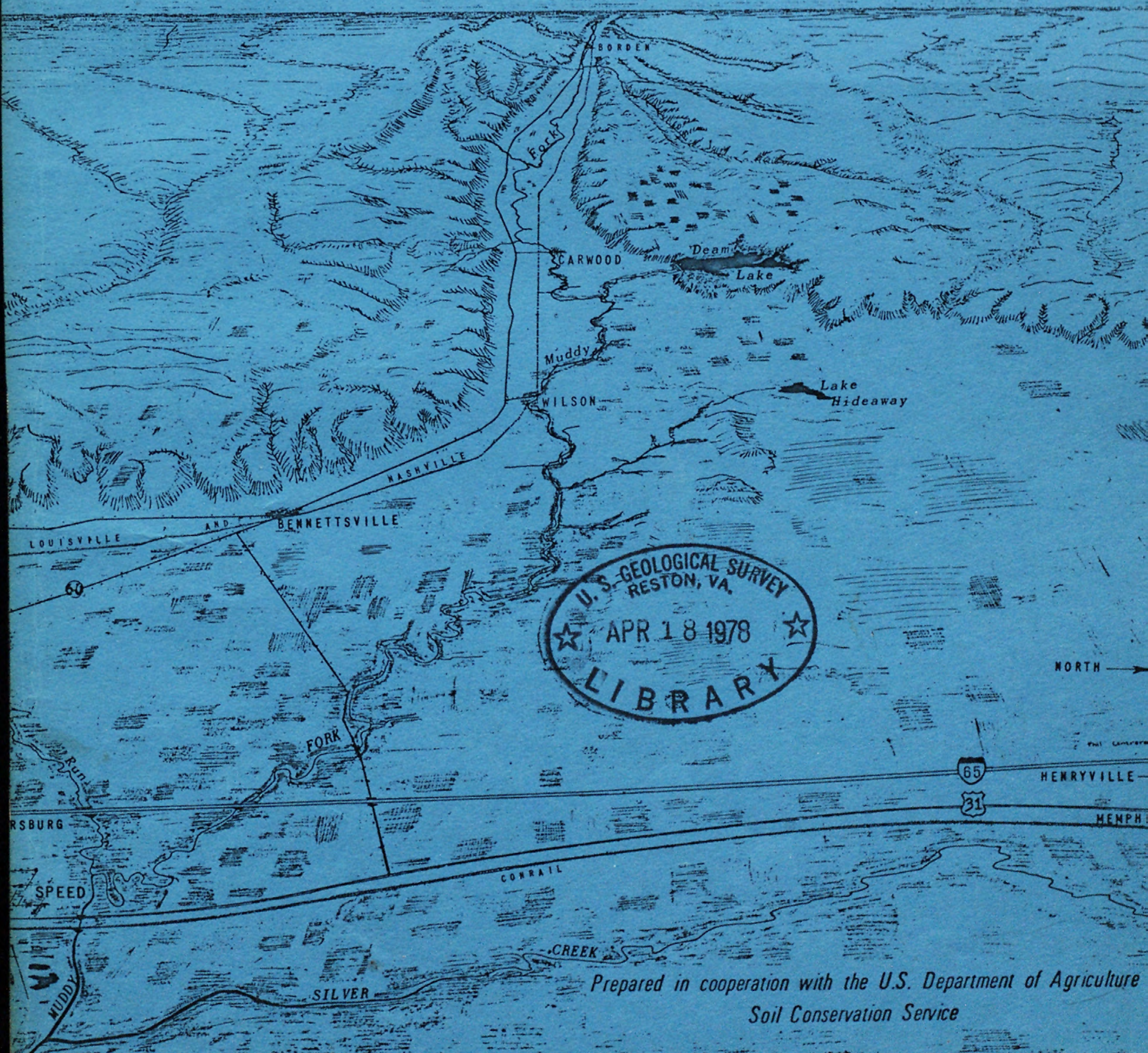
UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

Water-quality assessment of the Muddy Fork Silver Creek watershed, Clark, Floyd, and Washington Counties, Indiana

OPEN-FILE REPORT
78-202



Prepared in cooperation with the U.S. Department of Agriculture
Soil Conservation Service

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WATER-QUALITY ASSESSMENT OF THE MUDDY FORK SILVER CREEK WATERSHED, CLARK, FLOYD, AND WASHINGTON COUNTIES, INDIANA

By Mark A. Hardy

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METRIC CONVERSION FACTORS

The U.S. customary units used in this report can be converted to the metric system of units as follows:

Multiply U.S. customary units	By	To obtain metric unit
inch (in)	25.4	millimeters (mm)
foot (ft)	.3048	meter (m)
mile (mi)	1.609	kilometers (km)
square foot (ft^2)	.0929	square meter (m^2)
square mile (mi^2)	2.590	square kilometers (km^2)
cubic foot per second (ft^3/s)	.02832	cubic meter per second (m^3/s)
acre	.4047	hectare (ha)
acre-foot	1,233	cubic meters (m^3)

WATER-QUALITY ASSESSMENT OF THE MUDDY FORK SILVER CREEK WATERSHED, CLARK, FLOYD, AND WASHINGTON COUNTIES, INDIANA

By Mark A. Hardy

ABSTRACT

Data collected for a wide range of flow conditions from September 8, 1975, to July 13, 1976, reveal that human and animal waste loading of streams and pesticide use in the watershed are probably the most significant water-quality problems. Generally, the type(s) of water in tributary streams in the south and southwest parts of the watershed was calcium bicarbonate and in other tributaries were calcium sulfate and magnesium sulfate. Dissolved-solids concentrations of discharge from top-spill reservoirs were lower and more consistent over a range of flows than concentrations from uncontrolled streams. Chemical characteristics of discharges from bottom-draw reservoirs differed from those of discharges from the other reservoirs. More than half the manganese concentrations equaled or exceeded 0.05 milligrams per liter, the maximum concentration recommended for domestic water supplies. Leaf fall in forested parts of the watershed are probably a source of this manganese. Nitrate (as nitrogen) concentration of streams ranged from 0.00 to 2.5 milligrams per liter; orthophosphate (as phosphorus), from 0.00 to 0.29 milligrams per liter; and total organic carbon, from 2.0 to 14 milligrams per liter.

Concentrations of fecal coliform bacteria and fecal streptococcal bacteria ranged from 5 to 65,000 colonies per 100 milliliters and from 5 to 14,000 colonies per 100 milliliters, respectively. Occasional human-waste contamination is indicated downstream from the towns of Borden and Speed. Data on periphyton, phytoplankton, and benthic communities collected during low flow in September 1975 indicate organic loading of Muddy Fork downstream from the town of Speed. Phytoplankton community structures varied temporally and spatially.

Ranges of concentration of various chlorinated hydrocarbons in samples of bed materials (in micrograms per kilogram) were: chlordane, from 0 to 14; DDT, from 0 to 19; and PCB's, from 0 to 11. Concentrations of aldrin, DDD, DDE, heptachlor, and heptachlor epoxide of 5.1 micrograms per kilogram or less were also detected. The presence of these compounds makes them potentially available for accumulation in the biological food chain.

PURPOSE AND SCOPE

The purpose of this study, one in a series prepared by the U.S. Geological Survey in cooperation with the U.S. Soil Conservation Service, was to evaluate surface-water quality in the Muddy Fork Silver Creek watershed in order to determine existing and (or) potential water-quality problems. Particular attention was given to municipalities, reservoirs, and areas of proposed channel improvement as described by the Watershed Work Plan, Muddy Fork of Silver Creek Watershed (U.S. Soil Conservation Service, 1964).

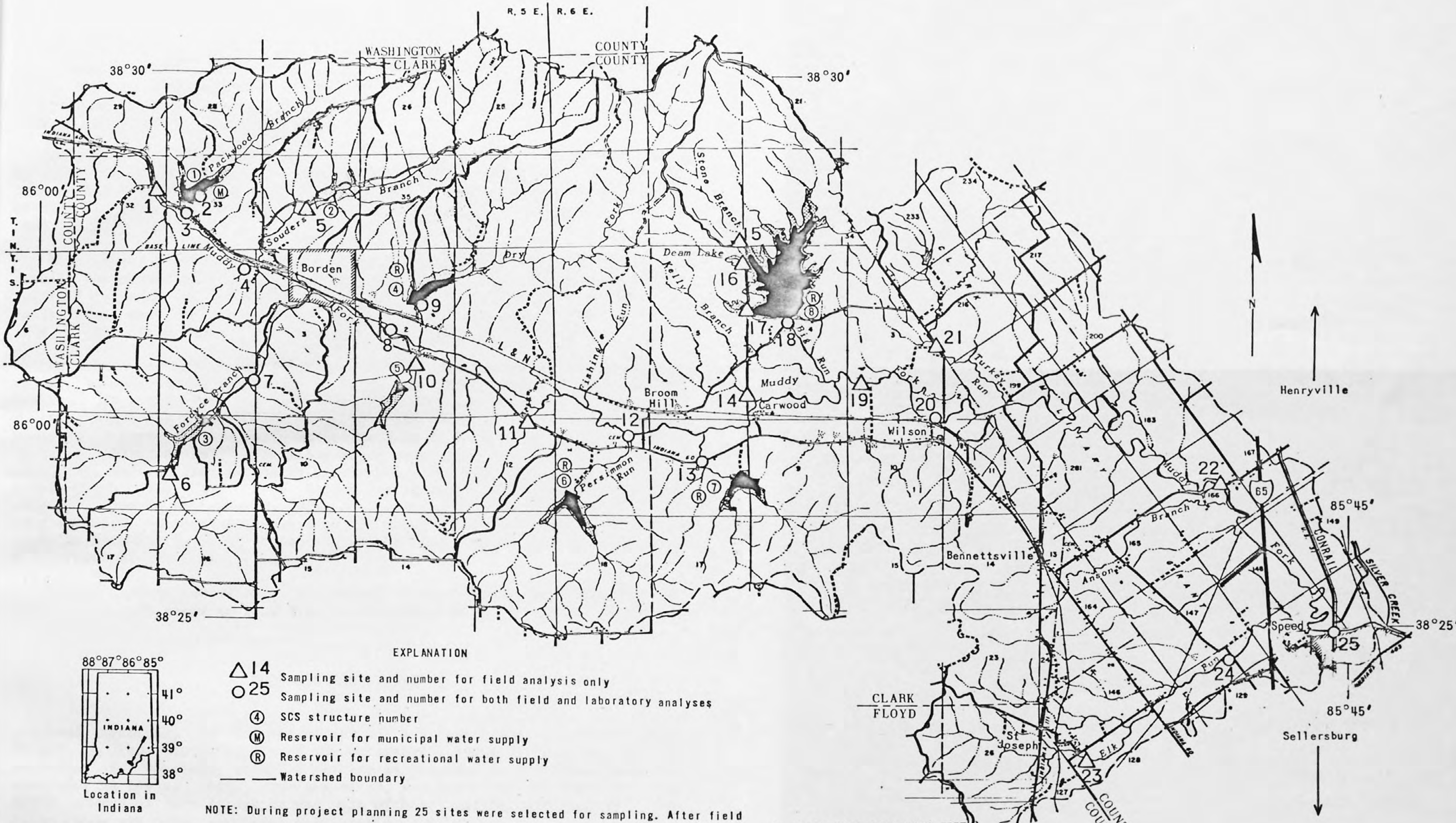
Data were collected from September 8, 1975, to July 13, 1976. Locations of sampling sites are shown in figure 1. Although 25 sites were selected in the project planning stage, only 16 were sampled. Of the sites sampled, sites 3, 4, 8, 19, 20, and 25 are on Muddy Fork. Sites 9, 12, 21, and 24 are on tributaries, and sites 2, 5, 7, 10, 13, and 18 are on tributaries downstream from reservoir discharges.

Field and laboratory data for water samples are summarized in table 1 (p. 33). Field data included water temperature, specific conductance, pH, dissolved oxygen, and estimates of stream discharge. Laboratory analyses of water samples included determination of concentrations of inorganic constituents, nutrients, and selected metals by methods of Brown, Skougstad, and Fishman (1970) and total organic carbon by the method of Goerlitz and Brown (1972, p. 4-6). Chlorinated hydrocarbons in bed materials were determined by methods of Goerlitz and Brown (1972).

Groups from the biological community included fecal bacteria, phytoplankton, periphyton, and benthic invertebrates and were sampled according to the methods of Slack, Averett, Greeson, and Lipscomb (1973). Samples for determination of fecal coliform and fecal streptococal populations were collected and analyzed on the same day. After they were preserved, samples of the phytoplankton, periphyton, and benthic invertebrate communities were sent to the U.S. Geological Survey laboratory in Doraville, Ga., for identification. The periphyton and benthic invertebrates were sampled only during the first sampling period. Other types of data collected at each site were dependent on site location relative to present or proposed watershed development and on data obtained as the project progressed.

ENVIRONMENTAL SETTING

The 67-mi^2 Muddy Fork Silver Creek watershed (fig. 1), within the boundaries of Clark, Floyd, and Washington Counties in southeast Indiana, is about 15 mi long and 4.5 mi wide. Elevation ranges from 437 ft at the mouth of Muddy Fork to approximately 980 ft in the uplands. The western half of the watershed, in the Norman Upland physiographic unit of Indiana, is characterized by steep hills, narrow ridge tops, and narrow flood plains. The



Base from Department of Agriculture, Soil Conservation Service, Milwaukee, Wisconsin 1964.

