UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

A water-quality assessment of the Busseron Creek watershed, Sullivan, Vigo, Greene, and Clay Counties, Indiana

OPEN-FILE REPORT
78-13

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

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ENGLISH TO METRIC (SI) SYSTEM CONVERSION FACTORS

The following factors may be used to convert the English units published herein to the International System of Units (SI):

English units	Multiplied by	To obtain SI units
inches (in)	25.4	millimeters (mm)
feet (ft)	.3048	meters (m)
miles (mi)	1.609	kilometers (km)
square feet (ft^2)	.0929	square meters (m^2)
square miles (mi^2)	2.590	square kilometers (km^2)
cubic feet per second (ft^3/s)	.02832	cubic meters per second (m^3/s)
cubic feet per second per square mile [$(ft^3/s)/mi^2$]	.01093	cubic meters per second per square kilometer [$(m^3/s)/km^2$]

A WATER-QUALITY ASSESSMENT OF THE BUSSERON CREEK WATERSHED, SULLIVAN, VIGO, GREENE, AND CLAY COUNTIES, INDIANA

By Stephen E. Eikenberry

ABSTRACT

Chemical quality of surface water in the 237-square mile Busseron Creek watershed is significantly affected by drainage from coal mines and municipalities. Drainage from coal mines is primarily a problem of higher than normal dissolved-solids concentration, whereas, drainage from municipalities is generally a problem of bacteria and phytoplankton. Generally, the water is calcium bicarbonate type, except in streams affected by drainage from coal mines, where the water is a mixed calcium and magnesium sulfate type.

Ranges of concentration (in milligrams per liter) of dissolved solids and of some of the chemical constituents dissolved in streams from September 1975 to July 1976 were: dissolved solids, from 104 to 2,610; iron, from 0.00 to 150; sulfate, from 14 to 1,900; chloride, from 3.3 to 130; nitrate (as nitrogen), from 0.01 to 5.3; phosphate (as phosphorus), from 0.1 to 1.7; and total organic carbon, from 2.4 to 60. Range of pH was from 2.7 to 9.6. Highest concentrations of iron and sulfate and lowest pH values were measured at sites draining areas mined for coal. Highest concentrations of chloride, phosphate, and total organic carbon were at sites downstream from municipalities.

Ranges of concentration of chlorinated hydrocarbons (in micrograms per kilogram) detected in bed material of streams were: aldrin, from 0.2 to 0.4; chlordane, from 0 to 13; DDE, from 0.0 to 0.3; dieldrin, from 0.0 to 9.8; and heptachlor epoxide, from 0 to 1.0. Source of these materials is probably drainage from croplands.

Streams draining municipalities were affected by human wastes and had high populations of fecal coliform bacteria (as many as 46,000 colonies per 100 ml) and phytoplankton (as many as 190,000 cells per milliliter). Dissolved-oxygen concentration ranged from 2.8 to 15.0 milligrams per liter (from 26 to 194 percent of saturation).

PURPOSE AND SCOPE

The purposes of this report, one in a series prepared by the U.S. Geological Survey in cooperation with the U.S. Soil Conservation Service, are to (1) measure variations in water quality; (2) observe the effect of potential sources of pollution on the streams within the watershed (for example, municipalities, industries, strip mines, oil wells, or farms); and (3) acquire data that will help in an understanding of the source and nature of background concentrations of nutrients (nitrogen and phosphorus), organic carbon, common inorganic constituents, and bacteria.

Field measurements (water temperature, specific conductance, dissolved oxygen, and pH), estimates of stream discharge, and visual observations during a basinwide reconnaissance on September 15-17, 1975, were used in selecting representative sites (table 1 and fig. 1) for detailed water-quality sampling at that time and for follow-up sampling in November 1975 and in February, April, and July 1976.

In addition to the field measurements in September 1975, water samples were collected at 14 representative sites for determining concentrations of common inorganic constituents, nutrients, bacteria, and phytoplankton. Bed materials were collected at four sites for determining concentrations of chlorinated hydrocarbons and at two sites for determining concentrations of selected trace metals. Macroinvertebrates were sampled at one site to identify the different insect communities, which indicate the biologic health of a stream. Subsequently, sites 6, 13, and 32 were sampled during every sampling run, whereas sites 26, 27, and 37 were sampled during every sampling run except the one on November 20, 1975. Site 31 was sampled on November 20, and site 46 was sampled on November 20, February 20, and April 22. Sampling near flood-retarding structures (U.S. Soil Conservation Service, 1965), municipalities, and coal mines was particularly emphasized.

ENVIRONMENTAL SETTING AND CONDITIONS

Physical Data

The 237-mi^2 Busseron Creek watershed south of Terre Haute (Hoggatt, 1975), includes most of Sullivan and parts of Vigo, Greene, and Clay Counties in southwest Indiana (fig. 1). The watershed is in the Wabash Lowland physiographic region (Schneider, 1966, p. 41) and is characterized by well-dissected, flat to gently rolling plains. Soils in the area consist of a veneer of windblown silt and sand that covers 15-20 ft of till of Illinoian age. Bedrock consists of interbedded layers of shale, sandstone, limestone, and coal (Early, Middle, and Late Pennsylvanian age) that dip 25-35 ft/mi to the southwest.

Mean monthly temperatures range from -2°C (Celsius) in January to 23°C in July. Mean annual rainfall is 41 in (Hoggatt, 1962, p. 8), and monthly extremes range from 26.2 to 46.8 in at Farmersburg (U.S. Soil Conservation Service, 1965). Rainfall is generally greatest in May and June. Mean annual runoff is 12 in (Hoggatt, 1962, p. 9). Maximum and minimum air temperatures and precipitation at the Sullivan weather station from September 1975

Table 1.--Locations of sites plotted on figure 1, Busseron Creek watershed

Site	Location	Site	Location
1	Busseron Creek near Farmersburg.	25	Mud Creek near Dugger (USGS gaging sta. 03342250).
2	Do.	26	Kettle Creek at Shelburn.
3	Unnamed Busseron Creek tributary near Farmersburg.	27	Kettle Creek near Shelburn.
4	Do.	28	Kettle Creek near confluence with Busseron Creek.
5	Busseron Creek near Farmersburg.	29	Morrison Creek near Shelburn, upstream from sawmill effluent.
6	Busseron Creek near Hymera (USGS gaging sta. 03342100).	30	Morrison Creek near Shelburn, downstream from sawmill effluent.
7	Hooker Creek near Hymera.	31	Morrison Creek near Sullivan.
8	Boston Creek near Hymera.	32	Busseron Creek near Sullivan (USGS gaging sta. 03342300).
9	East Fork Busseron Creek near Hymera.	33	Buttermilk Creek near Dugger.
10	Unnamed Busseron Creek tributary near Hymera.	34	Unnamed Buck Creek tributary near Dugger.
11	West Fork Busseron Creek tributary near Farmersburg.	35	Buck Creek at Sullivan.
12	Do.	36	Unnamed Buck Creek tributary near Sullivan.
13	West Fork Busseron Creek near Hymera (USGS gaging sta. 03342150).	37	Buck Creek near Sullivan.
14	Unnamed west fork of Busseron Creek tributary near Hymera.	38	Robbins Branch near Paxton.
15	Do.	39	Unnamed Busseron Creek tributary near Paxton.
16	Sulphur Creek east of Hymera.	40	Do.
17	Sulphur Creek south of Hymera.	41	Middle Fork Creek near Paxton.
18	Sulphur Creek near Hymera.	42	Unnamed Middle Fork tributary near Paxton.
19	Big Branch Creek near Jasonville.	43	Unnamed Middle Fork tributary near Carlisle.
20	Possum Hollow Creek near Jasonville.	44	Middle Fork Creek near Carlisle.
21	Powell Creek near Gilmore.	45	Busseron Creek near Carlisle (USGS gaging sta. 03342500).
22	Big Branch Creek near Dugger.	46	Mud Creek near Vicksburg.
23	Mud Creek near Antioch.		
24	Unnamed Mud Creek tributary near Dugger.		

through July 1976 are presented in figure 2. Ambient air temperatures in February 1976 were higher than normal. Thus, analyses of some water samples taken in February 1976 show warm-weather trends.

Flow-duration curves for selected stream-gaging stations in the Busseron Creek watershed are shown on figure 3. Shapes of flow-duration curves for Busseron Creek near Hymera, West Fork Busseron Creek near Hymera, and Busseron Creek near Sullivan are similar and are typical of curves for the basin. Higher sustained base flow depicted by the curve for Busseron Creek

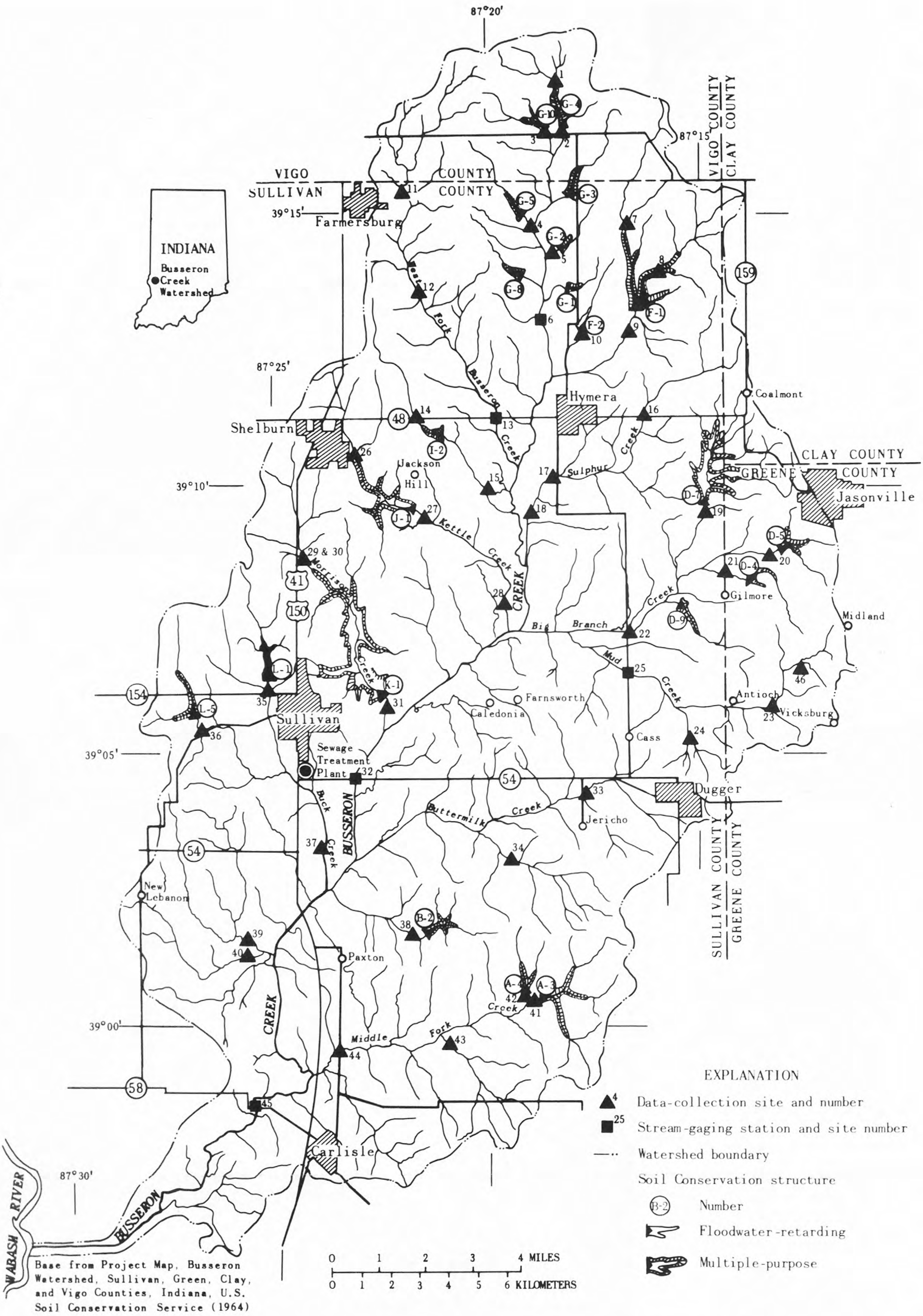

Figure 1.-- Location of data-collection sites in the Busseron Creek watershed.

