TIME OF TRAVEL, WATER QUALITY, AND BED-MATERIAL QUALITY IN THE CUYAHOGA RIVER WITHIN THE CUYAHOGA VALLEY NATIONAL RECREATION AREA, OHIO

By C. J. Oblinger Childress

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CONVERSION FACTORS

For the convenience of readers who prefer to use metric (International System) units, conversion factors for inch-pound terms used in this report are listed below:

Multiply inch-pound units	By	To obtain metric units
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

ABBREVIATIONS

°C	degrees Celsius
cols.	colonies
ft^3	cubic feet
kg	kilograms
L	liters
mg	milligrams
mi	miles
mi^2	square miles
mL	milliliters
s	seconds
µS/cm at 25°C	microsiemens per centimeter, at 25 degrees Celsius
--	data not available, or "not applicable"

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ABSTRACT

Three studies were conducted in the Cuyahoga Valley National Recreation Area (CVNRA) by the U.S. Geological Survey, in cooperation with the National Park Service, to (1) establish the relationship between time of travel and discharge through the park reach, (2) assess the impact of 13 tributaries within the park on dissolved-oxygen depletion and contamination by microorganisms on the main stem of the Cuyahoga River during a low-flow period, and (3) determine general areas that are being contaminated by trace metals by examining metals adsorbed to bed material at selected locations within the CVNRA.

Times of travel between Botzum and Independence (24 miles) at flows of 222 and 720 cubic feet per second (ft^3/s) at Independence were 38.7 and 19.9 hours, respectively. Time of travel in this reach of the Cuyahoga River is described by the equation $T = 46.9 - 0.038Q$, where T = time of travel, in hours, and Q = discharge at Independence, in ft^3/s. Times of travel between Botzum and Peninsula (9 miles) at flows of 222, 376, and 720 ft^3/s were 11.4, 8.8, and 6.4 hours, respectively, and are described by the equation $T = 13.0 - 0.009Q$. Pooling behind the Brecksville diversion dam significantly lengthened time of travel at a flow of 222 ft^3/s.

On the main stem during low flow, dissolved-oxygen concentrations were highest and ultimate carbonaceous biochemical oxygen demands (CBODu) were lowest on the upstream and downstream ends of the reach. Dissolved-oxygen concentrations below the Ohio minimum standard were recorded at Peninsula, Jaite, and Brecksville; the highest CBODu concentrations also were recorded at these sites. Ohio standards for dissolved oxygen were not exceeded on the tributaries, and 5-day biochemical oxygen demand (BOD_5) loads were low relative to loads on the main stem. CBODu loads on the main stem and BOD_5 loads on the tributaries at high flow generally exceeded loads at low flow.

The number of fecal coliform counts per 100 milliliters of sample ranged from 38 to 1,200,000. On the main stem, counts exceeded Ohio standards for primary contact recreation at all sites and for secondary contact recreation at all but Botzum and Peninsula. The highest tributary count was recorded on Langes Run (360,000). The following tributaries had counts that exceeded the Ohio standard for primary contact recreation: Haskell Run (6,600), Robinson Run (1,800), Brandywine Creek (4,200), Chippewa Creek (1,700), and the unnamed tributary (9,600). Haskell and Langes Runs exceeded the Ohio standard for secondary contact recreation.

Concentrations of arsenic, boron, cadmium, cobalt, selenium, and mercury analyzed from bed-material samples generally were below the limits of detection. Concentrations of aluminum, copper, iron, lead, manganese, nickel, strontium, and zinc generally were well above the limits of detection, but there were no anomalous concentrations. There were no major differences in concentration between sites on the main stem.

INTRODUCTION

The Cuyahoga Valley National Recreation Area (CVNRA) was established in 1974 under Public Law 93-555 to be administered and managed by the National Park Service. The CVNRA is located in the Akron-Cleveland metropolitan area in northeastern Ohio (fig. 1). The National Park Service is committed to developing the park to meet the recreational needs of the surrounding urban population while maintaining or enhancing the park's natural resources and historical features (U.S. Department of the Interior, 1977).

Water-based recreation has not been developed in the CVNRA because of current water-quality conditions. The major water-quality problems are low dissolved-oxygen concentrations, high fecal-bacteria counts, and contamination from industrial and municipal point-source discharges in the heavily urbanized area upstream of the CVNRA.

The large urban-industrial area above the CVNRA creates a potential for the accidental discharge of untreated effluent into the river. The ability to predict the time of travel through the CVNRA would be useful were such an accident to occur.

The Ohio Environmental Protection Agency has designated all surface waters in the State for warmwater habitat, industrial water supply, and primary contact recreation unless exempted. The following are exempted reaches in the study area. The reach of the Cuyahoga River from the Akron sewage-treatment plant to Peninsula (fig. 2) is designated for limited warmwater habitat.

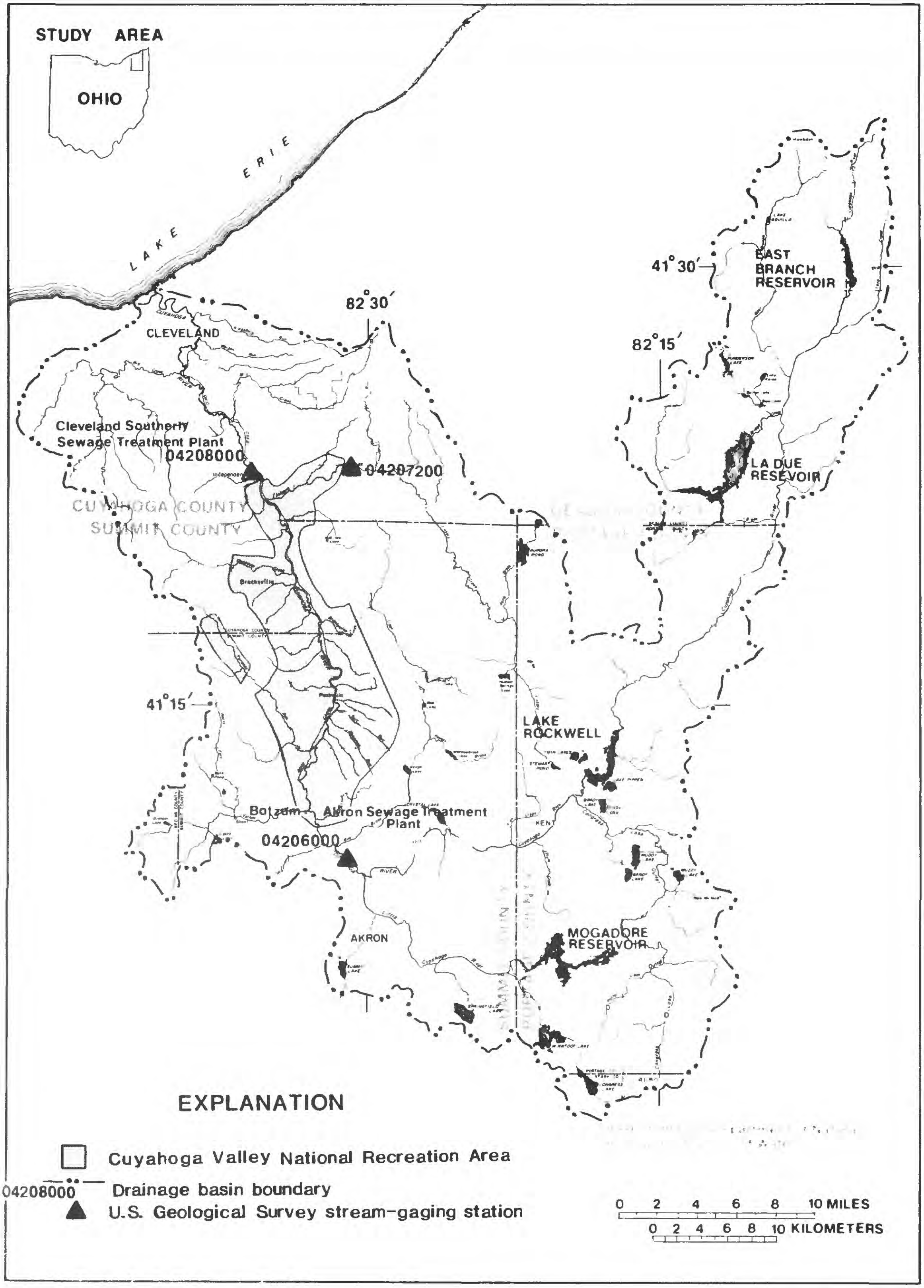

Figure 1--Location of the Cuyahoga Valley National Recreation Area and U.S. Geological Survey stream gages in the Cuyahoga River basin.

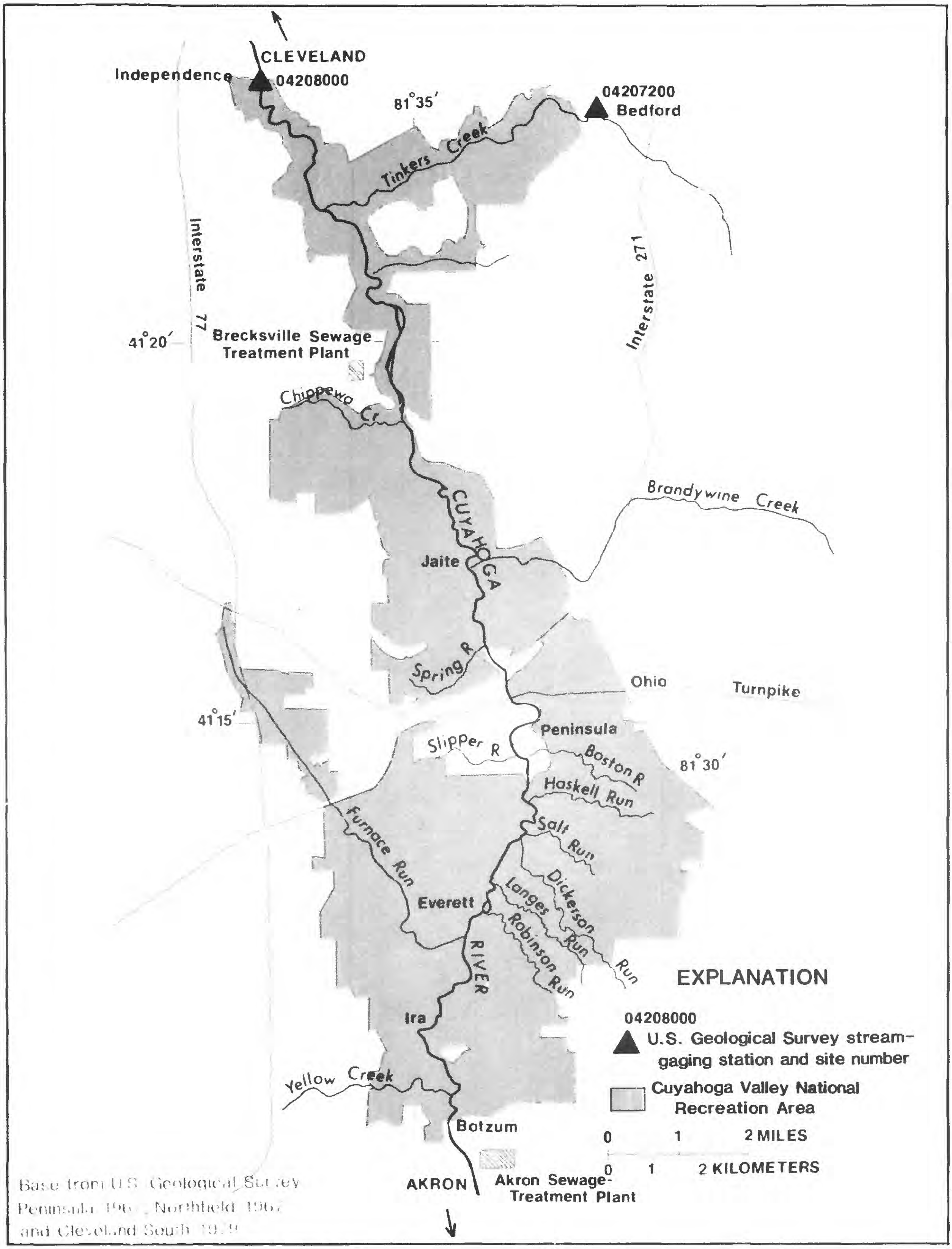

Figure 2.--The Cuyahoga Valley National Recreation Area.

In this reach, the ammonia standard normally required for streams designated as warmwater habitat is waived, and concentrations are permitted to reach 5 mg/L year round. The reach from the Little Cuyahoga River to Cleveland (fig. 1) is designated for secondary contact recreation; that is, it is considered unsuitable for full body contact. In addition to the above designations, the reach from Botzum to Independence (fig. 2) is designated as State and National Resource Water -- that is, the reach is not permitted to degrade below current water quality. The same designation has been given to the lower reaches of Tinkers Creek and Chippewa Creek, and much of Furnace Run.

During low-flow periods, waste discharges from industry and municipalities make up a large percentage of the total flow of the river (as much as two-thirds from the Akron sewage-treatment plant alone). The Cuyahoga River is impounded at Lake Rockwell, a water-supply reservoir for Akron; and at low flow, little or no water is released from Lake Rockwell. Most of the waste load in the park reach of the Cuyahoga River originates upstream of the CVNRA, from tributaries within the park that drain upland areas outside of the park boundaries, or from point sources within the park. However, nonpoint discharges from agricultural, residential, and recreational land within the CVNRA may make some contribution to the bacterial and organic and inorganic chemical waste load.

Although sources of contaminants outside of the park have been well documented, the extent of the nonpoint sources within the park boundaries is unknown. A better understanding of the relationship between land use in the CVNRA and river quality is needed if the National Park Service is to meet its resource-management goals.

Purpose and Scope

This report presents the results of three studies that were conducted within the CVNRA from 1981 through 1983. The three studies provide an overview of water quality in the CVNRA and identify areas that should be of greatest concern to the National Park Service when they evaluate land-use priorities in the basin as they relate to water quality. The objective of the first study was to establish the relationship between discharge of the Cuyahoga River and time of travel through the park reach so that the passage of any water-soluble contaminant discharged upstream of the park can be predicted. The objective of the second study was to assess the impact of 13 tributaries within the park on dissolved-oxygen depletion and contamination from microorganisms on the main stem during a low-flow period. Tributaries within the

CVNRA that need to be studied in more detail in terms of impact on the park's water quality are identified. The objective of the third study was to identify tributaries that are receiving trace-metal contamination by examining metals adsorbed to bed material at 18 locations within the CVNRA.

Acknowledgments

The author wishes to thank the staff of the Cuyahoga Valley National Recreation Area for providing space for a field office and laboratory.

Location and Description of the Study Area

The Cuyahoga River drains 813 square miles in northeastern Ohio (fig. 1). The river is 100 miles long and follows a U-shaped configuration. The headwaters rise only 30 miles from the mouth. From there, the river flows south to Cuyahoga Falls and Akron before turning north and emptying into Lake Erie.

The study reach is bracketed by two U.S. Geological Survey stream-gaging stations. The upstream gage (04206000) is on Old Portage Road in Akron (river mile 40.4)[1] and the downstream gage (04208000) is on Rockside Road in Independence (river mile 13.6). A third gage is located on Tinkers Creek (04207200). Twenty-four miles of the reach and one-fifth of the drainage area from Botzum (river mile 37.3) to Independence are included in the CVNRA (fig. 2).

Median flow from May 1 through November 30 is 240 ft^3/s at the Independence gage, 150 ft^3/s at the Old Portage gage in Akron, and 32 ft^3/s on Tinkers Creek (Johnson and Metzker, 1981). Two low-head dams are within the study reach -- one at Peninsula and the other at Brecksville (fig. 2). The latter diverts flow to the Ohio Canal, which runs parallel to the Cuyahoga River in the study reach.

From Botzum to Peninsula, land use is primarily recreational and residential. Land use becomes increasingly industrial and commercial in proximity to Cleveland, and the park is primarily confined to the Cuyahoga River valley. (Generalized land-use percentages have been compiled by the U.S. Army Corps of Engineers (1980), and it is these percentages that are referred to in the following paragraphs.)

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1 "River mile" is the distance from the mouth.

The area between Botzum and Peninsula is drained by Furnace, Robinson, Langes, Dickerson, Salt, and Haskell Runs and by local drainage. The areas drained by Robinson, Langes, Dickerson, Salt, and Haskell Runs, which are almost entirely within the CVNRA, are mostly in woodland and recreational land use. Only about 7 percent of the area is residential, less than 1 percent commercial or industrial, and less than 1 percent crops and pasture. The Furnace Run drainage basin is 67 percent woodland and recreational, 12 percent crops and pasture, 14 percent residential, and 7 percent other land uses such as industrial or commercial.

