A WATER-QUALITY ASSESSMENT OF THE LOST RIVER WATERSHED DUBOIS, LAWRENCE, MARTIN, ORANGE, AND WASHINGTON COUNTIES, INDIANA

U. S. GEOLOGICAL SURVEY
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75-646

UNITED STATES

DEPARTMENT OF THE INTERIOR

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METRIC 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	millimetres (mm)
miles (mi)	1.609	kilometres (km)
square miles (mi^2)	2.590	square kilometres (km^2)
cubic feet per second (ft^3/s)	.02832	cubic metres per second (m^3/s)

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ABSTRACT

A water-quality assessment of the Lost River watershed was made from data collected on November 11-14, 1974, and March 5, 1975. Surface waters in the watershed were calcium bicarbonate types of various levels of mineralization. Crawford-upland streamwaters were considerably less mineralized than waters from the Mitchell plain part of the watershed. Streamwaters contained between 0.06 and 5.9 milligrams per litre nitrate (as nitrogen), 0.25 milligram per litre or less phosphate (as phosphorus), and from 2.3 to 26 milligrams per litre organic carbon. Concentrations of fecal coliform bacteria ranged from 35 to 75,000 colonies per 100 millilitres and fecal streptococci bacteria from 15 to 49,000 colonies per 100 millilitres. Human waste contamination of streamwater is suspected downstream of Paoli and West Baden. Aldrin, dieldrin, chlordane, DDT, DDD, DDE and PCB's were detected in one or more of the four samples of stream-bed material. A very productive benthic community was found in upper Lost River. Midge larvae and aquatic sowbugs were the dominant invertebrates and Cladophora sp was the predominant periphyton at the site sampled.

PURPOSE AND SCOPE

The objective of this study was to identify existing and(or) potential water-quality problems within the Lost River watershed with two sample-collection efforts. Particular emphasis was placed on the areas of existing (French Lick Creek watershed) and planned flood-control structures and channel improvement as described in the preliminary draft of the Lost River watershed work plan, supplement no. 1 (U.S. Soil Conservation Service, 1975).

Field measurements of water temperature, specific conductance, pH, dissolved oxygen, and estimates of stream discharge were made at 21 stream sites on November 11-14, 1974 (fig. 1, sites 1, 3-5, 7, 8, 11, 13, 14, 17, 19, 21, 22, 26-29, 31, 32, 37, and 38). Water-quality field measurements and stream discharge measurements were made and representative water samples were collected at 17 additional sites (fig. 1, sites 2, 6, 9, 10, 12, 15, 16, 18, 20, 23-25, 30, and 33-36). Laboratory analysis of these samples included common inorganic constituents, bacteria, and nutrients at all 17 sites. Stream-bottom materials were collected for insecticide analysis at sites 10, 24, 33, and 34.

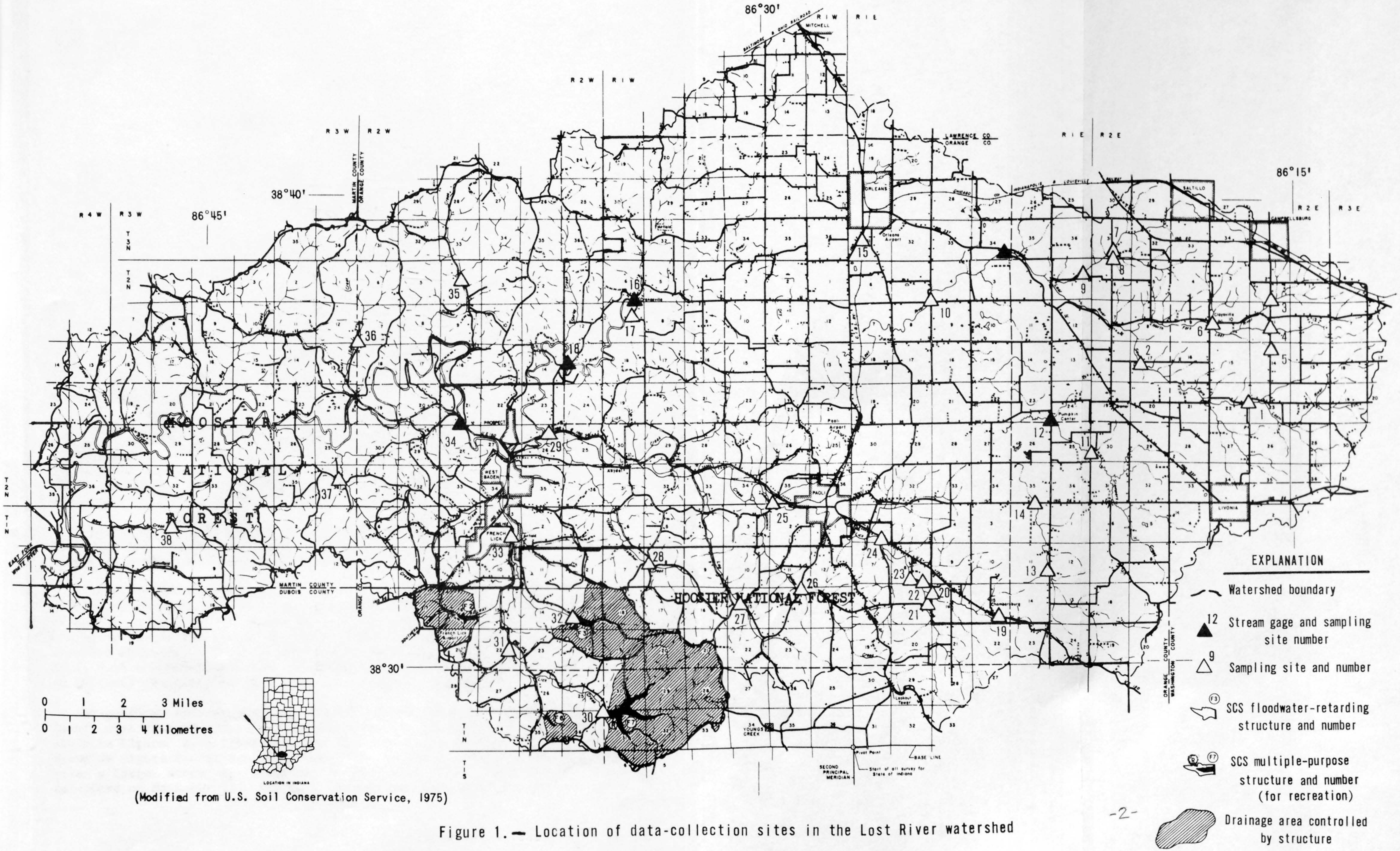


Figure 1.— Location of data-collection sites in the Lost River watershed

A follow-up collection effort on March 5, 1975, included water-quality field measurements and water samples at sites 10, 12, 16, 18, and 24. Also, samples of certain fractions of the biologic community were taken at sites 10, 16, 18, 24, and 33.