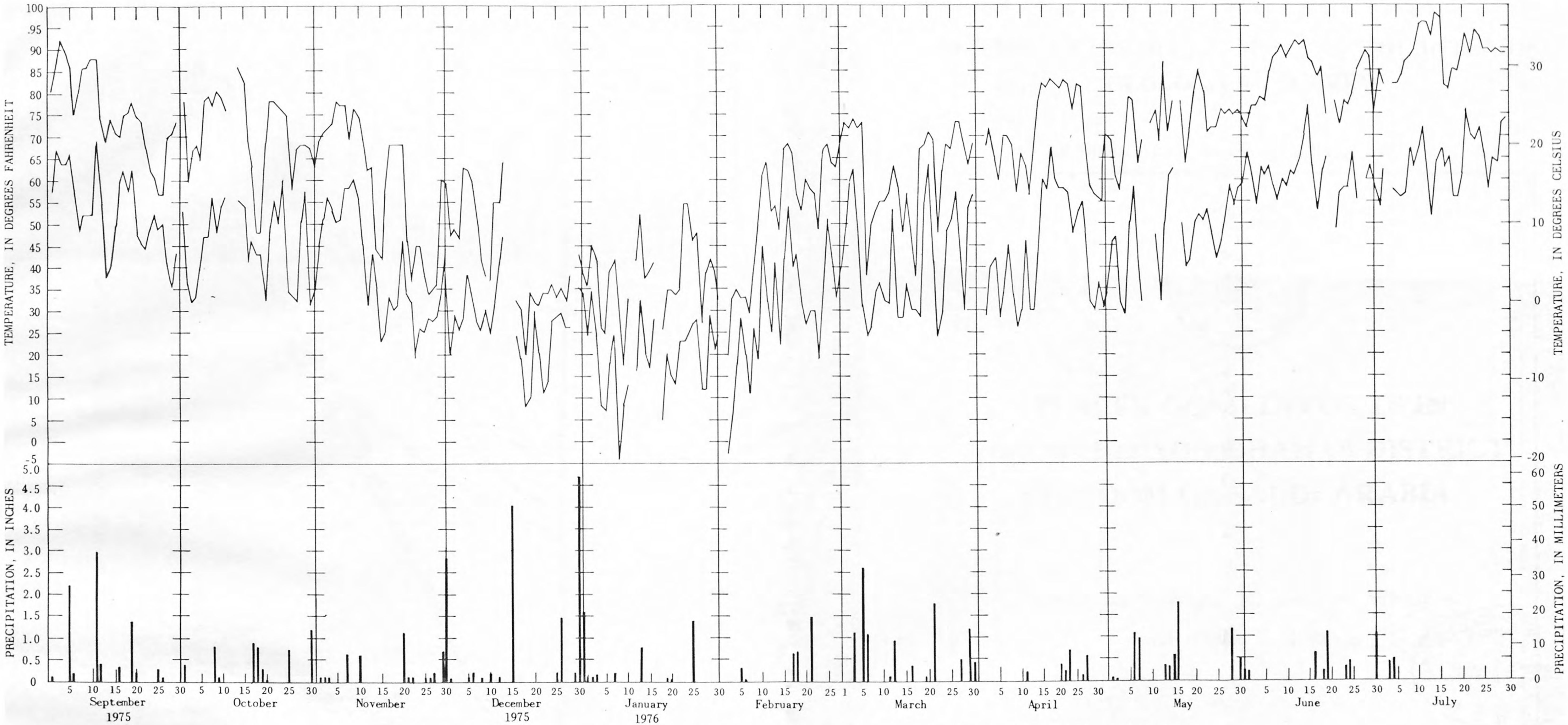

Figure 2. -- Precipitation and maximum and minimum air temperatures at the Sullivan weather station from September 1975 through July 1976.

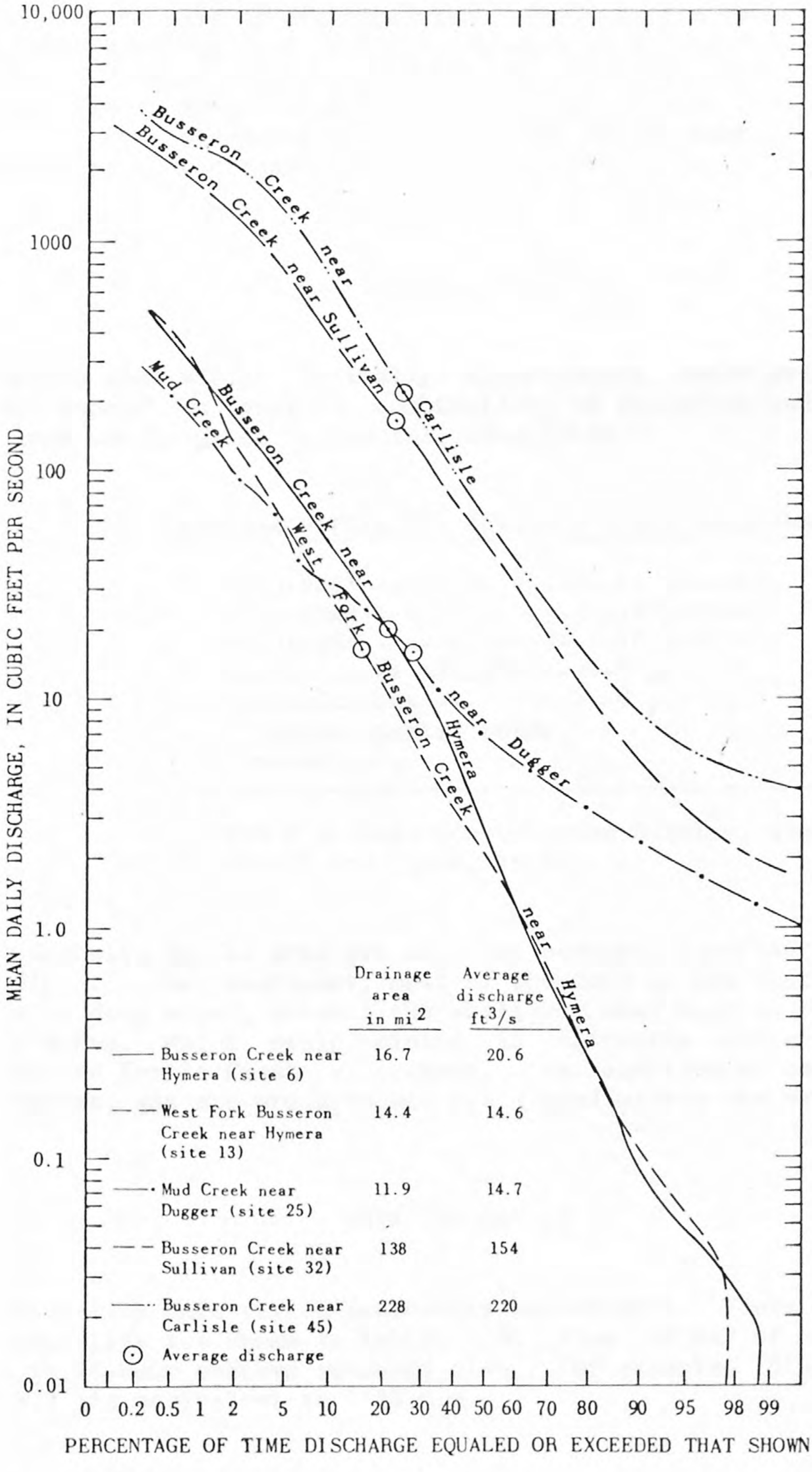

Figure 3.-- Flow-duration curves for streams in the Busseron Creek watershed, October 1966 through September 1973.

near Sullivan is a reflection of greater drainage area, as lower flows increase with increasing drainage area. The duration curve for Mud Creek near Dugger, drainage area 11.9 mi^2, shows higher base flow than expected, nearly that of Busseron Creek near Sullivan, drainage area 138 mi^2, which is almost 12 times the drainage area of Mud Creek. This higher flow is probably due to storage in cast overburden (from strip mining) in the Mud Creek watershed (Corbett and Agnew, 1968, p. 157).

Economic Data

Watershed land use is basically agricultural under private ownership. Most farms depend on various combinations of livestock and grain farming. Present land use is given in the following table:

Land use within the Busseron Creek watershed

Cropland[1]	54 percent
Grassland[1]	18 percent
Woodland[1]	10 percent
Surface coal mines[2]	9 percent
Miscellaneous[1] (urban, parks, roads, mines).	9 percent

[1] From U.S. Soil Conservation Service, 1965
[2] Corbett and Agnew, 1968.

Coal deposits in the area are of great economic importance. Because the bedrock dips to the southwest, most of the coal in the western part of the watershed is deep mined, whereas the shallower coal beds in the eastern part are strip mined. Major strip mining is currently concentrated in the Buttermilk and Kettle Creek watersheds. In addition to coal mining, some oil and natural gas are produced and are stored within the watershed.

DATA EVALUATION

Water-quality data varied seasonally and areally. These data and data for bed materials are shown in tables 2-6. Time of day of each sampling is reported in 24-hour eastern standard time. For example, 1315 hours for site 11, table 2, is equivalent to 1:15 p.m.

Field Measurements

Water temperatures at the sampling sites were generally near concurrent air temperatures and were normal for the sampling periods. The mean annual water temperatures for the gaging stations in the watershed are given in the following table (from Shampine, 1977, table 5, p. 45):

Mean annual water temperatures for stream-gaging stations in the Busseron Creek watershed

Site	Station number	Station name	Mean annual water temperature (°C)
6	03342100	Busseron Creek near Hymera	13.5
13	03342150	West Fork Busseron Creek near Hymera	11.6
25	03342250	Mud Creek near Dugger	14.2
32	03342300	Busseron Creek near Sullivan	12.7
45	03342500	Busseron Creek near Carlisle	12.5

Predicted mean annual water temperature for these sites ranges from 13.3° ± 0.7° to 13.4° ± 0.7°C (Shampine, 1977, p. 12). The higher than predicted mean annual water temperature at site 25 (Mud Creek) is probably due to denudation of much of the drainage area by strip mining, which allows direct sunlight to elevate stream temperatures. Lower than predicted mean annual water temperatures would usually result from higher than normal ground-water influx, which was not observed at sites 13 or 45.

Specific conductance ranged from 88 to 8,000 μmho/cm (micromhos per centimeter) at 25°C. Specific conductance of water draining strip mined areas is characteristically high and increases as the percentage of drainage area strip mined increases, as shown in figure 4, and decreases as discharge increases in drainage areas affected by strip mining (fig. 5). At affected sites, dilution of dissolved solids is continuous with increasing streamflow, whereas specific conductance at site 6 (0.1 percent of drainage area strip mined) is almost constant with increased discharge, except at high streamflows (fig. 5).

The pH ranged from 2.7 to 9.6. Streams with pH less than 6 drained coal-mine areas, and low pH coincided with low streamflow. However, streams draining mined areas had pH near or greater than 7 during periods of higher flow. Streams with pH higher than 9 also had high algal growth. At most of the sites pH was within the range from 6.5 to 8.5, common for Indiana streams.

