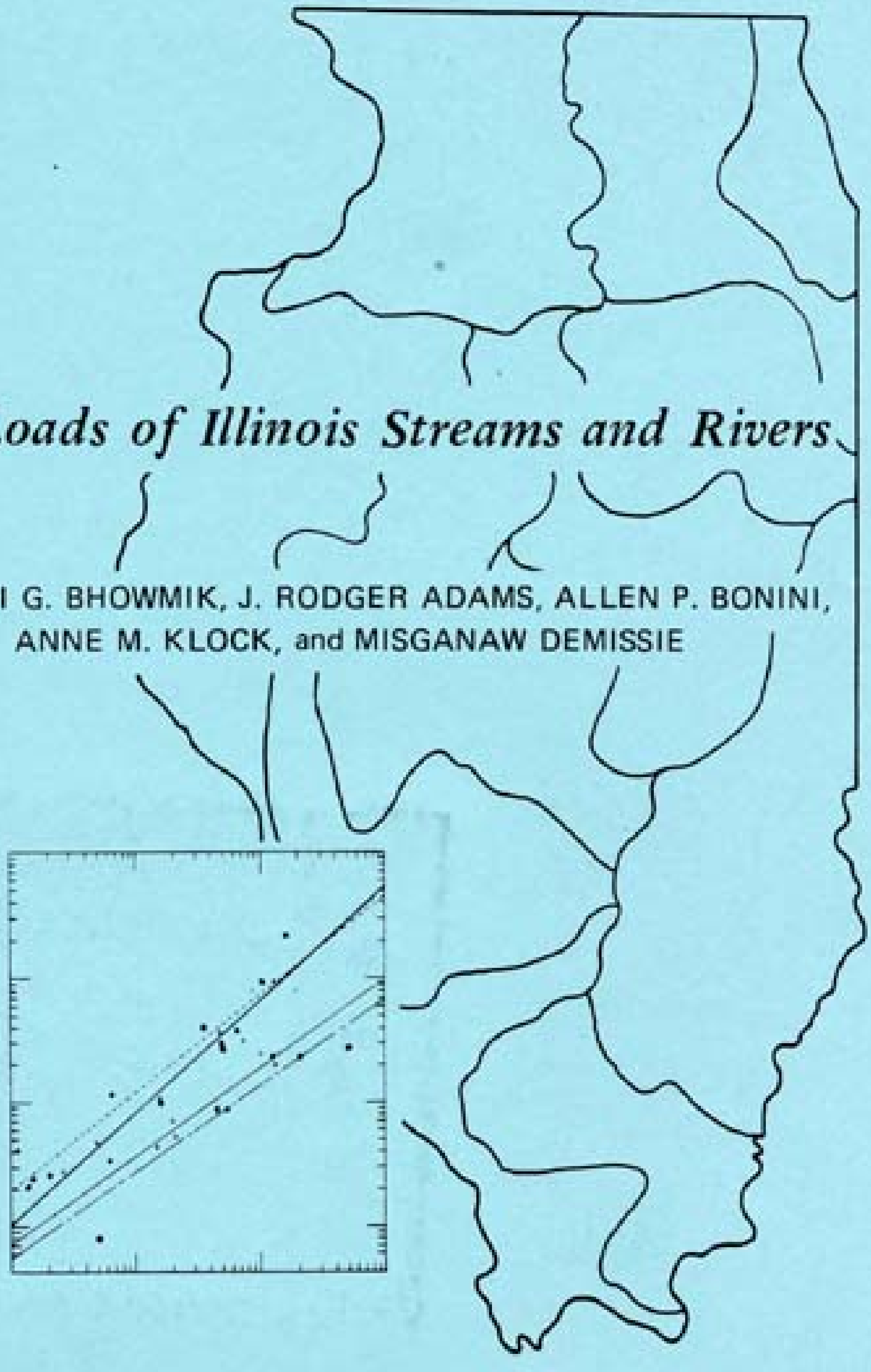
86
F INVESTIGATION 106
LLINOIS
EPARTMENT OF ENERGY AND NATURAL RESOURCES

Sediment Loads of Illinois Streams and Rivers

by NANI G. BHOWMIK, J. RODGER ADAMS, ALLEN P. BONINI,
ANNE M. KLOCK, and MISGANAW DEMISSIE



ILLINOIS STATE WATER SURVEY
CHAMPAIGN
1986

REPORT OF INVESTIGATION 106

Sediment Loads of Illinois Streams and Rivers

**by NANI G. BHOWMIK. J. RODGER ADAMS, ALLEN P. BONINI,
ANNE M. KLOCK, and MISGANAW DEMISSIE**

Title: Sediment Loads of Illinois Streams and Rivers.

Abstract: Many river projects require knowledge of the sediment load transported by the river. Suspended sediment load data for 63 locations on Illinois streams and lake sedimentation data from 24 lakes were compiled along with geomorphic information on each location. Station records were investigated, and annual and period-of-record regression equations are given for each station. Short record length (average of 2.25 years) limits the value of individual station data. Data from rivers in other midwestern states were investigated for longer-term variability. Average annual sediment loads were computed, using the period-of-record regression equation and the flow duration table for each station. These annual loads and the annual loads from the lake sedimentation studies were combined with watershed boundaries and physiographic and geomorphic data to delineate 11 Sediment Yield Areas (SYAs) within the state. Linear and multiple regression equations are presented for each SYA, and example problems outline use of the equations. Separate analyses are presented for stations on the Illinois and Mississippi Rivers.

Reference: Bhowmik, Nani G., J. Rodger Adams, Allen P. Bonini, Anne M. Klock, and Misganaw Demissie. Sediment Loads of Illinois Streams and Rivers. Illinois State Water Survey, Champaign, Report of Investigation 106, 1986.

Indexing Terms: Sediment transport, streams, rivers, lake sedimentation, suspended sediment, regional analysis, annual sediment loads.

STATE OF ILLINOIS
HON. JAMES R. THOMPSON, Governor

DEPARTMENT OF ENERGY AND NATURAL RESOURCES
DON ETCHISON, Ph.D., Director

STATE WATER SURVEY DIVISION
RICHARD G. SEMONIN, B.S., Chief

CHAMPAIGN
1986

Printed by authority of the State of Illinois

(8-86-200)

CONTENTS

Funds derived from University of Illinois administered grants and contracts were used to produce this report.

SEDIMENT LOADS OF ILLINOIS STREAMS AND RIVERS

by
Nani G. Bhowmik, J. Rodger Adams, Allen P. Bonini,
Anne M. Klock, and Misganaw Demissie

ABSTRACT

Sediment in Illinois streams is recognized as the number one pollution problem in the surface waters of the state. Data from 63 suspended sediment measuring stations and 24 lake sedimentation surveys were used to develop methods of estimating the annual sediment load at any point along any stream in Illinois. Because of the short (less than 3 years) period of record for suspended sediment stations in Illinois, several longer-term records from other midwestern states were investigated for changes in sediment-water relationships with time and increasing record length.

Each instream sediment data set was analyzed to produce annual and period-of-record regression equations relating daily sediment load to daily water discharge. Seasonal analyses were also performed for stations with three or more years of data. Three Mississippi River and two Illinois River stations were also investigated.

General analyses included sediment transport by floods, estimation of long-term average annual sediment loads, and multiple regression analysis. Eleven Sediment Yield Areas (SYAs) were delineated on the basis of physiographic divisions, watershed boundaries, geomorphic parameters, and annual sediment loads. For each SYA a regression equation was developed relating average annual sediment load and drainage area. Multiple regression equations were also developed for each SYA relating annual sediment load to drainage area, main stem length, and basin relief ratio. These parameters were selected from the 7 most important geomorphic and hydraulic parameters included in the multiple regression analysis.

The recommended methods for determining average annual sediment loads in Illinois streams are presented in concise format for quick reference. Examples outline the use of the equations.

INTRODUCTION

Erosion and sedimentation are natural processes that cannot be prevented. However, human activities have accelerated these processes. It is essential that functional relationships between the various physical, geomorphic, and sediment-related parameters be developed and presented in an understandable fashion so the amount of sediment eroded from a watershed can be estimated.

Erosion and sedimentation impact many agencies and businesses. The impacts of eroded soil on natural systems are also varied and widespread.

Sediment has been recognized by the Illinois State Water Plan Task Force (1984) as the number one pollution problem facing the State of Illinois. Even though a sufficient data base is not available at the present time, it is essential to quantify the amount of sediment carried by Illinois streams in order to help identify proper management techniques and practices to deal with sediment problems.

Background

The Illinois State Water Plan Task Force (1984) lists erosion and sediment control as the first of ten critical issues concerning the water resources of the state. The Task Force presents the rationale for research in this area very clearly: "The collection and dissemination of streamflow, water quality, and suspended sediment data suffers from serious funding problems resulting in part from the fragmentation that exists in planning, operation, and funding of these important information networks. Furthermore, end users of the data take the data collection effort for granted and do not participate in planning or funding."

The maximum suspended sediment data collection effort in Illinois was made in Water Year 1981, which was the first year of the Water Survey's Instream Sediment Monitoring Program. In that year the Water Survey operated 27 intensive and 23 weekly stations and the U.S. Geological Survey (USGS) monitored 29 stations. (The USGS sediment monitoring program was initiated in 1975.) Subsequent funding limits forced the USGS to reduce its sediment monitoring effort, so that in Water Year 1983, only four stations were monitored. Similarly, the Water Survey sediment monitoring effort was reduced to about 20 stations in Water Year 1983. Presently the Water Survey has 18 suspended sediment stations included in its benchmark network of water resources data.

As data collection efforts have declined, agencies have become concerned that their staffs would not have the time or interest to analyze the available data. Therefore the Illinois State Water Survey, in cooperation with the Illinois Department of Energy and Natural Resources and the U. S. Army Corps of Engineers, Rock Island District, initiated this cooperative project to determine the present state of knowledge with respect to instream sediment loads of Illinois streams and rivers.