Figure 1.-- Location of data-collection sites, Muddy Fork Silver Creek watershed, Ind.

author noted extensive timber cutting on some of the hills west of Borden. The eastern half of the watershed, in the glaciated Scottsburg Lowland, is characterized by low, gently rolling uplands and wide flood plains. Here, the bedrock is shale, except for some limestone near the mouth of Muddy Fork. Glacial drift and lacustrine soils are found in the flood plain. Soils along the Muddy Fork are alluvial (U.S. Soil Conservation Service, 1964, p. 56).

Mean monthly temperatures range from 0.6°C (Celsius) in January to 25°C in July. Recorded extremes are 43.9°C and -32.2°C. The average date of the last spring freeze is May 2 and the first fall freeze, October 6, an average of 157 days without freezing temperatures (U.S. Soil Conservation Service, 1964, p. 7).

Mean annual precipitation is 42.7 in, and April, May, and June are usually the months when precipitation is most intense. The minimum annual rainfall recorded at the Henryville weather station, 9 mi north of site 25, is 31.2 in, and the maximum is 59.6 in (U.S. Soil Conservation Service, 1964, p. 7). Mean annual runoff is 16.5 in (Hoggatt, 1962, p. 9).

No continuous streamflow data are available for the Muddy Fork of Silver Creek. Because conditions of Silver Creek and Muddy Fork of Silver Creek are similar, a flow-duration curve for Muddy Fork was derived from the flow-duration curve for Silver Creek (fig. 2). The curve for Silver Creek is based on 18 years of mean daily discharge data from the Sellersburg station (Horner, 1976, p. 39). A duration curve very similar to that for Silver Creek was derived from estimates of discharge at site 25 on Muddy Fork of Silver Creek (fig. 1). Flow during water sampling on Muddy Fork varied widely. Flow on September 8, 1976, was exceeded 91 percent of the time; on July 13, 1976, 51 percent of the time; on March 11, 1976, 20 percent of the time; on December 3, 1975, 17 percent of the time; and on June 6, 1976, only 0.9 percent of the time.

During extreme low flows, as during sampling from September 8 to 10, 1976, Muddy Fork seems to lose flow to the alluvium between sites 20 and 25.

ECONOMIC CONDITIONS

Land ownership is private except for a 5.8-mi^2 part of Clark State Forest in the northern part of the watershed. About 70 percent of the watershed is woodland, about 25 percent is cropland or grassland, and the remainder is towns, roads, surface water, and miscellaneous features. The major source of farm income is the sale of hogs, cattle, and poultry. The major crops are corn, soybeans, small grain, and hay.

The towns of Borden and Speed each have a population of about 300, and each support a small industry. Borden has a cabinet-making plant, and Speed has a cement company (U.S. Soil Conservation Service, 1964, p. 8-9).

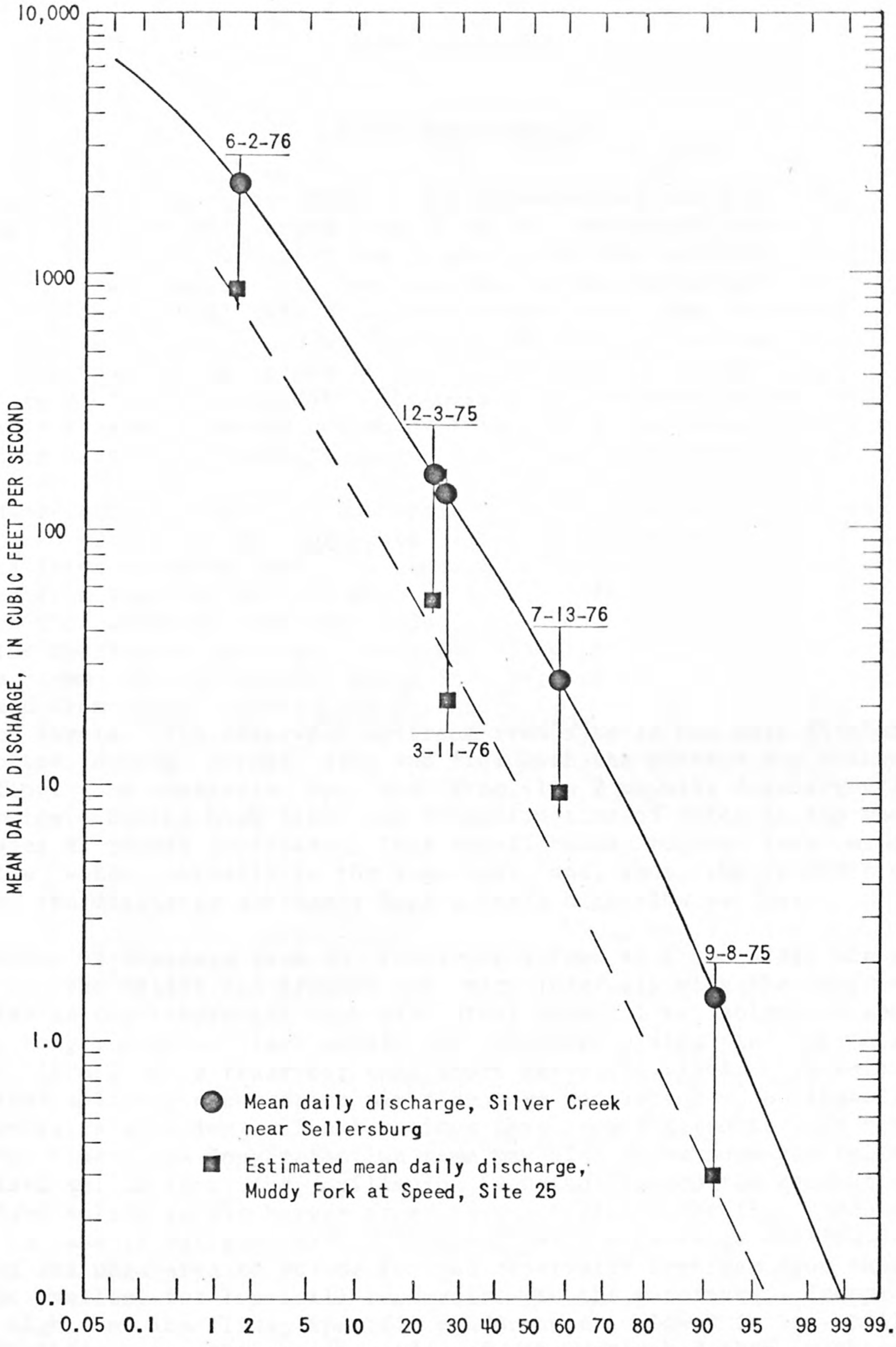


Figure 2.-- Flow-duration curves for Silver Creek near Sellersburg, Ind., and Muddy Fork Silver Creek at Speed, Ind. Site 25 is plotted on figure 1.

DATA EVALUATION

Field Measurements

Dissolved-oxygen concentration in the watershed was generally near theoretical saturation but ranged from 21 to 147 percent of saturation as shown in table 1. Supersaturation due to photosynthetic activity was often noted in the shallow streams of the western half of the watershed. Concentrations were below theoretical saturation downstream from two reservoirs (sites 2 and 13) during June and at sites 19, 20, and 25 from September 8 to 10, 1975. The unsaturated values at the latter three sites (57, 35, and 21 percent, respectively) indicate the possibility of organic enrichment beyond the assimilation capacity of Muddy Fork during low flow. Additional indicators of organic enrichment, cited later, support this contention.

The relation of specific conductance to discharge is presented in figures 3 and 4. Figure 3 represents sites on tributaries, and figure 4 represents sites on Muddy Fork. In general, specific conductance of water discharged from the top-spill reservoirs varied little with discharge, except at high flow when the specific conductance decreased significantly. Except for the reservoirs upstream from sites 2 and 13, all the reservoirs discharge from the epilimnion, which is generally well mixed. The reservoirs upstream from sites 2 and 13 can discharge from either the surface or subsurface levels. The reservoir upstream from site 13 can only discharge from the bottom during normal flow and from both the surface and bottom during high flow. The reservoir upstream from site 2 usually discharges from the epilimnion. During high flow, the retention time of water in the reservoirs decreases as runoff increases. This runoff tends to be less mineralized than the water normally in the reservoir, and, thus, the specific conductance of the discharge decreases during these high-flow periods.

Ratios of drainage area to reservoir volume at flood stage are shown in table 2. The ratios are assumed to vary inversely with the residence time of water in the reservoirs when all other physical variables are nearly the same. Long residence times permit more thorough mixing in the epilimnion (upper layer) of a reservoir than short residence times. Therefore, the dissolved-solids concentration might be more consistent in epilimnetic water in reservoirs with long retention times than from reservoirs with short retention times. A long retention time may also allow more precipitation of dissolved solids from the epilimnion and thus reduce the concentration of dissolved solids in discharges from this stratum. Specific conductance at sites 2 and 18 was generally consistent for a wide range of flow. The ratios of drainage area to volume for the reservoirs upstream from these sites are the smallest for top-spill reservoirs in the watershed. Except for extreme high and low flows, specific conductance is lower in top-spill reservoir discharges on the north side of the watershed than in those on the south side. The ratios of drainage area to volume are lower for top-spill reservoirs on the north side of the watershed than for those on the south side.

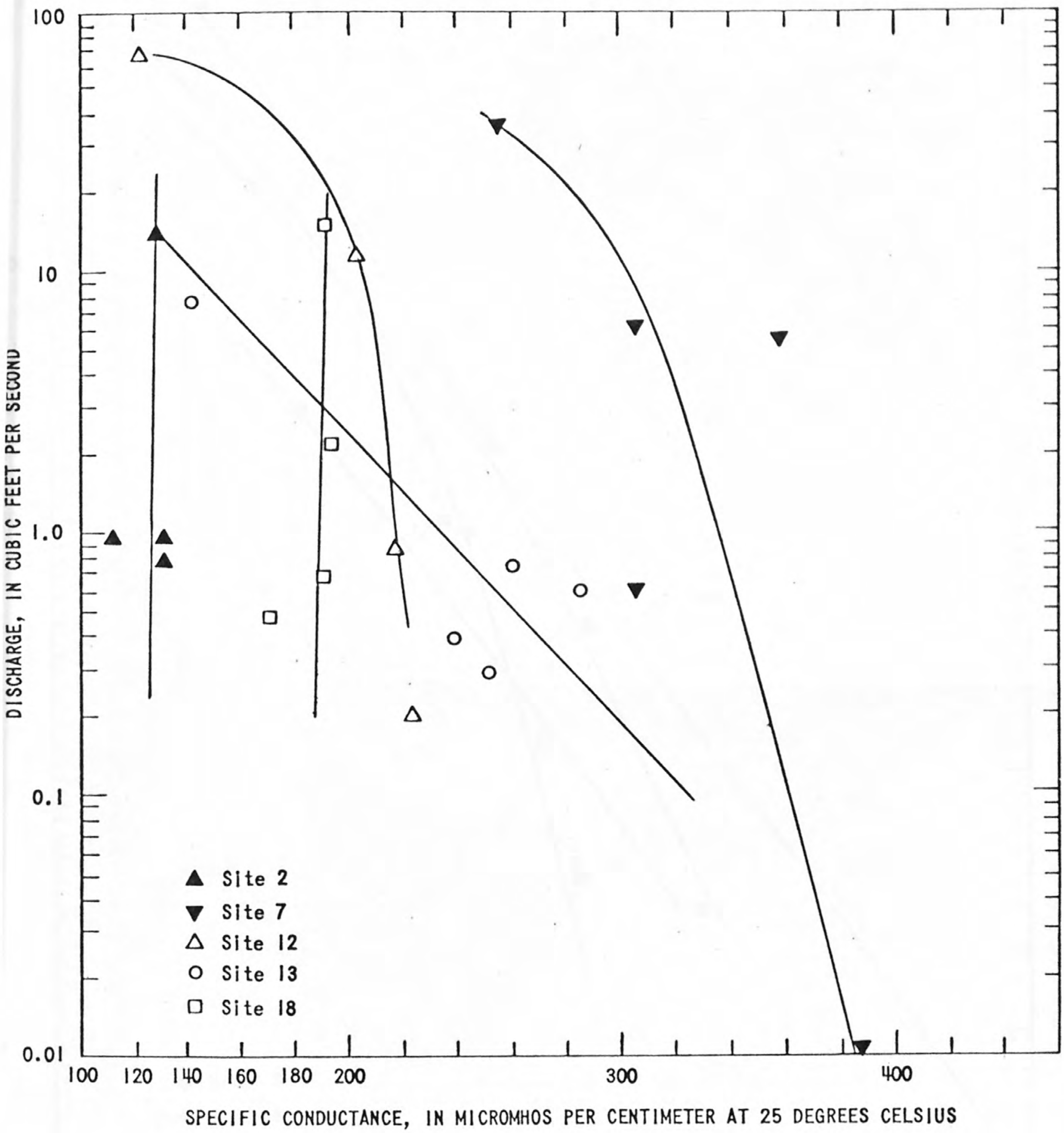


Figure 3.-- Relation of specific conductance to discharge for reservoirs and tributaries in Muddy Fork Silver Creek watershed, Ind., from September 1975 to July 1976. Site numbers are plotted on figure 1.