Dissolved-oxygen concentration was at or near saturation at most sites and during most samplings. However, at sites where the water was stagnant

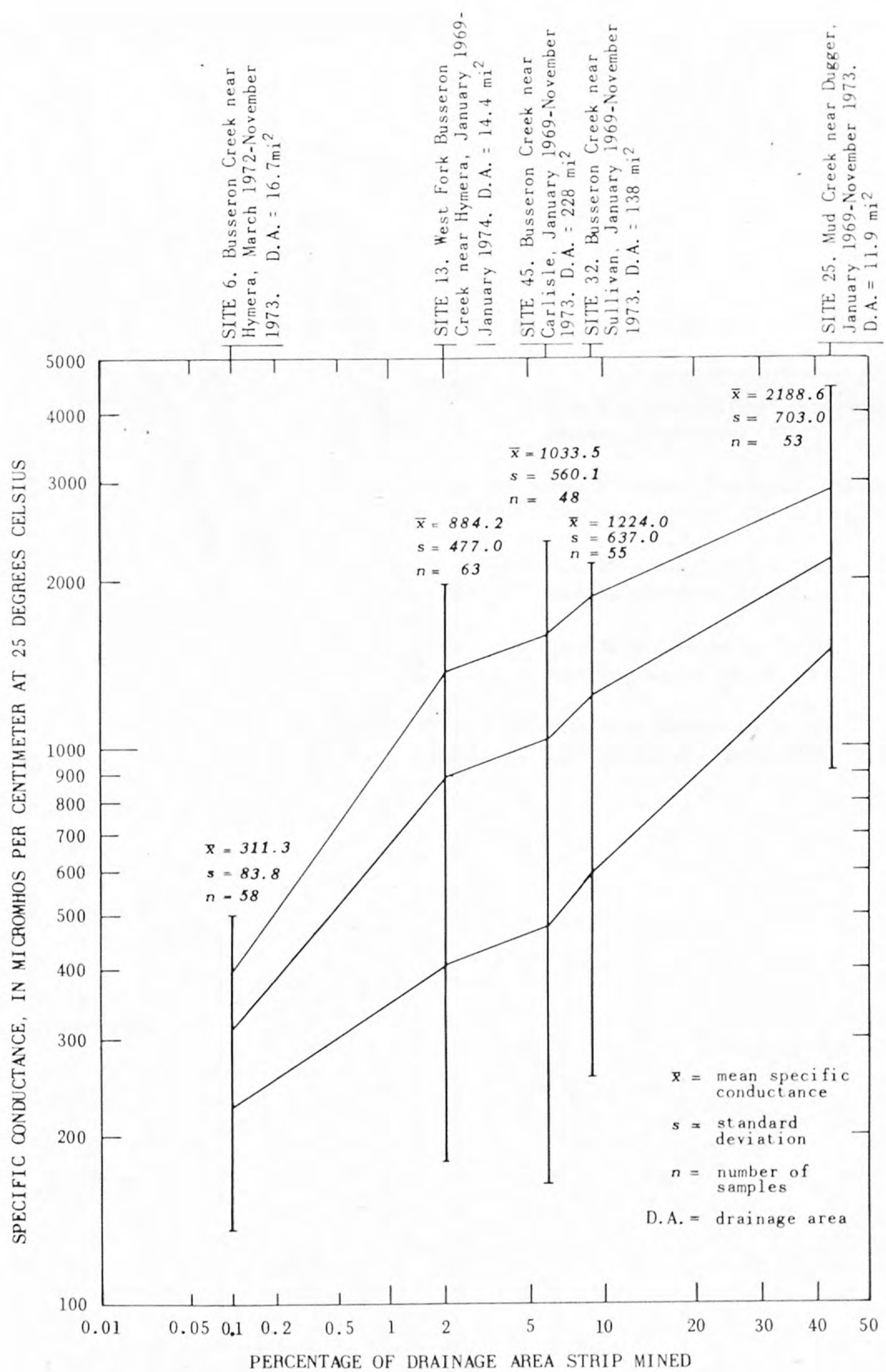

Figure 4.-- Relation of specific conductance to percentage of drainage area strip mined, Busseron Creek watershed.

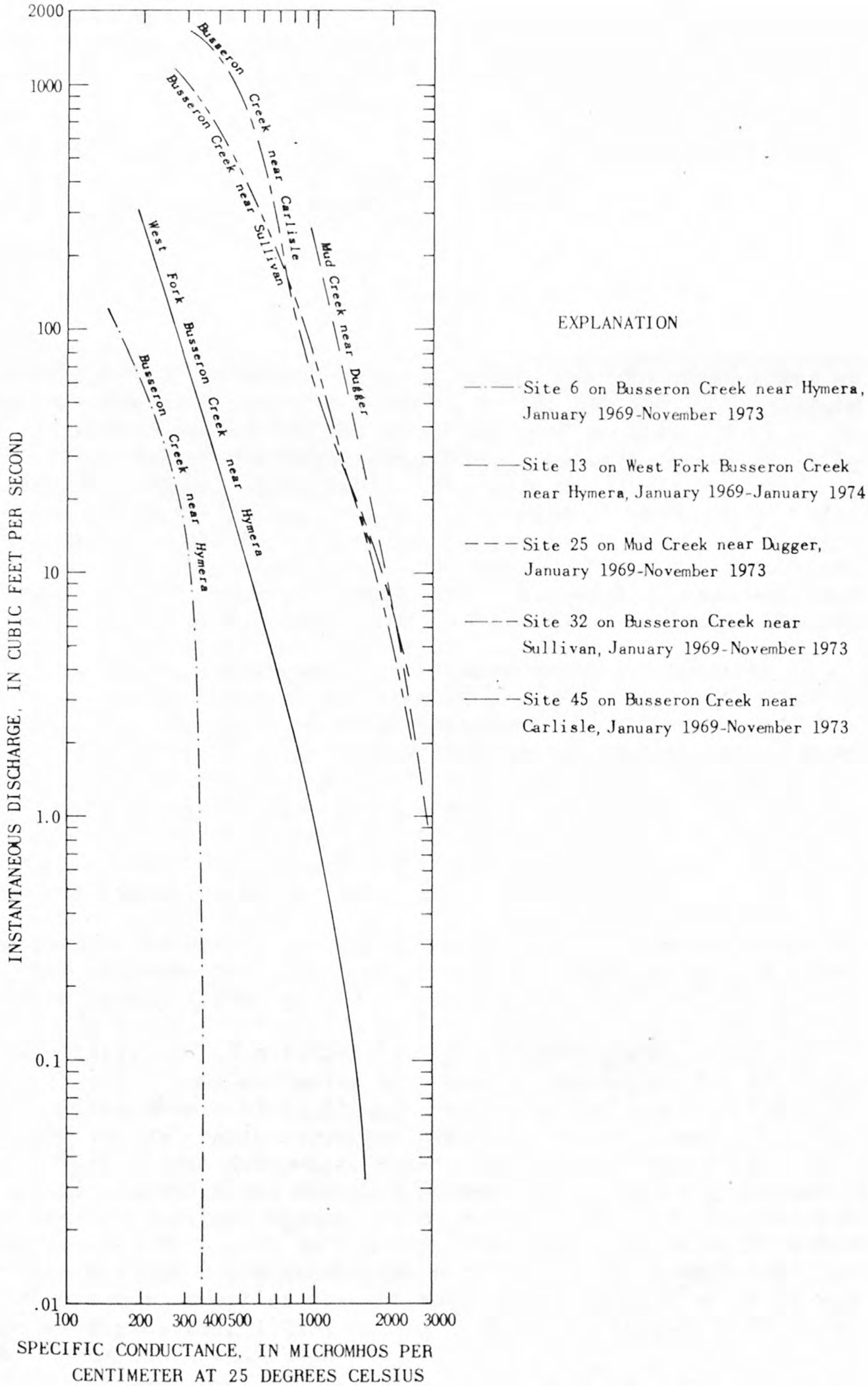

Figure 5.--Relation of specific conductance to discharge in the Busseron Creek watershed.

and enriched by organic matter, percent saturation of dissolved oxygen was generally less than 70, and at sites where the degree of photosynthesis was high, percent saturation was greater than 120.

Chemical Data

Inorganic

Stiff (1951) patterns (fig. 6) illustrate the water types within the watershed. The water type at sites 6, 9, 12, 31, and 37 is calcium bicarbonate, the type expected for the watershed, and at sites 13, 25, 32, 45, and 46, is mixed calcium and magnesium sulfate, characteristic of influence from coal-mine drainage. Water type at sites 26 and 27 is variable. Major dissolved constituents include sodium and chloride, indicating that the sites are affected by upstream municipal discharges. As shown in figure 6, concentrations of the common inorganic constituents vary seasonally. Concentrations are high during summer and fall low flows and are lowest during winter and spring high flows. Chemical data are summarized in table 3.

Dissolved-iron concentration in water samples taken at site 25 on all sampling dates, at site 13 on November 20, 1975, at sites 26 and 32 on February 20, 1976, and at site 37 on September 17, 1975, exceeded the 0.3-mg/L (milligrams per liter) limit recommended for domestic water supply by the U.S. Environmental Protection Agency (1976, p. 152). In addition, the iron concentration in all the preceding samples, except the two samples taken at site 13 on November 20, 1975, and at site 32 on February 20, 1976, exceeded the 1.0-mg/L limit recommended for freshwater aquatic life by the U.S. Environmental Agency (1976, p. 152).

Manganese concentration in most of the water samples exceeded the 0.05-mg/L limit recommended for public water supply by the U.S. Environmental Protection Agency (1976, p. 71).

Concentrations of nutrients (nitrogen, phosphorus, and total organic carbon) in water samples varied seasonally. Ammonia (as nitrogen) concentration ranged from 0.01 to 11 mg/L and, in most samples taken at sites 26 and 27 and in the sample taken at site 25 on September 17, 1975, exceeded the 0.5-mg/L limit for public water supplies recommended by the National Academy of Sciences and National Academy of Engineering for the U.S. Environmental Protection Agency (1973, p. 55). Nitrate (as nitrogen) concentration ranged from 0.01 to 5.3 mg/L and generally followed seasonal trends (fig. 7). All these concentrations were below the 10-mg/L limit recommended for public water supplies by the National Academy of Sciences and National Academy of Engineering (1973, p. 73). Nitrate concentration was highest during winter and spring high flows.

Phosphate (as phosphorus) concentration in water samples ranged from 0.1 to 1.7 mg/L and was highest at sites affected by human waste, downstream from municipalities.

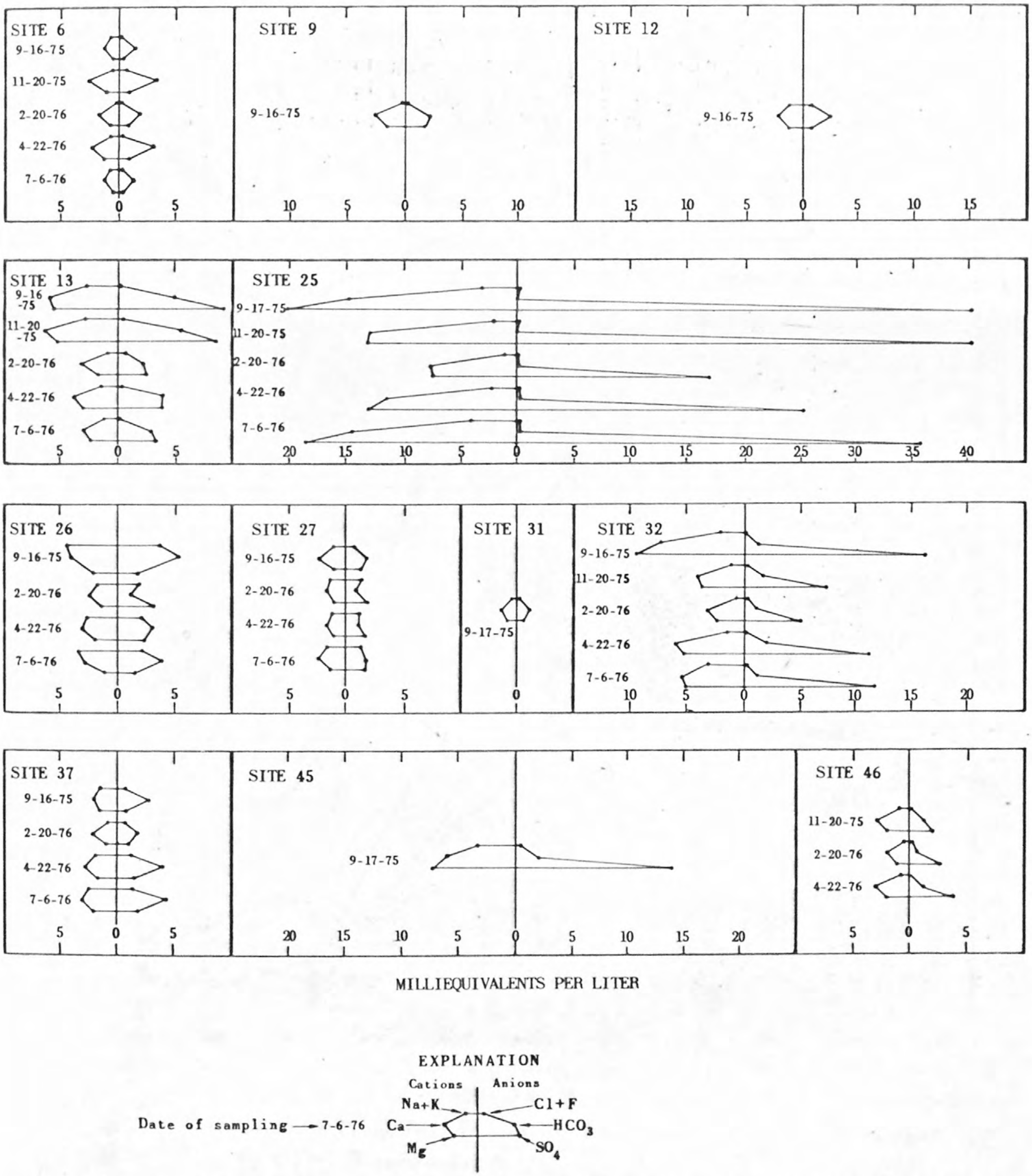

Figure 6.-- Water analyses represented by Stiff patterns based on milliequivalents per liter.