Blossom Music Center, a large outdoor concert theater, is located in the Robinson Run basin. Haskell Run drains a golf course, and there are a number of small businesses located in Peninsula. Discharge from the Akron sewage-treatment plant, located at Botzum, averages about 58 ft^3/s.

From Peninsula to Independence, the basin uplands are increasingly developed. The Brandywine Creek drainage basin is 54 percent woodland and recreational land use, 14 percent pasture and cropland, and 22 percent residential. The remaining 10 percent is in commercial, industrial, and other land uses. Chippewa Creek is 51 percent woodland and recreational; 5 percent pasture and cropland; 35 percent residential; and 9 percent industrial, commercial, and other land uses.

Tinkers Creek drainage basin above Bedford (site 24) is 44 percent recreation and woodland; 20 percent residential; 19 percent crop and pasture; and 17 percent commercial, industrial, and other land uses. The Tinkers Creek drainage basin below Bedford is 36 percent woodland and recreational, 3 percent pasture and cropland, 34 percent residential, and 27 percent other land uses such as commercial or industrial.

A paper mill discharges into Brandywine Creek. In addition, there are a number of small sewage-treatment plants, including one in Brecksville, that discharge to the main stem; several small sewage-treatment plants discharge into Tinkers Creek.

Since 1983, wastewater from Blossom Music Center has been directed to the Akron sewage-treatment plant. Sewage that had been treated at the small plant in Brecksville will be directed to the Cleveland sewage-treatment plant. The Jaite paper mill will close operation as of September 1984, when it will be purchased by the National Park Service (B. McHugh, National Park Service, oral commun., 1984). These changes should reduce some of the water-quality problems documented by this study.

METHODS OF STUDY

Time of Travel

The study reach was divided into three subreaches (fig. 3). Subreach 1 extends from Botzum to just below the dam in Peninsula. Subreach 2 extends from just below the Peninsula dam to just below the Brecksville diversion dam. Subreach 3 extends from below the diversion dam at Brecksville to Independence. Two flow regimes, as measured at the index gage at Independence, were preselected for study -- mean flow (about 30-percent duration) and flow at 70-percent duration. Time-of-travel results measured in 1981 between Botzum and Peninsula at a 50-percent flow duration also were used for analysis. Identical methods were followed at that time except that an additional sampling point at Everett (river mile 33.4) was included (fig. 3).

Traveltime was measured by simultaneously releasing a quantity of water-soluble fluorescent tracer (Rhodamine-WT dye) at the upstream terminus of all three subreaches. The time of arrival of the dye peak, as measured by its fluorescence, was recorded at one intermediate point and at the downstream terminus of each subreach. Samples were collected from the center of flow and dye concentrations determined in the field using a Turner model 10 Fluorometer[1]. Details of this procedure are described by Kilpatrick and others (1970).

Stage record from the index gage at Independence was used to determine discharge for each time of travel that was measured. In addition, instantaneous discharge was measured at Botzum and Everett in 1981 and at Botzum and Independence on August 17, 1983.

In the first subreach, dye was released in the Akron sewage-treatment plant effluent to enhance mixing. The time of the peak dye concentration 1,000 feet below the release point was considered the start of the time of travel (time = 0). Peaks were also determined just above the confluence with Furnace Run (river mile 33.6), at Peninsula just above the Peninsula dam (river mile 29.8), and just below the Peninsula dam (river mile 29.6).

In the middle subreach, dye was released at the upstream terminus (time = 0) and peaks were determined at Jaite (river mile 24.8), 500 feet above the diversion dam at Brecksville

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1 Use of trade names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

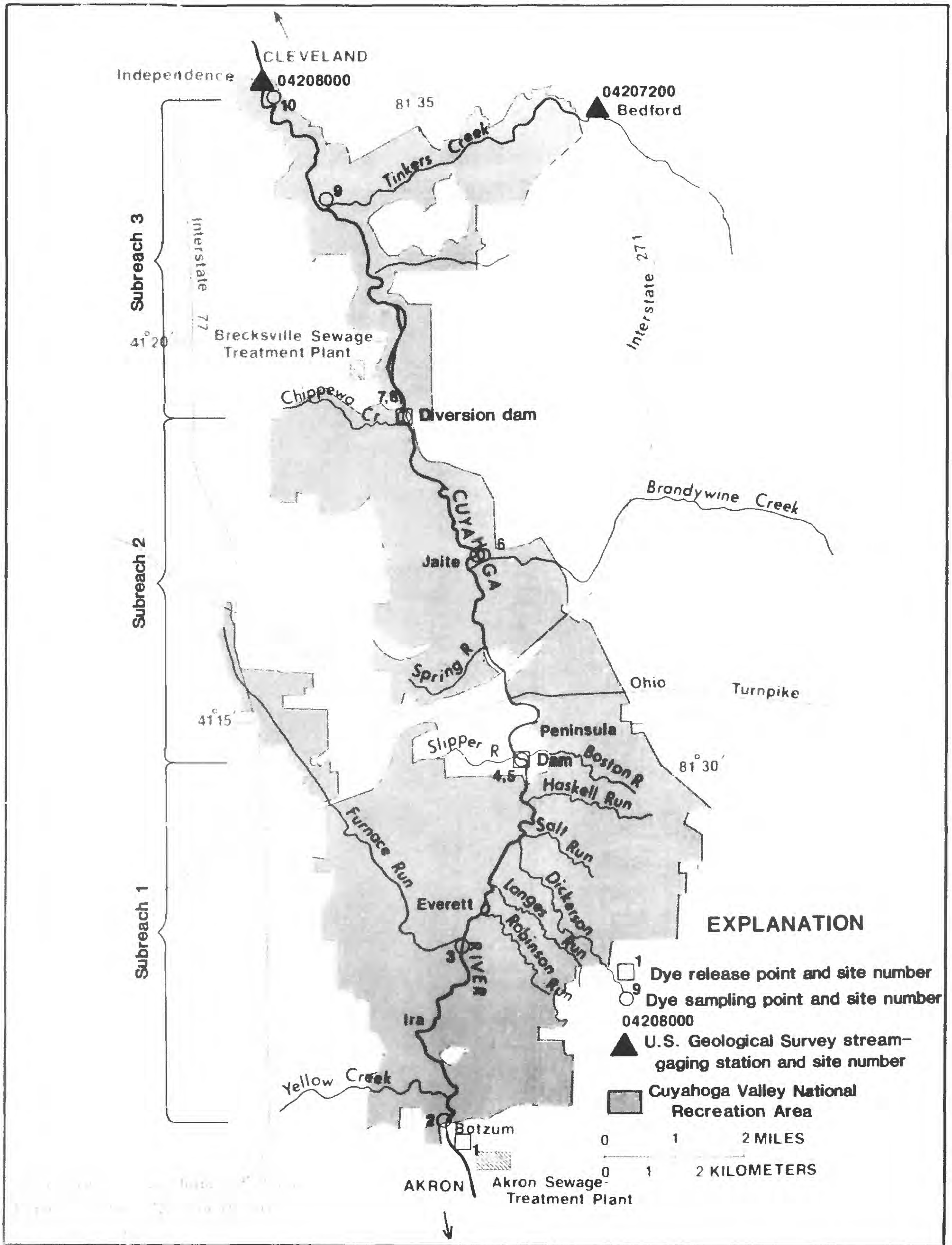

Figure 3.--Dye-release and sampling points for the time-of-travel study.

(river mile 21.5), and just below the diversion dam (river mile 21.3). In the last subreach, dye was released below the diversion dam at Brecksville (time = 0), and peaks were recorded below the confluence with Tinkers Creek (river mile 16.8) and at Independence (river mile 13.3).

Water-Quality Sampling and Analysis

Twenty-six sites were established between Botzum and Independence; 8 were on the main stem of the Cuyahoga River, and 18 were on 13 tributaries (fig. 4, table 1). A twenty-seventh site (site 1), used only for discharge measurement, was located at the U.S. Geological Survey gage on Old Portage Road in Akron (fig. 1). Site 2 was located above and site 3 below the Akron sewage-treatment plant outfall (river mile 37.5). Site 17 was located just below the effluent of the paper mill at Jaite; however, access to that site was denied after the first sample had been collected. To compensate, site 17A was established on the main stem just below the confluence with Brandywine Creek. Sites 12 and 18 were located above the dams at Peninsula and Brecksville, respectively.

Instantaneous discharge was measured (or calculated from established stage-discharge relationships when a gage was present) at the beginning of the sampling period when the flow was low and at the end of the sampling period after rain had increased the streamflow. Five-day biochemical oxygen demand (BOD5), fecal bacteria, dissolved oxygen, temperature, specific conductance, pH, and discharge were measured at each site. At main-stem sites, ultimate carbonaceous biochemical oxygen demand (CBODu) and the rate of deoxygenation (k1) were calculated from the 20-day test with a nonlinear least-squares regression (M. E. Jennings and D. P. Bauer, U.S. Geological Survey, written commun., 1976). Sampling began on September 14, 1982, at 0600 hours and continued every 4 hours until 1800 hours. Sampling then was interrupted until 0700 hours the following morning because of a local thunderstorm.

Samples for analysis of BOD5 were collected at 8-hour intervals (three times), whereas samples for analysis of CBODu were collected at 4-hour intervals (five times). On the smaller tributary sites, samples were taken from the center of flow. On the main stem and large tributary sites, a representative sample was obtained by compositing water collected at about 10 points along the cross section.

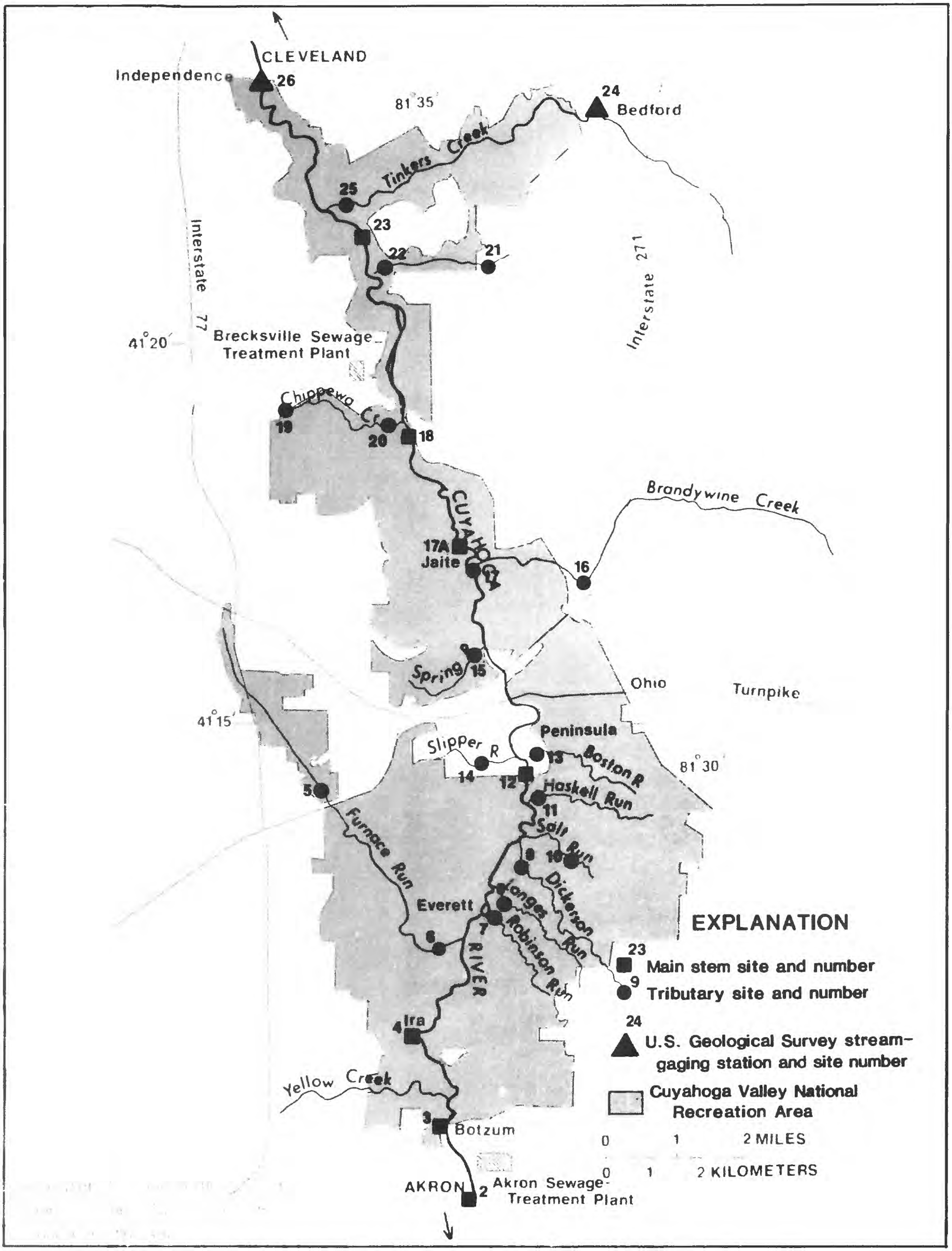

Figure 4.--Location of water-quality sampling sites

Table 1.--Identification and characteristics of sites for the water-quality survey

Site number	U.S. Geological Survey ID number	Site name	Drainage area (mi^2)	River[1] mile (mi)
1	04206000	Cuyahoga River at Old Portage	404	40.8
2	4109150813421	Cuyahoga River near Botzum	447	38.8
3	4110110813451	Cuyahoga River at Botzum	443	37.8
4	04206250	Cuyahoga River at Ira	478	35.8
5	4114250813651	Furnace Run at Richfield	17.1	--
6	4112050813424	Furnace Run at Everett	20.4	33.6
7	4112300813337	Robinson Run at Everett	1.5	32.9
8	4112410813322	Langes Run at Everett	1.5	32.2
9	4113060813307	Dickerson Run at Peninsula	2.1	31.4
10	4113110813204	Salt Run at Peninsula	1.3	31.0
11	4114040813249	Haskell Run at Peninsula	2.2	30.5
12	04206400	Cuyahoga River at Peninsula	492	29.8
13	4114410813245	Boston Run at Peninsula	2.5	29.6
14	4114310813344	Slipper Run at Peninsula	1.5	29.4
15	4115570813351	Spring Run near Peninsula	1.3	26.8
16	4116360813218	Brandywine Creek at Boston Heights	24.8	--
17	04206420	Brandywine Creek near Jaite	27.2	24.8
17A	4117470813413	Cuyahoga River at Jaite	555	24.75
18	4119010813507	Cuyahoga River near Brecksville	564	21.8
19	4119130813507	Chippewa Creek at Brecksville	14.7	--
20	04206450	Chippewa Creek near Brecksville	17.7	21.6
21	4121180813343	Unnamed tributary to Cuyahoga River near Northfield	5.3	--
22	4121050813532	Unnamed tributary to Cuyahoga River at Independence	7.0	18.8
23	4121240813552	Cuyahoga River near Independence	692	17.8
24	04207200	Tinkers Creek at Bedford	83.9	--
25	04207300	Tinkers Creek at Independence	96.0	16.9
26	04208000	Cuyahoga River at Independence	707	13.3

[1] Miles upstream of the mouth of the Cuyahoga River.

Samples were chilled and transported to the U.S. Geological Survey Ohio District laboratory in Columbus within 7 hours and were immediately processed. CBODu samples were treated with a nitrification inhibitor, measured for dissolved-oxygen concentration, and incubated at 20°C for 20 days. Dissolved-oxygen concentration was measured on days 0.5, 1, 2, 3, 4, 5, 6, 8, 10, 12, 16, and 20. A dissolved-oxygen probe with stirrer was used to measure dissolved oxygen; any sample water displaced during this procedure was replaced with a marble, to prevent the introduction of an air pocket in the sample container (R. J. Pickering, U.S. Geological Survey, written commun., 1980).

Samples collected for the BOD5 test were not nitrification inhibited. The samples were incubated for 5 days, and dissolved oxygen was measured as described above. Dissolved-oxygen concentration was measured on days 0.5, 1, and 5.

Specific conductance, water temperature, dissolved oxygen, and pH were measured in the field at 4-hour intervals (five times). Conductivity meters and pH meters were checked for calibration at least twice, at the beginning and end of the study. Dissolved-oxygen meters were checked by the air-calibration method before each use. A calibration record was maintained for each instrument.

Fecal bacteria samples were collected once at each sample site on the morning of September 14 according to methods described by Greeson and others (1977). The time between sample collection and arrival at the field laboratory was less than 3 hours. Each sample was used to inoculate two sets of plates at three different dilutions (six plates per site). One set of agar plates contained KF agar medium to promote the growth of fecal streptococci. The other set contained M-FC agar medium to promote the growth of fecal coliform. The plates were placed in portable incubators that were transported to Columbus, where colonies were counted after the appropriate incubation period. Details of the method are described by Greeson and others (1977).