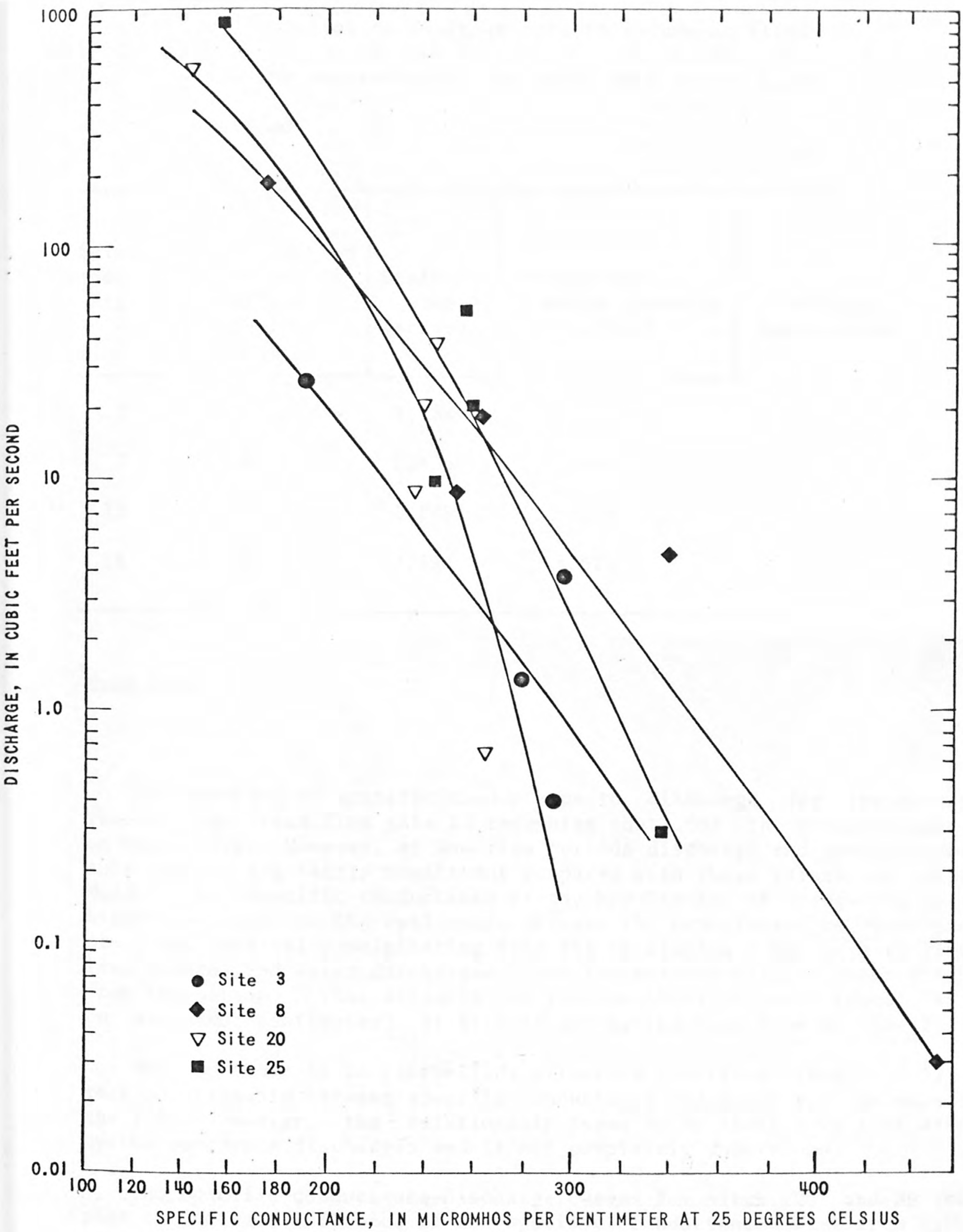


Figure 4.-- Relation of specific conductance to discharge on Muddy Fork Silver Creek watershed, Ind., September 1975 to July 1976. Site numbers are plotted on figure 1.

Table 2.--Ratios of drainage area to volume at flood stage for reservoirs in the Muddy Fork Silver Creek watershed

Site (*See* fig. 1.)	Soil Conservation Service structure number	Drainage area (acres)	Floodwater storage capacity (acre-feet)	Drainage area/volume
2	1	1,284	410	3.1
7	3	2,456	620	4.0
13	7	1,175	476	2.5
18	[1]8	2,394	8,625	.28

[1]Deam Lake.

The relation of specific conductance to discharge for the bottom-draw reservoir upstream from site 13 resembles that for the non-impounded water on Muddy Fork. However, at low-flow periods discharge and specific conductance values are fairly consistent compared with those values at sites on Muddy Fork. Specific conductance of the hypolimnion of reservoirs is often higher than that of the epilimnion because the hypolimnion receives and redissolves material precipitating from the epilimnion. During high flow, the less mineralized water discharged from the surface dilutes water discharged from the bottom. This accounts for the low specific conductance, 145 µmho/cm (micromhos/centimeter) at site 13 during the high flow on June 2, 1976.

Because there is no controlling structure upstream from site 12, a direct relationship between specific conductance and discharge was expected at the site. However, the relationship seems to be similar to that displayed by the reservoir discharges and is not completely understood.

The specific conductance-discharge curves for sites 20 and 25 (fig. 4) seem to indicate influence of low specific conductance water from tributary streams in the mid-reach area of the watershed. All measurements of specific conductance at site 20 were lower than those at site 8 because of the lower specific conductance of water entering Muddy Fork between these two sites. Higher specific conductance water from sites 21 and 24 probably accounts for the increase of specific conductance from site 20 to site 25. The highest specific conductance values in the watershed were measured at sites 4, 7, and 8 (517, 384, and 455 µmho/cm, respectively) during sampling on September 8 and 9, 1975. Chemical analyses show that sodium and chloride concentrations at these sites were much higher at this time than during other samplings. The significance of these sodium and chloride concentrations is discussed in the section, "Chemical Data."

The minimum and maximum pH values, 6.7 and 8.9, were recorded at site 3 on June 2 and July 13, 1976, respectively. These values, which suggest the influence of photosynthetic activity and residence time of soil water, are discussed in the section, "Chemical Data."

Stream temperature on Muddy Fork ranged from 4.9° to 42.0°C. The temperature of water discharged from the reservoir upstream from site 13 was lower than that of other flows during the September and July samplings because the water was discharged from the hypolimnion. The relatively low temperature (17.2°C, table 1) recorded at site 18 on July 13, 1976, is surprising, as the State of Indiana, Department of Natural Resources, has reported that the reservoir discharges from the surface.

Chemical Data

Inorganic

Stiff (1951) patterns representing water in the Muddy Fork Silver Creek watershed are shown on figure 5. Patterns for sites 12, 13, and 18 represent calcium sulfate and magnesium sulfate types of water. The sources of these ions are probably gypsum and other evaporite minerals in the New Providence Shale in Clark and Scott Counties (Erd and Greenberg, 1960). Water at site 13 was a calcium sulfate type on September 9, 1975, and was magnesium sulfate type on June 2, 1976. Calcium generally precipitates from solution more readily than magnesium in aquatic systems (Hem, 1970, p. 144-145). In the reservoir upstream from site 13, calcium probably precipitated from the epilimnion and redissolved in the hypolimnion, whereas magnesium remained dissolved in the epilimnion. If the calcium precipiated and redissolved, calcium would be the dominant cation in the discharge from the hypolimnion alone on September 9, whereas magnesium would be the dominant cation in the mixed discharge from the hypolimnion and epilimnion on June 2, 1976. The reservoir upstream from site 18 discharges a magnesium sulfate type of water from the surface. There is no controlling structure upstream from site 12, and calcium and magnesium are codominant cations in samples collected at that site.

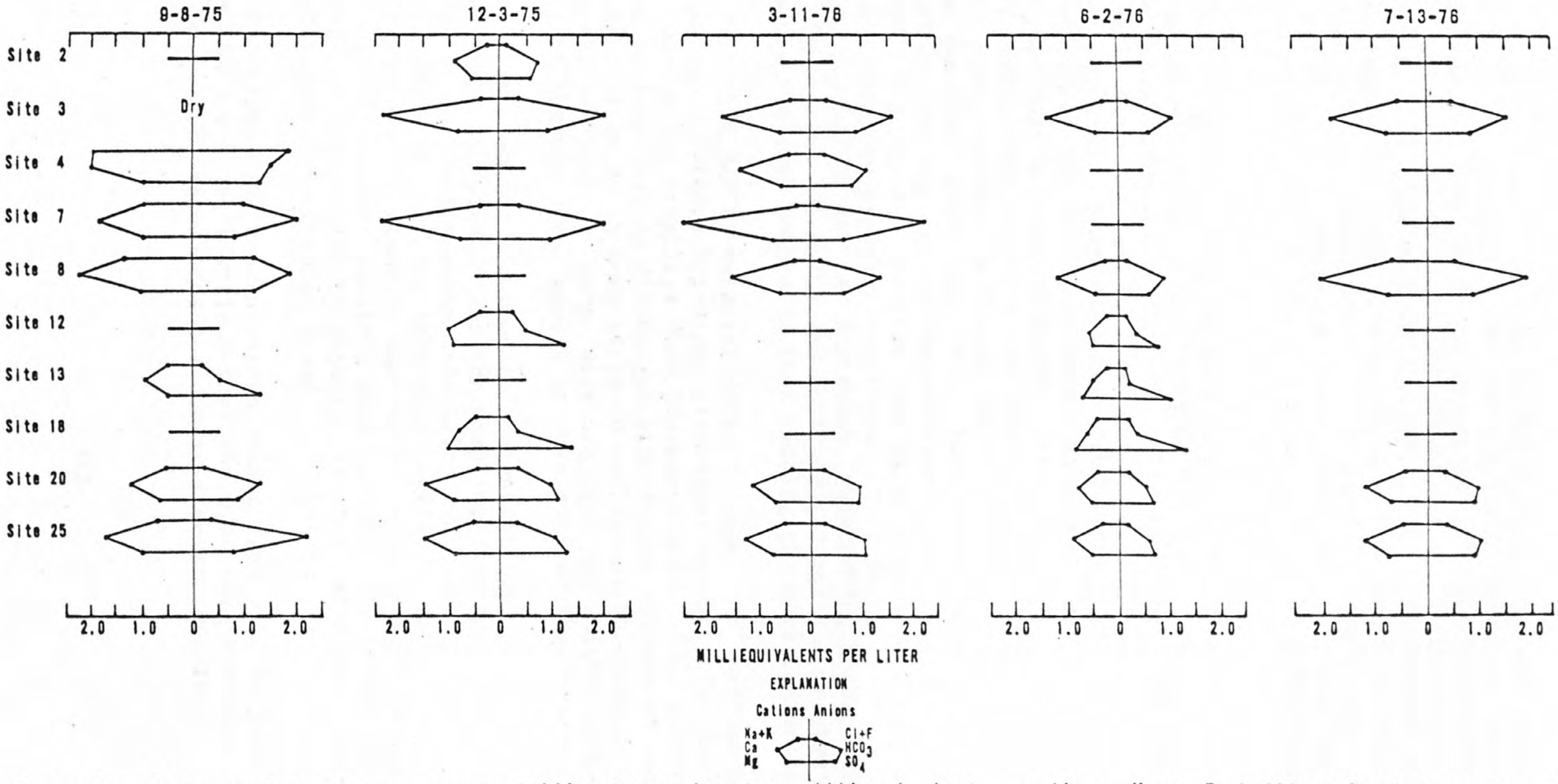


Figure 5.-- Water analyses represented by Stiff patterns based on milliequivalents per liter, Muddy Fork Silver Creek watershed, Ind. Patterns indicate water type. Site numbers are plotted on figure 1.

Coarse-grained limestone in the extreme west and southwest parts of the watershed is responsible for the calcium bicarbonate water type at sites 3, 4, 7, and 8. Because of the limestone, pH and bicarbonate concentration at these sites tend to be higher than they are farther east in the watershed. During the high flow on June 2, 1976, pH and bicarbonate at sites 3, 7, and 8 were lower than they were during low flow owing to reduced soil-residence time and reduced photosynthetic activity. The water type at site 2 was much less affected by limestone than that at the rest of the sites west of Borden, as indicated by the lower calcium and bicarbonate concentrations and lower pH at site 2.

