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A WATER-QUALITY ASSESSMENT OF THE FEATHER CREEK WATERSHED, VERMILLION COUNTY, INDIANA

By Stephen E. Eikenberry

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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):

Multiply English units	By	To obtain SI units
inches (in)	25.4	millimeters (mm)
feet (ft)	.3048	meters (m)
square feet (ft^2)	.0929	square meters (m^2)
miles (mi)	1.609	kilometers (km)
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 [$(m^3/s)/km^2$]

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ABSTRACT

Chemical quality of surface water within the Feather Creek watershed is generally good. However, fecal bacteria concentrations are high enough to represent a potential problem, especially because of the water-contact recreation proposed for the future reservoir.

Chemical analyses of surface-water samples collected on October 9, 1974, and periodically from October 1, 1975, to September 28, 1976, show that the water was calcium bicarbonate type at all sites except one, where it was calcium sulfate. Range of dissolved-solids concentration was from 290 to 1,080 milligrams per liter.

Ranges of concentrations (in milligrams per liter) of some of the dissolved constituents in water were: nitrate (as nitrogen), from 0.01 to 6.9; phosphate (as phosphorus), from 0.01 to 0.14; and total organic carbon, from 2.5 to 16. Concentrations of fecal coliform bacteria and fecal streptococci bacteria ranged from 60 to 6,700 and 70 to 18,000 colonies per 100 milliliters, respectively.

Concentration of dieldrin in bed materials from two sites was 0.4 microgram per kilogram, but aldrin, chlordane, DDD, DDE, DDT, endrin, heptachlor, heptachlor epoxide, lindane, Toxaphene, polychlorinated biphenyl (PCB), and polychlorinated naphthalene (PCN) compounds were not detected.

Navicula sp and Scenedesmus sp dominated the phytoplankton community at the site sampled and indicated an environment lacking in organic enrichment. Cladophora sp dominated the periphyton community sampled. Benthic invertebrates sampled were mostly caddis flies (Cheumatopsyche sp) and midges (Orthocladius sp) and had a diversity index of 2.3, which indicates some organic enrichment of the stream.

PURPOSE AND SCOPE

The purpose of this report, one in a series prepared by the U.S. Geological Survey in cooperation with the U.S. Soil Conservation Service, is to define variations in concentration of nutrients, inorganic constituents, and bacteria with time and changing streamflow in the Feather Creek watershed.

Field measurements (water temperature, pH, specific conductance, and dissolved oxygen), an estimate of stream discharge, and visual observations

during the basinwide reconnaissance on October 9, 1974, provided information needed in selecting representative sites for the more detailed water-quality sampling that began on October 1, 1975. Additionally, bed-material samples were taken for determining concentrations of sorbed chlorinated hydrocarbons and selected metals; also, water and substrate samples were obtained for determining phytoplankton populations and identifying periphyton.

On the basis of the reconnaissance data, two sites (sites 3 and 7, fig.1) were selected for sampling. Subsequent sampling included a repeat of field measurements, stream-discharge estimates, and collecting of representative water samples (Brown and others, 1970). Most of the samples were collected at the damsite of the proposed reservoir. Twelve sets of water samples were collected between October 1, 1975, and September 28, 1976.

Several attempts were made to sample Feather Creek in Clinton at old State Highway 63 (May 17, June 16, July 15, and September 1 and 28, 1976). However, this site was dry each time, even though there was some flow at upstream site 7.

ENVIRONMENTAL SETTING AND CONDITIONS

Feather Creek, a tributary of the Wabash River, drains 8.29 mi^2 (Hoggatt, 1975) of southern Vermillion County near Clinton in west-central Indiana (fig. 1). Most of Feather Creek watershed is nearly level to gently rolling upland underlain by till of Wisconsin age, ranging in thickness from a few feet to more than 100 ft. The eastern part is underlain by valley-train deposits of the Wabash River. Bedrock is shale, sandstone, limestone, coal, and clay of Pennsylvanian age that dips gently (25 to 30 ft per mile) to the southwest.

The economy is basically agricultural under private ownership. An urban area (principally Clinton) represents about 19 percent of land use. Present land use is shown in the following table (R. T. Schafer, written commun., 1975):

Land use	Percentage of total watershed
Cropland	41
Grassland	16
Forest	19
Urban	19
Other	5

Mean daily temperatures range from -2°C (Celsius) in January to 24°C in July (R. T. Schafer, Soil Conservation Service, written commun., 1975). Average annual rainfall is 40 inches (Hoggatt, 1962, p. 8). Rainfall is most intense in May and June and ranges from a monthly minimum of 2.36 inches in

