTION

Prompton Lake is in the northeastern corner of Pennsylvania about 5 miles northwest of the borough of Honesdale in Wayne County (fig. 1). The lake was created in 1960 when the U.S. Army Corps of Engineers constructed a rock and earth-fill dam on the West Branch Lackawaxen River. The project was authorized for the purpose of flood control under the authority of Section 203 of the Flood Control Act of 1948. During the design phase, a permanent pool was added for recreational purposes in accordance with Section 4 of the Flood Control Act of 1944.

Prompton Lake at the present normal pool elevation of 1,125 ft (feet) above sea level, is a 303-acre impoundment that has a capacity of 3,355 acre-ft (acre-feet), a maximum depth of 35 ft, and a mean depth of 12 ft. The proposed modification of the existing Prompton Dam and Lake would raise the lake level 55 ft for the purpose of providing additional supplies of water to "augment low flows in the Delaware River basin and to help meet the needs of recreation" (U.S. Army Corps of Engineers, 1986). At the proposed raised pool elevation of 1,180 ft, the capacity will increase to 31,900 acre-ft, the maximum depth to 90 ft, and the mean depth to 43 ft; the surface area will be 734 acres.

The 59.6-mi^2 (square miles) watershed basin is sparsely developed; agriculture is the leading industry (fig. 2). About 60 to 70 percent of the watershed is forested. The remaining land is a mixture of pasture, cultivated land, and villages that has changed little over the past 75 years.

The topography of the basin is characteristic of a glaciated terrain with rounded hills, U-shaped valleys, and numerous small lakes and marshes. The soils are formed on shales and sandstones of the Catskill Formation of Late Devonian and Early Mississippian age.

A complete description of basin characteristics including physiology, geology, soils, and climate has been published in a series of annual Water-Quality Data Reports prepared by the Philadelphia District of the U.S. Army Corps of Engineers (1976-81 and 1983-85).

Purpose and Scope

This report describes the water quality of the West Branch Lackawaxen River and the limnology and historical and current water quality of the lake. It also describes the hydrologic and water-quality effects of raising the normal pool level 55 ft on Prompton Lake. Data collection from October 1986 to September 1987 was directed toward documenting the temporal and spatial variations in selected physical, chemical, and biological characteristics of the water, estimating annual nutrient and suspended-sediment discharge to the reservoir, and evaluating the effect of the raised pool on the ground-water hydrology of the area adjacent to the reservoir.

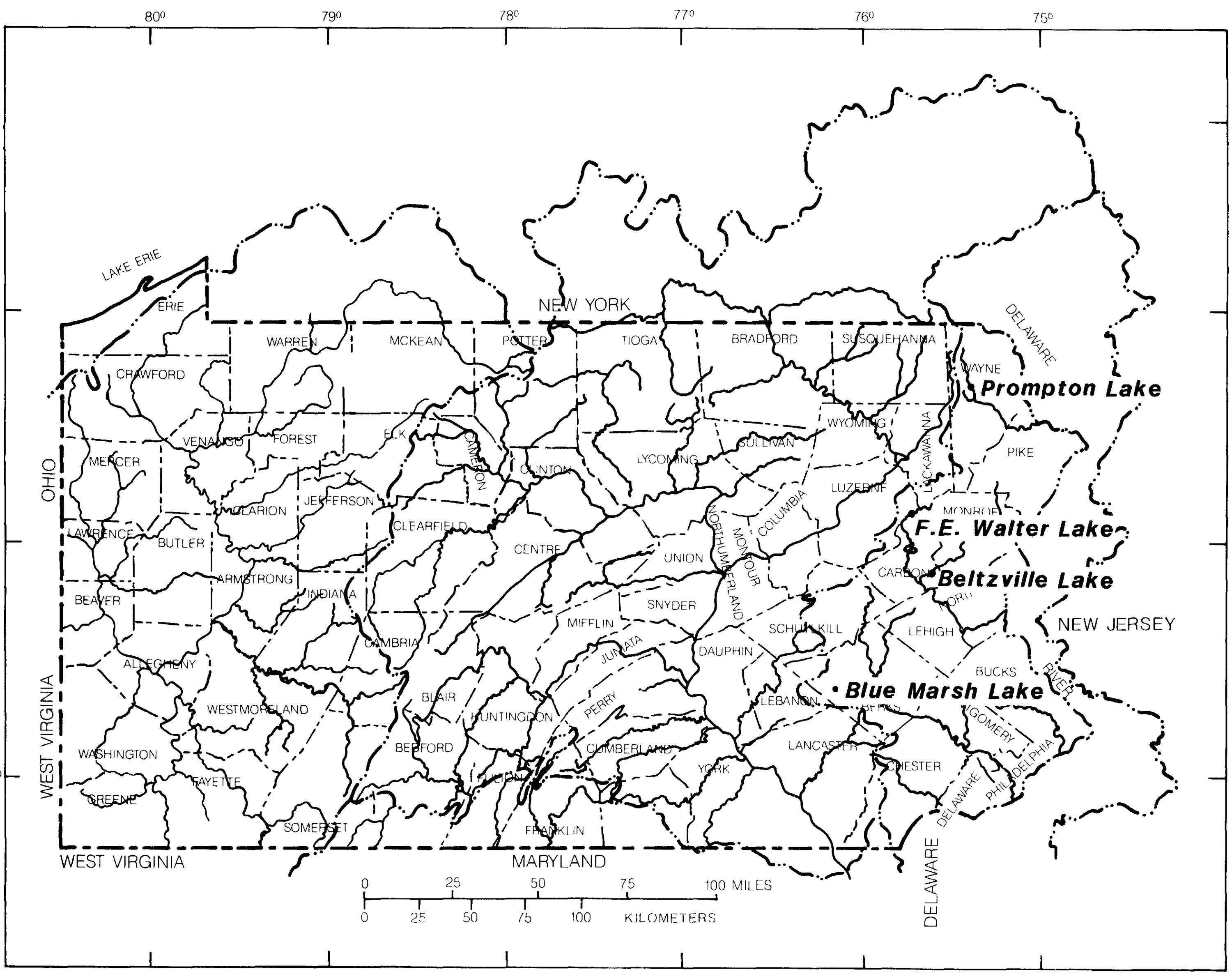


Figure 1. Location of U.S. Army Corps of Engineers lakes in eastern Pennsylvania.

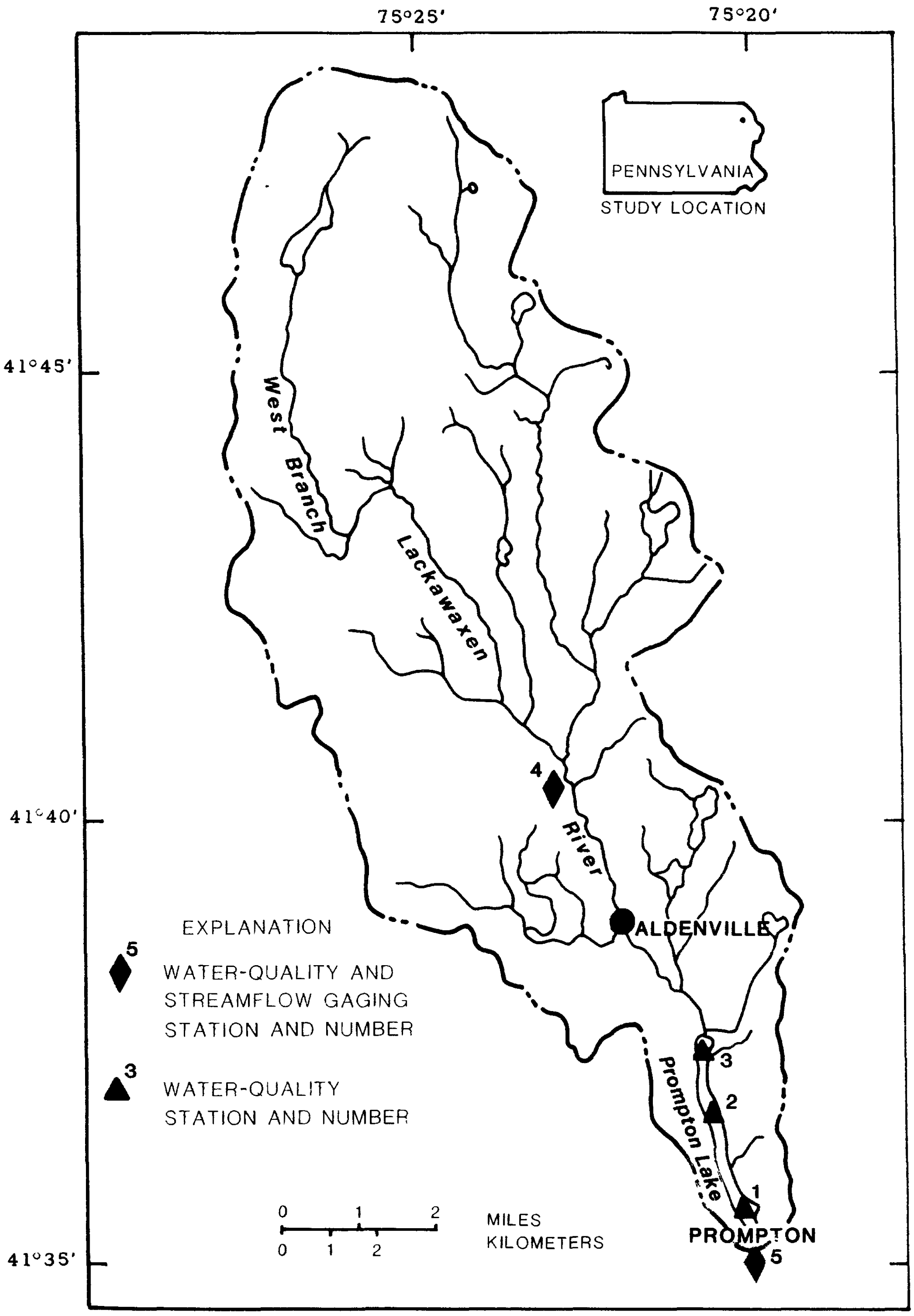


Figure 2.--Prompton Lake study area.