ENVIRONMENTAL SETTING AND CONDITIONS

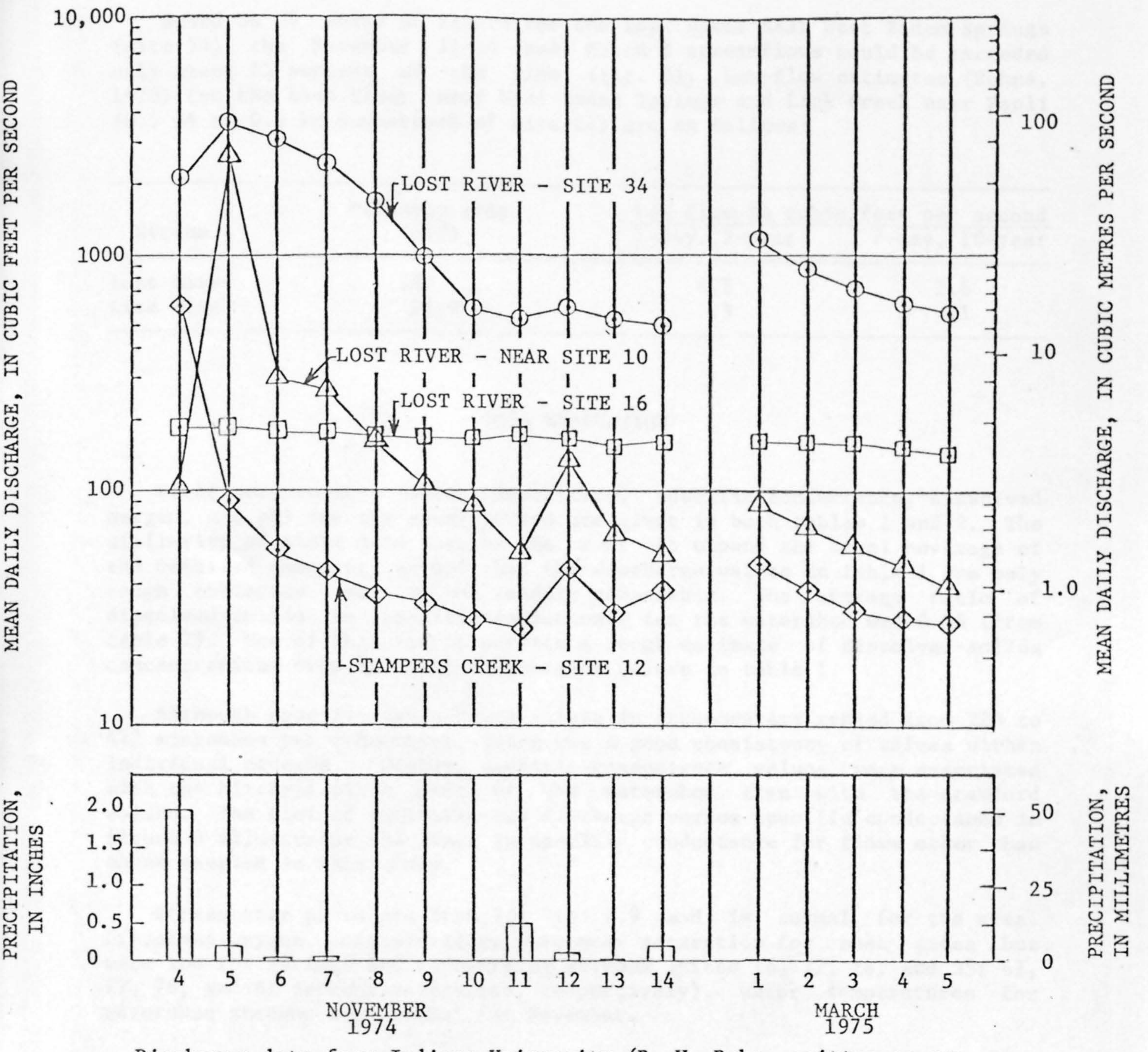
The Lost River watershed occupies 365 mi^2 (945 km^2) of south-central Indiana (fig. 1). The watershed is divided into three fairly distinct geomorphic areas. The eastern third of the watershed (Lost River above site 10 and Stampers Creek) has normal surface drainage, a deep clay overburden, and somewhat permeable limestone bedrock. The north-central part of the watershed (north of Paoli and between Orangeville and site 10) is a karst area characterized by shallow surface soils, short and irregular slopes, sinkholes, blind valleys, and disappearing streams. The normal drainage of the area is underground and in a westerly direction. Surface routes (dry beds) are active only during flood flows. Both of the above areas are within the Mitchell plain physiographic province. The remainder of the watershed (lower Lost River, Lick Creek, and French Lick Creek) has normal surface-drainage streams flowing through the steeply sloping Crawford upland physiographic province. Thin loess and residual soil mantles on interbedded sandstones, shales, and limestones characterize the Crawford upland.

The watershed is basically agricultural, with all but about 5 percent (Hoosier National Forest) under private ownership. Estimated land use within the watershed is as follows: 35 percent cropland, 28 percent pastureland, 26 percent woodland, and 11 percent other (U.S. Soil Conservation Service, 1969). Mixed livestock production is the major farm enterprise of the watershed.

Streams and wells supply water for urban and rural domestic use within the watershed. However, water supply is often a critical problem in the watershed during the summer and fall dry periods.

Average daily temperature for the area ranges from about 0.5°C in January to about 24.5°C in July. Average annual precipitation for the watershed is about 44 in (1,120 mm), with the more intense rains usually coming in the spring and early summer. The minimum annual precipitation recorded at Paoli is 29.7 in (754 mm) and the maximum is 63.5 in (1,610 mm) (U.S. Soil Conservation Service, 1969). The mean annual runoff is about 17 in (432 mm) (Hoggatt, 1962, p. 9).

Streamflow hydrographs for Stampers Creek at site 12 and for the Lost River near site 10 (2 mi or 3 km upstream) and at sites 16 and 34 are shown in figure 2. Precipitation for the Paoli weather station is also shown in figure 2. Streamflows for the November sampling were receding after a large storm on November 4 and were also affected some by a rainstorm on November 11. March 5 streamflows were receding after a large



Discharge data from Indiana University (R. V. Ruhe, written commun., 1975); precipitation data from National Oceanic and Atmospheric Administration (1974 and 1975).

Figure 2.--Precipitation at Paoli and mean daily discharge of streams in the Lost River watershed.

storm on February 23 but were not affected by any recent precipitation. As a result, flows in upstream reaches (sites 10 and 12) for the March sampling were considerably lower than those in the November period.

Based on 8 years of record for the Lost River near West Baden Springs (site 34), the November 11-14 and March 5 streamflows would be exceeded only about 15 percent of the time (fig. 3). Low-flow estimates (Rohne, 1972) for the Lost River near West Baden Springs and Lick Creek near Paoli (0.5 mi or 0.8 km downstream of site 24) are as follows:

Stream	Drainage area (mi^2)	Low flow in cubic feet per second	
		7-day, 2-year	7-day, 10-year
Lost River	287	4.5	2.6
Lick Creek	18.9	.3	.1

DATA EVALUATION

Field measurements (water temperature, specific conductance, dissolved oxygen, and pH) for the study period are given in both tables 1 and 2. The similarity of these data enables the user to expand the areal coverage of the detailed sampling, except that the discharge values in table 1 are only rough estimates and are not readily comparable. The average ratio of dissolved-solids to specific-conductance for the watershed was 0.55 (from table 2). Use of this factor permits a rough estimate of dissolved-solids concentrations from specific-conductance values in table 1.

Although specific-conductance values in streamwaters ranged from 226 to 472 micromhos per centimetre, there was a good consistency of values within individual streams. Higher specific-conductance values were associated with the Mitchell plain part of the watershed than with the Crawford upland. The plot of instantaneous discharge versus specific conductance in figure 4 illustrates the range in specific conductance for flows other than those sampled in this study.

Streamwater pH ranged from 7.1 to 7.9 and is normal for the area. Dissolved-oxygen concentrations were near saturation for most sites but were low for springs and re-emerging streams (sites 16, 17, 18, and 35; 67, 17, 76, and 81 percent saturation, respectively). Water temperatures for watershed streams were normal for November.