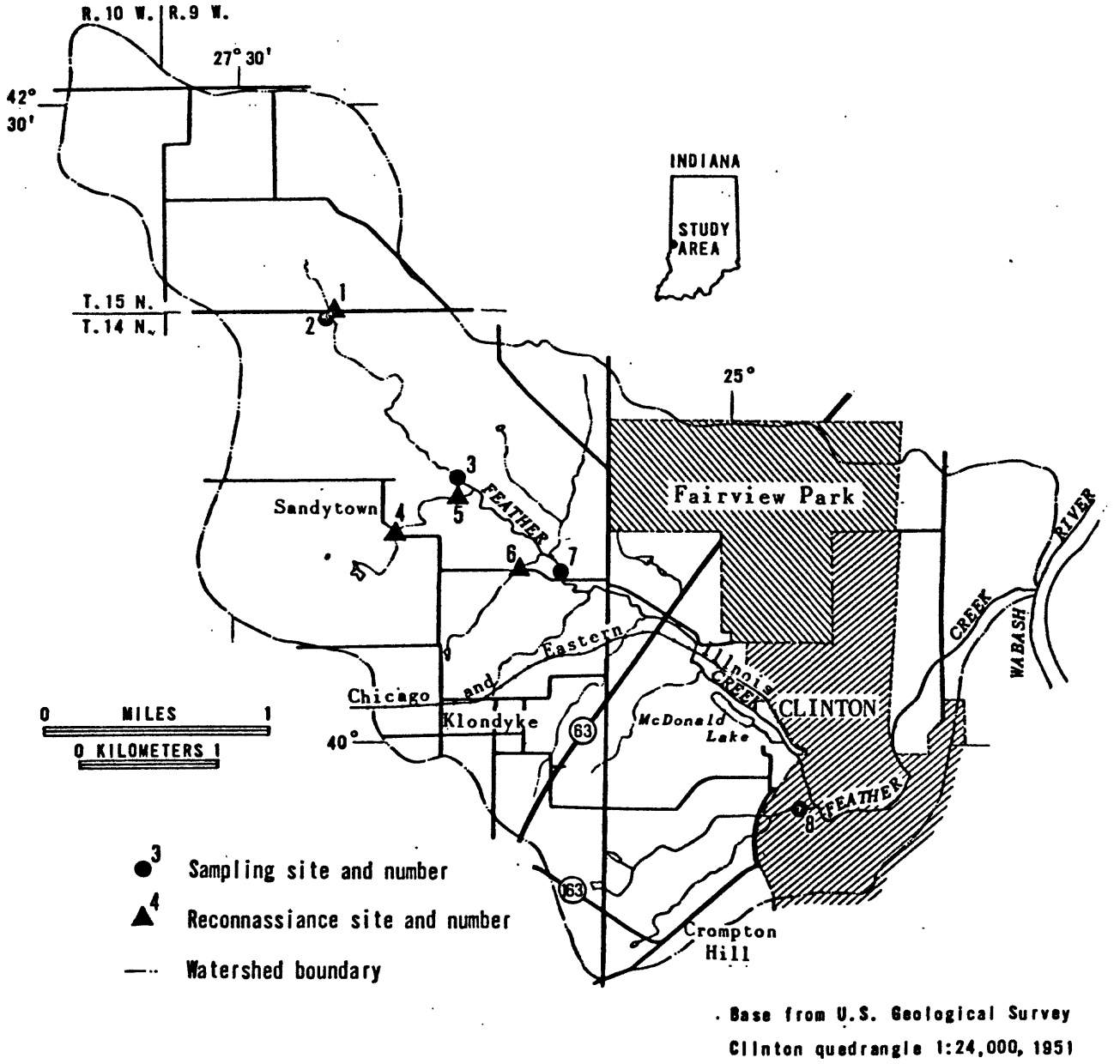

Figure 1.-- Location of data-collection sites in the Feather Creek Watershed.

December to a monthly maximum of 5.24 inches in June at Rockville, 12 mi to the northwest (R. T. Schafer, Soil Conservation Service, written commun., 1975). Mean annual runoff is 11.5 inches (Hoggatt, 1962, p. 9).

A flow-duration curve for Plum Creek near Bainbridge, 34 mi east and in an area hydrologically similar to Feather Creek, is presented in figure 2. Plum Creek near Bainbridge has a drainage area of 3.00 mi^2. Feather Creek at site 7 (fig. 1) has a drainage area of 3.6 mi^2.

DATA EVALUATION

Field Measurements

Water temperatures at the sampling sites were close to concurrent air temperatures and were normal for each of the samplings and seasons.

Dissolved-oxygen concentration ranged from 29 to 164 percent of saturation (table 1), and the range generally represented normal seasonal and flow variations during the sampling periods. Concentrations at the low end of the range represent periods of low biologic activity and those at the high end high activity.

The pH ranged from 7.3 to 8.6 for the sampling period and varied little during the individual sample runs. These data are within the range expected in natural streams.

Generation and use of a ratio of dissolved solids to specific conductance permits the user to estimate dissolved-solids concentration in water from one specific-conductance measurement. The ratio used was 0.60 (range 0.52 to 0.76), which is the average of the ratios calculated from table 1 for each sample. Specific conductance ranged from 380 to 1,540 µmhos/cm (micromhos per centimeter) at 25° Celsius throughout during the sampling periods, and the dissolved-solids concentration ranged from 290 to 1,080 mg/L (milligrams per liter).

Chemical Data

Inorganic

As illustrated in figure 3, surface water throughout is a calcium bicarbonate type, except at site 8 where it is a calcium sulfate type. The water type at site 8 differs because of drainage from an abandoned coal mine. Figure 3 also shows that dissolved-solids concentration varies little with time. Uniformity of chemical concentrations is an indication of the consistency of

