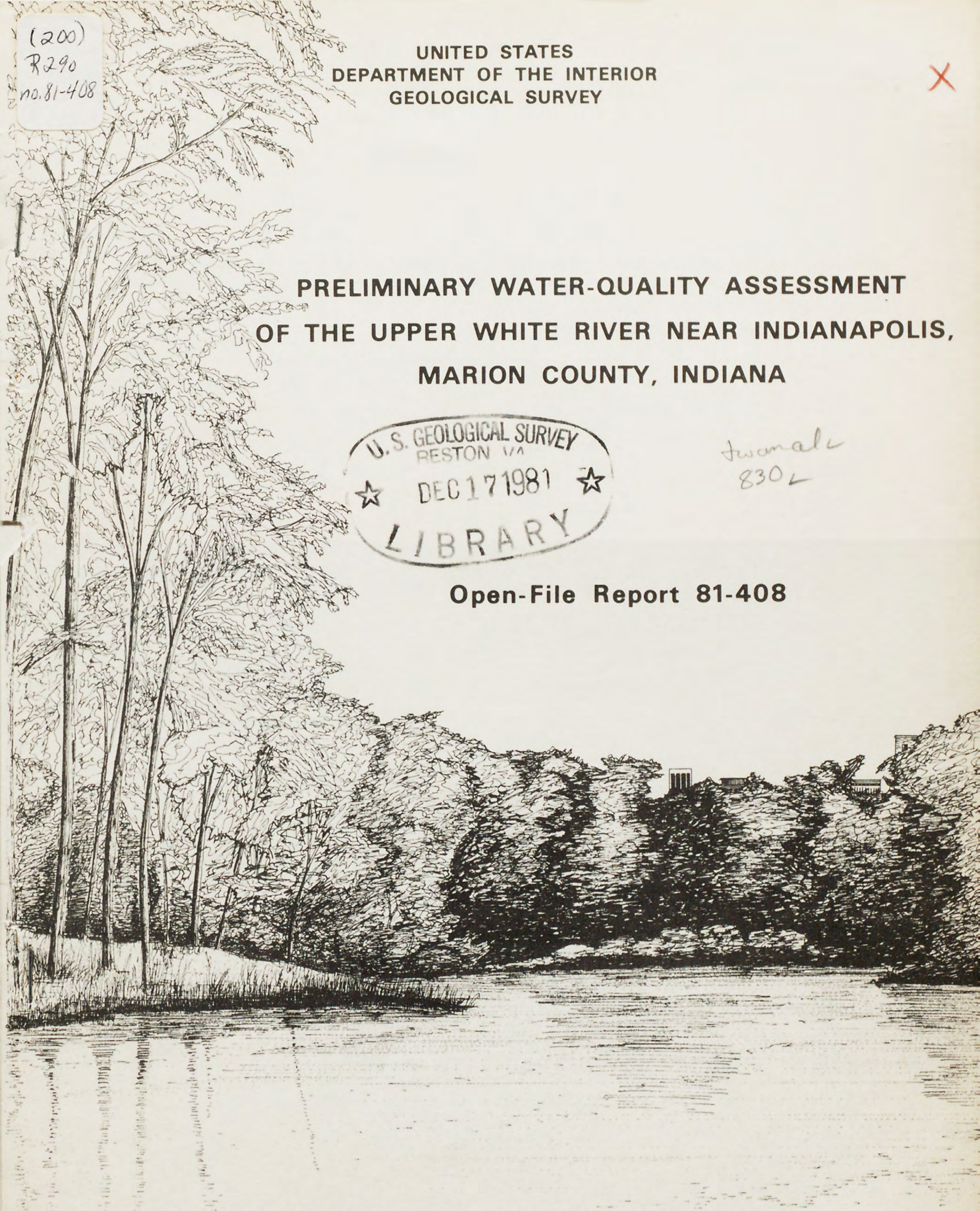
UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

PRELIMINARY WATER-QUALITY ASSESSMENT OF THE UPPER WHITE RIVER NEAR INDIANAPOLIS, MARION COUNTY, INDIANA

Open-File Report 81-408



Prepared in cooperation with the White River Park Commission

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By David J. Wangsness, Stephen E. Eikenberry,
William G. Wilber, and Charles G. Crawford

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Indianapolis, Indiana

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FACTORS FOR CONVERTING INCH-POUND UNITS TO INTERNATIONAL SYSTEM OF UNITS (SI)

Multiply inch-pound unit	By	To obtain SI unit
inch (in.)	2.540	centimeter (cm)
foot (ft)	0.3048	meter (m)
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
cubic foot per second (ft^3/s)	0.0283	cubic meter per second (m^3/s)
cubic foot per second per square mile [$(ft^3/s)/mi^2$]	0.01094	cubic meter per second per square kilometer [$(m^3/s)/km^2$]
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)

ABBREVIATIONS

Blvd.	Boulevard.
BOD	Biochemical-oxygen demand.
°C	Degree Celsius.
cells/mL	Cells per milliliter.
cells/100 mL	Cells per 100 milliliters.
Co.	County.
col	Colonies.
Cr.	Creek.
e.s.t.	Eastern standard time.
FC	Fecal coliform.
FS	Fecal streptococci.
ft^3/s	Cubic foot per second.
$(ft^3/s)/mi^2$	Cubic foot per second per square mile.
in.	Inch.
LC50	96-hour median lethal concentration.
mg/L	Milligram per liter.
mi^2	Square mile.
nr	Near.
NTU	Nephelometric turbidity units.
Q7,10	7-day, 10-yr low flow.
RM	River mile.
St.	Street.
TL50	96-hour median tolerance limit.
µ	Micron.
µg/g	Microgram per gram.
µg/kg	Microgram per kilogram.
µg/L	Microgram per liter.
µmho/cm	Micromho per centimeter.
USGS	U.S. Geological Survey.
yr	Year.

PRELIMINARY WATER-QUALITY ASSESSMENT OF THE UPPER WHITE RIVER NEAR INDIANAPOLIS, MARION COUNTY, INDIANA

By David J. Wangsness, Stephen E. Eikenberry,
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ABSTRACT

The White River Park Commission is planning the development of park facilities along the White River through Indianapolis. A key element in the planning is the determination of whether water quality of the river is suitable for recreation. A preliminary water-quality assessment of the river in Indianapolis on August 4-5, 1980, indicates that, during low-flow steady-state conditions, water quality of the river is suitable for partial body contact recreation (any contact with water up to, but not including, complete submergence). Dissolved-oxygen concentrations varied but were higher than the Indiana water-quality standards established to ensure conditions for the maintenance of a well-balanced, warm-water fish community. High fecal-coliform densities that have been observed in the White River during high streamflow are probably caused by stormwater runoff from combined sewers. However, during the low-flow steady-state conditions on August 4-5, 1980, fecal coliform densities were within the Indiana standards for partial body contact recreation.

Concentrations of organic matter (based on biochemical-oxygen demand and dissolved- and suspended-organic carbon concentrations), nutrients, and heavy metals in the White River were generally within the limits recommended by the U.S. Environmental Protection Agency and were generally similar to values for other Indiana rivers. Chromium, copper, lead, zinc, and mercury are accumulating in bottom materials downstream from 30th Street (river mile 235.58). The source of these metals is probably stormwater runoff from combined sewer overflows.

The phytoplankton densities of the White River were high (>500 cells per milliliter). The dominant phytoplankton species are indicative of rivers moderately affected by organic wastes. The highest cell concentrations, upstream from dams on the White River, significantly affected dissolved-oxygen concentration and pH.

INTRODUCTION

The White River Park Commission is planning the development of park facilities along the White River through Indianapolis. A key element in the planning is the determination of whether the water quality of the river is suitable for recreation.

Few water-quality data were collected for the upper White River (RM 247.87 to 230.30) during the last 5 yr (1975-80), and most of the data were collected upstream from the metropolitan area or downstream from the Indianapolis wastewater-treatment facilities.

Purpose and Scope

To determine the potential of the White River for recreational use, the U.S. Geological Survey, in cooperation with the White River Park Commission, did a preliminary water-quality assessment of the upper White River on August 4-5, 1980. The objectives of this assessment were to:

1. Define the chemical and biological quality of the White River. This included an evaluation of dissolved-inorganic constituents and properties (pH, alkalinity, major ions, trace metals, and nutrients), constituents and properties affecting the dissolved-oxygen dynamics of the stream (temperature, dissolved oxygen, 5-day biochemical-oxygen demand, ammonia nitrogen, nitrite nitrogen, and nitrate nitrogen), phytoplankton, fecal coliform, and fecal streptococci, and an analysis of bottom materials for trace metals, pesticide residues, and other chlorinated hydrocarbons.

2. Relate observed water quality to recommended water-quality criteria for recreational and other potential uses.

3. Identify, if possible, problem areas that contribute to poor water quality within the stream reach.

BASIN DESCRIPTION

The upper White River drains a 1,635-mi^2 area (upstream from USGS gage at Morris Street, Indianapolis) in east-central Indiana (fig. 1) and flows generally southwest to its confluence with the Wabash River in Knox County, Ind.

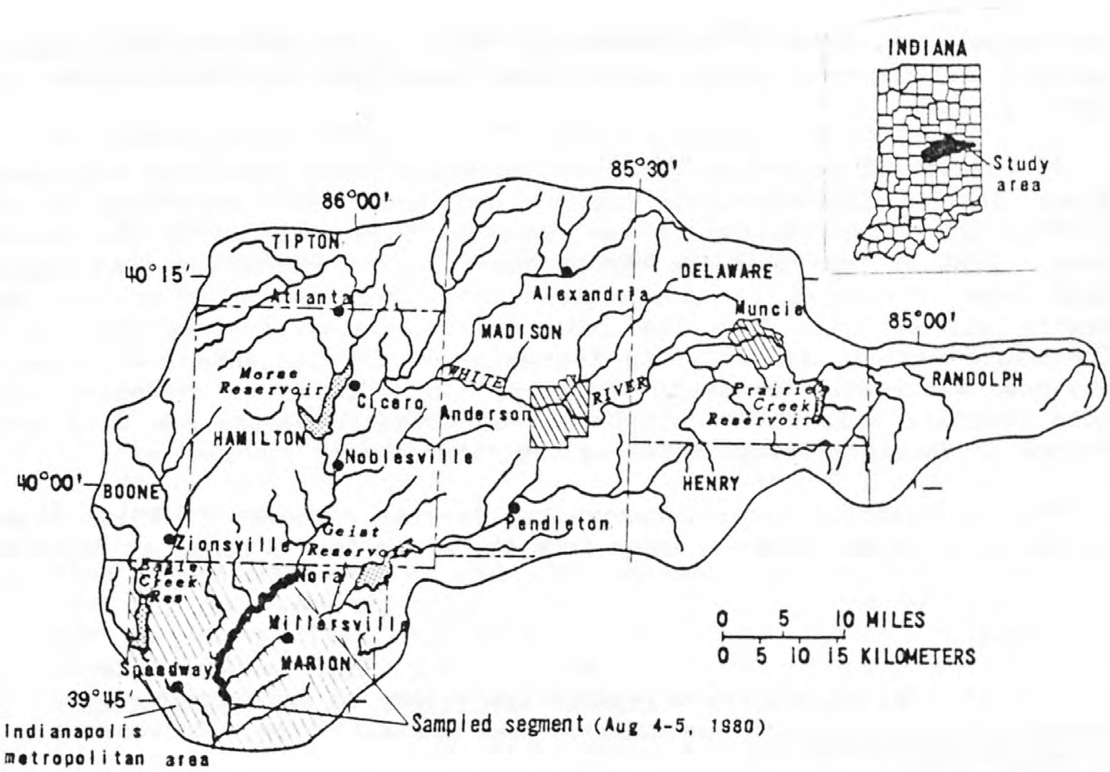

Figure 1.-- Location of sampled segment of White River study area.

(Cable and others, 1971). The topography of the upper White River watershed is typical of the Tipton Till Plain and is characterized by flat to gently rolling hills and stream valleys (Malott, 1922).

Wier and Gray (1961) indicated that silt, sand, and gravel overlie limestones, dolomites, and shale bedrock. Soils in the watershed are mostly Brookston silty-clay loams and Crosby silt loams (Storm and Gilbert, 1978; and Hosteter, 1978). These soils range from medium- to moderately fine texture and are not well drained. Land use in the watershed is primarily agriculture except for several major urban centers: Indianapolis, Muncie, and Anderson.

Annual precipitation is 38 to 40 in. (Schaal, 1966, p. 157). The average annual runoff is 12 to 13 in. (Hoggatt, 1962, p. 9).

The segment of the White River that was studied has three major tributaries: Fall Creek (drainage area, 318 mi^2), Williams Creek (drainage area, 22.2 mi^2), and Crooked Creek (drainage area, 20.1 mi^2). Howland ditch (drainage area, 8.16 mi^2), Haverstick Creek (5.00 mi^2), several minor tributaries, and numerous storm sewers also drain into the White River (Hoggatt, 1975, p. 142).

Virtually all potential point-source waste loads impacting the upper White River are in Indianapolis, Muncie, and Anderson. According to Shampine (1975), the water quality of the river is most affected by the Indianapolis area. Most of the water-quality problems in and downstream from Indianapolis have been attributed to stormwater runoff from both combined and separated sewers and effluent from the Indianapolis wastewater-treatment facilities. To reduce waste loads entering the White River, Indianapolis is building an advanced wastewater-treatment facility. In addition to secondary treatment, this facility will remove nitrogen from domestic wastes and will reduce the volume of combined sewage entering the river during storms.

The Indianapolis Water Company, the largest consumer of White River water in the study area, diverts water from the river into a canal at Broad Ripple.

WATER-QUALITY STANDARDS APPLICABLE TO THE WHITE RIVER

Water-quality standards for streams in Indiana, defined in Regulation SPC IR-4 (Indiana Stream Pollution Control Board, 1977), are designed to protect and maintain the following in-stream beneficial uses: recreation, aquatic life, domestic, industrial, and agricultural uses.

The upper White River was not incorporated into the Natural, Scenic, and Recreational Rivers System by the Indiana Department of Natural Resources. As a result, this stream reach is designated for only partial body contact recreation in addition to any other applicable use. Partial body contact is defined by the Indiana Stream Pollution Control Board (1977) as "Any contact with water up to, but not including, complete submergence." Partial body contact recreational activities include fishing, commerical or recreational boating, wading, and some shoreline contact. Pertinent water-quality standards (items 1-4) for the upper White River (quoted from the preceding reference) follow:

1. "All waters at all times and at all places shall meet the minimum conditions of being free from substances, materials, floating debris, oil or scum attributable to municipal, industrial, agricultural, and other land-use practices or other discharges:

   a. that will settle to form putrescent or otherwise objectionable deposits,
   b. that are in amounts sufficient to be unsightly or deleterious,

c. that produce color, odor or other conditions in such degree as to create a nuisance,

d. which are in amounts sufficient to injure, be toxic to or produce adverse physiological responses in humans, animals, aquatic life or plants. As a guideline toxic substances should be limited to the 96-hr median lethal concentration (LC50) for biota significant to the indigenous aquatic community,

e. which are in concentrations or combinations that will cause or contribute to the growth of aquatic plant algae in such a degree as to create a nuisance, be unsightly or deleterious, or be harmful to human, animal, plant or aquatic life or otherwise impair the designated use.