Stiff diagrams in figure 5 depict calcium bicarbonate type water of various levels of mineralization. Waters from the Mitchell plain section of the watershed (sites 2, 6, 9, 10, 12, 18, 24, and 25) were considerably more mineralized than waters from the Crawford upland part of the watershed (sites 30, 33, and 36). Sites 34 and 35 are mixtures of waters from both areas. The Stiff diagram for site 15 illustrates the quality of effluent from the Orleans sewage treatment plant.

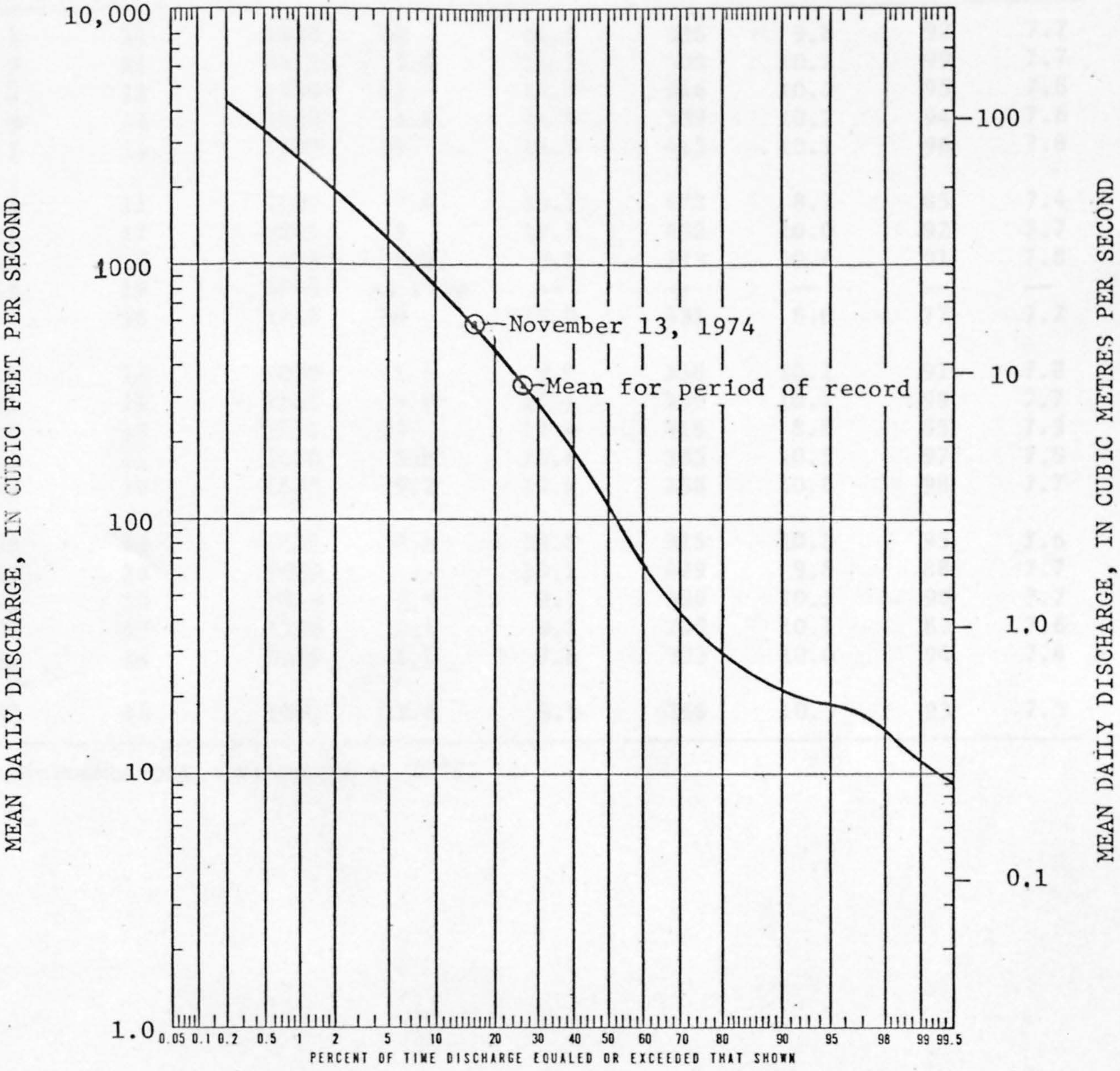


Figure 3.--Flow-duration curve of mean daily discharge for Lost River near West Baden Springs, October 1965 through September 1973.

Table 1.--Lost River watershed field data.

Site	Date (Nov. 1974)	Time (e.s.t.)	Est. disch. (ft^3/s)	Temp. (°C)	Spec. cond.[a]	Dissolved oxygen (mg/l)	Dissolved oxygen (% sat.)	pH
1	11	1230	30	11.5	386	9.8	92	7.7
3	11	1415	5.0	13.1	405	10.2	99	7.7
4	11	1430	11	11.3	346	10.2	95	7.8
5	11	1440	4.8	11.0	339	10.2	94	7.6
7	11	1550	12	11.8	415	10.1	96	7.8
8	11	1600	1.0	13.7	472	8.7	85	7.4
11	12	0845	19	10.7	432	10.0	92	7.7
13	12	1035	4.0	9.0	373	10.4	91	7.8
14	12	1045	no flow	--	--	--	--	--
17	13	1415	50	13.0	431	8.0	77	7.2
19	12	1050	1.5	9.9	358	10.1	91	7.8
21	12	1110	9.0	11.1	339	10.7	99	7.7
22	12	1130	23	13.4	418	8.8	85	7.3
26	12	1630	5.8	10.8	385	10.5	97	7.8
27	12	1620	9.2	10.6	288	10.6	98	7.7
28	12	1605	8.6	10.8	315	10.3	95	7.6
29	13	1600	--	10.1	429	9.8	88	7.7
31	13	1830	2.9	9.7	308	10.1	90	7.7
32	13	1700	1.4	9.1	290	10.1	89	7.6
37	14	0930	1.2	7.6	303	10.6	94	7.4
38	14	1000	1.2	8.5	266	10.3	93	7.3

[a] Micromhos per centimetre at 25°C.

Table 2.--Lost River watershed water-quality data.