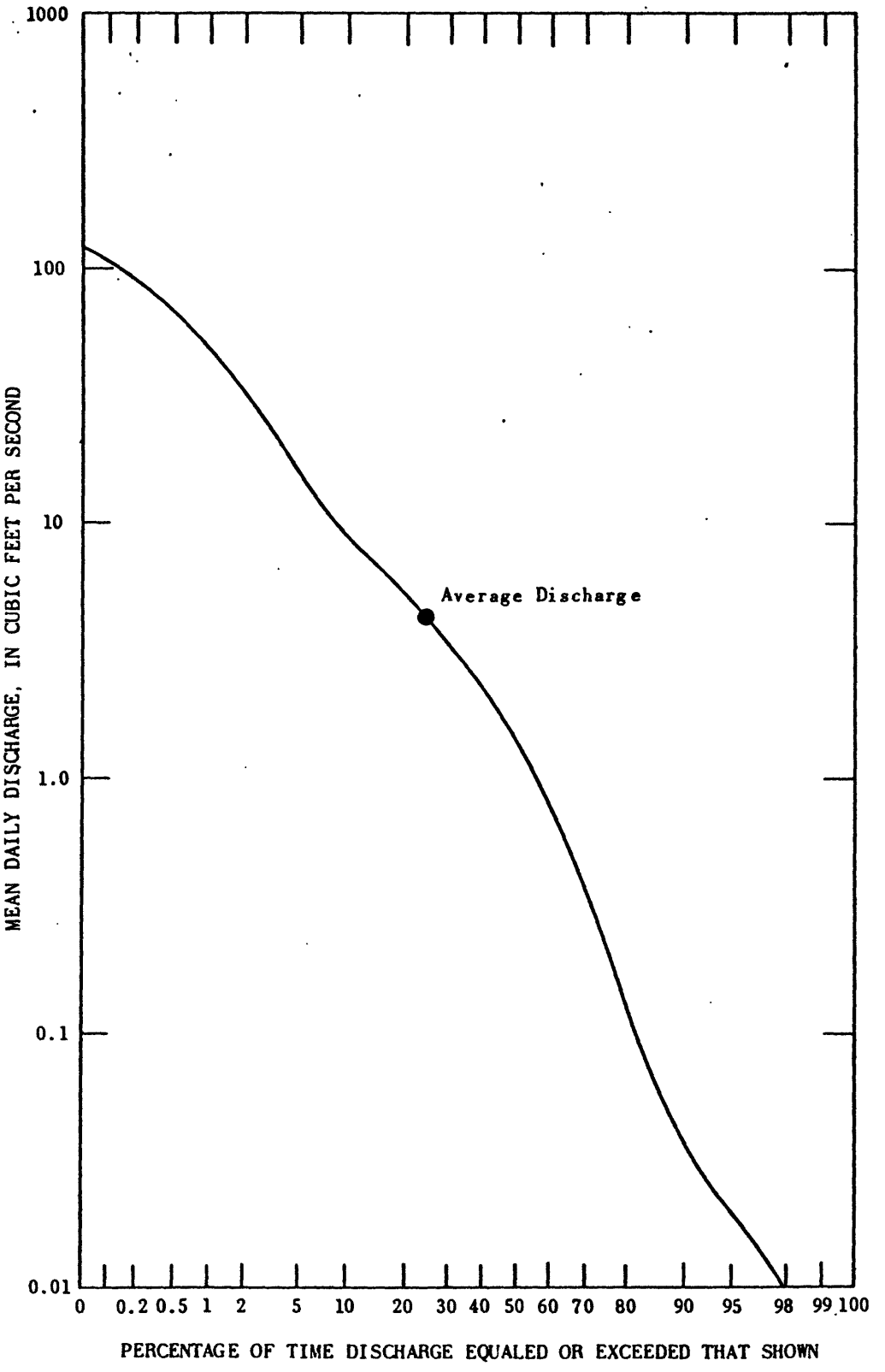

Figure 2.-- Flow-duration curve for Plum Creek near Bainbridge, October 1969-September 1975. (Drainage area is 3.0 square miles.)

Table 1.--Water-quality data in Feather Creek watershed

Site[1]	1			2		3					
Date	1-16-76	2-19-76	3-24-76	2-19-76	3-24-76	10-9-74	10-1-75	11-19-75	1-16-76	2-19-76	3-24-76
Eastern standard time	1140	1245	1145	1245	1145	1000	1400	1220	1100	1230	1130
Drainage area (mi^2)	1.3	1.3	1.3	----	----	2.2	2.2	2.2	2.2	2.2	2.2
Discharge (ft^3/s)[2]	.4	2.6	.1	.4	.04	.02	.01	.02	.9	4.8	.8
Water temp. (°C)[2]	1.9	5.9	13.7	4.8	8.0	10.3	15.6	9.9	.9	6.7	12.3
pH, field	8.2	7.9	8.5	8.0	8.0	7.8	8.2	8.6	8.2	8.4	8.6
Specific conductance (micromhos per centimeter at 25°C)	599	----	562	----	588	695	605	380	580	----	548
Dissolved oxygen (percent saturation)	74	95	145	61	83	71	91	164	90	97	122
Dissolved oxygen	10.2	11.7	14.8	7.7	9.7	8.0	8.9	18.5	10.8	11.7	13.1
Calcium						82				56	
Magnesium						33				24	
Potassium						4.0				1.0	
Sodium						8.4				3.8	
Bicarbonate						352				196	
Carbonate						0				0	
Chloride						9.2				15	
Fluoride						.1				.2	
Sulfate						47				54	
Silica, dissolved						5.5		— —		8.5	
Dissolved solids						364				290	
Total alkalinity (as $CaCO_3$)						289				161	
Total hardness (as $CaCO_3$)						340				240	
Noncarbonate hardness (as $CaCO_3$)						52				78	
Ammonia, dissolved (as N)					.03	.46				.04	
Organic nitrogen dissolved (as N)					.04	.27				.70	
Nitrogen, dissolved (as N)[3]					.00	.73				.74	
Nitrite, dissolved (as N)					.00	.01				.03	
Nitrate, dissolved (as N)					6.4	.08				6.9	
Orthophosphate, dissolved (as P)					.01	.01				.08	
Phosphate, dissolved (as P)					.02	.02				.05	
Organic carbon, total						7.4				3.7	
Iron, dissolved						.13				.04	
Manganese, dissolved						.28				.02	

Table 1.--Water-quality data in Feather Creek watershed--Continued

Site[1]	3		4	5		6	7			
Date	4-21-76	5-17-76	2-19-76	1-16-76	2-19-76	2-19-76	10-9-74	10-1-75	11-19-75	1-16-76
Eastern standard time	1230	1330	1215	1130	1235	1210	1100	1345	1200	1100
Drainage area (mi^2)	2.2	2.2	0.5	0.6	0.6	0.3	3.6	3.6	3.6	3.6
Discharge (ft^3/s)	.5	.3	2.3	.3	1.2	.6	.04	.01	.07	2.4
Water temp. (°C)[2]	19.7	15.4	7.6	.1	7.5	7.7	11.1	14.9	5.6	.2
pH, field	8.3	8.2	8.2	8.1	8.3	8.4	7.8	8.0	7.5	7.9
Specific conductance (micromhos per centimeter at 25°C)	540	576		528			720	595	474	604
Dissolved oxygen (percent saturation)	100	124	94	67	96	96	79	46	69	77
Dissolved oxygen	9.1	12.4	11.0	9.7	11.2	11.2	8.6	4.6	8.5	12.9
Calcium							88	78		68
Magnesium							32	29		33
Potassium							2.8	2.5		1.3
Sodium							8.9	8.1		6.8
Bicarbonate							373	356		280
Carbonate							0	0		0
Chloride							10	5.9		18
Fluoride							.3	.1		.0
Sulfate							51	31		74
Silica, dissolved							8.4	8.2		6.3
Dissolved solids							386	339		360
Total alkalinity (as $CaCO_3$)							306	292		230
Total hardness (as $CaCO_3$)							350	310		310
Noncarbonate hardness (as $CaCO_3$)							46	22		76
Ammonia, dissolved (as N)							.08	.01	.01	.02
Organic nitrogen dissolved (as N)							.00	.46	.29	.13
Nitrogen, dissolved (as N)[3]							.02	.47	.30	.15
Nitrite, dissolved (as N)							.00	.00	.01	.01
Nitrate, dissolved (as N)							.02	.01	.01	3.2
Orthophosphate, dissolved (as P)							.01	.03	.01	.03
Phosphate, dissolved (as P)							.02	.03	.02	.01
Organic carbon, total							5.6			2.6
Iron, dissolved							.06	.02		.01
Manganese, dissolved							.06	.39		.04

