

SUMMARY OF FLUVIAL-SEDIMENT STUDIES IN OHIO, THROUGH 1987

By Steven M. Hindall

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 89-4066

Columbus, Ohio
1989



DEPARTMENT OF THE INTERIOR
MANUEL LUJAN, JR., Secretary
U.S. GEOLOGICAL SURVEY
Dallas L. Peck, Director

For additional information
write to:

District Chief
U.S. Geological Survey
975 W. Third Avenue
Columbus, OH 43212-3192

Copies of this report can
be purchased from:

U.S. Geological Survey
Books and Open-File Reports
Box 25425, Federal Center
Building 810
Denver, CO 80225

CONTENTS

Glossary	v
Abstract	1
Introduction	2
Purpose and Scope	2
Acknowledgments	3
Fluvial-sediment investigations conducted by the U.S. Geological Survey in Ohio through 1987	3
Description and summary of available fluvial sediment data, through 1987	6
Analysis of suspended-sediment discharge data	7
Suspended-sediment discharge trends at selected sites on Ohio streams	8
Estimating mean annual suspended-sediment discharge for Ohio streams	12
Summary and Conclusions	13
References	18

ILLUSTRATIONS

Figure 1. Map showing locations of project areas of sediment studies and stations used in regression analysis	5
2. Map showing location of sediment-data-collection sites in Ohio, October 1987 (<i>in pocket</i>)	
3. Double mass curves of sediment and water discharge for Muskingum River at Dresden, Scioto River at Higby, and Maumee River at Waterville	10
4. Double mass curves of sediment and water discharge for Sandusky River near Fremont and Cuyahoga River at Independence	11
5. Scatter plot of mean annual suspended-sediment discharge and mean annual water discharge showing the regression line for equation 1	15
6. Scatter plot of mean annual suspended-sediment discharge and drainage area showing the regression line for equation 2	16

TABLES

Table 1. Available fluvial-sediment data in Ohio through October 1987	20
2. Regression equations for estimating the mean annual suspended-sediment discharge	13
3. Sediment stations used in regression analysis	14

GLOSSARY

The following are definitions of selected technical symbols and terms as they are used in this report. They are not necessarily the only valid definitions for these terms.

Bed Load.—the sediment that is transported in a stream by rolling, sliding, or skipping along the bed and very close to it. In this report, bed load is considered to consist of particles in transit within 0.25 foot of the streambed.

Bed Material.—the unconsolidated material comprising a streambed, or floor of a lake, pond, reservoir, or estuary.

Daily Sediment Record.—a record of sediment discharge prepared for sites where sufficient determinations of sediment concentration and water discharge are obtained to justify computation of daily sediment discharge (Porterfield, 1972).

Discharge of Water or Sediment.—time rate of movement of volume or weight of the water or sediment past a point or through a cross section (Colby, 1963).

Fluvial Sediment.—sediment that is transported by, or suspended in, water or has been deposited in beds by water (Colby, 1963).

Gaging Station.—a particular site on a stream, canal, lake, or reservoir where systematic observations of hydrologic data are obtained.

Intermittent Record.—same as periodic record for this report (see *periodic record*).

Particle Size.—the diameter, in millimeters, of suspended sediment or bed material as determined by sieve or sedimentation methods. Sedimentation methods (pipet, bottom-withdrawal tube, visual-accumulation tube) determine fall diameter of particles in distilled water (chemically dispersed) or native water (the river water at the time and point of sampling).

Periodic Record.—a record of sediment discharge prepared for sites where determinations of sediment concentrations and water discharge are not sufficient to justify computation of daily sediment discharges or where only miscellaneous samples are obtained (Porterfield, 1972).

Sediment.—fragmental material that originates from the disintegration of rocks and is transported by, suspended in, or deposited by air or water or is accumulated in beds by other natural agencies (Colby, 1963).

Sediment Concentration.—ratio of dry weight of sediment to the total weight of the water/sediment mixture (Colby, 1963).

Streamflow.—the discharge that occurs in a natural channel. Although the term “discharge” can be applied to the flow of a canal, the word “streamflow” uniquely describes the discharge in a surface stream course. The term “streamflow” is more general than “runoff,” as streamflow may be applied to discharge whether or not it is affected by diversion or regulation.

Suspended Sediment.—the sediment that at any given time is maintained in suspension by the upward components of turbulent currents or that exists in suspension as a colloid.

Suspended-Sediment Concentration.—the velocity-weighted concentration of suspended sediment in the sampled zone (from the water surface to a point approximately 0.25 ft. above the bed to be consistent with definition of bed load on p. iv) expressed as milligrams of dry sediment per liter of water-sediment mixture (mg/L).

Suspended-Sediment Discharge.—the rate at which dry weight of sediment passes a section of a stream or is the quantity of sediment, as measured by dry weight or volume, that passes a section in a given time. Discharge, in tons per day, is computed by multiplying water discharge in cubic feet per second, suspended-sediment concentration, in milligrams per liter, and then by 0.0027.

CONVERSION FACTORS

For use of readers who prefer to use metric (International System) units, rather than the inch-pound terms used in this report, the following conversion factors may be used:

<u>Multiply inch-pound unit</u>	<u>By</u>	<u>To obtain metric unit</u>
inches (in)	2.54	millimeters (mm)
feet (ft)	3.048	meters (m)
square mile (mi ²)	2.590	square kilometer (km ²)
cubic foot per second (ft ³ /s)	28.32	liter per second (L/s)
ton	0.9072	megagram (Mg)

SUMMARY OF FLUVIAL-SEDIMENT STUDIES IN OHIO, THROUGH 1987

By Steven M. Hindall

ABSTRACT

The U.S. Geological Survey, in cooperation with other State and local agencies, and with other Federal agencies, has been collecting fluvial-sediment data from Ohio streams since April 1950. The amount of data collected, period of data collection, and purpose of the networks have varied through the years. This report summarizes the data collected for the period April 1950 through September 1987. In addition, trends in annual suspended-sediment discharge in Ohio streams are examined and discussed; and a technique is presented for estimating discharge at ungaged points on Ohio streams.

Continuous record of 8 years or more is available for 14 of 68 daily sediment stations that have been operated in Ohio. Five years of data are available for an additional 39 intermittent or periodic-record stations. Available sediment data include suspended-sediment concentration and suspended- and bed-material particle-size-distribution data. Measured mean annual suspended-sediment discharge ranged from less than 1 ton per year to greater than 1,440,000 tons per year in Ohio streams.

Graphical and statistical analysis of long-term sediment record indicate that, in general, there has been no readily apparent long-term (greater than 3- to 5-year) trends in the relation between mean annual suspended-sediment discharge and water discharge in Ohio; however, some short-term, year-to-year changes in that relation occur in Ohio streams. Double-mass curves for five stations and Seasonal Kendall Analysis of data from eight stations clearly illustrate the lack of any discernable changes in the suspended-sediment-discharge/water-discharge relation or in suspended-sediment concentration for most Ohio streams over the past 36 years. Some short-term, year-to-year changes in suspended sediment discharge in Ohio streams, however, do occur.

Equations were developed through linear-regression analysis to estimate suspended-sediment discharge at sites on Ohio streams for which no sediment data are available. One equation uses mean annual water discharge as the explanatory variable and has a standard error of estimate of 39 percent and coefficient of multiple determination of 0.93. The second equation uses drainage area as the explanatory variable and has a standard error of estimate of 46 percent and a coefficient of multiple determination of 0.90.

INTRODUCTION

Fluvial sediment is recognized widely as a pollutant of surface waters. Erosion, transport, and deposition of sediment present significant economic and environmental problems. These problems include loss of arable land, aesthetic damage to surface waters, filling or scouring of stream channels, cost of removal of sediment from municipal and industrial water supplies, sediment deposition in reservoirs and harbors, and floodwater damage caused by sediment deposition and/or scour. Another problem of increasing importance associated with sediments is the sorption on sediment of toxic metals, pesticides and other toxic organic compounds, nutrients, and radionuclides. These sorbed substances can create a potential hazard to public health when transported into a water supply or concentrated in a depositional area.

Sediment problems are controlled and/or reduced by adequate conservation and management of surface-water and land resources. Resource management requires information about the quantity and characteristics of fluvial sediment. This information is of great value in Ohio because of the significant role of surface waters in the economic welfare of the State.

The U.S. Geological Survey, in cooperation with State and local agencies, and with other Federal agencies, began collecting fluvial-sediment data in Ohio in April 1950. Since that time, several agencies have cooperated with the U.S. Geological Survey in establishing sediment data-collection networks. However, the amount of data collected, period of data collection, and purpose of the networks have varied.