Bed-Material Sampling and Analysis

Bed-material samples were collected from three sites on the main stem of the Cuyahoga River and from sites on 15 tributaries (fig. 5) on August 17-18, 1982. Samples of bed material taken from depositional areas were scooped into plastic containers. Native water was used to rinse the material through a 2-millimeter sieve followed by a 200-micrometer sieve. The sample was chilled and sent to the District laboratory, where the <20-micrometer fraction was separated by settling. The resulting bed-material samples were sent to the U.S. Geological Survey central laboratory in Doraville, Ga., for analysis of total recoverable metals.

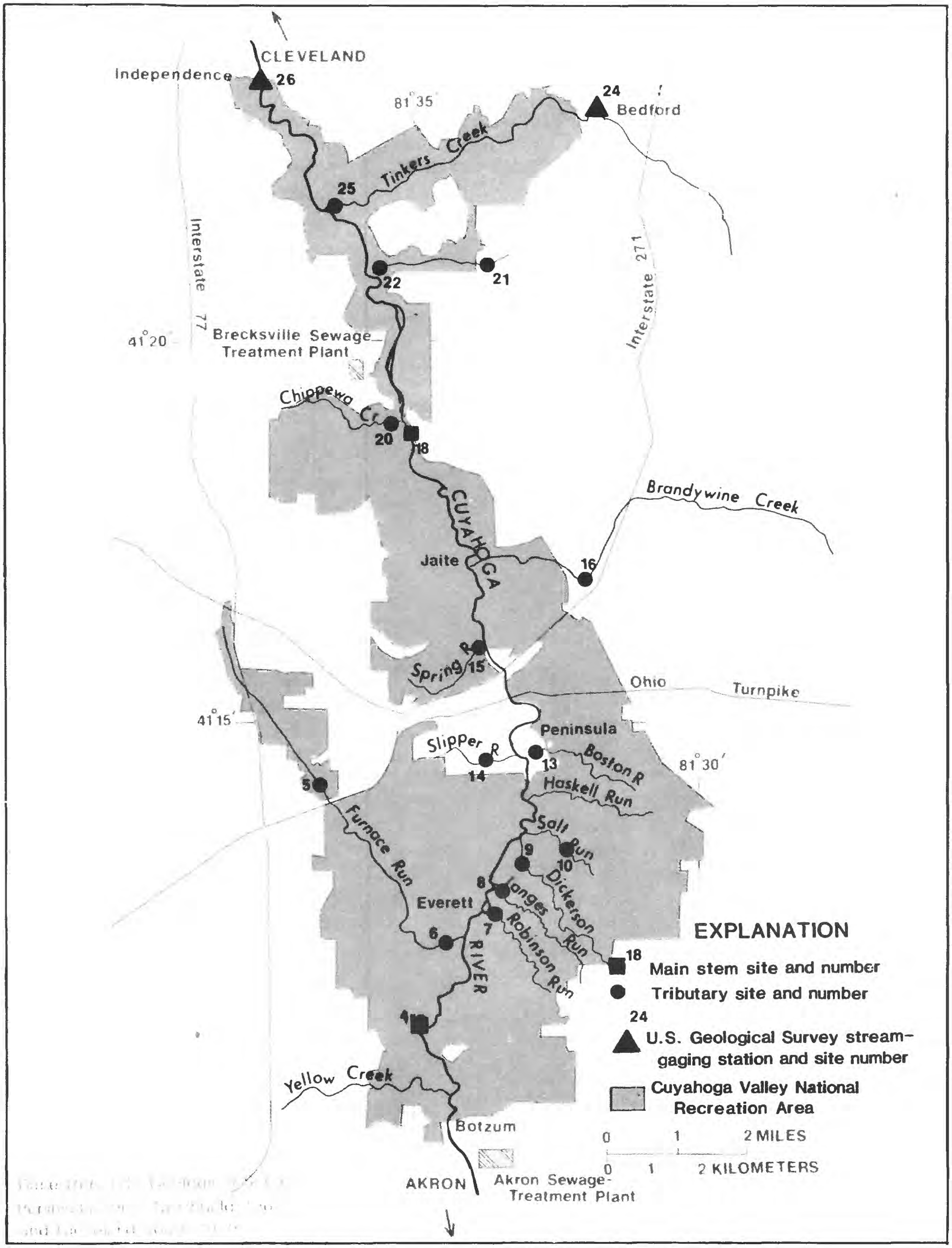

Figure 5.—Location of bed-material sampling sites

TIME OF TRAVEL

Traveltime is a measure of the movement of water-soluble material from point to point. It is a function of velocity and channel morphology. Traveltime can be used to predict the arrival of a water-soluble contaminant spill at selected points downstream.

When plotted on a logarithmic scale, discharge at an index point in the reach versus traveltime in the reach is usually linear (Kilpatrick and others, 1970). This relationship can be used to predict the traveltime given a specific discharge at an index point.

The gage at Independence was chosen as the index point. Traveltime between Botzum and Independence was measured at flows of 222 ft^3/s and 720 ft^3/s at the index gage; these represent flows of 35-percent and 70-percent duration, respectively (Johnson and Metzker, 1981). Traveltime between Botzum and Peninsula was measured at a flow of 376 ft^3/s at the index gage or 50-percent duration (Johnson and Metzker, 1981) in an earlier study.

The traveltimes measured between Botzum and Independence at flows of 222 ft^3/s and 720 ft^3/s were 38.7 and 19.9 hours, respectively (table 2). Pooling that occurred behind the Brecksville diversion dam at a flow of 222 ft^3/s lengthened traveltime. There was essentially no pooling behind the diversion dam at a flow of 720 ft^3/s (fig. 6). The traveltimes measured between Botzum and Peninsula at flows of 222, 376, and 720 ft^3/s were 11.2, 8.8, and 6.4 hours, respectively.

Assuming a linear relationship between discharge at the index gage and traveltime, traveltimes (T) can be predicted from Botzum to Peninsula and Independence (fig. 7). From Botzum to Independence, the equation is $T = 46.9 - 0.038Q$. From Botzum to Peninsula, the equation is $T = 13.0 - 0.009Q$. These relationships cannot be extrapolated beyond the measured traveltimes. This is particularly true for the Peninsula-to-Independence reach, where pooling behind the Brecksville diversion dam at very low flows may lengthen the traveltime significantly.

WATER QUALITY

Streamflow Conditions

Water quality is, in part, dependent on water quantity. Concentrations of all biochemical, chemical, and physical properties of water are altered by runoff from rainfall. Moreover, during periods of low flow, discharges from upstream impoundments on the Cuyahoga River are at a minimum, so that the source of most of the flow in the Cuyahoga River is ground-water seepage and point effluent discharges.

Table 2.--Time of travel at sites 1 through 10

Site	River mile	August 17, 1983 Time of peak		August 17, 1983 Hours between peaks	August 17, 1983 Cumulative elapsed time	June 1, 1983 Time of peak		June 1, 1983 Hours between peaks	June 1, 1983 Cumulative elapsed time	November 4, 1981 Time of peak	November 4, 1981 Hours between peaks	November 4, 1981 Cumulative elapsed time
1	37.6	[1]0630				[1]0700						
2	37.4	0649				0705						
				5.4	5.4			3.2				
3	33.6	1215				1020				[1]0645		
				5.8	11.2			3.2	6.4		4.5	4.5
4	29.8	1759				1330				1115		
				.2	11.4			0.0	6.4		4.2	8.8
5	29.7	1815	[1]0630			1330	[1]0700			1530		
				6.0	17.4			3.5	9.9			
6	24.8		1230				1030					
				6.2	23.7			3.4	13.3			
7	21.5		1845				1355					
				1.3	25.0			0.2	13.5			
8	21.3	[1]0630	2005			[1]0700	1405					
				7.5	32.5			3.5	17.0			
9	16.8	1400				1030						
				6.2	38.7			2.9	19.9			
10	13.3	2010				1325						

1 Time of dye release

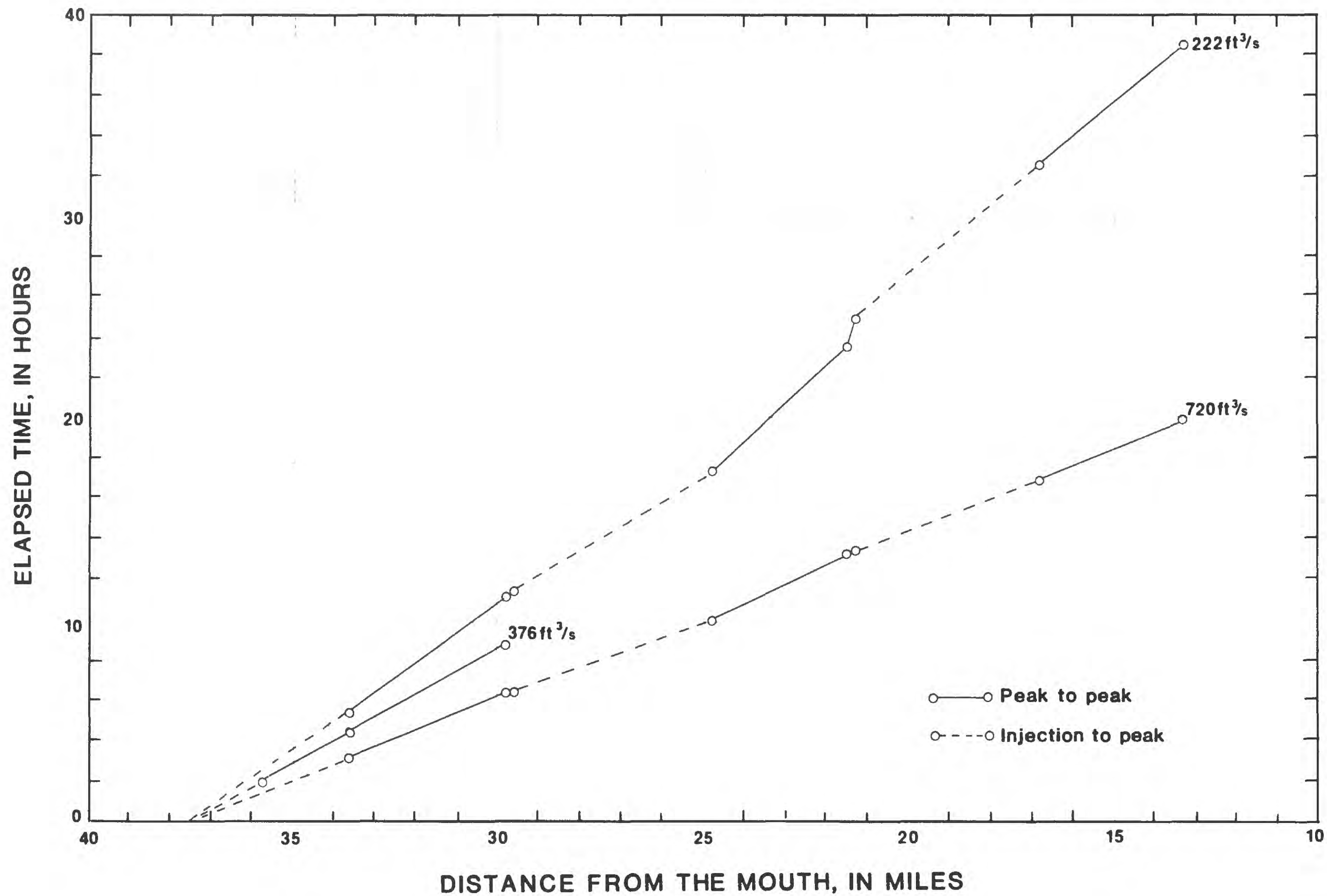

Figure 6.--Cumulative time of travel at three different discharges measured at Independence, Ohio

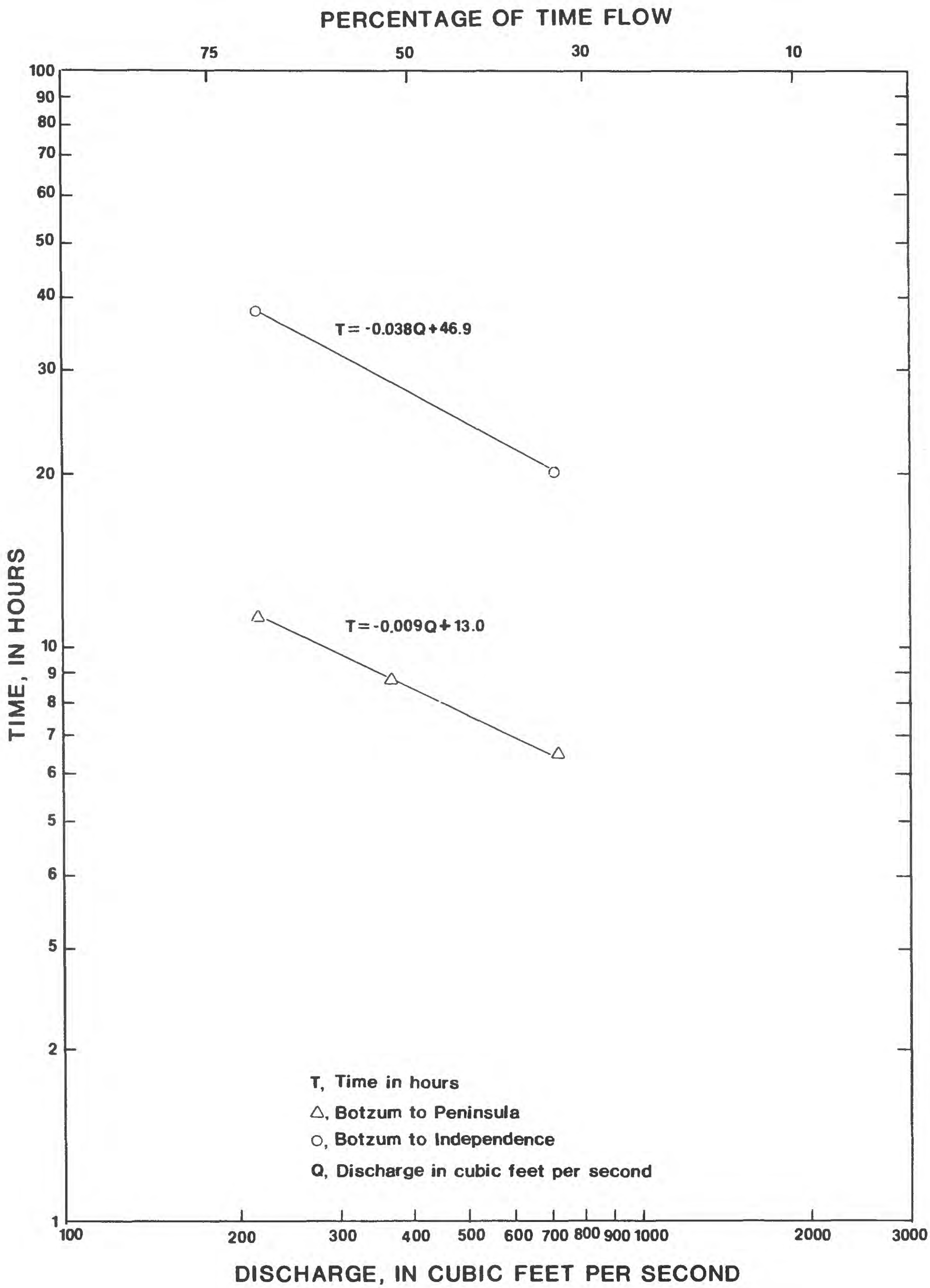

Figure 7.--Time of travel as a function of discharge at the index gage at Independence, Ohio.

Discharge was fairly steady during the first 12 hours of the study. Flow on the main stem averaged 180 ft^3/s (75-percent flow duration) at Independence and 90 ft^3/s (83-percent duration) at Old Portage (fig. 8).

Flow on Tinkers Creek, the largest tributary and the only one for which there is continuous record, averaged 16 ft^3/s (88-percent flow duration). The remaining tributaries have small drainage areas and comparatively low flows. The largest of these are Brandywine Creek (3.2 ft^3/s), Chippewa Creek (2.3 ft^3/s), Furnace Run (1.7 ft^3/s), and the unnamed tributary (1.3 ft^3/s). Flows in the remaining eight tributaries were less than 0.5 ft^3/s. A major contributor to flow in the main stem is the Akron sewage-treatment plant. The increase in flow between sites 2 and 3 (68 ft^3/s) is due to discharge from the plant.

A thunderstorm moving west to east caused a rise in stage beginning at 2200 hours and 1930 hours at Akron and Independence, respectively, on September 14 (fig. 8). Tributaries began rising about 1915 hours. Rainfall at the Cleveland Easterly Sewage-Treatment Plant (at the mouth of the Cuyahoga River) was 0.90 inches between 1800 and 1900 hours and 0.22 inches between 1800 and 2000 hours.