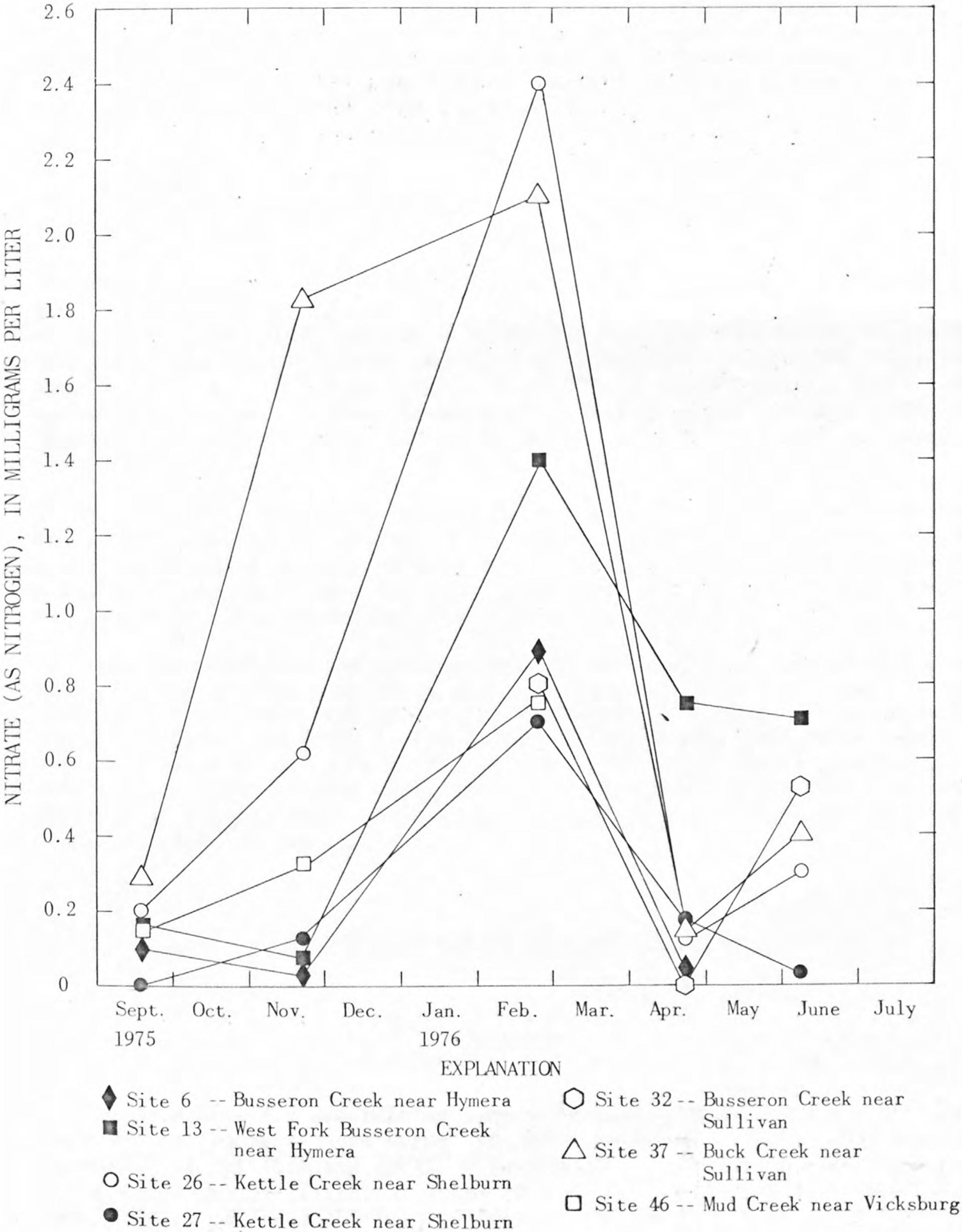

Figure 7. -- Relation of nitrate concentration and seasons in the Busseron Creek watershed.

Total organic carbon concentration in water samples ranged from 2.4 to 60 mg/L and was highest at sites downstream from municipalities in September 1975, probably because of increased organic breakdown during the warm, low-flow period. Concentration was lowest in November 1975, a time when breakdown of organic matter was slow and discharge was high.

Chlorinated Hydrocarbons in Bed Materials

Bed material for measuring chlorinated hydrocarbon concentrations was taken from streams at sites 6, 13, 32, and 45 in September 1975 and at sites 6 and 45 in July 1976. Laboratory analysis included determining concentrations of total organic carbon and the following chlorinated hydrocarbon compounds: aldrin, chlordane, DDD, DDE, DDT, dieldrin, endrin, heptachlor, heptachlor epoxide, lindane, Toxaphene,[1] polychlorinated biphenyl (PCB), and polychlorinated naphthalene (PCN) compounds. The results of these analyses are given in table 6.

Maximum concentrations (in micrograms per kilogram) of chlorinated hydrocarbons detected in September 1975 were: aldrin, 0.4; chlordane, 4; and dieldrin, 2.1; and in July 1976 were: chlordane, 13; DDE, 0.3; dieldrin, 9.8; and heptachlor epoxide, 1.0. These persistent compounds may possibly accumulate in local biological food chains.

Sources of chlorinated hydrocarbons in the bed materials would be difficult to locate with only four sampling sites. However, chlordane is commonly used for termite and ant control, around livestock, or on vegetable crops and lawns. Dieldrin is the decomposition product of aldrin, which is used extensively on corn crops. Dieldrin and aldrin have probably been washed into the streams along with sediment from adjacent cropland. The presence of aldrin, which is less stable than the other compounds, indicates recent insecticide applications.

Microbiological and Biological Data

Bacteria

Water samples for determining concentrations of fecal coliform and fecal streptococcal bacteria were taken at most sampling sites (table 3). The maximum fecal coliform and fecal streptococcal populations were 46,000 and 10,500 cells per milliliter at sites 26 and 37, downstream from municipalities. Ratios of fecal coliform to fecal streptococci can be used to define

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

their probable sources. Human wastes are indicated by ratios greater than 4, whereas animal wastes are indicated by ratios less than 1 (Geldreich, 1966). Ratios may be affected by differential die-off rates. Ratios at sites 26 and 37 indicate human-waste sources, and those for most samples at sites 6, 9, 12, 13, 25, 27, and 45, indicate animal-waste sources. A ratio between 1 and 4 for a sample taken at site 32 on September 17, 1975, indicates a mixed source.

Phytoplankton

Results of the phytoplankton samples collected at sites 6, 13, 26, 27, 31, 32, 37, and 45 are given in table 4. Generally, phytoplankton populations in a stream are low. Diatoms are dominant in cold months, and green and blue-green algae are dominant in warm months. Populations at sites 6 and 13 generally follow these trends. However, site 6 had a diversity of genera and high populations (as many as 39,000 cells/mL on July 6, 1976), probably because flow from upstream reservoirs was dominated by different phytoplankton populations.

High phytoplankton populations (2,900 or more cells/mL) at sites 26, 27, 31, 32, 37, and 45 were dominated by green and blue-green algae. Phytoplankton populations downstream from oxidation ponds at the Sullivan sewage treatment plant at site 37 were the most abundant, ranging from 14,000 to 190,000 cells/mL. These populations were dominated by green algae and indicate organic enrichment.

Macroinvertebrates

Kinds and numbers of organisms in a stream are governed in part by the physical and chemical characteristics of the stream. Furthermore, the condition and diversity of the stream's biologic community indicates the integrated effects of previous water quality and streamflow. A classification of representative macroinvertebrates according to their tolerance of organic wastes was compiled by the U.S. Environmental Protection Agency (1973). Accordingly, those organisms that are generally indicative of certain water-quality conditions are flagged in table 5 as tolerant (T): "Organisms frequently associated with gross organic contamination and are generally capable of thriving under anaerobic conditions;" facultative (F): "Organisms having a wide range of tolerance and frequently are associated with moderate levels of organic contamination;" and intolerant (I): "Organisms that are not found associated with even moderate levels of organic contamination and are generally intolerant of even moderate reductions in dissolved oxygen."

In this study, a quantitative sample of the benthic (bottom-dwelling) community at site 45 was taken on September 18, 1975, with a Surber sampler. Wet weight of the benthic organisms (class Insecta) at this site was

0.4 gram per square meter, which is low. Qualitative samples (synoptic survey) were also collected at the site by dip net and by hand picking from rocks, sticks, and aquatic plants. A 1-ft^2 sample was collected with a Surber sampler from a slow, shallow riffle in the streambed, which consisted of flat cobbles, pebbles, sand, and some coal fines. A comparison of the sample obtained by the Surber sampler with the synoptic-survey samples shows that most organisms in the former sample were bottom-dwelling types, such as caddis flies, midges, beetles, and clams. However, organisms in the synoptic-survey sample included more mobile, surface-dwelling aquatic bugs as well as caddis flies and some beetles.

The diversity index (for the Surber sample only) for site 45 (table 5) was 2.02, which probably indicates moderate organic enrichment. The moderate total organic carbon concentration at the site (9.0 mg/L) is in good agreement with the observed condition of the Busseron Creek community. However, many factors (including unstable streamflow, and highly turbid, low-temperature, coal-fine-laden streams) affect the stream's biologic community and the diversity index. Different biologic communities were observed with the various types of bed materials at the site. The variety of benthic invertebrates was greatest in gravel riffles, whereas there were no invertebrates in the stream in areas covered with coal fines. Therefore, as different diversity indices would normally change during different seasons as well as during different weather, water quality, and flow, data for the single sample from site 45 must be considered only as approximations of the biologic health of the stream.

WATER-QUALITY PROBLEMS

Analysis of the water-quality data revealed two significant water-quality problems: drainage from coal mines and drainage from municipalities. Drainage from coal mines, in most of the watershed, is primarily a problem of higher than normal dissolved-solids concentrations, although ionic concentrations and pH are affected to varying degrees. Drainage from municipalities mostly in the west part of the watershed, is generally a biological problem of high populations of bacteria and phytoplankton, although concentrations of nutrients are affected to varying degrees.

Drainage from Coal Mines

Most of the sites sampled in the Busseron Creek watershed are affected in varying degrees by coal-mine drainage (sites 7-9, 13-28, 32-34, and 45 and 46 on fig. 1). Effects of drainage from strip mines on water quality can be seen by examining data collected in the Mud Creek watershed at the downstream site 25 and at the upstream site 46 (table 2). Forty-three percent of the Mud Creek watershed upstream from site 25 (fig. 1) has been strip mined (Corbett and Agnew, 1968), whereas none of the watershed upstream from site 46 has been strip mined. Comparison of the Stiff patterns (fig. 6) representing chemical analyses of water samples taken at sites 25 and 46 shows much higher sulfate concentrations at site 25 than at site 46. Dissolved-solids concentrations at site 46 are significantly lower than they are at site 25. The downstream increases in dissolved solids, particularly sulfate, are due to drainage from areas where strip mining has exposed iron sulfide minerals. The range in pH at site 25 (from 3.1 to 7.0) indicates that acid production in the strip mined area is significant at times.

Dissolved iron, manganese, and aluminum concentrations were also high in samples taken at site 25. Dissolved-iron concentrations ranged from 12 to 150 mg/L and manganese from 5.0 to 16 mg/L. The one aluminum concentration was 41 mg/L. The limits of 0.3 mg/L for iron and 0.05 mg/L for manganese, recommended for domestic water supplies by the U.S. Environmental Protection Agency (1976), were exceeded in all samples taken at sites in coal-mine-drainage areas.