Septic systems upstream from sites 4 and 7 probably account for the high sodium (41 and 20 mg/L) and chloride (65 and 36 mg/L) concentrations at these sites on September 8, 1975 (table 1). Most of the other sodium concentrations are 10 mg/L or less, and most of the chloride concentrations are 17 mg/L or less. Bedrock is near land surface in this area and could affect the efficiency of septic systems. At one of the houses upstream from site 4, a pipe that may be connected to the septic system seems to be intermittently discharging to Packwood Branch, just above the confluence with Muddy Fork. Also, refuse is dumped and is sometimes burned streamside at several sites upstream from site 4. This could also be a source of sodium and chloride. The septic system upstream from site 7 may be the source of high sodium (20 mg/L) and chloride (36 mg/L) concentrations at site 7. Although these inputs are probably continuous, less water is available to dilute them during low flow, as in September, than during higher flow. The source of the high sodium (26 mg/L) and chloride (42 mg/L) concentrations at site 8 is probably the same source as that causing the high concentrations at site 4.

The Stiff (1951) patterns (fig. 5) show the influence of the sulfate-dominated, mid-reach tributary discharges on the water types at sites 20 and 25. During the samplings from September 8-10, 1975, when only the reservoir upstream from site 13 discharged significant volumes of water to Muddy Fork, the type of water at both sites 20 and 25 was calcium bicarbonate. However, when all tributaries were discharging, the sulfate concentration at these sites increased, often enough to make sulfate the dominant anion.

The calcium and bicarbonate concentrations at site 25 are much higher than those at site 20 for the sampling from September 8 to 10, 1975. This could be due to limestone underlying contributing tributaries or to the ground water discharging into this section of Muddy Fork. Cement-dust fall-out from a cement plant in Louisville, when streamflow was too low to dilute the dust, is another possible explanation. The amount of cement dust in the atmosphere and settled on objects in the area was considerable when water samples were collected at Speed.

Dissolved-iron concentration ranged from 0.00 to 0.20 mg/L and was less than the 0.3 mg/L maximum that the U.S. Environmental Protection Agency (1976, p. 152) recommends for domestic water supplies.

Manganese concentrations ranged from 0.00 to 0.73 mg/L. More than half of these concentrations equaled or exceeded 0.05 mg/L, the maximum recommended in domestic water supplies (U.S. Environmental Protection Agency, 1976, p. 178). Consumers generally find concentrations of more than 0.15 mg/L objectionable because of staining and taste problems associated with them. Freshly fallen leaves of trees and other plants are an important source of manganese in forested areas (Hem, 1964, p. B2-B3). Leaching often removes a high percentage of the manganese from leaves soon after they fall (Oborn, 1964, p. C12). Naturally occurring organic substances, especially fulvic acids, are important in the solubilization and transport of manganese in aquatic systems. The hypolimnion of reservoirs can accumulate manganese released from sediments and that precipitated from the epilimnion. During overturn, manganese may be recycled from the hypolimnion, causing a temporary increase in concentration in the epilimnion.

Seasonal fluctuations of dissolved manganese concentration at several sites are presented in figure 6. In September the concentration of manganese was more than 0.35 mg/L at sites 13, 20, and 25 but was 0.04 mg/L at site 8. A black coating, which may be composed of manganese oxides, was observed on rocks upstream from site 13. The concentrations of dissolved manganese at sites 20 and 25 seem to be dependent on the concentration being discharged from the bottom-draw structure upstream from site 13. Concentrations of manganese were consistently 0.01 mg/L or less at site 3 and 0.04 mg/L or less at site 8, except during July at site 8, when the concentration was 0.17 mg/L. Data were insufficient to determine the source of manganese at site 8 during July 1976, but discharge from the hypolimnion in the structure upstream from site 2 is probably the source. Concentration of manganese was high (0.37 mg/L) at site 2 in December 1975. Data were insufficient to determine the reason for the low concentration of manganese (0.06 mg/L) at site 25 in July 1976 and for the high concentration (0.73 mg/L) at site 18 in June 1976.

The concentration of total organic carbon ranged from 2.0 to 14 mg/L. Construction of a sewage-treatment plant at Borden resulted in very turbid water (from soil pushed into Muddy Fork) at site 8 during sampling on July 13, 1976. Organic-carbon concentrations at sites 8 and 20 were at their highest on this sampling date and were probably caused by the soil load.

Orthophosphate concentration as phosphorus ranged from 0.00 to 0.29 mg/L, and total dissolved-phosphorus concentration ranged from 0.01 to 0.34 mg/L. These concentrations were less than 0.10 mg/L in most samples, the maximum concentration desired for flowing water preventing plant nuisances (U.S. Environmental Protection Agency, 1976, p. 356). Maximum orthophosphate and total dissolved-phosphorus concentrations, at site 25 on September 10, 1976, probably resulted from sewage. The total dissolved-phosphorus concentration at site 8 on July 8, 1976, was higher than on other sampling dates, probably because of the soil that was pushed into Muddy Fork during construction of the sewage-treatment plant. Correlation of total organic carbon and phosphorous nutrients with time and discharge was poor.

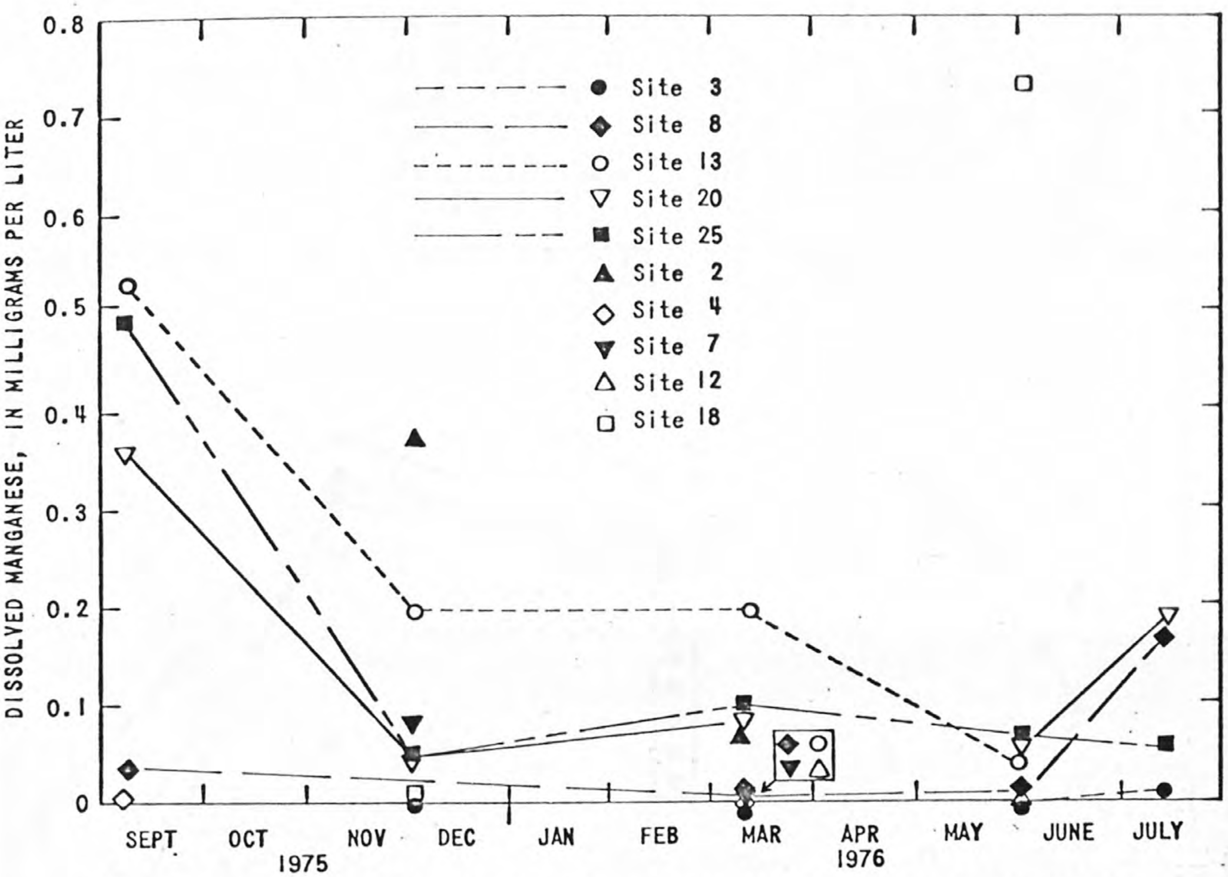


Figure 6.-- Seasonal fluctuation of manganese concentration, Muddy Fork Silver Creek watershed, Ind. Site numbers are plotted on figure 1.

Seasonal fluctuation of nitrate concentration at several sites is presented in figure 7. Nitrate (as nitrogen) concentration ranged from 0.00 to 2.5 mg/L. Generally, the concentration was lowest during the low flow in September 1976 and was highest when soil-moisture content was high, from December through May. Concentrations were high (1.2-1.9 mg/L) at sites 3, 7, and 8, relative to other sites during the high flow in June 1976, when the soil was flushed by precipitation. Nitrate concentrations at all sites except site 8 were less in July than they were in June, where, again, soil disturbance due to sewage-treatment-plant construction is the probable reason. Nitrate concentrations at sites 2 and 18 on December 3, 1975, (0.21 and 0.03 mg/L) and at site 13 on June 2, 1976, (0.08 mg/L) were significantly lower than the concentrations at other sites on these dates. The low

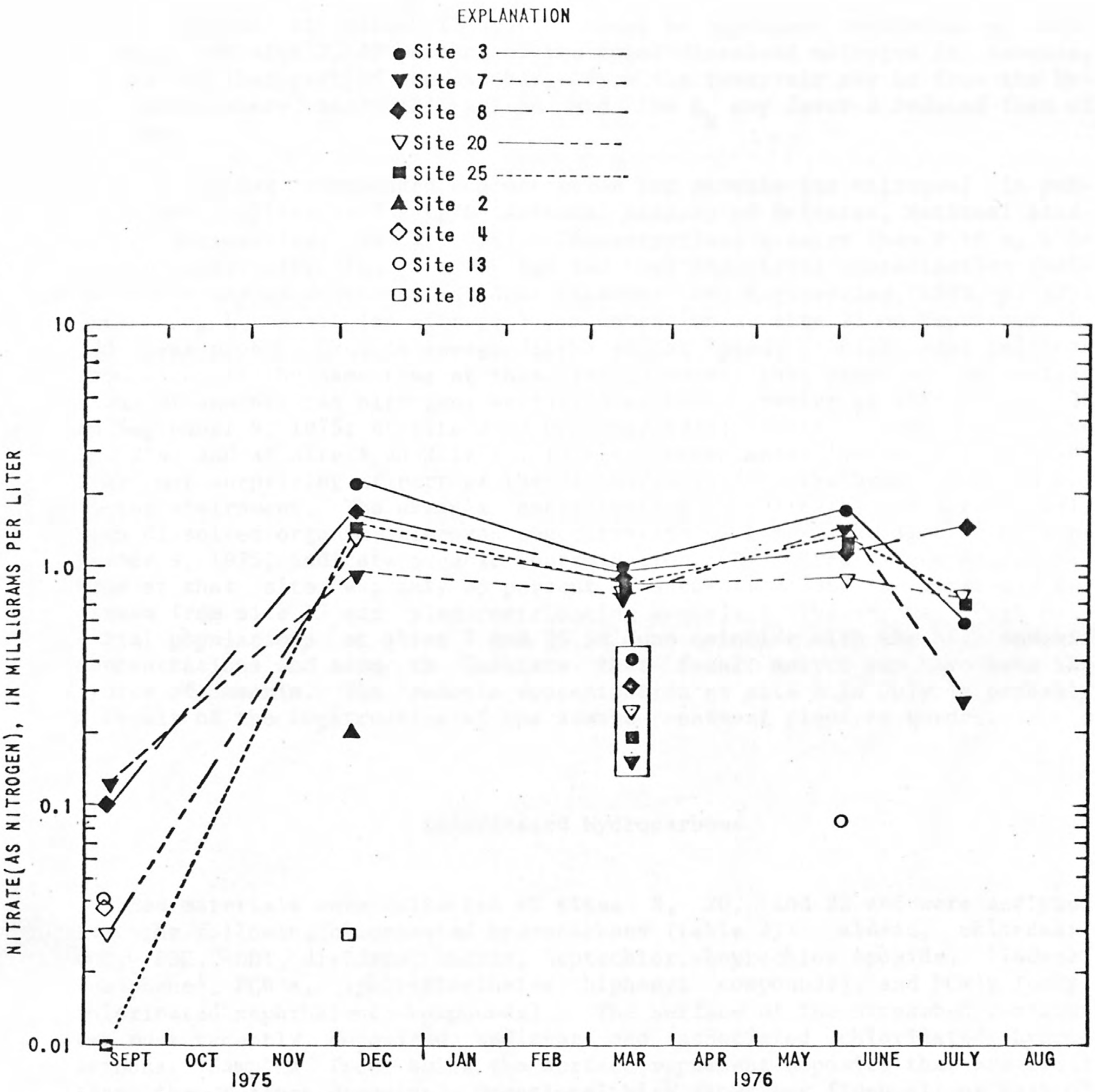


Figure 7.-- Seasonal fluctuation of nitrate concentration, Muddy Fork Silver Creek watershed, Ind. Site numbers are plotted on figure 1.

concentrations at sites 13 and 18 cannot be explained by available data. However, at site 2, 49 percent of the total dissolved nitrogen is ammonia, indicating that part of the discharge from the reservoir may be from the hypolimnion, where microbial action and low E_h may favor a reduced form of nitrogen.