Purpose and Scope

This report summarizes the fluvial-sediment data collected in Ohio by the U.S. Geological Survey for the period April 1950 through September 1987. In addition, trends in annual suspended-sediment discharge in Ohio streams are examined and discussed; and a technique is presented for estimating sediment discharge at ungaged points on Ohio streams.

The basic suspended-sediment data summarized and discussed in this report are published in the U.S. Geological Survey annual publication series, "Water Resources Data for Ohio," for water years 1964-86. Data collected before the 1963 water year are published in the U.S. Geological Survey Water-Supply Paper series, "Quality of Surface Waters of the United States, parts 3 and 4, Ohio River Basin and St. Lawrence River Basin." Most recent suspended-sediment data also are available from the U.S. Geological Survey's computerized data bases.

Acknowledgments

Acknowledgement is made of the Ohio Department of Natural Resources, Ohio Environmental Protection Agency, Miami Conservancy District, and the U.S. Army Corps of Engineers, who were principal cooperating agencies over the years in the U.S. Geological Survey's fluvial-sediment programs in Ohio. Other agencies and local governments, such as the Ohio Department of Transportation, Cuyahoga County, the City of Akron, the U.S. Forest Service, and the U.S. Bureau of Land Management, also have played significant roles in the Ohio District's sediment programs. The author would like to thank Jeffrey DeRosa, a volunteer for the U.S. Geological Survey, for his efforts in retrieving sediment and streamflow data from historical files.

FLUVIAL-SEDIMENT INVESTIGATIONS CONDUCTED BY THE U.S. GEOLOGICAL SURVEY IN OHIO, THROUGH 1987

Besides fluvial-sediment data-collection activities, which began in 1950 and continues to date, the U.S. Geological Survey in Ohio has conducted 10 detailed studies through 1987 in which sedimentation investigations were an important part (fig. 1). The following brief descriptions of sediment-related projects are listed chronologically by study objective and then chronologically within the group.

Early fluvial-sediment investigations in Ohio consisted primarily of reservoir-accumulation studies and collection of suspended-sediment data from several daily record stations. Most daily sediment stations were located on larger streams in Ohio. Data from these stations include daily suspended-sediment discharges, daily mean sediment concentration, and periodic particle-size distributions. From the establishment of the first sediment station on the Maumee River at Waterville in April 1950, the cooperative fluvial sediment program in Ohio quickly expanded to 13 daily sediment stations by the end of 1952. Continuous record of 8 years or more is available for 14 of 68 daily sediment stations that have been operated in Ohio. All daily stations operated by the U.S. Geological Survey since 1950 are listed in table 1 (at back of report).

In October 1969, the U.S. Geological Survey, in cooperation with the Ohio Department of Natural Resources, established a fluvial-sediment-inventory network to provide data sufficient to define the quantities and characteristics of fluvial sediment on a state-wide basis (Anttila and Tobin, 1978). In 1970, State cooperation with the U.S. Geological Survey was transferred to the Ohio Environmental Protection Agency. The network consisted of 39 intermittent- or periodic-record stations that met the following criteria: Wide geographical distribution, drainage area of 85 mi² (square miles) or more, representation of major soil associations, and unregulated flow conditions. Sediment and related

data were collected on a periodic basis at each station for the 5-year period, October 1969 through September 1974. Data collection included suspended-sediment samples, bed-material samples, water discharges, and water temperatures. These stations also are listed in table 1 and plotted in figure 2 (in pocket).

The next significant sediment data-collection program was initiated in 1978, in cooperation with the Ohio Department of Transportation, to quantify the effects of highway construction on stream-transported sediment (Helsel, 1985). Sediment data were collected daily at six gaging stations on the Olentangy River and selected tributaries above, below, and within the active construction area of State Highway 315 near Columbus. During the 3-year monitoring program, suspended-sediment data were collected at tributaries draining suburban land as well as the highway-construction site itself.

Sedimentation and erosion are very important concerns in mining and reclamation processes. The enactment of Public Law 95-87, "Surface Mining Control and Reclamation Act of 1977," marked the beginning of a new phase of sediment-data-collection activities for the Ohio District. Six projects to study the effects of mining and reclamation have been initiated since 1978. In all of the projects, sediment-data collection and analysis have played an important role. The data collected have added significantly to the sediment data base for Ohio.

The first project that was a direct result of the passage of Public Law 95-87 was a study to determine the influences of surface-mining on sedimentation characteristics of basins in the Allegheny and Monongahela Formations in Ohio. Sediment transportation and deposition were compared in small unmined basins and in basins with reclaimed surface mines. Suspended-sediment concentration and suspended and bed material particle-size data were collected over a period of 3 years at four stations during the 1979-81 water years. The four basins were located near Bloomingdale, Crooksville, Tuscarawas, and Wakatomika. A report was not published on this effort; however, the basic data are available on file at the U.S. Geological Survey office in Columbus, Ohio.

As part of a study to determine the effects of reclaiming abandoned surface mines in the Wayne National Forest, one small basin (Yost Run) near Nelsonville was instrumented; and suspended-sediment data were collected on an intermittent basis from May 1981 through November 1982 (Hindall, 1984). The study was funded jointly by the U.S. Forest Service and U.S. Bureau of Land Management.

Intensive suspended-sediment data collection and analysis were important parts of a project funded by the U.S. Geological Survey to evaluate the effects of different land-use practices in two basins in Ohio's coal areas. An unmined area near Coshocton and an actively mined area near Belmont were studied in detail in this 4-year project. Daily suspended-sediment data were collected at one site in each basin from March 1982 through September 1983.

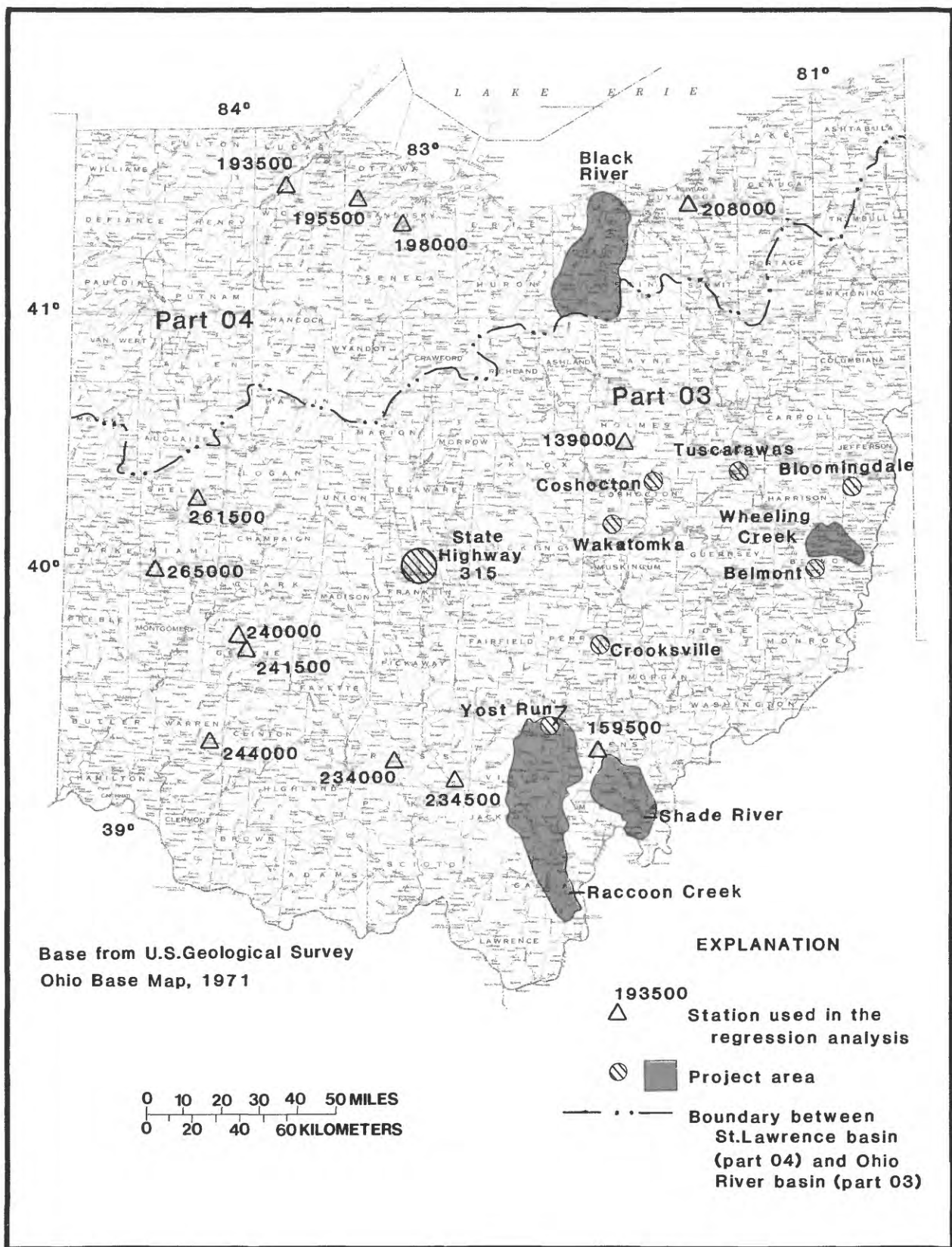


Figure 1.—Locations of project areas of sediment studies and stations used in regression analysis.