The objectives of the present investigation are as follows:

a) Compile available data. This includes suspended sediment data for all the sediment stations within the state as well as all lake sedimentation data.

b) Perform statistical analyses of the data.
   1) Develop predictive sediment load equations as a function of water discharge for each station.
   2) For stations with three or more years of continuous daily sediment data, develop seasonal sediment transport equations and sediment load duration curves.

3) Evaluate and select watershed geomorphic and hydraulic parameters to correlate with the instream sediment load.

4) Develop watershed and regional sediment loads and compare with existing estimates of sediment production rates for various land resource areas.

c) Recommend a technique for estimating the stream sediment load from existing information.

Plan of Report

The report first reviews the fundamentals of sediment transport in rivers and describes the study area. It then discusses the available data and the methods used to analyze station data. The next two sections present the generalized and regional analyses performed for the project. Recommended techniques for the determination of sediment loads of Illinois streams are then given, and they are followed by a brief summary of the research.

Acknowledgments

Administrative guidance was provided by Stanley A. Changnon, Jr., Chief Emeritus, and Richard J. Schicht, Acting Chief, Illinois State Water Survey, and by Michael L. Terstriep, Head of the Surface Water Section.

The Illinois Department of Energy and Natural Resources (DENR) and the Rock Island District, U.S. Army Corps of Engineers, each provided partial support for this research. Tim Warren was project coordinator for DENR, and George Johnson and Clinton Beckert provided liaison for the Rock Island District. The Illinois Environmental Protection Agency provided some data and the Illinois District, Water Resources Division, U.S. Geological Survey, was instrumental in obtaining much of the data.

Undergraduate students Bradley Albrecht, Amy Bari, Cheryl Peterson, and Marcia Schulmeister measured geomorphic and hydraulic parameters and entered data into the computer for analysis. The illustrations were prepared by John Brother, Jr., and Linda Riggin. Kathleen Brown, Becky Howard, and Patty Odencrantz prepared the rough drafts and camera-ready text, and Gail Taylor edited the report.

LITERATURE REVIEW

As noted by Rouse and Ince (1957), river hydraulics has been vital to human endeavor since the beginning of recorded history. Unless otherwise credited, this brief historical review follows their account. The first clear and correct qualitative description of streams transporting sediment in alluvial channels was given by Domenico Guglielmini about 1700. In 1796 Pierre du Buat discussed the scour of a channel by the water flowing in it

(Graf, 1971). The gradual discovery of the proper relation between velocity, depth, channel roughness, and slope occupied open channel researchers through the 19th century. From 1908 to 1914 G. K. Gilbert conducted the classic series of experiments on sediment transport by flowing water. His results have been used by modern researchers who have added much to our fundamental knowledge of sediment transport.

In 1938 Rouse considered sediment transport important enough to include it in his seminal book, Fluid Mechanics for Hydraulic Engineers. A collection of fourteen significant papers in hydraulics between 1935 and 1960 included three on sediment transport and four on open channel flow (McNown, 1982).

In the 1970's comprehensive texts on sediment transport were produced by Graf (1971), an American Society of Civil Engineers (ASCE) committee (Vanoni, 1975), and Simons and Senturk (1977). A brief summary of sediment transport was given by Bhowmik et al. (1980), in the first of a series of reports on the Kankakee River. The following review and definitions are purposely brief, and the reader is referred to the above-mentioned sources for greater detail.

Analytical Approaches

For the purpose of analysis, the total sediment load is often split into two parts: bed load and suspended load. Bed load is defined as that sediment in the bed layer moved by saltation, rolling, or sliding. The bed layer is a flowing layer several grain diameters thick immediately above the bed. Suspended load is defined as that sediment load that is moved by upward components of turbulent currents and that stays in suspension for a considerable time. There is no sharp division between saltation and suspension. The distinction is made between two different methods of hydraulic transport: movement due to shear force and movement due to suspension (Simons and Senturk, 1977).

Many empirical and semi-theoretical equations have been proposed to predict bed load. These expressions fall into one of three different but related approaches: 1) the du Boys-type equations (shear stress relationships); 2) the Schoklitsch-type equations (discharge relationships); and 3) the Einstein-type equations, based upon statistical considerations of the lift force (Graf, 1971). When any of these equations are applied, care should be taken to limit their use to similar flow conditions and particle characteristics, since they contain many experimentally determined constants.

As stated previously, suspended load is defined as that sediment surrounded by fluid that stays in suspension for an appreciable length of time. Sediment particles settle because of their weight, but fluid turbulence counterbalances this motion. Just as there exists an active exchange between bed material and bed load, so there is an active exchange between bed load and suspended load.

The suspended load per unit width of channel q_s is

$$q_s = \gamma_s \int_t^D \overline{V}\,\overline{C}\,dy \tag{1}$$

where $\overline{V}$ and $\overline{C}$ are the time averaged velocity and concentration distributions, γ_s is the unit weight of the sediment particles, D is the depth, and t is the thickness of the bed layer. The total suspended load for a stream can be obtained by integrating equation 1 across the width of the stream. An expression for $\overline{C}$ in terms of C_t at a distance t above the bed can be obtained on the basis of assumptions about the sediment diffusion coefficient and the velocity distribution. This equation is:

$$\overline{C}/C_t = \{[(D-y)/y]\ t/(D-t)\}^z \tag{2}$$

where

$$z = \omega/\beta k V_* \tag{3}$$

Here β is a constant, k is the von Karman constant, and ω is the particle fall velocity. Several researchers have shown that for fine particles $\beta = 1$ and for coarse particles $\beta < 1$. Von Karman's constant k is equal to 0.4 in open channel flow without sediment but is reduced for sediment laden flow (Vanoni and Nomicos, 1960). In general, many researchers have found agreement with equation 2; but the values of z have been determined by fitting the data and not from theory. Equation 2 is used in equation 1 to determine q_s. When attempting to determine the suspended load one must remember that only the suspended load due to bed material is calculated from the above equations. Considerable quantities of fine particles may be carried into a stream from erosion of adjacent land surfaces and may be transported in suspension. This component of the suspended sediment load is called the wash load.

The total load is equal to the sum of the bed load and suspended load. Some researchers have done work on obtaining total load directly, rather than as a sum of two components. Actually the total load that can be predicted is the total bed material load, which is made up of particle sizes that can be found in the bed. The wash load is made up of particles finer than those found in the bed and is dependent on the supply available from the watershed. Selected references from many research efforts are those by Lane and Kalinske (1941), Einstein (1950), Laursen (1958), Bagnold (1966), Toffaleti (1969), and Shen and Hung (1971).

Still, the question remains as to how to determine the total load if some field data are available. If the hydraulic and suspended sediment load data are available, the total suspended sediment load can be computed. In many instances, especially in the case of streams flowing on sandy beds, it is easy to measure the suspended sediment load. However, instruments to measure the bed load are not yet well developed. Thus, an empirical relationship is needed to determine the total load from the hydraulic data and the measured suspended sediment load. Simons and Senturk (1977) have indicated that for large and deep rivers, the amount of bed load may be 5 to 25 percent of the suspended load. Total bed load may be small in these rivers, but it is important since bed load influences the bed stability and determines the bed form and particle roughness of the channel.

Sediment Measurement Studies

Field methods for sediment transport data collection have been developed and standardized by U.S. agencies with interest and responsibility for streams, rivers, lakes, and navigation. Guy and Norman (1970) describe the instruments and methods for obtaining suspended sediment samples for concentration and particle size determination. The samplers obtain depth-integrated isokinetic samples over the water depth from the surface to about 0.3 feet above the bed. Some samplers can collect a time-integrated sample at a point. The unmeasured zone near the bed is often considered to be bed load. A bed load sampler is under development (Helley and Smith, 1971), but calibration for different-sized particles and clogging by fines. and organic particles are serious problems. A recent field study in Illinois (Graf, 1983) used this sampler to obtain bed load data from nine streams. Graf reported some problems but concluded that the data were useful.

When attempting to extend suspended sediment transport data by means of any of the analytical methods, a major problem results from using a "total suspended load" measurement with equations which describe the transport of bed material. In Illinois, many stream channels are formed in geologically homogeneous materials. Thus it will be extremely difficult to divide the measured load into wash load and stream bed material load.

A sediment-budget study in the Rock Island District reach of the Mississippi River concluded that bed load ranged from 6 to 26 percent of the suspended load and averaged 11 percent for the tributaries (Nakato, 1981). This is compatible with the estimate given by Simons and Senturk (1977).

The Illinois State Water Survey has studied sediment for many years. The earlier studies were devoted to the problem of sediment deposition in lakes. Approximately 100 lakes have been surveyed for sediment accumulation, a number of them more than once. An example of a frequently surveyed lake is Lake Decatur on the Sangamon River, for which the sixth sedimentation survey was completed early in 1984 (Bogner et al., 1984). This lake has lost 35 percent of its capacity due to sediment in 61 years for an average capacity loss rate of 0.58 percent per year. Recently, erosion of topsoil from prime farmland and its contribution to instream sediment and lake sedimentation has become a critical issue. The Illinois State Water Plan Task Force (1984) identified erosion and sediment control as the top priority critical issue for the state, and stream and lake use management and stream data measurements as the top two operating issues.

Bank erosion and sediment transport by the Illinois River are the subjects of two reports (Lee and Bhowmik, 1979; Bhowmik and Schicht, 1980).

Sedimentation in backwater lakes along the Illinois River is of concern to fish and waterfowl interests as well as to hydrologists and sedimentation engineers. Sedimentation surveys of a number of these lakes were reported by Lee and Stall (1976, 1977). Bellrose et al. (1983) summarized the impact of backwater lake sedimentation on the useful life of these lakes for recreation or as productive aquatic habitats.