2. "For streamflows greater than the average, minimum, 7-consecutive day low flows which occur once in 10 yr (70 and 49 ft^3/s, for the White River near Nora and at Morris Street, respectively) (Rohne, 1972, p. 171) the following stream standards were established to ensure conditions necessary for the maintenance of a well-balanced fish community.

   a. (Taste and odor).--There shall be no substances which imparts unpalatable flavor to fish or result in noticeable offensive odors in the vicinity of the water.

   b. (Toxic substances).--Concentrations of toxic substances shall not exceed one-tenth of the 96-hr median-lethal concentration for important indigenous aquatic species.

   c. (Persistent or bioconcentrating substances).--Concentrations of organic contaminants which can be demonstrated to be persistent, to have a tendency to bioconcentrate in the aquatic biota, and are likely to be toxic on the basis of available scientific evidence, shall be limited as determined by the Board after public notice and opportunity for hearing.

   d. (pH).--No pH values below 6.0 nor above 9.0, except daily fluctuations which exceed pH 9.0 and are correlated with photosynthetic activity, shall be permitted.

3. "(Water quality for warm-water fish).--The following standards were established in addition to those in (2.) above to ensure conditions necessary for the maintenance of a well-balanced, warm-water fish community.

a. (Dissolved oxygen).--Dissolved oxygen concentrations shall average at least 5.0 mg/L per calendar day and shall not be less than 4.0 mg/L at any time.

b. (Temperature).--There shall be no abnormal temperature changes that may affect aquatic life unless caused by natural conditions.

4. "(Bacterial quality for partial-body contact).--The criteria for maintaining partial body contact recreation at any point in waters outside of a wastewater effluent mixing zone is that the fecal-coliform bacteria content shall not exceed 1,000 colonies per 100 mL as a geometric mean based on not less than five samples per month; nor exceed 2,000 colonies per 100 mL in more than one sample."

DATA COLLECTION

A reconnaissance of the upper White River was done in May 1980 to determine (1) the number of tributaries and outfalls discharging into the study reach, (2) accessibility of potential sampling sites, and (3) physical characteristics of the stream reach such as the extent of backwater upstream from dams, types of bottom material, and depths of water.

On the basis of information obtained from the reconnaissance, 16 sampling sites were studied on August 4-5, 1980 (fig. 2).

All water samples except those for bacterial analysis were collected in equal-width increments across the stream transect and were composited so that the sample from each increment was proportional to streamflow. Bacterial populations (fecal coliform and fecal streptococci) for individual "grab" samples collected from the center of flow at 13 sites were counted, and water temperature, dissolved-oxygen concentration, pH, specific conductance, and alkalinity were measured. Water samples from 12 sites were analyzed for nutrients, 5-day biochemical-oxygen demand, organic carbon, turbidity, and suspended sediment. Water samples collected at 5 sites were analyzed for major ions, total metals, and phytoplankton. Three bottom-material samples were oven dried and were passed through a 0.062 mm stainless-steel sieve. The material smaller than 0.062 mm was analyzed for metals because according to Rickert and others (1977) and Wilber and Hunter (1979), the concentration of metals in bottom materials is strongly dependent on the particle-size distribution of the sample, and in general, the quantity of metals on bottom-material samples increases with decreasing particle size.

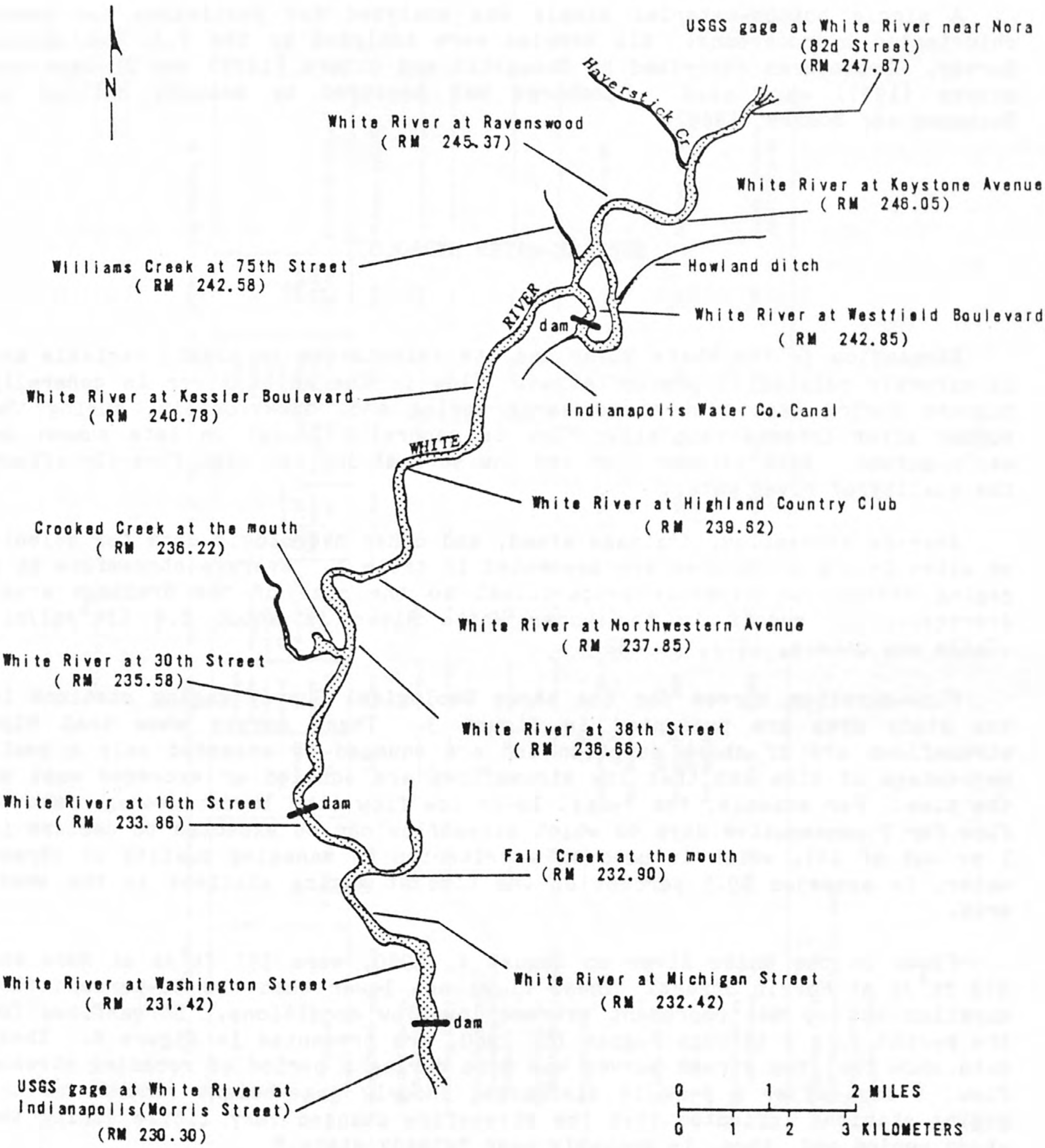

Figure 2.-- Locations of sampling stations in the sampled segment.

A single bottom-material sample was analyzed for pesticides and other chlorinated hydrocarbons. All samples were analyzed by the U.S. Geological Survey. Procedures described by Skougstad and others (1979) and Greeson and others (1977) were used. Discharge was measured by methods defined by Buchanan and Somers (1969).

SURFACE-WATER HYDROLOGY

Streamflow in the White River and its tributaries is highly variable and is directly related to precipitation. Flow in the White River is generally highest during late winter and early spring and, occasionally, during the summer after intense rainfall. Flow is generally lowest in late summer or early autumn. Both extreme high and low streamflows can significantly affect the quality of river water.

Average streamflow, drainage areas, and other hydrologic data for selected sites in the study area are presented in table 1. Average streamflow at a gaging station is directly proportional to the size of the drainage area. Average-annual runoff in the upper White River is about 0.9 $(ft^3/s)/mi^2$ (Cable and others, 1971, p. C22).

Flow-duration curves for the three Geological Survey gaging stations in the study area are presented in figure 3. These curves show that high streamflows are of short duration and are equaled or exceeded only a small percentage of time and that low streamflows are equaled or exceeded most of the time. For example, the 7-day, 10-yr low flow (the lowest average rate of flow for 7 consecutive days to which streamflow can be expected to decline in 1 yr out of 10), which is used as a criterion in managing quality of stream water, is exceeded 99.5 percent of the time at gaging stations in the study area.

Flows in the White River on August 4, 1980, were 392 ft^3/s at Nora and 373 ft^3/s at Morris Street. These flows are lower than the 50-percent flow duration but do not represent extreme low-flow conditions. Streamflows for the period July 1 through August 15, 1980, are presented in figure 4. These data show that the stream survey was done during a period of receding streamflow, 6 days after a peak in discharge. Hourly gage-height records at the gaging stations indicated that the streamflow changed very little during the study period and, thus, is probably near "steady state."

Flow in the White River is partly regulated by upstream reservoirs on Prairie, Cicero, and Fall Creeks and also by the withdrawal of water for municipal water supply by the Indianapolis Water Co. The Indianapolis Water Co. withdrew water at a rate of 138 and 142 ft^3/s per day at their treatment plant on August 4-5, 1980, respectively (J. Broyles, Indianapolis Water Co., oral commun., December 23, 1980).

Table 1.--Streamflow measurements and calculations at sampling stations in the upper White River basin, Marion County, Ind.

Station	River mile	Drainage area[1] (mi^2)	Average streamflow--period of record (ft^3/s)	Measured streamflow--August 4, 1980 (ft^3/s)	Streamflow (Period of record) Maximum (ft^3/s)	Streamflow (Period of record) Minimum (ft^3/s)	Minimum streamflow--1979 water year[2] (ft^3/s)	7-day, 10-year low flow (ft^3/s)	Period of record[2]
White River near Nora	247.88	1,219	1,091	392	32,400	49	199	[3]70	October 1929-80
White River at Broad Ripple	243.06	-------	-------	194	-----	-----	-----	---	-------------------
Williams Creek	242.58	-------	-------	4.3	-----	-----	-----	---	-------------------
White River cutoff including Williams Creek	242.58	-------	-------	50	-----	-----	-----	---	-------------------
White River at Northwestern Avenue	237.86	-------	-------	283	-----	-----	-----	---	-------------------
Crooked Creek	------	17.9 (at gage) 20.0 (at mouth)	19.5	-----	5,500	.47	2.9	---	June 1969-80
Fall Creek	232.90	298 (at gage) 318 (at mouth)	282	-----	12,900	7.8	73	[4]18	October 1929-80
White River at Morris Street	230.30	1,635	1,398	373	37,200	8.0	176	[3]49	March 1904-July 1906 April 1930-80

[1]Hoggatt, 1975.

[2]U.S. Geological Survey, 1980.

[3]Rohne, 1972.

[4]Hoggatt, 1962.

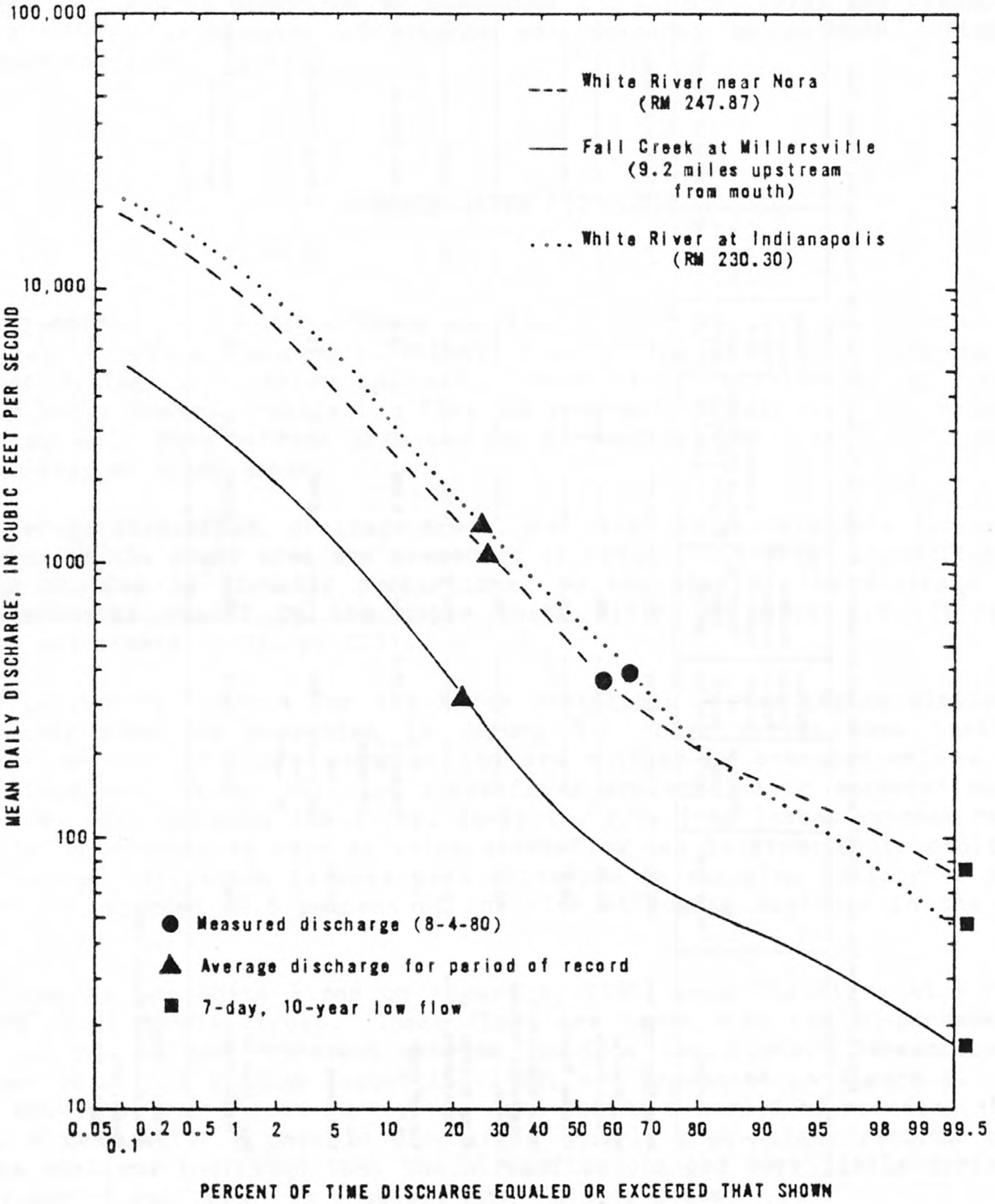

Figure 3.-- Relation of mean daily discharge to percent flow duration.