Three projects, done in cooperation with Ohio Department of Natural Resources, Division of Reclamation, are studying the effects of surface-mine reclamation on sedimentation and water quality in three river basins. The first project was in the Wheeling Creek basin. One daily and four periodic sediment-sampling sites were established in November 1982 to describe storm-period subbasin contributions to the sediment load in the Wheeling Creek basin. The periodic sites were operated through December 1983 and the daily site operated through September 1987. Two reports have been published on this study (Kolva and Koltun, 1987; Koltun, 1988).

In the second of the three reclamation studies, three daily suspended-sediment stations were established in the Shade River basin. Two stations were located in areas of abandoned mines undergoing reclamation and the third in an unmined area. Data collection began in May 1983 and continued through September 1985. Three reports have been published from this study (Childress and Jones, 1985a; Childress and Jones, 1985b; and Childress and Jones, 1988).

The latest reclamation study funded by Ohio Department of Natural Resources, in which sediment was a significant concern, involved the Raccoon Creek basin. The first phase of the study was a reconnaissance in which suspended-sediment data were collected once at 41 sites throughout the basin (Wilson, 1985). The second phase was a more intensive effort in which daily suspended-sediment data were collected at five sites on the mainstem of Raccoon Creek for differing lengths of time during 1984 and 1985 (Wilson, 1988). In both phases, sediment was only part of an overall study to determine the areas of the basin that were most severely affected by abandoned and unreclaimed surface and underground coal mines and to determine the effects of reclaiming some of those mines.

A quantitative assessment of the suspended-sediment loads from nonpoint sources in the Black River basin was the main objective of a 1-year study done in 1981 in cooperation with the U.S. Army Corps of Engineers. Data were collected at five sites in the basins, two of which were sampled daily and three of which were sampled intermittently. The study provided the Corps with data that would allow them to plan and evaluate dredging and possible upstream sediment trapping and land management.

DESCRIPTION AND SUMMARY OF AVAILABLE FLUVIAL-SEDIMENT DATA, THROUGH 1987

Sediment data are available for 107 sites in Ohio. Sites at which more than one sample has been collected are listed in table 1 and located on figure 2. A daily sediment record is one in which suspended-sediment samples are collected at such frequency that daily sediment discharges can be calculated on a daily basis. A suspended-sediment sample usually is collected once each day (or more frequently during high-flow events)

to compute this record. However, samples may be collected less frequently during low or steady flow. A periodic record is one in which samples are not collected at a frequency which allows calculation of a daily sediment discharge. Samples generally are collected at monthly to bimonthly intervals, as well as during high-flow events, to compile a periodic record.

The period of sediment record for Ohio streams ranges from less than 1 year for several stations to more than 37 years for the Maumee River at Waterville. The average period of record through the 1987 water year was 5.8 years for the daily-record stations and 5.5 years for the periodic-record stations.

Four types of basic sediment data may be collected at a sediment station. Suspended-sediment-concentration data are by far the most commonly collected. Concentration data provide the data base for many sediment analyses. These data, when combined with water discharge, are used to determine sediment discharge for the time interval required in an analysis. All the stations listed in table 1 have at least suspended-sediment-concentration data available for the indicated period of record. Particle-size distribution of suspended material is the second most commonly collected type of sediment data, followed by particle-size distribution of bed material. Of the 107 sediment stations that have been in service in Ohio, suspended-material particle-size data are available for 49 stations; and bed-material particle-size data are available for 42 stations. Some bed-load data have been collected at a few sites in Ohio.

Analysis of Suspended-Sediment-Discharge Data

The primary purpose of almost all sediment studies and data-collection networks is to determine sediment discharge at some point on a stream or location in a basin. The following analyses are based on mean annual suspended-sediment-discharge data for Ohio streams as determined from routine record computation or previous sediment-related studies.

Table 1 presents three suspended-sediment discharges, each for different periods of record. The first is for the entire period of sediment record and contains data for only daily stations. These data simply represent the mean of all the annual suspended-sediment discharges for a particular station for whatever record is available. These data cannot be directly compared due to the nonconcurrent periods of record for the various stations.

The second mean annual suspended-sediment discharge listed in table 1 is for the 1946-70 period. These data, from both daily and periodic stations, are from an earlier study by Anttila and Tobin (1978). The 1946-70 period was selected because continuous water-discharge data were available at most of the stations listed for that period. Actual

records of suspended-sediment discharge were extended to this base period by analytical procedures. These extended records must be considered approximations because actual sediment data were not collected over the complete 1946-70 period.

Ten years (1977-86) are used as the period of record for the third set of the mean annual suspended-sediment discharge data presented in table 1. Only daily stations active for at least 3 full years during that period are included. Annual suspended-sediment discharge records for stations with fewer than 10 years of data collection were extended to cover the 1977-86 period by use of a technique developed by Nelson (1970) and modified by Anttila and Tobin (1978). Data from these 10 stations represent recent sediment data-collection activity.

The mean annual suspended-sediment discharge for the active periods of record category ranged from less than 1 ton in Big Four Hollow near Lake Hope to 1,320,000 tons for the Maumee River at Waterville (table 1). For the 1946-70 period, the range was from 19,300 tons at Chippewa Creek at Easton to 1,210,000 tons for the Scioto River at Higby. For the 1977-86 period, the range was from 32,000 tons for Cuyahoga River at Old Portage to 1,440,000 tons for the Maumee River at Waterville.

Suspended-Sediment Discharge Trends at Selected Sites on Ohio Streams

Trends in sediment discharge for Ohio streams can be analyzed qualitatively by direct comparison of sediment-discharge data at stations with different but concurrent periods of record. Mean annual suspended-sediment discharge data are available for 14 stations for at least two of the three period-of-record categories, and discharge data in all three categories are available for three stations. Direct comparison of data is possible for the four stations that have mean annual suspended-sediment discharge in both the 1946-70 and 1977-86 periods. Suspended-sediment discharge has increased significantly at three of the four stations. However, an increase in sediment discharge does not necessarily mean a corresponding increase in erosion of the land surface. Erosion of the stream-bank or streambed, or changes in water discharge, could cause increases in sediment discharge. Detailed examination of the corresponding streamflow record and determination of channel erosion is necessary to draw any definitive conclusions on the increases in sediment discharge based on this data comparison. This type of analysis is beyond the scope of this report. For each of the three stations mentioned above, the increase in mean annual suspended-sediment discharge corresponded to an increase in mean annual streamflow. Therefore, in this case, the simple qualitative analysis is inadequate to make any judgments as to trends in sediment discharge in Ohio, and additional analysis techniques are necessary before trend analysis is possible.

A graphical procedure using a double-mass curve was the first technique applied to the available data. In this procedure, cumulative annual sediment discharge is plotted

against cumulative annual water discharge on arithmetic graph paper. Figures 3 and 4 show the plots of the data from the five stations, Muskingum River at McConnellsville, Scioto River at Higby, Maumee River at Waterville, Sandusky River near Fremont, and Cuyahoga River at Independence, used in this graphical analysis. The double-mass curve defines the relation between stream discharge and sediment discharge, and a break in slope of the line joining the plotted points indicates a change in the trend of annual sediment discharge, annual water discharge, or both. Four of the five plots indicate that there are no significant or sustained changes in slopes of the graphs for those four stations over their period of record. This indicates that, over the last 30 to 35 years, no consistent upward or downward long-term (greater than 3 to 5 years) trends in the relation between suspended-sediment discharge and water discharge for those Ohio streams can be detected. The fifth graph for the Scioto River at Higby does show a reduction in slope starting about 30 million cubic feet per second, which occurred in 1971 (18 years after data collection began). This change in slope indicates a reduction in sediment discharge for a given water discharge, possibly caused by completion of two major upstream multiple-use reservoirs at about that time.