Peak discharge (caused by local runoff) on the main stem at Independence was 1,024 ft^3/s at 0200 hours on September 15. A second rise, beginning at 0700, was the result of the arrival of runoff from the upper basin. Peak discharge at the Old Portage gage was 1,250 ft^3/s at 2330 hours on September 14.

Specific Conductance, pH, and Water Temperature

During base flow, water temperatures (table 3) ranged from 13°C at Dickerson Run (0600 hours) to 24°C at Peninsula and above the Akron sewage-treatment plant (1400 and 1800 hours, respectively); the median temperature was 21°C. The median change in temperature between morning and afternoon was 2.5°C. Lowest temperatures were recorded early in the morning, whereas highest temperatures generally were recorded in the middle of the afternoon.

The small tributaries between Botzum and Peninsula (Robinson, Langes, Dickerson, Salt, and Haskell Runs) had a median temperature of 17°C at base flow. These tributaries drain small, primarily forested areas, most of which are within the CVNRA. As a result, base flow is from ground-water seepage that is not augmented by major point sources.

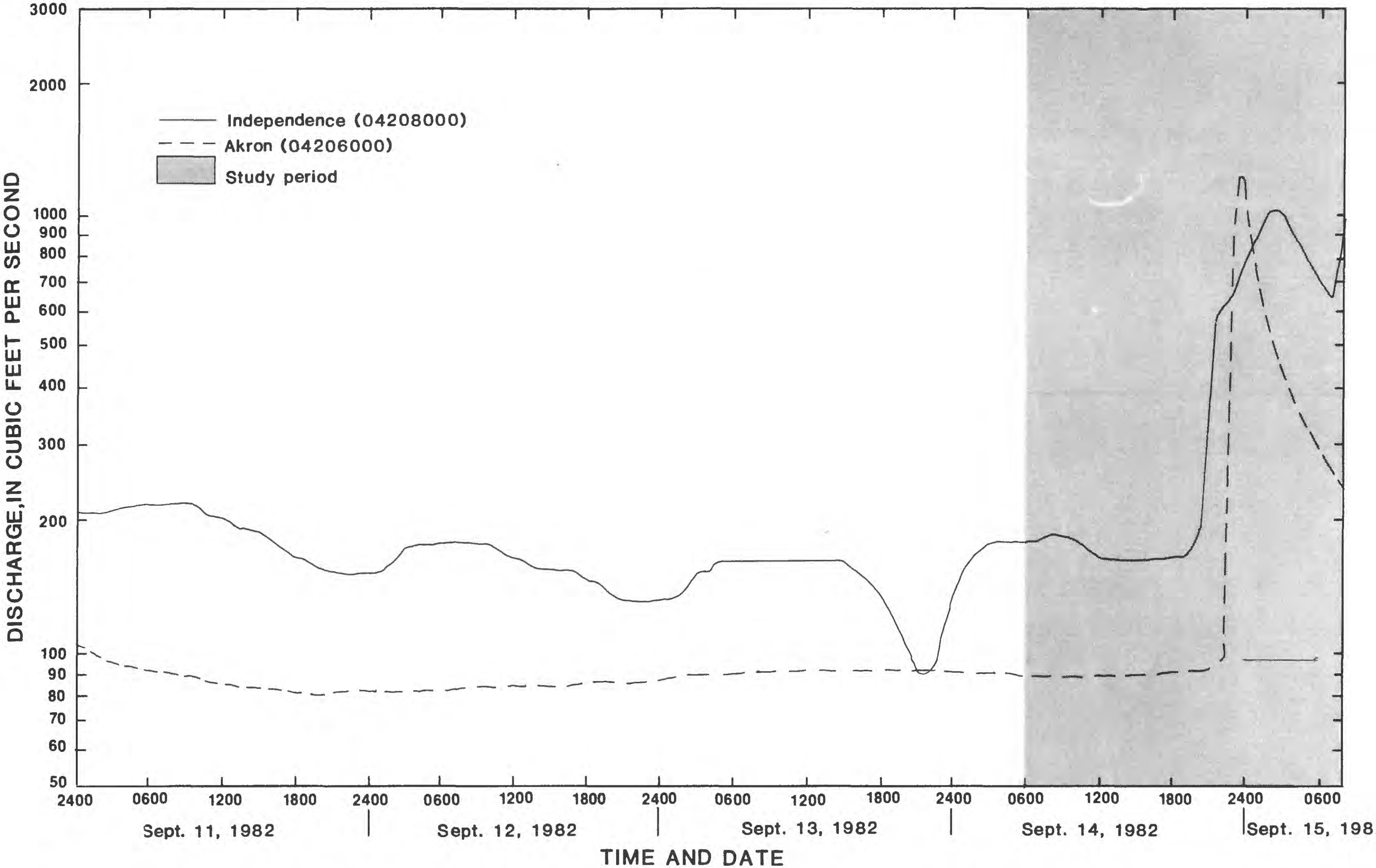

Figure 8.--Hydrograph for the gages at Independence and Akron from September 11 – 15, 1982

Table 3.--Water quality and discharge at selected sites

[ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter]

Date	Time	Instantaneous discharge (ft^3/s)	Specific conductance (µS/cm)	pH	Water temperature (°C)
Site 1-- Cuyahoga R at Old Portage, OH					
09/14/82	0620	81.0	-	-	-
Site 2-- Cuyahoga R nr Botzum, OH					
09/14/82	0605	-	820	7.8	21.0
09/14/82	0950	82.0	-	-	-
09/14/82	1005	-	820	7.9	22.0
09/14/82	1400	-	830	8.2	23.0
09/14/82	1800	-	825	8.1	24.0
09/15/82	0730	226.0	-	-	-
09/15/82	0745	-	625	7.9	23.0
Site 3-- Cuyahoga R at Botzum, OH					
09/14/82	0610	[1]150.0	870	7.7	21.0
09/14/82	1000	-	960	7.6	22.0
09/14/82	1400	-	970	7.5	22.5
09/14/82	1800	-	950	7.6	22.5
09/15/82	0700	[1]400.0	690	7.1	22.5
Site 4-- Cuyahoga R at Ira, OH					
09/14/82	0720	-	890	7.7	21.5
09/14/82	0910	161.0	-	-	-
09/14/82	1050	-	960	7.8	21.5
09/14/82	1455	-	1000	7.6	22.5
09/14/82	1850	-	980	7.6	23.0
09/15/82	0740	432.0	-	-	-
09/15/82	0830	-	610	7.4	22.5
Site 5-- Furnace Rn at Richfield, OH					
09/14/82	0630	1.9	-	-	-
09/14/82	0730	-	655	7.9	18.2
09/14/82	1105	-	648	7.8	20.4
09/14/82	1450	-	632	7.9	22.2
09/14/82	1855	-	637	8.3	21.4
09/15/82	0800	-	642	-	19.0
09/15/82	1100	6.2	-	-	-
Site 6-- Furnace Rn at Everett, OH					
09/14/82	0800	-	810	7.8	19.0
09/14/82	1120	1.7	-	-	-
09/14/82	1130	-	790	8.0	20.0
09/14/82	1520	-	805	8.2	23.0
09/14/82	1920	-	800	7.8	23.5
09/15/82	0850	-	710	7.5	20.0
09/15/82	0950	15.0	-	-	-
Site 7-- Robinson Rn at Everett, OH					
09/14/82	0800	-	1500	7.9	15.0
09/14/82	1000	-	1500	7.9	15.5
Site 7-- Robinson Rn at Everett, OH -- Continued					
09/14/82	1230	0.4	-	-	-
09/14/82	1400	-	1400	8.0	17.0
09/14/82	1800	-	1400	8.0	17.5
09/15/82	0720	-	1450	7.9	15.2
09/15/82	1045	.5	-	-	-
Site 8-- Langes Rn at Everett, OH					
09/14/82	0737	-	1300	7.9	13.5
09/14/82	1021	-	1300	7.9	16.0
09/14/82	1325	.1	-	-	-
09/14/82	1426	-	1350	7.9	20.0
09/14/82	1827	-	1400	7.8	18.2
09/15/82	0740	-	1690	7.9	15.0
09/15/82	1125	.1	-	-	-
Site 9-- Dickerson Rn at Peninsula, OH					
09/14/82	0716	-	1000	8.0	13.0
09/14/82	0805	.3	-	-	-
09/14/82	1130	-	1000	7.9	13.5
09/14/82	1449	-	1025	7.9	15.0
09/14/82	1845	-	1000	7.9	15.4
09/15/82	0725	.3	-	-	-
09/15/82	0800	-	1000	7.9	13.5
Site 10-- Salt Rn at Peninsula, OH					
09/14/82	0648	-	710	8.1	19.5
09/14/82	0725	.4	-	-	-
09/14/82	0952	-	710	8.1	20.5
09/14/82	1509	-	710	8.1	22.0
09/14/82	1905	-	705	7.8	21.5
09/15/82	0810	.6	-	-	-
09/15/82	0820	-	695	8.2	20.6
Site 11-- Haskell Rn at Peninsula, OH					
09/14/82	0600	-	1050	7.8	17.5
09/14/82	0630	.2	-	-	-
09/14/82	1114	-	1200	7.8	16.0
09/14/82	1534	-	875	7.8	20.0
09/14/82	1930	-	880	7.6	19.2
09/15/82	0845	-	778	7.8	19.0
09/15/82	0906	.2	-	-	-
Site 12-- Cuyahoga R at Peninsula, OH					
09/14/82	0750	-	985	7.6	20.7
09/14/82	0905	205.0	-	-	-
09/14/82	1130	-	927	7.7	22.1
09/14/82	1515	-	868	7.7	24.1
09/14/82	1930	-	895	7.6	23.6
09/15/82	0840	-	484	-	22.0
09/15/82	1035	477.0	-	-	-

Table 3.--Water quality and discharge at selected sites--Continued

Site 13--
Boston Rn at Peninsula, OH

Date	Time	Instantaneous discharge (ft^3/s)	Specific conductance (µS/cm)	pH	Water temperature (°C)
09/14/82	0835	-	737	8.0	18.3
09/14/82	1210	-	748	8.1	20.2
09/14/82	1430	.3	-	-	-
09/14/82	1545	-	742	7.9	21.9
09/14/82	2005	-	749	7.5	20.1
09/15/82	0810	.9	-	-	-
09/15/82	0820	-	688	-	18.0

Site 14--
Slipper Rn at Peninsula, OH

Date	Time	Instantaneous discharge (ft^3/s)	Specific conductance (µS/cm)	pH	Water temperature (°C)
09/14/82	0700	-	680	8.0	17.7
09/14/82	1040	-	680	7.8	19.5
09/14/82	1410	.1	-	-	-
09/14/82	1425	-	669	7.9	20.4
09/14/82	1825	-	680	8.2	19.1
09/15/82	0740	-	497	-	19.0
09/15/82	0950	.8	-	-	-

Site 15--
Spring Rn nr Peninsula, OH

Date	Time	Instantaneous discharge (ft^3/s)	Specific conductance (µS/cm)	pH	Water temperature (°C)
09/14/82	0615	-	1160	8.1	18.5
09/14/82	1015	-	1157	8.4	20.6
09/14/82	1100	.3	-	-	-
09/14/82	1405	-	1125	8.1	23.0
09/14/82	1800	-	1137	8.3	22.1
09/15/82	0720	-	1137	-	18.5
09/15/82	0810	1.4	-	-	-

Site 16--
Brandywine C at Boston Heights, OH

Date	Time	Instantaneous discharge (ft^3/s)	Specific conductance (µS/cm)	pH	Water temperature (°C)
09/14/82	0600	-	1034	7.5	20.0
09/14/82	0935	2.5	-	-	-
09/14/82	1125	-	1067	7.6	20.0
09/14/82	1440	-	1095	7.8	21.5
09/14/82	1805	-	1106	8.0	22.8
09/15/82	0750	19.0	-	-	-
09/15/82	0910	-	660	7.3	20.0

Site 17--
Brandywine C nr Jaite, OH

Date	Time	Instantaneous discharge (ft^3/s)	Specific conductance (µS/cm)	pH	Water temperature (°C)
09/14/82	0700	-	1050	7.8	19.5
09/14/82	0850	3.2	-	-	-

Site 17A--
Cuyahoga R at Jaite, OH

Date	Time	Instantaneous discharge (ft^3/s)	Specific conductance (µS/cm)	pH	Water temperature (°C)
09/14/82	1030	[1]208.0	945	7.5	21.5
09/14/82	1400	-	978	7.5	22.5
09/14/82	1830	-	948	7.4	23.5
09/15/82	0840	-	570	7.5	20.5
09/15/82	1030	592.0	-	-	-

Site 18--
Cuyahoga R nr Brecksville, OH

Date	Time	Instantaneous discharge (ft^3/s)	Specific conductance (µS/cm)	pH	Water temperature (°C)
09/14/82	0900	-	840	7.4	22.0

Site 18--
Cuyahoga R nr Brecksville, OH -- Continued

Date	Time	Instantaneous discharge (ft^3/s)	Specific conductance (µS/cm)	pH	Water temperature (°C)
09/14/82	0920	210.0	-	-	-
09/14/82	1145	-	870	7.4	22.5
09/14/82	1515	-	920	7.7	23.0
09/14/82	1825	-	925	7.7	23.0
09/15/82	0850	-	870	7.6	22.0
09/15/82	0945	776.0	-	-	-

Site 19--
Chippewa C at Brecksville, OH

Date	Time	Instantaneous discharge (ft^3/s)	Specific conductance (µS/cm)	pH	Water temperature (°C)
09/14/82	0755	2.2	-	-	-
09/14/82	0815	-	1010	8.0	19.5
09/14/82	1215	-	1025	8.3	20.0
09/14/82	1530	-	1015	8.6	21.0
09/14/82	1915	-	885	8.7	21.5
09/15/82	0812	-	655	8.0	20.0
09/15/82	0845	12.0	-	-	-

Site 20--
Chippewa C at Riverview Road nr Brecksville, OH

Date	Time	Instantaneous discharge (ft^3/s)	Specific conductance (µS/cm)	pH	Water temperature (°C)
09/14/82	0705	2.3	-	-	-
09/14/82	0730	-	1007	7.6	19.0
09/14/82	1150	-	1013	7.9	19.5
09/14/82	1510	-	998	8.3	21.5
09/14/82	1900	-	1002	8.3	22.0
09/15/82	0725	-	692	8.0	20.0
09/15/82	0940	16.0	-	-	-

Site 21--
Unnamed Tr to Cuyahoga R nr Northfield, OH

Date	Time	Instantaneous discharge (ft^3/s)	Specific conductance (µS/cm)	pH	Water temperature (°C)
09/14/82	0610	1.1	-	-	-
09/14/82	0615	-	720	7.7	19.5
09/14/82	1055	-	730	7.8	20.5
09/14/82	1415	-	720	8.0	22.0
09/14/82	1950	-	670	8.0	22.0
09/15/82	0730	4.7	-	-	-
09/15/82	0750	-	605	8.1	20.0

Site 22--
Unnamed Tr to Cuyahoga R at Independence, OH

Date	Time	Instantaneous discharge (ft^3/s)	Specific conductance (µS/cm)	pH	Water temperature (°C)
09/14/82	0730	-	830	7.6	18.5
09/14/82	0735	1.3	-	-	-
09/14/82	1110	-	815	7.7	19.5
09/14/82	1430	-	830	8.0	22.0
09/14/82	1930	-	735	7.8	21.0
09/15/82	0815	-	615	8.0	20.0
09/15/82	0918	5.9	-	-	-

Site 23--
Cuyahoga R nr Independence, OH

Date	Time	Instantaneous discharge (ft^3/s)	Specific conductance (µS/cm)	pH	Water temperature (°C)
09/14/82	0945	-	880	7.7	22.5
09/14/82	1045	219.0	-	-	-
09/14/82	1120	-	875	7.7	22.5
09/14/82	1445	-	850	7.9	23.5
09/14/82	1915	-	850	7.8	23.5
09/15/82	0815	1190	-	-	-

Table 3.--Water quality and discharge at selected sites--Continued

Date	Time	Instantaneous discharge (ft³/s)	Specific conductance (μS/cm)	pH	Water temperature (°C)
Site 23-- Cuyahoga R nr Independence, OH -- Continued					
09/14/82	0830	-	830	7.7	21.5
Site 24-- Tinkers C at Bedford, OH					
09/14/82	0600	-	906	7.8	20.8
09/14/82	0640	17.0	-	-	-
09/14/82	1030	-	810	7.8	21.5
09/14/82	1415	-	794	8.1	22.5
09/14/82	1900	-	820	7.5	22.0
09/15/82	0900	[2]56.0	616	8.0	21.1
Site 25-- Tinkers C nr Independence, OH					
09/14/82	0700	-	797	7.9	20.5
09/14/82	0815	23.0	-	-	-
09/14/82	1100	-	788	8.3	20.7
09/14/82	1500	-	780	9.2	23.1
09/14/82	1840	-	752	8.4	23.6
09/15/82	0800	114.0	-	-	-
09/15/82	0830	-	492	8.0	21.3
Site 26-- Cuyahoga R at Independence, OH					
09/14/82	0745	-	849	7.9	22.1
09/14/82	0955	181.0	-	-	-
09/14/82	1130	-	849	7.9	22.2
09/14/82	1530	-	853	8.3	23.4
09/14/82	1815	-	856	7.6	23.5
09/15/82	0745	[2]885.0	656	7.7	19.8

[1]Estimated discharge.
[2]Discharge calculated from stage record.