Previous Studies

Monthly physical, chemical, and biological data during the open water season for Prompton Lake and the West Branch Lackawaxen River, dating back to 1968, provide a comprehensive record of water-quality conditions. The data collected by State and Federal agencies, as well as by private consultants under contract to the U.S. Army Corps of Engineers, have been reproduced, summarized, and evaluated in a series of Water-Quality Data Reports by the U.S. Army Corps of Engineers (1977-81 and 1985). Table 1 summarizes about 10 years of selected data for the West Branch Lackawaxen River that were taken from these reports.

The statistical summary shows that the water quality of the West Branch Lackawaxen River near Aldenville generally meets the State standards for high-quality waters that support the maintenance and propagation of cold-water fishes. Nitrogen concentrations in the River are elevated because of the presence of a fish hatchery at Mt. Pleasant and the large number of dairy cattle in the basin, but these concentrations do not appear harmful to most varieties of fish or other aquatic life.

A paper by Barker (1976) and annual data reports by the U.S. Geological Survey contain additional streamflow and water-quality data.

Table 1.--Summary of historical water-quality data for West Branch Lackawaxen River near Aldenville, Pa.[1/]

[N is the number of samples, units are milligrams per liter, except as noted; µS/cm is microsiemens per centimeter at 25 degrees Celsius]

Variable	N	Mean	Median	Standard deviation	Minimum	Maximum	Range	Variance
pH (units)	94	--	7.1	0.63	5.1	8.6	3.5	0.39
Dissolved oxygen	93	8.7	9.2	3.16	.4	13.9	13.5	10
Specific conductance (µS/cm)	91	70	70	26	10	250	240	684
Total-dissolved solids	75	64	61	34	1	170	169	1,148
NO_2 + NO_3, as N	78	.40	.35	.29	.01	1.39	1.38	.08
Total phosphorus	61	.12	.08	.15	0	.77	.77	.02
Ammonia as N	77	.15	.09	.27	0	1.7	1.7	.07

[1/]Data computed from U.S. Army Corps of Engineers annual Water-Quality Data Reports, 1976-81, 1983-85.

Geohydrologic Setting

by C.R. Wood

Geology

The Prompton Dam and Lake are underlain by the sandstones and shales of the Catskill Formation of Late Devonian and Early Mississippian age (Trexler and others, 1961, p. 84). These rocks dip northward 1 to 3 degrees. The bedrock is partly covered by ground moraine of Woodfordian age, and a thin layer (10 to 50 ft) of till consisting of an unsorted mixture of clay, silt, sand, pebbles, cobbles, and boulders. It has low permeability. Ice-contact stratified drift of Woodfordian age consisting of sand, gravel, cobbles, and boulders, is present locally. This material has a high permeability.

Ground Water

The Catskill Formation is a moderately productive aquifer. Carswell and Lloyd (1979, p. 11) noted that, "On the average, one of every four wells located, drilled, and developed for high yield will probably produce about 75 gal/min (gallons per minute) or more, with 50 ft of drawdown after 24 hours of pumping." They also noted that the dissolved-solids concentration in water from the Catskill Formation averages about 100 mg/L and that, "The water is soft and acidic, and locally contains excessive concentrations of iron and manganese."

METHODS OF STUDY

Streamflow on the West Branch Lackawaxen River was monitored at a stream-gaging station downstream from the dam at the village of Prompton (site 5, fig. 2) and at a station upstream from the lake near the village of Aldenville (site 4, fig. 2). The upstream site has been in operation only since July 9, 1987. Prior to that date, streamflow measurements and estimates were obtained intermittently.

Water chemistry and suspended sediment of the West Branch Lackawaxen River were measured monthly and weekly, respectively, and during storms beginning October 15, 1986. Prompton Lake was sampled five times during the open-water season at three locations. These sampling stations coincide with U.S. Geological Survey streamflow-gaging stations and lake stations sampled in previous studies summarized in Water-Quality Data Reports by the U.S. Army Corps of Engineers, Philadelphia District. Table 2 lists the locations of the sampling sites in the West Branch Lackawaxen River basin used in this study.

Water-quality samples were collected in clean polyethylene plastic bottles near the surface in the centroid of flow. Water samples for dissolved constituents were filtered through 0.45-micrometer polycarbonate filters. Nitrogen and phosphorus samples were preserved with mercuric chloride and chilled to 39 °F (degrees Fahrenheit) until analyzed at the U.S. Geological Survey Central Laboratory in Arvada, Colorado. All inorganic constituents were determined by methods described by Skougstad and others (1979), chlorophyll by methods described by Greeson and others (1977), and suspended sediment by methods described by Guy (1969). Depth-integrated sediment samples were collected by methods described by Guy and Norman (1970) and were analyzed at the U.S. Geological Survey sediment laboratory in Harrisburg, Pennsylvania.

Table 2.--Water-quality sampling sites in West Branch Lackawaxen River basin

U.S. Geological Survey station number	U.S. Army Corps of Engineers reference number[1/]	Location
01427950	4	West Branch Lackawaxen R. at Rt 247 bridge near Aldenville
01429000	5	West Branch Lackawaxen R. below dam at Prompton
413735075203101	3	Prompton Reservoir inflow pool
413657075203701	2	Prompton Reservoir mid-lake pool
413539075194801	1	Prompton Reservoir spillway pool

[1/] Locations of these stations are shown on figure 1.

Instantaneous constituent discharge was calculated from the equation:

$$L = C\ Q\ F, \qquad (1)$$

where

L = constituent discharge, in tons per day;
C = measured concentration, in milligrams per liter;
Q = instantaneous streamflow, in cubic feet per second; and
F[1/] = 0.0027

The calculated constituent discharge for nitrogen and phosphorus was then plotted against streamflow to construct a transport curve for each constituent. Simple linear-regression was performed to fit a line to the data that best defined the relation between streamflow and constituent discharge. Constituent loads and streamflow were transformed to base 10 logarithms to normalize the data. Annual load and yield for selected constituents were determined by the flow-duration, constituent-transport curve method described by Miller (1951) and Porterfield (1972).

[1/]Coefficient to convert weight of water volume, in cubic feet per second, to short tons per day.

WATER QUALITY OF THE WEST BRANCH LACKAWAXEN RIVER AND ITS EFFECTS ON PROMPTON LAKE

The West Branch Lackawaxen River is the chief input to Prompton Lake. Therefore, its water quality is critical to maintaining an acceptable water quality in the lake.

Hydrology

Streamflow has been measured by the U.S. Geological Survey at the West Branch Lackawaxen River below the dam at Prompton (fig. 1, table 2) since 1944. The average daily discharge for 41 years of record (1944-85) is 109 ft^3/s (cubic feet per second), or 24.85 in./yr (inches per year), adjusted for storage in Prompton Lake since January 1961. For the period of record, a maximum discharge of 5,860 ft^3/s, at a gage height of 9.24 ft, was estimated for the August 1955 flood. However, flood marks at a stage of 16.7 ft indicated that the flood of May 1942 was substantially greater (U.S. Geological Survey, 1976-87).

Long-term streamflow estimates for the gaging station upstream from Prompton Lake near Aldenville (fig. 2, table 2) were determined by correlation with gaging stations on the West Branch Lackawaxen River at Prompton and Dyberry Creek near Honesdale, U.S. Geological Survey station number 01429500. The long-term average streamflow for the West Branch Lackawaxen River near Aldenville is calculated to be about 90 ft^3/s. Flow-duration curves (fig. 3) were computed for the two West Branch Lackawaxen River gaging stations on the basis of 41 years of records (1944-85).

Streamflow in the West Branch Lackawaxen River near Aldenville during the 1987 water year averaged 92 ft^3/s, or just 2 percent more than the estimated average. Daily mean streamflow ranged from 6.7 to 1,040 ft^3/s; the peak instantaneous streamflow of 2,263 ft^3/s occurred on April 4, 1987. Stormflows contributed about 58 percent of the total flow past the gage.