The maximum recommended concentration for ammonia (as nitrogen) in public water supplies is 0.5 mg/L (National Academy of Sciences, National Academy of Engineering, 1973, p. 55). Concentrations greater than 0.10 mg/L in surface water often indicate sewage and (or) industrial contamination (National Academy of Sciences, National Academy of Engineering, 1973, p. 55). The 1.5-mg/L ammonia (as nitrogen) concentration at site 25 on September 10, 1975, was probably due to sewage discharge at Speed. A high fecal coliform population at the same time at this site supports this premise. Concentrations of ammonia (as nitrogen) were 0.10 mg/L or greater at sites 13 and 20 on September 9, 1975; at site 2 in December 1975; at sites 7 and 25, on June 2, 1975; and at site 8 on July 13, 1976. The concentrations at sites 13 and 2 are not surprising if part of the discharge is from the hypolimnion, a reducing enviroment. The ammonia concentration (0.14 mg/L) and a relatively high dissolved organic nitrogen concentration (1.1 mg/L) at site 20 on September 9, 1975, indicate organic contamination. Dissolved-oxygen concentration at that site was only 35 percent of saturation, and the reservoir upstream from site 13 was also contributing ammonia to the stream. High bacterial populations at sites 7 and 25 in June coincide with the high ammonia concentrations and seem to indicate that fecal matter may have been the source of ammonia. The ammonia concentration at site 8 in July is probably a result of the construction of the sewage-treatment plant at Borden.

Chlorinated Hydrocarbons

Bed materials were collected at sites 8, 20, and 25 and were analyzed for the following chlorinated hydrocarbons (table 3): aldrin, chlordane, DDD, DDE, DDT, dieldrin, endrin, heptachlor, heptachlor epoxide, lindane, Toxaphene[1], PCB's, (polychlorinated biphenyl compounds), and PCN's (polychlorinated naphthalene compounds). The surface of the streambed contains the most recently deposited sediment and associated chlorinated hydrocarbons. Samples from below the surface represent deposits that are older than the surface deposits. Occasional high flows may flush all or part of the settled sediment from the site, followed by a new layer as flow returns to normal. Only the upper layer of the bed material was sampled in an attempt to obtain only recent deposits.

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[1]The use of the brand name in this report is for identification purposes only and does not imply endorsement by the U.S. Geological Survey.

Table 3.--Concentrations of chlorinated hydrocarbons (micrograms per kilogram) in bed material, Muddy Fork Silver Creek watershed

(Analyses by U.S. Geological Survey)

Date of sampling	9-10-75	12-3-75	3-11-76			6-15-76	7-13-76
Site (*See* fig. 1.)	25	20	8	20	25	25	25
Aldrin	0.5	5.1	ND	1.1	0.7	1.1	0.1
Chlordane	12	4	ND	ND	2	14	3
DDD	1.6	1.6	ND	.5	ND	1.8	.6
DDE	1.2	1.4	ND	.7	.7	1.9	.5
DDT	1.3	19	ND	1.7	ND	2.2	1.0
Dieldrin	1.3	6.8	.7	2.5	2.4	6.4	2.4
Endrin	ND	ND	ND	ND	ND	ND	ND
Heptachlor	ND	ND	ND	ND	ND	.1	ND
Heptachlor epoxide	.2	ND	ND	ND	.4	1.0	.4
Lindane	ND	ND	ND	ND	ND	ND	ND
PCB (polychlorinated biphenyl)	11	5	ND	ND	ND	ND	ND
PCN (polychlorinated naphthalene)	ND	ND	ND	ND	ND	ND	ND
Toxaphene	ND	ND	ND	ND	ND	ND	ND

ND Not detected

Aldrin and its decomposition product, dieldrin, are commonly sorbed on bed materials in the Muddy Fork watershed, probably owing to application of the insecticide to cornfields. The highest concentrations of aldrin and dieldrin were 5.1, and 6.8 μg/kg (micrograms/kilogram), respectively, at site 20 on December 3, 1975. This sampling was the first after corn in the flood plain had been harvested, and soil was more subject to rain erosion than it was before the harvest. The samples probably included new sediment that had been washed into Muddy Fork.

Presence of DDT and its decomposition products, DDD and DDE, indicate past use of DDT in the watershed. Recent use of the banned insecticide in the watershed (probably in the Wilson area) is suggested by the high concentration of DDT (19 μg/kg) at site 20 on December 3, 1975.

Chlordane is commonly used for termite control and is sometimes used around livestock and lawns. Heptachlor, commonly a component of commercial-grade chlordane, is unstable and decomposes to heptachlor epoxide. The town of Speed is probably a major source of chlordane. The highest concentration of chlordane in the watershed was 14 μg/kg at site 25 on June 15, 1976, after an extremely high flow. The detection of a 0.1-μg/kg concentration of heptachlor at this site on this date indicates that recent applications of chlordane may have been washed into Muddy Fork during the storm. Concentrations of PCB's at sites 20 and 25 were 5 and 11 μg/kg on December 3, and September 10, 1975, respectively. Sediment containing these compounds was flushed from the sites after December, and subsequent sampling indicated that, at least temporarily, none of these compounds was entering Muddy Fork. The source of these very stable compounds is unknown because their use has been widespread in the past. The compounds have been used as insulating fluids in electrical and heat transfer equipment and as hydraulic fluids in automobiles and farm machinery.

Microbiological and Biological Data

Bacteria

Distribution of bacterial populations in the Muddy Fork Silver Creek watershed is shown in figure 8. In human fecal material, the ratio of fecal coliform to fecal streptococcal bacteria is greater than 4; in animal fecal material the ratio is less than 1 (Geldreich, 1966). Ratios between 1 and 4 in water samples can be due to different dieoff rates between the two bacterial groups or to mixed sources of bacteria. Populations of fecal coliform bacteria ranged from 5 to 65,000 col/100 mL (colonies per 100 milliliters) and of fecal streptococcal bacteria, from 5 to 14,000 col/100 mL (table 4). Generally, bacterial populations for all sites sampled were highest in June 1976, probably because animal fecal material was washed into

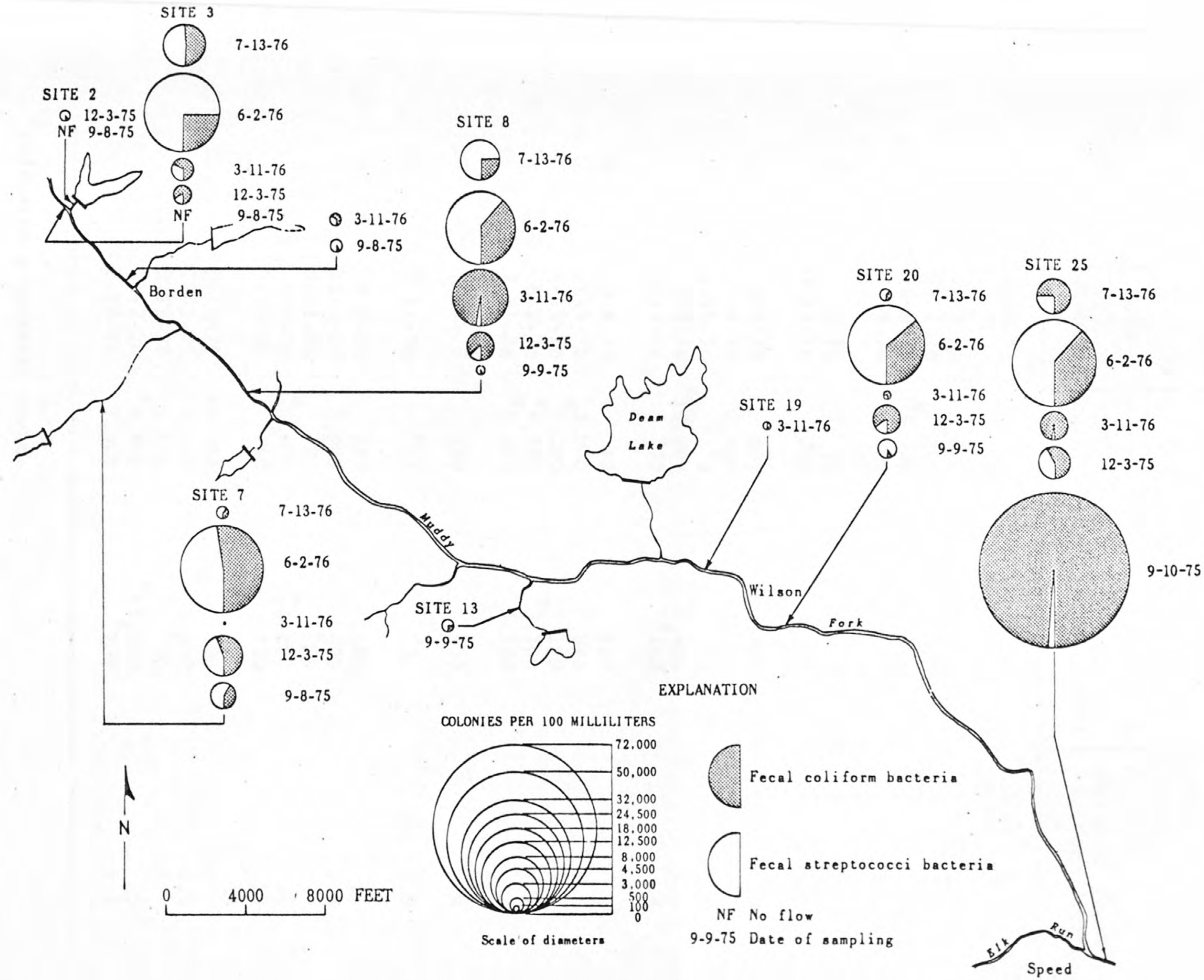

Figure 8.-- Bacterial populations, Muddy Fork Silver Creek watershed, Ind.

Table 4.--Bacterial data for Muddy Fork Silver Creek watershed

(Analyses by U.S. Geological Survey)

Site (*See* fig. 1.)	Date of sampling	Total count (colonies/100 mL)		Ratio of fecal coliform to fecal streptococci
		Fecal coliform	Fecal streptococci	
2	12-3-75	72	300	0.2
3	12-3-75	600	230	2.7
	3-11-76	[a]800	[a]420	1.9
	6-2-76	[a]4,300	[a]13,000	.3
	7-13-76	2,500	2,200	1.1
4	7-8-75	25	520	.1
	3-11-76	280	150	1.9
7	9-8-75	800	1,200	.7
	12-3-75	2,400	2,000	1.2
	3-11-76	[a]5	[a]5	1.0
	6-2-76	[a]10,000	[a]9,400	1.1
	7-13-76	[a]70	[a]160	.4
8	9-9-75	15	120	.1
	12-3-75	3,000	540	5.6
	3-11-76	[a]9,200	140	69
	6-2-76	[a]4,500	[a]9,700	.5
	7-13-76	[a]1,000	3,200	.3
13	9-9-75	150	430	.4
19	3-11-76	[a]35	[a]35	1.0
20	9-9-75	140	1,100	.1
	12-3-75	1,900	520	3.8
	3-11-76	[a]80	[a]30	2.7
	6-2-76	[a]4,400	[a]1,100	.4
	7-13-76	[a]140	320	.4
25	9-10-75	65,000	640	100
	12-3-75	2,200	1,000	2.2
	3-11-76	2,400	[a]50	48
	6-2-76	[a]6,800	[a]14,000	.5
	7-13-76	3,000	[a]900	3.3

[a]Indicates a nonideal count.

the streams during the storm preceding the sampling. Human waste is indicated at site 25 on September 10, 1975, and on March 11, 1976; and at site 8 on December 3, 1975, and March 11, 1976. Bacterial populations at site 3 were fairly high in June and July 1976. A feedlot just upstream from the site is probably the source of these populations at site 3. Bacterial populations at site 7 were variable, but the ratio of fecal coliform to fecal streptococcal bacteria, ranging from 0.44 to 1.15, indicated animal sources.

Benthic Invertebrates

Benthic invertebrate organisms are generally excellent long-range indicators of water quality because many have specific water-quality requirements for survival. Because these communities are virtually stationary, their structures generally reflect the quality of water moving past the areas that they inhabit. Benthic invertebrates collected at sites 8, 20, and 25 are listed in table 5. The general sensitivity of each genus is indicated by one of the following notations (U.S. Environmental Protection Agency, 1973):

Facultative (f): Organisms that have a wide range of tolerance and are frequently associated with moderate levels of organic loading.

Intolerant (I): Organisms that are not associated with even moderate levels of organic loading and are generally intolerant of each moderate reductions in dissolved-oxygen concentration.

Each of the three sites has significant percentages of genera that may be tolerant of moderate levels of organic loading. Eighty-two percent of the genera sampled at site 25 were Chironomus sp, which are often associated with organic contamination.