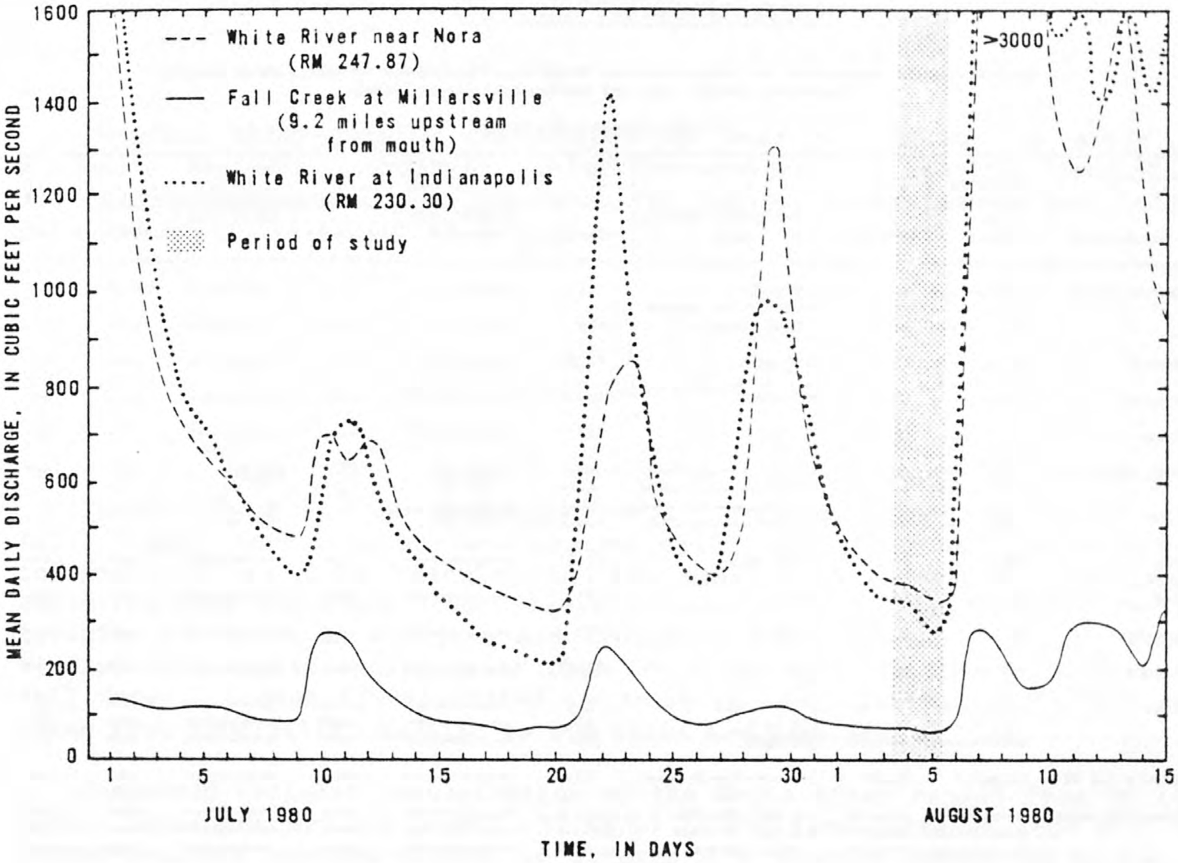

Figure 4.-- Relation of discharge to time.

The velocity of streamflow in the White River is affected by the channel slope and also by dams at Broad Ripple, 16th Street, and downstream from Washington Street. Velocities in free-flowing reaches are significantly greater than in pooled reaches behind dams. The slow velocities upstream from the dams significantly influence the chemical and biological characteristics of the stream. The characteristics of some pooled reaches are very similar to those of small lakes.

WATER QUALITY

Water-quality criteria recommended by the U.S. Environmental Protection Agency (1976) and the Indiana State Board of Health (1977) are presented in table 2. Water-quality data collected in the study area on August 4-5, 1980, are presented in tables 3 through 13. Values of the constituents and properties were usually lower than the recommended limits for recreational uses, which indicate generally good water quality.

Table 2.--Limits recommended for constituents and properties for domestic or public-water supply, freshwater aquatic life, and recreational use in Indiana

[1 mg/L equals 1,000 μg/L]

Constituent	Domestic or public water supply	Reference	Freshwater aquatic life	Reference	Recreation: Partial body contact	Reference	Recreation: Whole body contact	Reference	Notes
Ammonia (as N)	---	---	2.5 mg/L	(1)	---	---	---	---	---
	---	---	.02 mg/L as union-ized ammonia	(2)	---	---	---	---	---
Cadmium	10 μg/L	(2)	12.0 μg/L	(1,2)	---	---	---	---	(3)
Chromium	50 μg/L	(1,2)	100 μg/L	(1,2)	---	---	---	---	---
Copper	1,000 μg/L	(2)	20 μg/L	(4)	---	---	---	---	(5)
Fecal coliform	---	---	---	---	1,000 col/100 mL	(6)	200 col/100 mL	(6)	---
	---	---	---	---	2,000 col/100 mL max.		400 col/100 mL		
Iron	300 μg/L	(1,2)	1,000 μg/L	(1,2)	---	---	---	---	---
Lead	50 μg/L	(2)	50 μg/L	(4)	---	---	---	---	---
Manganese	50 μg/L	(1,2)	1,000 μg/L	(7)	---	---	---	---	---
Mercury	2.0 μg/L	(2)	0.05 μg/L	(1,2)	---	---	---	---	---
Nickel	---	---	390-420 μg/L	(1,2)	---	---	---	---	(8)
	---	---	430 μg/L	(9)	---	---	---	---	(8)
	---	---	500 μg/L	(4)	---	---	---	---	---
Nitrate (as N)	10 mg/L	(1,2)	---	---	---	---	---	---	---
Dissolved oxygen	---	---	4.0 mg/L minimum	---	---	---	---	---	---
	---	---	5.0 mg/L minimum daily average	(1,2)	---	---	---	---	---
pH	5.0-9.0	(1)	6.5-9.0	(1,2)	---	---	---	---	---
Dissolved solids	250 mg/L (chlorides and sulfates)	(1,2,9)	---	---	---	---	---	---	---
	500 mg/L (sulfates)	---	---	---	---	---	---	---	---
Temperature	---	---	Maximum 2.8° C above natural conditions	(9)	---	---	---	---	---
	---	---	32.2° C June-Sept.	---	---	---	---	---	---
Zinc	5,000 μg/L	(2)	80-210 μg/L	(2)	---	---	---	---	(8)
	---	---	330 μg/L	(9)	---	---	---	---	(8)
	---	---	1,000 μg/L	(4)	---	---	---	---	---

1. Indiana State Board of Health, 1977.
2. U.S. Environmental Protection Agency, 1976.
3. Limit is for hard water only.
4. Used by Indiana State Board of Health for the National Pollutant Discharge Elimination System Program (L. Bridges, Indiana State Board of Health, oral commun., October 6, 1980).
5. Based on 0.1 times the acute toxicity of copper (96-hour TL50) for Brown bullhead (Ictalurus nebulosus) in hard water (U.S. Environmental Protection Agency, 1976, p. 114).
6. Indiana Stream Pollution Control Board, 1977.
7. McKee and Wolf, 1963.
8. Based on 0.01 times the 96-hour LC50 for the fathead minnow (Pimephales promelas) or other species in hard water (U.S. Environmental Protection Agency, 1976).
9. National Academy of Sciences and National Academy of Engineering, 1972.

Physical Characteristics

Physical water-quality characteristics measured during the study were suspended sediment, turbidity, water temperature, and specific conductance. All measurements are within the range for natural waters in central Indiana. Data are presented in tables 3-5.

Turbidity and Suspended Sediment

Turbidity in streams generally results from suspended colloidal material. Highly turbid waters are aesthetically unpleasing and can reduce the intensity of sunlight reaching aquatic plants. The turbidity of samples collected from the White River (table 3) ranged from 11 to 28 NTU. The turbidities of water in Williams and Crooked Creeks (1.6 and 2.2 NTU, respectively) were significantly lower than those of water in the White River and Fall Creek. Oosten (1945), cited in McKee and Wolf (1963, p. 290-291) indicates that turbidities as high as 200 units are harmless to fish.

Suspended-sediment concentration of the White River ranged from 49 to 83 mg/L. Concentration was lowest (32 mg/L) in Williams Creek at 75th St. Suspended-sediment concentrations of streams are usually lowest in winter and during steady-state low flows when there is little overland runoff.

Water Temperature

Surface-water temperature varies daily and seasonally. Daily temperature is highest in late afternoon, and seasonal temperature is highest in summer. Man's activities usually raise water temperatures. High water temperatures lower the solubility of some gases, such as oxygen, sufficiently to kill some species of fish. Water temperature in the White River during the study period (tables 4 and 5) ranged from 22.5° C to 28.5° C. Water temperatures in stream reaches just upstream from dams were higher and more variable than water temperatures in free-flowing stream reaches (fig. 5).

Table 3.--Turbidity and suspended-sediment concentrations at sampling stations in the upper White River basin, Marion County, Ind., August 4-5, 1980

[Water-quality data collected and analyzed by U.S. Geological Survey]

Stream	River mile	Turbidity (Nephelometric turbidity units)	Suspended sediment (mg/L)
White River near Nora (82d St.)	247.87	22	76
White River at Ravenswood	245.37	11	77
White River at Westfield Blvd.	242.85	26	83
Williams Creek at 75th St.	242.58	1.6	32
White River at Kessler Blvd.	240.78	20	79
White River at 38th St.	236.66	22	82
Crooked Creek at mouth	236.22	2.2	--
White River at 30th St.	235.58	28	76
White River at 16th St.	233.86	19	56
Fall Creek at mouth	232.90	24	63
White River at Michigan St.	232.42	18	62
White River at Washington St. (US 40)	231.42	19	49

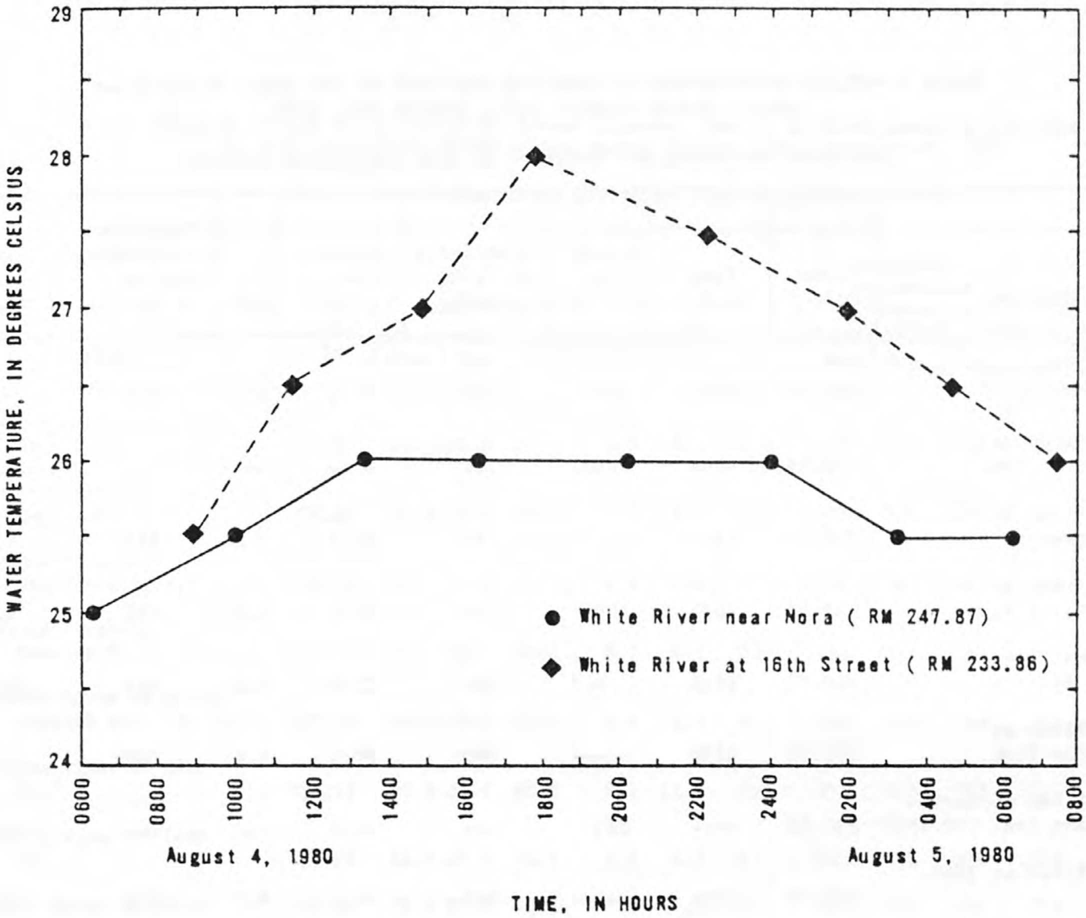

Figure 5.-- Relation of temperature to time.

Specific Conductance

Specific conductance is a measure of water's ability to conduct an electric current, and is, therefore, an indication, within wide limits, of the ionic strength of the solution (Brown and others, 1970, p. 148). The specific conductance of stream samples from the White River ranged from 579 to 736 µmho/cm at 25° C (tables 4 and 5). These specific-conductance values are well within the range of values reported for other Indiana streams draining areas with similar land use and glaciation. Specific-conductance values were generally higher at night than during the day because during respiration (which exceeds photosynthesis in darkness) carbon dioxide is released and reacts with the relatively insoluble monocarbonates of calcium and magnesium to form soluble bicarbonates. The disassociation of the calcium and magnesium bicarbonates results in an increase in dissolved solids and, therefore, specific conductance.

Table 4.--Field measurements at sampling stations in the upper White River basin, Marion County, Ind., August 4-5, 1980

[All data collected and analyzed by U.S. Geological Survey]

Station	River mile	Time[1] (e.s.t.)	Stream-flow (ft^3/s)	Alkalinity as $CaCO_3$ (mg/L)	Tempera-ture (°C)	pH	Specific conductance[2] μmho/cm at 25° C)	Dissolved oxygen (mg/L)
White River near Nora (82d St.)	247.87	0800	392	250	25.5	8.1	674	7.2
White River at Keystone Ave.	246.05	----	-----	---	----	---	---	----
White River at Ravenswood	245.37	1200	-----	240	26.0	7.6	682	7.6
White River at Westfield Blvd.	242.85	1030	194	240	27.0	8.3	656	8.4
Williams Creek at 75th St.	242.58	0930	4.3	260	22.5	8.2	682	10.3
White River at Kessler Blvd.	240.78	1230	-----	240	27.5	8.4	660	9.9
White River at North-western Ave. (US 421)	237.86	----	283	---	----	---	---	----
White River at 38th St.	236.66	1500	-----	240	26.0	8.0	656	8.6
Crooked Creek at mouth	236.22	1315	3.1	240	27.5	8.2	794	9.9
White River at 30th St.	235.58	1645	-----	230	26.5	7.9	640	10.0
White River at 16th St.	233.86	1840	-----	220	26.5	8.0	610	11.1
Fall Creek at mouth	232.90	1400	87	230	27.0	8.0	672	8.8
White River at Michigan St.	232.42	1330	-----	---	26.5	8.8	648	8.8
White River at Washington St.	231.42	0010	373	210	26.5	7.9	608	9.2

[1]For example, 1500 hours is 3:00 p.m.
[2]Values corrected to laboratory measurements.