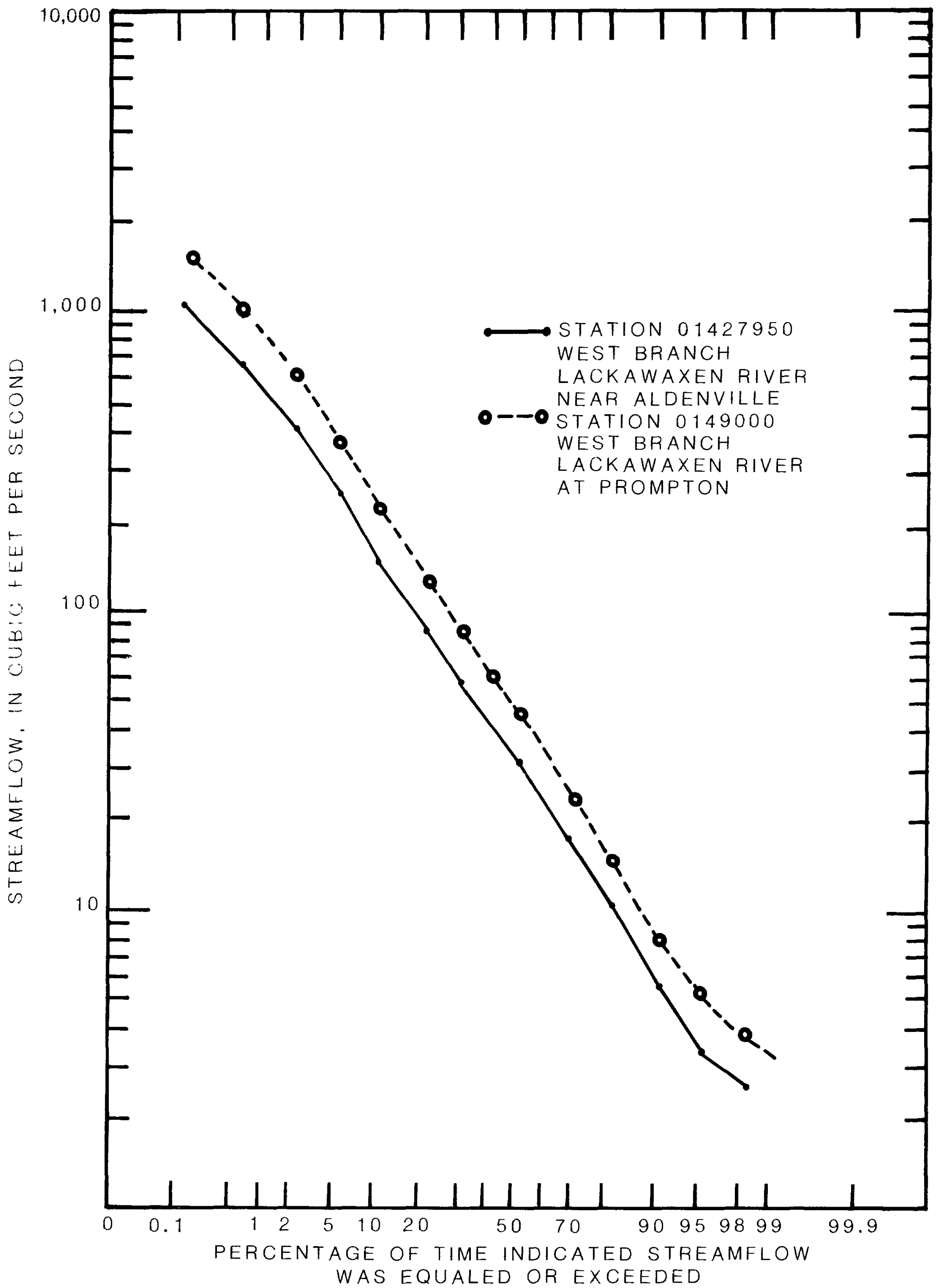


Figure 3.--Flow-duration curves of daily streamflow for West Branch Lackawaxen River at Prompton and near Aldenville, 1944-85.

Nitrogen and Phosphorus

The West Branch Lackawaxen River from its source to Prompton Lake is classified by the Pennsylvania Sanitary Water Board (1979) as a high-quality, cold-water fishery. This classification indicates the stream has excellent quality waters that require special protection for the maintenance and propagation of salmonids (trout) as well as other fauna and flora indigenous to the stream.

State water-quality standards for the stream require that nitrite plus nitrate nitrogen not exceed 10 mg/L (milligrams per liter) (Pennsylvania Sanitary Water Board, 1979). The literature further suggests that 0.3 mg/L of total inorganic nitrogen and 0.01 mg/L of total phosphorus are critical concentrations, that, when exceeded, can stimulate excessive growth of algae (McKee and Wolf, 1963). The U.S. Environmental Protection Agency (1976) recommends that total phosphorus concentrations should not exceed 0.05 mg/L at the point where it enters a lake or reservoir. An N:P (nitrogen to phosphorus) ratio of 10:1 is considered normal (National Technical Advisory Committee, 1968).

Monthly and stormflow constituent analyses for nitrogen and phosphorus species during October 1986 through September 1987 are presented in table 3 and summarized in table 4. These analyses indicate that, although State standards are being met, criteria recommended for controlling excessive algae growth are exceeded most, if not all, of the time for nitrogen and half of the time for phosphorus. The N:P ratio ranged from 22:1 to 110:1, indicating the phytoplankton production is limited by the amount of phosphorus not by the amount of nitrogen.

While no relation exists between nitrogen and phosphorus species concentration and streamflow, maximum concentrations of nitrogen species were measured during early March, coincident with runoff of manure and snowmelt from barn yards and fields and maximum phosphorus concentrations were measured during late summer.

The estimated average annual loads and yields of nitrogen and phosphorus to Prompton Lake are given in table 5. The estimates were calculated from the transport-curve regressions and flow durations for the West Branch Lackawaxen River near Aldenville. Regression statistics in table 6 show that coefficients of determination were 0.77, or greater, for all constituents.

The total nitrogen load and yield was estimated to be about 114 tons/yr and 1.9 tons/mi^2, respectively. About 36 percent or 41 tons of the total nitrogen load was nitrite plus nitrate nitrogen, 42 percent, or 48 tons, was organic nitrogen, and 22 percent, or 25 tons, was ammonia nitrogen. Nitrite nitrogen was an insignificant part of the inorganic nitrogen. The high 22-percent ammonia nitrogen component may be indicative of animal waste.

The long-term average annual load and yield of total phosphorus to Prompton Lake is estimated to be 4.7 tons and 0.08 tons/mi^2, respectively. About 62 percent, or 2.9 tons, of the phosphorus was dissolved and readily available for plant assimilation.

Transport curves for nitrogen and phosphorus species, based upon the 1987 chemical analyses, are presented in figures 4 and 5. Because streamflow during the 1987 water year was nearly equal to the long-term normal, the constituent loads should be representative of long-term conditions.

Chemical characteristics of the lake outflow were measured monthly. The water-quality data, presented in table 7 and summarized in table 8, indicate that some of the available nutrients are assimilated by plants (algae) within the lake. Unless a nutrient budget is calculated for the lake, it is difficult to assess the outflow chemistry and its relation to the inflow because of the influence of biological uptake and volume, and depth of water withdrawals from the lake. Because nutrients tend to concentrate in the hypolimnetic or bottom waters of the lake during stratification, the outflow-water chemistry varies significantly both seasonally and with streamflow.

Table 3.--Water-quality data, October 1986 through September 1987 at station 01427950 - West Branch Lackawaxen River near Aldenville, Pa.

[ft3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; --, no data; <, less than]