The diversity index, a measure of community structure, permits inter- and intra-site comparisons of populations. High diversity generally indicates a healthy community structure, whereas low diversity indicates an environmental stress on the community. Primary causes of the stress are poor water quality and lack of a suitable substrate for the organism to inhabit. Many benthic samples from different substrates cannot be compared because the substrates are radically different from each other. Commonly, species diversity indices of 3 or more have been considered representative of well-balanced benthic communities, indices between 1 and 3 have been considered representative of communities under moderate pollution stress, and indices less than 1 have been considered representative of heavy pollution stress (Wilhm and Dorris, 1968). However, this classification can be misleading

Table 5.--Benthic-invertebrate data for Muddy Fork Silver Creek watershed, September 10, 1975

(Analyses by U.S. Geological Survey; Pollution tolerance: F, facultative; I, intolerant; F/I represents both F and I; site numbers are plotted on fig. 1)

Organism	Pollution tolerance	Number of organisms in wet sample		
		Site 8	Site 20	Site 25
Arthropoda				
Crustacea				
Decapoda				
Astacidae sp	---	--	--	1
Orconectes sp	F/I	3	--	--
Insecta				
Coleoptera				
Dytiscidae				
Hydrovatus sp	---	--	--	1
Elmidae				
Macronychus sp	I	--	5	--
Stenelmis sp	---	1	8	17
Psephenidae				
Psephenus sp	---	2	--	--
Diptera				
Chironomidae				
Chironomus sp	---	--	--	82
Dicrotendipes sp	---	33	--	--
Pentaneura sp	---	2	--	--
Tipulidae				
Eriocera sp	F	--	2	--
Ephemeroptera				
Ephermeridae				
Caenis sp	---	2	--	--
Heptagenidae				
Stenonema sp	F/I	1	--	--
Megaloptera				
Corydalidae				
Corydalus sp	F/I	7	--	--
Sialidae				
Sialis sp	F/I	1	--	--
Odonata				
Agrionidae				
Argia sp	F/I	--	4	--
Tricoptera				
Hydropsychidae				
Cheumatopsyche sp	F	1	--	--
Chimmara sp	I	1	--	--
Mollusca				
Bivalvia				
Nuculoidea				
Sphaeriidae				
Sphaerium sp	---	--	10	--
Gastropoda				
Basommatophora				
Physidae				
Physa sp	---	--	1	--
Mesogastropoda				
Pleuroceridae				
Goniobasis sp	---	--	2	--
Total count	---	54	32	101
Area sampled (m^2)	---	.28	.28	.09
Total number organisms/m^2	---	193	115	1,120
Total biomass (g/m^2)	---	2.15	6.35	18.1
Diversity index, genus level	---	2.1	2.4	.8

because it does not consider substrate limitations. Owing to the restrictive environment provided by a heavy organic load (mainly a low dissolved-oxygen concentration and a low reaeration rate) a few types of organisms thrive without competition from other organisms. As a result, many communities in organically enriched water have low diversity and high total biomass.

Invertebrates were sampled from several types of bottom substrata in riffles at each site. The major differences in substrata were those between site 8 and sites 20 and 25. Site 8 had some sand, a fairly unproductive substrate, whereas sites 20 and 25 had some fine sediment, which might favor burrowing organisms. Gravel and cobble were the dominant bed materials at the sites. Therefore, these sites are probably comparable, and major differences in community structure can probably be attributed to water-quality differences. The genera diversity indices at sites 8, 20, and 25 are 2.1, 2.4, and 0.8, respectively, whereas the total biomass values for these sites are 2.15, 6.35, and 18.08 g/m^2, respectively. These data further indicate increased organic loading upstream from site 25. Considering the differences in substrata at sites 8 and 20, the community structural differences between these sites is not significant enough to attribute the structure differences to water-quality differences.

Phytoplankton

There are conflicting opinions on the existence of a real, riverine phytoplankton community. Some studies have concluded that indeed such a community exists, whereas others have indicated that sources of phytoplankton in flowing water are constant or frequent drainage from lentic water and from dislodged periphyton (Hynes, 1970, p. 94-111). This presents a problem in interpretation of phytoplankton data in flowing systems because the organisms might indicate some process upstream rather than water-quality at the collection site.

Phytoplankton data for the Muddy Fork watershed are presented in table 6. Algal population ranged from 230 to 5,600 cells/mL, and genus diversity indices ranged from 0.4 to 3.2. Generally, diatoms dominated the samples collected in spring, whereas the relative numbers of green and blue-green algae increased during other samplings. Phytoplankton populations were not large enough to be considered nuisance levels when samples were collected.

The diversity indices for phytoplankton are probably not valuable indicators of water quality in Muddy Fork because reservoirs and dislodged periphyton are probably the major sources of algae. The low cell counts at sites 3, 20, and 25 during sampling on June 2, 1976, are probably due to dilution of reservoir storm discharge and scouring of periphyton early in the high-flow period. Also, growth and reproduction of organisms would have

Table 6.--Phytoplankton data for Muddy Fork Silver Creek watershed

(Analyses by U.S. Geological Survey. Percentage of count: T = less than 1 percent)

Organism	Percentage of total count						
	September 8-10, 1975			December 3, 1975			
	Site 8	Site 20	Site 25	Site 2	Site 3	Site 13	Site 18
Chlorophyta (green algae)							
Ankistrodesmus sp	3	---	8	---	---	2	---
Chlamydomonas sp	33	---	---	---	---	---	---
Closteriopsis sp	---	---	---	---	---	---	---
Crucigenia sp	---	24	---	4	---	16	---
Dictyosphaerium sp	---	---	---	---	---	---	---
Kirchneriella sp	---	---	---	---	---	9	---
Oocystis sp	---	---	---	---	---	---	---
Scendesmus sp	---	24	---	2	---	5	---
Schroederia sp	---	---	---	T	---	3	---
Sphaerocystis sp	---	---	52	7	---	---	---
Tetraedron sp	---	---	---	T	---	---	---
Treubaria sp	---	---	---	---	---	9	---
(placoderm desmids)							
Cosmarium sp	---	---	---	---	---	---	---
Closterium sp	---	---	---	---	---	---	---
Spondylosium sp	---	---	---	---	---	---	---
Chrysophyta (yellow-brown algae and diatoms)							
(centric diatoms)							
Cyclotella sp	3	---	---	T	---	---	85
Melosira sp	---	---	---	---	---	---	---
(pennate diatoms)							
Achnanthes sp	15	---	---	---	31	1	5
Asterionella sp	---	---	---	T	---	---	---
Cocconeis sp	---	---	---	---	---	---	---
Cymbella sp	12	---	---	---	T	---	---
Diatoma sp	---	---	---	---	---	---	---
Gomphonema sp	---	---	---	---	57	1	---
Rhoiocosphenia sp	1	---	---	---	---	---	---
Synedra sp	---	---	---	---	---	---	---
(naviculoid)							
Gyrosigma sp	---	---	---	---	---	---	---
Meridion sp	---	---	---	---	---	---	---
Navicula sp	18	---	3	---	3	T	---
Nitzschia sp	11	---	16	---	9	5	5
Surirella sp	---	---	---	---	---	1	---
(yellow-brown algae)							
Dinobryon sp	---	---	---	5	---	---	5
Cyanophyta (blue-green algae)							
(coccoid)							
Agmenellum sp	---	---	---	---	---	---	---
Anacystis sp	---	---	---	---	---	46	---
(filamentous)							
Anabaena sp	---	---	---	82	---	---	---
Oscillatoria sp	---	---	---	---	---	---	---
Euglenophyta (euglenoids)							
Euglena sp	---	34	10	---	---	---	---
Phacus sp	---	---	3	---	---	---	---
Trachelomonas sp	---	18	8	---	---	2	---
Pyrrhophyta							
Glenudinium sp	---	---	---	---	---	---	---
Gymnudenium sp	4	---	---	---	---	---	---
Total count (cells/mL)	950	360	1,100	5,600	430	1,900	280
Genera diversity index	2.7	2.0	2.1	1.3	1.5	2.6	.8

Table 6.--Phytoplankton data for Muddy Fork Silver Creek watershed--Continued

Organism	Percentage of total count							
	March 11, 1976				June 2, 1976			
	Site 3	Site 8	Site 20	Site 25	Site 3	Site 8	Site 20	Site 25
Chlorophyta (green algae)								
Ankistrodesmus sp	---	---	---	---	7	1	6	---
Chlamydomonas sp	---	8	---	---	1	---	---	---
Closteriopsis sp	---	---	---	---	---	2	---	---
Crucigenia sp	---	---	---	---	---	---	---	---
Dictyosphaerium sp	---	---	---	---	---	7	13	---
Kirchneriella sp	---	---	---	---	---	---	---	---
Oocystis sp	---	---	---	---	---	14	---	---
Scendesmus sp	---	---	---	---	---	3	---	---
Schroederia sp	---	---	---	---	---	1	---	---
Sphaerocystis sp	---	---	---	---	---	---	---	---
Tetraedron sp	---	---	---	---	---	---	---	---
Treubaria sp	---	---	---	---	---	---	---	---
(placoderm desmids)								
Cosmarium sp	---	---	---	---	---	---	---	---
Closterium sp	---	---	---	---	T	---	---	---
Spondylosium sp	---	---	---	---	1	---	---	---
Chrysophyta (yellow-brown algae and diatoms)								
(centric diatoms)								
Cyclotella sp	---	53	68	82	---	5	3	10
Melosira sp	---	---	---	---	---	---	10	---
(pennate diatoms)								
Achnanthes sp	13	4	---	---	8	2	6	---
Asterionella sp	---	---	---	---	---	---	---	---
Cocconeis sp	---	---	---	---	1	---	---	---
Cymbella sp	5	15	T	---	2	3	17	10
Diatoma sp	3	12	8	6	---	---	---	---
Gomphonema sp	43	4	---	---	5	2	13	---
Rhoiocosphenia sp	---	---	---	---	---	---	---	10
Synedra sp	---	T	---	---	---	---	---	10
(naviculoid)								
Gyrosigma sp	---	---	4	---	---	---	3	---
Meridion sp	---	T	---	---	---	---	---	---
Navicula sp	23	T	8	---	9	1	20	30
Nitzschia sp	5	4	12	11	2	1	3	30
Surirella sp	8	---	---	---	---	---	6	---
(yellow-brown algae)								
Dinobryon sp	---	---	---	---	---	---	---	---
Cyanophyta (blue-green algae)								
(coccoid)								
Agmenellum sp	---	---	---	---	4	---	---	---
Anacystis sp	---	---	---	---	---	41	---	---
(filamentous)								
Anabaena sp	---	---	---	---	---	14	---	---
Oscillatoria sp	---	---	---	---	60	2	---	---
Euglenophyta (euglenoids)								
Euglena sp	---	---	---	T	---	---	---	---
Phacus sp	---	---	---	---	---	---	---	---
Trachelomonas sp	---	---	---	---	---	---	---	---
Pyrrhophyta								
Glenudinium sp	---	---	---	---	---	1	---	---
Gymnudenium sp	---	---	---	---	---	---	---	---
Total count (cells/mL)	1,700	2,100	1,300	550	530	1,800	290	480
Genera diversity index	2.3	2.1	1.6	.8	2.1	2.8	3.2	2.4

Table 6.--Phytoplankton for Muddy Fork Silver Creek watershed--Continued

Organism	Percentage of total count			
	July 13, 1976			
	Site 3	Site 8	Site 20	Site 25
Chlorophyta (green algae)				
Ankistrodesmus sp	---	---	---	7
Chlamydomonas sp	---	---	---	21
Closteriopsis sp	---	---	---	---
Crucigenia sp	---	---	---	7
Dictyosphaerium sp	---	---	---	---
Kirchneriella sp	2	---	---	---
Oocystis sp	---	---	---	---
Scendesmus sp	13	---	---	3
Schroederia sp	---	---	---	---
Sphaerocystis sp	---	---	---	---
Tetraedron sp	---	---	---	---
Treubaria sp	---	---	---	---
(placoderm desmids)				
Cosmarium sp	---	---	---	T
Closterium sp	---	---	---	---
Spondylosium sp	---	---	---	---
Chrysophyta (yellow-brown algae and diatoms)				
(centric diatoms)				
Cyclotella sp	---	---	---	9
Melosira sp	---	---	---	---
(pennate diatoms)				
Achnanthes sp	21	---	---	---
Asterionella sp	---	---	---	---
Cocconeis sp	---	---	---	---
Cymbella sp	8	13	---	3
Diatoma sp	---	---	---	2
Gomphonema sp	---	7	---	2
Rhoiocosphenia sp	---	---	---	---
Synedra sp	---	---	---	---
(naviculoid)				
Gyrosigma sp	---	---	---	---
Meridion sp	---	---	---	---
Navicula sp	2	7	8	7
Nitzschia sp	23	73	92	24
Surirella sp	---	---	---	---
(yellow-brown algae)				
Dinobryon sp	---	---	---	---
Cyanophyta (blue-green algae)				
(coccoid)				
Agmenellum sp	4	---	---	---
Anacystis sp	---	---	---	---
(filamentous)				
Anabaena sp	---	---	---	---
Oscillatoria sp	27	---	---	---
Euglenophyta (euglenoids)				
Euglena sp	---	---	---	12
Phacus sp	---	---	---	---
Trachelomonas sp	---	---	---	3
Pyrrhophyta				
Glenudinium sp	---	---	---	---
Gymnudenium sp	---	---	---	---
Total count (cells/mL)	5,600	2,100	310	230
Genera diversity index	2.5	1.2	.4	3.1

been limited by suspended sediment. The cell count at site 8 was several times greater than counts at sites 3, 20, and 25 on June 2. Flushing of three reservoirs on tributaries immediately upstream from site 8 is probably the reason for this higher cell count. Dilution and organism mortality accounts for the cell count reduction from site 8 to site 20.