A controversy over the effect of channelization and channel maintenance along the Kankakee River in Indiana on the hydrology and sediment transport of the river in Illinois led to an intensive, multi-year investigation of the Kankakee River. The first report (Bhowmik et al., 1980) included an extensive hydrologic analysis and presented a comprehensive picture of the river basin characteristics. As the data base increased in length, additional analysis was completed (Bhowmik and Bogner, 1981), and a clear understanding of the sediment transport characteristics and the impact of channel clearing on the floods and hydraulics of the river was presented (Demissie et al., 1983).

On the basis of the lake sedimentation data and the concern about the fate of erosion products from the land surface, a program for instream sediment measurement was proposed. After an ambitious beginning in 1981 with 50 suspended sediment monitoring stations (Bonini et al., 1983), in Water Year 1984 this program was merged into the Water Survey's statewide benchmark network with 18 stations. The U.S. Geological Survey has also monitored suspended sediment transport in Illinois since 1975 and has published the results in their annual water resources data reports. Lazaro et al. (1984) used five years of weekly suspended sediment data to determine the long-term sediment transport by Bay Creek at Nebo, Illinois.

Although much interest is focused on the local streams in Illinois, the state is bounded by many miles of the Mississippi and Ohio Rivers and is divided by the Illinois River. Navigation has secondary but definite impacts on the sediment transport and suspension characteristics of these rivers. While participating in the development of a master plan for managing the Upper Mississippi River, Water Survey scientists investigated several impacts which are proportional to the frequency and size of barge tows. Resuspension and lateral redistribution of sediment by commercial tows were studied by Bhowmik et al. (1981a). Pulse inputs of water and sediment to side channels and backwater lakes occur as the result of the hydrodynamics of tow passage (Bhowmik et al., 1981b). The Master Plan (Upper Mississippi River Basin Commission, 1982) recommended long-term resource monitoring, erosion control, and navigation traffic impact monitoring.

Following this involvement in a multi-disciplinary project on large river dynamics, resources, biology, and uses, the Water Survey became a part of the large river project in the National Science Foundation Long Term Ecological Research (LTER) program. The water, sediment, and nutrient fluxes are the environment and the energy source for the biota that live in the river. Sediment budget calculations for Pool 19 were reported by Adams and Bhowmik (1983). Adams (1984) has also discussed the implications of LTER for the future management of the Upper Mississippi River.

Regional Studies

Since sediment transport or lake sedimentation data are available at only a few locations in individual river basins or even in an entire state, several larger regional studies have been made. In 1970, the Upper Mississippi River Comprehensive Basin Study (UMRCBS) Coordinating Committee published Appendix G: Fluvial Sediment (UMRCBS,1970). A method based on a relation between annual sediment yield and drainage area for each of a number of areas designated as Land Resource Areas (LRAs) was proposed and has been used since then to estimate sediment loads. The LRAs are determined by similarity of factors such as soils, climate, water resources, land use, and type of agriculture.

Researchers at the University of Wisconsin investigated the relation between floods and sediment yield, and variations in climate and land use (Knox et al., 1975), in the Upper Mississippi Valley. A general, broad-area description of sediment transport in the Mississippi River Basin has been compiled by the Environmental Laboratory at the Waterways Experiment Station (Keown et al., 1981). Griffiths (1982) studied suspended sediment yields of watersheds in New Zealand. He used various regression techniques and regional analysis to relate sediment yields in 47 river basins.

PHYSICAL AND CLIMATIC SETTING

Physical Characteristics

Figure 1 is a map of Illinois with the major rivers and river basin boundaries delineated. The physiographic divisions of Illinois (Leighton et al., 1948) are outlined in figure 2. Most of the state is in the Central Lowland Province. Except for the Wisconsin Driftless Section in the northwest corner, the entire area was glaciated. The large valleys of the Mississippi and Illinois Rivers were formed during glacial recession by meltwater.

The Galesburg, Springfield, and Bloomington Ridged Plains differ in number of moraines and amount of valley incision. The Springfield Plain is flat and has shallow stream valleys. The Galesburg Plain has four moraines and large, steep-walled, and terraced stream valleys. The Bloomington Ridged Plain has low, broad morainic ridges with intervening wide and flat or gently rolling ground moraine deposits.

The Rock River Hill Country has a mature drainage pattern with deep valleys and occasional bedrock exposure. The Wheaton Morainal Country has more lakes and swamps than does the Bloomington Ridged Plain. The morainal pattern follows the shoreline of Lake Michigan. The Fox Chain of Lakes is a distinctive surface water resource of this area. The Kankakee Plain is a mixture of glacial features with some ancient sand deposits of glacial Lake Chicago as well as later morainal features.