Date	Time	Stream-flow, instan-taneous (ft3/s)	Spe-cific con-duct-ance (µS/cm)	pH (stand-ard units)	Nitro-gen, ammonia total (mg/L as N)	Nitro-gen, nitrite total (mg/L as N)	Nitro-gen, am-monia + organic total (mg/L as N)	Nitro-gen, NO2+NO3 total (mg/L as N)	Nitrogen total (mg/L)	Phos-phorus, total (mg/L)	Phos-phorus, dis-solved (mg/L)	Sedi-ment sus-pended (mg/L)
OCT 1986												
20...	1120	31	--	--	--	--	--	--	--	--	--	1
28...	1135	63	--	--	--	--	--	--	--	--	--	2
NOV												
03...	1205	28	--	--	--	--	--	--	--	--	--	2
08...	0845	98	--	--	<0.01	<0.01	<0.2	0.3	<0.5	0.03	0.05	9
08...	1300	167	--	--	.01	<.01	1.4	.3	1.7	.06	.05	85
08...	1645	414	--	--	.03	<.01	.7	.3	1.0	.07	.02	36
12...	1045	145	--	--	--	--	--	--	--	--	--	2
13...	0930	133	--	--	<.01	<.01	.4	.4	.8	.01	.04	--
19...	1500	110	--	--	--	--	--	--	--	--	--	4
21...	0800	677	--	--	.03	.02	2.5	.4	2.9	.05	.03	25
21...	1205	556	--	--	.03	.02	.7	.4	1.1	.02	.02	19
21...	1655	455	--	--	.04	.02	.8	.4	1.2	.03	.02	12
26...	0815	218	--	--	.05	<.01	.6	.5	1.1	.03	.02	8
26...	1210	657	--	--	.02	.02	.8	.5	1.3	.07	.03	47
26...	1645	677	--	--	.04	.02	.8	.4	1.2	.06	.03	25
27...	0805	648	--	--	.03	<.01	.6	.3	.9	.05	.02	--
27...	1210	565	--	--	.03	<.01	.7	.3	1.0	.03	.02	20
27...	1630	506	--	--	.33	<.01	.5	.3	.8	.02	.01	17
DEC												
04...	0955	190	--	--	--	--	--	--	--	--	--	10
13...	0920	83	--	--	--	--	--	--	--	--	--	3
20...	1045	54	--	--	--	--	--	--	--	--	--	1
28...	0920	94	--	--	--	--	--	--	--	--	--	3
FEB 1987												
18...	1000	--	--	--	.01	<.01	<.2	.7	<.9	.01	.01	--
MAR												
08...	1045	264	--	--	--	--	--	--	--	--	--	24
09...	0845	400	--	--	<.01	<.01	.4	.9	1.3	.02	.03	41
09...	1330	407	--	--	<.01	<.01	.3	.9	1.2	.07	.03	42
09...	1730	383	--	--	<.01	<.01	.4	.9	1.3	.02	.02	29
17...	1355	80	--	--	--	--	--	--	--	--	--	2
18...	0915	77	--	7.9	.05	<.01	.6	.6	1.2	.03	.01	--
25...	1015	186	--	--	--	--	--	--	--	--	--	8
APR												
02...	1115	145	--	--	--	--	--	--	--	--	--	2
04...	0710	624	--	--	.06	.02	.5	.5	1.0	.04	.04	147
04...	1325	1,220	--	--	.02	.01	1.6	.5	2.1	.04	.04	447
04...	1705	1,990	--	--	.05	<.01	.6	.5	1.1	.07	.07	760
13...	1145	292	--	--	--	--	--	--	--	--	--	16
15...	0930	124	--	8.0	<.01	<.01	.7	.4	1.1	.01	.02	--
MAY												
13...	0900	30	88	7.7	.02	<.01	.4	.3	.7	.01	.01	--
22...	0825	23	--	--	--	--	--	--	--	--	--	1
24...	0730	153	--	--	--	--	--	--	--	--	--	12
24...	0830	141	--	--	--	--	--	--	--	--	--	8
24...	0930	127	--	--	--	--	--	--	--	--	--	9
24...	1030	116	--	--	--	--	--	--	--	--	--	7
24...	1100	113	--	--	--	--	--	--	--	--	--	6
24...	1130	110	--	--	--	--	--	--	--	--	--	5
24...	1205	20	--	--	--	--	--	--	--	--	--	1
JUN												
01...	0830	28	--	--	--	--	--	--	--	--	--	1
10...	0915	16	70	7.3	.03	<.01	.4	.5	.9	.04	.03	7
15...	0810	25	--	--	--	--	--	--	--	--	--	11
22...	0825	16	--	--	--	--	--	--	--	--	--	4

Table 3.--Water-quality data, October 1986 through September 1987 at station 01427950 - West Branch Lackawaxen River near Aldenville, Pa.--Continued

[ft3/s, cubic feet per second; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; --, no data; <, less than]

Date	Time	Stream-flow, instan-taneous (ft^3/s)	Spe-cific con-duct-ance (µS/cm)	pH (stand-ard units)	Nitro-gen, ammonia total (mg/L as N)	Nitro-gen, nitrite total (mg/L as N)	Nitro-gen, am-monia + organic total (mg/L as N)	Nitro-gen, NO_2+NO_3 total (mg/L as N)	Nitrogen total (mg/L)	Phos-phorus, total (mg/L)	Phos-phorus, dis-solved (mg/L)	Sedi-ment sus-pended (mg/L)
JUL 1987												
06...	0945	13	--	--	--	--	--	--	--	--	--	2
09...	0900	36	80	7.6	<0.01	<0.01	0.6	0.5	1.1	0.05	0.04	5
12...	1045	14	--	--	--	--	--	--	--	--	--	3
14...	1730	176	--	--	.08	.01	1.0	.4	1.4	.09	.02	68
14...	1800	192	--	--	.07	.01	1.4	.4	1.8	.10	.06	52
14...	1830	190	--	--	.06	.01	1.3	.5	1.8	.10	.01	41
14...	1900	187	--	--	.08	.01	.7	.5	1.2	.08	.07	36
14...	2030	176	--	--	.04	<.01	.8	.4	1.2	.08	.05	23
14...	2130	167	--	--	.07	.01	1.3	.7	2.0	.09	.01	22
14...	2200	155	--	--	.04	<.01	.8	.4	1.2	.08	.01	18
14...	2230	139	--	--	.06	<.01	1.0	.4	1.4	.08	.02	21
20...	1145	18	--	--	--	--	--	--	--	--	--	2
AUG												
09...	1040	13	--	--	--	--	--	--	--	--	--	2
12...	0920	21	79	7.5	.01	<.01	.5	.2	.7	.04	.03	--
16...	1050	13	--	--	--	--	--	--	--	--	--	3
24...	1425	8	--	--	--	--	--	--	--	--	--	2
29...	0100	157	88	--	.03	<.01	.7	.4	1.1	.07	.05	34
29...	0130	165	87	--	.04	<.01	.9	.4	1.3	.09	.09	26
29...	0200	176	--	--	.06	<.01	.6	.4	1.0	.11	.08	--
29...	0230	199	--	--	.06	<.01	.9	.4	1.3	.10	.06	--
29...	0300	250	109	--	.06	<.01	1.3	.4	1.7	.13	.10	230
29...	0330	400	81	--	.06	<.01	.8	.5	1.3	.11	.08	290
29...	0400	474	78	--	.05	<.01	.7	.4	.9	.09	.07	280
29...	0430	474	76	--	.05	<.01	.7	.4	.9	.10	.07	250
29...	0500	455	77	--	.04	<.01	1.0	.4	1.4	.10	.08	67
29...	0530	455	73	--	.04	<.01	.7	.5	1.2	.10	<.01	60
29...	0600	400	78	--	.05	<.01	.8	.4	1.2	.13	.06	67
29...	0630	367	70	--	.07	<.01	.7	.5	1.2	.11	.08	67
29...	0730	320	75	--	.05	<.01	.8	.4	1.2	.12	.09	34
29...	0830	291	72	--	.05	<.01	.6	.5	1.1	.12	.08	34
29...	1030	253	74	--	.03	<.01	1.3	.5	1.8	.07	.05	13
31...	1410	28	--	--	--	--	--	--	--	--	--	3
SEP												
07...	1140	15	--	--	--	--	--	--	--	--	--	3
08...	1500	110	--	--	.04	<.01	.4	.4	.8	.09	.09	13
08...	1530	110	--	--	--	--	--	--	--	--	--	15
08...	1600	133	--	--	.04	<.01	.5	.4	.9	.10	.09	19
08...	1630	137	--	--	--	--	--	--	--	--	--	22
08...	1700	178	--	--	.03	<.01	.5	.3	.8	.08	.08	30
08...	1730	305	--	--	.03	<.01	.7	.3	1.0	.06	.06	100
08...	1800	414	--	--	.03	<.01	.8	.3	1.1	.07	.06	100
08...	1830	494	--	--	.03	<.01	.8	.3	1.1	.08	.07	96
08...	1900	523	--	--	.04	<.01	1.3	.3	1.6	.07	.07	81
08...	1930	503	--	--	--	--	--	--	--	--	--	170
08...	2000	600	--	--	.04	<.01	1.0	.3	1.3	.08	.08	110
08...	2030	623	--	--	--	--	--	--	--	--	--	98
08...	2100	672	--	--	.03	<.01	.7	.3	1.0	.08	.08	100
24...	0900	65	62	8.6	<.01	<.01	.2	.3	.5	.03	<.01	--

Table 4.--Summary of nitrogen and phosphorus analyses at West Branch Lackawaxen River near Aldenville for the 1987 water year

[Results are in milligrams per liter; <, less than]

Constituent	Number of observations[1]	Mean	Median	Standard deviation	Minimum	Maximum	Range
Nitrogen, ammonia, total as nitrogen	18	0.03	0.03	0.021	<0.01	0.08	0.07
Nitrogen, ammonia plus organic, total as nitrogen	18	.58	.6	.22	<.2	1.0	0.8
Nitrite plus nitrate, total as nitrogen	18	.44	.4	.17	.2	.9	.7
Nitrogen total[2]	18	1.02	1.1	.24	<.5	2.9	2.4
Phosphorus total	18	.05	.05	.030	.01	.13	.12
Phosphorus dissolved	18	.03	.03	.022	<.01	.08	.07

[1]Summary data represents mostly base flow plus peak streamflow sample during storms.

[2]Calculated from sum of nitrogen species.