	Site	2	6	9	10	12	15
	Date	11-11-74	11-11-74	11-11-74	11-11-74	11-12-74	11-13-74
	Time (e.s.t.)	1300	1500	1630	1730	0945	1200
	Discharge (ft^3/s)	43	26	19	163	34	0.1
	Water temp. (°C)	11.8	12.0	12.3	12.5	9.9	12.6
	pH, Field	7.8	7.7	7.6	7.7	7.9	7.6
	Specific conductance[a]	380	408	439	432	363	1,300
	Dissolved oxygen[b]	102	94	92	92	94	65
Milligrams per litre	Dissolved oxygen	10.7	9.8	9.6	9.6	10.4	6.8
	Calcium	49	49	56	63	69	130
	Magnesium	7.5	9.8	12	11	5.4	56
	Potassium	3.5	6.0	3.8	1.8	2.2	14
	Sodium	6.8	9.0	14	25	5.0	96
	Bicarbonate	150	162	183	208	190	382
	Carbonate	0	0	0	0	0	0
	Chloride	13	16	16	15	11	100
	Fluoride	.2	.3	.3	.2	.2	1.6
	Sulfate	19	23	34	19	23	350
	Silica, dissolved	8.3	8.6	8.2	9.6	9.2	16
	Dissolved solids	199	218	247	274	237	1,010
	Total alkalinity (as $CaCO_3$)	123	133	150	171	156	313
	Total hardness (as $CaCO_3$)	150	160	190	200	190	560
	Noncarb. hardness (as $CaCO_3$)	30	30	39	32	39	240
	Ammonia, total	--	--	--	.04	.12	27
	dissolved (as N)	.01	.34	.08	.00	--	27
	Organic nitrogen, tot.	--	--	--	.25	.53	.00
	dissolved (as N)	.12	.60	.53	.18	.19	.00
	Kjeldahl nitrogen, tot.	--	--	--	.29	.65	26
	dissolved (as N)	.13	.94	.61	.18	.41	--
	Nitrite, total	--	--	--	.00	.00	.17
	dissolved (as N)	.01	.02	.01	.00	.00	.15
	Nitrate, total	--	--	--	5.6	4.0	1.2
	dissolved (as N)	3.8	3.4	2.7	5.4	3.9	1.1
	Orthophosphate, total	--	--	--	.05	.16	5.7
	dissolved (as P)	.06	.21	.08	.03	.12	5.3
	Phosphate, total	--	--	--	.05	.11	6.1
	dissolved (as P)	.06	.25	.08	.03	.04	5.5
	Organic carbon, total	5.9	6.3	8.4	7.0	8.3	33
	dissolved	--	--	--	--	--	--
	Iron, dissolved	.09	.07	.05	.04	.04	.08
	Manganese, dissolved	.03	.03	.02	3.3	.03	.06
	Fecal coliform[c]	13,000[d]	75,000[d]	12,000[d]	7,100[d]	7,800[d]	0
	Fecal streptococci[c]	9,000[d]	49,000[d]	16,000[d]	4,400[d]	2,500	0

Table 2.--Lost River watershed water-quality data--Continued.

	Site	16	18	20	23	24	25
	Date	11-13-74	11-13-74	11-12-74	11-12-74	11-12-74	11-12-74
	Time (e.s.t.)	1330	1445	1130	1200	1345	1515
	Discharge (ft^3/s)	135	347	11	48	50	54
	Water temp. (°C)	13.2	12.8	12.6	12.5	11.9	11.4
	pH, Field	7.1	7.2	7.5	7.3	7.6	7.8
	Specific conductance[a]	432	439	418	401	362	435
	Dissolved oxygen[b]	67	76	93	92	93	99
Milligrams per litre	Dissolved oxygen	7.0	8.0	9.8	9.7	9.9	10.6
	Calcium	73	75	69	67	70	75
	Magnesium	8.0	8.0	6.6	6.0	6.2	6.5
	Potassium	2.4	2.3	1.4	1.4	1.4	1.6
	Sodium	4.7	5.0	4.0	8.0	3.2	4.6
	Bicarbonate	210	211	211	201	204	222
	Carbonate	0	0	0	0	0	0
	Chloride	8.4	8.8	4.8	4.4	5.4	5.8
	Fluoride	.2	.1	.2	.2	.1	.2
	Sulfate	25	23	25	23	22	24
	Silica, dissolved	9.3	9.1	8.8	8.8	8.7	8.8
	Dissolved solids	251	252	229	227	225	244
	Total alkalinity (as $CaCO_3$)	172	173	173	165	167	182
	Total hardness (as $CaCO_3$)	220	220	200	190	200	210
	Noncarb. hardness (as $CaCO_3$)	43	47	26	27	33	32
	Ammonia, total	.05	.06	--	--	--	--
	dissolved (as N)	.00	.00	.00	.00	.01	.15
	Organic nitrogen, tot.	.41	.35	--	--	--	--
	dissolved (as N)	.26	.18	.21	.29	.34	.45
	Kjeldahl nitrogen, tot.	.46	.41	--	--	--	--
	dissolved (as N)	.26	.18	.21	.29	.35	.60
	Nitrite, total	.00	.00	--	--	--	--
	dissolved (as N)	.00	.00	.00	.00	.00	.00
	Nitrate, total	3.6	3.7	--	--	--	--
	dissolved (as N)	3.6	3.7	1.2	1.8	1.7	1.7
	Orthophosphate, total	.07	.07	--	--	--	--
	dissolved (as P)	.04	.04	.05	.04	.02	.05
	Phosphate, total	.11	.12	--	--	--	--
	dissolved (as P)	.04	.04	.02	.02	.01	.05
	Organic carbon, total	7.4	4.6	--	--	4.1	--
	dissolved	3.6	--	--	--	--	--
	Iron, dissolved	.05	.06	.04	.02	.03	.05
	Manganese, dissolved	.03	.04	.03	.62	.03	.05
	Fecal coliform[c]	2,400	3,200	17,000[d]	7,500[d]	7,000[d]	49,000[d]
	Fecal streptococci[c]	1,100	600[d]	5,200[d]	2,900	2,200	1,900

Table 2.--Lost River watershed water-quality data--Continued.

Milligrams per litre

Site	30	33	34	35	36	10
Date	11-13-74	11-13-74	11-13-74	11-14-74	11-14-74	03-05-75
Time (e.s.t.)	1620	1900	1930	1200	1045	1100
Discharge (ft^3/s)	21	58	540	33	11	73
Water temp. (°C)	12.0	11.1	11.6	12.4	8.6	7.0
pH, Field	7.3	7.4	7.4	7.3	7.2	
Specific Conductance[a]	226	279	419	347	260	447
Dissolved oxygen[b]	93	91	90	81	92	108
Dissolved oxygen	9.9	9.8	9.6	8.2	10.2	12.9
Calcium	21	32	66	45	23	69
Magnesium	3.6	4.6	7.5	7.0	3.7	9.3
Potassium	1.8	1.6	2.0	1.6	1.0	1.2
Sodium	2.0	2.8	5.0	4.7	2.5	8.5
Bicarbonate	68	97	198	110	62	202
Carbonate	0	0	0	0	0	0
Chloride	1.8	2.5	12	5.0	1.5	10
Fluoride	.2	.1	.2	.1	.1	.3
Sulfate	14	20	25	54	24	12
Silica, dissolved	5.2	7.0	8.8	8.0	8.7	9.0
Dissolved solids	85	120	236	181	96	247
Total alkalinity (as $CaCO_3$)	56	80	162	90	51	166
Total hardness (as $CaCO_3$)	67	99	200	140	73	210
Noncarb. hardness (as $CaCO_3$)	11	19	33	51	22	45
Ammonia, total	--	--	--	--	--	.02
dissolved (as N)	.41	.09	.04	.00	.00	.00
Organic nitrogen, tot.	--	--	--	--	--	.35
dissolved (as N)	.11	.15	.25	.12	.39	.14
Kjeldahl nitrogen, tot.	--	--	--	--	--	.37
dissolved (as N)	.52	.24	.29	.12	.39	.14
Nitrite, total	--	--	--	--	--	.01
dissolved (as N)	.00	.00	.00	.00	.00	.01
Nitrate, total	--	--	--	--	--	5.7
dissolved (as N)	.13	.22	2.7	.22	.06	--
Orthophosphate, total	--	--	--	--	--	.02
dissolved (as P)	.00	.00	.03	.01	.01	.01
Phosphate, total	--	--	--	--	--	.06
dissolved (as P)	.00	.00	.03	.00	.00	.05
Organic carbon, total	--	--	--	--	--	2.3
dissolved	--	8.8	26	--	--	--
Iron, dissolved	.03	.08	.06	.05	.09	.01
Manganese, dissolved	.97	.29	.09	.01	.05	1.70
Fecal coliform[c]	35[d]	120	5,200[d]	150	45[d]	30[d]
Fecal streptococci[c]	15[d]	40[d]	330	160	210	15[d]

Table 2.--Lost River watershed water-quality data--Continued.