Cell counts decreased downstream from site 8 in March, June, and July, probably because there are fewer reservoir sources of algae downstream from site 8 than there are upstream. The increase in cell numbers at site 25 in September may have been due to ponding of water at low flow and an excess of nutrients from sewage discharge providing a suitable environment for algal reproduction.

Communities dominated by euglenoids are often associated with saprobic conditions. During the sampling from September 8 to 10, 1975, these organisms comprised 52 percent of the algal population at site 20 and 21 percent at site 25. The low cell count (360 cells/mL) at site 20 was due to a lack of diatoms in the samples. Apparently, conditions in the water did not permit their survival.

Periphyton

Only the algal part of the periphyton was identified in this study. Since periphyton communities are attached to fixed substrata, they might be a better indicator of water quality than phytoplankton communities are. Unfortunately, only qualitative samples were taken, limiting the information that can be obtained from this community.

Samples of periphyton were taken at sites 20 and 25 on September 10, 1975 (table 7). The community at site 20 was dominated by a diatom, *Fragilaria* sp, and at site 25, by another diatom, *Nitzschia* sp, which includes many species associated with organic loading (Kolkwitz, 1908). There were fewer genera at site 25 than at site 20, indicating that the periphyton community at site 25 may not be as healthy as the one at site 20. The genera unique to the periphyton community at site 25 are *Cymbella* sp, *Pinnularia* sp, *Oscillatoria* sp, *Euglena* sp, and *Phacus* sp. Palmer (1969) considers all these genera pollution tolerant.

Table 7.--Periphyton data for Muddy Fork Silver Creek watershed, September 10, 1975

(Analyses by U.S. Geological Survey; X = sample contains organism; D = dominant organism)

Organism	Site 20	Site 25
Chlorophyta (green algae)		
Spirogyra sp	X	--
Chrysophyta (yellow-brown algae and diatoms)		
(pennate diatoms)		
Achnanthes sp	X	--
Amphipeura sp	X	--
Caloneis sp	X	X
Cocconeis sp	X	--
Cymbella sp	--	X
Eunotia sp	X	--
Fragilaria sp	D	--
Gomphonema sp	X	X
Gyrosigma sp	X	X
Navicula sp	X	X
Nitzschia sp	X	D
Pinnularia sp	--	X
Surirella sp	X	--
Synedra sp	X	--
Cyanophyta (blue-green algae)		
Lyngbya sp	X	X
Oscillatoria sp	--	X
Euglenophyta (euglenoids)		
Euglena sp	--	X
Phacus sp	--	X
Trachelomonas sp	X	--

SUMMARY AND CONCLUSIONS

Generally, calcium bicarbonate water was dominant in tributaries in the south and southwest parts of the watershed, whereas calcium sulfate and magnesium sulfate types of water were dominant in tributaries in other parts of the watershed. These tributary water types effected variable water types in the lower reaches of Muddy Fork. Airborne calcium carbonate from a cement factory at Speed may enter Muddy Fork and influence the water type downstream from Speed.

Top-spill reservoirs had lower and more consistent dissolved-solids concentrations than uncontrolled areas of the watershed. Temperature, manganese and ammonia-nitrogen concentrations, and water type of discharge from some bottom-draw reservoirs differed from those of discharge from other reservoirs.

Manganese concentration varied seasonally and at times exceeded the maximum recommended concentration for domestic supplies (0.05 mg/L). The manganese probably comes from a natural source and may be concentrated in reservoirs on tributaries.

Nitrate (as nitrogen) concentrations ranged from 0.00 to 2.5 mg/L and varied with seasonal soil-moisture content. Nearly all total dissolved-phosphorus concentrations were less than the 0.10-mg/L maximum desired for preventing plant nuisances in flowing streams. Concentrations greater than 0.10 mg/L are associated with sewage discharge or introduction of soil into Muddy Fork. Total organic carbon concentrations ranged from 2.0 to 14 mg/L. Neither phosphorus nor total organic carbon displayed any recognizable temporal or spatial trends.

The major problem areas are in the eastern part of the watershed, where contamination by human waste in the Speed area is probable. During low flow in September, dissolved oxygen, total dissolved phosphorus, orthophosphate, ammonium nitrogen, bacteria, phytoplankton, and periphyton data all indicate loading by sewage at site 25. Also during September, ammonia, organic nitrogen, dissolved oxygen, and phytoplankton data indicated some organic loading at site 20. Benthic invertebrate diversity indices indicated a degradation of water quality near the mouth of Muddy Fork. Samples of periphyton at site 25 contained more tolerant genera than samples at site 20, which seemed to support the trend shown by invertebrate data. Euglenoids made up a high percentage of phytoplanktonic communities at both sites 20 and 25 and may indicate saprobic conditions in September 1975. In addition, bacterial data indicated contamination from human fecal material at site 25 in March 1976 and at site 8 in December 1975 and March 1976.

Periodic loading of animal fecal material into streams upstream from sites 3 and 7 may cause water-quality problems. Domestic waste disposal and inefficient septic systems may also constitute a loading source to Muddy Fork, as indicated by the sodium and chloride concentrations at sites 4 and 7 during the September sampling.

Soil introduced into Muddy Fork from the construction of a sewage-treatment plant at Borden probably caused the increased concentrations of ammonia and nitrate nitrogen, total dissolved phosphorus, and total organic carbon immediately downstream from Borden.

Analysis of bed-material samples indicated that aldrin, chlordane, DDD, DDE, DDT, dieldrin, heptachlor, heptachlor epoxide, and PCB's were entering Muddy Fork. Their presence makes them potentially available to enter into biological food chains.

This general water-quality assessment of the Muddy Fork watershed has identified some areas that may require further investigation. Additional intensive sampling of aquatic chemical, biological, and physical conditions would be necessary to locate actual sources, define ranges and variations of particular constituents, and determine their impact on the aquatic ecosystem.

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Table 1.--Water-quality data for Muddy Fork Silver Creek watershed

(Analyses by U.S. Geological Survey)

Date of sampling	September 8, 1975		September 9, 1975				September 10, 1975
Site (*See* fig. 1.)	4	7	8	13	19	20	25
Eastern standard time	[a] 1430	1700	1125	1240	1600	1630	1000
Drainage area (mi^2)	6.60	3.84	17.3	1.84	42.5	47.2	66.7
Discharge (ft^3/s)[b]	.1	.0	.0	.4	---	.6	.3
Water temp. (°C)	42.0	35.1	29.2	16.4	23.5	21.0	23.6
pH, field	8.7	8.4	8.2	7.8	8.7	7.1	7.6
Specific conductance (micromhos per cm at 25°C)	517	384	455	238	315	266	338
Dissolved oxygen (percent saturation)	147	131	109	85	57	35	21
Milligrams per liter							
Dissolved oxygen	9.4	9.3	8.4	8.4	4.8	3.1	1.8
Calcium	39	37	45	20	---	25	36
Magnesium	12	12	12	6	---	7.9	12
Potassium	5.4	4.0	4.4	3.5	---	4.2	6.2
Sodium	41	20	26	9.3	---	10	13
Bicarbonate	92	126	119	34	---	82	140
Carbonate	0	0	0	0	---	0	0
Chloride	65	36	42	4.1	---	5.5	12
Fluoride	.2	.1	.1	.2	---	.2	.2
Sulfate	64	38	58	67	---	39	34
Silica, dissolved	3.7	5.0	4.6	8.1	---	5.9	9.4
Dissolved solids	276	215	251	136	---	139	195
Total alkalinity (as $CaCO_3$)	75	103	98	28	---	67	115
Total hardness (as $CaCO_3$)	150	140	160	75	---	95	140
Noncarbonate hardness (as $CaCO_3$)	71	38	64	47	---	28	24
Ammonia, dissolved (as N)	.01	.04	.04	.13	---	.14	1.5
Organic nitrogen, dissolved (as N)[c]	.32	.43	.36	.40	---	1.1	.90
Nitrite, dissolved (as N)	.01	.01	.01	.01	---	.01	.01
Nitrate, dissolved (as N)	.04	.12	.10	.04	---	.03	.00
Orthophosphate, dissolved (as P)	.00	.01	.01	.01	---	.01	.29
Phosphorus, total dissolved (as P)	.01	.03	.03	.01	---	.01	.34
Organic carbon, total	4.9	11	7.9	13	---	9.1	9.2
Iron, dissolved	.03	.07	.03	.03	---	.12	.20
Manganese, dissolved	.01	.03	.04	.53	---	.36	.49

Table 1.--Water-quality data for Muddy Fork Silver Creek watershed--Continued

Date of sampling	December 3, 1975						
Site (*See* fig. 1.)	2	3	5	7	8	9	10
Eastern standard time	1100	1135	1215	1255	1415	1430	1500
Drainage area (mi^2)	2.01	3.88	3.19	3.84	17.33	4.33	2.40
Discharge (ft^3/s)[b/]	1.0	3.8	2.5	5.1	19	1.2	2.4
Water temp. (°C)	6.1	6.7	5.2	6.7	7.4	6.0	6.7
pH, field	8.7	8.3	8.1	8.0	8.0	7.4	7.5
Specific conductance (micromhos per cm at 25°C)	134	295	162	358	264	171	200
Dissolved oxygen (percent saturation)	88	98	84	95	95	85	89
Milligrams per liter							
Dissolved oxygen	11.0	12.0	10.8	11.6	11.6	10.6	10.9
Calcium	18	47	---	47	---	---	---
Magnesium	6.5	9.7	---	11	---	---	---
Potassium	2.6	2.0	---	3.0	---	---	---
Sodium	3.3	7.2	---	8.4	---	---	---
Bicarbonate	48	130	---	160	---	---	---
Carbonate	0	0	---	0	---	---	---
Chloride	3.3	11	---	16	---	---	---
Fluoride	.2	.2	---	.3	---	---	---
Sulfate	32	42	---	50	---	---	---
Silica, dissolved	3.4	8.6	---	4.5	---	---	---
Dissolved solids	95	203	---	224	---	---	---
Total alkalinity (as $CaCO_3$)	39	107	---	131	---	---	---
Total hardness (as $CaCO_3$)	72	160	---	160	---	---	---
Noncarbonate hardness (as $CaCO_3$)	32	51	---	31	---	---	---
Ammonia, dissolved (as N)	.18	.01	---	.07	.02	---	---
Organic nitrogen, dissolved (as N)[c/]	.03	.16	---	.27	.29	---	---
Nitrite, dissolved (as N)	.01	.01	---	.03	.01	---	---
Nitrate, dissolved (as N)	.21	2.5	---	.94	1.8	---	---
Orthophosphate, dissolved (as P)	.01	.01	---	.02	.01	---	---
Phosphorus, total dissolved (as P)	.02	.04	---	.04	.02	---	---
Organic carbon, total	6.2	2.7	---	5.7	4.7	---	---
Iron, dissolved	.17	.04	---	.05	---	---	---
Manganese, dissolved	.37	.00	---	.08	---	---	---

Table 1.--Water-quality data for Muddy Fork Silver Creek watershed--Continued

Date of sampling	December 3, 1975						
Site (*See* fig. 1.)	12	13	18	20	21	24	25
Eastern standard time	1515	1545	1615	1635	1705	1755	1720
Drainage area (mi^2)	2.60	1.84	3.74	47.23	2.67	4.43	66.67
Discharge (ft^3/s)[b/]	13	.8	.7	38	.2	1.3	53
Water temp. (°C)	4.9	7.3	6.8	4.9	5.8	6.2	4.6
pH, field	7.5	7.3	7.4	7.4	7.2	7.4	7.5
Specific conductance (micromhos per cm at 25°C)	202	260	190	244	301	370	254
Dissolved oxygen (percent saturation)	88	85	89	86	78	85	86
Milligrams per liter							
Dissolved oxygen	11.3	10.4	10.9	11.0	9.8	1.06	11.0
Calcium	20	---	16	29	---	---	29
Magnesium	11	---	12	10	---	---	10
Potassium	2.5	---	2.4	2.8	---	---	3.1
Sodium	7.4	---	9.1	9.0	---	---	10
Bicarbonate	32	---	23	67	---	---	62
Carbonate	0	---	0	0	---	---	0
Chloride	7.6	---	65	11	---	---	12
Fluoride	.1	---	.1	.1	---	---	.2
Sulfate	61	---	70	56	---	---	64
Silica, dissolved	9.6	---	2.0	7.5	---	---	8.3
Dissolved solids	145	---	130	165	---	---	174
Total alkalinity (as $CaCO_3$)	26	---	19	55	---	---	51
Total hardness (as $CaCO_3$)	95	---	89	110	---	---	110
Noncarbonate hardness (as $CaCO_3$)	69	---	71	59	---	---	63
Ammonia, dissolved (as N)	.01	---	.03	.02	---	---	.09
Organic nitrogen, dissolved (as N)[c/]	.16	---	.18	.18	---	---	.17
Nitrite, dissolved (as N)	.01	---	.01	.01	---	---	.01
Nitrate, dissolved (as N)	2.3	---	.03	1.4	---	---	1.5
Orthophosphate, dissolved (as P)	.01	---	.01	.01	---	---	.01
Phosphorus, total dissolved (as P)	.01	---	.01	.01	---	---	.02
Organic carbon, total	2.0	---	5.6	3.8	---	---	5.9
Iron, dissolved	.02	---	.04	.05	---	---	.03
Manganese, dissolved	.00	---	.01	.05	---	---	.05