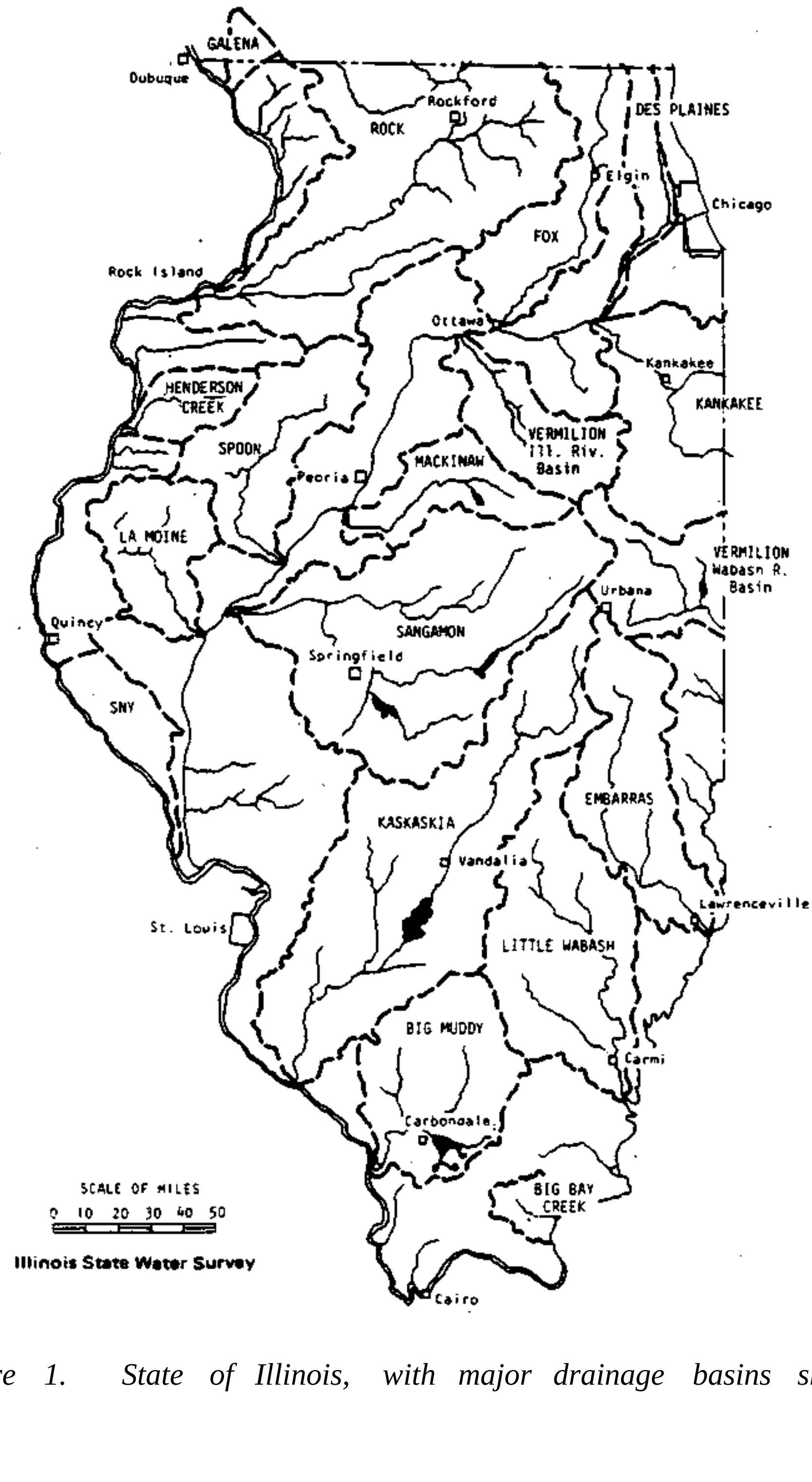


Figure 1. State of Illinois, with major drainage basins shown

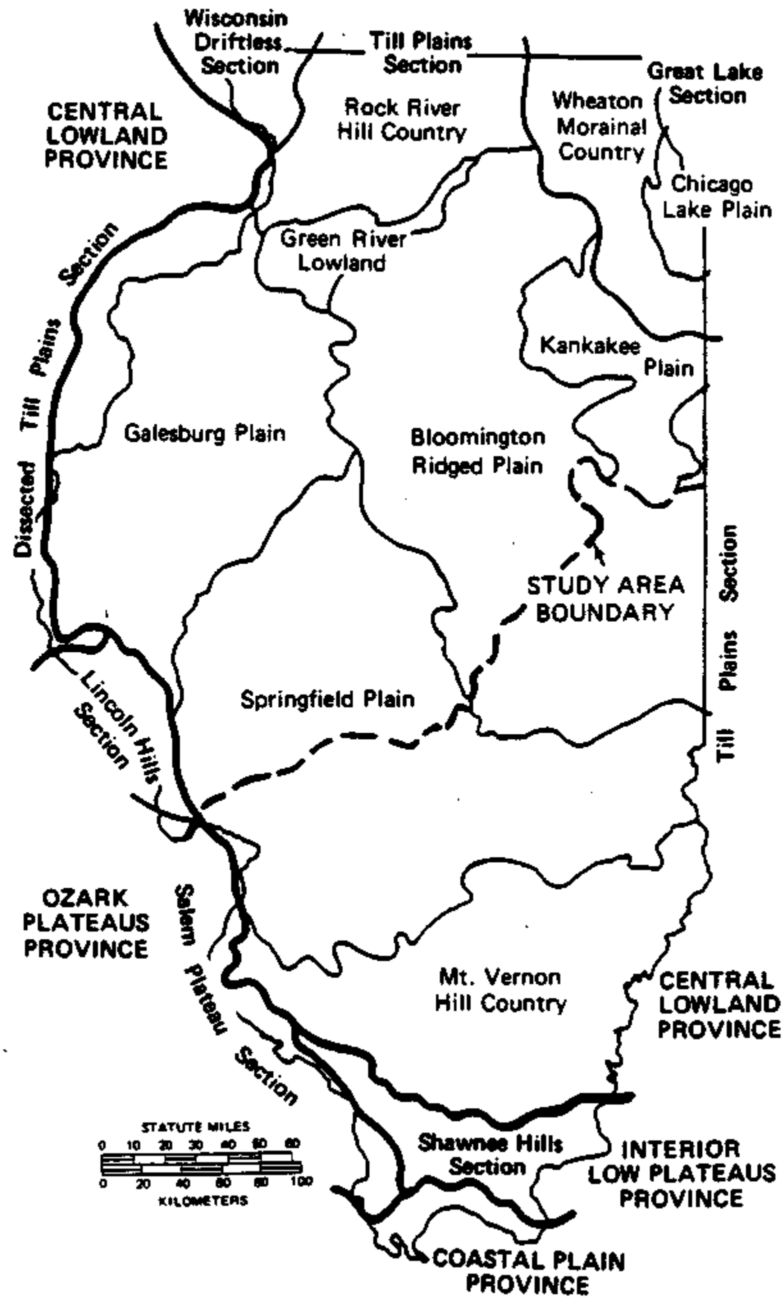


Figure 2. Physiographic divisions of Illinois (after Leighton et al., 1948)

The Mount Vernon Hill Country is the southernmost portion of the Illinoian Drift and has a mature topography with restricted upland prairies and broad alluvial valleys along larger streams. The southern tip of the state includes the Shawnee Hills Section of the Interior Low Plateaus Province and a small portion of the Coastal Plain Province. The maturely dissected Pennsylvanian cuesta forms the Shawnee Hills Section which crosses the state. To the south it is buried by the alluvial plains of the Cache and Mississippi Rivers which are in the Coastal Plain Province.

The state is also described by nine Land Resource Areas (LRAs) as shown in figure 3. The delineation of LRAs is based on agricultural utility. Each LRA is characterized by a particular combination of soil type, slope, erodibility, climate, water, land use, and type of farming. These are described in detail in Appendix G of the comprehensive basin study (UMRCBS, 1970).

LRA 108, the Illinois and Iowa deep loess and drift area, includes much of the upland portions of the Galesburg, Springfield, and Bloomington Ridged Plains. LRA 105, the northern Mississippi Valley loess hills area, is nearly coterminous with the Wisconsin driftless section. LRA 109 is the Iowa and Missouri heavy till plain, and LRA 110 is the northern Illinois and Indiana heavy till plain. LRA 111 is the Indiana and Ohio till plain, LRA 113 is the central claypan area, and LRA 114 is the southern Illinois and Indiana thin loess and till plain. LRA 115, the Central Mississippi Valley wooded slopes area, occurs in the Illinois and Mississippi River Valleys and adjoining bluffs. Finally, there is a small portion of LRA 95, the southeastern Wisconsin drift plain.

Climatic Conditions

Climate, especially precipitation, has a significant impact on soil erosion and thus, presumably, on instream sediment loads. Average annual temperatures in Illinois increase from 48°F in the north to 59°F in the extreme south. The number of frost-free days also increases from about 160 in the north to about 205 in the south. Average annual snowfall is about 32 inches in the north and just 8 inches in the south.

The mean annual precipitation in inches for the period 1951 to 1980 is shown by the isohyetal lines in figure 4. There is a difference of about 10 inches per year between the northern and southern parts of the state. The isohyetal lines do not follow a clear trend but are quite convoluted. The nine crop reporting districts and the average precipitation in each district are also shown in figure 4.

Significantly more sediment is transported in streams and rivers during floods and storm events than during low flow periods. The summation of rainfall events and sediment loads over the period of a year masks the event-related effects, so annual precipitation is not a good indicator of sediment yield. Also a relatively short sediment record may not be representative of long-term average conditions for either annual precipitation or the number of intense rains per year.

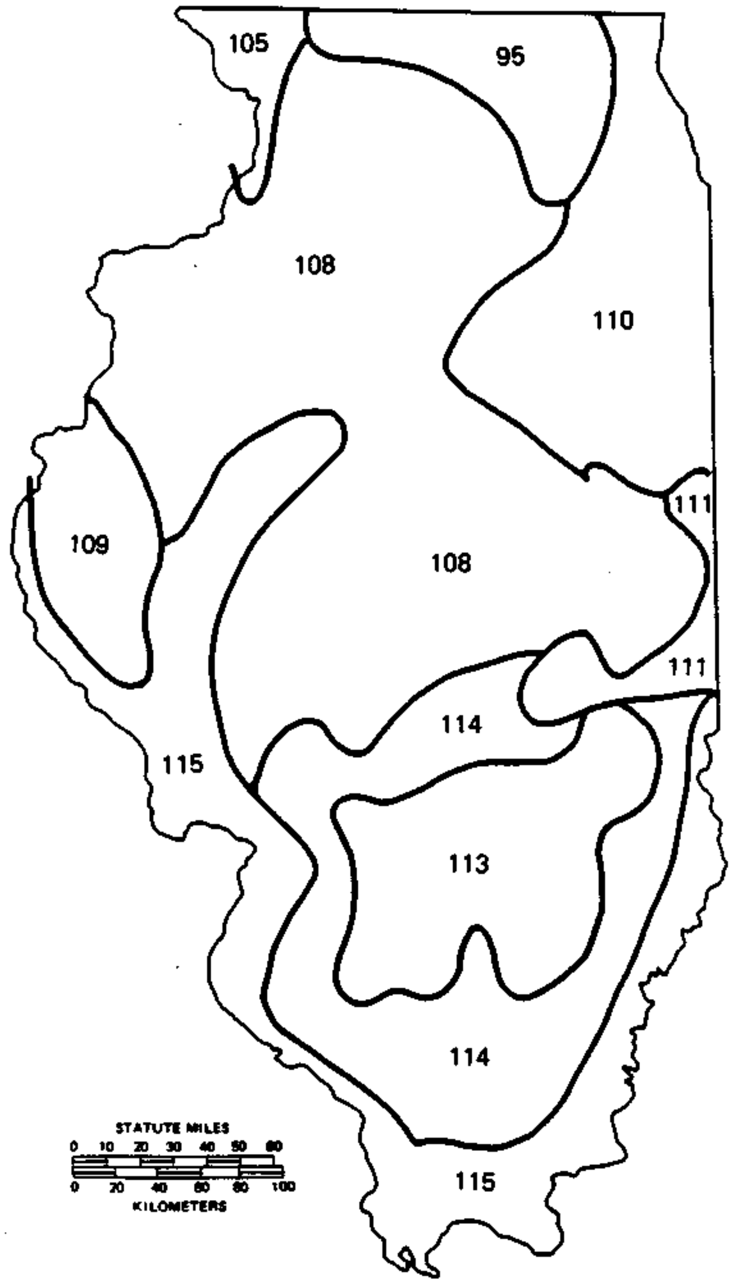


Figure S. Land Resource Areas in Illinois (after UMRCBS, 1970)

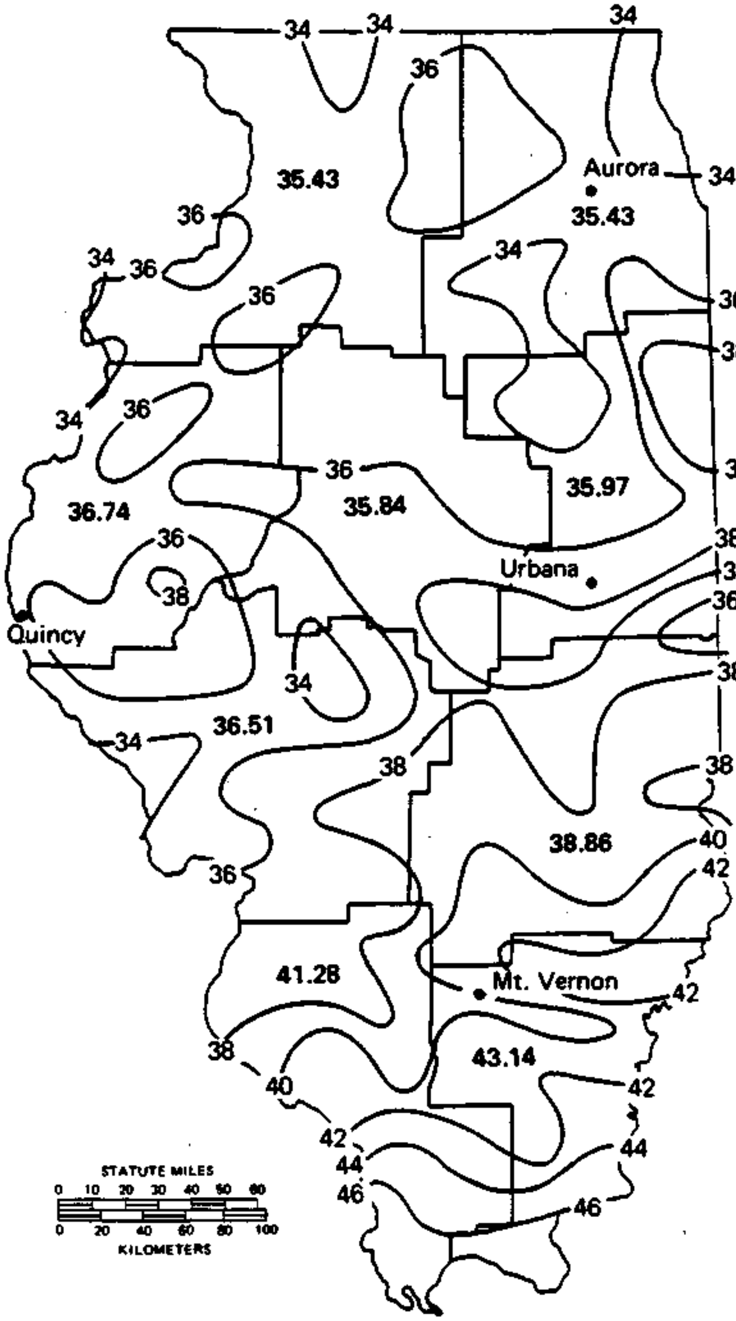


Figure 4. Average annual precipitation in Illinois (inches), 1951-1980
(The nine crop reporting districts, average precipitation in each district, and four selected precipitation stations are also shown)