Site		12	16	18	24
Date		03-05-75	-3-05-75	03-05-75	03-05-75
Time (e.s.t.)		1500	1730	1700	1530
Discharge (ft^3/s)		21	145	331	--
Water temp. (°C)		9.0	10.0	9.5	6.5
ph, Field		--	--	--	--
Specific Conductance[a]		431	452	443	366
Dissolved oxygen[b]		114	77	88	108
Milligrams per litre	Dissolved oxygen	13.0	8.6	9.8	13.2
	Calcium	--	--	--	--
	Magnesium	--	--	--	--
	Potassium	--	--	--	--
	Sodium	--	--	--	--
	Bicarbonate	--	--	--	--
	Carbonate	--	--	--	--
	Chloride	--	--	--	--
	Fluoride	--	--	--	--
	Sulfate	--	--	--	--
	Silica, dissolved	--	--	--	--
	Dissolved solids	--	--	--	--
	Total alkalinity (as $CaCO_3$)	--	--	--	--
	Total hardness (as $CaCO_3$)	--	--	--	--
	Noncarb. hardness (as $CaCO_3$)	--	--	--	--
	Ammonia, total	.05	.02	.04	--
	dissolved (as N)	--	--	--	--
	Organic nitrogen, tot.	.29	.31	.21	--
	dissolved (as N)	--	--	--	--
	Kjeldahl nitrogen, tot.	.34	.33	.25	--
	dissolved (as N)	--	--	--	--
	Nitrite, total	.01	.01	.01	--
	dissolved (as N)	--	--	--	--
	Nitrate, total	4.6	4.0	4.0	--
	dissolved (as N)	--	--	--	--
	Orthophosphate, total	.15	.20	.20	--
	dissolved (as P)	--	--	--	--
	Phosphate, total	.11	.17	.17	--
	dissolved (as P)	--	--	--	--
	Organic carbon, total	5.2	4.2	4.0	--
	dissolved	--	--	--	--
	Iron, dissolved	--	--	--	--
	Manganese, dissolved	--	--	--	--
Fecal coliform[c]		50[d]	100[d]	90[d]	100
Fecal streptococci[c]		50[d]	50[d]	170	250

[a] Micromhos/cm at 25°C.
[b] Percent saturation.
[c] Colonies per 100 millilitres.
[d] Estimated value based on nonideal colony count.

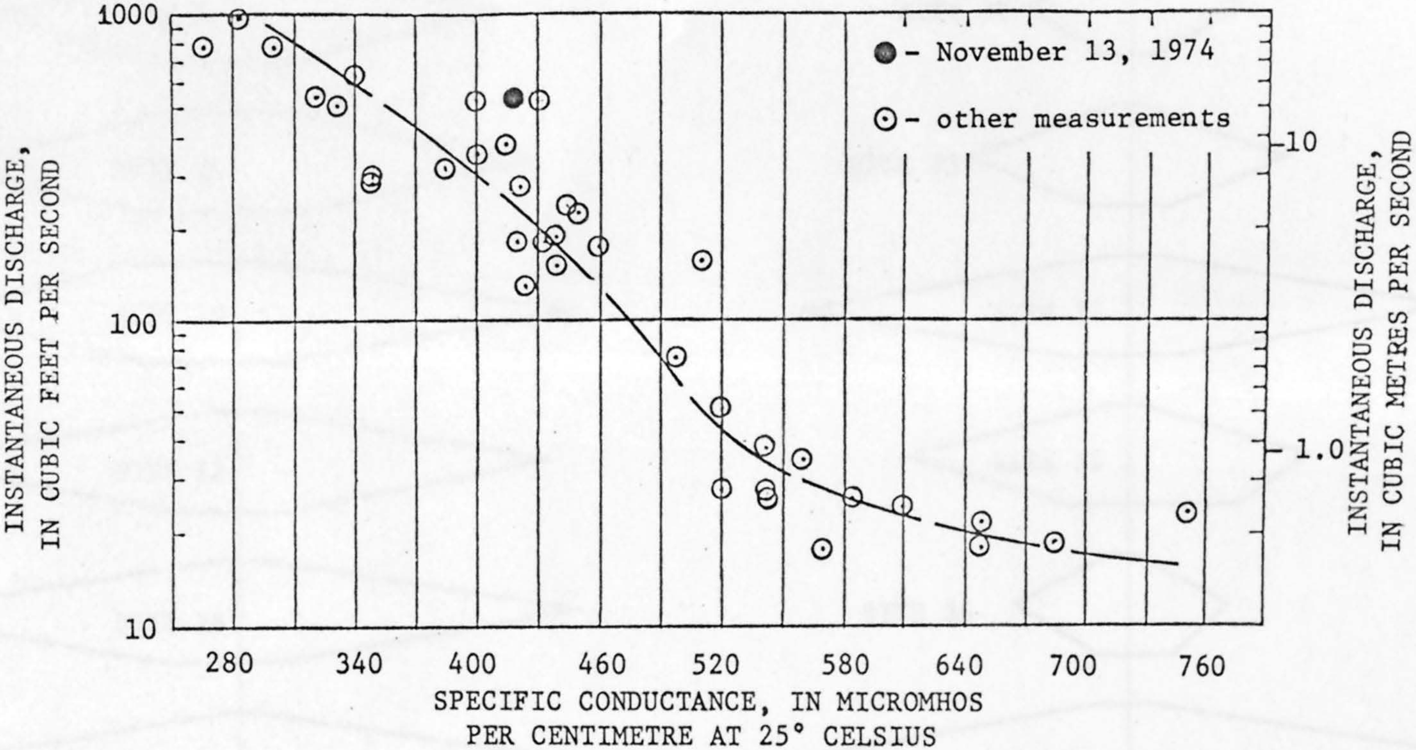


Figure 4.--Discharge versus specific conductance for Lost River near West Baden Springs, January 1969 through October 1973.