Dissolved-iron concentrations in samples from other sites (9, 13, 32, 45 and 46) affected by coal-mine drainage were less than 0.3 mg/L, except in samples taken at site 13 (0.49 mg/L), on November 20, 1975, and site 32 (0.73 mg/L), on February 20, 1976.

Water-quality trends in streams whose drainage areas have also been strip mined would probably be similar to those in Mud Creek. Coal was strip mined in the Kettle Creek watershed upstream from site 28 during the study. Effects of strip mining on the water quality of Kettle Creek at site 28 can be seen in the following comparison of sampling dates and field measurements of pH and specific conductance.

Field measurements at site 28

Sampling date	pH	Specific conductance
September 16, 1975	8.2	420
February 20, 1976	7.7	---
April 22, 1976	7.5	740
July 6, 1976	5.6	7,180

Also, Buttermilk Creek would be expected to show water-quality trends similar to those in Mud Creek. Dominance of calcium, magnesium, and sulfate water-types in Busseron Creek at sites 32 and 45 (fig. 6) shows the influence of Mud Creek and other coal-mine drainage on the water quality of Busseron Creek. However, pH at site 32 ranged from 7.1 to 8.3, indicating that any acidic coal-mine drainage has been neutralized before reaching this downstream sampling point.

The effects of coal-mine drainage, high dissolved-solids concentrations, and, occasionally, low pH, are evident throughout the Busseron Creek watershed and constitute the most significant, areal water-quality problem in the watershed.

Drainage from Municipalities

Drainage from municipalities significantly degrades surface-water quality in parts of the watershed. Human waste is responsible for this degradation as indicated by high bacterial counts, large phytoplankton populations, and high sodium and chloride concentrations. Human waste was detected in Kettle Creek, which flows along the east side of Shelburn; Buck Creek, downstream from the Sullivan sewage-treatment plant; and West Fork Busseron Creek at site 12.

The two sites selected for sampling in the Kettle Creek watershed were site 26 in the municipality of Shelburn and site 27 just downstream from the U.S. Soil Conservation Service reservoir J-1. The pH of Kettle Creek ranged from 6.5 to 8.8 and was consistently higher at site 27 than at site 26. Dissolved-oxygen concentration, however, was lower at site 26 than at site 27 in three of the five sets of samples from the two sites, but percentage saturation of all samples from site 27 was higher than that of samples from site 26. Percentage saturation at site 26 ranged from 26 to 124 and that at site 27 from 84 to 132. All measurements of specific conductance at site 26 were higher than those at site 27. The lower specific conductance, higher pH, and generally higher dissolved-oxygen concentration downstream from the reservoir at site 27 indicate dilution effects by water in the reservoir of site 26 inflows.

Stiff patterns (fig. 6) show mixed water types for sites 26 and 27, effects of dilution by the reservoir at site 27, and elevated sodium and chloride concentrations at site 26.

Ammonia (as nitrogen) concentration and total organic carbon concentration as high as 11 and 31 mg/L, respectively, at site 26, suggest organic enrichment.

At site 26, concentrations of fecal coliform bacteria and fecal streptococcal bacteria ranged from 1,250 to 46,000 col/100 mL, and 1,000 to 4,700 col/100 mL, respectively. At site 27, concentrations of the same two types of bacteria ranged from 5 to 150 col/100 mL, and from 10 to 430 col/100 mL, respectively. Lower bacterial counts at site 27 probably represent the effect of dieoff due to residence time in the reservoir. The ratio of concentrations of fecal coliform to fecal streptococcal bacteria at site 26 indicates human or mixed sources of bacteria in the samples, whereas the ratios for site 27 indicate animal sources.

Phytoplankton populations at sites 26 and 27 were high and were dominated by blue-green algae in most samples. Dominance by blue-green algae usually indicates organic enrichment and agrees with the chemical and bacterial data for Kettle Creek.

Water-quality problems in Buck Creek were similar to those in Kettle Creek, as shown by analyses of water samples taken at site 37, downstream from the Sullivan sewage-treatment plant. As shown in the Stiff patterns (fig. 6), water type at site 37 is calcium bicarbonate, and the water has higher sodium and chloride concentrations than that sampled in other parts of the watershed.

Ammonia (as nitrogen) and total organic carbon concentrations at site 37 were high; maximum concentrations were 4.3 and 60 mg/L, respectively. The pH, which ranged from 7.7 to 9.6, was higher in some of the samples than that common in streams. Dissolved-oxygen concentrations ranged from 57 to 194 percent saturation and from 5.9 to 15 mg/L. The high dissolved-oxygen concentrations indicate vigorous photosynthetic activity and also correlate with high pH. Dissolved-oxygen concentration and pH at site 37 are compared in the following table:

		Dissolved oxygen	
Sampling date	pH	mg/L	Percent saturation
September 17, 1975	8.8	12.0	141
November 20, 1975	7.7	5.9	57
February 20, 1976	7.9	10.7	93
April 22, 1976	9.6	13.2	162
July 6, 1976	9.2	15.0	194

Fecal coliform and fecal streptococcal bacteria were also high, concentrations ranging from 900 to 7,500 col/100 mL and 700 to 10,500 col/100 mL, respectively. Ratios of fecal coliform to fecal streptococcal bacteria in Buck Creek indicate human sources in all but one sample. The source of the high phytoplankton populations dominated by green algae is probably the oxidation ponds of the Sullivan sewage-treatment plant.

Probable human waste was detected at site 12 on West Fork Busseron Creek. The sample taken on September 16, 1975, had the highest nitrate (as nitrogen) concentration in the watershed (5.3 mg/L) at a time when nitrate concentrations should be low. Total organic carbon was moderate (18 mg/L), and sodium and chloride concentrations were higher than expected. Inexplicably, water-quality data downstream at site 13 showed no evidence of human waste.

Organic enrichment in Morrison Creek is indicated by data collected at sites 29 and 30 (table 3) on September 17, 1975. Site 29 is about 30 ft upstream from a drain that was discharging sawmill leachate, and site 30 is about 100 ft downstream from the drain. Dissolved-oxygen concentration was 6.7 mg/L (74 percent saturation) at site 29, whereas it was 4.8 mg/L (53 percent saturation) at site 30. Specific conductance was 373 μmho/cm at site 29, whereas it was estimated to be 620 μmho/cm at site 30. Similarly, total organic carbon concentration increased from 17 mg/L at site 29 to 57 mg/L at site 30. However, there was no evidence of the sawmill leachate downstream from reservoir K-1 (fig. 1 and table 3).

SUMMARY AND CONCLUSIONS

Chemical quality of surface water in the Busseron Creek watershed is significantly affected by drainage from coal mines and municipalities. Drainage from coal mines in most of the watershed is primarily a problem of higher than normal dissolved-solids concentration, although ionic concentrations, and pH are affected to varying degrees. Drainage from municipalities, mostly in the west part of the watershed, is generally a biological problem of high populations of bacteria and phytoplankton, although concentrations of nutrients are affected to varying degrees.

Water temperatures generally reflected ambient air temperatures. However, water temperatures were highest in Mud Creek near Dugger, an area that has been extensively strip mined, and in Buck Creek downstream from the Sullivan sewage-treatment plant. Acidic drainage from coal mines caused pH to decrease to a low of 2.7 (sites 14 and 16, table 2). Dissolved-oxygen concentrations were high (194 percent of saturation at site 37, July 6, 1976) at sites affected by human waste where photosynthetic activity was high. At times, these sites had low dissolved-oxygen concentrations (10 percent of saturation at site 14, April 22, 1976) when conditions such as stagnant water or low pH were not favorable for growth of aquatic plants. At most sites, however, dissolved-oxygen concentration was within the range expected in natural streams. Specific conductance, was high (as much as 8,000 μmho/cm at site 14, table 2) in areas affected by coal-mine drainage and correlated well with the percentage of a drainage basin that had been strip mined.

Water in the Busseron Creek watershed is generally a calcium bicarbonate type, except in the watersheds affected by coal-mine drainage. Affected drainages have water that is a mixed calcium and magnesium sulfate type and that typically has high dissolved-solids concentrations (as much as 2,610 mg/L at site 25, table 3).

Dissolved-iron concentrations were very high (as much as 150 mg/L, at site 25, table 3) at Mud Creek near Dugger, where the effect of strip mining on surface-water quality is greatest. Dissolved-iron concentrations were low at all the other sites. Dissolved-manganese concentrations were high (a maximum of 16 mg/L at site 25, table 3) in most samples, exceeding the 0.3-mg/L limit for drinking water specified by the U.S. Environmental Protection Agency, 1976, p. 152).

Concentrations of dissolved nutrients (nitrogen, phosphorus, and organic carbon) typically were high (maximums: nitrate, as nitrogen, 5.3 mg/L at site 12; phosphate, as phosphorus, 1.7 mg/L at site 26; and total-organic carbon, 60 mg/L at site 37) at sites affected by human waste on Kettle and Buck Creeks. Nitrate and total organic carbon concentrations followed seasonal trends at all sites.

Concentrations of fecal coliform and fecal streptococcal bacteria were very high at sampling sites on Kettle Creek (maximums: fecal coliform 46,000 col/100 mL and fecal streptococcal bacteria 4,700 col/100 mL) and Buck Creek (maximums: fecal coliform bacteria 7,500 col/100 mL and fecal streptococcal bacteria 10,500 col/100 mL), but were within expected ranges in most samples at other sites. The ratio of fecal coliform bacteria to fecal streptococcal bacteria, which can be used to help define sources of fecal organisms, indicated human sources at site 26 on Kettle Creek and at site 37 on Buck Creek. The ratios for all other sites indicated animal sources.

Concentration of dieldrin, the decomposition product of aldrin, ranged from 0.0 to 9.8 μg/kg in bed materials at sites 6, 13, 32, and 45 in Busseron and West Fork Busseron Creeks. Concentrations of aldrin at site 13 on the West Fork Busseron Creek and at site 45 on Busseron Creek were low (0.2 and 0.4 μg/kg, respectively). The maximum chlordane concentration at the downstream site of Busseron Creek (site 45) was 13 μg/kg. Although concentrations this low probably do not represent a water-quality problem, these persistent compounds are definitely in residence in the bed materials.

Phytoplankton samples taken at sites 26 and 37 on Kettle and Buck Creeks, respectively, had high cell counts (as much as 14,000 and 190,000 cells/mL) and are evidence of organic enrichment. Evidence of organic enrichment at the downstream Busseron Creek site 45 consisted of a phytoplankton population (28,000 cells/mL) dominated by blue-green algae, benthic organisms dominated by species that can survive moderate levels of organic contamination, and a diversity index of 2.02 (table 5). Areas of the stream bottom covered with coal fines in lower Busseron Creek were generally devoid of benthic invertebrates.