Milligrams per liter

Table 1.--Water-quality data in Feather Creek watershed--Continued

Site[1]	7								8	
Date	2-19-76	3-24-76	4-21-76	5-17-76	6-16-76	7-15-76	9-1-76	9-28-76	10-9-74	7-15-76
Eastern standard time	1200	1115	1210	1300	1450	1315	1330	1045	1230	1330
Dreinage area (mi^2)	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	0.5	0.5
Discharge (ft^3/s)	9.6	1.3	2.0	.30	.10	.003	.01	.01	.44	
Water temp. (°C)[2]	7.1	9.9	17.3	15.0	26.3	27	19.3	14.1	14.2	19.9
pH, field	8.5	7.3	8.0	8.1	7.7	7.9	7.3	7.4	7.6	8.1
Specific conductance (micromhos per centimeter at 25°C)	-----	567	538	611	390	536	434	431	1,540	1,450
Dissolved oxygen (percent saturation)	98	107	109	109	87	91	48	29	106	92
Dissolved oxygen	11.8	12.3	10.0	12.4	6.8	7.3	5.9	3.5	10.8	8.0
Calcium	57	71	64	73	60	60			180	
Magnesium	25	30	30	31	27	28			52	
Potassium	1.4	.9	2.7	1.6	3.2	2.1			5.2	
Sodium	4.7	7.1	7.3	7.1	7.3	7.9			81	
Bicarbonate	198	260	256	314	238	284			265	
Carbonate	0	0	0	0	0	0			0	
Chloride	15	14	11	13	13	13			11	
Fluoride	.1	.2	.2	.2	.2	.2			.4	
Sulfate	60	70	61	58	53	43			600	
Silica, dissolved	8.4	4.4	6.2	6.7	15	9.8			17	
Dissolved solids	294	337	313	349	296	305			1,080	
Total alkelinity (as $CaCO_3$)	162	213	210	258	195	233			217	
Total hardness (as $CaCO_3$)	250	300	280	310	260	270.			660	
Noncarbonate hardness (as $CaCO_3$)	83	88	73	52	66	32			450	
Ammonia, dissolved (as N)	.01	.01	.04	.02	.02	.07			.42	
Organic nitrogen dissolved (as N)	.55	.18	.49	.36	.41	.38			.00	
Nitrogen, dissolved (as N)[3]	.56	.19	.53	.38	.43	.45			.23	
Nitrite, dissolved (as N)	.01	.02	.92	.80	.02	.01			.00	
Nitrate, dissolved (as N)	5.5	2.4	.92	.80	.01	.23			.21	
Orthophosphate, dissolved (as P)	.03	.00	.01	.01		.01			.00	
Phosphate, dissolved (as P)	.05	.01	.03	.02	.03	.14			.00	
Organic carbon, total	6.3	2.5	7.7	4.9	8.0	16				
Iron, dissolved	.03	.05	.06	.05	.10	.01			.08	
Manganese, dissolved	.03	.05	.03	.02	.12	.16			1.2	

Milligrams per liter

[1] Site numbers are plotted on map (fig. 1).

[2] Degrees Celsius.

[3] Determined by Kjeldahl method.

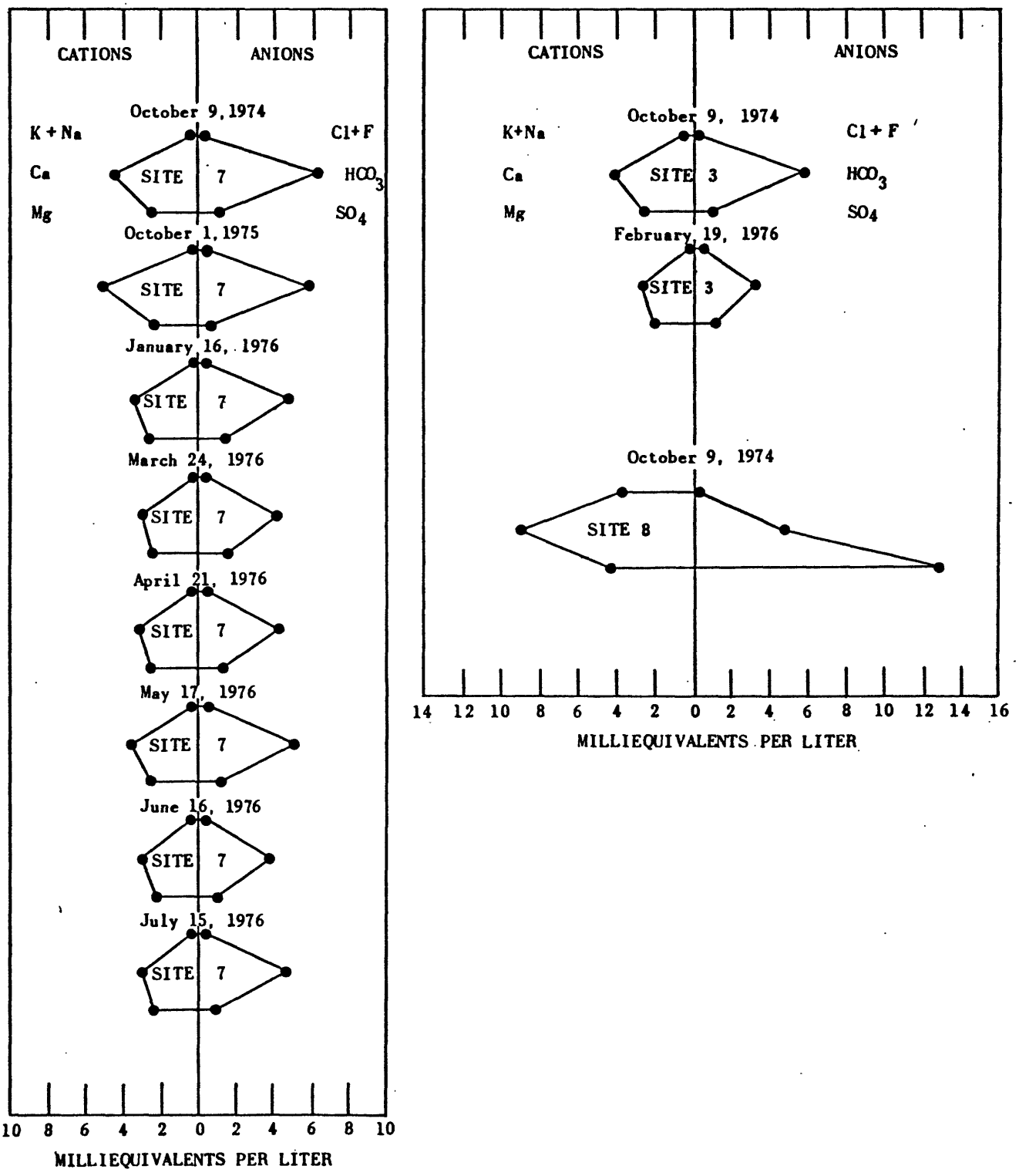

Figure 3.--Analyses represented by Stiff patterns based on milliequivalents per liter, Feather Creek watershed. (See Stiff, 1951.)

geomorphic and hydrologic characteristics. Thick till permits much of the precipitation to infiltrate the soil mantle. The consistent quality of drainage water is the result of long contact time between water and the soil buffering system and the uniformity of soils and lithology.