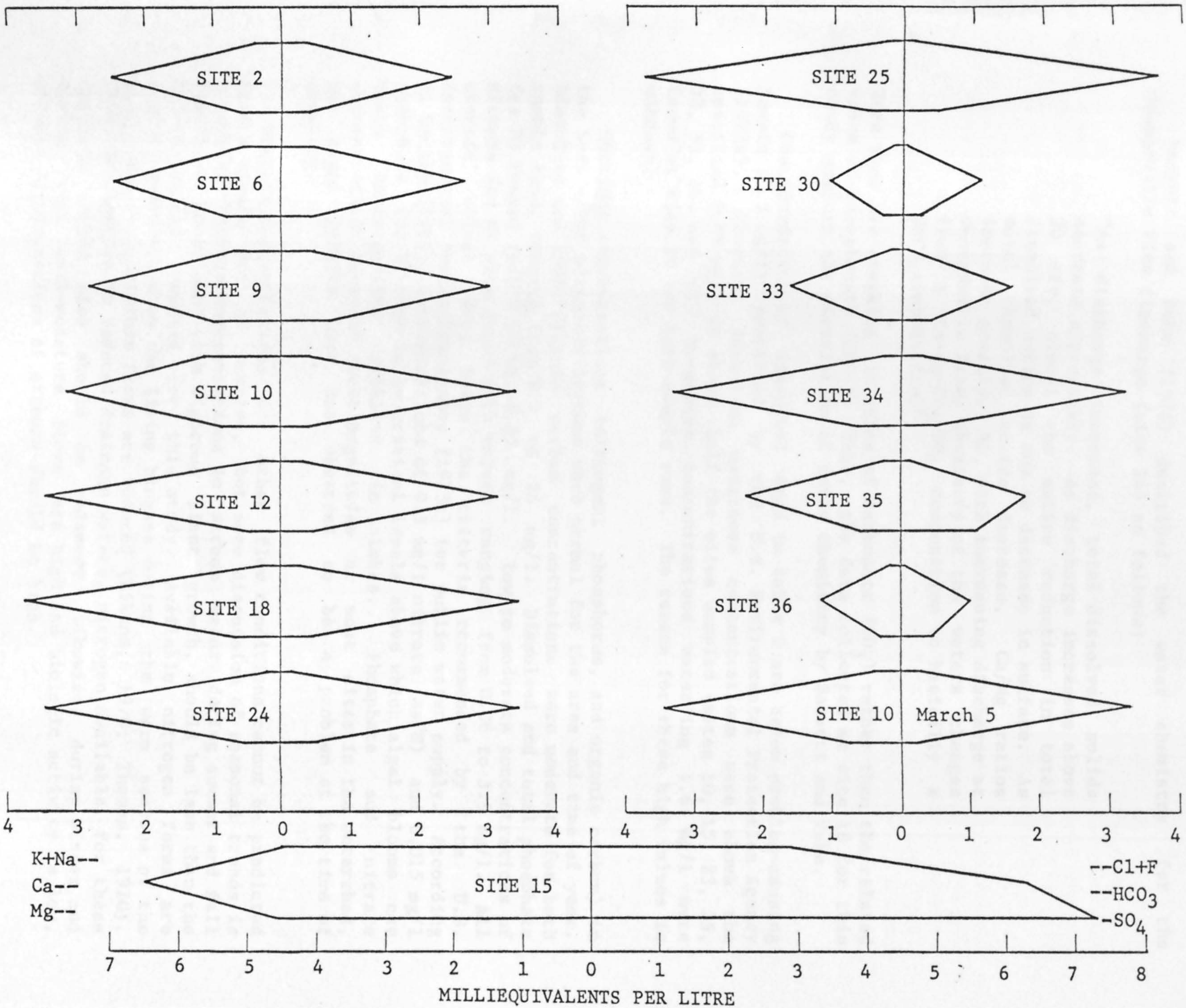


Figure 5.--Stiff diagrams for chemical analyses of Lost River watershed samples.

Bassett and Ruhe (1974) described the water chemistry for the Orangeville Rise discharge (site 16) as follows:

> "As discharge increases, total dissolved solids decrease appreciably. As discharge increases above 20 cfs, almost the entire reduction in total dissolved solids is due to decrease in sulfate. As total dissolved solids decrease, Ca/Mg ratios increase greatly. So, with increasing discharge at Orangeville Rise, chemistry of the waters changes from a $Ca-Mg-CO_3-SO_4$ composition to basically a $CaCO_3$ composition."

Here they are speaking in terms of carbonate (CO_3) rather than the related value of bicarbonate (HCO_3). Thus, the data collected at site 16 for this study support the description of water chemistry by Bassett and Ruhe.

Concentrations of dissolved iron in table 2 are below problem-causing levels (0.3 mg/l) specified by the U.S. Environmental Protection Agency (1973a). However, dissolved manganese concentrations were above the specified 0.05 mg/l at about half the sites sampled (sites 10, 15, 23, 25, 30, 33, 34, and 36). Manganese concentrations exceeding 1.6 mg/l were found at site 10 for both sample runs. The reason for these high values is unknown.

Nutrient concentrations (nitrogen, phosphorus, and organic carbon) in the Lost River watershed streams were normal for the area and time of year. Dissolved and total organic carbon concentrations were moderate for both sample runs, ranging from 2.3 to 26 mg/l. Dissolved and total phosphate (as P) ranged from 0.00 to 0.25 mg/l. Low to moderate concentrations of nitrate (as N) were found with values ranging from 0.06 to 5.9 mg/l. All nitrate values were below the criteria recommended by the U.S. Environmental Protection Agency (1973a) for public water supply. According to Lackey (1961), concentrations of 0.3 mg/l nitrate (as N) and 0.015 mg/l phosphate (as P) seem to be critical levels above which algal blooms can cause water-quality problems in lakes. Phosphate and nitrate concentrations exceeded these magnitudes at most sites in the watershed, but algal growths were not observed to be a problem at the time of sampling.

Nitrate concentrations for other flow conditions cannot be predicted from a single set of samples, but some discussion of seasonal trends is possible. Nitrate concentrations in stream water during summer and fall low flows, coincident with vigorous plant growth, should be less than the concentrations reported for this study. Available nitrogen forms are readily assimilated by the living biomass during the warm seasons of the year, and soil moisture flows are reduced (Likens, 1970; Thomas, 1970). Thus, in addition to reduced drainage waters, nitrogen available for these drainage waters also should be reduced. Likewise, during winter and spring, when soil-moisture flows are high and biologic activity is low, nitrate concentrations of streams should be high.

Nitrate data collected on the Patoka River near English (8 mi or 13 km south of Paoli) illustrate these seasonal trends in nitrate concentration--high concentration during winter and spring flows and low concentration during summer and fall low flows (fig. 6). Similar seasonal trends have been found in numerous Illinois streams (Harmeson and others, 1971) and in other Indiana streams for both agricultural and forested watersheds. Similar trends probably occur in the Lost River watershed.

Significant differences in nitrate concentrations across the watershed seemed related to land use. Nitrate concentrations were highest in the upper Lost River area (sites 10 and 12), where land use for agriculture is high, and lowest in the French Lick Creek, Sams Creek, and Sulphur Creek areas (sites 30, 33, 35, and 36), which are largely forested. Again, similar trends have been found in Illinois streams (Harmeson and others, 1971) and in other Indiana streams.

Concentrations of fecal coliform bacteria in the November streamwater samples ranged from 35 to 75,000 col/100 ml (colonies per 100 millilitres) and fecal streptococci bacteria from 15 to 49,000 col/100 ml (table 2). In the analysis of fecal bacteria with the use of fecal coliform/fecal streptococci ratios, some delineation of source can be made. In human wastes, the ratio tends to be considerably greater than 4; in animal wastes the ratio tends to be markedly less than 1 (Geldreich, 1966). Accordingly, ratios for upper Lost River (above the karst area) seem to indicate animal sources of bacteria. Samples were collected during a storm, and the high concentrations were likely the result of runoff of surficially deposited animal wastes. The ratios for Lick Creek above Paoli, Stampers Creek, and Orangeville Rise were intermediate. Human waste contamination of streamwater, however, is indicated by high ratios downstream from Paoli (Lick Creek) and West Baden (Lost River), and perhaps in the Lost River downstream of Orangeville. Concentrations of fecal bacteria were not significant (not greater than 200 col/100 ml) for other November samples and for the five March samples.

Bed-material samples for insecticide analysis were taken on Lost River at sites 10 and 34, on Lick Creek at site 24, and on French Lick Creek at site 33. Laboratory analysis included the following chlorinated hydrocarbons: aldrin, DDD, DDE, DDT, dieldrin, endrin, heptachlor, heptachlor epoxide, lindane, chlordane, and polychlorinated biphenyl (PCB) and polychlorinated napthalene (PCN) compounds. Those compounds found at each site are given in table 3.