Four precipitation stations were selected for study of precipitation patterns throughout the state (see figure 4 for their locations). Since the sediment load data were almost entirely from the 1976 to 1983 period, the annual precipitation for each station during that period was compared with the normal precipitation for the years 1951 through 1980. The maximum, minimum, and average annual precipitation for the four stations are given in table 1. The increase in precipitation from north to south is apparent. Also, during this period all the stations had average annual precipitation which exceeded the normal by 2 to 3 inches.

As a measure of the frequency of major storms, one-day precipitation amounts exceeding 1 and 2 inches were tabulated for the 83-year period from 1900 to 1983 in 5-year blocks. Table 2 presents a summary of these results, including the 1976-1983 period of primary interest. From Aurora to Mt. Vernon the number of storms exceeding 1 or 2 inches in one day increases by about 50 percent. In the 1976-1983 period the number of days with precipitation greater than 1 inch ranged from 5 below to 12 above average. The number of days when precipitation exceeded 2 inches was 1 less than average except at Mt. Vernon where it was 4 above average. There is more variation in the number of days with intense storms (as measured by days with more than 1 or 2 inches of precipitation) than is indicated by the variability in annual precipitation (table 1). On a station or watershed level of analysis, storm frequency may be included as another variable. At this time, for a statewide study, the refinement of analysis required to use individual precipitation station records for each sediment sampling site or watershed is not practical.

Table 1. Annual Precipitation 1976-1983, Inches

	AURORA	QUINCY	URBANA	MT. VERNON
Maximum	43.76	51.39	50.28	53.41
Minimum	27.92	26.77	31.73	31.71
Average	38.24	39.42	40.14	41.42
Normal (1951-1980)	35.64	37.65	37.04	39.92

Table 2. Frequency of One-Day Precipitation Exceeding 1 and 2 Inches

	AURORA	QUINCY	URBANA	MT. VERNON
A. Number of storms ≥ i inch per 5-year period, 1900-1980				
Average	38.1	45.9	43.5	54.2
Maximum	49	60	57	64
Minimum	29	31	27	42
B. Number of storms ≥ 2 inches per 5-year period, 1900-1980				
Average	6.1	8.6	6.9	9.2
Maximum	10	14	12	14
Minimum	1	,5	3	4
C. Number of storms, 1976-1983				
≥ 1 inch	73	68	76	87
Difference from average	+12	-5	+6	0
≥ 2 inches	9	13	10	19
Difference from average	-1	-1	-1	+4

DATA SOURCES AND TYPES

A key element in this project was the creation and maintenance of a data base that would be used in all analyses. The basic information was divided into two major categories: sediment data and geomorphic data. Descriptions of the sources and types of information that were obtained for each of these categories are given below.

It was apparent from the start of the data gathering process that the only manageable way to handle the large amount of data was to store, retrieve, and manipulate the data sets in a computer. The University of Illinois' Control Data Corporation Cyber 175 and IBM 4341 were chosen as the hardware systems to handle the various data sets. FORTRAN programs, some of which had been developed for the Water Survey's Sediment Monitoring Program, were adopted, modified, and developed to process the data sets and to generate the results presented later in this report.

Suspended Sediment Data

The first step in gathering all pertinent sediment data for this project was to identify the agency sources for sediment data. The U.S. Geological Survey (USGS), Illinois State Water Survey (SWS), U.S. Army Corps of Engineers (COE), and Illinois Environmental Protection Agency (IEPA) were all identified as having some sediment data on file. Lists of available sediment data from these agencies were compiled. It became obvious in compiling these lists that the data involved a heterogeneous mix of record lengths, data types, and collection frequencies. The USGS data were the most numerous and included mean daily water and suspended sediment discharge data for 33 stations with record lengths of from 1 to 8 years. The SWS data included instantaneous daily and instantaneous weekly water and suspended sediment discharge data for 56 stations with record lengths of from 1 to 2 years. The COE data included instantaneous daily suspended sediment concentration data and daily water discharge data for 3 stations with record lengths of 14 or 15 years. Seven of these stations were monitored by more than one agency during their period of record.

Table 3 summarizes the data obtained from these three agencies. This table includes a listing of each of the 85 stations by SWS station code and includes the USGS station number and name. The drainage area, river basin, period of record, and type and frequency of record, including the monitoring agencies and years that they collected data, are also listed. The data used in this report reflect data collected through Water Year 1983. All of these data were obtained in machine-readable form.

Figure 5 shows the locations of the suspended sediment monitoring stations in Illinois. The stations are identified by their SWS 3-digit station codes. Of the 85 stations, three are located on the main stem of the Mississippi River and two are located on the main stem of the Illinois River.

The IEPA sediment data, collected as part of their Ambient Water Quality Monitoring Network, were obtained through the USGS WATSTORE system and included instantaneous water discharge and suspended sediment concentration data for approximately 113 stations. Record lengths varied tremendously, ranging from 4 to more than 20 years. Sampling frequency ranged from bi-weekly to monthly to bi-monthly. The IEPA data set was not used in the statistical analyses generated for this report because the sampling frequency was sporadic, many stations did not have a continuous record of water discharge, and in most cases depth integrating techniques were not used to measure the suspended load.

Bed Load Data

The bed load carried by a stream can be determined either by measuring the sediment moving near the bed or by monitoring the movement of bed forms such as sand bars.

A review of available instrumentation for bed load measurement indicates that basically one field instrument is available for measuring the

3. Summary of Available Sediment Data for Illinois

STA. CODE	USGS STA.NO.	USGS STATION NAME	DRAINAGE AREA	RIVER BASIN	PERIOD OF RECORD	TYPE AND FREQUENCY OF RECORD (COLLECTING AGENCY, YEARS COLLECTED) MEAN DAILY	INSTANTANEOUS DAILY	INSTANTANEOUS WEEKLY
101	05418950	APPLE RIVER NEAR ELIZABETH	207	APPLE	1981-32			SWS 1981-82
102	05435500	PECATONICA RIVER AT FREEPORT	1326	ROCK	1981-82			SWS 1981-82
103	05437500	ROCK RIVER AT ROCKTON	6363	ROCK	1981-83		SWS 1981	SWS 1981-83
104	05438500	KISHWAUKEE RIVER AT BELVIDERE	538	ROCK	1981-82			SWS 1981-82
105	05440000	KISHWAUKEE RIVER NEAR PERRYVILLE	1099	ROCK	79-81,83	USGS 4/79-81		SWS 1983
106	05439500	SOUTH BRANCH KISHWAUKEE RIVER NEAR FAIRDALE	387	ROCK	1981-82		SWS 1981	SWS 1981-82
107	05550000	FOX RIVER AT ALGONQUIN	1403	FOX	1981		SWS 1981	SWS 1981
108	05529000	DES PLAINES RIVER AT DES PLAINES	360	DES PLAINES	1981			SWS 1981
109	05532500	DESPLAINES RIVER AT RIVERSIDE	630	DES PLAINES	4/79-82	USGS 4/79-82		
110	05551200	FERSON CREEK NEAR ST. CHARLES	51.7	FOX	1981-82			SWS 1981-82
111	05439000	SOUTH BRANCH KISHWAUKEE RIVER AT DEKALB	77.7	ROCK	1980-81	USGS 1980-81		
112	05444000	ELKHORN CREEK NEAR PENROSE	146	ROCK	1981		SWS 1981	SWS 1981
113	05446500	ROCK RIVER NEAR JOSLIN	9549	ROCK	5/80-83	USCS 5/80-82		SWS 1983
114	05551540	FOX RIVER AT MONTGOMERY	1732	FOX	1981-83			SWS 1981-83
115	05539000	HICKORY CREEK AT JOLIET	107	DES PLAINES	1981			SWS 1981
116	05540500	DUPAGE RIVER AT SHOREWOOD	324	DUPAGE	1981		SWS 1981	SWS 1981
117	05552500	FOX RIVER AT DAYTON	2642	FOX	1981			SWS 1981
118	05556500	BIG BUREAU CREEK AT PRINCETON	196	BUREAU	1981-83		SWS 1981	SWS 1981-83
119	05447500	GREEN RIVER NEAR GENESEO	1003	GREEN	78-81,83	USGS 3/78-81		SWS 1983
120	05466500	EDWARDS RIVER NEAR NEW BOSTON	445	EDWARDS	1/79-81	USGS 1/79-81		
121	05466000	EDWARDS RIVER NEAR ORION	155	EDWARDS	1981-82			SWS 1981-82
122	05555300	VERMILION RIVER NEAR LENORE	1251	VERMILION	6/80-81	USGS 6/80-81		
123	05542000	MAZON RIVER NEAR COAL CITY	455	MAZON	1981-83		SWS 1981	SWS 1981-83
124	05527500	KANKAKEE RIVER NEAR WILMINGTON	5150	KANKAKEE	1979-83	USGS 1979-82	SWS 1983	SWS 1983
125	05520500	KANKAKEE RIVER AT MOMENCE	2294	KANKAKEE	1979-83	USGS 1979-81	SWS 1982-83	SWS 1983
126	05568800	INDIAN CREEK NEAR WYOMING	62.7	SPOON	1981	USGS 1981		
127	05467000	POPE CREEK NEAR KEITHSBURG	183	POPE CR	1981		SWS 1981	SWS 1981
191		MISSISSIPPI RIVER AT EAST DUBUqUE	81600	MISSISSIPPI	1967-81		COE 1967-81	
203	05437630	SPRING CR. AT MCFARLAND RD. NEAR ROCKFORD	2.44	ROCK	6/79-81	USGS 6/79-81		
204	05437632	SPRING CR. AT ROCK VALLEY COLLEGE AT ROCKFORD	2.81	ROCK	6/79-81	USGS 6/79-81		
227	05543500	ILLINOIS RIVER AT MARSEILLES	8259	ILLINOIS	1975-82	USGS 1975-82(INTERMITTENT)		
228	05469000	HENDERSON CREEK NEAR OQUAWKA	432	HENDERSON	4/78-81	USGS 4/78-81		
229	05569500	SPOON RIVER AT LONDON MILLS	1062	SPOON	1981-83		SWS 1981	SWS 1981-83
230	05566500	EAST BRANCH PANTHER CREEK AT EL PASO	30.5	MACKINAW	1981			SWS 1981
231	05554490	VERMILION RIVER AT MCDOWELL	551	VERMILION	1981			SWS 1981
232	05526000	IROQUOIS RIVER NEAR CHEBANSE	2091	KANKAKEE	1979-83	USGS 1979-81	SWS 1982-83	SWS 1983
233	05525000	IROQUOIS RIVER AT IROQUOIS	686	KANKAKEE	1979-83	USGS 1979-80	SWS 1981-83	SWS 1983
234	05525500	SUGAR CREEK AT MILFORD	446	KANKAKEE	1981			SWS 1981
235	05564400	MONEY CREEK NEAR TOWANDA	49.0	MACKINAW	1981			SWS 1981
216	05567510	MACKINAW RIVER BELOW CONCERVILLE	776	MACKINAW	1981			SWS 1981
237	05568005	MACKINAW RIVER BELOW GREEN VALLEY	1092	MACKINAW	1981		SWS 1981	SWS 1981
238	05570350	BIG CREEK AT ST. DAVID	28.0	SPOON	1976-80	USCS 1976-80		
239	05570370	BIG CREEK NEAR BRYANT	41.2	SPOON	1976-83	USGS 1976-83		
240	05570380	SLUG RUN NEAR BRYANT	7.12	SPOON	1976-80	USCS 1976-80		