Table 5.--Estimated average annual loads and yields of nitrogen and phosphorus to Prompton Lake

[tons/mi², tons per square mile]

Constituent	Load (tons)	Yield (tons/mi²)
Nitrogen, nitrite plus nitrate, total as nitrogen	41	0.7
Nitrogen, ammonia, total as nitrogen	25	.4
Nitrogen, ammonia plus organic, total as nitrogen	73	1.2
Nitrogen total	114	1.9
Phosphorus dissolved	2.9	.05
Phosphorus total	4.7	.08

Table 6.--Regression statistics for nitrogen and phosphorus loads as a function of streamflow

Constituent	Number of observations	Intercept	Antilog of intercept	Slope	Standard error of estimate
Nitrogen, nitrite plus nitrate, total as nitrogen	18	-3.08	0.00083	1.06	0.138
Nitrogen, ammonia, total as nitrogen	18	-4.35	.00045	1.11	.264
Nitrogen, ammonia plus organic, total as nitrogen	18	-3.11	.00078	1.17	.175
Phosphorus, total	18	-4.22	.00006	1.16	.264
Phosphorus, dissolved	18	-4.68	.00002	1.27	.284

Table 7.--Water-quality data, October 1986 through September 1987, station 01429000 - West Branch Lackawaxen River at Prompton, Pa.

[ft^3/s, cubic feet per second; μS/cm, microsiemens per centimeter; mg/L, milligrams per liter; double dash indicates no data; <, less than]

Date	Time	Streamflow, instantaneous (ft^3/s)	Specific conductance (μS/cm)	pH (standard units)	Nitrogen, ammonia total (mg/L as N)	Nitrogen, nitrite total (mg/L as N)	Nitrogen, ammonia + organic total (mg/L as N)	Nitrogen, NO_2+NO_3 total (mg/L as N)	Nitrogen total (mg/L)	Phosphorus, total (mg/L)	Phosphorus, dissolved (mg/L)
OCT 1986											
15...	1225	69	72	6.3	0.11	0.01	0.8	0.20	1.0	0.03	<0.20
FEB 1987											
18...	1030	5.0	--	--	.04	<0.01	3.0	.50	3.5	.01	.01
MAR											
18...	0930	108	--	8.0	.01	<0.01	.4	.70	1.1	.01	.01
APR											
15...	1045	219	--	7.4	.02	<0.01	1.0	.40	1.4	.01	.01
MAY											
13...	0945	47	70	7.6	.03	<0.01	.6	<0.10	0.6	.17	.14
JUN											
10...	1000	40	74	6.9	.05	<0.01	.4	<0.10	.4	.02	.01
JUL											
09...	1045	43	76	7.7	.15	.01	.8	.20	1.0	.02	<0.01
AUG											
12...	1145	29	113	7.2	.33	.01	1.0	.10	1.1	.03	.03
SEP											
24...	1030	133	60	8.2	.03	<0.01	1.0	.20	1.2	.05	<0.01

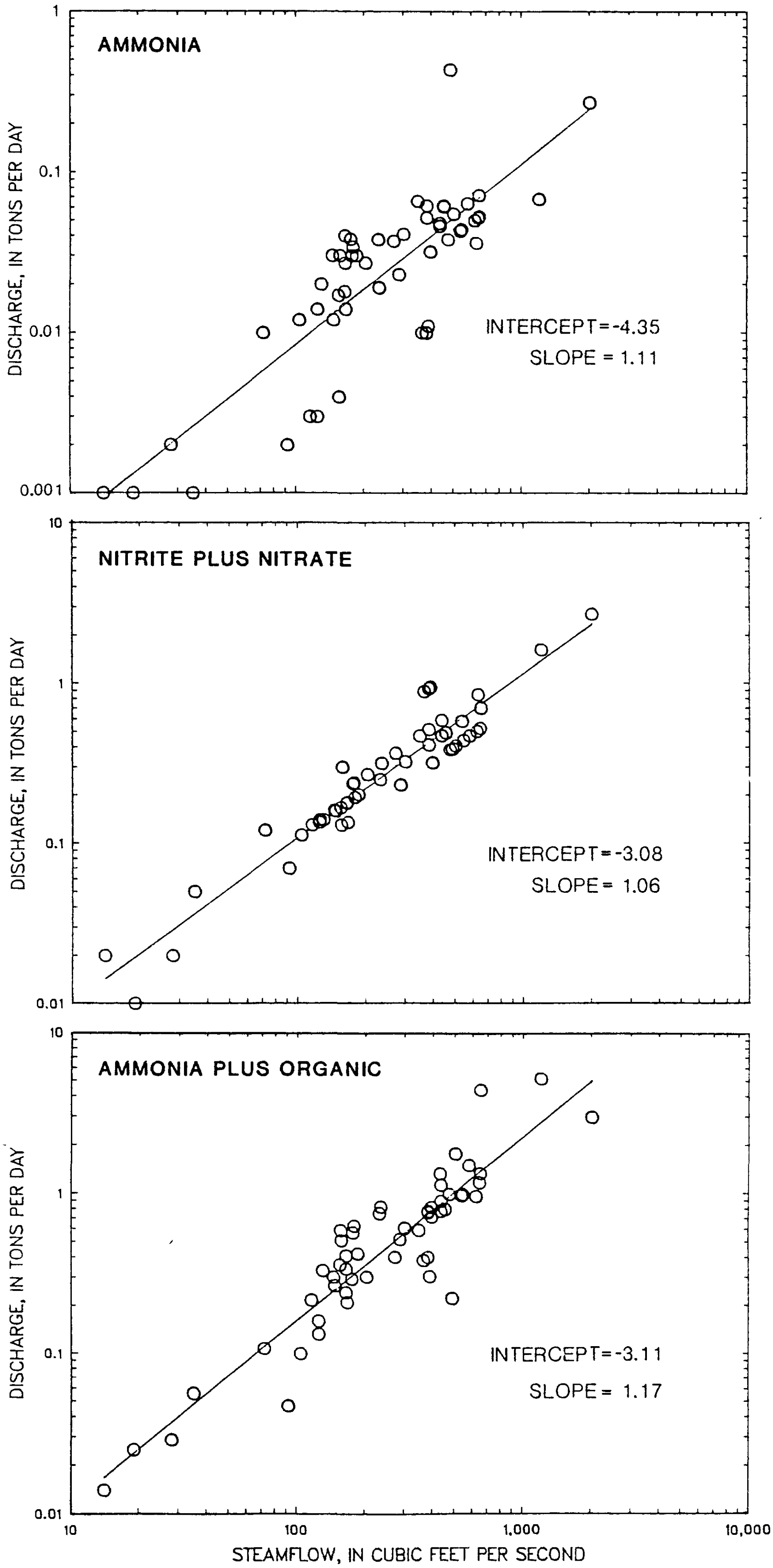


Figure 4.--Relation between nitrogen species discharge and streamflow.

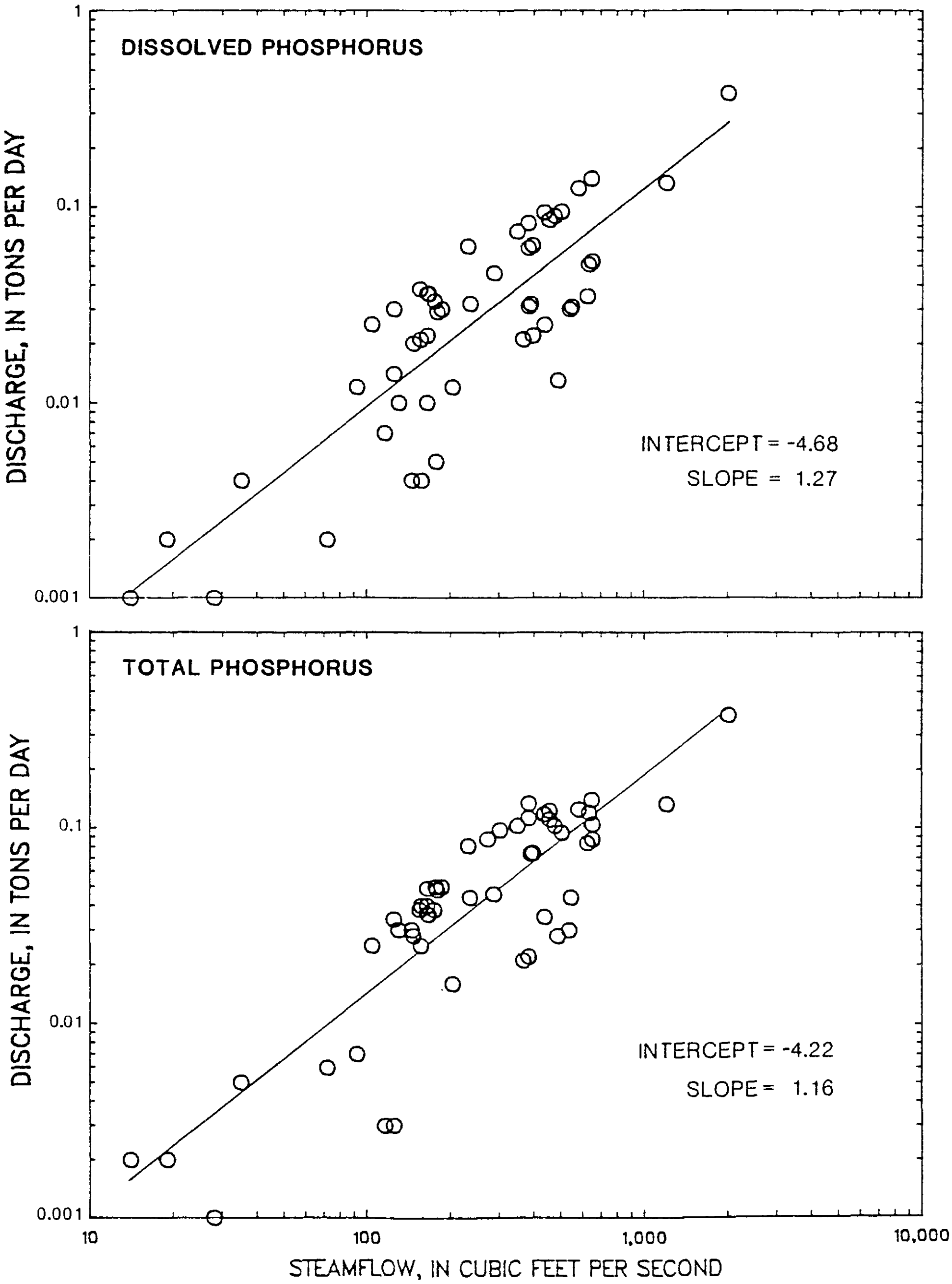


Figure 5.—Relation between phosphorus-species discharge and streamflow.