Many short-term (less than 3- to 5-year) changes in slope can be seen on each of the graphs, indicating year-to-year variations in water discharge and suspended-sediment discharge do occur in Ohio streams. However, analysis of these short-term trends was beyond the scope of this report.

A statistical technique called the Seasonal Kendall Analysis (Hirsch and Slack, 1984) also was applied to the data to assess trends in sediment discharge. Eight stations, Scioto River at Higby, Muskingum River at Dresden, Muskingum River at McConnellsville, Little Miami River at Milford, Hocking River at Athens, Maumee River at Waterville, Sandusky River near Fremont, and Cuyahoga River at Independence, were used for this statistical analysis. The annual suspended-sediment load was converted to an annual mean concentration to reduce the effect of water discharge. A sustained increase or decrease in concentration, therefore, would indicate a trend in sediment discharge. The Seasonal Kendall test was chosen because (1) no assumptions about the underlying distribution of data were required, (2) the test is resistant to outliers, and (3) the test is unaffected by periods of missing data (Hirsch and Slack, 1984).

A trend in any direction significant at the 0.05 level was seen at only one of the eight stations, Scioto River at Higby, Ohio. A slightly decreasing trend in annual mean concentration was seen at the trend-slope estimate as -3.4 milligrams per liter per year. This trend, detected through the statistical analysis, supports the trend noticed in the double-mass-curve analysis for the same station and, as stated previously, could be the result of the completion of two major upstream multiple-use reservoirs during the period of sediment-data collection. Significance levels for trends at the other seven sites ranged from 0.13 to 0.75.

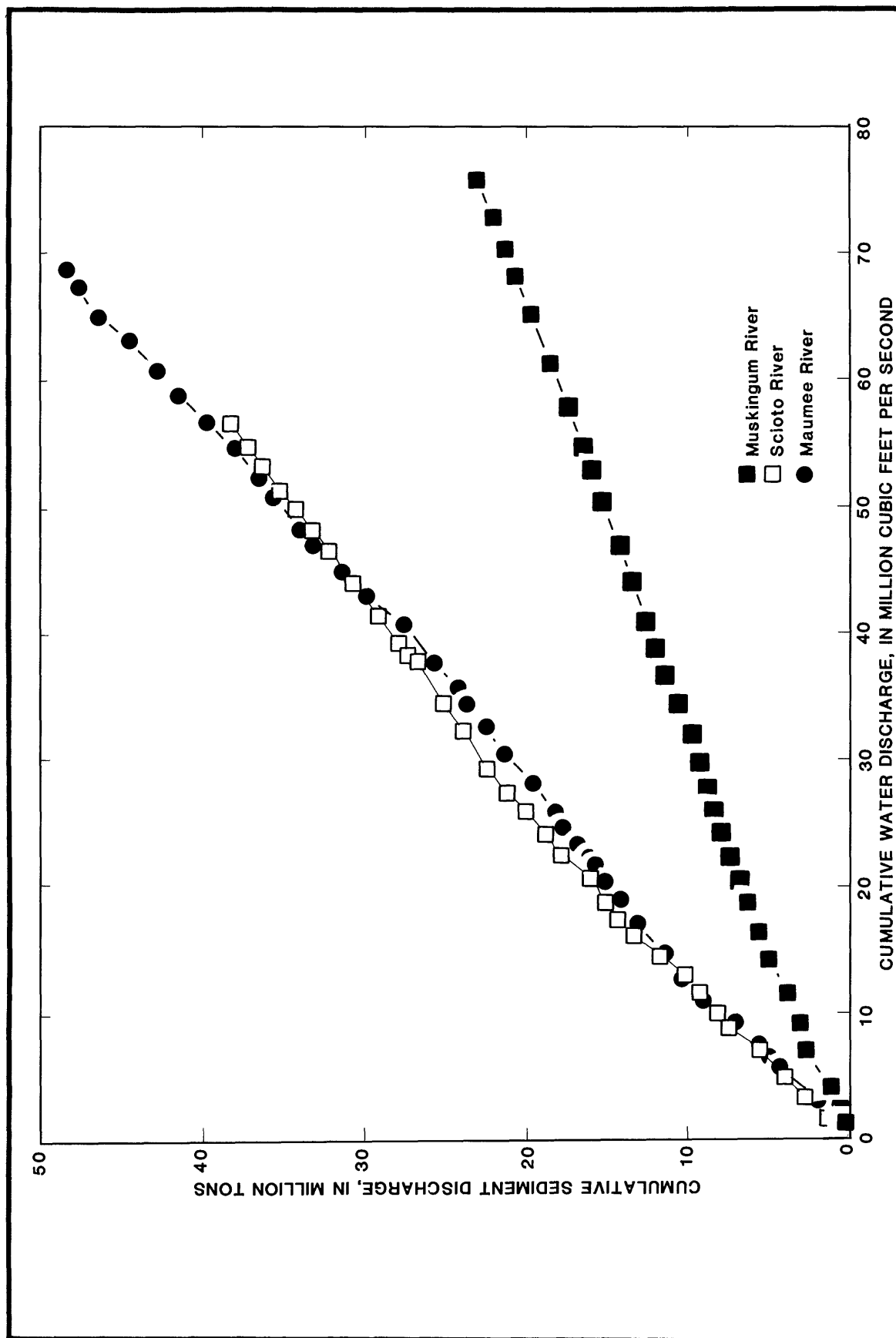


Figure 3.--Double mass curves of sediment and water discharge for Muskingum River at Dresden, Scioto River at Higby, and Maumee River at Waterville.

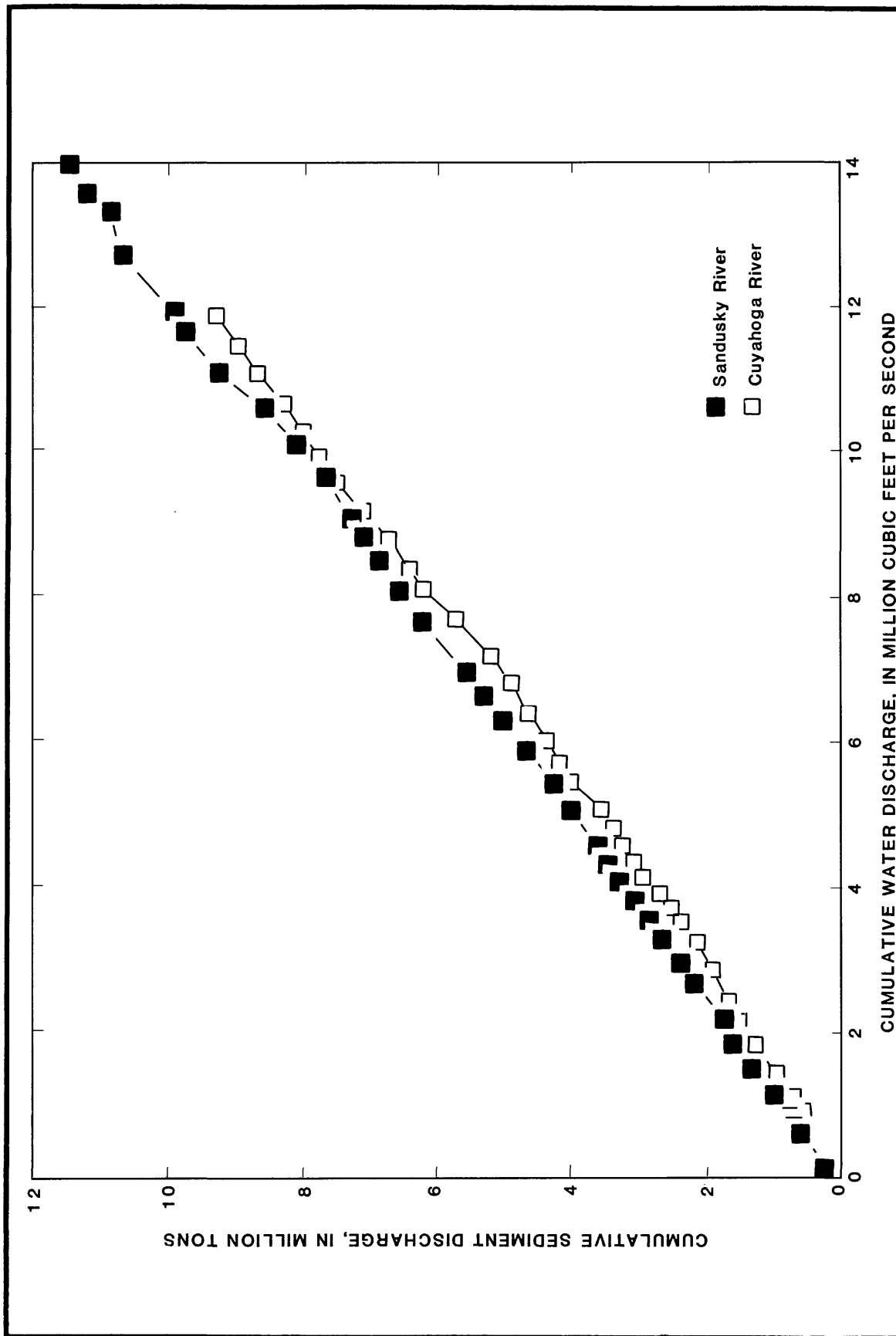


Figure 4.--Double mass curves of sediment and water discharge for Sandusky River near Fremont and Cuyahoga River at Independence.