Specific conductance is an indirect measure of dissolved-solids concentration. The Ohio standard is 2,400 microsiemens per centimeter at 25°C (µS/cm) or no more than 240 µS/cm attributable to human activities (Ohio Environmental Protection Agency, 1978). Specific conductance generally is highest during the first flush of a storm, and decreases because of decreased dissolved-solids concentration due to dilution. The samples collected on September 15 were collected well after the first storm flush.

The range before rain was 632 to 1,500 µS/cm at Furnace Run and Robinson Run, respectively; the median was 875. After the rain, on the morning of September 15, specific conductance ranged from 484 to 1,690 µS/cm at Peninsula and Langes Run, respectively; the median was 660. Discharge in the small tributaries had decreased to near the levels of the previous day by the time the streams were sampled, and specific-conductance values were nearly the same as on September 14. Langes Run was the only site where specific conductance increased after the rain (from 1,350 to 1,690 µS/cm).

Specific conductances were highest at four of the small tributaries between Botzum and Peninsula that drain forested areas primarily fed by ground-water seepage: Robinson, Langes, Dickerson, and Haskell Runs. Specific conductances were at similar levels at Spring Run, Brandywine Creek, and Chippewa Creek, all of which drain areas with multiple land uses.

pH is a measure of the hydrogen-ion concentration. The Ohio standard is 6.5 to 9.0. The pH (table 3) ranged from 7.1 (below the Akron sewage-treatment plant at 0700 hours on September 15) to 9.2 (Tinkers Creek, downstream, at 1400 hours); the median is 7.9. The maximum value was the only pH value exceeding Ohio standards. No difference due to runoff was observed.

Fecal Bacteria

Fecal bacteria are nonpathogenic microorganisms that are used as indicators of the potential presence of pathogenic microorganisms. Certain members of both the genus streptococcus and the coliform group are primarily found in the fecal material of warm-blooded animals, including humans. The presence of those microorganisms in water indicates that there is contamination from animal waste. When the number of fecal bacteria is high, there is a high probablity that pathogenic organisms are present as well. The Ohio standards for primary and secondary contact recreation are 1,000 and 5,000 fecal coliform counts per 100 milliliters (mL), respectively. The tributaries in the study area are designated for primary contact recreation and the main stem for secondary contact recreation (Ohio Environmental Protection Agency, 1978).

Fecal bacteria counts generally were quite high throughout the reach (table 4). Counts range from 38 to 1,900,000 and from 790 to 600,000 per 100 mL of sample for fecal coliform (fig. 9) and fecal streptococcus (fig. 10), respectively. Highest fecal bacteria counts were on the main stem at Peninsula and Jaite, and from Langes Run, which drains some pasture (fig. 9). The relatively low fecal coliform counts just below the Akron sewage-treatment plant outfall could be due to chlorination of effluent.

On the main stem from Ira to Peninsula, fecal streptococcus and coliform counts increased by a factor of about 100 and fecal coliform counts were above the standard for secondary contact recreation. Among the tributaries to that reach, coliform counts above the standard were recorded at Robinson, Langes, and Haskell Runs; streptococcus counts greater than 1,000 per 100 mL were recorded at all but Dickerson Run.

On the main stem, from just below Peninsula to Independence, counts higher than the standard for secondary contact recreation were recorded at Jaite and Brecksville. However, it is possible for enriched waters to support the survival and reproduction of coliform bacteria, and thereby falsely indicate a health hazard (Dutka, 1979). The paper mill at Jaite would supply the necessary enrichment. Among the tributaries to that reach, fecal coliform counts greater than the standard were recorded at Brandywine Creek (16), Chippewa Creek (19), and both unnamed tributary sites; fecal streptococcus counts greater than 1,000 per 100 mL were recorded at all sites (except Spring Run, where a fecal streptococcus count was not made).

The highest fecal bacteria counts recorded were on the main stem at Jaite. Below Jaite, counts were progressively lower. Near Independence (sites 23 and 26) levels were equivalent to those recorded above Ira.

Dissolved Oxygen and Biochemical Oxygen Demand

Dissolved-oxygen concentration is a critical factor to the aquatic community because most organisms cannot survive at low dissolved-oxygen concentrations. Low in-stream dissolved-oxygen concentrations can result from thermal discharges that raise streamwater temperatures (oxygen is less soluble at high temperatures) or from biochemical oxygen demands (BOD) from unoxidized carbonaceous or nitrogenous organic material.

Dissolved oxygen fluctuates diurnally in response to aquatic life. Dissolved oxygen is normally at a maximum in the late afternoon and at a minimum in early morning. Photosynthesis usually exceeds respiration during the day, which results in net oxygen production. Respiration in the absence of photosynthesis at night results in net oxygen consumption.

Table 4.--Fecal streptococcus and coliform counts at selected sites

[mL, milliliter]

Site number	Site name	Date	Time	Fecal streptococcus (colonies per 100 mL)	Fecal coliform (colonies per 100 mL)
2	Cuyahoga R nr Botzum, OH-------------	09/14/82	1005	2,200	2,900
3	Cuyahoga R at Botzum, OH-------------	09/14/82	1000	12,000	2,500
4	Cuyahoga R at Ira, OH----------------	09/14/82	1050	1,600	9,700
5	Furnace Rn at Richfield, OH----------	09/14/82	1105	1,500	300
6	Furnace Rn at Everett, OH------------	09/14/82	1130	2,300	100
7	Robinson Rn at Everett, OH-----------	09/14/82	1000	2,200	1,800
8	Langes Rn at Everett, OH-------------	09/14/82	1021	150,000	360,000
9	Dickerson Rn at Peninsula, OH--------	09/14/82	1130	790	100
10	Salt Rn at Peninsula, OH-------------	09/14/82	0952	5,800	700
11	Haskell Rn at Peninsula, OH----------	09/14/82	1114	5,400	6,600
12	Cuyahoga R at Peninsula, OH----------	09/14/82	1130	110,000	1,200,000
13	Boston Rn at Peninsula, OH-----------	09/14/82	1210	1,400	400
14	Slipper Rn at Peninsula, OH----------	09/14/82	1040	2,300	38
15	Spring Rn nr Peninsula, OH-----------	09/14/82	1015	--	310
16	Brandywine C at Boston Heights, OH---	09/14/82	1125	4,800	4,200
17	Brandywine C nr Jaite, OH------------	09/14/82	0700	10,000	360
17A	Cuyahoga R at Jaite, OH--------------	09/14/82	1030	600,000	1,900,000
18	Cuyahoga R nr Brecksville, OH--------	09/14/82	1145	19,000	27,000
19	Chippewa C at Brecksville, OH--------	09/14/82	1215	2,900	1,700
20	Chippewa C at Riverview Road nr Breck, OH--------------------------	09/14/82	1150	1,300	260
21	Unnamed Tr to Cuyahoga R nr Northfield, OH---------------------	09/14/82	1055	6,800	1,100
22	Unnamed Tr to Cuyahoga R at Independence, OH-------------------	09/14/82	1110	5,900	9,600
23	Cuyahoga R nr Independence, OH-------	09/14/82	1120	1,300	530
24	Tinkers C at Bedford, OH-------------	09/14/82	1030	1,200	580
25	Tinkers C nr Independence, OH--------	09/14/82	1100	4,900	460
26	Cuyahoga R at Independence, OH-------	09/14/82	1130	1,500	3,100

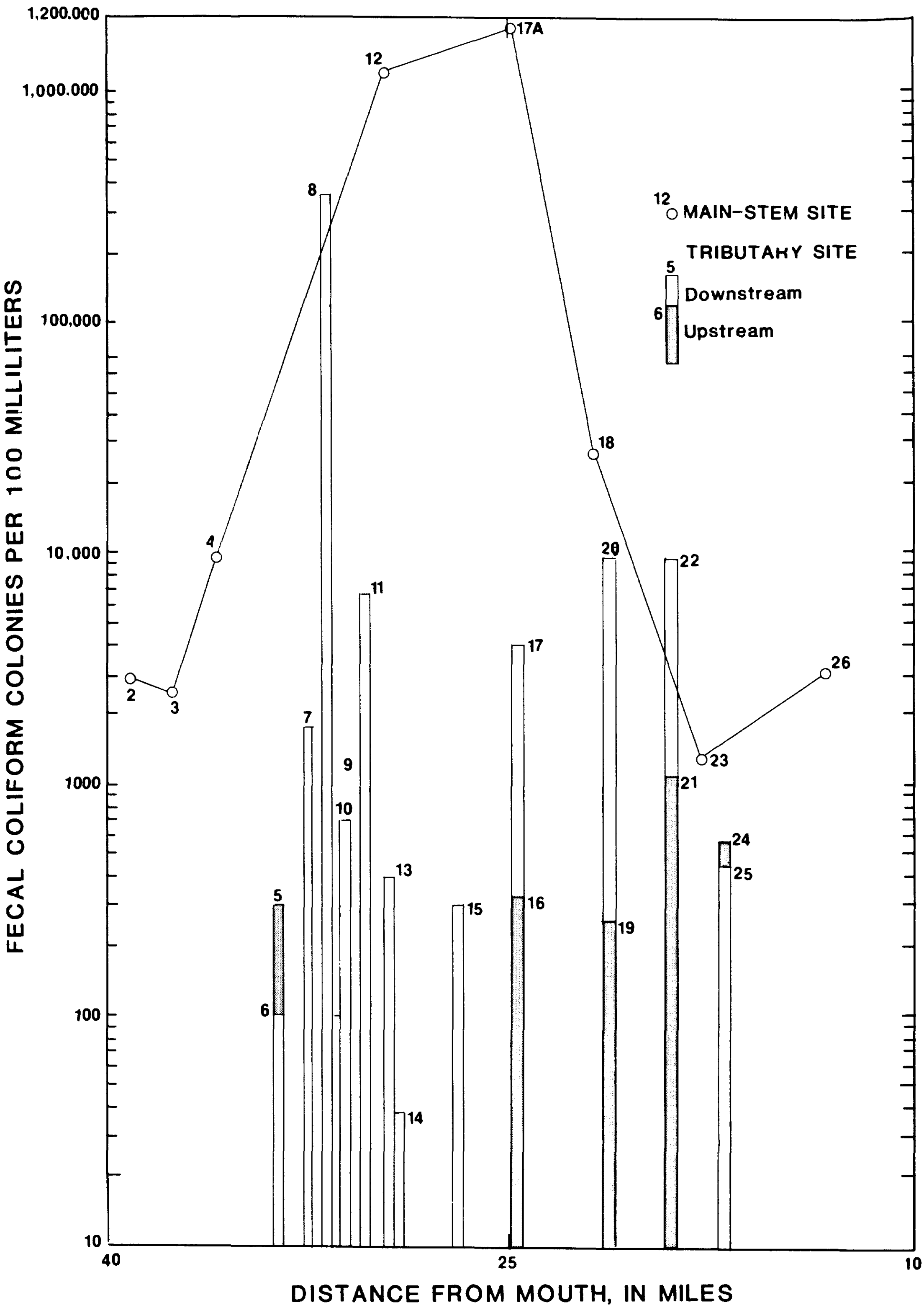

Figure 9.--Fecal-coliform counts on the main stem and tributaries, September 14, 1982.

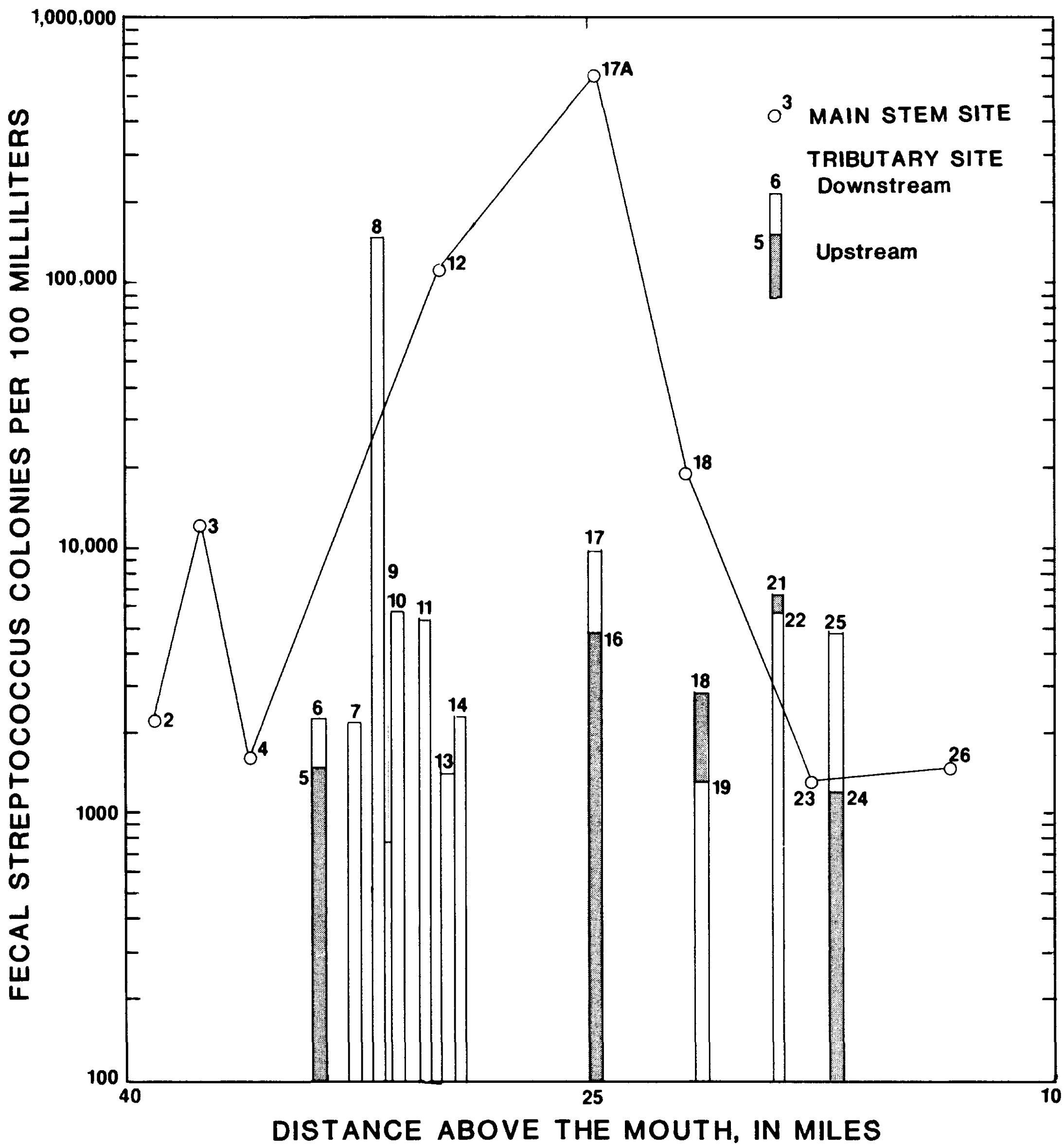

Figure 10.--Fecal-streptococcus counts on the main stem and tributaries, September 14, 1982.

The minimum allowable dissolved-oxygen concentration for streams designated by the Ohio Environmental Protection Agency as warmwater habitat (and for all of the stream segments in the study area designated as limited warmwater habitat except the upper end of Brandywine Creek) is 4 mg/L. In addition, dissolved oxygen may be less than 5 mg/L for a period not to exceed 8 hours in a 24-hour day (1978). Concentrations below this standard occurred on the main stem at Peninsula, Jaite, and Brecksville. The limit for the upper end of Brandywine Creek is 2.0 mg/L from June through October.

Dissolved-oxygen data are presented in table 5. Percent dissolved-oxygen saturation was calculated from measured dissolved-oxygen concentration and water temperature (American Public Health Association, 1975, p. 446) and is used to compensate for the effect of temperature on dissolved-oxygen concentration.

In general, dissolved oxygen was relatively high entering the study reach, decreased at Peninsula, and regained higher levels near Independence (fig. 11). Lowest concentrations generally were found from Peninsula (site 12) to Brecksville (site 18).