concluded on next page

Table 3. Concluded

STA. CODE	USGS STA.NO.	USGS STATION NAME	DRAINAGE AREA	RIVER BASIN	PERIOD OF RECORD	TYPE AND FREQUENCY OF RECORD (COLLECTING AGENCY, YEARS COLLECTED) MEAN DAILY	INSTANTANEOUS DAILY	INSTANTANEOUS WEEKLY
241	05570000	SPOON RIVER AT SEVILLE	1636	SPOON	1981	USGS 1981		
242	05584500	LA MOtNE RIVER AT COLMAR	655	LA MOINE	1981-83		SWS 1981	SWS 1981-83
243	05495500	BEAR CREEK NEAR MARCELLINE	349	BEAR CREEK	1981		SWS 1981	SWS 1981
244	055B4685	GRINDSTONE CREEK NEAR BIRMINGHAM	45.4	LA MOINE	1981	USGS 1981		
245	05585000	LA MOINE RIVER AT RIPLEY	1293	LA MOINE	1981	USGS 1981		
246	05583000	SANGAMON RIVER NEAR OAKFORD	5093	SANGAMON	1981	USGS 1981		
247	05582000	SALT CREEK NEAR CREENVIEW	1804	SANGAMON	1981-83			SWS 1981-83
248	05578500	SALT CREEK NEAR ROWELL	355	SANCAMON	1981-83		SWS 1981	SWS 1981-83
249	05572000	SANGAMON RIVER AT MONTICELLO	550	SANCAMON	1981-83			SWS 1981-83
250	03336900	SALT FORK NEAR ST. JOSEPH	134	VERMILION	1981-82		SWS 1981	SWS 1981-82
251	03339000	VERMILION RIVER NEAR DANVILLE	1290	VERMILION	1981			SWS 1981
252	05576500	SANGAMON RIVER AT RIVERTON	2618	SANCAMON	1981-83		SWS 1981	SWS 1981-83
253	05586100	ILLINOIS RIVER AT VALLEY CITY	26564	ILLINOIS	2/80-83	USGS 2/80-83		
254	05576022	SOUTH FORK SANCAMON RIVER BELOW ROCHESTER	870	SANGAMON	1981-82		SWS 1981	SWS 1981-82
255	05591200	KASKASKIA RIVER AT COOKS MILLS	473	KASKASKIA	1/79-83	USGS 1/79-83		
292		MISSISSIPPI RIVER AT BURLINGTON	113600	MISSISSIPPI	1968-81		COE 1968-81	
293	05474500	MISSISSIPPI RIVER AT KEOKUK	119000	MISSISSIPPI	1968-81		COE 1968-81	
356	03343550	EMBARRAS RIVER NEAR OAKLAND	542	EMBARRAS	1/79-82	USGS 1/79-82		
357	03344000	EMBARRAS RIVER NEAR DIONA	919	EMBARRAS	1981-83		SWS 1981	SWS 1981-83
358	05592100	KASKASKIA RIVER NEAR COWDEN	1330	KASKASKIA	1981		SWS 1981	SWS 1981
359	05587000	MACOUPIN CREEK NEAR KANE	868	MAC0UP1N	1981		SWS 1981	SWS 1981
360	05592800	HURRICANE CREEK NEAR MULBERRY GROVE	152	KASKASKIA	1981		SWS 1981	SWS 1981
361	05592500	KASKASKIA RIVER AT VANDALIA	1904	KASKASKIA	1981-83		SWS 1981	SWS 1981-83
362	03345500	EMBARRAS RIVER AT STE. MARIE	1516	EMBARRAS	1981-83		SWS 1981	SWS 1981-83
363	03346000	NORTH FORK EMBARRAS RIVER NEAR OBLONG	318	EMBARRAS	1981-83			SWS 1981-83
364	03378900	LITTLE WABASH RIVER AT LOUISVILLE	745	L. WABASH	3/77-81	USGS 3/77-81		
365	05593520	CROOKED CREEK NEAR HOFFMAN	254	KASKASKIA	1981		SWS 1981	SWS 1981
366	05594000	SHOAL CREEK NEAR BREESE	735	KASKASKIA	1981-83			SWS 1981-83
367	05594800	SILVER CREEK NEAR FREEBURG	464	KASKASKIA	1981-83		SWS 1981	SWS 1981-83
368	03380500	SKILLET FORK AT WAYNE CITY	464	L. WABASH	1981			SWS 1981
369	03379600	LITTLE WABASH RIVER AT BLOOD	1387	L. WABASH	1981-82			SWS 1981-82
370	03381500	LITTLE WABASH RIVER AT CARMI	3102	L. WABASH	1981-83		SWS 1981	SWS 1981-83
371	05597000	BIG MUDDY RIVER AT PLUMFIELD	794	BIG MUDDY	1981-82			SWS 1981-82
373	05599500	BIG MUDDY RIVER AT MURPHYSBORO	2169	BIG MUDDY	5/80-83	USCS 5/80-83		
374	05597500	CRAB ORCHARD CREEK NEAR MARION	31.7	BIG MUDDY	1981			SWS 1981
375	03382170	BRUSHY CREEK NEAR HARCO	13.3	SALINE	2/80-81	USGS 2/80-81		
376	03382100	SOUTH FORK SALINE RIVER NEAR CARRIER MILLS	147	SALINE	1980-81	USCS 1980-81		
377	03384450	LUSK CREEK NEAR EDDYVILLE	42.9	LUSK	1/80-81	USGS 1/80-81		
378	03612000	CACHE RIVER AT FORMAN	244	CACHE	1981-83		SWS 1981	SWS 1981-83
379	05594100	KASKASKIA RIVER NEAR VENEDY STATION	4393	KASKASKIA	5/80-83	USGS 5/80-83		
444	05584680	GRINDSTONE CREEK NEAR INDUSTRY	35.5	LA MOINE	1981	USGS 1981		