Suspended-sediment-discharge/water-discharge relations and mean annual suspended-sediment concentrations in Ohio streams appear, on the basis of these rather limited analyses, to have remained relatively constant since the first data were collected in the early 1950's. The decrease noted in one stream may be representative of only that stream.

ESTIMATING MEAN ANNUAL SUSPENDED-SEDIMENT DISCHARGE FOR OHIO STREAMS

Sediment-discharge data are available for only a relatively small percentage of Ohio streams—and at only a few points on those streams. A method has been developed to estimate mean annual suspended-sediment discharge in the unmonitored streams of the State. The procedure makes use of regression equations that relate mean annual suspended-sediment discharge to drainage area or water discharge.

A linear regression model was used to evaluate the relation between mean annual suspended-sediment discharge and mean annual water discharge or drainage area. From 6 to 34 years of annual sediment-discharge data were compiled for the 13 daily-record stations used in the analysis. The Statistical Analysis System¹ procedure, REG, was used to perform the regression analysis (SAS Institute, 1982). Linear regression involves finding appropriate linear relations between the logs of a response variable (sediment discharge), and an explanatory variable (drainage area, water discharge). The resulting regression equations are in the power form:

$$Q_s = a_1 Q_a^{b_1} \text{ and} \quad (1)$$

$$Q_s = a_2 DA^{b_2} \quad (2)$$

where Q_s is a mean annual suspended sediment discharge, in tons;

Q_a is mean annual water discharge, in cubic feet per second;

DA is drainage area, in square miles;

a_1 and a_2 are regression constants; and

b_1 and b_2 are coefficients obtained by regression.

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

Two statistics of importance in regression analysis are the standard error of estimate (SEE) and the coefficient of multiple determination (R^2). The SEE is a measure of the dispersion in the data around the regression line. The smaller the SEE, the more precise estimates of the response variable are likely to be. The R^2 is a measure of the proportion of the variation in the response variable that is attributed to the estimated regression line. An R^2 of 1 means that all of the variation in the response is explained by the regression equation. Smaller R^2 values indicate that a smaller proportion of the variation in the response is explained by the regression equation.

Two equations were developed that can be used to estimate mean annual suspended-sediment discharge (table 2). The first equation employs the variable Qa (mean annual water discharge, in cubic feet per second). The second equation employs the variable DA (drainage area, in mi^2). If mean annual water discharge is available, the first equation should be used because of the lower standard error of estimate and higher

Table 2.—Regression equations for estimating the mean annual suspended-sediment discharge

Equations		R^2	SEE	dfe
(1)	$\text{SEDQ} = 203 \text{ Qa}^{1.030}$	0.93	39	12
(2)	$\text{SEDQ} = 209 \text{ DA}^{1.005}$	0.90	46	12

VARIABLES:

SEDQ is mean annual suspended-sediment discharge, in tons per year

DA is drainage area, in square miles

Qa is mean annual water discharge, in cubic feet per second

STATISTICS:

R^2 is coefficient of multiple determination

SEE is standard error of estimate, expressed as a percentage

dfe is degrees of freedom in the error term

coefficient of multiple determination. The two regression equations are presented in power form in table 2 as equations 1 and 2, respectively. The regression lines plotted on the log-log scatter plots of DA and Qa and Qs on figures 5 and 6 illustrate how closely the regression equations fit the data. The relatively low SEE, 39 and 46 percent, respectively, for equations 1 and 2 are evident in the small amount of scatter about the regression lines. The stations used for the regression analysis are listed on table 3 and shown on figure 2. Only daily suspended-sediment stations with mean annual suspended-sediment discharge determined for the 1946-70 period were used in the regression analysis.

Equations 1 and 2 should be used with caution and not for conditions significantly different than those for which they were developed. Those conditions are a drainage-area range of 63 to 6,300 mi² and a mean annual water discharge of 57 to 4,900 cubic feet per second. Available data on small (less than 50-mi²) basins in Ohio are insufficient to adequately define the relations in that range.

Table 3.—Sediment stations used in regression analysis

Station number	Station name	Drainage area (square miles)	<u>Mean annual discharge</u>	
			Water (cubic feet per second)	Suspended sediment (tons/year)
3139000	Killbuck Cr at Killbuck	462	402	77,500
3159500	Hocking R at Athens	943	935	193,000
3234000	Paint Cr near Bourneville	807	790	294,000
3234500	Scioto R at Higby	5,131	4,500	1,210,000
3240000	Little Miami R nr Oldtown	129	104	16,400
3241500	Massie Cr at Wilberforce	63.2	57.5	12,200
3244000	Todd Fork nr Roachester	219	217	137,000
3261500	Great Miami R at Sidney	541	466	77,600
3265000	Stillwater R at Pleasant Hill	503	440	91,500
4193500	Maumee R at Waterville	6,330	4,910	1,180,000
4195500	Portage R at Woodville	428	312	78,9900
4198000	Sandusky R nr Fremont	1,251	957	235,000
4208000	Cuyahoga R at Independence	707	760	207,000

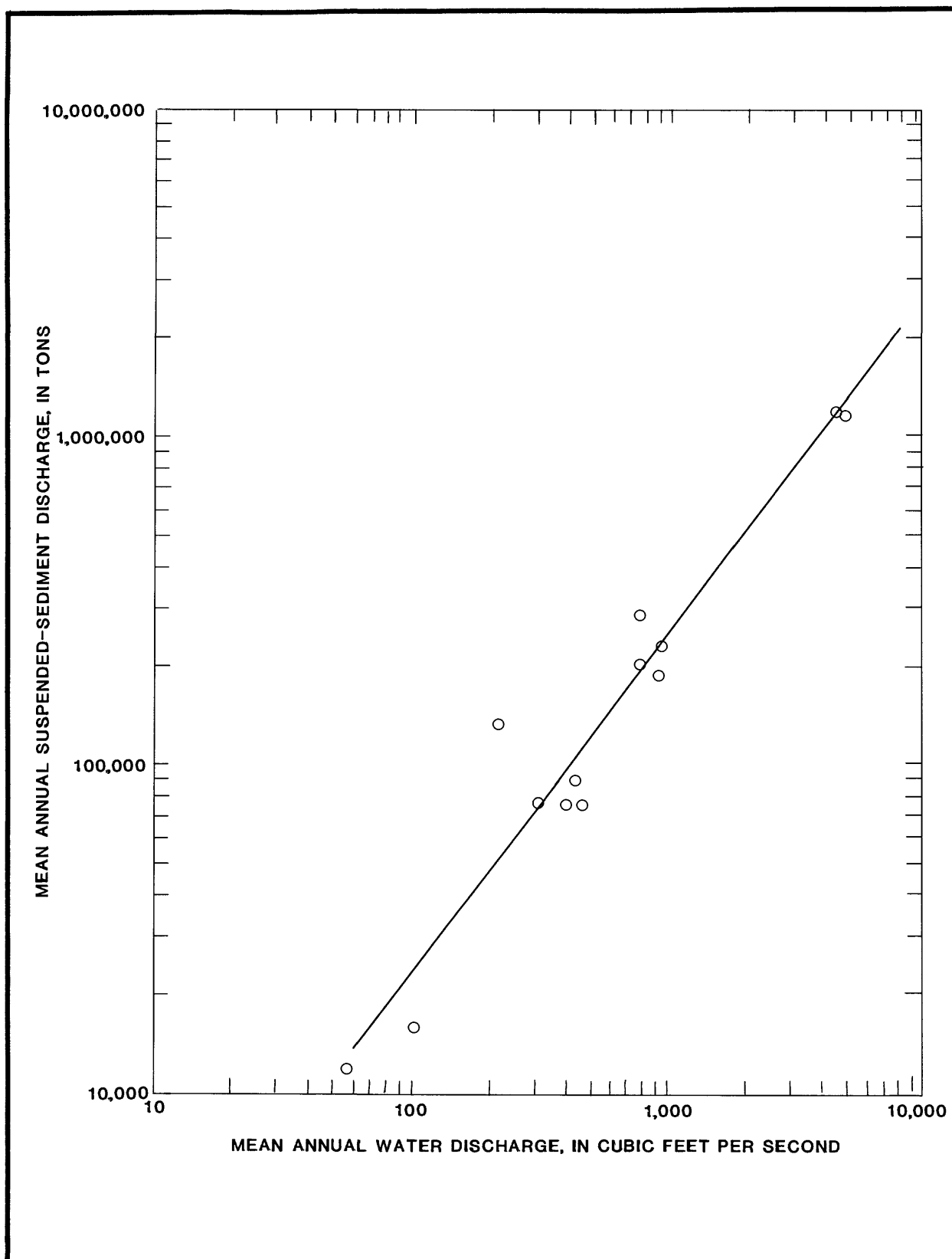


Figure 5.--Scatter plot of mean annual suspended-sediment discharge and mean annual water discharge showing the regression line for equation 1.