Table 5.--Field measurements at 3-hour intervals for 24 hours at sampling stations in the upper White River basin, Marion County, Ind., August 4-5, 1980

[All data collected and analyzed by U.S. Geological Survey]

Station	River mile	Temperature (°C)			pH			Specific conductance[2] (µmho/cm at 25° C)			Dissolved oxygen (mg/L)		
		Mean	Max.	Min.	Med.	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.
White River near Nora (82d St.)	247.87	26.8	26.8	25.0	8.0	8.1	7.9	725	736	700	7.6	8.9	6.8
White River at Keystone Ave.	246.05	26.0	27.0	25.0	8.0	8.1	7.9	709	726	680	8.3	9.5	7.1
White River at Westfield Blvd.	242.85	26.5	27.0	26.0	8.2	8.4	8.1	684	713	662	8.3	9.2	7.4
White River at Kessler Blvd.	240.78	26.5	28.0	25.0	8.3	8.3	8.0	686	711	662	8.6	11.4	6.9
White River at North-western Ave. (US 421)	237.85	26.0	28.0	25.0	8.2	8.5	8.0	683	703	658	9.0	13.1	6.5
White River at 38th St.[3]	236.66	27.0	27.5	25.0	9.1	11.9	8.4	674	686	645	11.1	14.8	8.3
White River at 16th St.	233.86	26.5	28.0	25.5	8.2	8.6	7.7	623	658	579	11.0	14.0	8.3
Fall Creek at mouth	232.90	26.0	27.0	25.0	7.8	7.9	7.7	687	711	666	7.6	9.3	6.6
White River at Michigan St.	232.42	26.5	28.5	25.5	8.2	8.5	8.0	639	666	568	9.3	13.4	7.2
White River at Washington St.	231.42	26.5	28.5	26.5	9.2	8.5	8.1	610	640	545	12.1	19.0	8.0

[1]For example, 1500 hours is 3:00 p.m.
[2]Values corrected to laboratory measurements.

Chemical Characteristics

Chemical water-quality characteristics measured during the study were pH, major cations and anions, hardness, dissolved oxygen, biochemical-oxygen demand, organic carbon, nutrients, and metals in both the water column and on bottom material. Data are presented in tables 6-12.

pH

The pH of a solution refers to its hydrogen-ion activity and can range from 0, very acidic, to 14, very alkaline. The pH of most natural waters is in the range from 6.0 to 8.5 (Hem, 1970, p. 93). Where photosynthesis by aquatic organisms takes up dissolved carbon dioxide during the daylight hours, pH may fluctuate diurnally, and the maximum pH value may sometimes reach as high as 9.0 (Hem, 1970, p. 93). The pH of the White River during the study ranged from 7.6 to 11.9 (tables 4 and 5). Larger fluctuations in pH (fig. 6) were observed during the study upstream from dams than in free-flowing reaches, probably because of photosynthetic activity.

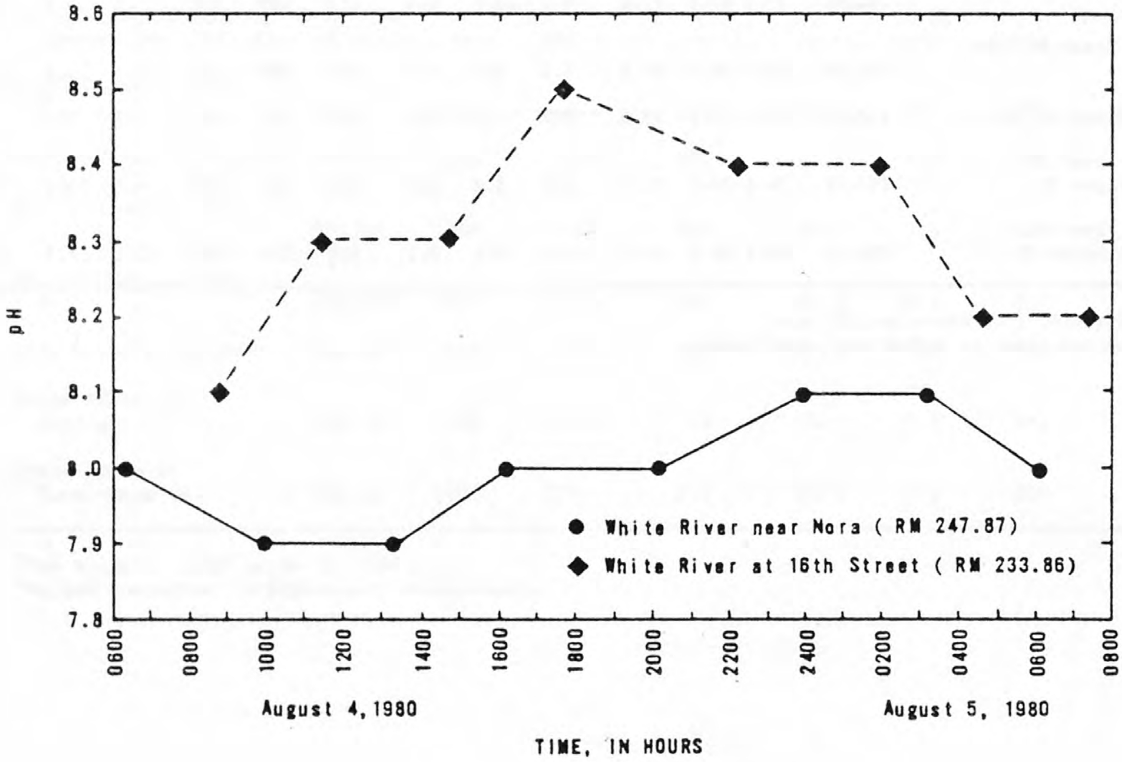

Figure 6.-- Relation of pH to time.

Major Cations and Anions

The cations calcium, magnesium, sodium, and potassium, and the anions chloride, fluoride, sulfate, and bicarbonate are the ions generally having the highest concentration in water. Concentrations of most of these ions in samples collected from the upper White River basin are presented in table 6.

Stream waters can be classified by water type, depending on the major cations and anions in solution. The water type of streams not significantly affected by pollution is dependent on the mineralogical makeup of the surficial and bedrock materials drained. The water type of streams can be significantly affected by waste loads. For example, the high sodium chloride concentrations of untreated sewage and runoff from salted highways can change the water type of a stream.

The major cation-anion distribution of water samples collected in the study area are represented by Stiff (1951) patterns (fig. 7). The water type of these samples, calcium bicarbonate, is typical of surface water and ground water in central Indiana unaffected by man's activities. This water type is due to the calcium carbonate (calcite) in the glacial material of the drainage basin.

Table 6.--Concentrations of major ions and hardness of water in the upper White River basin, Marion County, Ind., August 4-5, 1980

[All concentrations reported in milligrams per liter ; water-quality data collected and analyzed by the U.S. Geological Survey]

Station	River mile	Calcium	Magnesium	Sodium	Potassium	Chloride	Fluoride	Sulfate	Hardness noncarbonate	Hardness as $CaCO_3$
White River near Nora	247.87	79	26	25	3.2	40	0.4	56	54	300
White River near Kessler Blvd.	240.78	76	25	23	3.1	39	.3	54	53	290
White River at 30th St.	235.58	72	24	22	3.0	38	.3	51	49	280
Fall Creek at mouth	232.90	71	25	24	2.9	46	.3	54	50	280
White River at Washington St. (US 40)	231.42	67	23	21	3.0	38	.3	51	52	260

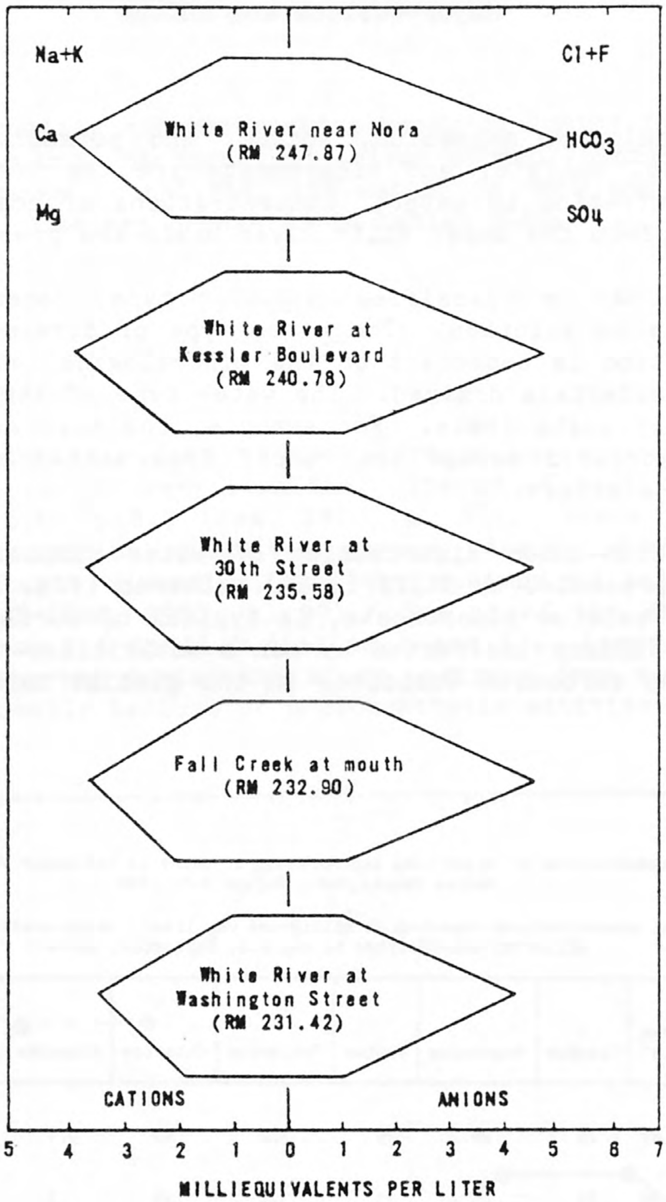

Figure 7.-- Stiff (1951) patterns representing analyses of water samples collected on August 4-5, 1980.

Hardness

Hardness of water in the study area is directly related to the concentration of dissolved cations and anions in the water. Hardness of water samples from the White River (table 6) ranged from 260 to 300 mg/L as $CaCO_3$. These concentrations represent very hard water (Hem, 1970, p. 225). Hardness is important because of its effect on domestic water supplies. The toxicity of trace metals to freshwater aquatic life is generally lower in hard water than in soft water.

Dissolved Oxygen

Dissolved oxygen, the most important parameter in a natural water body, is essential to all biota that respire aerobically. Fish and other desirable clean-water organisms require high dissolved-oxygen concentration to survive and propagate. Indiana water-quality standards require an average of at least 5.0 mg/L per calendar day and a minimum concentration of 4.0 mg/L at any time. This standard was established to ensure conditions for the maintenance of a well-balanced warm-water fish community.

The dissolved-oxygen concentration of flowing water is highly variable because of the changing nature of factors affecting it. Oxygen in rivers is consumed by bacterial decomposition of suspended and dissolved organic matter, deposits of sludge or other organic matter, oxidation of ammonia by nitrifying bacteria (nitrification), and the respiration of aquatic organisms. Oxygen is replenished in natural waters primarily by diffusion of oxygen into the water from the atmosphere and, in some instances, photosynthesis. Atmospheric diffusion cannot result in dissolved-oxygen concentrations greater than the saturation value (the concentration of oxygen in the water that is in equilibrium with the oxygen concentration in the atmosphere). Oxygen solubility in water is a function of temperature and atmospheric pressure. At 10° C, water is saturated with oxygen when it contains about 11.3 mg/L. At 30° C, water is saturated with oxygen when it contains only about 7.6 mg/L.

During summer months, when streamflow is low and water temperature is high, the dissolved-oxygen concentration of a stream can be depleted by high organic loadings. Such loadings are common when combined sewers overflow after intense summer rainstorms. A fish kill in the White River downstream from Washington Street was observed by the Indiana State Board of Health in August 1974 after a rainstorm. The dissolved-oxygen concentration of this stream reach was only 3.5 mg/L at the time of the fish kill (Steve Boswell, Indiana State Board of Health, written commun., 1980).

Oxygen can also be added to water by algal photosynthesis. Algae, like other green plants, consume carbon dioxide and release oxygen in sunlight. In some favorable river environments, this oxygen production can raise dissolved-oxygen concentrations much higher than the saturation value. Likely places for this condition are slow-moving rivers with an adequate nutrient supply during summer. During such periods, algae can become a larger contributor of oxygen to the river than atmospheric diffusion. At night, in the absence of light, algae, like other aquatic organisms, consume oxygen. Where algal photosynthesis has resulted in supersaturated oxygen concentrations, oxygen diffuses from the water until it is again in equilibrium with the atmosphere. Because of the net oxygen production during the day, and losses to respiration and diffusion at night, the diurnal pattern is high dissolved-oxygen concentrations during the day and low concentrations during the night. This pattern is characteristic of waters with high algal productivity.

Dissolved-oxygen concentration of the White River was measured approximately every 3 hours for a 24-hour period (table 5). Average dissolved-oxygen concentration for the 24-hour period ranged from 7.6 mg/L (95-percent saturation) near Nora (RM 242.87) to 12.1 mg/L (154-percent saturation) at Washington Street (RM 231.42). The minimum dissolved-oxygen concentration observed was 6.5 mg/L (81-percent saturation) at 0700 hours at Northwestern Avenue (RM 237.85). The dissolved-oxygen concentration was generally lowest in the early morning hours at all sampling sites. This condition is due to the cumulative effect of nighttime respiration. At all sampling stations the stream was supersaturated with oxygen during the peak daylight hours, which indicates that photosynthetic activity was significant during the survey. Dissolved-oxygen concentration was highest (19 mg/L or 250-percent saturation) at Washington Street (RM 231.42) at 1830 hours. In general, the dissolved-oxygen concentration was highest in the reaches slowed by small dams, where conditions were favorable for large algal populations and diffusion of oxygen from the water into the atmosphere was low. The diurnal patterns of dissolved-oxygen concentration for a deep, slow, impounded station (Washington Street) and a shallow, free-flowing station (Westfield Boulevard) are presented in figure 8. The diurnal fluctuation at Westfield Boulevard was much lower than that at Washington Street because of higher atmospheric diffusion even though algal populations were similar.