Although small, variation in dissolved-solids concentration is directly proportional to discharge (fig. 4). The scattered low-discharge data indicate two or more sources of dissolved solids, which vary during low flow. Some dilution of dissolved-solids concentration should be observed at high flows; however, this was not observed.

Site of the highest dissolved-solids concentration (1,080 mg/L) was site 8, on October 9, 1974, on an unnamed Feather Creek tributary draining an area of deep coal mining.

Maximum limits recommended by U.S. Environmental Protection Agency (1973a, p. 69 and 71) for dissolved iron and manganese in public water supplies are 0.3 and 0.05 mg/L, respectively. Dissolved-iron concentration exceeded 0.3 mg/L only at sites 3 and 8 on October 9, 1974, but dissolved-manganese concentration in samples from site 7 exceeded 0.05 mg/L on October 9, 1974, June 16, 1976, and July 15, 1976.

Bed material for determination of metal concentrations was collected at site 7 on July 15, 1976. Of the metal concentrations determined (table 2), those of iron, aluminum, and manganese were dominant, as would be expected.

Table 2.--Concentrations of metals extracted from bed material from site 7, Feather Creek watershed, July 15, 1976

Metals	Micrograms per gram
Aluminum	1,100
Cadmium	2
Chromium	3
Cobalt	6
Copper	4
Iron	4,800
Lead	12
Manganese	370
Nickel	7
Zinc	24

Although most of the watershed upstream from site 7 is farmed or is in pasture, concentrations of nutrients (total organic carbon, nitrogen, and phosphorus) were generally low. Total-organic-carbon concentration ranged from 2.5 to 16 mg/L and was a maximum 16 mg/L at site 7, on July 15, 1976,

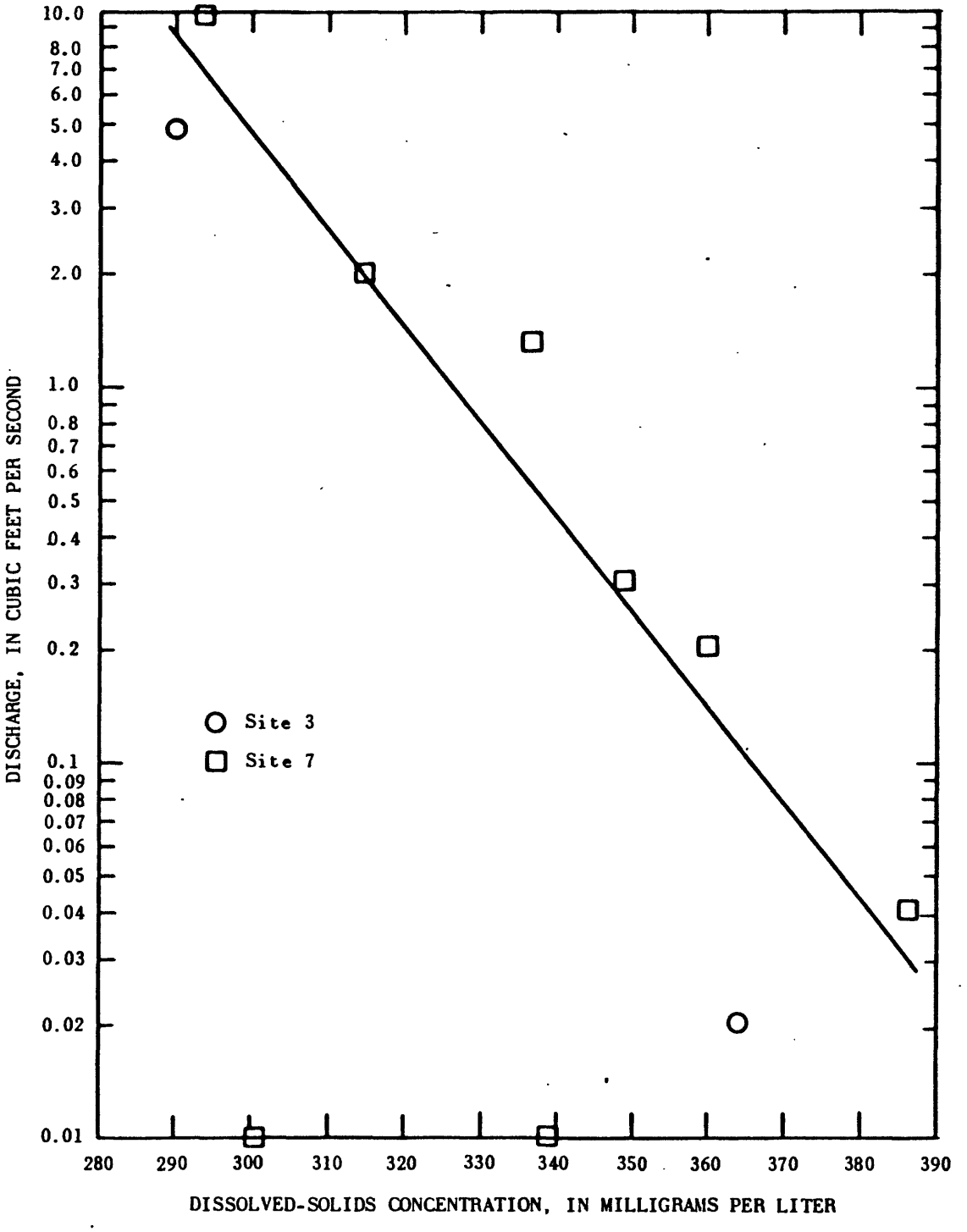

Figure 4.--Relation of dissolved-solids concentration to discharge in the Feather Creek watershed, October 9, 1974, through July 15, 1976.

when flow was low and biologic activity was high. The concentrations of total organic carbon are considered to be background levels and do not represent a water-quality problem. Nitrate (as nitrogen) concentration ranged from 0.01 to 6.9 mg/L, varying in response to seasonal trends and discharge. Nitrate (as nitrogen) concentration of samples at sites 3 and 7, on February 19, 1976 (6.9 and 5.5 mg/L, respectively), represent the highest flow sampled. Nitrate (as nitrogen) concentration at site 2, a field-tile drain, was 6.4 mg/L on March 24, 1976. Dissolved phosphate (as phosphorus) concentration ranged from 0.01 to 0.14 mg/L at all sites and was highest on July 15, 1976.

According to Lackey (1961), 0.3 mg/L nitrate (as nitrogen) and 0.015 mg/L phosphate (as phosphorus) concentrations seem to be critical values above which algal blooms can cause water-quality problems. Several sites had nitrate and phosphate concentrations of this magnitude, although algal blooms were not observed at those sites. However, large mats of algae were observed at site 1 on March 24, April 21, and May 17, 1976.