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Tables 2-6

Table 2.--Busseron Creek watershed reconnaissance data

[Analyses by U.S. Geological Survey]

Site	Time[a]	Date of collection	Drainage area (mi²)	Discharge (ft³/s)	Water temp. (°C)	pH, field	Spec. cond.[b]	Dissolved oxygen (percent of saturation)	Dissolved oxygen (mg/L)
1	1020	9-16-75	1.2	No flow	----	---	-----	---	---
2	1040	9-16-75	3.4	1.1	20.6	---	194	73	6.6
3	1100	9-16-75	1.3	.2	20.4	---	186	76	6.8
4	1110	9-16-75	1.5	.1	20.3	---	220	80	7.2
5	1120	9-16-75	13.6	1.3	19.8	---	190	96	8.6
7	1130	9-16-75	2.5	<.1	20.6	---	296	80	7.2
8	1140	9-16-75	3.8	.4	26.5	---	528	99	8.1
10	1220	9-16-75	.6	.1	18.6	---	88	72	6.5
11	1315	9-16-75	3.6	.1	18.7	---	215	79	7.1
14	1340	9-16-75	2.2	<.01	27.8	---	528	105	8.3
15	1600	9-16-75	3.6	.2	16.9	7.7	[c]650	74	7.1
16	0930	9-17-75	2.0	.7	17.1	2.7	[c]1,900	73	7.0
17	0940	9-17-75	9.5	[d]BW	17.1	5.9	[c]950	75	7.2
18	0945	9-17-75	10.2	.8	16.4	5.3	[c]900	72	7.1
20	1000	9-17-75	1.9	.6	18.0	7.9	[c]1,750	80	7.5
21	1010	9-17-75	2.0	.4	18.7	7.6	[c]1,100	78	7.0
22	1020	9-17-75	18.2	1.5	18.2	7.7	[c]2,000	77	7.2
23	1040	9-17-75	4.2	.3	17.8	6.9	[c]2,400	70	6.6
24	1100	9-17-75	2.2	.5	18.0	6.3	[c]2,990	77	7.2
28	1700	9-16-75	10.3	[c].6	18.3	8.2	[c]420	82	7.7
33	1200	9-17-75	4.0	.8	18.7	6.8	[c]4,200	84	7.6
34	1215	9-17-75	4.6	No flow	----	---	-----	--	---
35	1640	9-17-75	2.5	.2	22.0	8.5	[c]152	86	7.5
36	1650	9-17-75	2.2	.3	20.5	7.8	[c]165	81	7.3
38	1700	9-17-75	1.4	No flow	----	---	-----	--	---
39	1710	9-17-75	3.4	No flow	----	---	-----	--	---
40	1720	9-17-75	9.7	.03	21.6	8.4	[c]580	92	8.0
41	1730	9-17-75	4.6	.2	21.2	8.0	[c]200	86	7.7
42	1735	9-17-75	1.1	.02	21.6	8.7	[c]210	85	7.4
43	1740	9-17-75	2.8	.1	19.8	8.0	[c]320	96	8.6
44	1745	9-17-75	22.0	No flow	----	---	-----	--	---
14	0955	2-20-76	2.2	.3	4.4	4.2	-----	89	11.6
28	1055	2-20-76	10.3	4.5	6.4	7.7	-----	82	10.1
14	1020	4-22-76	----	<.01	13.9	2.7	8,000	10	<1
28	1150	4-22-76	----	.3	16.0	7.5	740	49	4.7
28	1800	7-06-76	10.3	.1	23.4	5.6	7,180	56	4.8

a Eastern standard time. (Twenty-four hour time is used; for example, 1340 is the same as 1:40 p.m.)

b Specific conductance, in micromhos per centimeter at 25°C (Celsius).

c Estimated.

d Backwater.

Table 3.--Summary of Busseron Creek watershed water-quality data

[Analyses by U.S. Geological Survey]

	Site (fig. 1)	6	9	12	13	19	25
	Date (1975)	Sept. 16	Sept. 16	Sept. 16	Sept. 16	Sept. 16	Sept. 17
	Time (eastern stand.)	1230	1200	1315	1630	0950	1115
	Drainage area (mi^2)	16.7	9.97	2.5	14.4	4.8	11.9
	Discharge (ft^3/s)	3.3	2.0	.2	.40	<.1	3.6
	Water temp. (°C)	20.8	23.8	24.3	15.8	18.2	20.3
	pH, field	------	------	------	-------	7.1	4.4
	Specific cond.[a]	178	412	460	1,290	208	2,970
	Dissolved oxygen[b]	102	88	74	78	33	79
Milligrams per liter	Dissolved oxygen	9.1	7.4	6.2	7.7	3	7.2
	Calcium	23	52	48	130	------	300
	Magnesium	6.3	17	15	68	------	250
	Potassium	4.1	3.9	6.1	5.1	------	4.7
	Sodium	5.0	4.3	27	62	------	68
	Bicarbonate	98	145	156	297	------	0
	Carbonate	0	0	0	0	------	0
	Chloride	3.9	3.3	28	6.9	------	3.5
	Fluoride	.1	.2	.1	.1	------	.7
	Sulfate	14	92	45	450	------	1,900
	Silica, dissolved	3.0	7.7	9.1	8.5	------	17
	Dissolved solids	108	253	281	879	------	2,590
	Total alkalinity (as $CaCO_3$)	80	119	128	244	------	acidity (as H^+) 3.0
	Total hardness (as $CaCO_3$)	83	200	180	600	------	1,800
	Noncarbonate hardness (as $CaCO_3$)	3	81	54	360	------	1,800
	Ammonia, dissolved (as N)	.06	.09	.06	.18	------	.84
	Organic nitrogen, dissolved (as N)[c]	.75	1.9	1.2	.23	------	.36
	Nitrite, dissolved (as N)	.01	.01	.05	.01	------	.01
	Nitrate, dissolved (as N)	.10	.11	5.3	.16	------	.10
	Orthophosphate, dissolved (as P)	.01	.01	.43	.01	------	.01
	Phosphate, dissolved (as P)	.04	.04	.49	.01	------	.10
	Organic carbon, total	9.2	6.6	18	17	------	9.0
	Aluminum, dissolved	-------	-------	------	------	------	-------
	Iron, dissolved	.06	.04	.04	.22	------	26
	Manganese, dissolved	.11	.60	.40	.78	------	14
	Detergents	.0	-------	-------	.0	------	-------
	Turbidity (Jtu)[d]	13	20	11	10	------	190
µg/g	Aluminum (bed material)	-------	-------	-------	------	------	-------
	Iron (bed material)	-------	-------	-------	------	------	-------
	Manganese (bed material)	-------	-------	-------	------	------	-------
	Fecal coliform[e]	170	[f]640	[f]700	250	130	[f]5
	Fecal streptococci[e]	700	1,700	1,450	1,000	350	77

Table 3.--Summary of Busseron Creek watershed water-quality data--Continued

	Site (fig. 1)	26	27	29	30	31	32
	Date (1975)	Sept. 16	Sept. 16	Sept. 17	Sept. 17	Sept. 17	Sept. 17
	Time (eastern stand.)	1430	1530	1510	1520	1530	1300
	Drainage area (mi^2)	2.8	6.5[f]	3.6	3.6	11.6	138
	Discharge (ft^3/s)	.2	.4	.01	.02	.3	12
	Water temp. (°C)	17.7	21.0	19.2	21.1	23.8	19.1
	pH, field	7.7	7.9	7.4	7.2	9.1	7.1
	Specific cond.[a]	1,100	426	373	[f]620	243	1,520
	Dissolved oxygen[b]	38	84	74	53	126	81
Milligrams per liter	Dissolved oxygen	3.4	7.6	6.7	4.8	10.6	7.3
	Calcium	84	44	------	------	28	150
	Magnesium	28	13	------	------	7.9	110
	Potassium	10	4.9	------	------	3.0	4.8
	Sodium	100	20	------	------	7.1	44
	Bicarbonate	365	119	169	------	87	77
	Carbonate	0	0	0	------	0	0
	Chloride	130	26	11	------	6.9	5.4
	Fluoride	.2	.2	.3	------	.0	.2
	Sulfate	81	64	26	------	34	770
	Silica, dissolved	20	2.1	7.2	------	2.0	7.4
	Dissolved solids	653	233	------	------	132	1,130
	Total alkalinity (as $CaCO_3$)	299	98	139	------	71	63
	Total hardness (as $CaCO_3$)	330	160	------	------	100	830
	Noncarbonate hardness (as $CaCO_3$)	26	66	------	------	31	760
	Ammonia, dissolved (as N)	10	.12	.06	.04	.06	.15
	Organic nitrogen, dissolved (as N)[c]	4.0	1.2	1.7	.96	.57	.03
	Nitrite, dissolved (as N)	.27	.01	.04	.01	.03	.01
	Nitrate, dissolved (as N)	.20	.01	.28	.03	.09	.15
	Orthophosphate, dissolved (as P)	1.4	.01	.03	.16	.01	.01
	Phosphate, dissolved (as P)	1.7	.04	.09	.24	.04	.12
	Organic carbon, total	16	16	17	57	33	19
	Aluminum, dissolved	-------	-------	-------	-------	-------	-------
	Iron, dissolved	.05	.01	-------	-------	.01	.20
	Manganese, dissolved	.79	.15	-------	-------	.03	3.8
	Detergents	.5	.0	-------	-------	-------	.0
	Turbidity (Jtu)[d]	8	6	11	-------	4	21
μg/g	Aluminum (bed material)	-------	-------	-------	-------	-------	-------
	Iron (bed material)	-------	-------	-------	-------	-------	-------
	Manganese (bed material)	-------	-------	-------	-------	-------	-------
	Fecal coliform[e]	3,300	50	54	-------	25	1,350
	Fecal streptococci[e]	1,000	280	250	-------	55	470

Table 3.--Summary of Busseron Creek watershed water-quality data--Continued

	Site (fig. 1)	37	45	6	12	13
	Date (1975)	Sept. 17	Sept. 17	Nov. 20	Nov. 20	Nov. 20
	Time (eastern stand.)	1600	1800	1040	-------	1010
	Drainage area (mi^2)	14.3	228	16.7	-------	14.4
	Discharge (ft^3/s)	1.3	21	.35	-------	1.4
	Water temp. (°C)	23.4	18.5	10.2	-------	10.3
	pH, field	8.8	7.6	8.0	-------	7.7
	Specific cond.[a]	496	1,470	292	-------	947
	Dissolved oxygen[b]	141	82	91	-------	71
Milligrams per liter	Dissolved oxygen	12.0	7.4	10.3	-------	7.7
	Calcium	39	120	53	-------	130
	Magnesium	17	88	16	-------	64
	Potassium	6.4	5.3	3.3	-------	4.7
	Sodium	30	72	11	-------	64
	Bicarbonate	183	130	208	-------	334
	Carbonate	0	0	0	-------	0
	Chloride	32	8.8	8.6	-------	19
	Fluoride	.1	.1	.1	-------	.1
	Sulfate	35	660	30	-------	410
	Silica, dissolved	11	6.8	5.5	-------	7.0
	Dissolved solids	267	1,030	231	-------	865
	Total alkalinity (as $CaCO_3$)	150	107	171	-------	950
	Total hardness (as $CaCO_3$)	170	660	200	-------	590
	Noncarbonate hardness (as $CaCO_3$)	17	560	28	-------	310
	Ammonia, dissolved (as N)	.71	.17	.01	-------	.21
	Organic nitrogen dissolved (as N)[c]	2.2	.48	.33	-------	.28
	Nitrite, dissolved (as N)	.34	.02	.01	-------	.01
	Nitrate, dissolved (as N)	.29	.38	.03	-------	.07
	Orthophosphate, dissolved (as P)	.77	.01	.01	-------	.03
	Phosphate, dissolved (as P)	.95	.14	.03	-------	.02
	Organic carbon, total	60	9.0	5.0	-------	4.6
	Aluminum, dissolved	------	-------	-------	-------	------
	Iron, dissolved	.04	.04	.10	-------	.49
	Manganese, dissolved	.15	1.7	.32	-------	.56
	Detergents	.3	.0	.04	-------	------
	Turbidity (Jtu)[d]	10	10	------	-------	------
µg/g	Aluminum (bed material)	------	-------	.92	-------	------
	Iron (bed material)	------	-------	3.60	-------	------
	Manganese (bed material)	------	-------	.39	-------	------
	Fecal coliform[e]	[fg]3,700	[f]2,300	55	35	30
	Fecal streptococci[e]	[fg]700	[f]5,500	100	45	40