Table 8.--Summary of nitrogen and phosphorus analyses at West Branch Lackawaxen River at Prompton for the 1987 water year

[Results in milligrams per liter]

Constituent	Number of observations	Mean	Median	Standard deviation	Minimum	Maximum	Range
Nitrogen, ammonia, total as nitrogen	9	0.09	0.04	0.10	0.01	0.33	0.32
Nitrogen, ammonia plus organic, total as nitrogen	9	.1	.8	.79	.4	3	.26
Nitrite plus nitrate, total as nitrogen	9	.28	2	.21	.1	.7	.6
Nitrogen total[1/]	9	1.3	1.1	.89	.4	3.5	3.1
Phosphorus total	9	.04	.02	.05	.01	.17	.16
Phosphorus dissolved	9	.05	.01	.07	.01	.2	.09

[1/]Calculated from sum of nitrogen species.

Suspended Sediment

Weekly base-flow and storm samples collected at the gaging station near Aldenville show that suspended-sediment concentrations averaged 3.6 mg/L during base flow and 78 mg/L during storms. Concentrations ranged from 1 mg/L to 760 mg/L. The turbidity is low except during storms and the stream bottom is readily visible.

An average annual load near Aldenville of about 2,800 tons of suspended sediment was estimated by applying the sediment-transport curve (fig. 6) to the duration of streamflow. The maximum suspended-sediment discharge during the 1987 water year was 400 ton/d (ton per day) and the minimum was 0.05 ton/d. About 51 percent of the annual sediment load was transported during 7 days of stormwater runoff. The average yield for the basin was estimated to be about 70 (ton/mi^2)/yr (ton per square mile per year) by dividing 2,800 ton/yr by the drainage area above the Aldenville gage, 40.6 mi^2.

If the sediment-trap efficiency of the lake is assumed to be 100 percent and the density of the deposited sediment is assumed to be 70 lbs/ft^3 (pound per cubic foot), the sediment-load space allocated in the raised pool (774 acre-ft) will have a life expectancy of about 287 years.

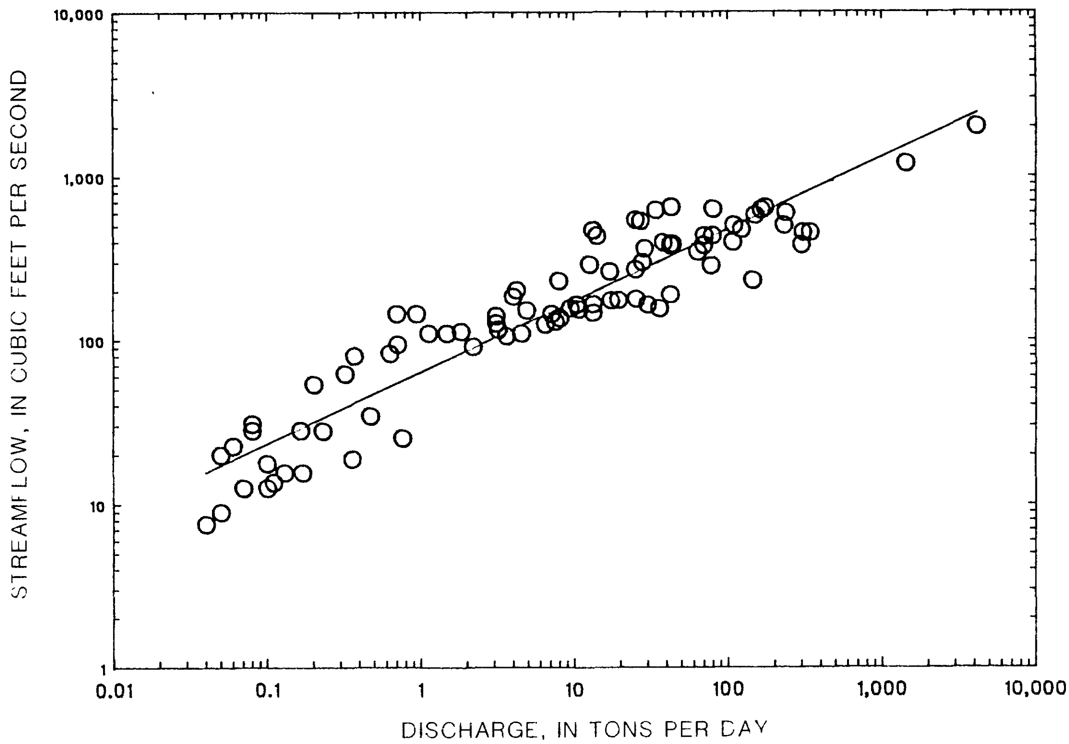


Figure 6.--Relation between suspended-sediment discharge and streamflow.

Life expectancy of sediment pool was calculated as follows:

Drainage area = 59.6 mi^2
Capacity of sediment reserve pool = 774 acre-ft
Sediment yield = 70 $(tons/mi^2)/yr$
70 $(ton/mi^2)/yr$ X 2,000 lbs/ton = 140,000 $(lbs/mi^2)/yr$
Density of deposited sediment = 70 lbs/ft^3

$$\frac{140{,}000\ (lbs/mi^2)/yr}{70\ lbs/ft^3} = 2{,}000\ (ft^3/mi^2)/yr \text{ deposited sediment}$$

$$2{,}000\ (ft^3/mi^2)/yr \times 59.6\ mi^2 = 119{,}200\ ft^3/yr$$

$$\frac{119{,}200\ ft^3/yr}{43{,}560\ ft^3/acre\text{-}ft} = 2.7\ acre\text{-}ft/yr$$

$$\frac{774\ acre\text{-}ft}{2.7\ acre\text{-}ft/yr} = 287 \text{ yrs life sediment reserve pool}$$

As stated by Miller (1951, p. 14), "the sediment-rating curve, flow-duration curve method of estimating sediment yield appears to be sufficiently accurate for practical application. When applied to the flow-duration curve the correlation between sediment and discharge based upon the 19 years of record at Bluff, Utah, checks the 19-year measured quantity within 4 percent.

Specific Conductance and pH

Specific conductance was inversely related to streamflow and ranged from 62 to 109 $\mu S/cm$ (microsiemens per centimeter at 25 degrees Celsius) during the study period. These values are well within the range found in other Pennsylvania uncontaminated, predominantly-forested drainages in similar geologic environments.

Values of pH are influenced by the biological activity and carbonate equilibrium throughout the diel and seasonal cycle. Observed inflow pH values (table 3) ranged from 7.3 to 8.6; the median observed value was 7.6. Outflow pH values (table 7) were also generally within this range but appeared to be influenced by the seasonal biological and chemical activity within the lake. The median outflow pH value was 7.5. All pH values were within State and Federal guidelines.

LIMNOLOGY OF PROMPTON LAKE

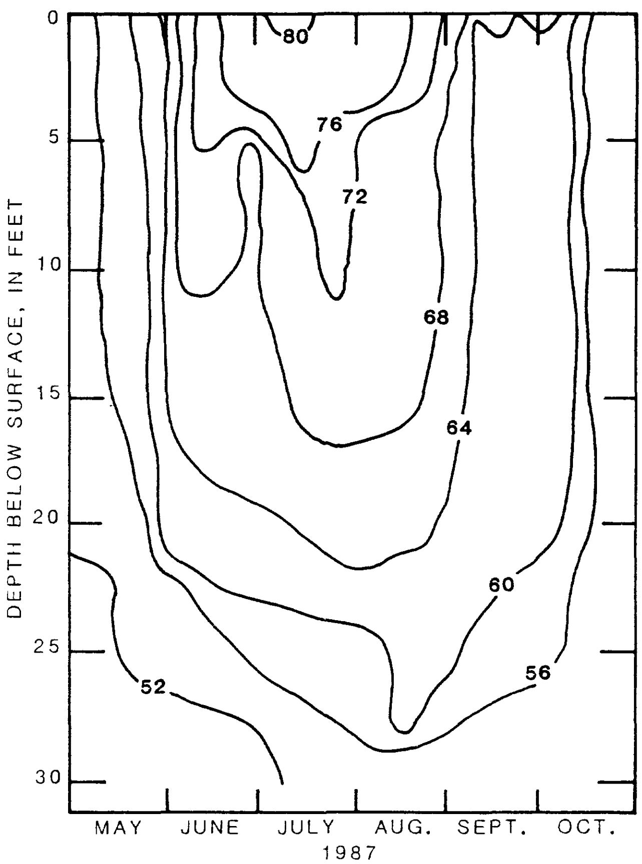
The raising of the pool level in Prompton Lake will change the retention time of the inflow and possibly change the water quality as well. The present conditions of the lake and the possible effects of raising the pool level are discussed below.