Nitrate concentrations vary seasonally and with discharge (figs. 5 and 6). Highest nitrate concentrations are associated with winter and spring high flows, when biologic activity is low and soil-moisture is high (Likens, 1970; Thomas, 1970). Lowest nitrate concentrations are observed during summer and fall low flows, when biologic activity is high and soil moisture is low. Similar seasonal trends and concentration levels have been observed in numerous Illinois streams draining agricultural areas (Harmeson and others, 1971) and in other Indiana streams.

Chlorinated Hydrocarbons

Bed material for determining chlorinated-hydrocarbon concentrations was taken at sites 3 and 7 on October 9, 1974. Laboratory analysis included determinations of the following chlorinated hydrocarbons: aldrin, chlordane, DDD, DDE, DDT, dieldrin, endrin, heptachlor, heptachlor epoxide, lindane, Toxaphene,[1] polychlorinated biphenyl (PCB), and polychlorinated naphthalene (PCN) compounds. Concentration of dieldrin in bed materials was 0.4 µg/kg (microgram per kilogram) at sites 3 and 7, but none of the other chlorinated hydrocarbons was detected.

Sources of the chlorinated hydrocarbons in the bed materials would be difficult to locate from only the two sampling sites. However, dieldrin is the decomposition product of aldrin, which is used extensively on corn crops in the area. Dieldrin and aldrin have probably been washed into the streams with sediment from adjacent cropland.

[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.

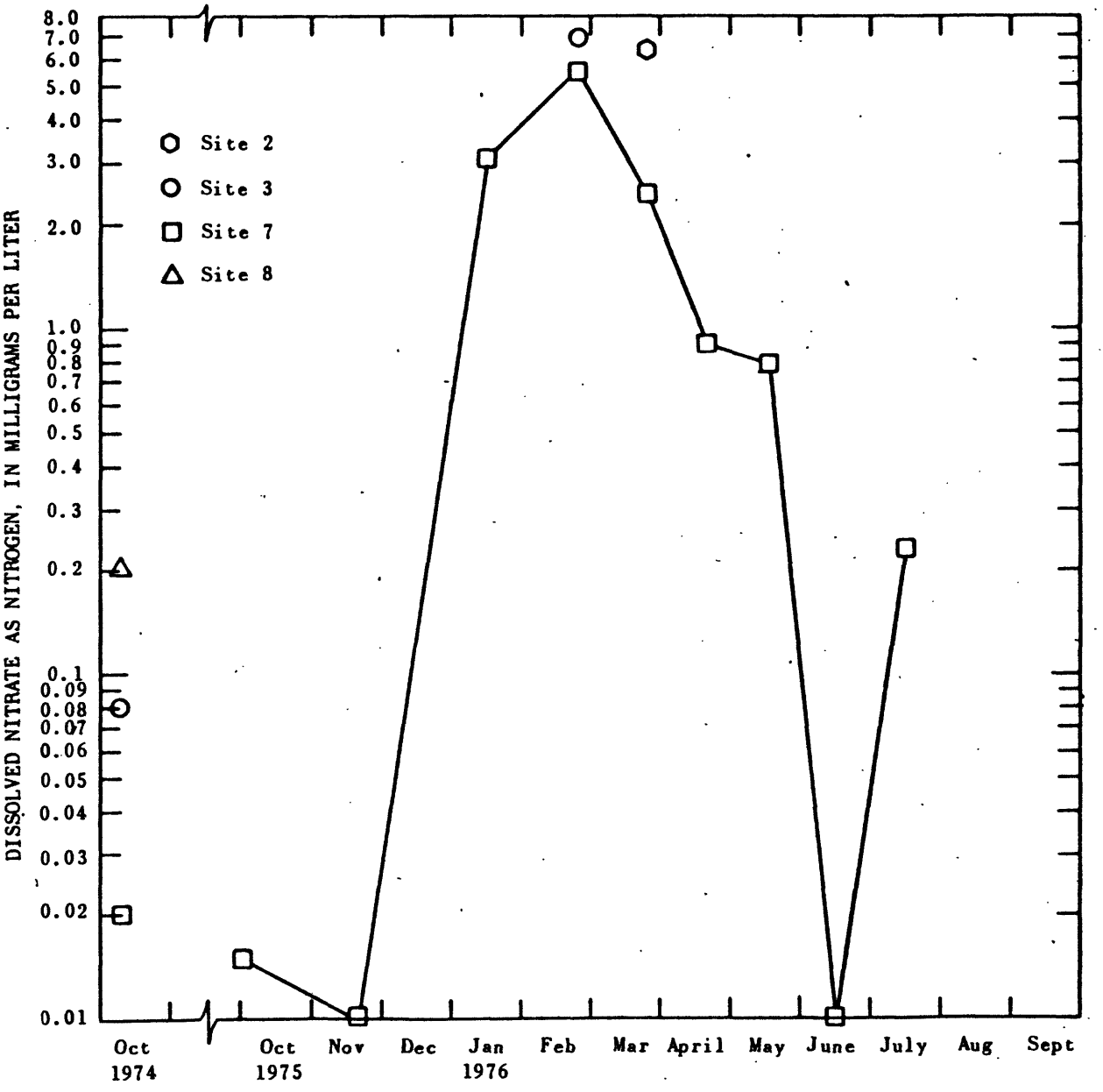

Figure 5.--Dissolved-nitrate concentration of surface water in the Feather Creek watershed.