Although dissolved-oxygen concentrations less than 4.0 mg/L were not observed during this study, Shampine (1975) reported that dissolved-oxygen concentrations in the White River at Indianapolis fell below the 4.0 mg/L minimum at least once per year from 1925 to 1972.

Biochemical-Oxygen Demand and Organic Carbon

Biochemical-oxygen demand (BOD) and dissolved and suspended-organic carbon were used in this study to estimate the quantity of organic matter in the

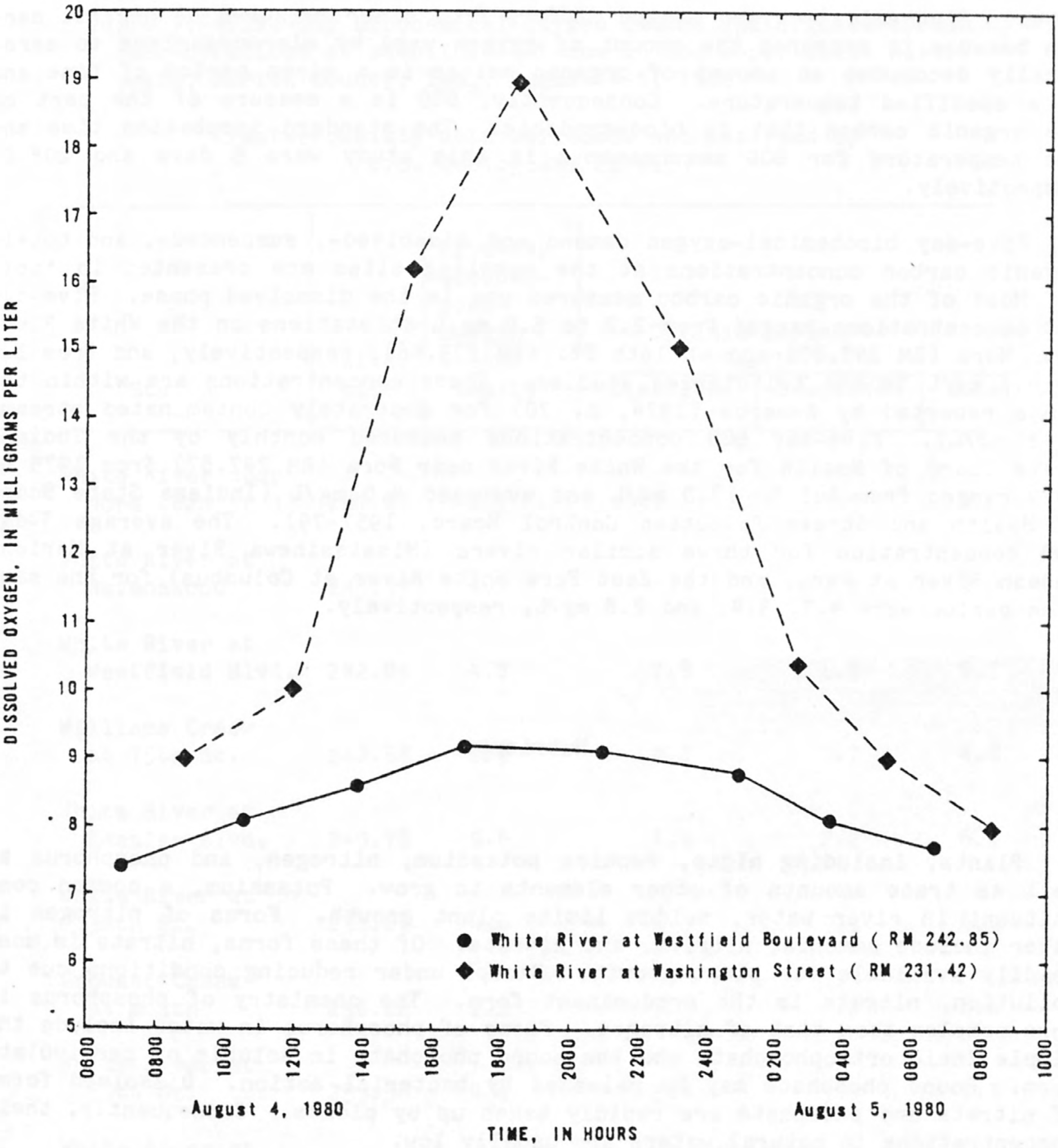

Figure 8.-- Relation of dissolved-oxygen concentration to time.

water. Biochemical-oxygen demand differs from other measures of organic carbon because it measures the amount of oxygen used by microorganisms to aerobically decompose an amount of organic matter in a given period of time and at a specified temperature. Consequently, BOD is a measure of the part of the organic carbon that is biodegradable. The standard incubation time and the temperature for BOD measurements in this study were 5 days and 20° C, respectively.

Five-day biochemical-oxygen demand and dissolved-, suspended-, and total-organic carbon concentrations at the sampling sites are presented in table 7. Most of the organic carbon measured was in the dissolved phase. Five-day BOD concentrations ranged from 2.2 to 5.0 mg/L at stations on the White River near Nora (RM 247.87) and at 16th St. (RM 233.86), respectively, and from 1.9 to 4.1 mg/L in the tributaries studied. These concentrations are within the range reported by Nemerow (1974, p. 70) for moderately contaminated streams (1-8 mg/L). Five-day BOD concentrations measured monthly by the Indiana State Board of Health for the White River near Nora (RM 247.87) from 1975 to 1979 ranged from 1.1 to 18.0 mg/L and averaged 4.0 mg/L (Indiana State Board of Health and Stream Pollution Control Board, 1957-79). The average 5-day BOD concentration for three similar rivers (Mississinewa River at Marion, Wabash River at Peru, and the East Fork White River at Columbus) for the same time period were 4.7, 3.4, and 2.8 mg/L, respectively.

Nutrients

Plants, including algae, require potassium, nitrogen, and phosphorus as well as trace amounts of other elements to grow. Potassium, a common constituent in river water, seldom limits plant growth. Forms of nitrogen in water include ammonia, nitrite, and nitrate. Of these forms, nitrate is most readily available for plant growth. Except under reducing conditions due to pollution, nitrate is the predominant form. The chemistry of phosphorus is more complex than that of nitrogen. Forms of phosphorus in water include the simple ionic orthophosphate and the bound phosphate in soluble or particulate form. Bound phosphate may be released by bacterial action. Dissolved forms of nitrate and phosphate are rapidly taken up by plants. Consequently, their concentrations in natural waters are usually low.

Nutrient enrichment may encourage blooms of nuisance algae. Such blooms are common in lakes (Wetzel, 1975, p. 659) but are seldom seen in rivers. The effect of nutrient enrichment from agricultural practices or sewage seems to be canceled by stream turbidities from soil erosion or suspended-sediment concentrations of effluents (Hynes, 1970, p. 446).

Two major sources of nitrogen and phosphorus in the White River are fertilizers and municipal sewage (Shampine, 1975). Dissolved nitrate was the predominant form of nitrogen determined in samples from the White River during the survey on August 4-5, 1980 (table 8). Nitrate accounted for 90 percent or more of the total nitrogen in all samples collected from the White

Table 7.--Five-day biochemical-oxygen demand and organic carbon concentrations at sampling stations in the upper White River basin, Marion County, Ind., August 4-5, 1980

[Water-quality data collected and Analyzed by U.S. Geological Survey]

Station	River mile	Five-day biochemical-oxygen demand (mg/L)	Organic carbon (mg/L) Dissolved	Suspended	Total
White River near Nora (82d St.)	247.87	2.2	13	1.5	14
White River at Ravenswood	245.37	4.2	6.3	1.6	7.9
White River at Westfield Blvd.	242.85	4.2	7.8	1.9	9.7
Williams Creek at 75th St.	242.58	1.9	4.1	.7	4.8
White River at Kessler Blvd.	240.78	3.8	4.7	2.2	6.9
White River at 38th St.	236.66	4.6	4.6	2.3	6.9
Crooked Creek at mouth	236.22	2.1	5.7	.9	6.6
White River at 30th St.	235.58	4.6	5.9	3.4	9.3
White River at 16th St.	233.86	5.0	4.0	2.7	6.7
Fall Creek at mouth	232.90	4.1	5.1	2.5	7.6
White River at Michigan St.	232.42	6.4	4.7	3.2	7.9
White River at Washington St. (US 40)	231.42	4.5	6.9	2.4	9.3

Table 8.--Nutrient concentrations at sampling stations in the upper White River basin, Marion County, Ind., August 4-5, 1980

[Water-quality data collected and analyzed by the U.S. Geological Survey]

Station	River mile	Ortho-phosphate phosphorus, total (mg/L)	Ortho-phosphate phosphorus, dissolved (mg/L)	Ammonia nitrogen, total (mg/L)	Ammonia nitrogen, dissolved (mg/L)	Nitrate nitrogen, total (mg/L)	Nitrate nitrogen, dissolved (mg/L)	Nitrite nitrogen, total (mg/L)	Nitrite nitrogen, dissolved (mg/L)
White River near Nora (82d St.)	247.87	0.19	0.12	0.10	0.04	2.5	2.5	0.05	0.03
White River at Ravenswood	245.37	.13	.08	.16	.01	2.4	2.4	.03	.03
White River at Westfield Blvd.	242.85	.10	.06	.20	.02	2.3	2.3	.02	.02
Williams Creek at 75th St.	242.58	0	0	.06	.04	.38	.51	.01	.01
White River at Kessler Blvd.	240.78	.09	.06	.16	.01	2.2	2.2	.02	.02
White River at 38th St.	236.66	.08	.05	.19	.02	2.2	2.2	.02	.02
Crooked Creek at mouth	236.22	.02	0	.09	.03	.18	.16	.01	.01
White River at 30th St.	235.58	.07	.04	.16	.03	2.1	2.1	.02	.02
White River at 16th St.	233.86	.07	.02	.24	.03	2.1	2.1	.03	.03
Fall Creek at mouth	232.90	.05	.02	.23	.07	1.5	1.5	.05	.04
White River at Michigan St.	232.42	.06	.01	.27	.01	1.7	1.7	.04	.04
White River at Washington St. (US 40)	231.42	.06	0	.17	.03	1.8	1.8	.05	.04

River basin. The concentration of nitrate (as nitrogen) ranged from 1.7 to 2.5 mg/L. Concentration of nitrate decreased with distance downstream, probably because of algal uptake.

The concentrations of both nitrite and ammonia in stream samples from the White River were low compared to the concentration of nitrate. The concentration of ammonia in all samples was less than the recommended water-quality limit in table 2. Both of these forms of nitrogen are converted to nitrate by biological processes and are rarely found in natural waters in high concentrations except in the vicinity of municipal or industrial effluents.

Concentration of nitrite plus nitrate (as nitrogen) of samples collected by the Indiana State Board of Health from the White River near Nora (RM 247.87) from 1975 to 1979 ranged from 0.7 to 6.0 mg/L and averaged 2.8 mg/L. Average concentrations of nitrite plus nitrate (as nitrogen) were 2.5 mg/L for the Mississinewa River at Marion, 3.0 mg/L for the Wabash River at Peru, and 2.9 mg/L for East Fork White River at Seymour.

Total orthophosphate concentrations of samples from the White River ranged from 0.06 to 0.19 mg/L at Michigan St. (RM 232.42) and near Nora (RM 247.87), respectively. Concentrations of dissolved orthophosphate ranged from less than the detection limit at Washington St.(RM 231.42) to 0.12 mg/L near Nora (RM 247.87). This downstream decrease was probably due to algal activity because dissolved orthophosphate is readily available to aquatic plants.

Metals and Trace Elements

Metals and other trace elements may enter receiving water from a variety of sources. Rocks and soils directly exposed to surface water and ground water are usually the largest natural source. Dead and decomposing vegetation and animal matter also contribute small amounts of the constituents to the environment. High concentrations of some metals have been observed in both dry and wet atmospheric precipitation (Lazrus and others, 1970). Many of these metals were associated with the combustion of fossil fuels and the processing of metals.

Urban stormwater runoff has also been shown to contain significant concentrations of lead, zinc, copper, and other metals (Wilber and Hunter, 1975). Sources of these metals are probably automotive exhaust, precipitation, and other local activities in the watershed. Other man-induced sources of metals to streams include domestic wastewaters, industrial plating wastes, paints, biocides, and fertilizers.

Concern about the contamination of receiving waters by metals has increased during the last several years. Many metals, such as cadmium, copper, lead, and mercury, can be toxic to aquatic organisms when present in critical concentrations. These constituents are nondegradable and persist in the environment for extended periods of time. In addition, metals may precipitate out of solutions of near neutral pH and of slight alkalinity and may be adsorbed on clay particles or other materials. As a result, metals are concentrated in the solid phases of aquatic systems. Even though the water may contain only small amounts of these constituents, the particulate matter in the water and especially the benthic or bottom materials may contain considerable quantities of them.

Because metals are nondegradable, their concentrations may be magnified in the food chain. Concentrations of metals in the upper trophic levels may be orders of magnitude greater than those originally in the water.

The total concentrations of selected metals (dissolved plus suspended phases) in water samples from the White River are presented in table 9. Water-quality limits recommended by the Indiana State Board of Health (1977), the U.S. Environmental Protection Agency (1976), McKee and Wolf (1963), and National Academy of Sciences and National Academy of Engineering (1972) for these metals are presented in table 2. The limits are generally based on the toxicity of the metals to sensitive fresh-water aquatic organisms. The toxicity of metal concentrations to aquatic life is dependent on several factors, which include the species considered, water temperature, hardness, and

Table 9.--Total-metal concentrations at sampling stations in the upper White River basin, Marion County, Ind., August 4-5, 1980

[Water-quality data collected by the U.S. Geological Survey; all concentrations in micrograms per liter]

Station	River mile	Cadmium	Chromium	Copper	Iron	Lead	Manganese	Mercury	Nickel	Zinc
White River near Nora (82d St.)	247.87	1	10	5	1,400	9	100	<0.1	12	20
White River at Kessler Blvd.	240.78	<1	20	5	1,460	6	110	<.1	9	20
White River at 30th St.	235.58	<1	10	5	1,400	6	110	<.1	8	20
Fall Creek at mouth	232.90	<1	10	4	880	5	120	<.1	5	30
White River at Washington St. (US 40)	231.42	<1	10	5	930	6	100	<.1	6	10

pH. As a result, a single metal concentration is not applicable as a limit for all species and environmental conditions. Water-quality standards for some metals, such as copper, lead, nickel, and zinc, are based on the concentration that is lethal to 50 percent of a population of sensitive resident organisms during a 96- hour test (96-hour LC50) of the receiving water or water of similar chemistry. Data for 96-hour LC50 concentrations of copper, lead, nickel and zinc were not available for Indiana streams. Toxicant concentrations for the 96- hour median tolerance limit (96-hour TL50), the concentration of a test material of which just 50 percent of the test animals are able to survive, were estimated from published data (U.S. Environmental Protection Agency, 1976). The 96-hour TL50 values should be approximately equal to the 96-hour LC50 values. The limits reported here were obtained by multiplying the 96-hour TL50 for fathead minnows, bluegills, brown bullheads, and unnamed fish species by a safety factor of 0.01 for lead, nickel, mercury, and zinc and by 0.1 for copper (U.S. Environmental Protection Agency, 1976).