Minimum concentrations were reported in the afternoon at Jaite (2.3 and 1.8 mg/L) and exceeded the Ohio standard. Maximum concentrations, near 9.0 mg/L (100 percent) were reported in the afternoon at both ends of the reach. Concentrations at those same locations were about 6.0 mg/L (70 percent) in the morning.

Dissolved oxygen was uniformly low throughout the reach at 0600 hours. The range was 4.3 mg/L (48 percent) at Ira to only 5.8 mg/L (64 percent) above the Akron sewage-treatment plant near Botzum (fig. 11, table 5); dissolved oxygen was not measured at Jaite (site 17A) at that time.

Dissolved-oxygen concentrations on the tributaries were above 7 mg/L, with several exceptions. Downstream on Furnace Run, upstream on Brandywine Creek, both upstream and downstream on Tinkers Creek, and Langes Run all had concentrations recorded below 7.0 mg/L. However, none were below the Ohio standard (table 5).

The natural process of decay of organic wastes requires oxygen. CBODu is a measure of the amount of oxygen, in mg/L, needed to complete the decay process. It is thus an indirect measure of the amount of organic waste present in the watercourse. An estimate of CBODu traditionally is made with the BOD5 test. BOD5, in mg/L, is equal to the total amount of oxygen consumed in 5 days.

Table 5.--CBOD and dissolved-oxygen results at selected sites

[Underlined sites are on main stem. Ft^3/s, cubic foot per second; kg/d, kilogram per day; mg/L, milligram per liter. Dash indicates data are not available.]

Date	Time	Instantaneous discharge (ft^3/s)	Dissolved oxygen (mg/L)	Dissolved oxygen (percent saturation)	Biochemical oxygen demands 5-day (mg/L)	Ultimate (mg/L)	Reaction rate[1]	5-day load (kg/d)	Ultimate load (kg/d)
SITE 1 -- CUYAHOGA R AT OLD PORTAGE, OH									
09/14/82	0620	81.00	-	-	-	-	-	-	-
SITE 2 -- CUYAHOGA R NR BOTZUM, OH									
09/14/82	0605	-	5.8	64	2.2	4.8	.05	442.0	964.3
09/14/82	0950	82.00	-	-	-	-	-	-	-
09/14/82	1005	-	6.2	70	2.4	6.8	.04	482.2	1,366
09/14/82	1400	-	8.0	92	2.8	5.3	.07	562.5	1,065
09/14/82	1800	-	8.7	102	3.6	7.1	.07	723.2	1,426
09/15/82	0730	226.00	-	-	-	-	-	-	-
09/15/82	0745	-	6.4	74	7.0	12.0	.08	3,876	6,644
SITE 3 -- CUYAHOGA R AT BOTZUM, OH									
09/14/82	0610	150.00[2]	4.9	54	3.9	11.0	.03	1,433	4,042
09/14/82	1000	-	6.2	70	-	-	-	-	-
09/14/82	1400	-	6.9	79	18.0	66.0	.03	6,615	24,255
09/14/82	1800	-	7.6	87	-	-	-	-	-
09/15/82	0700	400.00[2]	7.0	80	7.2	15.0	.06	7,056	14,700
SITE 4 -- CUYAHOGA R AT IRA, OH									
09/14/82	0720	-	4.3	48	7.1	18.0	.04	2,801	7,100
09/14/82	0910	161.00	-	-	-	-	-	-	-
09/14/82	1050	-	6.1	69	3.0	11.0	.03	1,183	4,339
09/14/82	1455	-	6.5	74	4.8	13.0	.04	1,893	5,128
09/14/82	1850	-	6.5	75	4.1	9.7	.05	1,617	3,826
09/15/82	0740	432.00	-	-	-	-	-	-	-
09/15/82	0830	-	5.7	65	7.7	15.0	.07	8,150	15,876
SITE 5 -- FURNACE RN AT RICHFIELD, OH									
09/14/82	0630	1.90	-	-	-	-	-	-	-
09/14/82	0730	-	8.5	89	1.3	-	-	6.1	-
09/14/82	1105	-	9.0	99	-	-	-	-	-
09/14/82	1450	-	9.2	105	1.5	-	-	7.0	-
09/14/82	1855	-	8.4	94	-	-	-	-	-
09/15/82	0800	-	8.2	87	2.6	-	-	39.5	-
09/15/82	1100	6.20	-	-	-	-	-	-	-

Table 5.--CBOD and dissolved-oxygen results at selected sites--Continued

Date	Time	Instantaneous discharge (ft^3/s)	Dissolved oxygen (mg/L)	Dissolved oxygen (percent saturation)	Biochemical oxygen demands: 5-day (mg/L)	Ultimate (mg/L)	Reaction rate[1]	5-day load (kg/d)	Ultimate load (kg/d)
SITE 6 -- FURNACE RN AT EVERETT, OH									
09/14/82	0800	-	4.9	52	-	-	-	-	-
09/14/82	1120	1.70	-	-	-	-	-	-	-
09/14/82	1130	-	5.9	64	-	-	-	-	-
09/14/82	1520	-	7.2	83	.8	-	-	3.3	-
09/14/82	1920	-	6.8	79	-	-	-	-	-
09/15/82	0850	-	7.4	80	3.8	-	-	139.6	-
09/15/82	0950	15.00	-	-	-	-	-	-	-
SITE 7 -- ROBINSON RN AT EVERETT, OH									
09/14/82	0800	-	9.6	94	1.4	-	-	1.5	-
09/14/82	1000	-	9.8	97	-	-	-	-	-
09/14/82	1230	.45	-	-	-	-	-	-	-
09/14/82	1400	-	9.6	99	1.1	-	-	1.2	-
09/14/82	1800	-	8.8	92	-	-	-	-	-
09/15/82	0720	-	8.6	85	.9	-	-	1.2	-
09/15/82	1045	.53	-	-	-	-	-	-	-
SITE 8 -- LANGES RN AT EVERETT, OH									
09/14/82	0737	-	9.3	88	1.5	-	-	.4	-
09/14/82	1021	-	6.7	67	-	-	-	-	-
09/14/82	1325	.12	-	-	-	-	-	-	-
09/14/82	1426	-	5.7	62	10.8	-	-	3.2	-
09/14/82	1827	-	5.8	63	-	-	-	-	-
09/15/82	0740	-	8.1	79	4.1	-	-	1.1	-
09/15/82	1125	.11	-	-	-	-	-	-	-
SITE 9 -- DICKERSON RN AT PENINSULA, OH									
09/14/82	0716	-	9.6	90	.1	-	-	.1	-
09/14/82	0805	.29	-	-	-	-	-	-	-
09/14/82	1130	-	9.4	90	-	-	-	-	-
09/14/82	1449	-	9.3	91	1.0	-	-	.7	-
09/14/82	1845	-	8.4	83	-	-	-	-	-
09/15/82	0725	.34	-	-	-	-	-	-	-
09/15/82	0800	-	9.2	88	.3	-	-	.2	-

Table 5.--CBOD and dissolved-oxygen results at selected sites--Continued

Date	Time	Instantaneous discharge (ft^3/s)	Dissolved oxygen (mg/L)	Dissolved oxygen (percent saturation)	Biochemical oxygen demands 5-day (mg/L)	Ultimate (mg/L)	Reaction rate[1]	5-day load (kg/d)	Ultimate load (kg/d)
SITE 10 -- SALT RN AT PENINSULA, OH									
09/14/82	0648	-	9.0	97	.6	-	-	.6	-
09/14/82	0725	.40	-	-	-	-	-	-	-
09/14/82	0952	-	8.9	98	-	-	-	-	-
09/14/82	1509	-	8.8	100	1.1	-	-	1.1	-
09/14/82	1905	-	7.8	88	-	-	-	-	-
09/15/82	0810	.60	-	-	-	-	-	-	-
09/15/82	0820	-	8.8	96	.5	-	-	.7	-
SITE 11 -- HASKELL RN AT PENINSULA, OH									
09/14/82	0600	-	9.0	94	1.3	-	-	.7	-
09/14/82	0630	.22	-	-	-	-	-	-	-
09/14/82	1114	-	8.8	88	-	-	-	-	-
09/14/82	1534	-	9.0	98	1.3	-	-	.7	-
09/14/82	1930	-	7.7	82	-	-	-	-	-
09/15/82	0845	-	8.0	85	1.0	-	-	.5	-
09/15/82	0906	.22	-	-	-	-	-	-	-
SITE 12 -- CUYAHOGA R AT PENINSULA, OH									
09/14/82	0750	-	4.4	48	21.0	34.0	.08	10,547	17,076
09/14/82	0905	205.00	-	-	-	-	-	-	-
09/14/82	1130	-	4.0	45	13.0	27.0	.06	6,529	13,561
09/14/82	1515	-	5.4	64	5.7	13.0	.05	2,863	6,529
09/14/82	1930	-	6.1	71	4.4	9.4	.06	2,210	4,721
09/15/82	0840	-	3.9	44	11.0	23.0	.06	12,855	26,879
09/15/82	1035	477.00	-	-	-	-	-	-	-
SITE 13 -- BOSTON RN AT PENINSULA, OH									
09/14/82	0835	-	8.8	93	1.0	-	-	.8	-
09/14/82	1210	-	8.9	97	-	-	-	-	-
09/14/82	1430	.31	-	-	-	-	-	-	-
09/14/82	1545	-	8.8	100	1.7	-	-	1.3	-
09/14/82	2005	-	7.6	83	-	-	-	-	-
09/15/82	0810	.93	-	-	-	-	-	-	-
09/15/82	0820	-	7.3	77	.6	-	-	1.4	-

Table 5.--CBOD and dissolved-oxygen results at selected sites--Continued

Date	Time	Instantaneous discharge (ft^3/s)	Dissolved oxygen (mg/L)	Dissolved oxygen (percent saturation)	Biochemical oxygen demands: 5-day (mg/L)	Ultimate (mg/L)	Reaction rate[1]	5-day load (kg/d)	Ultimate load (kg/d)
SITE 14 -- SLIPPER RN AT PENINSULA, OH									
09/14/82	0700	-	9.3	97	.8	-	-	0.2	-
09/14/82	1040	-	8.9	96	-	-	-	-	-
09/14/82	1410	.11	-	-	-	-	-	-	-
09/14/82	1425	-	8.6	95	1.5	-	-	.4	-
09/14/82	1825	-	8.5	101	-	-	-	-	-
09/15/82	0740	-	8.7	93	.4	-	-	.7	-
09/15/82	0950	.75	-	-	-	-	-	-	-
SITE 15 -- SPRING RN NR PENINSULA, OH									
09/14/82	0615	-	9.2	97	1.5	-	-	1.1	-
09/14/82	1015	-	9.3	102	-	-	-	-	-
09/14/82	1100	.30	-	-	-	-	-	-	-
09/14/82	1405	-	9.4	108	1.9	-	-	1.4	-
09/14/82	1800	-	8.8	100	-	-	-	-	-
09/15/82	0720	-	9.0	95	1.5	-	-	5.1	-
09/15/82	0810	1.40	-	-	-	-	-	-	-
SITE 16 -- BRANDYWINE C AT BOSTON HEIGHTS, OH									
09/14/82	0600	-	5.1	55	2.7	-	-	16.5	-
09/14/82	0935	2.50	-	-	-	-	-	-	-
09/14/82	1125	-	5.9	64	-	-	-	-	-
09/14/82	1440	-	8.1	91	2.6	-	-	15.9	-
09/14/82	1805	-	8.1	93	-	-	-	-	-
09/15/82	0750	19.00	-	-	-	-	-	-	-
09/15/82	0910	-	9.5	103	3.6	-	-	167.6	-
SITE 17 -- BRANDYWINE C NR JAITE, OH									
09/14/82	0700	-	7.0	75	4.2	-	-	32.9	-
09/14/82	0850	3.20	-	-	-	-	-	-	-

Table 5.--CBOD and dissolved-oxygen results at selected sites--Continued

Date	Time	Instantaneous discharge (ft^3/s)	Dissolved oxygen (mg/L)	Dissolved oxygen (percent saturation)	Biochemical oxygen demands: 5-day (mg/L)	Ultimate (mg/L)	Reaction rate[1]	5-day load (kg/d)	Ultimate load (kg/d)
SITE 17A -- CUYAHOGA R AT JAITE, OH									
09/14/82	1030	208.00[2]	3.7	42	13.0	23.0	.07	6,625	11,721
09/14/82	1400	-	2.3	26	15.0	24.0	.08	7,644	12,230
09/14/82	1830	-	1.8	21	13.0	23.0	.07	6,625	11,721
09/15/82	0840	-	4.8	53	10.0	22.0	.05	14,504	31,909
09/15/82	1030	592.00	-	-	-	-	-	-	-
SITE 18 -- CUYAHOGA R NR BRECKSVILLE, OH									
09/14/82	0900	-	4.9	55	3.4	9.7	.04	1,749	4,991
09/14/82	0920	210.00	-	-	-	-	-	-	-
09/14/82	1145	-	4.5	51	7.8	48.0	.02	4,013	24,696
09/14/82	1515	-	4.2	48	11.0	20.0	.07	5,659	10,290
09/14/82	1825	-	4.3	49	13.0	22.0	.07	6,688	11,319
09/15/82	0850	-	3.0	34	6.7	14.0	.06	12,738	26,617
09/15/82	0945	776.00	-	-	-	-	-	-	-
SITE 19 -- CHIPPEWA C AT BRECKSVILLE, OH									
09/14/82	0755	2.20	-	-	-	-	-	-	-
09/14/82	0815	-	8.0	86	1.0	-	-	5.4	-
09/14/82	1215	-	9.3	101	-	-	-	-	-
09/14/82	1530	-	10.3	114	1.5	-	-	8.1	-
09/14/82	1915	-	8.3	93	-	-	-	-	-
09/15/82	0812	-	9.1	99	4.5	-	-	132.3	-
09/15/82	0845	12.00	-	-	-	-	-	-	-
SITE 20 -- CHIPPEWA C AT RIVERVIEW ROAD NR BRECKSVILLE, OH									
09/14/82	0705	2.30	-	-	-	-	-	-	-
09/14/82	0730	-	7.6	81	1.0	-	-	5.6	-
09/14/82	1150	-	9.1	98	-	-	-	-	-
09/14/82	1510	-	11.5	129	1.4	-	-	7.9	-
09/14/82	1900	-	9.5	108	-	-	-	-	-
09/15/82	0725	-	9.2	100	3.9	-	-	152.9	-
09/15/82	0940	16.00	-	-	-	-	-	-	-

Table 5.--CBOD and dissolved-oxygen results at selected sites--Continued

Date	Time	Instantaneous discharge (ft^3/s)	Dissolved oxygen (mg/L)	Dissolved oxygen (percent saturation)	Biochemical oxygen demands: 5-day (mg/L)	Biochemical oxygen demands: Ultimate (mg/L)	Biochemical oxygen demands: Reaction rate[1]	Biochemical oxygen demands: 5-day load (kg/d)	Biochemical oxygen demands: Ultimate load (kg/d)
SITE 21 -- UNNAMED TR TO CUYAHOGA R NR NORTHFIELD, OH									
09/14/82	0610	1.10	-	-	-	-	-	-	-
09/14/82	0615	-	8.2	88	3.4	-	-	9.2	-
09/14/82	1055	-	8.0	88	-	-	-	-	-
09/14/82	1415	-	8.6	98	2.9	-	-	7.8	-
09/14/82	1950	-	7.3	83	-	-	-	-	-
09/15/82	0730	4.70	-	-	-	-	-	-	-
09/15/82	0750	-	7.9	86	4.2	-	-	48.4	-
SITE 22 -- UNNAMED TR TO CUYAHOGA R AT INDEPENDENCE, OH									
09/14/82	0730	-	8.3	88	1.0	-	-	3.2	-
09/14/82	0735	1.30	-	-	-	-	-	-	-
09/14/82	1110	-	8.1	87	-	-	-	-	-
09/14/82	1430	-	8.7	99	2.1	-	-	6.7	-
09/14/82	1930	-	7.0	78	-	-	-	-	-
09/15/82	0815	-	7.5	82	2.8	-	-	40.5	-
09/15/82	0918	5.90	-	-	-	-	-	-	-
SITE 23 -- CUYAHOGA R NR INDEPENDENCE, OH									
09/14/82	0945	-	5.8	66	3.6	11.0	.03	1,932	5,902
09/14/82	1045	219.00	-	-	-	-	-	-	-
09/14/82	1120	-	6.1	70	2.7	10.0	.03	1,449	5,365
09/14/82	1445	-	6.8	79	3.4	7.4	.06	1,824	3,970
09/14/82	1915	-	6.7	78	5.8	12.0	.06	3,112	6,439
09/15/82	0815	1190	-	-	-	-	-	-	-
09/15/82	0830	-	5.7	64	5.3	12.0	.06	15,452	34,986
SITE 24 -- TINKERS C AT BEDFORD, OH									
09/14/82	0600	-	6.2	68	3.9	-	-	162.4	-
09/14/82	0640	17.00	-	-	-	-	-	-	-
09/14/82	1030	-	6.7	75	-	-	-	-	-
09/14/82	1415	-	9.0	103	3.5	-	-	145.8	-
09/14/82	1900	-	6.7	76	-	-	-	-	-
09/15/82	0900	56.00	7.6	84	4.5	-	-	617.4	-

Table 5.--CBOD and dissolved-oxygen results at selected sites--Continued

Date	Time	Instantaneous discharge (ft^3/s)	Dissolved oxygen (mg/L)	Dissolved oxygen (percent saturation)	Biochemical oxygen demands: 5-day (mg/L)	Ultimate (mg/L)	Reaction rate[1]	5-day load (kg/d)	Ultimate load (kg/d)
SITE 25 -- TINKERS C NR INDEPENDENCE, OH									
09/14/82	0700	-	5.8	64	2.4	-	-	135.2	-
09/14/82	0815	23.00	-	-	-	-	-	-	-
09/14/82	1100	-	9.0	99	-	-	-	-	-
09/14/82	1500	-	15.6	179	1.8	-	-	101.4	-
09/14/82	1840	-	11.0	128	-	-	-	-	-
09/15/82	0800	114.00	-	-	-	-	-	-	-
09/15/82	0830	-	7.7	87	5.1	-	-	1,424	-
SITE 26 -- CUYAHOGA R AT INDEPENDENCE, OH									
09/14/82	0745	-	5.5	62	3.0	14.0	.02	1,330	6,208
09/14/82	0955	181.00	-	-	-	-	-	-	-
09/14/82	1130	-	6.2	70	2.2	10.0	.02	975.6	4,434
09/14/82	1530	-	8.8	102	2.9	7.4	.05	1,286	3,282
09/14/82	1815	-	8.7	101	4.1	8.7	.06	1,818	3,858
09/15/82	0745	885.00	6.1	66	6.4	15.0	.05	13,877	32,524

[1]Reported as base 10 logarithm.
[2]Estimated.
[3]Calculated from stage.