Table 3.--Lost River watershed insecticide data.

Site no.	Concentration in micrograms per kilogram						
	aldrin	dieldrin	chlordane	DDD	DDE	DDT	PCB
10	5.0	33	6	3.4	3.4	0.0	0
24	0.8	1.5	0	0.3	0.2	0.0	0
33	0.0	0.5	1	0.0	0.0	0.0	0
34	1.2	4.3	23	1.5	0.3	2.5	9

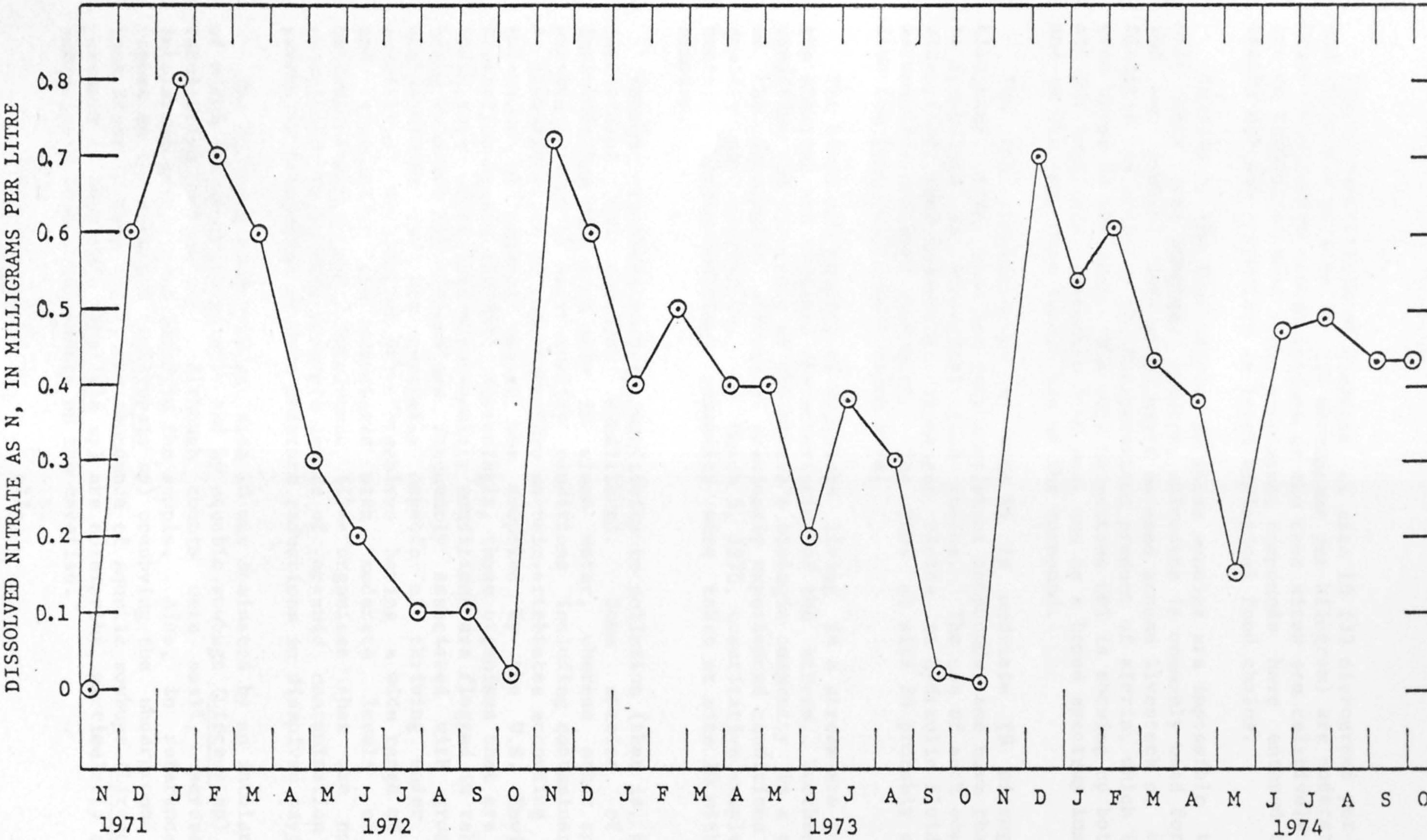


Figure 6.--Dissolved nitrate in samples from the Patoka River near English, November 1971 through October 1974.

The concentrations of dieldrin at site 10 (33 micrograms per kilogram) and chlordane at site 34 (23 micrograms per kilogram) are moderately high. Other insecticide concentrations at the four sites are relatively small but are an indication that these persistent compounds have entered the stream system and may accumulate in local biological food chains.

Sources of the insecticides in these samples are impossible to locate with only four samples. However, chlordane is commonly used for termite and ant control and also might be used around livestock or on lawns. Dieldrin is probably the decomposition product of aldrin, which is used on corn crops in the area. The once ubiquitous DDT is showing up both as DDD and DDE residuals, probably from past use as a broad spectrum insecticide, and as DDT from more recent use of the compound.

The PCB concentration at site 34 is moderate (9 micrograms per kilogram). PCBs also are very persistent compounds and have the tendency to accumulate in biological food chains. The use of such compounds is widespread, from industrial exchanger fluids to hydraulic fluids used in automobiles and farm equipment. The PCBs at site 34 probably originated from the French Lick-West Baden area.

The kinds and numbers of organisms living in a stream are governed by the physical and chemical characteristics of the stream. Furthermore, the condition and diversity of the stream's biologic community is a reflection of the integrated effects of previously experienced conditions of water quality and streamflow. On March 5, 1975, quantitative samples of the benthic (bottom-dwelling) community were taken at site 10 with a Surber sampler.

Benthic organisms vary in sensitivity to pollution (that is, changes in nutritional and physical conditions). Some species of benthic invertebrates will live only in clean water, whereas other species can survive a range of water-quality conditions including contaminated water. A classification of representative macroinvertebrates according to their tolerance of organic wastes was compiled by the U.S. Environmental Protection Agency (1973b). Accordingly, those organisms that are generally indicative of certain water-quality conditions are flagged in table 4 as being 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 biologic community at site 10 was dominated by an intolerant genus of midge larvae (Diamesa sp) and by aquatic sowbugs (Lirceus sp) which are facultative organisms. Although counts were small, several other intolerant genera were found in the sample. Also, in reference to the report on the cavefish (Amblyopsis sp) occupying the underground part of Lost River (Woods, 1971), the abundance of aquatic sowbugs (Lirceus sp) and presence of amphipods (Hyallela sp) are noteworthy, particularly since both are primary food requirements of the cavefish.

Table 4.--Biological data for site 10, benthic invertebrates, March 5, 1975.