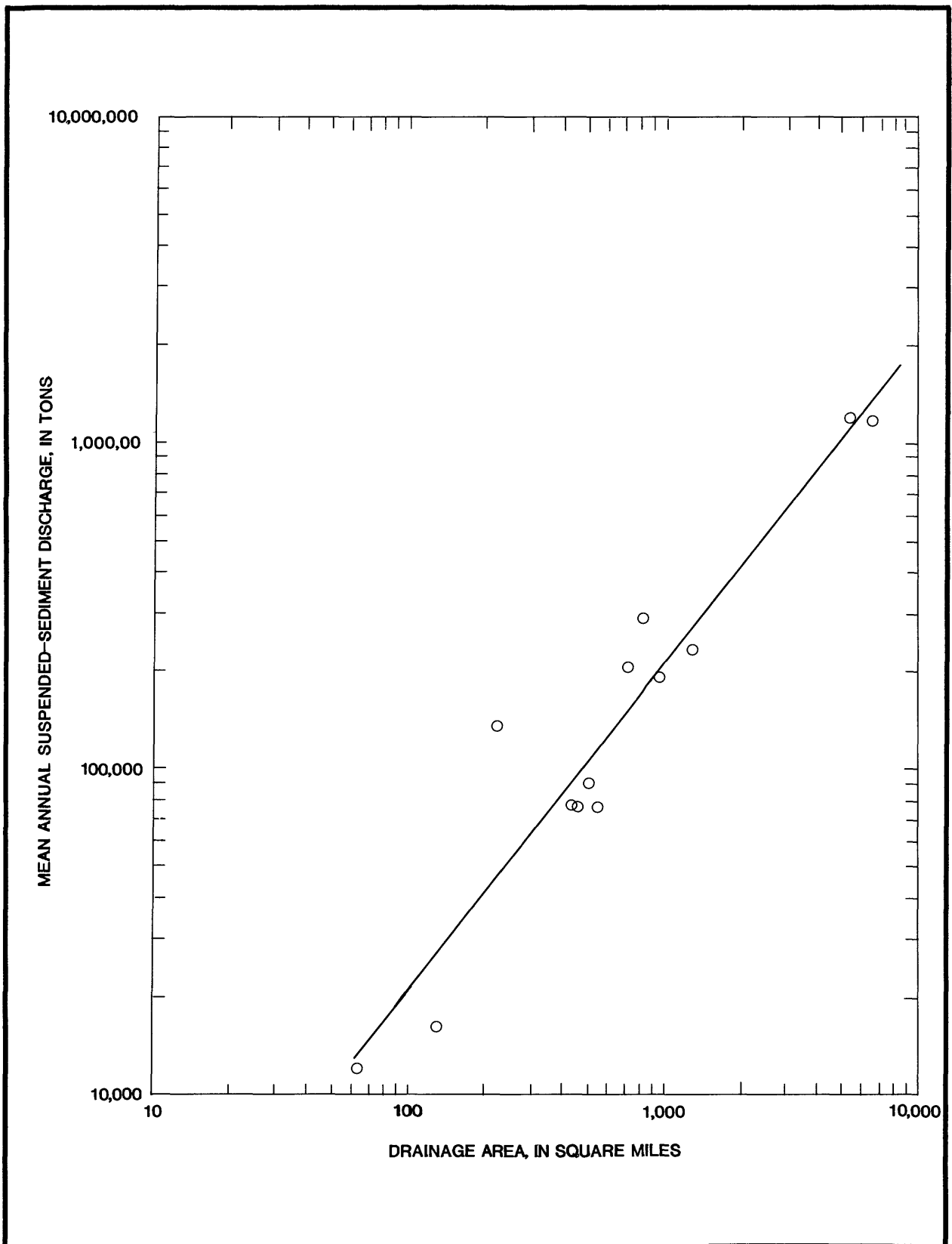


Figure 6.--Scatter plot of mean annual suspended-sediment discharge and drainage area showing the regression line for equation 2.

SUMMARY AND CONCLUSIONS

Fluvial-sediment investigations in Ohio originated with reservoir-accumulation studies and collection of suspended-sediment-concentration data on the Maumee River at Waterville in April 1950. Since then, sediment programs in Ohio have spanned periods of both high and low activity. At the end of water year 1987, the U.S. Geological Survey's sediment program in Ohio consisted of operation of four intermittent and nine daily sediment data-collection stations.

Fluvial-sediment data of one type or another collected by the U.S. Geological Survey are available for 107 sites in Ohio. The periods of record at these sites range from less than 1 year to longer than 37 years; the average period for daily-record stations is 5.8 years, and the average period is 5.5 years for intermittent-record stations. Of the three basic types of sediment data available, suspended-sediment-concentration data are the most common. However, a considerable amount of suspended- and bed-material particle-size-distribution data are available for many sites.

Measured mean annual suspended-sediment discharge ranged from less than 1 ton per year for the entire period of sediment record at Big Four Hollow near Lake Hope to 1,440,000 tons per year for the 1977-86 period for the Maumee River at Waterville. Graphical and statistical analysis of long-term sediment record indicate that, in general, there has been no readily apparent long-term (greater than 3- to 5-year) trends in the relation between mean annual suspended-sediment discharge and water discharge in Ohio; however, some short-term, year-to-year changes in that relation occur in Ohio streams. Double-mass curves for five stations and Seasonal Kendall Analysis of data from eight stations clearly illustrate the lack of any discernable changes in the suspended-sediment-discharge/water-discharge relation or in suspended-sediment concentration for most Ohio streams over the past 36 years. A slight decreasing trend in concentration was detected in the Scioto River at Higby. This decrease may have been caused by completion of two major upstream multiple-use reservoirs.

Mean annual suspended-sediment discharge may be estimated at ungaged sites on Ohio streams by use of regression equations. Two equations were developed through linear regression analysis—one using mean annual water discharge as the explanatory variable, and another using drainage area. The standard error of estimate was 39 percent for the equation using mean annual water discharge and 46 percent when drainage area was used. The coefficients of multiple determination were 0.93 and 0.90, respectively, for the two equations.

REFERENCES

- Anttila, S.M., and Tobin, R.L. 1978, Fluvial sediment in Ohio: U.S. Geological Survey Water-Supply Paper 2045, 58 p.
- Childress, C.J.O., and Jones, R.L., 1985a, Sediment and water-quality data for the West Branch and East Branch Shade River basins, 1983 water year: U.S. Geological Survey Open-File Report 85-187, 16 p.
- _____. 1985b, Sedimentation and water quality in the West Branch Shade River basin, Ohio, 1984 water year: U.S. Geological Survey Open-File Report 85-552, 26 p.
- _____. 1988, Sedimentation and water quality in West Branch Shade River basin, Ohio: U.S. Geological Survey Water-Resources Investigations Report 87-4262, 56 p.
- Colby, B.R., 1963, Fluvial Sediments—A summary of source, transportation, deposition and measurement of sediment discharge: U.S. Geological Survey Bulletin 1181-A, 47 p.
- Helsel, D.R., 1985, Contributions of suspended sediment from highway construction and other land uses to the Olentangy River, Columbus, Ohio: U.S. Geological Survey Water-Resources Investigations Report 84-4336, 31 p.
- Hindall, S.M., 1984, Effects of surface coal mine reclamation in a small watershed near Nelsonville, Ohio: U.S. Geological Survey Water-Resources Investigations Report 84-4179, 28 p.
- Hirsch, R.M., and Slack, J.R., 1984, A nonparametric trend test for seasonal data with serial dependence: Water Resources Research, v. 20, no. 6, p. 727-732.
- Kolva, J.R., and Koltun, G.F., 1987, Flooding and sedimentation in Wheeling Creek basin, Belmont County, Ohio: U.S. Geological Survey Water-Resources Investigations Report 87-4053, 33 p.
- Koltun, G.F., 1988, Analysis of postdredging bed-level changes in selected reaches of Wheeling Creek, eastern Ohio: U.S. Geological Survey Water-Resources Investigations Report 88-4119, 14 p.
- Nelson, L.M., 1970, A method of estimating annual suspended-sediment discharge, *in* Geological Survey Research 1970: U.S. Geological Survey Paper 700-C, p. C233-C236.