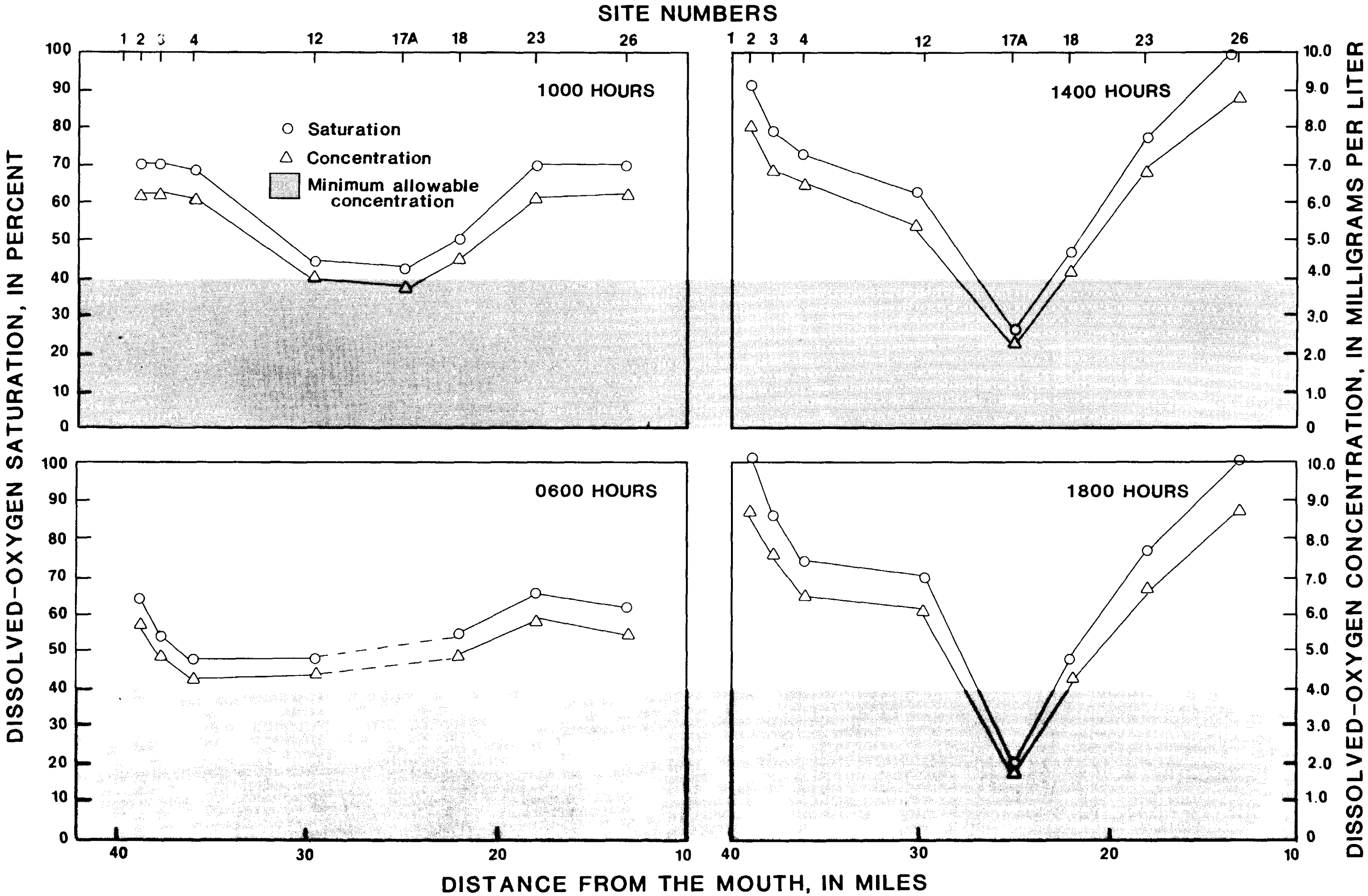

Figure 11.--Dissolved-oxygen saturation and concentration on the main stem of the Cuyahoga River at 0600, 1000, 1400, and 1800 hours, September 14, 1982

A significant concentration of ammonium, which typically is present in municipal wastewater, interferes with the CBODu test. Because the Akron sewage-treatment plant discharges effluent just upstream of the study reach, a nitrification inhibitor was used in the CBODu test. The naturally occurring bacteriological oxidation of ammonia (nitrification) uses significant amounts of oxygen (about 4.6 milligrams of oxygen for every milligram of NH_4 as N). However, unlike oxidation of carbonaceous organic material, nitrification does not represent a permanent loss of oxygen from the system because oxygen is available from nitrate when dissolved oxygen has been depleted. Interference normally is not a problem with the BOD5 test because nitrification usually does not begin until several days after incubation of the sample.

According to Phelps' Law, "the rate of biochemical oxidation of organic matter is proportional to the remaining concentration of unoxidized substance, measured in terms of oxidizability" (Velz, 1970). Expressed mathematically, Phelps' Law states that

$$\frac{L_t}{L} = 10^{-kt}$$

where L is the ultimate demand,
L_t is the remaining demand at time t, and
k is the deoxygenation rate.

The normal rate of deoxygenation is k = 0.10 at 20°C. At this rate, after the first day, deoxygenation is 20.6 percent complete and 20.6 percent of the remaining unoxidized organic material is oxidized each following day. The half life is 3 days, and at the end of 5 days, 68 percent of the ultimate demand remains. Therefore, if k is assumed to be normal, CBODu is calculated from BOD5 by dividing by 0.68. The deoxygenation rate calculated during this study ranged from 0.02 to 0.08. The mean of the observed k rates was 0.05; this is a decay rate of 11 percent per day with a half life of 6 days. The 95-percent confidence limits around the mean are 0.04 and 0.06. Only the mean k rate calculated at Jaite was outside that range (0.07), which indicates a faster rate of deoxygenation at that site. Because deoxygenation rates are less than 0.10, CBODu calculated from measured BOD5 should be adjusted to reflect the lower rate.

Peak concentrations of CBODu were at Peninsula at 0600 hours, at Peninsula, Jaite, and Brecksville at 1000 hours, below the Akron sewage-treatment plant and at Jaite and Brecksville at 1400 hours, and at Jaite and Brecksville at 1800 hours (fig. 12, table 5). CBODu concentrations at Peninsula fluctuated over the

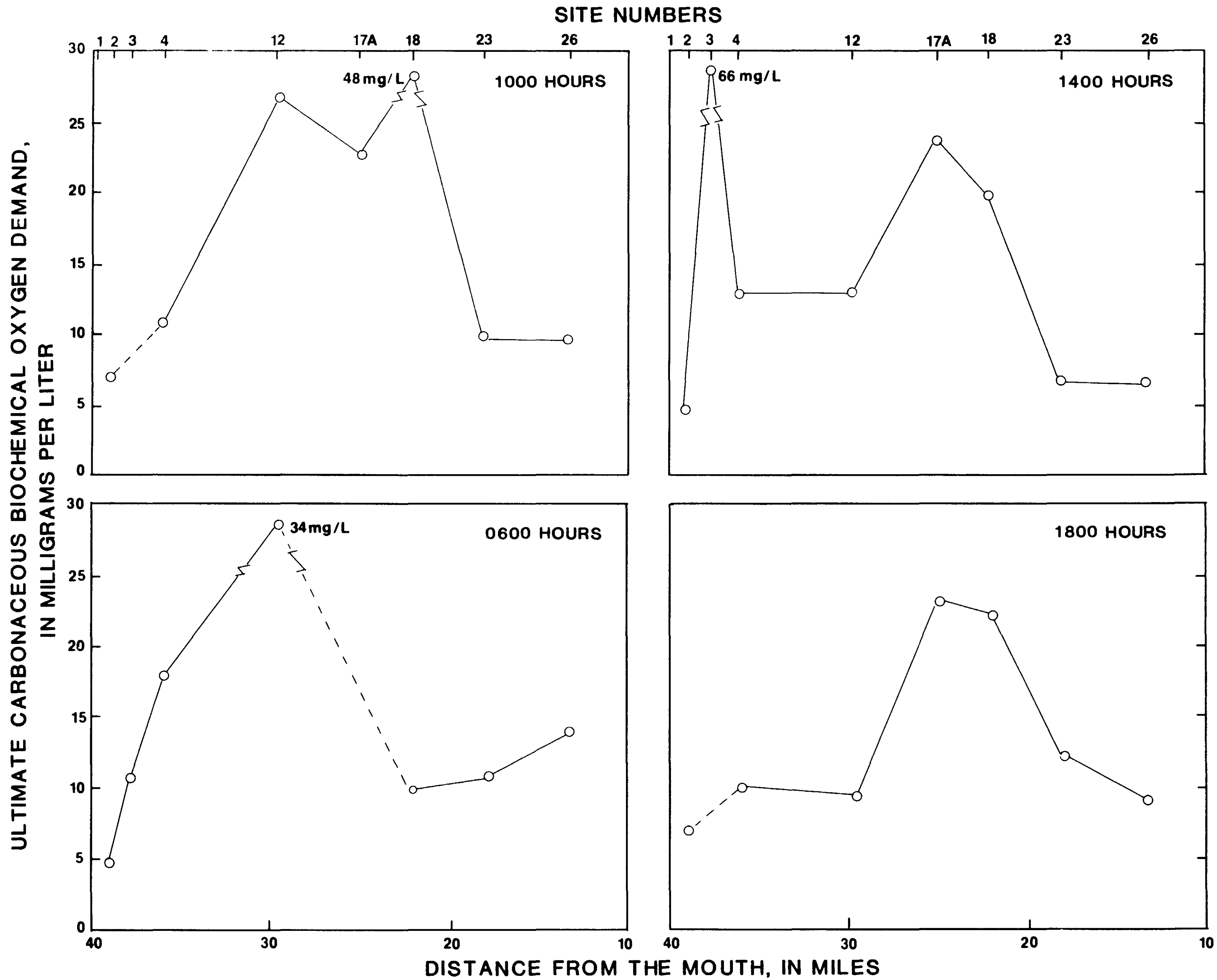

Figure 12.--Ultimate carbonaceous biochemical oxygen demand at selected sites on the Cuyahoga River

study period; this is possibly due to fluctuating concentrations from the Akron sewage-treatment plant, which is the only major point source between the Old Portage gage (site 1) and Peninsula. CBODu concentrations at Jaite, however, were consistently high throughout the study period (it was not measured at 0600 hours). One possible source is effluent from the paper mill. Brandywine Creek was sampled only once below the paper-mill outfall because access was denied, therefore, the concentration of BOD from the effluent could not be estimated. The load from the Akron sewage-treatment plant, estimated as the difference between the load above and below Botzum, was 3,100, 23,000, and 8,100 kilograms per day (kg/d) at 0600 and 1400 hours on September 14 and at 0700 hours on September 15, respectively.

At 0600 hours, instantaneous BOD5 loads ranged from 440 to 10,500 kg/d on the main stem above the Akron sewage-treatment plant and at Peninsula, respectively (fig. 13, table 5). The load from the Akron sewage-treatment plant was approximately 990 kg/d. Tributary loads were small relative to loads on the main stem, and could not cause the observed dissolved-oxygen sag. Tributary loads ranged from 0.1 to 160 kg/d. Highest tributary loads of 160, 140, 16, and 33 kg/d were for the upstream and downstream sites on Tinkers Creek and Brandywine Creek, respectively.

At 1400 hours, BOD5 loads ranged from 560 to 7,600 kg/d on the main stem above the Akron sewage-treatment plant and at Jaite, respectively. The BOD5 load below the Akron sewage-treatment plant was 6,600 kg/d. The Akron sewage-treatment plant effluent load was approximately 6,000 kg/d. The tributaries contributing the highest loads were upstream and downstream Tinkers Creek, and Brandywine Creek, with 150, 100, and 16 kg/d, respectively.

Samples collected beginning at 0700 hours on September 15 reflect conditions with runoff. Rainfall delivers organic material that has accumulated on the land surface to streams and rivers. In addition, when the Akron sewage-treatment plant becomes overloaded with combined sewage and runoff, wastewater entering the plant is bypassed or residence time in the plant is too short for proper treatment. As a result, BOD loads during runoff were higher than at base flow. The estimated CBODu load from the Akron sewage-treatment plant was 8,100 kg/d at 0700 hours, 7 hours after the peak discharge. CBODu and BOD5 loads on the main stem were uniformly high throughout the reach (fig. 14) and were higher than loads at base flow. BOD5 loads ranged from 3,900 to 15,500 kg/d above the sewage-treatment plant and near Independence, respectively.

On the tributaries, BOD5 loads and discharge after the rain were higher than before the rain except at six sites. At Robinson, Dickerson, Salt, and Haskell Runs, discharge on September 15 was very near the discharge of the previous day and BOD5 load was not significantly different.