	Organism	Count
	Arthropoda	--
	Crustacea	--
	Isopoda (aquatic sowbugs)	--
	Asellidae	--
F	Lirceus sp	158
	Amphipoda (scuds)	--
	Talitridae	--
T/F	Hyallela sp	9
	Decapoda (crayfish)	--
	Astacidae	1
	Insecta	--
	Diptera (2-winged fly larvae)	--
	Chironomidae (midge larvae)	--
	Pentaneura sp	22
I	Diamesa sp	168
I	Microtendipes sp	14
	Rheotanytarsus sp	31
	Trichoptera (caddisfly larvae)	--
	Hydropsychidae	--
F/I	Hydropsyche sp	2
F	Cheumatopsyche sp	51
	Rhyacophilidae	--
I	Rhyacophila sp	2
	Hydroptilidae	--
I	Ochrotrichia sp	1
	Philoptomaidae	--
	Chimarra sp	1
	Limnephilidae	--
	Pycnopsyche sp	2

Organism	Count
Ephemeroptera (mayfly nymphs)	--
Heptangenidae	--
Stenonema sp	3
Baetidae	--
Isonychia sp	1
Plecoptera (stonefly nymphs)	--
Perlidae	--
Neophasganophora sp	1
Odonata (damselfly naiads)	--
Agrionidae	1
Coleoptera (water beetles)	--
Elmidae	--
Stenelmis sp	8
Psephenidae	--
Psephenus sp	21
Mollusca	--
Gastropoda (snails)	--
Ctenobranchiata	--
Pleuroceridae	--
Goniobasis sp	22
Pulmonata	--
Physidae	--
Physa sp	1
Pelecypoda (clams)	--
Heterodonta	--
Sphaeriidae	--
Sphaerium sp	1
Total count	521
Insecta wet weight (grams)	3.2
Diversity index	2.8

F=facultative, I=intolerant, F/I=occupies both categories, T=tolerant, T/F=occupies both categories.

The diversity index is a measure of community structure that makes possible inter- and intra-site comparisons of structure (Wilhm and Dorris, 1968). Diversity indices of 3 or more are representative of well-balanced benthic communities (clean-water types); indices between 1 and 3 are representative of communities under moderate pollution stress, and indices less than 1 indicate heavy pollution stress (Wilhm and Dorris, 1968).

The diversity index for site 10 was 2.8. Nutrient enrichment, rather than organic pollution, was probably a reason for the somewhat less than ideal diversity, especially since Cladophora sp (green algae) was present in moderate amounts. Physical environmental constraints, such as the low temperatures and variable streamflows of winter, are additional reasons for a less-than-ideal diversity.

The calculated biomass of benthic organisms (for class Insecta only) for site 10 was 17 grams per square metre. This rather high biomass is another indication of an enriched environment. Overall, the high productivity of the site and the relative abundance of good indicator organisms suggests the presence of a very "healthy" benthic community at site 10.

Phytoplankton data collected on March 5, 1975, are presented in table 5. With the exception of site 16, diatoms dominated the phytoplankton communities at each site and populations were very low. Low streamwater temperatures and high flows coincident with the winter season are the likely reasons for the low populations. Pollution tolerance indices (Palmer, 1969) for all sites were 8 or less (table 5) and suggest a lack of organic enrichment.

Table 5.--Biological data, phytoplankton, March 1975.

Genus	Group[a]	Percent of total count Site 10	Site 16	Site 18	Site 24	Site 33
Gomphonema sp	d	36	--	11	--	4
Nitzschia sp	d	29	5	33	50	4
Navicula sp	d	--	9	45	--	--
Oscillatoria sp	bg	--	81	--	--	--
Asterionella sp	d	--	--	--	--	43
Tabellaria sp	d	--	--	--	50	--
Cymbella sp	d	--	5	11	--	--
Fragilaria sp	d	--	--	--	--	--
Oocystis sp	g	--	--	--	--	13
Ankistrodesmus sp	g	--	--	--	--	7
Surirella sp	d	--	--	--	--	4
Cyclotella sp	d	--	--	--	--	4
Dinobryon sp	f	--	--	--	--	4
Trachelomonas sp	f	--	--	--	--	4
Chlamydomonas sp	f	7	--	--	--	--
Achnanthes sp	d	7	--	--	--	--
Cocconeis sp	d	7	--	--	--	--
Cymatopleura sp	d	7	--	--	--	--
Rhoicosphenia sp	d	7	--	--	--	--
Total percent		100	100	100	100	100
Total count (cells/ml)		140	780	78	31	130
Pollution tolerance index		1	8	0	0	0

[a] d=diatom; bg=blue-green algae; g=green algae; f=flagellate.

SUMMARY AND CONCLUSIONS

In general, quality of streamwater in the Lost River watershed was good. However, some potential water-quality problems could arise from fertilizer and insecticide applications to cropland, and perhaps from human waste contamination from the Paoli and West Baden areas.

Streamwaters in the study area were calcium bicarbonate types, with the least mineralized waters being found in the Crawford upland part of the watershed, and the most mineralized waters in the Mitchell plain part. Concentrations of dissolved iron in the watershed streams were less than problem-causing levels (0.3 mg/l), but concentration of dissolved manganese exceeded problem-causing levels (0.05 mg/l) at about half the sites sampled. Manganese concentrations exceeding 1.6 mg/l were found in upper Lost River for both sample runs.

Nutrient concentrations (nitrogen, phosphorus, and organic carbon) in streamwaters were normal for the area and the time of year. Concentrations of nitrate (as N) in streamwater ranged from 0.06 to 5.6 mg/l in November and from 4.0 to 5.9 mg/l in March. These concentrations are sufficient to cause enrichment and undesirable biologic growth but are not significant with respect to public use. Nutrient concentrations for streamflow conditions other than sampled in this survey could not be adequately predicted from the data. However, nitrate concentrations in the Lost River watershed are probably related directly to streamflow and time of year, with high concentrations being associated with winter and spring high flows and lowest concentrations with summer and fall low flows. Streamwater nitrate concentrations also appear to be related to the level of agricultural use, with highest concentrations being associated with heavily cropped areas (upper Lost River) and lowest concentrations being associated with forested areas (French Lick Creek).

Fecal coliform bacteria concentrations in the November samples ranged from 0 to 75,000 colonies per 100 millilitres and fecal streptococci bacteria from 0 to 49,000 colonies per 100 millilitres. Samples were collected during a small storm and the high concentrations were likely the result of runoff of surficially deposited animal wastes. Ratios of fecal coliform to fecal streptococci for many sites with significant bacterial concentrations were intermediate, but tended more toward indication of animal sources of bacteria. Human waste contamination of streamwater is suspected downstream of Paoli (Lick Creek) and West Baden (Lost River), and perhaps downstream of Orangeville (Lost River).

The March samples at five sites contained considerably fewer fecal bacteria than November samples. Fecal coliform concentrations were less than 100 colonies per 100 millilitres, and fecal streptococci concentrations were less than 250 colonies per 100 millilitres.

The upper Lost River site contained aldrin, dieldrin, chlordane, DDD, and DDE; the lower Lost River site contained aldrin, dieldrin, chlordane, DDT, DDD, DDE, and PCB compounds. The bed materials in Lick Creek above Paoli contained aldrin, dieldrin, DDD, and DDE. Dieldrin and chlordane were found in French Lick Creek bottom materials. Concentrations of 33 micrograms per kilogram or less were found and are important as an indication that insecticides are entering the waterways and so may have the potential for accumulating in local biological food chains.

A diversity index of 2.8 was found in an upper Lost River site, where midge larvae and aquatic sowbugs were dominant. Nutrient enrichment, rather than organic pollution, probably was a reason for the somewhat less than ideal diversity, especially since <u>Cladophora</u> sp (green algae) were present in moderate amounts. Overall, the productivity of the site and the relative abundance of good indicator organisms suggests the presence of a very "healthy" benthic community.

As yet, however, none of the problem areas discussed have been fully defined. The data and discussion in this report simply serve to establish areas of convern that may require further definition. Considerably more detailed sampling over a range in streamflow, biologic, and climatic conditions would be necessary to define concentration ranges and variations or to locate actual sources of the constituents of interest.

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