Table 3.--Summary of Busseron Creek watershed water-quality data--Continued

	Site (fig. 1)	25	26	27	31	32	37	46
	Date (1975)	Nov. 20	Nov. 20	Nov. 20	Nov. 20	Nov. 20	Nov. 20	Nov. 20
	Time (eastern stand.)	1500	1140	1220	1335	1400	1415	1550
	Drainage area (mi^2)	11.9	2.8	6.5	11.6	138	14.3	1.5
	Discharge (ft^3/s)	4.0	1.2	.8	22	43	2.0	1.5
	Water temp. (°C)	10.7	10.4	10.2	10.3	10.3	11.7	9.8
	pH, field	3.1	7.4	8.0	8.9	7.5	7.7	7.2
	Specific cond.[a]	2,250	632	282	174	595	384	411
	Dissolved oxygen[b]	88	26	89	88	88	57	87
Milligrams per liter	Dissolved oxygen	9.6	2.8	9.6	9.9	9.9	5.9	9.8
	Calcium	260	------	------	------	86	------	54
	Magnesium	160	------	------	------	44	------	22
	Potassium	3.9	------	------	------	3.8	------	5.9
	Sodium	45	------	------	------	23	------	16
	Bicarbonate	0	------	------	------	93	------	76
	Carbonate	0	------	------	------	0	------	0
	Chloride	4.3	------	------	------	8.7	------	9.2
	Fluoride	.8	------	------	------	.2	------	.1
	Sulfate	1,900	------	------	------	340	------	200
	Silica, dissolved	15	------	------	------	3.9	------	8.5
	Dissolved solids	2,610	------	------	------	557	------	355
	Total alkalinity (as $CaCO_3$)	acidity (as H^+) 16	------	------	------	76	------	62
	Total hardness (as $CaCO_3$)	1,300	------	------	------	400	------	230
	Noncarbonate hardness (as $CaCO_3$)	1,300	------	------	------	320	------	160
	Ammonia, dissolved (as N)	--------	11	.07	.05	-------	4.3	.08
	Organic nitrogen dissolved (as N)[c]	--------	0	.77	.60	-------	4.9	.43
	Nitrite, dissolved (as N)	--------	.11	.01	.01	-------	.27	.03
	Nitrate, dissolved (as N)	--------	.62	.13	.16	-------	1.8	.32
	Orthophosphate, dissolved (as P)	--------	1.2	.10	.01	-------	.09	.02
	Phosphate, dissolved (as P)	--------	1.2	.70	.02	.30	.96	.04
	Organic carbon, total	--------	31	9.4	4.2	5.0	24	8.0
	Aluminum, dissolved	41	-------	------	-------	--------	-------	-------
	Iron, dissolved	150	-------	------	-------	.09	-------	.02
	Manganese, dissolved	16	-------	------	-------	.04	-------	.02
	Detergents	--------	-------	------	-------	--------	-------	-------
	Turbidity (Jtu)[d]	--------	-------	------	-------	--------	-------	-------
µg/g	Aluminum (bed material)	1.8	-------	-------	-------	--------	-------	-------
	Iron (bed material)	6.4	-------	------	-------	--------	-------	-------
	Manganese (bed material)	[d].93	-------	------	-------	--------	-------	-------
	Fecal coliform[e]	--------	[f]46,000	140	20	90	[g]7,500	-------
	Fecal streptococci[e]	--------	1,100	75	30	130	[g]360	-------

Table 3.--Summary of Busseron Creek watershed water-quality data--Continued

	Site (fig. 1)	6	13	25	26	27	32	37	46
	Date (1976)	Feb. 20	Feb. 20	Feb. 20	Feb. 20	Feb. 20	Feb. 20	Feb. 20	Feb. 20
	Time (eastern stand.)	0910	0935	1120	1015	0955	1300	1340	1145
	Drainage area (mi^2)	16.7	14.4	11.9	2.8	6.5	138	14.3	1.5
	Discharge (ft^3/s)	9.6	7.3	12	2.5	6.2	140	30	1.4
	Water temp. (°C)	4.9	5.3	7.1	4.7	7.7	6.8	9.1	7.0
	pH, field	8.5	8.0	6.9	6.6	7.2	7.9	7.9	7.5
	Specific cond.[a]	-----	-----	-----	-----	-----	-----	-----	-----
Milligrams per liter	Dissolved oxygen[b]	94	89	96	91	95	90	93	99
	Dissolved oxygen	11.9	11.2	11.5	11.6	11.3	10.9	10.7	11.9
	Calcium	35	55	150	50	33	68	40	38
	Magnesium	11	21	90	17	11	30	12	13
	Potassium	3.7	4.5	2.8	4.7	4.4	3.7	3.8	2.6
	Sodium	9.0	16	25	39	29	18	17	8.3
	Bicarbonate	116	147	5	71	52	82	118	52
	Carbonate	0	0	0	0	0	0	0	0
	Chloride	14	21	4.3	68	49	13	31	5.1
	Fluoride	.1	.1	.1	.1	.1	.2	.3	.1
	Sulfate	45	120	800	150	94	240	49	130
	Silica, dissolved	5.6	8.9	13	11	5.7	7.4	8.3	11
	Dissolved solids	186	326	1,120	392	259	426	230	237
	Total alkalinity (as $CaCO_3$)	95	121	4	58	43	67	97	43
	Total hardness (as $CaCO_3$)	130	220	750	190	130	290	150	150
	Noncarbonate hardness (as $CaCO_3$)	38	100	740	140	85	230	53	110
	Ammonia, dissolved (as N)	.21	.07	.25	.60	.44	.15	.67	.03
	Organic nitrogen dissolved (as N)[c]	1.3	.59	.12	.90	.39	.56	1.4	.18
	Nitrite, dissolved (as N)	.05	.01	.0	.05	.04	.05	.08	.0
	Nitrate, dissolved (as N)	.89	1.4	.24	2.4	1.1	.80	2.1	.55
	Orthophosphate, dissolved (as P)	0.0	.03	.01	.01	.01	.02	.01	0.0
	Phosphate, dissolved (as P)	.04	.06	.02	.03	.04	.03	.17	.02
	Organic carbon, total	7.0	8.2	-----	7.7	4.9	6.1	9.3	2.4
	Aluminum, dissolved	-------	-------	------	-------	------	-------	-------	------
	Iron, dissolved	.13	.21	24	4.6	.1	.73	.06	.04
	Manganese, dissolved	.43	.18	5.0	.89	1.4	.91	.20	.36
	Detergents	-------	-------	------	-------	------	-------	-------	------
	Turbidity (Jtu)[d]	-------	-------	------	-------	------	-------	-------	------
µg/g	Aluminum (bed material)	-------	-------	------	-------	------	-------	-------	------
	Iron (bed material)	-------	-------	------	-------	------	-------	-------	------
	Manganese (bed material)	-------	-------	------	-------	------	-------	-------	------
	Fecal coliform[e]	150	560	------	1,250	5	250	2,870	------
	Fecal streptococci[e]	360	700	------	1,000	10	700	10,500	------

Table 3.--Summary of Busseron Creek watershed water-quality data--Continued

	Site (fig. 1)	6	13	25	26	27	32	37	46
	Date (1976)	Apr. 22	Apr. 22	Apr. 22	Apr. 22	Apr. 22	Apr. 22	Apr. 22	Apr. 22
	Time (eastern stand.)	0925	1010	1205	1040	1120	1300	1300	1230
	Drainage area (mi^2)	16.7	14.4	11.9	2.8	6.5	138	14.3	1.5
	Discharge (ft^3/s)	21	5.0	7.0	.1	.5	49	2.4	.3
	Water temp. (°C)	13.8	13.6	19.9	14.7	19.2	16.2	25.2	18.0
	pH, field	8.1	7.8	7.0	6.5	7.5	7.8	9.6	8.4
	Specific cond. [a]	460	770	2,100	860	485	1,220	580	520
	Dissolved oxygen [b]	92	86	64	55	98	76	162	100
Milligrams per liter	Dissolved oxygen	9.5	8.9	5.8	5.6	9.0	7.4	13.2	9.4
Milligrams per liter	Calcium	48	78	230	63	35	120	56	56
Milligrams per liter	Magnesium	16	38	160	24	11	65	21	22
Milligrams per liter	Potassium	3.1	3.5	4.0	5.0	4.5	3.3	4.8	2.9
Milligrams per liter	Sodium	11	31	47	58	27	35	37	15
Milligrams per liter	Bicarbonate	188	242	12	187	62	120	214	76
Milligrams per liter	Carbonate	0	0	0	0	0	0	0	0
Milligrams per liter	Chloride	8.7	13	3.8	70	38	6.4	40	5.4
Milligrams per liter	Fluoride	.2	.2	.4	.2	.2	.3	.2	.2
Milligrams per liter	Sulfate	44	190	1,200	120	88	520	70	190
Milligrams per liter	Silica, dissolved	3.6	4.7	12	8.7	4.4	6.9	11	8.8
Milligrams per liter	Dissolved solids	228	482	1,680	448	240	819	350	338
Milligrams per liter	Total alkalinity (as $CaCO_3$)	154	198	10	153	51	98	176	62
Milligrams per liter	Total hardness (as $CaCO_3$)	190	350	1,200	260	130	570	230	230
Milligrams per liter	Noncarbonate hardness (as $CaCO_3$)	32	150	1,200	100	82	470	51	170
Milligrams per liter	Ammonia, dissolved (as N)	.04	.05	.33	3.0	.08	.10	.04	.04
Milligrams per liter	Organic nitrogen, dissolved (as N) [c]	.41	.37	.10	.90	.45	.18	1.4	.16
Milligrams per liter	Nitrite, dissolved (as N)	.01	.06	.01	1.7	.02	.29	.70	.00
Milligrams per liter	Nitrate, dissolved (as N)	.03	.75	.10	1.7	.17	.02	.70	.02
Milligrams per liter	Orthophosphate, dissolved (as P)	.01	.01	.01	.09	.01	.00	.36	.01
Milligrams per liter	Phosphate, dissolved (as P)	.02	.01	.01	.12	.02	.01	.42	.01
Milligrams per liter	Organic carbon, total	12	5.3	11	11	8.3	7.8	13	4.3
Milligrams per liter	Aluminum, dissolved	-------	-------	------	------	-------	------	-------	-------
Milligrams per liter	Iron, dissolved	.10	.18	12	.08	.06	.10	.17	.03
Milligrams per liter	Manganese, dissolved	.14	.28	7.6	1.5	.59	1.8	.14	.01
Milligrams per liter	Detergents	-------	-------	------	------	-------	------	-------	-------
	Turbidity (Jtu) [d]	-------	-------	------	------	-------	------	-------	-------
μg/g	Aluminum (bed material)	-------	-------	------	------	-------	------	-------	-------
μg/g	Iron (bed material)	-------	-------	------	------	-------	------	-------	-------
μg/g	Manganese (bed material)	-------	-------	------	------	-------	------	-------	-------
	Fecal coliform [e]	3,100	500	-----	11,000	150	5	900	-----
	Fecal streptococci [e]	5,500	2,200	-----	4,700	430	150	270	-----

Table 3.--Summary of Busseron Creek watershed water-quality data--Continued

	Site (fig. 1)	6	13	25	26	27	32	37
	Date (1976)	July 6	July 6	July 7	July 6	July 6	July 6	July 6
	Time (eastern stand.)	1050	1130	0925	1340	1500	1715	1600
	Drainage area (mi^2)	16.7	14.4	11.9	2.8	6.5	138	2.4
	Discharge (ft^3/s)	11	.32	1.3	.01	.6	82	.80
	Water temp. (°C)	22.5	19.4	21.4	17.8	29.5	22.3	28.6
	pH, field	7.4	7.5	5.7	8.2	8.8	8.3	9.2
	Specific cond.[a]	195	579	2,340	766	476	1,100	698
	Dissolved oxygen[b]	103	89	94	124	132	89	194
Milligrams per liter	Dissolved oxygen	8.9	8.2	8.3	11.7	10.1	7.7	15.0
	Calcium	23	62	290	61	47	110	62
	Magnesium	6.0	29	230	17	13	62	25
	Potassium	3.6	4.1	4.7	8.2	5.2	4.7	7.7
	Sodium	4.8	23	90	76	33	67	57
	Bicarbonate	83	182	16	238	111	76	268
	Carbonate	0	0	0	0	0	0	0
	Chloride	5.6	11	5.4	69	48	12	67
	Fluoride	.2	.2	.4	.0	.3	.3	.3
	Sulfate	15	160	1,700	77	84	550	62
	Silica, dissolved	4.3	8.8	15	.1	2.6	6.7	18
	Dissolved solids	104	392	2,370	441	288	855	443
	Total alkalinity (as $CaCO_3$)	68	149	13	195	91	62	220
	Total hardness (as $CaCO_3$)	82	270	1,700	220	170	530	260
	Noncarbonate hardness (as $CaCO_3$)	14	130	1,700	27	80	470	38
	Ammonia, dissolved (as N)	------	.10	.45	6.8	.06	.22	3.3
	Organic nitrogen, dissolved (as N)[c]	------	.30	.05	1.9	.72	.33	2.4
	Nitrite, dissolved (as N)	------	.04	.01	.70	.02	.03	1.0
	Nitrate, dissolved (as N)	------	.71	.21	.30	.03	.52	.40
	Orthophosphate, dissolved (as P)	------	.03	.04	.56	.01	.05	.56
	Phosphate, dissolved (as P)	.02	.04	.03	.60	.04	.05	.81
	Organic carbon, total	11	7.8	-------	17	12	5.9	44
	Aluminum, dissolved	------	-------	-------	-------	-------	-------	--------
	Iron, dissolved	.02	.02	13	.01	.00	.01	.03
	Manganese, dissolved	.11	.24	12	.30	.11	2.3	.13
	Detergents	------	-------	-------	-------	-------	-------	--------
	Turbidity (Jtu)[d]	------	-------	-------	-------	-------	-------	--------
μg/g	Aluminum, (bed material)	------	-------	-------	-------	-------	-------	--------
	Iron (bed material)	------	-------	-------	-------	-------	-------	--------
	Manganese (bed material)	------	-------	-------	-------	-------	-------	--------
	Fecal coliform[e]	------	-------	-------	-------	-------	-------	--------
	Fecal streptococci[e]	------	-------	-------	-------	-------	-------	--------

a Micromhos per centimeter at 25°C (Celsius).
b Percent saturation.
c Nitrogen determined by Kjeldahl method minus ammonia nitrogen.
d Jackson turbidity unit.
e Colonies per 100 milliliters.
f Estimated.
g Sampled 1.4 miles upstream.