Hydrology

The mean theoretical hydraulic retention time for an average annual discharge of 109 ft^3/s presently is about 16 days but will increase to about 140 days at the raised pool volume. The theoretical retention time will increase from about 85 days to about 780 days for late-summer streamflows that average about 20 ft^3/s.

Thermal and Chemical Stratification

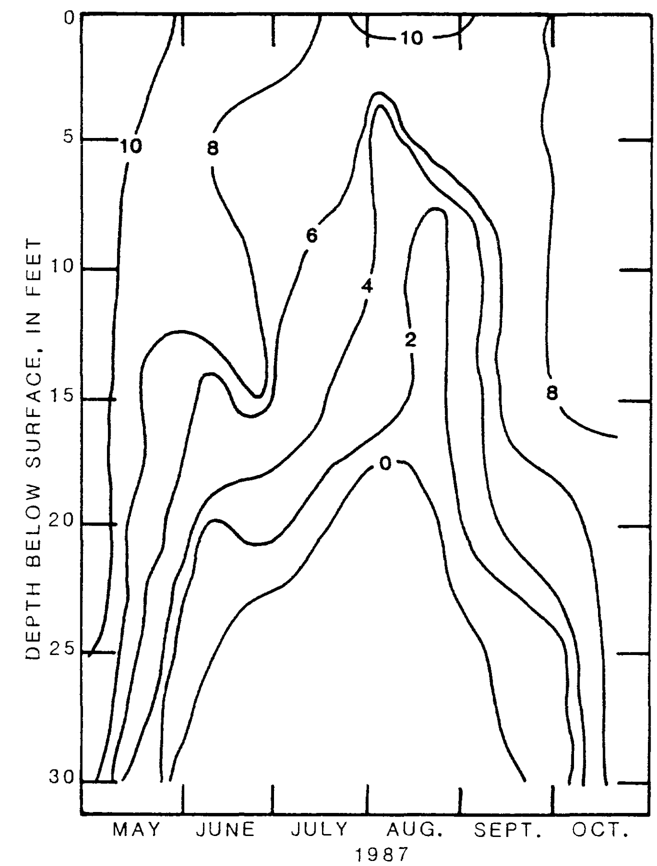
Temperature and chemical profile studies of Prompton Lake have been done by and for the U.S. Army Corps of Engineers nearly annually since 1972. The profile studies show that (1) thermal and chemical stratification usually develops in early June and, unless disrupted by large storms, persists through late September or early October; (2) a thermocline generally is established at a depth of 14 to 20 ft; (3) dissolved-oxygen concentrations below the thermocline are usually less than 2 mg/L; and (4) by mid-July the water below a depth of about 20 ft is anoxic, or nearly so, until the autumnal overturn period. Figures 7 and 8 illustrate the seasonal cycle of temperature and oxygen conditions in Prompton Lake during most of the ice-free period of 1987.



EXPLANATION

-60- LINE OF EQUAL WATER TEMPERATURE, IN DEGREES FAHRENHEIT. CONTOUR INTERVAL FOUR DEGREES FAHRENHEIT

Figure 7.--Water temperature at Prompton Lake Spillway Pool, May through October 1987.



EXPLANATION

-4- LINE OF EQUAL DISSOLVED OXYGEN CONCENTRATIONS, IN MILLIGRAMS PER LITER . CONTOUR INTERVAL TWO MILLIGRAMS PER LITER.

Figure 8.--Dissolved-oxygen concentrations in Prompton Lake Spillway Pool, May through October 1987.

Chemical Constituents

Nitrogen and Phosphorus

As the two major essential elements for plant growth, the concentrations of nitrogen and phosphorus available during the growing season (May through October) are principal components of the trophic state. Nitrogen is present in natural water as organic nitrogen and as inorganic nitrogen in the form of ammonia, nitrite, nitrate, and elemental nitrogen. Phosphorus is present in the form of phosphates in several common minerals and all living matter and often is the limiting factor in the development of algal blooms.

Total nitrogen concentrations in the surface waters of the lake ranged from 0.8 to 2.4 mg/L; the mean was 0.15 mg/L. Total phosphorus concentrations ranged from 0.02 to 0.06 mg/L; the mean was 0.04 mg/L (table 9). Concentrations of total nitrogen and phosphorus in the surface water of the lake generally were sufficient to stimulate algae growth to densities indicative of eutrophic conditions.

Chlorophyll *a* and *b*

Chlorophyll *a* and *b* are complex organic chemicals that enable green plants to transform light energy into plant tissue during photosynthesis. As such, the amount of chlorophyll present at any time is a measure of the quantity of living plant cells, such as algae, in water.

Chlorophyll was measured in the surface waters of the lake from June through September 1987. Chlorophyll *a* concentrations reached a peak of 73 μg/L (micrograms per liter) during August in the mid-lake pool, whereas chlorophyll *b* concentrations reached a peak of 1.2 μg/L during June in the inflow pool (table 9). The summer concentrations of chlorophyll, indicative of eutrophic conditions, are enhanced by adequate supplies of nutrients and long retention times.

Table 9.--Water-quality data, October 1986 and June 1987 through September 1987 in Prompton Lake

[μS/cm, microsiemens per centimeter at 25 degrees Celsius; μg/L, micrograms per liter; mg/L, milligrams per liter; --, no data; <, less than]

413735075203101 - Prompton Lake-Inflow Pool

Date	Time	Specific conductance (μS/cm)	pH (standard units)	Nitrogen, organic total (mg/L as N)	Nitrogen, ammonia total (mg/L as N)	Nitrogen, nitrite total (mg/L as N)	Nitrogen, ammonia + organic total (mg/L as N)	Nitrogen, NO_2+NO_3 total (mg/L as N)	Nitrogen, total (mg/L)	Phosphorus, total (mg/L)	Phosphorus, dissolved (mg/L)	Chlor-a phytoplankton chromo fluorom (μg/L)	Chlor-b phytoplankton chromo fluorom (μg/L)
OCT 1986 15...	1030	68	6.5	0.66	0.14	0.01	0.8	0.20	1.0	0.04	<0.20	--	--
JUN 1987 10...	1100	--	--	.56	.04	<0.01	.6	.20	0.8	.05	.02	13	1.2
JUL 09...	1245	74	7.6	--	<0.01	<0.01	.9	<0.10	<1.0	.04	<0.01	27	1.0
AUG 12...	1045	87	7.4	1.5	.02	<0.01	1.5	<0.10	<1.6	.06	.03	42	<0.1
SEP 24...	0930	63	7.8	.56	.04	<0.01	.6	.20	.8	.04	<0.01	13	0.4

413657075203701 - Prompton Lake - Mid-Lake Pool

Date	Time	Specific conductance (μS/cm)	pH (standard units)	Nitrogen, organic total (mg/L as N)	Nitrogen, ammonia total (mg/L as N)	Nitrogen, nitrite total (mg/L as N)	Nitrogen, ammonia + organic total (mg/L as N)	Nitrogen, NO_2+NO_3 total (mg/L as N)	Nitrogen, total (mg/L)	Phosphorus, total (mg/L)	Phosphorus, dissolved (mg/L)	Chlor-a phytoplankton chromo fluorom (μg/L)	Chlor-b phytoplankton chromo fluorom (μg/L)
OCT 1986 15...	1000	64	6.5	0.98	0.12	<0.01	1.1	0.20	1.3	0.03	<0.20	--	--
JUN 1987 10...	1115	--	--	.86	.04	<0.01	0.9	.10	1.0	.02	.01	20	0.6
JUL 09...	1300	74	8.4	--	<0.01	<0.01	1.4	<0.10	<1.5	.03	<0.01	31	.8
AUG 12...	1100	85	7.6	1.7	.02	<0.01	1.7	<0.10	<1.8	.05	.02	73	<0.2
SEP 24...	0945	59	7.8	.59	.01	<0.01	0.6	.20	.8	.04	<0.01	21	.6

413539075194801 - Prompton Lake - Spillway Pool

Date	Time	Specific conductance (μS/cm)	pH (standard units)	Nitrogen, organic total (mg/L as N)	Nitrogen, ammonia total (mg/L as N)	Nitrogen, nitrite total (mg/L as N)	Nitrogen, ammonia + organic total (mg/L as N)	Nitrogen, NO_2+NO_3 total (mg/L as N)	Nitrogen, total (mg/L)	Phosphorus, total (mg/L)	Phosphorus, dissolved (mg/L)	Chlor-a phytoplankton chromo fluorom (μg/L)	Chlor-b phytoplankton chromo fluorom (μg/L)
OCT 1986 15...	0930	68	6.4	2.1	0.12	0.01	2.2	0.2	2.4	0.03	<0.20	--	--
JUN 1987 10...	1130	--	--	0.88	.02	<0.01	0.90	<0.1	<1.0	.02	.02	14	0.5
JUL 09...	1315	0	8.4	--	<0.01	<0.01	.70	<0.1	<0.9	.02	<0.01	20	.7
AUG 12...	1115	85	7.9	1.1	.02	<0.01	1.1	<0.1	<1.2	.04	.02	67	<0.1
SEP 24...	1000	58	7.7	.69	.01	<0.01	.70	.2	0.9	.06	<0.01	27	.9