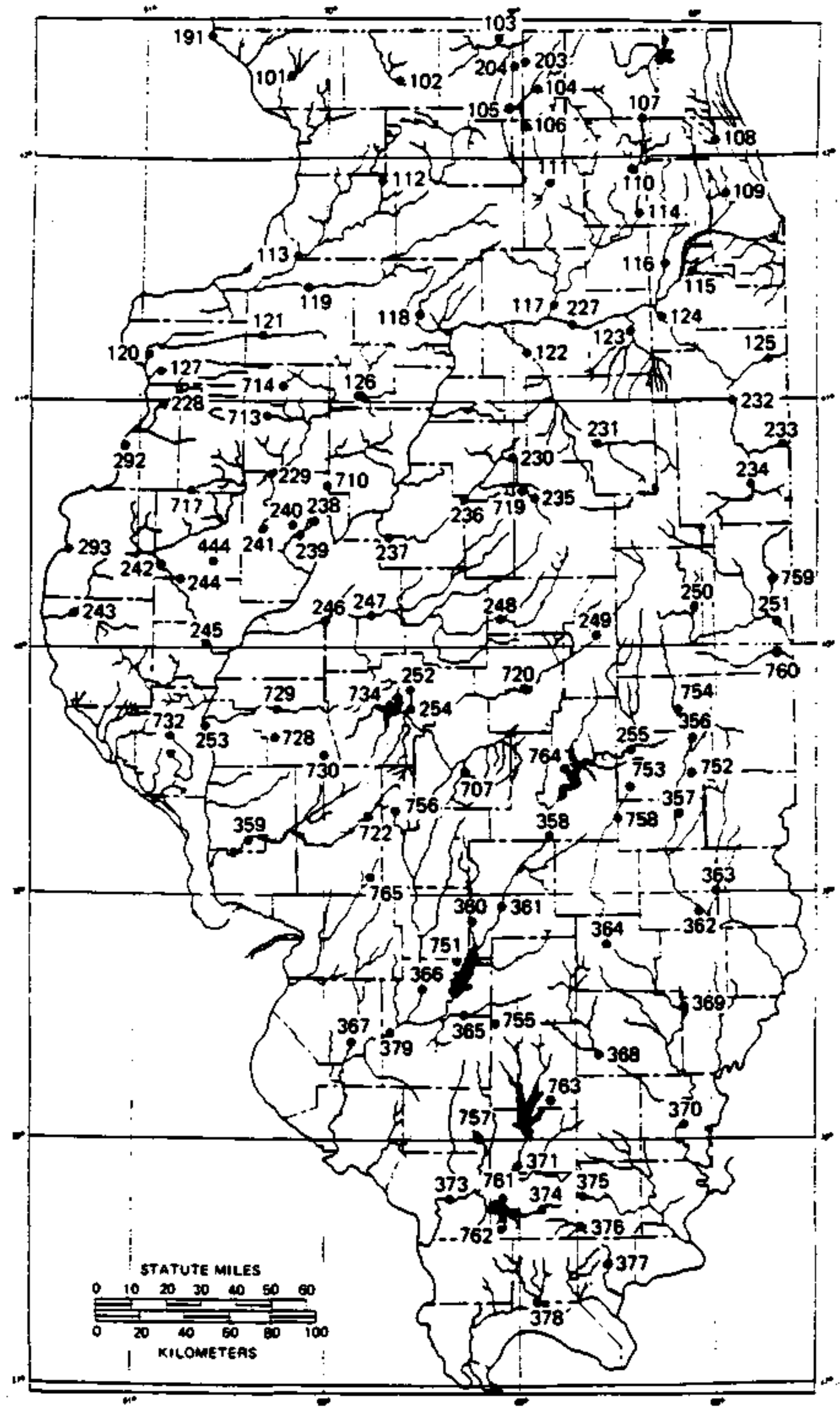


Figure 5. Suspended sediment and lake monitoring stations in Illinois

bed load (Hubbell, 1964; Helley and Smith, 1971). This is an experimental sampler called the Helley-Smith Bed Load Sampler. Its development and limitations are given by Helley and Smith (1971). This sampler was designed for sampling coarse materials where the diameter of the bed materials varies from 2 to 10 mm and the flow velocity ranges up to 10 feet per second. The mesh opening of the collection bag is 0.25 mm. Therefore, when the median diameter of the bed materials is less then 0.25 mm the mesh may get clogged or some of the bed load collected inside the bag may pass through the mesh.

Very few attempts have been made to measure the bed load in Illinois. The Helley-Smith sampler was used by Bhowmik et al. (1980) to collect bed load samples from three sites on the Kankakee River. Analyses of these data indicated that at the state line bridge about 1.6 percent of the total load was bed load. At another station, about 1 percent of the total load was bed load. However, at the state line bridge a sand bar was monitored, and indications were that between 9 and 14 percent of the total sediment load that year was contributed by this sand bar. Movement of the sand bar at this location is a special case (Bhowmik et al., 1980), and similar movement in other streams and rivers may or may not occur regularly.

Graf (1983) analyzed bed load data from nine streams and developed rating curves for the bed load transport for six river basins. Bed load data that were collected were in the sand-sized fraction, with median diameters from 0.25 to 0.50 mm. Bed load rating curves for gaging stations on Henderson Creek and the Kaskaskia, Edwards, Kishwaukee, Spoon, and Rock Rivers were developed. Some of these rating curves are:

Rock River near Joslin

$$Q_{sb} = 6.55 \times 10^{-7} Q_w^{2.0} \quad (4)$$

where Q_{sb} is bed load discharge in tons per day and Q_w is the water discharge in cfs.

Edwards River near New Boston

$$Q_{sb} = 7.0 \times 10^{-3} Q_w^{1.5} \quad (5)$$

based on the Schoklitsch relationship (Shulits, 1935).

Henderson Creek near Oquawka

$$Q_{sb} = 7.1 \times 10^{-10} Q_w^{3.3} \quad (6)$$

Kaskaskia River near Venedy Station

$$Q_{sb} = 6.1 \times 10^{-11} Q_w^{3.0} \quad (7)$$

In addition to the above rating equations, Graf (1983) developed preliminary rating curves for a few other locations. However, the preliminary rating curves were developed from very few measurements, and their use is limited.

Lake Sedimentation Data

Long-term lake sedimentation data from the state of Illinois can also be used in the analysis of sediment yields of Illinois streams. The Illinois State Water Survey has been conducting lake sedimentation surveys since the mid-1930's and has data for a number of lakes. All of the available lake sedimentation data were compiled and reduced to a standard format for use in this project.

Lake sedimentation data are given in terms of the total volume of deposited sediment from the date of construction of the lake to the last sedimentation survey. A methodology was developed to convert this accumulated volume of sediment into an equivalent sediment load at a hypothetical section located at the spillway.

Brune (1953) developed an empirical relationship between trap efficiency of reservoirs and their capacity-inflow ratio (figure 6). The trap efficiency for a particular lake is used to convert the volume of deposited sediment in the lake to the volume of the sediment delivered to it by the stream.

In order to use Brune's relationship, the capacity-inflow ratio must be computed. Sedimentation surveys yield an accurate value for the capacity of a lake. Since most spillways are not maintained as gaging stations, long-term inflow data are not available at these locations. An estimate of the long-term average inflow rates must be made for each of the lakes.

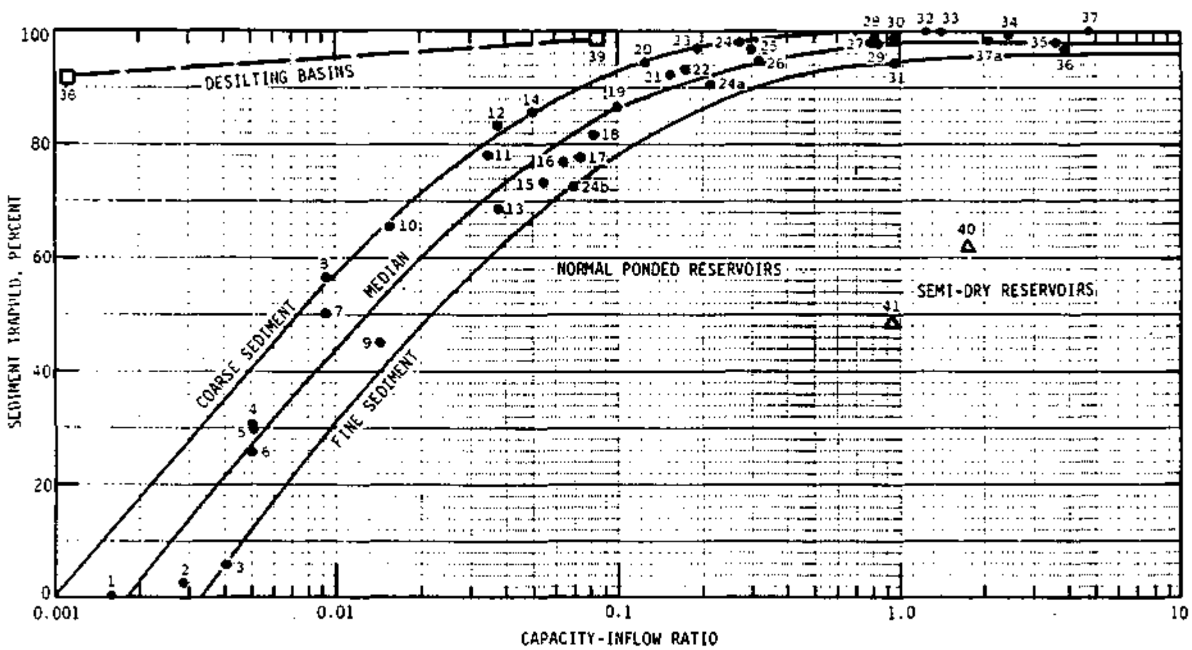


Figure 6. Trap efficiency of a man-made lake (after Brune, 1953)

Terstriep et al. (1982) divided the state of Illinois into ten areas of hydrologic homogeneity for low flow analyses. They observed that a fairly good relationship exists between the drainage areas of the gaging stations and the average annual flows within each region of hydrologic homogeneity. Relationships between drainage area, DA, and the average annual flow, AQW, were developed for each of the regions by using existing gaging station records. These relationships can be used to estimate the average annual flow for each of the lakes within each region. This average annual flow, when converted into inflow volume for a year, yields the inflow needed in Brune's curve (see figure 6).

Lake sedimentation data for Illinois lakes with drainage areas equal to or greater than 8 square miles were selected. These lakes are identified in figure 5 by the 700-series station codes. The data for these lakes were tabulated (table 4), and the total annual sediment yield was computed as follows:

1) With known DA, the average annual inflow, AQW, was computed from the regional AQW versus DA relationship.

2) The capacity-inflow ratio, C/I, was then computed. The capacity used was the original capacity of the lake (table 4).

3) With known C/I values, the trap efficiency was estimated from figure 6.

4) The measured volume of the sediment within each lake was then multiplied by the average unit weight (50 pounds/ft^3 was used for lakes with insufficient data) and divided by the trap efficiency to determine the average annual sediment load at the dam site.