Porterfield, George, 1972, Computation of fluvial-sediment discharge, Techniques of Water-Resources Investigations of the U.S. Geological Survey, book 3, chap. C3, 66 p.

SAS Institute, Inc., 1982, SAS User's Guide—Statistics: Cary, North Carolina, 584 p.

Wilson, K.S., 1985, Surface-water quality in coal-mine lands in Raccoon Creek basin, Ohio: U.S. Geological Survey Water-Resources Investigations Report 85-4060, 61 p.

_____ 1988, Chemical and biological characteristics and sedimentation for streams draining coal-mined lands in Raccoon Creek basin Ohio: U.S. Geological Survey Water-Resources Investigations Report 88-4022, 80 p.

Table 1.--Available fluvial-sediment data for Ohio through October 1987

[BL, bed load; BM, bed material particle size; SC, suspended concentration; and SM, suspended material particle size. Dashes indicate no data available.]

Station name	Station number	Drainage area (square miles)	Type of sediment record	Period of sediment record	Type of sediment data	Mean annual suspended sediment discharge, in tons		
						Entire period of record	1946-70	1977-86
Little Beaver Cr near East Liverpool	03109500	496	Periodic	1970-74	SC, SM, BM	--	62,200	--
Yellow Cr near Hammondville	03110000	147	Periodic	1970-74	SC, SM, BM	--	26,100	--
Consol Run near Bloomingdale	03110983	.98	Daily	10/79-9/81	SC	128	--	--
Short Cr near Dillonville	03111500	123	Periodic Daily	1970-74 5/80-9/81	SC, SM, BM SC	-- 67,300	30,000 --	-- --
Wheeling Cr below Blaine	03111548	97.7	Daily	12/82-9/87	SC, BM, BL	27,400	--	--
Unnamed tributary to Bend Fork near Belmont	03113950	.70	Daily	6/82-9/83	SC	59.1	--	--
Captina Cr at Armstrong Mills	03114000	134	Periodic	1970-74	SC, SM, BM	--	30,400	--
Little Muskingum R at Bloomfield	03115400	210	Periodic	1970-74	SC, SM, BM	--	33,700	--
Chippewa Cr at Easton	03116200	146	Periodic	1970-74	SC, SM, BM	--	19,300	--
Sandy Cr at Waynesburg	03117500	253	Periodic	1970-74	SC, SM, BM	--	23,900	--

Table 1.--Available fluvial-sediment data for Ohio through October 1987--Continued

Station name	Station number	Drainage area (square miles)	Type of sediment record	Period of sediment record	Type of sediment data	Mean annual suspended sediment discharge, in tons		
						Entire period of record	1946-70	1977-86
Huff Run at Lindentree	03121800	7.57	Daily	4/81-9/81	SC	--	--	--
Sugar Cr at Beach City	03123000	160	Periodic	1970-74	SC, SM, BM	--	21,500	--
Mud Run near Tuscarawas	03128690	8.42	Daily	6/80-9/81	SC	10,400	--	--
Kokosing R at Millwood	03137000	455	Periodic	1970-74	SC, SM, BM	--	78,200	--
Killbuck Cr at Killbuck	03139000	462	Daily	10/62-9/69	SC	82,400	77,500	--
Little Mill Cr near Coshocton	03139940	1.44	Daily	3/82-9/83	SC	745	--	--
Sugartree Fork near Birmingham	03142240	3.45	Daily	7/81-9/81	SC	--	--	--
Wakatomica Cr near Frazeysburg	03144000	140	Periodic	1970-74	SC, SM, BM	--	21,800	--
Sand Fork near Wakatomika	03144400	1.34	Daily	10/78-9/81	SC	1,210	--	--
Muskingum R at Dresden	03144500	5,993	Daily	10/52-10/74	SC, SM	635,000	--	--
N Fork Licking R at Utica	03146000	116	Periodic	1970-74	SC, SM, BM	--	16,500	--

Table 1.--Available fluvial-sediment data for Ohio through October 1987--Continued

Station name	Station number	Drainage area (square miles)	Type of sediment record	Period of sediment record	Type of sediment data	Mean annual suspended sediment discharge, in tons		
						Entire period of record	1946-70	1977-86
Moxahala Cr near Crooksville	03148150	28.9	Daily	7/80-9/81	SC	14,200	--	--
Muskingum R at McConnelsville	03150000	7,422	Daily	11/78-9/85	SC	1,192,000	--	1,126,000
N Branch Hunters Run near Hooker	03155900	1.4	Daily	5/56-9/62	SC	--	--	--
Snow Fork Monday Cr at Buchtel	03158195	24.4	Daily	4/81-9/81	SC	--	--	--
Hocking R at Athens	03159500	943	Daily	10/56-9/65	SC	183,000	193,000	--
Hocking R below Athens	03159510	957	Daily Periodic	11/78-9/82 1982-87	SC SC, SM	361,000 251,000	-- --	339,000 304,000
W Branch Shade R near Harrisonville	03159532	.99	Daily	6/83-9/85	SC, BL	6,850	--	--
W Branch Shade R near Burlington	03159534	22.2	Daily	6/83-9/85	SC, BL	9,190	--	--
Shade R near Chester	03159540	156	Periodic	1970-74	SC, SM, BM, BL	--	53,200	--
E Branch Shade R near Tupper's Plains	03159555	37.5	Daily	4/80-9/85	SC, BL	7,170	--	--
Yost Run near Nelsonville	03201535	.53	Periodic	1982-83	SC	1,500	--	--

Table 1.--Available fluvial-sediment data for Ohio through October 1987--Continued

Station name	Station number	Drainage area (square miles)	Type of sediment record	Period of sediment record	Type of sediment data	Mean annual suspended sediment discharge, in tons		
						Entire period of record	1946-70	1977-86
Raccoon Cr near New Plymouth	03201555	22.7	Daily	7/84-9/85	SC	3,050	--	--
Big Four Hollow near Lake Hope	03201700	.98	Daily	10/78-6/83	SC	.75	--	--
Raccoon Cr near Bolins Mills	03201902	205	Daily	10/84-6/85	SC	--	--	--
Little Raccoon Cr near Ewington	03201980	99.7	Daily	8/84-6/85	SC	--	--	--
Little Raccon Cr near Vinton	03201988	154	Daily	8/84-9/85	SC	6,370	--	--
Raccoon Cr at Adamsville	03202000	585	Periodic Daily	1970-74 7/84-9/85	SC, SM, BM SC	-- 32,400	39,700 --	-- --
Scioto R near Prospect	03219500	567	Daily	4/51-9/53	SC	69,600	--	--
Olentangy R at Claridon	03223000	157	Periodic	1970-74	SC, SM, BM	--	24,200	--
Olentangy R at Worthington	03226800	496	Daily	10/78-9/81	SC	67,745	--	--
Rush Run at Worthington	03226865	1.65	Daily	10/78-9/81	SC	1,152	--	--
Linworth Road Cr at Columbus	03226870	2.03	Daily	10/78-9/81	SC	757	--	--

Table 1.--Available fluvial-sediment data for Ohio through October 1987--Continued