Table 1.--Water-quality data for Muddy Fork Silver Creek watershed--Continued

Date of sampling	March 11, 1976						
Site (*See* fig. 1.)	2	3	4	7	8	12	13
Eastern standard time	1015	1045	1115	1145	1230	1315	1330
Drainage area (mi^2)	2.01	3.88	6.60	3.84	17.33	2.60	1.84
Discharge (ft^3/s)[b/]	.8	1.3	1.5	6.0	8.8	.9	.6
Water temp. (°C)	10.9	10.6	11.4	11.3	11.9	9.0	10.0
pH, field	7.7	8.8	8.8	8.6	8.8	8.2	7.9
Specific conductance (micromhos per cm at 25°C)	154	280	237	302	252	215	284
Dissolved oxygen (percent saturation)	79	111	113	106	121	97	98
Milligrams per liter							
Dissolved oxygen	8.6	12.2	12.2	11.5	12.9	11.2	11.0
Calcium	---	35	27	49	32	---	---
Magnesium	---	7.1	7.2	7.7	6.5	---	---
Potassium	---	1.7	1.8	1.7	1.9	---	---
Sodium	---	7.8	7.7	4.2	5.7	---	---
Bicarbonate	---	102	72	146	96	---	---
Carbonate	---	0	0	0	0	---	---
Chloride	---	11	11	7.2	8.2	---	---
Fluoride	---	.1	.1	.1	.1	---	---
Sulfate	---	42	40	32	36	---	---
Silica, dissolved	---	5.8	5.3	.7	2.8	---	---
Dissolved solids	---	165	140	178	145	---	---
Total alkalinity (as $CaCO_3$)	---	84	59	120	79	---	---
Total hardness (as $CaCO_3$)	---	120	97	150	110	---	---
Noncarbonate hardness (as $CaCO_3$)	---	33	38	34	28	---	---
Ammonia, dissolved (as N)	---	.02	.02	.04	.03	---	.06
Organic nitrogen, dissolved (as N)[c/]	---	.11	.14	.09	.15	---	.22
Nitrite, dissolved (as N)	---	.02	.01	.04	.02	---	.02
Nitrate, dissolved (as N)	---	.98	.93	.79	.98	---	.18
Orthophosphate, dissolved (as P)	---	.01	.01	.04	.01	---	.01
Phosphorus, total dissolved (as P)	---	.01	.01	.06	.01	---	.01
Organic carbon, total	---	5.4	3.9	3.4	6.4	---	---
Iron, dissolved	.06	.03	.05	.02	.04	---	.05
Manganese, dissolved	.07	.00	.00	.01	.01	---	.20

Table 1.--Water-quality data for Muddy Fork Silver Creek watershed--Continued

Date of sampling	March 11, 1976			
Site (*See* fig. 1.)	18	19	20	25
Eastern standard time	1400	1435	1450	1530
Drainage area (mi^2)		42.53	47.23	66.67
Discharge (ft^3/s)[b/]	2.2	---	21	21
Water temp. (°C)	10.6	10.7	10.7	10.8
pH, field	8.0	7.6	7.5	7.6
Specific conductance (micromhos per cm at 25°C)	193	238	239	260
Dissolved oxygen (percent saturation)	91	94	94	95
Milligrams per liter				
Dissolved oxygen	10.0	10.3	10.3	10.5
Calcium	---	---	23	25
Magnesium	---	---	7.5	8.7
Potassium	---	---	2.2	2.4
Sodium	---	---	4.8	8.8
Bicarbonate	---	---	62	68
Carbonate	---	---	0	0
Chloride	---	---	8.6	9.5
Fluoride	---	---	.0	.1
Sulfate	---	---	49	54
Silica, dissolved	---	---	4.8	5.3
Dissolved solids	---	---	137	151
Total alkalinity (as $CaCO_3$)	---	---	51	56
Total hardness (as $CaCO_3$)	---	---	88	98
Noncarbonate hardness (as $CaCO_3$)	---	---	37	42
Ammonia, dissolved (as N)	---	---	.04	.07
Organic nitrogen, dissolved (as N)[c/]	---	---	.15	.00
Nitrite, dissolved (as N)	---	---	.03	.04
Nitrate, dissolved (as N)	---	---	.84	.80
Orthophosphate, dissolved (as P)	---	---	.01	.01
Phosphorus, total dissolved (as P)	---	---	.01	.07
Organic carbon, total	---	---	3.8	2.9
Iron, dissolved	---	---	.13	.17
Manganese, dissolved	---	---	.09	.10

Table 1.--Water-quality data for Muddy Fork Silver Creek watershed--Continued

Date of sampling	June 2, 1976				
Site (*See* fig. 1.)	2	3	7	8	12
Eastern standard time	1235	1210	1315	1340	1420
Drainage area (mi^2)	2.01	3.88	3.84	17.33	2.60
Discharge (ft^3/s)[b/]	16	26	34	180	70
Water temp. (°C)	20.6	15.6	16.9	16.4	14.5
pH, field	7.2	6.7	7.3	7.3	7.2
Specific conductance (micromhos per cm at 25°C)	127	192	257	174	122
Dissolved oxygen (percent saturation)	64	83	74	85	84
Dissolved oxygen	5.7	8.1	7.1	8.2	8.4
Calcium	---	28	---	24	11
Magnesium	---	4.9	---	5.7	6.2
Potassium	---	1.9	---	2.0	2.0
Sodium	---	4.1	---	3.5	3.7
Bicarbonate	---	67	---	59	20
Carbonate	---	0	---	0	0
Chloride	---	6.0	---	4.9	2.8
Fluoride	---	.1	---	.1	.1
Sulfate	---	28	---	30	38
Silica, dissolved	---	10	---	9.9	7.7
Dissolved solids	---	125	---	115	81
Total alkalinity (as $CaCO_3$)	---	55	---	48	16
Total hardness (as $CaCO_3$)	---	90	---	83	53
Noncarbonate hardness (as $CaCO_3$)	---	35	---	35	37
Ammonia, dissolved (as N)	---	.03	.10	.04	---
Organic nitrogen, dissolved (as N)[c/]	---	.42	.28	.29	---
Nitrite, dissolved (as N)	---	.01	.02	.01	---
Nitrate, dissolved (as N)	---	1.9	1.6	1.2	---
Orthophosphate, dissolved (as P)	---	.02	.02	.01	---
Phosphorus, total dissolved (as P)	---	.04	.05	.04	---
Organic carbon, total	---	6.6	7.4	6.6	---
Iron, dissolved	---	.04	---	.09	.07
Manganese, dissolved	---	.00	---	.01	.00

Milligrams per liter

Table 1.--Water-quality data for Muddy Fork Silver Creek watershed--Continued

Date of sampling	June 2, 1976			
Site (*See* fig. 1.)	13	18	20	25
Eastern standard time	1440	1510	1535	1635
Drainage area (mi^2)	1.84	3.74	47.23	66.67
Discharge (ft^3/s)[b/]	8.0	16	600	900
Water temp. (°C)	15.8	14.9	16.4	17.5
pH, field	6.9	6.9	6.9	7.1
Specific conductance (micromhos per cm at 25°C)	145	191	142	158
Dissolved oxygen (percent saturation)	64	75	78	74
Milligrams per liter				
Dissolved oxygen	6.3	7.5	7.6	7.0
Calcium	9.4	13	15	18
Magnesium	8.2	10.0	5.7	5.5
Potassium	1.7	2.3	2.4	2.8
Sodium	3.8	8.3	4.5	4.7
Bicarbonate	14	23	31	36
Carbonate	0	0	0	0
Chloride	4.5	6.2	5.0	5.7
Fluoride	.1	.1	.1	.1
Sulfate	51	66	34	35
Silica, dissolved	3.9	4.5	9.7	9.0
Dissolved solids	90	123	96	106
Total alkalinity (as $CaCO_3$)	11	19	25	30
Total hardness (as $CaCO_3$)	57	74	61	68
Noncarbonate hardness (as $CaCO_3$)	48	55	36	38
Ammonia, dissolved (as N)	.01	---	.04	.17
Organic nitrogen, dissolved (as N)[c/]	.24	---	.36	.46
Nitrite, dissolved (as N)	.01	---	.01	.02
Nitrate, dissolved (as N)	.08	---	.83	1.5
Orthophosphate, dissolved (as P)	.01	---	.01	.03
Phosphorus, total dissolved (as P)	.03	---	.04	.03
Organic carbon, total	9.8	---	10	13
Iron, dissolved	.12	.06	.04	.06
Manganese, dissolved	.04	.73	.05	.06

Table 1.--Water-quality data for Muddy Fork Silver Creek watershed--Continued

Date of sampling	July 13, 1976				
Site (*See* fig. 1.)	2	3	7	8	12
Eastern standard time	1130	1200	1330	1400	1445
Drainage area (mi^2)	2.01	3.88	3.84	17.33	2.60
Discharge (ft^3/s)[b]	.1	.4	.6	4.9	.2
Water temp. (°C)	27.4	30.4	32.7	29.5	22.9
pH, field	7.5	8.9	8.3	8.0	7.7
Specific conductance (micromhos per cm at 25°C)	112	291	305	339	221
Dissolved oxygen (percent saturation)	85	120	117	90	99
Milligrams per liter					
Dissolved oxygen	68	91	8.4	6.9	8.4
Calcium	---	37	---	42	---
Magnesium	---	8.3	---	9.0	---
Potassium	---	2.4	---	4.0	---
Sodium	---	11	---	14	---
Bicarbonate	---	100	---	122	---
Carbonate	---	0	---	0	---
Chloride	---	16	---	17	---
Fluoride	---	.1	---	.1	---
Sulfate	---	41	---	42	---
Silica, dissolved	---	6.2	---	5.9	---
Dissolved solids	---	174	---	202	---
Total alkalinity (as $CaCO_3$)	---	82	---	100	---
Total hardness (as $CaCO_3$)	---	130	---	140	---
Noncarbonate hardness (as $CaCO_3$)	---	45	---	42	---
Ammonia, dissolved (as N)	---	.02	.05	.13	---
Organic nitrogen, dissolved (as N)[c]	---	.31	.40	.15	---
Nitrite, dissolved (as N)	---	.01	.02	.03	---
Nitrate, dissolved (as N)	---	.62	.28	1.6	---
Orthophosphate, dissolved (as P)	---	.01	.01	.03	---
Phosphorus, total dissolved (as P)	---	.01	.02	.26	---
Organic carbon, total	---	4.6	---	11	---
Iron, dissolved	---	.00	---	.02	---
Manganese, dissolved	---	.01	---	.17	---

Table 1.--Water-quality data for Muddy Fork Silver Creek--Continued

Date of sampling	July 13, 1976			
Site (*See* fig. 1.)	13	18	20	25
Eastern standard time	1500	1515	1530	1605
Drainage area (mi^2)	1.84	3.74	47.23	66.67
Discharge (ft^3/s)[b/]	.3	.5	9.4	9.9
Water temp. (°C)	17.2	17.5	22.8	23.8
pH, field	7.5	7.3	7.5	7.5
Specific conductance (micromhos per cm at 25°C)	252	172	236	243
Dissolved oxygen (percent saturation)	99	91	82	83
Milligrams per liter				
Dissolved oxygen	9.5	8.6	7.0	7.0
Calcium	---	---	24	25
Magnesium	---	---	9.1	9.0
Potassium	---	---	3.1	3.2
Sodium	---	---	8.5	9.3
Bicarbonate	---	---	62	65
Carbonate	---	---	0	0
Chloride	---	---	9.8	10
Fluoride	---	---	.1	.1
Sulfate	---	---	46	47
Silica, dissolved	---	---	7.3	7.5
Dissolved solids	---	---	142	147
Total alkalinity (as $CaCO_3$)	---	---	51	53
Total hardness (as $CaCO_3$)	---	---	97	100
Noncarbonate hardness (as $CaCO_3$)	---	---	47	46
Ammonia, dissolved (as N)	---	---	.03	.06
Organic nitrogen, dissolved (as N)[c/]	---	---	.25	.32
Nitrite, dissolved (as N)	---	---	.01	.01
Nitrate, dissolved (as N)	---	---	.73	.74
Orthophosphate, dissolved (as P)	---	---	.01	.01
Phosphorus, total dissolved (as P)	---	---	.02	.05
Organic carbon, total	---	---	14	5.1
Iron, dissolved	---	---	.14	.10
Manganese, dissolved	---	---	.19	.06

a/ 1430 = 2:30 p.m.

b/ Estimated.

c/ Nitrogen determined by Kjeldahl method minus ammonia nitrogen.