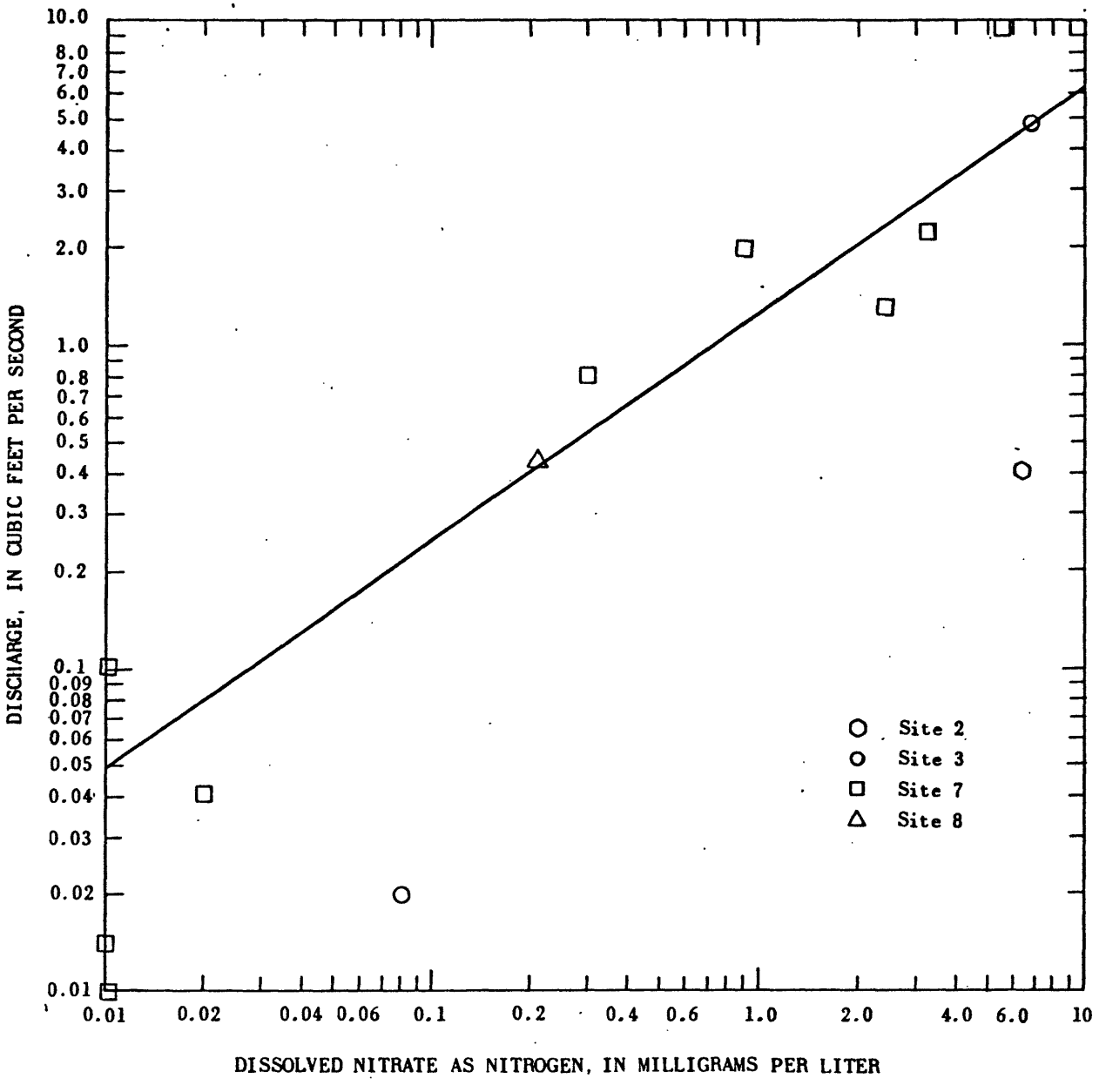

Figure 6.--Relation of dissolved-nitrate concentration to discharge in the Feather Creek watershed, October 9, 1974, through July 15, 1976.

Microbiological and Biological Data

Water samples for determining concentrations of fecal coliform and fecal streptococci bacteria were collected eight times at site 3, 10 times at site 7, and once each at sites 5 and 8. Bacterial concentrations (table 3) varied considerably between samplings at a given site and between sites 3 and 7 during a given sampling. Concentration of fecal coliform bacteria ranged from 60 to 6,700 col/100 ml (colonies per 100 milliliters) and of fecal streptococci bacteria, from 70 to 18,000 col/100 ml between October 9, 1974, and September 28, 1976. Bacterial concentrations in the upper end of the range may represent a water-quality problem in the watershed.

Ratios of fecal coliform to fecal streptococci bacteria are useful in determining sources of bacteria for bacterial concentrations above background, 200 col/ml. In human wastes, this ratio tends to be greater than 4, whereas in animal wastes, the ratio tends to be less than 1 (Geldreich, 1966). However, factors such as differing die-off rates of the two bacterial types and mixing of bacteria from several different sources can affect the ratio of fecal coliform to fecal streptococci bacteria in streams. Use of this source analysis gives mixed results at both sites 3 and 7. The analysis indicates either a mixed (fecal coliform:fecal streptococci greater than 1 but less than 4) or an animal source in all but two samples (January 16 and March 24, 1976) at site 3, whereas it indicates mixed or animal sources in all but one sample (October 1, 1975) from site 7. Bacteria from animal waste would be expected in the watershed, since the fields upstream of site 3 have been used for pasture; however, human waste is also an expected bacterial source in parts of the watershed.

Phytoplankton, periphyton, and benthic invertebrate samples were collected at site 7, October 9, 1974. The phytoplankton sample contained 220 cells per milliliter and was dominated by Navicula sp (38 percent of count), a diatom, and Scenedesmus sp (30 percent of count), a green algae (table 4). The periphyton sample was dominated by Cladophora sp. This and other periphyton species collected at site 7 are listed in table 5.

Palmer (1969) presented a method for calculating a pollution-tolerance index for phytoplankton communities. The index is the summation of pollution-index factors for each genus in the water in amounts greater than 50 cells per milliliter. A sum of 20 or more for a sample is assumed to be evidence of high organic pollution, whereas a sum of 15 to 19 is assumed to be probable evidence of high organic pollution. Lower figures either do not give evidence of high organic pollution, because of other environmental factors, or indicate lack of enrichment. The pollution tolerance index, 7, at site 7 on October 9, 1974, indicates a lack of organic enrichment at the site.

Kinds and numbers of benthic organisms in a stream are governed by the physical and chemical characteristics of that stream. Furthermore, the condition and the diversity of that stream's biologic community is an indication of the integrated effects of previous conditions of water quality and streamflow.

Table 3.--Concentrations of fecal coliform and fecal streptococci bacteria in the Feather Creek watershed

Date of sampling	Site 3		Site 5		Site 7		Site 8	
	Fecal coliform (colonies/100 ml)	Fecal strepto-cocci (colonies/100 ml)	Fecal coliform (colonies/100 ml)	Fecal strepto-cocci (colonies/100 ml)	Fecal coliform (colonies/100 ml)	Fecal strepto-cocci (colonies/100 ml)	Fecal coliform (colonies/100 ml)	Fecal strepto-cocci (colonies/100 ml)
Oct. 9, 1974	4,950	1,550	-----	----	70	95	120	1,250
Oct. 1, 1975	1,500	450	-----	----	6,700	880	-----	-----
Nov. 19	130	210	-----	----	425	710	-----	-----
Jan. 16, 1976	1,300	290	-----	----	640	210	-----	-----
Feb. 19	190	320	60	80	250	300	-----	-----
Mar. 24	1,000	95	-----	----	250	90	-----	-----
Apr. 21	3,600	18,000	-----	----	2,900	15,000	-----	-----
May 17	-----	140	-----	----	-----	70	-----	-----
July 15	-----	------	-----	----	230	280	-----	-----
Sept. 28	-----	------	-----	----	70	1,400	-----	-----