As is common for Indiana streams, total iron and manganese concentrations of water samples from the White River exceeded public and domestic water supply standards. However, concentrations of all the metals studied were less than concentrations considered by the U.S. Environmental Protection Agency (1976) to be toxic to aquatic life.

Bottom materials.--There are several reasons why bottom materials are a good sampling medium for an assessment of metals and organic compounds in streams. First, concentrations of many of these materials in water are usually low. Secondly, nonpoint-source contributions of metals and organic compounds (such as stormwater runoff) may be intermittent or storm related. As a result, single or periodic water samples may not detect these materials. Because many of the bottom materials associate strongly with particulates, these materials can act as accumulators during periods of low velocity when the streambed is not being scoured. During these periods, the stream bottom acts as a depository for incoming sediment. This sediment, as well as the bottom materials already in place, can accumulate dissolved metals and organic compounds from the water column. Thus, bottom materials provide an opportunity to obtain information on the distribution of the metals and the organic compounds over an extended period of time. The concentration of metals and organic compounds in samples of bottom materials collected from the White River are presented in tables 10 and 11.

Although the concentration of metals in the bottom materials is variable, a significant enrichment of several of the metals is evident in the bottom materials from the White River at Washington Street (RM 231.42) when the concentrations of metals at the three sites are compared. The average enrichment factors for several metals in the bottom materials at Washington Street, compared with concentrations at two other sites, are: chromium (3.0), copper (9.6), lead (5.5), mercury (5.3), and zinc (1.7). Cadmium, iron, manganese, and nickel showed no significant enrichment in the bottom materials. The source(s) of chromium, copper, lead, mercury, and zinc in the White River can not be determined precisely from the samples of bottom materials. However, except for mercury, these metals have been found in significant concentrations in urban stormwater runoff (Wilber and Hunter, 1975). Therefore, stormwater is probably their most likely source.

Table 10.--Quantities of metals adsorbed on the <0.062-mm fraction of bottom materials at sampling stations in the upper White River, Marion County, Ind., August 4-5, 1980

[All concentrations reported in micrograms per gram; data collected and analyzed by the U.S. Geological Survey]

Station	River mile	Cadmium	Chromium	Copper	Iron	Lead	Manganese	Mercury	Nickel	Zinc
White River at Nora (82d St.)	247.87	<10	10	50	19,000	70	620	0.31	70	160
White River at 30th St.	235.58	<10	<10	40	18,000	80	550	.33	60	140
White River at Washington St. (US 40)	231.42	<10	30	430	20,000	410	490	1.7	70	260

Table 11.--Quantities of pesticide residues and chlorinated hydrocarbons adsorbed on bottom materials from the Upper White River at Washington Street, Marion County, Ind., August 4-5, 1980

[All concentrations reported in micrograms per kilogram; data collected and analyzed by the U.S. Geological Survey; ND, not detected]

Constituents	Quantity
Aldrin	ND
Chlordane	8.6
DDD	1.6
DDE	ND
DDT	ND
Dieldrin	ND
Endosulfin I	ND
Endrin	ND
Heptachlor	ND
Heptachlor epoxide	ND
Lindane	ND
Mirex	ND
Methoxychlor	ND
Total PCB (polychlorinated biphenyl)	50
Total PCN (polychlorinated naphthalene)	ND
Perthane	ND
Toxaphene	ND

Quantities of selected metals adsorbed on unsieved bottom-material samples from the White River were determined by the Indianapolis and Marion County Health Department, August 1979, and are presented in table 12. Quantities of cadmium and chromium are generally in good agreement with the quantities of those metals reported for this study (table 10), but quantities of copper, lead, nickel, and zinc reported by the Indianapolis and Marion County Health Department are less than those reported in table 10.

Table 12.--Metal concentrations of bottom materials at sampling stations in the upper White River basin, Marion County, Ind., August 17, 1979

[All concentrations reported in micrograms per gram; data collected and analyzed by the Indianapolis and Marion County Health Department]

Station	River mile	Cadmium	Chromium	Copper	Lead	Nickel	Zinc
White River at 82d St.	247.87	<10	20	13	17	17	63
White River at College Ave.	242.40	<10	22	12	34	13	55
White River at 30th St.	235.58	<10	20	16	30	22	66
White River at Washington St.	231.42	<10	30	19	60	30	86
White River at Harding St.	227.86	<10	25	20	63	25	100
White River at I-465	224.37	<10	37	24	76	24	160
White River at Southport Rd.	221.72	<10	40	16	51	16	150

Quantities of the three pesticides and chlorinated hydrocarbons detected on bottom materials from the White River at Washington Street (RM 231.42) were: chlordane, 8.6 μg/kg; DDD, 1.6 μg/kg; and PCB (polychlorinated biphenyls), 50 μg/kg. These quantities of chlordane and DDD were lower than those reported by Shampine (1975, p. 34) for bottom materials in the White River at Waverly, Ind., downstream from the study reach. However, the quantities of PCB's on bottom materials at the Washington Street sampling station were 2.5 times the quantity at Waverly. Chlordane, an insecticide commonly used for control of ants, termites, and grasshoppers, is commonly found on bottom materials of streams draining both urban and rural areas. DDD is a degredation product of DDT, whose use was banned in 1972. PCB's were in wide use before 1971 as industrial cooling fluids and as insecticide carriers. Their sale and use were banned in 1977. PCB's are nondegradable and may persist in the environment for long periods of time.

Although the data indicate that some metals are accumulating on bottom materials of the upper White River, the availability of these sediment-bound constituents to aquatic organisms, the water column, and possibly man remains unknown.

Before the ecological effect of pesticides and related organic compounds could be determined, additional information would be needed: (1) the physiological and ecological characteristics of the organisms present and (2) the chemical forms of the sorbed metals.

Biological Characteristics

Phytoplankton

Phytoplankton, the algal or plant part of the plankton, are an assemblage of microscopic organisms that drift passively with the currents of rivers and lakes. The species composition and abundance of phytoplankton are significantly affected by water quality. As a result, for water-quality assessments, phytoplankton are good indicators of general water quality.

Phytoplankton populations can directly affect the pH, dissolved-oxygen concentration, concentrations of certain inorganic constituents (particularly nutrients), turbidity, and color of surface water. They become problems in domestic water supplies when their concentrations reach nuisance levels. Some of the problems caused by nuisance organisms are taste, odor, clogging of sand filters, and production of toxin. Toxin production is most often associated with a small group of blue-green algae that were not observed in any of the samples collected during this study.

There are no applicable water-quality standards for phytoplankton in water used for recreation. However, aesthetic considerations by users may limit recreational use when algal blooms are present. In addition to imparting turbidity and color, algal blooms have been known to impart grassy, moldy, or fish odors to water (Palmer, 1962). Also, many species of phytoplankton grow in colonies that can form large floating mats that can cover boats, beach areas, or swimmers.

High phytoplankton concentrations in the White River have been reported by Coffing (1937), Denham (1938), Brinley (1942), Hupp (1943), Lackey and Hupp (1956), Shampine (1975), and the Indiana State Board of Health and Stream Pollution Control Board (1957-79). Cell concentrations reported in these studies during late summer ranged from 3,000 to over 100,000 cells/mL. According to Lackey and Hupp (1956), 500 cells/mL is a high cell concentration.

Data collected during the study (table 13) represent summer conditions--low flow, high temperature, and probably maximum cell concentration. Cell concentration during the study ranged from 40,000 to 80,000 cells/mL (fig. 9). Most of the 81 species that were identified are diatoms (48 species) and green algae (24 species). Many of the species identified in the White River were listed by Palmer (1969) as being tolerant of organic wastes.

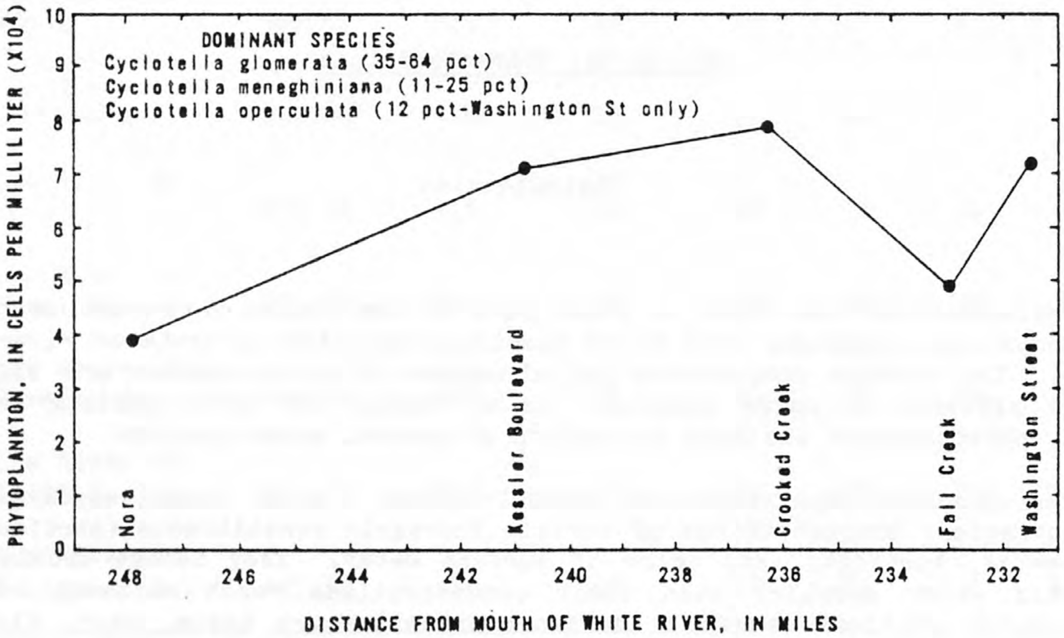

Figure 9.-- Relation of phytoplankton concentration to distance, August 4-5, 1980.

Table 13.--Phytoplankton genera, species, and densities at sampling stations in the upper White River basin, Marion County, Ind., August 4-5, 1980

[Phytoplankton density in cells per milliliter]

Phytoplankton genera and specie	White River near Nora (RM 247.87)	White River at Kessler Blvd. (RM 240.78)	White River at 30th St. (RM 235.58)	Fall Creek at mouth (RM 232.90)	White River at Washington St. (RM 231.42)
Bacillariophyta (Diatoms)					
Achnanthes affinis	272	------	------	------	------
A. lanceolata	151	------	365	------	------
A. linearis	151	607	365	------	------
A. linearis f. curta	272	------	511	------	557
A. microcephala	------	607	------	------	------
A. minutissima	272	607	------	------	------
Amphora perpusilla	574	304	656	------	------
A. submontana	------	304	------	------	------
Asterionella formosa v. gracillima	------	607	------	------	------
Cocconeis placentula	151	304	------	170	------
Cyclotella comta	------	304	------	------	------
C. glomerata	13,692	25,864	51,704	18,053	29,469
Cyclotella kutzingiana v. planetophora	272	911	365	681	248
C. meneghiniana	5,562	17,850	12,908	5,552	15,292
C. operculata	1,421	1,214	1,677	1,533	8,482
C. pseudostelligeria	151	------	------	1,022	2,724
C. stelligera	423	607	656	1,192	1,362
Cymbella minuta v. silesiaca	272	------	------	------	------
C. sinuata v. antiqua	------	------	------	170	------
Diatoma tenue v. elongatum	------	------	365	------	------
Fragilaria pinnata	------	304	365	------	------
Gomphonema angustatum	423	------	------	------	------
G. olivaceum	------	304	------	------	------
G. parvulum	------	------	------	------	248
Melosira granulata	------	------	------	681	248

Table 13.--Phytoplankton genera, species, and densities at sampling stations in the upper White River basin, Marion County, Ind., August 4-5, 1980--Continued

Phytoplankton genera and specie	White River near Nora (RM 247.87)	White River at Kessler Blvd. (RM 240.78)	White River at 30th St. (RM 235.58)	Fall Creek at mouth (RM 232.90)	White River at Washington St. (RM 231.42)
Bacillariophyta (Diatoms)--Continued					
Melosira granulata v. angustissima	151	1,761	656	511	1,114
Navicula cryptocephala	725	911	365	-----	-----
N. graciloides	725	304	---	-----	-----
N. minima	-----	607	656	-----	-----
Navicula mutica v. tropica	-----	607	---	-----	-----
N. pupula	-----	-----	---	170	-----
N. rhyncocephala	151	-----	---	-----	-----
N. viridula	-----	-----	---	170	-----
Navicula viridula v. avenacea	-----	607	---	-----	-----
Nitschia acicularis	423	-----	---	-----	248
N. amphibia	151	304	---	-----	-----
N. capitellata	272	-----	---	-----	-----
Nitzchia communis v. abbreviata	151	304	---	-----	-----
N. commutata	-----	911	---	-----	248
N. dissipata	725	607	---	170	-----
N. palea	2,267	1,214	365	3,031	1,610
N. tryblionella	-----	304	---	-----	-----
Stephanodiscus astraea v. minutula	151	-----	365	-----	-----
Surirella ovata	151	607	365	-----	-----
Synedra delicatissima	-----	-----	---	170	-----
Synedra filiformis v. exilis	151	1,214	365	341	-----
S. radians	-----	-----	365	-----	-----
S. ulna	-----	-----	365	-----	-----

Table 13.--Phytoplankton genera, species, and densities at sampling stations in the upper White River basin, Marion County, Ind., August 4-5, 1980--Continued

Phytoplankton genera and specie	White River near Nora (RM 247.87)	White River at Kessler Blvd. (RM 240.78)	White River at 30th St. (RM 235.58)	Fall Creek at mouth (RM 232.90)	White River at Washington St. (RM 231.42)
Cyanophyta (Blue-green algae)					
Chroococcus dispersus v. *minor*	1,133	341	737	1,252	-----
Dactylococcopsis Smithii	945	-----	---	-----	-----
Microcystis incerta	-----	-----	---	250	354
Oscillatoria sp.	-----	887	331	1,202	708
Chlorophyta (Green algae)					
Actinastrum Hantzschii	-----	-----	368	-----	-----
Ankistrodesmus convolutus	-----	-----	-----	751	-----
A. falcatus	945	682	737	2,254	1,769
Chlorella sp.	-----	-----	-----	-----	1,061
Closterium acutum v. *variabile*	-----	341	-----	-----	-----
Closterium sp.	189	-----	-----	250	-----
Coelastrum cambricum	-----	341	-----	1,002	354
Crucigenia quadrata	-----	-----	368	751	-----
Dictyosphaerium pulchellum	-----	-----	-----	250	-----
Elakatothrix gelatinosa	-----	-----	368	-----	-----
Golenkinia radiata	189	-----	-----	-----	-----
Kirchneriella lunaris v. *irregularis*	3,212	1,705	-----	1,002	1,061
K. obesa	-----	-----	-----	501	-----
K. subsolitaria	-----	-----	-----	501	-----
Lagerheimia quadriseta	-----	-----	-----	751	-----
Lagerheimia sp.	-----	-----	-----	250	-----
Oocystis borgei	-----	341	737	1,252	354
Oocystis sp.	-----	-----	-----	-----	354
Quadriqula Chodatii	-----	-----	-----	250	-----
Scenedesmus dimorphus	-----	341	-----	-----	-----
S. quadricauda	567	341	737	250	354