Table 4.--Busseron Creek watershed phytoplankton data

(d = diatoms, g = green algae, bg = blue-green algae, yb = yellow-brown algae, fl = flagellate. Analyses by U.S. Geological Survey)

		9-16-75		9-17-75		11-20-75			
		Site 6	Site 13	Site 32	Site 45	Site 6	Site 13	Site 27	Site 31
Organism	Group	Percentage of total count							
Achnanthes sp	d	----	----	----	----	9	----	1	2
Cocconeis sp	d	----	----	----	----	3	----	----	----
Cyclotella sp	d	2	----	----	----	----	----	----	6
Cymtopleura sp	d	----	----	5	----	----	----	----	----
Gyrosigma sp	d	----	----	----	----	3	----	----	----
Melosira sp	d	3	----	----	----	----	----	----	11
Navicula sp	d	5	53	2	----	9	17	1	----
Nitzschia sp	d	7	5	3	1	29	83	25	9
Surirella sp	d	----	5	----	----	3	----	----	----
Synedra sp	d	----	----	2	----	----	----	----	----
Chodatella	g	----	----	----	----	----	----	----	1
Coelastrum sp	g	----	----	----	----	----	----	----	7
Crucigenia sp	g	6	----	----	----	----	----	8	5
Dictyosphaerium sp	g	----	----	----	4	----	----	----	----
Krichneriella sp	g	----	----	----	----	----	----	----	3
Micractinium sp	g	----	----	----	----	----	----	----	1
Oocystis sp	g	2	----	----	----	----	----	----	6
Scenedesmus sp	g	4	----	6	----	----	----	4	9
Selenastrum sp	g	----	----	----	----	----	----	4	----
Sphaerocystis sp	g	8	----	----	----	----	----	----	----
Tetraedon sp	g	----	----	----	----	----	----	----	1
Agmenellum sp	bg	----	----	----	----	12	----	----	----
Anacystis sp	bg	23	----	----	----	----	----	----	19
Ankistrodesmus sp	bg	7	5	----	2	2	----	4	5
Dactylococcopsis sp	bg	----	----	----	----	----	----	----	----
Lyngbya sp	bg	----	22	----	----	----	----	----	----
Oscillatoria sp	bg	27	----	87	93	25	----	52	----
Phormidium sp	bg	----	----	----	----	----	----	----	13
Ceratium sp	fl	1	----	----	----	----	----	----	----
Chlamyodomonas sp	fl	2	----	----	----	2	----	----	----
Cryptomonas sp	fl	----	----	----	----	3	----	----	----
Euglena sp	fl	----	----	----	----	----	----	----	----
Trachelomonas sp	fl	3	5	----	----	----	----	1	2
Total count (cells/mL)		8,000	320	8,700	28,000	2,900	190	7,600	3,000
Diversity index (d)		3.2	2.1	.8	.5	2.8	.7	2.0	3.6

Table 4.--Busseron Creek watershed phytoplankton data--Continued

		2-20-76					4-22-76			7-6-76				
		Site 6	Site 13	Site 27	Site 32	Site 37	Site 6	Site 27	Site 37	Site 6	Site 13	Site 26	Site 32	Site 37
Organism	Group	Percentage of total count												
Achnanthes sp	d	2	--	--	--	--	2	--	--	--	2	--	--	--
Cocconeis sp	d	--	--	--	--	--	--	--	--	--	2	--	--	--
Cyclotella sp	d	--	8	4	11	--	21	3	--	--	14	1	--	--
Cymatopleura sp	d	--	--	--	--	--	--	--	--	--	--	--	--	--
Gomphonema sp	d	4	1	--	4	--	4	7	--	--	7	--	--	--
Gyrosigma sp	d	--	--	--	2	--	--	--	--	--	--	--	--	--
Melosira sp	d	--	--	--	2	--	--	2	--	--	--	3	--	--
Navicula sp	d	8	2	7	6	--	7	--	--	--	20	2	1	1
Nitzchia sp	d	16	2	9	15	--	34	37	--	--	27	5	3	4
Pinnularia sp	d	--	--	--	--	--	--	--	--	--	2	--	--	--
Surirella sp	d	14	1	2	9	--	2	--	--	--	10	--	2	--
Synedra sp	d	4	--	1	--	--	4	5	--	--	--	--	--	--
Selenastrum sp	g	--	--	--	--	--	--	--	--	--	--	2	--	--
Carteria sp	g	--	--	--	--	--	--	--	--	--	--	2	--	--
Coelastrum sp	g	--	--	--	--	--	--	--	--	--	--	--	--	--
Crucigenia sp	g	--	--	--	--	--	--	--	--	--	--	5	--	--
Cymbella sp	g	--	--	--	--	--	9	1	--	--	2	--	--	--
Dictyosphaerium sp	g	--	--	--	--	--	--	--	--	--	--	5	--	--
Golenkia sp	g	--	--	--	--	--	--	--	--	--	--	--	17	--
Krichneriella sp	g	--	--	--	--	--	--	--	--	--	--	--	4	2
Micractinium sp	g	--	--	--	--	45	--	--	1	--	--	--	--	12
Oocystis sp	g	--	--	--	--	--	--	--	--	--	--	--	3	--
Pediastrum sp	g	--	--	--	--	--	--	--	--	--	--	--	--	6
Scenedesmus sp	g	--	--	7	--	54	9	9	99	2	--	3	--	36
Schroedecia sp	g	20	--	--	--	--	--	--	--	--	--	--	--	--
Sphaerocystis sp	g	--	--	--	--	--	--	--	--	26	--	--	--	--
Staurastrum sp	g	--	--	--	--	--	--	1	--	--	--	--	--	--
Tetrastrum sp	g	--	--	--	--	--	--	--	--	--	--	--	--	1
Tetraedron sp		--	--	--	--	--	--	--	--	--	5	--	--	--
Anabaena sp	bg	--	--	--	--	--	--	--	--	71	--	--	--	--
Anacystis sp	bg	--	--	4	--	--	--	2	--	--	--	41	--	--
Ankistrodesmus sp	bg	--	--	35	2	--	2	1	--	--	--	2	--	--
Aphanizomenon sp	bg	--	--	--	38	--	--	--	--	--	--	--	--	--
Dactyloccopsis sp	bg	--	--	--	--	1	--	--	--	--	--	--	--	--
Lyngbya sp	bg	--	--	--	--	--	--	22	--	--	--	--	--	--
Oscillatoria sp	bg	--	84	--	--	--	--	--	--	1	--	24	62	6
Chrysococcus sp	yb	--	--	--	--	--	--	--	--	--	--	3	--	--
Dinobyron sp	yb	--	--	16	9	--	--	1	--	--	--	--	--	--
Ochromonas sp	yb	--	--	--	--	--	--	--	--	--	5	--	2	--
Ceratium sp	fl	--	--	--	--	--	--	--	--	--	2	--	--	--
Chlamyodomonas sp	fl	2	--	7	--	--	--	4	--	--	2	--	3	30
Cryptomonas sp	fl	28	--	--	--	--	4	3	--	--	--	--	--	--
Euglena sp	fl	--	--	4	--	--	--	2	--	--	--	--	--	2
Trachelomonas sp	fl	2	2	4	2	--	2	--	--	--	--	2	3	--
Total count (cells/mL)		860	3,100	2,900	3,100	14,000	1,200	2,700	190,000	39,000	720	14,000	4,500	180,000
Diversity index (d)		2.8	1.0	3.0	2.8	1.1	3.0	3.0	.2	1.1	3.1	2.8	2.0	2.5

Table 5.--Busseron Creek macroinvertebrate data, site 45, September 18, 1975

(Pollution tolerance: T=tolerant organisms; F=facultative organisms; I=intolerant organisms; and F/I=occupies both categories. Analyses by U.S. Geological Survey)

Organisms	Pollution tolerance	Count	
		Surber sampler	Synoptic survey
Arthropoda	--	--	--
Crustacea	--	--	--
Cladocera (water fleas)	--	--	--
Daphnidae	--	--	--
Daphnia sp	--	--	1
Decapoda (crayfish)	--	--	--
Astacidae	--	--	--
Orconectes sp	F/I	1	--
Isopoda (aquatic sow bugs)	--	--	--
Asellidae	--	--	--
Asellus sp	--	1	1
Insecta	--	--	--
Coleoptera (beetles)	--	--	--
Elmidae (riffle beetles)	--	--	--
Dubiraphia sp	F	2	--
Macronychus sp	I	--	1
Stenelmis sp	--	46	6
Hydrophilidae (water-scavenger)	--	--	--
Tropisternus sp	--	--	2
Diptera	--	--	--
Chironomidae (midges)	--	--	--
Cricotopus sp	--	5	--
Dicrotendipes sp	--	28	--
Pentaneura sp	--	3	--
Polypedilum sp	--	2	2
Tanytarsus sp	F/I	1	--
Culicidae (mosquitoes)	--	--	--
Anopheles sp	I	--	1
Ephemeroptera (mayflies)	--	--	--
Baetidae	--	--	--
Baetis sp	I	--	2
Ephemeridae	--	--	--
Caenis sp	--	1	--
Hemiptera (aquatic bugs)	--	--	--
Corixidae (water boatmen)	--	--	--
Trichocorixa sp	--	--	15
Gerridae (water striders)	--	--	--
Gerris sp	T	--	3
Rheumatobates sp	--	--	1
Veliidae (broad water striders)	--	--	--
Rhagovelia sp	--	--	16
Odonata (damselfly)	--	--	1
Agrionidae	--	--	--
Argia sp	F/I	1	3
Trichoptera (caddis flies)	--	--	--
Hydropsychidae	--	--	--
Cheumatopsyche sp	F	127	17
Hydropsyche sp	F/I	--	3
Mollusca	--	--	--
Bivalvia (clams)	--	--	--
Nuculoidea	--	--	--
Sphaeriidae (fingernail clams)	--	--	--
Sphaerium sp	--	12	--
Total count		230	75
Wet weight (grams)		4.3	--
Diversity index ($\bar{d}$)		2.02	--
Area sampled (square meters)		.09	--

Table 6.--Concentrations of chlorinated hydrocarbons and total organic carbon in bed materials, Busseron Creek watershed

[Analyses by U.S. Geological Survey]

	Micrograms per kilogram					
Date	9-16-75		9-17-75		7-6-76	
Site	6	13	32	45	6	45
Aldrin	0.0	0.2	0.0	0.4	0.0	0.0
Chlordane	0	0	0	4	12	13
DDD	.0	.0	.0	.0	.0	.0
DDE	.0	.0	.0	.0	.2	.3
DDT	.0	.0	.0	.0	.0	.0
Dieldrin	.2	.3	2.1	.0	2.1	9.8
Endrin	.0	.0	.0	.0	.0	.0
Heptachlor	.0	.0	.0	.0	.0	.0
Heptachlor epoxide	.0	.0	.0	.0	.0	1.0
Lindane	.0	.0	.0	.0	.0	.0
PCB (polychlorinated biphenyl)	0	0	0	0	0	0
PCN (polychlorinated naphthalene)	0	0	0	0	0	0
Toxaphene	0	0	0	0	0	0
Total organic carbon	---	---	---	---	90	3,000