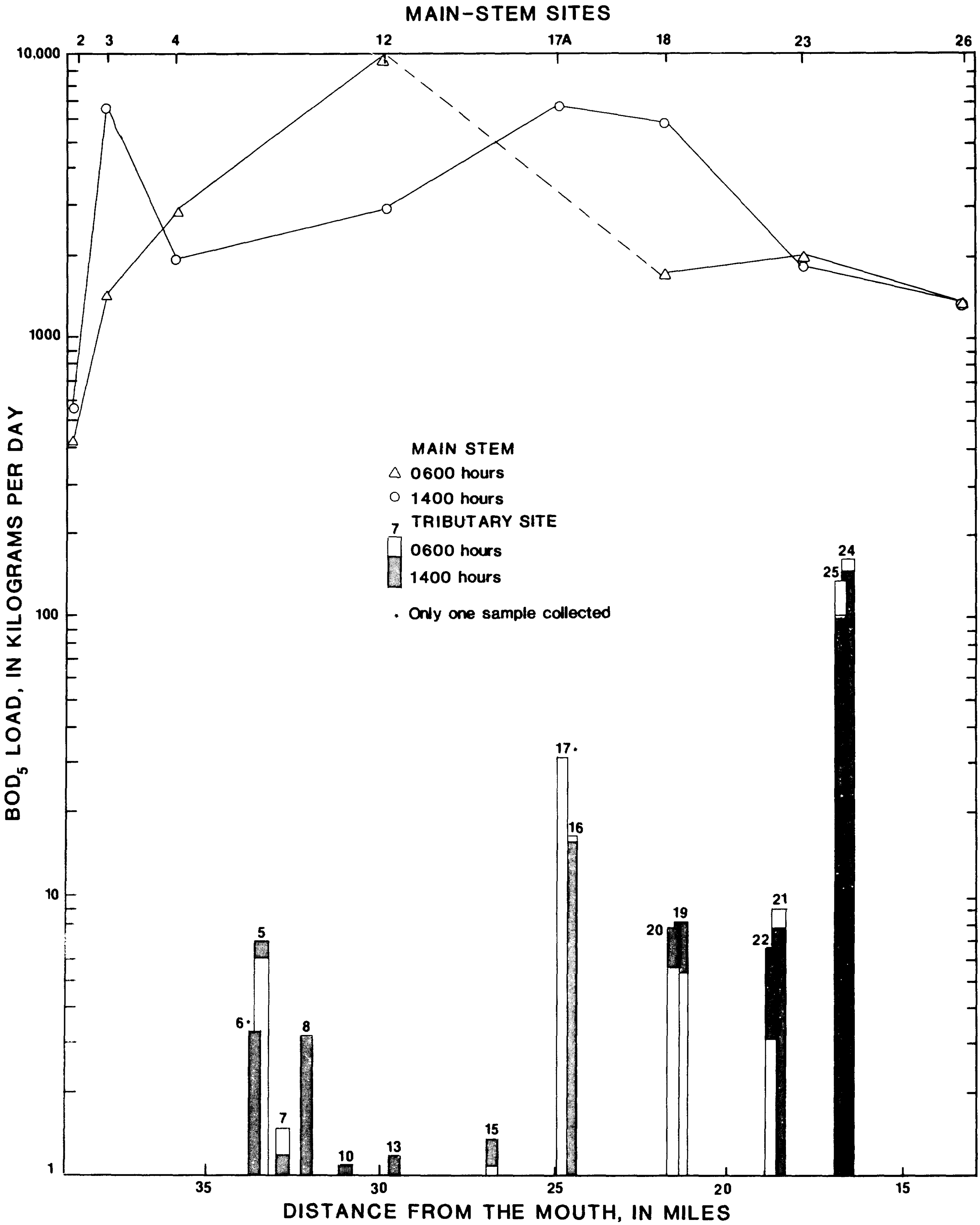

Figure 13.--Daily BOD_5 load on the main stem and tributary sites at 0600 and 1400 hours on September 14, 1982.(loads less than 1 kilogram per day are not shown)

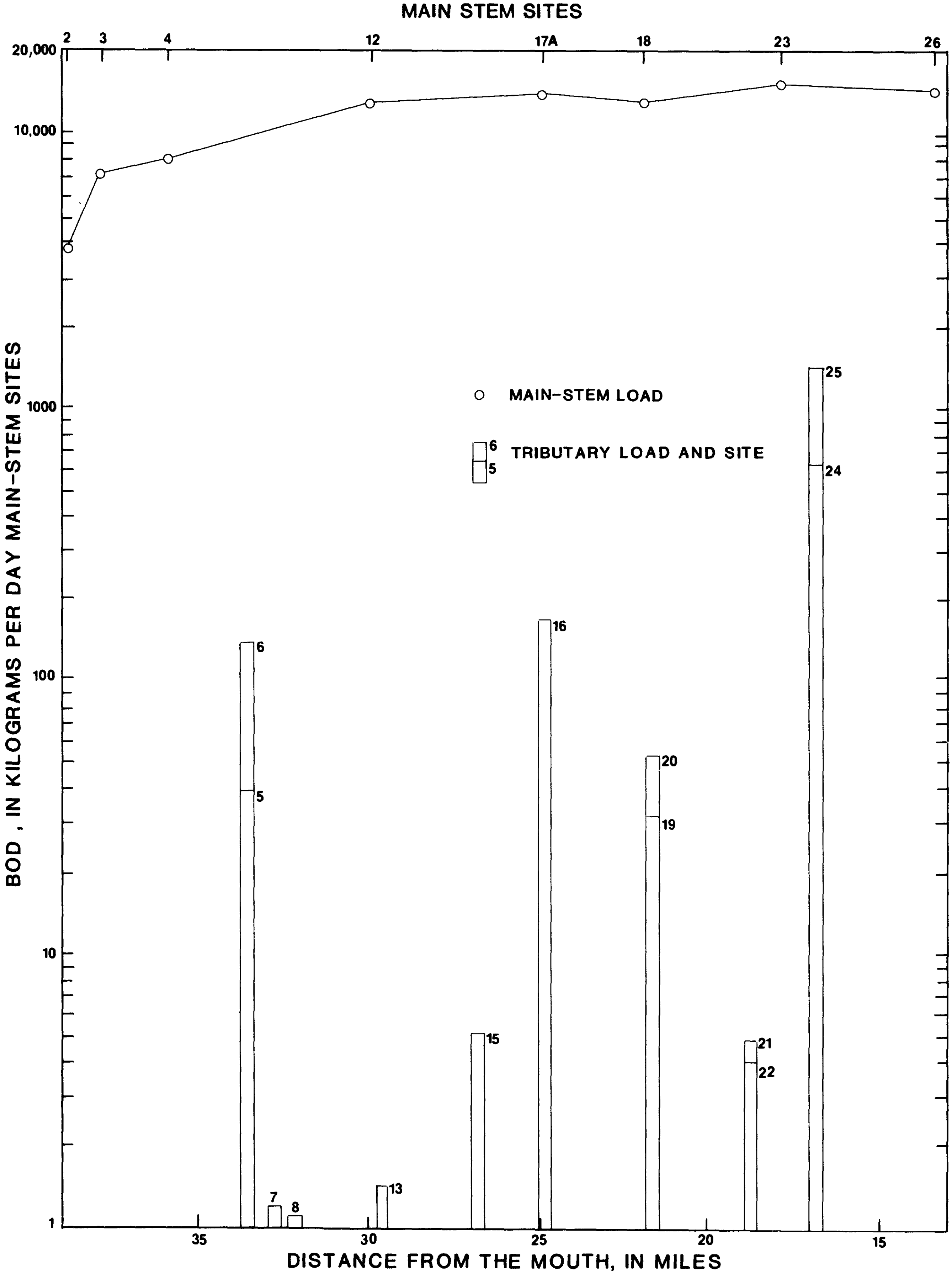

Figure 14.—Daily BOD_5 load on the main stem and tributaries at 0700 hours on September 15, 1982. (loads less than 1 kilogram per day are not shown)

At Boston Run, discharge was somewhat higher than before the rain, but BOD5 load was not significantly different; thus, the concentration of BOD5 actually had decreased. At Langes Run, BOD5 load was between the two levels measured the previous day, but discharge was unchanged.

On tributaries where BOD5 loads were higher than at base flow, the increases ranged from 2.5 to 42 times at Slipper Run and Furnace Run (site 6), respectively. Large increases also were recorded at Chippewa Creek (site 20; 22 times), Tinkers Creek (site 25; 12 times), and Brandywine Creek (site 16; 11 times).

BED-MATERIAL QUALITY

Toxic substances, such as heavy metals, usually are found in low concentrations in water. Furthermore, contributions of these materials by nonpoint sources may be intermittent, particularly if storm related. As a result, these constituents may not be detected in a single, randomly collected water sample.

Many constituents, particularly metals, are adsorbed to particulates. As particulates accumulate on the stream bed, toxic constituents may be found in higher concentrations than in the water column. As a result, bed material often integrates the effects of upstream point and nonpoint sources.

Concentrations of arsenic, boron, cadmium, cobalt, selenium, and mercury generally were below the limit of detection (table 6). Concentrations of copper, lead, manganese, nickel, strontium, zinc, aluminum, and iron were generally present at concentrations well above the detection limit. Medians, 25 percentiles, and 75 percentiles are shown in table 6.

Six tributaries accounted for all of the metals concentrations that are "outside values" (table 6): Robinson Run (aluminum, manganese, iron, strontium, and cobalt); Langes Run (arsenic); Dickerson Run (iron, manganese, arsenic, and lead); Salt Run (arsenic); Chippewa Creek (aluminum, boron, cadmium, and chromium); and Tinkers Creek (nickel, cadmium, and chromium).

Aluminum, iron, and manganese -- found in highest concentrations at Robinson Run, Dickerson Run, and Chippewa Creek -- are abundant in rocks and soils and are toxic only in very large concentrations. Rock is also the primary source for boron, which was highest at Chippewa Creek (20 µg/g). Although boron is not abundant, it is important for plant growth (Hem, 1970). Cobalt generally is present only in trace amounts in water but is readily adsorbed to colloidal particles of iron and manganese hydroxides. In Robinson Run, where cobalt was found in greatest abundance (40 µg/g), iron and manganese concentrations also were highest.

Table 6.--Concentrations of selected constituents recoverable from bottom material from samples collected on August 17 and 18, 1982

Site number		Concentration of constituent, in micrograms per gram						
Main stem	Tributary	Aluminum	Iron	Manganese	Arsenic	Boron	Cadmium	Chromium
4----------		3,100	15,000	610	1	10	2	20
	5	2,900	9,100	720	1	10	1	20
	6	3,900	17,000	1,000	<1	<10	1	10
	7	*7,800	*36,000	*6,900	<1	10	2	10
	8	3,900	16,000	1,200	*5	10	<1	6
	9	3,100	*34,000	*4,700	*5	10	1	5
	10	2,800	13,000	1,000	*4	10	1	4
	13	2,000	6,600	670	2	10	<1	5
	14	2,500	10,000	1,100	2	10	1	4
	15	2,300	8,000	400	2	10	1	5
	16	2,700	8,300	1,000	<1	<10	1	8
18----------		3,100	16,000	790	<1	<10	2	20
	20	*5,100	11,000	480	1	*20	*6	*30
	21	1,100	4,200	350	2	10	1	20
	22	2,900	9,700	1,100	<1	<10	1	10
	24	2,700	10,000	890	1	10	2	20
	25	2,800	8,400	900	1	10	*8	*30
26----------		1,900	7,400	240	2	10	2	7
Summary statistics								
75 percentile		3,300	16,000	1,100	2	10	2	20
Median--------		2,850	10,000	900	1	10	1	10
25 percentile		2,450	8,200	580	<1	<10	<1	5

Table 6.--Concentrations of selected constituents recoverable from bottom material from samples collected on August 17 and 18, 1982--Continued

Site number: Main stem	Site number: Tributary	Concentration of constituent, in micrograms per gram: Copper	Lead	Mercury	Nickel	Selenium	Strontium	Zinc	Cobalt
4----------		39	70	<0.10	20	<1	13	200	10
	5	19	50	<.01	30	<1	28	72	10
	6	15	20	<.01	20	<1	20	61	10
	7	34	100	<.01	60	<1	*120	140	*40
	8	22	40	<.01	20	<1	19	82	10
	9	16	*130	<.01	20	<1	20	58	10
	10	19	100	<.01	30	<1	18	72	10
	13	7	20	<.01	10	<1	21	48	10
	14	15	30	<.01	10	<1	14	67	10
	15	14	20	<.01	20	<1	27	33	10
	16	51	30	<.01	10	<1	21	59	<10
18----------		42	70	<.01	20	<1	17	220	10
	20	27	50	<.01	50	<1	38	210	10
	21	16	40	<.01	<10	<1	12	51	10
	22	54	30	<.01	20	<1	21	67	<10
	24	29	60	<.01	*80	<1	20	140	10
	25	58	70	<.01	50	<1	31	190	10
26----------		26	60	<.01	30	<1	12	130	<10
Summary statistics									
75 percentile		40	70	<.01	35	--	28	150	10
Median-------		24	50	<.01	20	--	20	72	10
25 percentile		16	30	<.01	18	--	16	69	10

*Outside value: Any value greater than 75 percentile + (interquartile range), where interquartile range = 75 percentile - 25 percentile.

The remaining constituents are not abundant in rocks and usually are associated with a cultural source. The heavy metal cadmium and the metals chromium and nickel, found in highest concentration at Chippewa Creek and Tinkers Creek, generally are associated with industry (Hem, 1970).

Highest concentrations of lead were found on Dickerson Run (130 µg/g); concentrations were nearly as high on Robinson and Salt Runs (100 µg/g). The introduction of lead to natural water usually is associated with urban areas where lead from the combustion of gasoline accumulates on road surfaces and subsequently is washed into streams.

Highest arsenic concentrations (about 5 µg/g) were found at Langes, Dickerson, and Salt Runs, all of which drain an area that is largely in forest or crops. Certain herbicides and insecticides contain arsenic. Arsenic is persistent in soils and can accumulate with repeated applications of such compounds (McEwen and Stephenson, 1979).

There were no significant differences between the concentrations of constituents sampled at the main-stem sites; thus, none of the tributaries could be singled out as a potential source of toxic material. However, concentrations of manganese, lead, nickel, and zinc were higher on the main stem than at most of the tributary sites.

SUMMARY AND CONCLUSIONS

Three studies were conducted in the Cuyahoga River basin within the Cuyahoga Valley National Recreation Area: (1) Measurement of time of travel, (2) a 24-hour water-quality survey, and (3) a survey of concentrations of metals in bed materials.

Time of travel was measured on the main stem (with discharge at the Independence gage used as an index) from the upstream to the downstream terminus of the CVNRA at 222 and 720 ft^3/s in 1983 and from the upstream end of the CVNRA to Peninsula at 376 ft^3/s in 1981. Time of travel is described by the following equations:

$$T = -0.038Q + 46.9 \quad \text{(between Botzum and Independence)} \quad (1)$$

$$T = -0.009Q + 13.0 \quad \text{(between Botzum and Peninsula)} \quad (2)$$

These equations are valid only for discharges (measured at the Independence gage) ranging from 222 to 720 ft^3/s. At a flow of 222 ft^3/s, some pooling occurred behind the diversion dam at Brecksville. The pooling effect would be even greater at lower flows and would significantly lengthen the time of travel.

A water-quality survey was conducted over a 12-hour low-flow period on September 14, and water quality was measured at high flow on September 15, 1982. The following constituents were measured: Water temperature, specific conductance, pH, dissolved oxygen, biochemical oxygen demand, and fecal bacteria. In addition, discharge was measured at each site.

Dissolved-oxygen concentrations ranged from 1.8 to 10.3 mg/L. The Ohio standard for dissolved oxygen was exceeded on the main stem at Jaite, Peninsula, and Brecksville. Dissolved-oxygen concentrations were above 7 mg/L on the tributaries except on Tinkers Creek, Brandywine Creek, and Langes Run, but Ohio standards were not exceeded.

CBODu loads on the main stem ranged from 960 to 35,000 kg/d. Highest loads were observed at high flow at all sites on the main stem. Peak CBODu loads at low flow were recorded at Peninsula, Jaite, and Brecksville in the morning and at Botzum, Jaite, and Brecksville in the afternoon. CBODu loads at Peninsula fluctuated over the study period; CBODu at Jaite was high throughout the study period. Rates of carbonaceous deoxygenation ranged from 0.02 to 0.08.

Tributary BOD5 loads ranged from 0.1 to 1,400 kg/d. Loads from the tributaries at low flow were not high enough to cause the dissolved-oxygen sag observed on the main stem. The highest loads occurred during high flow on Furnace Run, Brandywine Creek, Chippewa Creek, and Tinkers Creek. BOD loads during high flow were higher than during low flow, except on the 6 smallest tributaries between Botzum and Peninsula. The increase in BOD loads at high flow is attributed to nonpoint sources.

Fecal bacteria samples were collected once (in the morning). The number of fecal coliform colonies per 100 mL of sample ranged from 38 to 1,900,000. On the main stem, counts were highest at Peninsula and Jaite. Counts at all of the main-stem sites exceeded Ohio standards for primary contact recreation, and counts at all but Botzum and Independence exceeded the Ohio standard for secondary contact recreation. The relatively low fecal coliform counts just below the Akron sewage-treatment plant may be due to chlorination of effluent. An extremely high count was recorded at Langes Run, which drains pasture. Ohio fecal coliform standards for primary recreation were exceeded at Haskell Run, Langes Run, Robinson Run, Brandywine Creek, Chippewa Creek, and the unnamed tributary. Counts from Langes and Haskell Runs also exceeded the Ohio standards for secondary contact recreation.

Although several of the tributaries (such as Langes, Robinson, and Haskell Runs and the unnamed tributary at Independence) were found to contribute significantly greater BOD loads or bacterial contamination than the other tributaries, their contribution is small relative to that already present in the main stem from upstream sources. Two of the larger tributaries, Tinkers Creek and Brandywine Creek, contribute a relatively larger share of the BOD load and bacterial contamination, but it is still small when compared to the main stem.

Median pH was 7.9 and median specific conductance was 850 µS/cm. The highest specific conductances were measured at Langes Run and Robinson Run.

Bed-material samples were collected from 18 sites on the main stem and tributaries for analysis of aluminum, arsenic, boron, cadmium, cobalt, copper, iron, lead, manganese, mercury, nickel, selenium, strontium, and zinc. Concentrations of arsenic, boron, cadmium, cobalt, selenium, and mercury generally were below the limit of detection. Concentrations of aluminum, copper, iron, lead, manganese, nickel, strontium, and zinc generally were well above the limit of detection, but there were no anomalous concentrations.

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