Environmental Effects of Raising the Level of Prompton Lake

Raising the pool elevation from 1,125 ft to 1,180 ft will (1) increase lake habitat for fish and wildlife and increase the volume of cold water available for release to the tail-water trout fishery; and (2) change water quality by decreasing the loading rate of nutrients. Detrimental effects will include the flooding of existing wetland, woodland, farmland, and the impounding of 1½-miles of free-flowing trout stream. As illustrated in figure 9, the total phosphorus loading rate will decrease from 0.00072 $(lb/ft^2)/yr$ (pound per square foot per year) to 0.00029 $(lb/ft^2)/yr$ because of the increase in the area of the lake. However, the ratio of mean depth to hydraulic residence time will be such that the lake may continue to be somewhat eutrophic. Table 10 summarizes morphometric, hydrologic, and phosphorus-budget data for Prompton Lake and for three other northeastern Pennsylvania U.S. Army Corps of Engineer lakes.

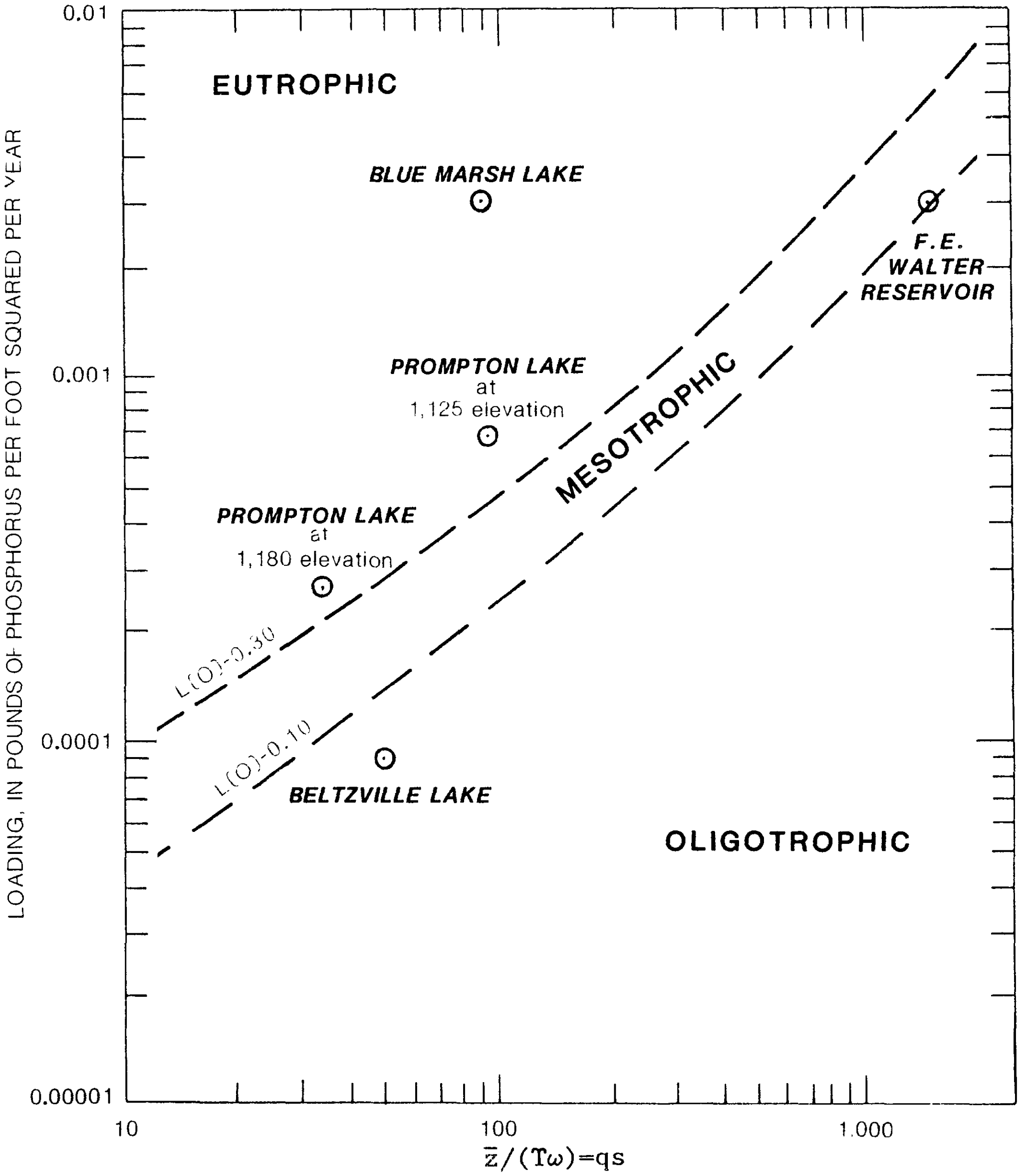


Figure 9.--Relation of total phosphorus loading to the ratio of mean depth ($\bar{z}$) to hydraulic residence time ($T\omega$) and to the eutrophication potential of a lake.

Table 10.--Summary of morphometric, hydrologic, and phosphorus-budget data for Prompton Lake and three other eastern Pennsylvania lakes[1/]

	Beltzville Lake	F.E. Walter Lake	Blue Marsh Lake	Prompton Lake: Present at elevation of 1,125 ft	Prompton Lake: Proposed at elevation of 1,180 ft
Drainage area (km^2)	249.4	749	453	154.4	154.4
Lake area (km^2)	3.83	.36	3.89	1.17	2.91
Drainage area/ lake area	65	2,081	116.5	131.97	53.06
Volume ($10^6 m^3$)	49.3	2.47	15.4	4.22	38.11
Mean depth (m)	12.9	6.8	5.6	3.7	13.1
Total discharge units	192	538	247	97.3	97.3
Flushing rate (/yr)	3.9	217.8	15.8	23	2.6
Hydraulic residence time in years	.26	.0045	.06	.04	.38
Aerial loading as P [(g/m^2)/yr]	.47	15.3	10.6	3.58	1.44
Volumetric loading as P [(g/m^3)/yr]	.04	2.25	2.7	.79	.11
Mean depth/hydraulic residence time	49.1	1,511	88.9	92.5	34.5

1/Data is in metric units to be comparable with published data.

Raising the normal pool level from the present 1,125-ft elevation to the designed 1,180-ft level will change hydraulic gradients in the aquifers near the lake. This change will be 55 ft at the lake. However, both the land surface and the water table slope steeply (several hundred feet per mile) towards the reservoir; therefore, the change in head caused by raising the pool will be, at most, a few feet at distances of greater than one-half mile from the lake. Only about 30 wells are near enough to the lake (within one-half mile) to have any substantial rise in water level. Raising the pool level will have no effect on wells downstream, except those very near the dam. The yield of these wells will probably increase slightly.

The mineral content of water in the aquifer may increase slightly as lake water enters the aquifer when the stage in the lake is being raised. Concentrations of iron and manganese within 100 ft of the lake may be higher than background. This should be a transient effect, because after a new equilibrium is reached, water will again flow from the aquifer to the lake. This will flush the lake water that entered the aquifer back into the pool. The water quality of wells close to the lake may be affected.

SUMMARY

Past and present water-quality data indicate that the waters of the West Branch Lackawaxen River contain elevated concentrations of nitrogen and phosphorus. The elevated supplies of nutrients and long retention times in Prompton Lake increase concentrations of chlorophyll to eutrophic levels during the summer.

Total annual loads to Prompton Lake for total nitrogen, phosphorus, and suspended sediment were estimated to be 114 tons, 4.6 tons, and 2,800 tons, respectively. Suspended-sediment yields of about 70 (tons/mi^2)/yr can be expected with current land use. Life expectancy of the proposed sediment-load space in the lake is about 287 years.

The lake is thermally and chemically stratified from June through September, and a large volume of water is anoxic below a depth of about 20 ft.

Raising the pool elevation from 1,125 ft to 1,180 ft above sea level is expected to have a beneficial effect on the water quality by reducing the nutrient loading rate per unit area. However, the lake can be expected to remain eutrophic. Raising the elevation will increase the mean depth from 12 ft to 43 ft and increase the volume from 3,355 acre-ft to 31,900 acre-ft. This nearly tenfold increase in volume will increase theoretical retention times from 16 to 140 days at mean streamflows and from 86 to 780 days at summer streamflows.

Ground water in the region of Prompton Lake is soft and acidic and locally contains elevated concentrations of iron and manganese. Raising the normal pool elevation from 1,125 ft to 1,180 ft will change the head in the water table only a few feet at distances greater than one-half mile from the lake. Yields of wells close to the lake probably will increase slightly. Ground-water quality may degrade slightly because of infiltration of lake water but only until a new hydraulic equilibrium is reached.

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