Table 13.--Phytoplankton genera, species, and densities at sampling stations in the upper White River basin, Marion County, Ind., August 4-5, 1980--Continued

Phytoplankton genera and specie	White River near Nora (RM 247.87)	White River at Kessler Blvd. (RM 240.78)	White River at 30th St. (RM 235.58)	Fall Creek at mouth (RM 232.90)	White River at Washington St. (RM 231.42)
Chlorophyta (Green algae)--Continued					
Scenedesmus sp.	-----	341	-----	1,503	-----
Schroederia setigera	-----	-----	-----	250	-----
colonial green alga	-----	-----	368	-----	-----
Cryptophyta (Protozoan-like)					
Cryptomonas sp.	378	2,388	2,946	501	1,415
Cryptophyte sp.	945	1,364	------	250	1,769
Euglenophyta (Euglenoids)					
Phacus sp.	------	341	------	-------	------
Trachelomonas sp.	------	------	------	250	------
Others					
unidentified phytoflagellates	189	682	------	250	708
Total number of cells (cells/mL)	38,945	71,396	80,990	49,851	72,111
Diversity index	3.71	3.51	2.14	3.98	2.94
Number of species	38	43	29	39	25

Several species of _Euglena_ and of blue-green algae are listed by Palmer (1969) as being common in streams with severe organic wastes. None of these organisms were identified during the study, but some of these species were identified as dominant organisms in studies by Brinley (1942) and Lackey and Hupp (1956). Several species of the diatom _Cyclotella_ were dominant in the White River during the study period. This observation agrees with the data reported by Shampine (1975, p. 39) and the Indiana State Board of Health and Stream Pollution Control Board (1957-79). Many of the _Cyclotella_ species are indicators of waters enriched with organic wastes, but do not indicate the severe waste problem indicated by species of _Euglena_ and some of the blue-green algae.

Diversity indices for phytoplankton, calculated with an equation by Shannon (Wilhm and Dorris, 1968), are presented in figure 10. The range of indices from 2.14 to 3.98, indicates diverse to very diverse phytoplankton communities. Diversities less than 1 indicate large concentrations of only a few species and usually also indicate organic pollution. As the effect due to organic wastes decreases, the diversity index generally increases. In the other studies of the White River (listed in the second paragraph of page 34) diversities were not computed, but extensive lists of algal species were reported. These lists indicate that diverse communities of phytoplankton have been common in the White River.

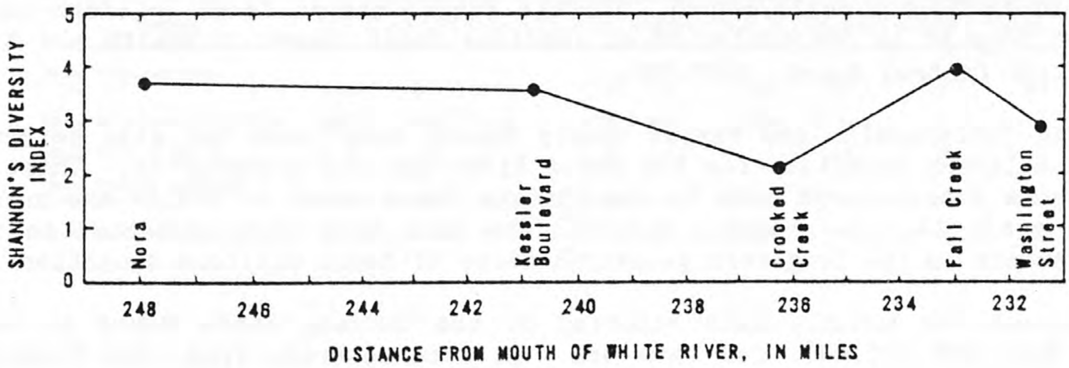

Figure 10.-- Relation of phytoplankton diversity to distance, August 4-5, 1980.

In summary, phytoplankton species and concentrations in the White River are indicative of streams affected by moderate amounts of organic wastes. High organic waste loadings were not observed during the study, and the river is probably less affected by organic wastes today than it was during the 1940's and 1950's.

Fecal Coliform and Fecal Streptococci

The coliform group of bacteria are normal inhabitants of the large intestine of man and animals and have been used in water-quality assessments as indicators of fecal wastes. Recently, because some coliform bacteria can originate from nonfecal sources, an elevated temperature test was standardized to distinguish fecal coliform bacteria from those of other environmental sources. (See Greeson and others, 1977.) Fecal streptococci, a group of bacteria that are also normal inhabitants of the large intestines of warm-blooded animals are used in conjunction with fecal coliform counts to distinguish between wastes of human and animal origin.

The criterion for maintaining partial body contact recreation in stream waters outside the mixing zone of wastewaters is that the fecal coliform bacteria density shall not exceed 1,000 cells/mL as a geometric mean based on not less than 5 samples per month; nor shall it exceed 2,000 cells/mL in more than one sample. The U.S. Environmental Protection Agency is unclear about the rationale for this standard, but some publications (U.S. Environmental Protection Agency, 1976, p. 79; National Academy of Sciences and National Academy of Engineering, 1972, p. 57; and McKee and Wolf, 1963, p. 308) reported increases in eye, ear, nose, and throat ailments and skin irritations where fecal coliform density exceeded approximately 2,000 cells/100 mL.

The Indiana State Board of Health has reported monthly coliform data for the White River near Nora from 1957 to 1979. Fecal coliform density ranged from 10 to 89,000 cells/100 mL, and the annual median fecal coliform density ranged from 30 to 385 cells/100 mL (Indiana State Board of Health and Stream Pollution Control Board, 1957-79).

The Indianapolis and Marion County Health Department has also determined fecal coliform densities for the White River and its tributaries. These data and those from surveys done by the Indiana State Board of Health are presented in table 14. In general, insufficient data have been collected to indicate trends in the long-term geometric means of fecal coliform densities.

Except for monthly data reported by the Indiana State Board of Health near Nora (RM 247.87), few data are available upstream from 16th Street (RM 233.86), and none of these data can be represented by a geometric mean. Fecal coliform data from river surveys indicate lower densities upstream from 10th Street than downstream. Williams Creek seems to be discharging high densities of fecal coliforms and fecal streptococci to the White River, and Crooked Creek seems to be discharging high densities of fecal coliforms. Downstream from both tributaries in the White River, the fecal coliform densities are lower because of dilution.

Downstream from 16th Street to Morris Street the fecal coliform densities generally increase, and at most sites the densities determined by the Indiana State Board of Health and the Indianapolis and Marion County Health Department exceed the limits for partial body contact recreation. Fecal coliform densities were highest in samples from Fall Creek and the White River at

Table 14.--Fecal coliform and fecal streptococci densities and discharge measurements at sampling stations in the upper White River basin, Marion County, Ind.

[Discharge measured by the U.S. Geological Survey]

Station	River mile	Fecal coliform density per 100-milliliter sample and discharge in cubic feet per second										
		1971[1]		1974[1]								
		July 19-23		August 19		August 28		August 29		September 10		
		Maximum fecal coliform	Discharge	Fecal coliform	Discharge	Fecal coliform[2]	Discharge	Fecal coliform[2]	Discharge	Fecal coliform[2]	Discharge	1974 Geometric mean of fecal coliform
White River near Nora (82d St.)	247.87	------	208	------	285	------	244	-------	585	------	273	------
White River at Westfield Blvd.	242.85	70	---	------	---	------	---	-------	-----	------	---	------
Williams Creek at 75th St.	242.58	3,400	---	------	---	------	---	-------	-----	------	---	------
White River at 38th St.	236.66	180	---	------	---	------	---	-------	-----	------	---	------
White River at 16th St.[3]	233.86	230	---	>10	---	2,100	---	800	-----	35	---	156
White River at 10th St.[3]	232.81	------	---	1,100	---	24,600	---	42,000	-----	11,600	---	10,715
Fall Creek at mouth[3]	232.90	------	---	11,000	---	24,000	---	120,000	-----	42,000	---	33,963
White River at Michigan St.[3]	232.42	1,800	---	------	---	------	---	-------	-----	------	---	------
White River at Washington St. (US 40)[3]	231.42	44,000	---	1,900	---	------	---	23,300	-----	5,900	---	5,856
White River at Morris St.	230.30	------	213	------	441	------	743	------	1,054	------	231	------

Station	River mile	Fecal-coliform density per 100 milliliter sample and discharge in cubic feet per second[4]							
		June 17, 1976		June 23, 1977		August 10, 1978		August 17, 1979	
		Fecal coliform	Discharge	Fecal coliform	Discharge	Fecal coliform	Discharge	Fecal coliform	Discharge
White River near Nora (82d St)	247.87	930	567	91	175	230	393	230	593
White River at Westfield Blvd.	242.85	2,400	---	230	---	230	---	150	-----
White River at 30th St.	235.58	230	---	91	---	91	---	30	-----
White River at Washington St. (US 40)[3]	231.42	230	---	24,000	---	4,600	---	2,400	-----
White River at Morris St.	230.30	-----	359	------	234	-----	565	-----	680

Table 14.--Fecal coliform and fecal streptococci densities and discharge measurements at sampling stations in the upper White River basin, Marion County, Ind.,--Continued

Station	River mile	Fecal coliform density per 100 milliliter sample and discharge in cubic feet per second, 1980[4]: July 28 Fecal coliform	July 28 Discharge	July 29 Fecal coliform	July 29 Discharge	July 30 Fecal coliform	July 30 Discharge	July 31 Fecal coliform	July 31 Discharge	August 1 Fecal coliform	August 1 Discharge	Geometric mean of fecal coliform
White River near Nora (82d St.)	247.87	-------	539	------	1,310	-------	880	-------	654	------	503	------
White River at 16th St.[3]	233.86	15,000	---	1,500	-----	750	---	11,000	---	4,600	---	3,857
White River at 10th St.[3]	232.81	9,300	---	4,600	-----	11,000	---	15,000	---	2,400	---	7,011
White River at Michigan St.[3]	232.42	4,600	---	11,000	-----	110,000	---	4,300	---	2,400	---	14,186
White River at New York St.[3]	232.16	46,000	---	4,300	-----	11,000	---	11,000	---	1,500	---	8,147
White River at Washington St. (US 40)[3]	231.42	11,000	---	43,000	-----	15,000	---	7,500	---	15,000	---	15,150
White River at Morris St.	230.30	110,000	861	24,000	988	460,000	898	240,000	653	1,500	486	53,472

Station	River mile	Fecal-coliform density per 100 milliliter sample and discharge in cubic feet per second, August 5, 1980[5]: Fecal coliform	Fecal streptocci	Discharge
White River near Nora (82d St.)	247.87	420	140	392
White River near Ravenswood	245.37	100	86	-----
White River at Westfield Blvd.	242.85	124	440	194
Williams Creek at 75th St.	242.58	147	840	43
White River at Kessler Blvd.	240.78	240	120	-----
White River near Highland Country Club	239.62	220	100	-----
White River at 38th St.	280	54	280	-----
Crooked Creek at mouth	236.22	340	66	3.1
White River at 30th St.	235.58	130	10	-----
White River at 16th St.[3]	233.86	50	18	-----
Fall Creek at mouth	232.90	550	120	87
White River at Michigan St.[3]	232.42	130	76	-----
White River at Washington St. (US 40)[3]	231.42	900	50	-----
White River at Morris St.	230.30	----	---	373

[1]Fecal coliform densities determined by the Indiana State Board of Health, written commun., July 1980.
[2]Mean of 2 or 3 samples collected from cross section at sample site.
[3]Sites within potential park area.
[4]Fecal coliform densities determined by the Indianapolis and Marion County Health Department, Robert S. Morse, written commun., September 1980.
[5]Fecal coliform densities determined by the U.S. Geological Survey.

Washington and Morris Streets. Most of the samples analyzed by the Indiana State Board of Health and the Indianapolis and Marion County Health Department were collected during periods of high flow, when the stream was probably affected by stormwater runoff from combined sewers. Increased fecal coliform densities during high flows or storms have also been observed by Lin and others (1974) and Davis and others (1977).

The fecal coliform density data collected during the study (table 14) complement the other data by representing low-flow, steady-state conditions of the White River. Although the data are limited and are not representative of a geometric mean, they do suggest that the fecal coliform densities decrease during low-flow, steady-state conditions and that the densities during low-flow, steady-state conditions are within the limits for partial body contact recreation (fig. 11).

The ratio of fecal coliform to fecal streptococci densities (fig. 12) suggest that the source of wastes are of human origin rather than from animals or other environmental sources.