Table 4.--Phytoplankton data for site 7, Feather Creek watershed, October 9, 1974 (d, diatom; g, green algae)

Organism	Group	Percentage of total count
Navicula sp	d	38
Scenedesmus sp	g	30
Nitzchia sp	d	8
Gomphonema sp	d	8
Achnanthes sp	d	8
Synedra sp	d	8
Total percent		100
Total count (cells per milliliter)		220
Pollution-tolerance index		7

Table 5.--Periphyton data for site 7, Feather Creek watershed, October 9, 1974 (Group: d, diatom; g, green algae; bg, blue-green algae)

Organism	Group
Achnanthes sp	d
Cladophora sp	g
Cocconeis sp	d
Cyclotella sp	d
Cymatopleura sp	d
Cymbella sp	d
Fragilaria sp	d
Gomphonema sp	d
Gyrosigma sp	d
Lyngbya sp	bg
Melosira sp	d
Navicula sp	d
Nitzschia sp	d
Oedogonium sp	g
Surirella sp	d
Synedra sp	d

Benthic organisms vary in sensitivity to pollution (that is, changes in nutritional and physical conditions). Some species of benthic invertebrates can live only in clean water, whereas other species can survive a variety of water-quality conditions, including polluted water. A classification of representative macroinvertebrates according to their tolerance of organic

wastes was compiled by the U.S. Environmental Protection Agency (1973b). Organisms that are generally indicative of certain water-quality conditions are 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." The sample collected at site 7 on October 9, 1974, contained no tolerant organisms. Dominance of intolerant organisms at site 7 indicates low levels of organic enrichment in the stream.

The diversity index (table 6) is a measure of community structure (Wilhm and Dorris, 1968). Diversity indices of 3 or more indicate well-balanced benthic communities (clean water types), indices between 1 and 3 indicate communities under stress of moderate pollution, and indices less than 1 indicate communities under stress of heavy organic pollution (Wilhm and Dorris, 1968). The diversity index for the sample collected on October 9, 1974, at site 7 on Feather Creek, 2.3, indicates moderate organic loading. The moderate amount of total organic carbon at site 7 (5.6 mg/L) on the same date suggests the slight organic loading of the Feather Creek benthic community. However, many other factors, including unstable flow conditions and highly turbid, low-temperature streams coincident with winter and spring, affect the stream's biologic community and the diversity index. Therefore, because different diversity indices would be expected during different seasons, weather conditions, and flow conditions, the diversity index for a single sample must be considered as representing only an approximation of the biologic health of the stream.

SUMMARY AND CONCLUSIONS

The most significant water-quality problem in the Feather Creek watershed was the high concentrations of fecal coliform (6,700 col/100 ml maximum) and fecal streptococci bacteria (18,000 col/100 ml maximum) at sites 3 and 7. Surface water was calcium bicarbonate type at all sites except site 8, where it was calcium sulfate type. Specific conductance ranged from 380 to 1,540 micromhos per centimeter at 25°C, and the dissolved-solids concentration ranged from 290 to 1,080 mg/L. Concentrations of dissolved iron were less than the drinking-water-quality limit of 0.3 mg/L recommended by the U.S. Environmental Protection Agency (1973a) at all sites except site 8 on October 9, 1974. Concentrations of dissolved manganese at site 7 on October 9, 1974, and June 16 and July 15, 1976, exceeded the drinking-water-quality limit of 0.05 mg/L recommended by the U.S. Environmental Protection Agency (1973a).

Dissolved-nutrient concentrations were typical for the time of year and streamflow conditions. Nitrate (as nitrogen) concentration ranged from 0.01 to 6.9 mg/L, and phosphate (as phosphorus) concentration ranged from 0.01 to

Table 6.--Benthic-invertebrate data for site 7, Feather Creek watershed, October 9, 1974

(Area sampled: 0.20 m^2; wet weight of sample: 3.7 g; pollution tolerance: F, facultative; I, intolerant)

Organism	Pollution tolerance	Number of organisms in wet sample
Arthropoda		
Insecta		
Orthocladius sp	F/I	86
Thienemanniella sp	I	3
Polypedilum sp	-	9
Tipulidae (crane flies)	-	3
Simuliidae (black flies)	-	14
Trichoptera (caddis flies)		
Hydropsychidae		
Cheumatopsyche sp	F	140
Ephemerotera (mayflies)		
Heptageniidae		
Stenonema sp	F/I	21
Baetidae		
Baetis sp	I	37
Ephemeridae		
Caenis sp	-	2
Odonata		
Calopterygidae (damsel flies)		
Calopteryx sp	-	2
Gomphidae (dragon flies)		
Progomphus sp	I	2
Mollusca		
Gastropoda (snails)		
Pulmonata (lung breathers)		
Ancylidae		
Ferrissia sp	-	46
Total count		365
Diversity index		2.3

0.14 mg/L. Total-organic-carbon concentration ranged from 2.5 to 16 mg/L. Highest concentrations of nitrate can be expected during winter and spring high flows; lowest concentrations, during summer and fall low flows.

Two bed-material samples were analyzed for the chlorinated hydrocarbons aldrin, chlordane, dieldrin, DDD, DDE, DDT, endrin, heptachlor, heptachlor epoxide, lindane, Toxaphene, polychlorinated biphenyl and polychlorinated naphthalene compounds. Of these compounds, only dieldrin was detected. The concentration of dieldrin was 0.4 microgram per kilogram of bed material.

Concentrations of fecal coliform and fecal streptococci bacteria in the watershed fluctuated widely and may represent the greatest water-quality problem in the watershed. At sites 3, 5, 7, and 8, fecal coliform bacteria ranged from 60 to 6,700 col/100 ml, and fecal streptococci bacteria ranged from 70 to 18,000 col/100 ml. Concentrations at the upper ends of these ranges represent a potential water-quality problem.

The phytoplankton community was dominated by the diatom Navicula sp and by the green algae Scenedesmus sp. The pollution tolerance index (7) for the sample suggests a lack of organic enrichment.

A periphyton sample from site 7 was dominated by Cladophora sp. Benthic (bottom-dwelling) invertebrates were dominated by caddis flies (Cheumatopsyche sp) and midges (Orthocladius sp). The diversity index of 2.3 indicates the possibility of some organic enrichment.

The overall water quality of the Feather Creek watershed is good, except for the high concentrations of fecal coliform and fecal streptococci bacteria. In addition to the high bacterial concentrations, future water-quality problems could develop if the use of farm chemicals is not carefully managed.

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