Station name	Station number	Drainage area (square miles)	Type of sediment record	Period of sediment record	Type of sediment data	Mean annual suspended sediment discharge, in tons		
						Entire period of record	1946-70	1977-86
Unnamed tributary to Olentangy R at Columbus	03226872	2.50	Daily	7/79-10/81	SC	822	--	--
Bethel Road Cr at Columbus	03226875	.22	Daily	10/78-9/81	SC	416	--	--
Olentangy R at Henderson Road at Columbus	03226885	518	Daily	10/78-9/81	SC	158,033	--	--
Big Walnut Cr at Central College	03228500	190	Daily	10/51-9/53	SC	31,900	--	--
Alum Cr at Africa	03228805	122	Periodic	1964-74	SC	--	--	--
Alum Cr at Columbus	03229000	189	Daily	10/60-9/65	SC	38,300	--	--
Big Darby Cr at Darbyville	03230500	534	Periodic	1970-74	SC, SM, BM	--	120,000	--
Deer Cr at Mt. Sterling	03230800	228	Periodic	1970-74	SC, SM, BM	--	45,100	--
Paint Cr near Greenfield	03232000	249	Periodic	1970-74	SC, SM, BM	--	53,900	--
Paint Cr near Bourneville	03234000	807	Daily	10/56-9/62	SC, BM	288,000	294,000	--
Scioto R at Higby	03234500	5,131	Daily	10/53-9/74 1/79-9/82	SC, SM, BM	1,200,000	1,210,000	1,100,000
			Periodic	1982-87	SC, SM	826,000	--	970,000

Table 1.--Available fluvial-sediment data for Ohio through October 1987--Continued

Station name	Station number	Drainage area (square miles)	Type of sediment record	Period of sediment record	Type of sediment data	Mean annual suspended sediment discharge, in tons		
						Entire period of record	1946-70	1977-86
Upper Twin Cr at McGaw	03237280	12.8	Daily Periodic	10/69-9/73 1964-69 1974-87	SC	--	--	--
Ohio Brush Cr at West Union	03237500	387	Periodic	1970-74	SC, SM, BM	--	213,000	--
Whiteoak Cr near Georgetown	03238500	222	Periodic	1970-74	SC, SM, BM	--	102,000	--
Little Miami R near Selma	03239000	48.9	Daily	9/52-9/58	SC	4,660	--	--
N Fork Little Miami R near Pitchen	03239500	28.9	Daily	8/51-9/58	SC	1,230	--	--
Little Miami R near Oldtown	03240000	129	Daily	8/52-9/58	SC	12,700	16,400	--
S Fork Massie Cr at Cedarville	03241000	28.9	Daily	7/54-9/58	SC	2,640	--	--
Massie Cr at Wilberforce	03241500	63.2	Daily	10/52-9/58	SC	9,490	12,200	--
Todd Fork near Roachester	03244000	219	Daily	9/52-9/58	SC	123,000	137,000	--
Little Miami R at Milford	03245500	1,203	Daily	12/78-9/87	SC	478,000	--	474,000
E Fork Little Miami R near Marathon	03246200	195	Periodic	1970-74	SC, SM, BM	--	51,000	--

Table 1.--Available fluvial-sediment data for Ohio through October 1987--Continued

Station name	Station number	Drainage area (square miles)	Type of sediment record	Period of sediment record	Type of sediment data	Mean annual suspended sediment discharge, in tons		
						Entire period of record	1946-70	1977-86
Great Miami R at Sidney	03261500	541	Daily	10/67-9/75	SC	86,500	77,600	--
Loramie Cr near Newport	03261950	152	Daily	10/67-9/75	SC	26,600	--	--
Great Miami R at Troy	03262700	926	Periodic	1970-74	SC, SM, BM	--	135,000	--
Greenville Cr near Bradford	03264000	193	Periodic	1970-74	SC, SM, BM	--	34,800	--
Stillwater R at Pleasant Hill	03265000	503	Daily	10/63-9/75	SC	82,900	91,500	--
Mad R near Urbana	03267000	162	Periodic	1960-61, 1970-74	SC, SM, BM	--	22,300	--
Mad R at Eagle City	03267800	307	Daily	10/65-9/69	SC	41,200	--	--
Great Miami R at Dayton	03270400	2,510	Daily	10/52-9/53	SC	218,000	--	--
Great Miami R at Dayton	03270500	2,511	Daily	10/51-9/53	SC	412,000	--	--
Twin Cr near Ingomar	03271800	197	Periodic	1970-74	SC, SM, BM	--	72,500	--
Sevenmile Cr at Collinsville	03272800	120	Periodic	1970-74	SC, SM, BM	--	49,100	--

Table 1.--Available fluvial-sediment data for Ohio through October 1987--Continued

Station name	Station number	Drainage area (square miles)	Type of sediment record	Period of sediment record	Type of sediment data	Mean annual suspended sediment discharge, in tons		
						Entire period of record	1946-70	1977-86
Great Miami R at New Baltimore	03274600	3,814	Periodic	1966-87	SC, SM	1,100,000	--	1,130,000
Tiffen R at Stryker	04185000	410	Periodic	1952, 62-63, 70-74	SC, SM, BM	--	22,800	--
Auglaize R near Fort Jennings	04186500	332	Periodic	1970-74	SC, SM, BM	--	64,900	--
Blanchard R near Findlay	04189000	346	Periodic	1970-74	SC, SM, BM	--	51,700	--
Augalize R at Defiance	04191500	2,318	Periodic	1952, 63, 70-74	SC, SM, BM	--	373,000	--
Maumee R at Waterville	04193500	6,330	Daily Periodic	4/50-9/84 1985-87	SC SC, SM	1,320,000	1,180,000	1,440,000
Portage R at Woodville	04195500	428	Daily	10/50-9/56	SC	90,000	78,900	--
Portage R at Railroad Bridge at Woodville	04195600	433	Daily	10/50-9/53	SC	110,000	--	--
Sandusky R near Bucyrus	04196000	88.8	Periodic	1970-74	SC, SM, BM	--	17,700	--
Tymochtee Cr at Crawford	04196800	229	Periodic	1970-74	SC, SM, BM	--	47,200	--
Sandusky R near Mexico	04197000	774	Periodic	1970-74	SC, SM, BM	--	140,000	--

Table 1.--Available fluvial-sediment data for Ohio through October 1987--Continued

Station name	Station number	Drainage area (square miles)	Type of sediment record	Period of sediment record	Type of sediment data	Mean annual suspended sediment discharge, in tons		
						Entire period of record	1946-70	1977-86
Sandusky R near Fremont	04198000	1,251	Daily	10/50-9/56 10/78-9/87	SC, SM	347,000	235,000	405,000
Huron R at Milan	04199000	371	Periodic	1970-74	SC, SM, BM	--	134,000	--
Vermilion R near Fitchville	04199287	112	Daily	5/87-9/87	SC	--	--	--
Vermilion R near Vermilion	04199500	262	Periodic	1970-74	SC, SM, BM	--	93,900	--
E Branch Black R near LaGrange	04199750	136	Daily	6/80-6/81	SC, BM	15,700	--	--
W Branch Black R near Oberlin	04200050	81.9	Daily	6/80-6/81	SC, BM	18,300	--	--
W Branch Black R at Lake St at Elyria	04200430	174	Daily	6/80-6/81	SC, SM, BM	44,000	--	--
Black R at Elyria	04200500	396	Periodic Daily	1970-74 6/80-6/81	SC, SM, BM SC	-- 118,000	84,400 --	-- --
Black R at Lorain	04200620	467	Periodic	4/81	SC, SM, BM	--	--	--
Rocky R near Berea	04201500	267	Daily	6/69-9/81	SC, SM	84,000	--	--
Cuyahoga R at Hiram Rapids	04202000	151	Daily	2/85-9/86	SC	3,130	--	--
Cuyahoga R at Old Portage	04206000	401	Daily	3/72-9/81	SC	37,700	--	32,000

Table 1.--Available fluvial-sediment data for Ohio through October 1987--Continued

Station name	Station number	Drainage area (square miles)	Type of sediment record	Period of sediment record	Type of sediment data	Mean annual suspended sediment discharge, in tons		
						Entire period of record	1946-70	1977-86
Tinkers Cr at Bedford	04207200	83.9	Daily	3/72-6/72 9/74-9/79	SC	32,200	--	--
Cuyahoga R at Independence	04208000	707	Daily	10/50-9/74 3/76-9/84	SC, SM, BM	239,000	207,000	307,000
Euclid Cr at Euclid	04208690	22.6	Daily	7/77-9/78	SC	22,300	--	--
Chagrin R at Willoughby	04209000	246	Daily	7/69-9/81	SC, SM	162,000	--	110,000
Grand R near Madison	04212000	581	Periodic	1970-74	SC, SM, BM	--	69,700	--
Grand R near Painesville	04212100	685	Daily	11/78-9/87	SC	145,000	--	143,000
Grand R at Painesville	04212200	701	Periodic	1972-87	SC, SM	167,000	--	169,000
Ashtabula R near Ashtabula	04212500	121	Periodic	1970-74	SC, SM, BM	--	12,200	--
Conneaut Cr at Conneaut	04213000	175	Periodic	1970-74	SC, SM, BM	--	42,700	--

At least 12 consecutive months with less than 20 percent missing record.