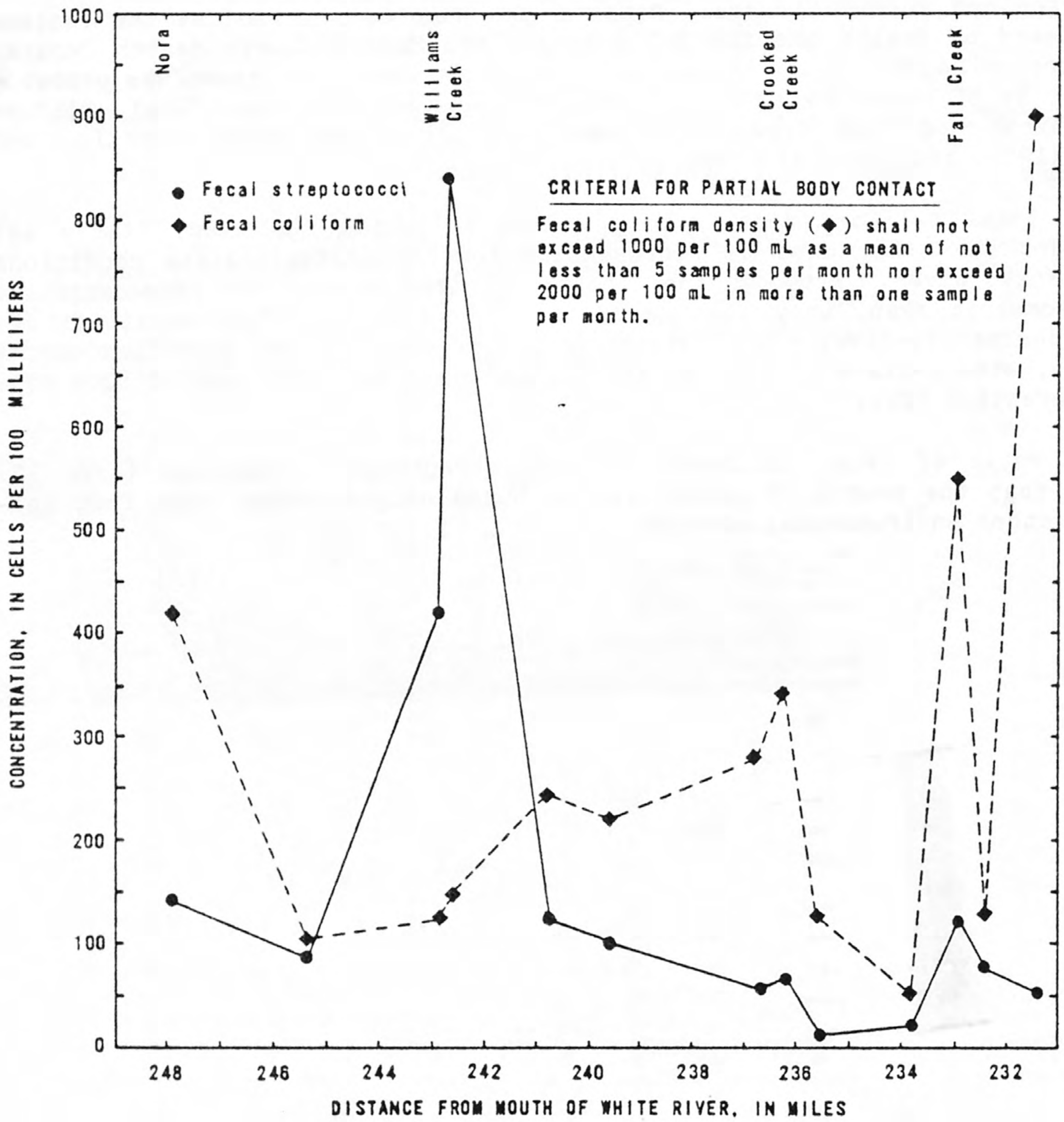

Figure 11.-- Relation of fecal coliform and fecal streptococci concentrations to distance, August 4 5, 1980.

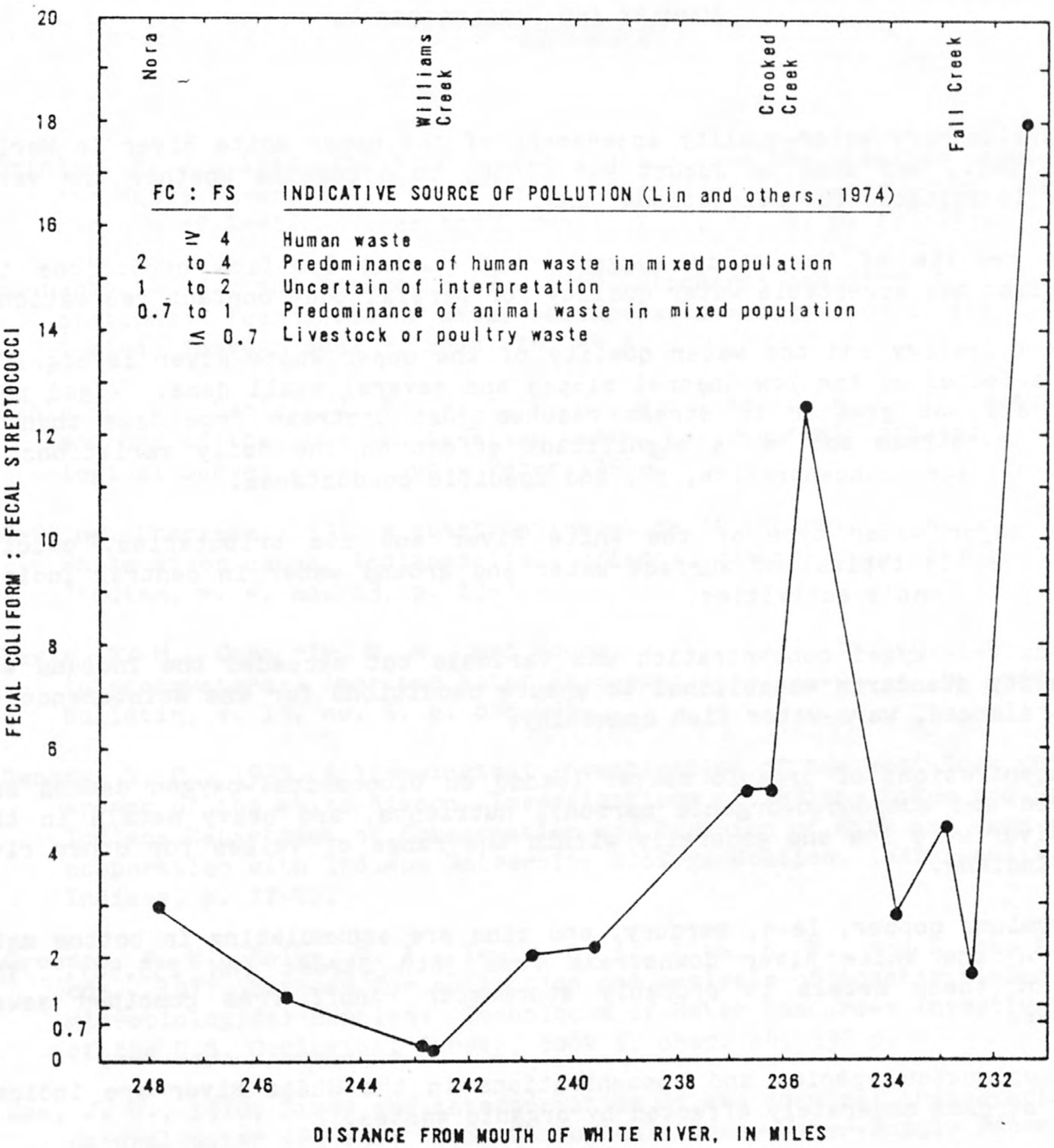

Figure 12.-- Relation of fecal coliform:fecal streptococci to distance, August 4-5, 1980.

SUMMARY AND CONCLUSIONS

A preliminary water-quality assessment of the upper White River in Marion County, Ind., was done on August 4-5, 1980, to determine whether the water quality is suitable for recreational use.

The results of the study suggest that during low-flow conditions the White River has acceptable water quality for partial body contact recreation.

The hydrology and the water quality of the upper White River is significantly affected by the low channel slopes and several small dams. Algal photosynthesis was greater in stream reaches just upstream from dams than in reaches downstream and had a significant effect on the daily variations of dissolved-oxygen concentration, pH, and specific conductance.

The major water type of the White River and its tributaries, calcium bicarbonate, is typical of surface water and ground water in central Indiana unaffected by man's activities.

Dissolved-oxygen concentration was variable but exceeded the Indiana water-quality standards established to ensure conditions for the maintenance of a well-balanced, warm-water fish community.

Concentrations of organic matter (based on biochemical-oxygen demand and dissolved- and suspended-organic carbon), nutrients, and heavy metals in the White River were low and generally within the range of values for other rivers in Indiana.

Chromium, copper, lead, mercury, and zinc are accumulating in bottom materials of the White River downstream from 30th Street (RM 235.58). The source of these metals is probably stormwater runoff from combined sewer overflows.

Phytoplankton species and concentrations in the White River are indicative of streams moderately affected by organic wastes.

Fecal coliform densities in the White River are generally higher downstream from 16th Street (RM 233.86) than upstream. High fecal coliform densities have been observed in the White River during high streamflows and are probably caused by stormwater runoff from combined sewers.

REFERENCES

Brinley, F. J., 1942, The effect of pollution upon the plankton population of the White River, Indiana: Indiana Department of Conservation, Investigations of Indiana Lakes and Streams, v. 2, no. 9, p. 137-143.

Buchanan, T. J., and Somers, W. P., 1969, Discharge measurements at gaging stations: Techniques of Water Resources Investigations of the U.S. Geological Survey, book 3, chap. A8, 65 p.

Cable, L. W., Daniel, J. F., Wolf, R. J., and Tate, C. H., 1971, Water resources of the upper White River basin, east-central Indiana: U.S. Geological Survey Water-Supply Paper 1999-C, 38 p.

Coffing, Charlene, 1937, A quantitative study of the phytoplankton of the White River canal, Indianapolis, Indiana: Butler University Botanical Studies, v. 4, no. 13, p. 13-31.

Davis, E. M., Casserly, D. M., and Moore, J. D., 1977, Bacterial relationships in stormwaters: American Water Resources Association, Water Resources Bulletin, v. 13, no. 5, p. 895-905.

Denham, S. C., 1938, A limnological investigation of the West Fork and Common Branch of the White River: Investigations of Indiana Lakes and Streams, Indiana Department of Conservation and Division of Fish and Game in cooperation with Indiana University Biology Station, Indianapolis, Indiana, p. 17-71.

Greeson, P. E., Ehlke, T. A., Irwin, G. A., Lium, B. W., and Slack, K. V., eds., 1977, Methods for collection and analysis of aquatic biological and microbiological samples: Techniques of Water Resources Investigations of the U.S. Geological Survey, book 5, chap. A4, 332 p.

Hem, J. D., 1970, Study and interpretation of the chemical characteristics of natural water (2d ed): U.S. Geological Survey Water-Supply Paper 1473, 363 p.

Hoggatt, R. E., 1962, Low-flow characteristics of Indiana streams: Indiana Stream Pollution Control Board, 171 p.

______ 1975, Drainage areas of Indiana streams: Indiana Department of Natural Resources, 231 p.

Hosteter, W. D., 1978, Soil survey of Hamilton County, Indiana: U.S. Department of Agriculture, 87 p.

Hupp, E. R., 1943, Plankton and its relationship to chemical factors and environment in White River canal, Indianapolis, Indiana: Butler University Botanical Studies, v. 6, no. 30, p. 30-53.

Hynes, H. B. N., 1970, The ecology of running waters: Toronto, University of Toronto Press, 555 p.

Indiana State Board of Health, 1977, Guidelines for waste load allocations and total maximum daily loads: Indiana State Board of Health, Water Pollution Control Division, 24 p.

Indiana Stream Pollution Control Board, 1970, Water quality standards for waters of Indiana: Indiana Stream Pollution Control Board, Regulation SPC IR-2, 6 p.

______ 1977, Water-quality standards for all waters within the State of Indiana: Indiana State Board of Health, Water Pollution Control Division, Regulation SPC IR-4, 11 p.

Indiana State Board of Health and Stream Pollution Control Board, 1957-79, Indiana water quality: Annual reports, 1957-79.

Lackey, J. G., 1961, Algal density as related to nutritional threshholds, in Transactions of seminar on algae and metropolitan wastes: Cincinnati, Ohio, April 27-29, 1960, U.S. Department of Health, Education, and Welfare, p. 56-60.

Lackey, J. B., and Hupp, E. R., 1956, Plankton populations in Indiana's White River: Journal of American Water Works Association, v. 48, no. 8, p. 1024-1036.

Lazrus, A. L., Lorange, E., and Lodge, J. P., Jr., 1970, Lead and other metal ions in United States precipitation: Environmental Science and Technology, v. 4, p. 55-58.

Lin, Shundar, Evans, R. L., and Beuscher, D. B., 1974, Bacteriological assessment of Spoon River water quality: Applied Microbiology, v. 28, no. 2, p. 288-297.

Malott, C. A., 1922, The physiography of Indiana, in Handbook of Indiana geology: Indiana Department of Conservation, Division of Geology, 1,120 p.

McKee, J. E., and Wolf, H. W., eds., 1963, Water quality criteria: The Resources Agency of California State Water Quality Control Board, Publication no. 3-A, 548 p.

National Academy of Sciences and National Academy of Engineering, 1972 [1974], Water quality criteria: Washington, D.C., U.S. Government Printing Office, 594 p.

Nemerow, N. L., 1974, Scientific stream pollution analysis: Washington, Scripto Book Co., 358 p.

Oosten, J. V., 1945, Turbidity as a factor in the decline of Great Lakes fishes with special reference to Lake Erie: Transactions of the American Fisheries Society, v. 75, p. 182.

Palmer, C. M., 1962, Algae in water supplies: an illustrated manual on the identification, significance, and control of algae in water supplies: U.S. Department of Health, Education, and Welfare, Public Health Service Publication no. 657, 88 p.

Palmer, C. M., 1969, A composite rating of algae tolerating organic pollution: Journal of Phycology, v. 5, p. 78-82.

Rickert, D. A., Kennedy, V. C., McKenzie, S. W., and Hines, W. G., 1977, A synoptic survey of trace metals in bottom sediments of the Willamette River, Oregon: U.S. Geological Survey Circular 715-F, 27 p.

Rohne, P. B., Jr., 1972, Low-flow characteristics of Indiana streams: U.S. Geological Survey open-file report, 322 p.

Schaal, L. A., 1966, Climate, in Lindsey, A. A., ed., Natural features of Indiana: Indiana Academy of Science and Indiana State Library, p. 156-170.

Shampine, W. J., 1975, A river-quality assessment of the upper White River, Indiana: U.S. Geological Survey Water-Resources Investigations 10-75, 68 p.

Skougstad, M. W., Fishman, M. J., Friedman, L. C., Erdmann, D. E., and Duncan, S. S., eds., 1979, Methods for determination of inorganic substances in water and fluvial sediments: Techniques of Water Resources Investigations of the U.S. Geological Survey, book 5, chap. A1, 626 p.

Storm, R. H., and Gilbert, R. H., 1978, Soil survey of Marion County, Indiana: U.S. Department of Agriculture, 63 p.

Stiff, H. A., Jr., 1951, The interpretation of chemical water analysis by means of patterns: Journal of Petroleum Technology, v. 3, no. 10, p. 15-17.

U.S. Environmental Protection Agency, 1976, Quality criteria for water: U.S. Environmental Protection Agency, 501 p.

U.S. Geological Survey, 1980, Water-resources data for Indiana, 1979: U.S. Geological Survey Water-Data Report IN-79-1, 419 p.

U.S. Soil Conservation Service, 1968, Indiana soil and water conservation needs inventory: Purdue University Cooperative Extension Service, 244 p.

Wetzel, R. G., 1975, Limnology: Philadelphia, W. B. Saunders, 743 p.

Wier, C. E., and Gray, H. H., 1961, Geologic map of the 1°x2° Indianapolis quadrangle, Indiana and Illinois, showing bedrock and unconsolidated deposits: Indiana Department of Natural Resources, Geological Survey Division.

Wilber, W. G., and Hunter, J. V., 1975, Contributions of metals resulting from stormwater runoff and precipitation in Lodi, New Jersey, in Whipple, William, Jr., Urbanization and water quality control: Minneapolis, Minn., American Water Resources Association, p. 45-54.

Wilhm, J. L., and Dorris, T. C., 1968, Biological parameters of water quality: Bioscience, v. 18, p. 447-481.