5) The sediment load determined in step 4 was then used as the sediment load of the stream at that particular section (table 4).
)

Numerical values for four geomorphic variables for all of the lakes (drainage area, basin length, total basin relief, and main stem length) are also given in table 4. These are the geomorphic parameters that were selected by the multiple regression method for use in the regional analysis of sediment yields of Illinois streams.

Geomorphic and Hydraulic Data

The geomorphic characteristics of a river basin play an important role in the determination of soil erosion and its delivery to the stream. Thus it is quite feasible to develop functional relationships between the geomorphic and hydraulic parameters and the sediment load transported by streams in a basin. On the basis of this premise, a number of these parameters were determined for the river basins and gaging stations where suspended sediment or lake sedimentation data are available. The numerical values for the geomorphic and hydraulic parameters for all of the sediment monitoring stations used in this study are given in appendix A. The specific parameters for lakes are given in table 4. The definitions of all

Table 4. Hydraulic, Sediment Load, and Geomorphic Data for Reservoirs in Illinois

STA. CODE	NAME OF LAKE	YEAR OF LAST SEDIMENT SURVEY	AGE SINCE ORIGINAL CAPACITY SURVEYED	DRAINAGE AREA (SQ.MI.)	ORIGINAL CAPACITY (ACRE-FT)	INFLOW (I) (ACRE-FT)	C/I	TRAP EFFICIENCY	DEPOSITED SEDIMENT (TONS/ACRE)	ANNUAL SEDIMENT YIELD (TONS/SQMI)	ANNUAL SEDIMENT LOAD (TONS)	BASIN LENGTH LB(MI)	TOTAL BASIN RELIEF H(FT)	MAIN STEM LENGTH LS(MI)
707	TAYLORVILLE	1977	15	131	9406	82052	.11	.87	1.60	1177	154340	14. 50	180	24.1
710	CANTON NO.36	1960	21	15.0	3513	7154	.49	.96	2.40	1600	24000	7.44	210	9.0
713	BRACHEN	1962	39	8.9	2881	4234	.68	.97	2.80	1847	16442	375.	91	4.2
714	CALHOUN	1947	23	13.1	425	6205	.07	.82	2.00	1561	20449	4.25	120	6.9
717	SPRINC	1962	35	20.2	609	14308	.04	.74	1.48	1280	25856	5.48	51	7.1
719	BLOOHINCTON	1955	26	61.0	6654	30879	.22	.93	.80	550	33581	19.50	180	27.0
720	DECATUR	1983	61	925	27900	491144	.06	.80	.27	216	199800	28.10	237	40.3
722	CARLINVILLE	1959	30	26.1	1725	13505	.13	.88	1.45	1055	27522	5.58	119	7.8
728	JACKSONVILLE	1952	12	10.8	7058	5694	1.24	.98	1.69	1104	11920	7.25	90	7.5
729	MAUVAISSETERRE	1979	58	32.6	1505	16863	.09	.85	.77	580	18901	12.75	115	13.0
730	LAKE WAVERLY	1971	33	9.2	308	4891	.06	.80	.80	640	5888	2.19	90	4.3
732	PITTSFIELD(NEW)	1979	18	11.2	3454	8614	.40	.95	5.59	3766	42178	5.71	200	7.0
734	SPRINGFIELD	1977	42	265	61039	143080	.43	.96	.89	593	157233	20.88	115	15.3
751	CARLYLE LAKE	1971	4	2680.	280595	1370064	.20	.92	1.47	1023	2740568	124.00	300	197.9
752	LAKE CHARLESTON	1974	27	811	2129	490414	.004	.21	.14	427	346054	44.35	120	66.8
753	PARADISE LAKE	1979	71	18.1	2042	10293	.20	.92	.80	557	10073	1.88	34	5.8
754	LAKE OAKLAND	1954	17	14.3	94	8030	.012	.44	.17	247	3536	17.00	50	6.3
755	RACCOON LAKE	1959	16	48.4	4496	27959	.16	.91	.73	513	24849	11.50	170	15.3
757	LAKE DUQUOIN	1957	18	10.7	2003	6059	.33	.94	.81	552	5901	5.30	50	6.3
758	LAKE MATTOON	1980	22	56.0	13160	32412	.41	.95	1.57	1058	59231	4.75	128	12.3
759	LAKE VERMILLION	1980	22	298	8514	160600	.05	.77	.49	407	121375	30.80	150	39.8
760	GEORGETOWN LAKE	1976	51	120	219	65481	.003	.14	.04	183	21948	1.91	70	26.5
762	LITTLE GRASSY LK	1951	9	15.1	26116	12556	2.08	.98	3.70	2416	36486	5.38	449	7.0
765	HIGHLAND SILVER	1981	20	48.4	7331	24820	.30	.94	1.45	987	47780	13.91	130	15.3

these parameters (plus four related parameters), as well as the techniques that were used for determining the parameters, are given below.

Definitions and Methodology

Drainage Area, DA. The drainage area is defined as the watershed area above a specific stream location on a river basin. The drainage area, in square miles, is determined by planimetering this area from topographic maps. The drainage areas of Illinois streams at various locations are given by Ogata (1975).

Stream Order. SO. According to Strahler (1957), the visible, unbranched streams shown on topographic maps are defined as first-order streams. Where two first-order streams join, a second-order stream begins, and so forth.

Figure 7 shows a hypothetical example of this stream order method. This technique was used by Stall and Fok (1968) and by Bhowmik and Stall (1979) to determine the stream order of many Illinois streams. Data from these studies were used to determine the stream order of the various streams used in this project.

Total Number of Stream Segments. NU. A stream segment is a single stream path uninterrupted or forked by tributaries. If the stream path forks or is intersected by a tributary, then two new segments are formed. For example, branch A of the hypothetical stream in figure 7 has a total of 17 stream segments. For a detailed description, see Chow (1964).

Total Stream Length. LU. The total stream length is the sum of the lengths of all the streams within a drainage basin. Stream lengths can be

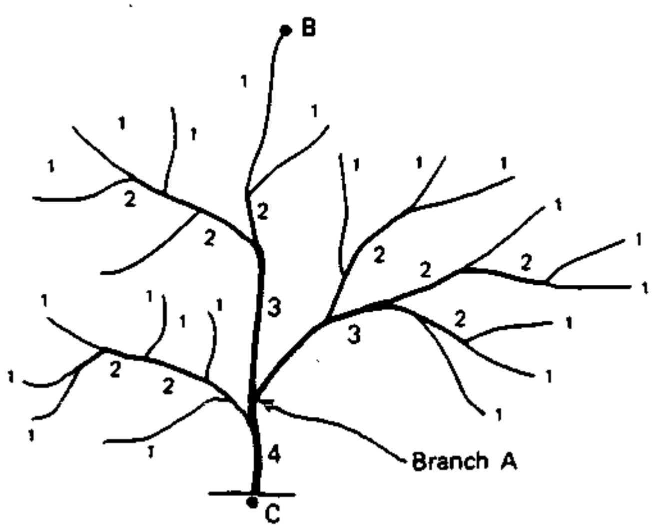


Figure 7. Horton-Strahler stream ordering system

measured from topographic maps with either a map wheel or a digitizer. Stream length is expressed in miles.

Mean Stream Length, LA. The mean stream length is defined as the ratio of the total stream length, LU, to the number of stream segments, NU. It is expressed in miles.

Drainage Density, DD. The drainage density is defined as the ratio of the total stream length, LU, to the drainage area, DA, of the basin. This parameter is expressed in miles per square mile.

Basin Length, LB. The basin length is measured as the distance in a straight line from the basin outlet to the most distant point at the headwaters of the main stream (figure 8). Basin length is expressed in miles.

Basin Width, BW. The basin width is defined as the distance of a straight line drawn normal to the basin length line at the point at which the basin has maximum width (figure 8). Basin width is expressed in miles.

Total Basin Relief, H. The total basin relief is the difference in elevation between the highest point on the headwaters of the main stem of the stream and the outlet point of the stream. In figure 7, H is the difference in elevations between points B and C. Normally, topographic maps

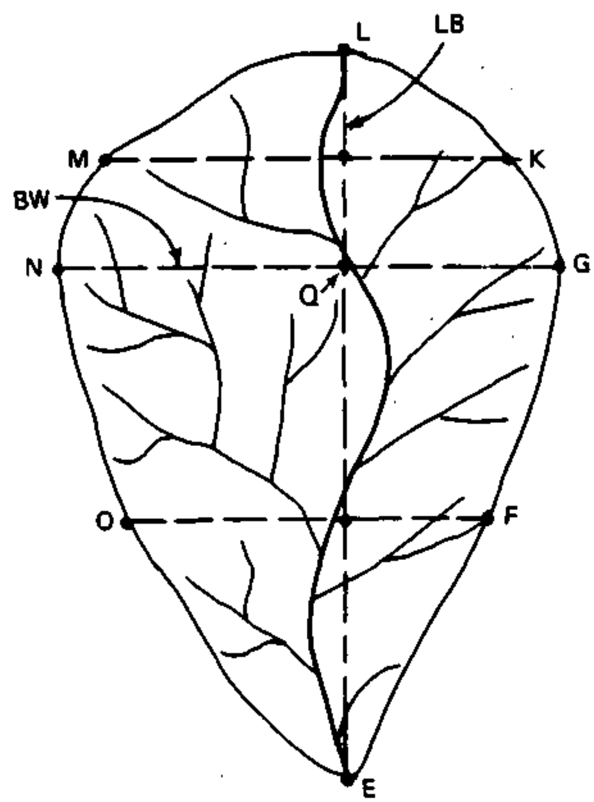


Figure 8. Definition sketch for basin length, basin width, and average basin relief

are used to determine the total basin relief. Total basin relief is expressed in feet.

Average Basin Relief, HA. The average basin relief is determined by the following technique, which refers to information given in figure 8. Lines MK and OF are drawn parallel to the basin width line, NG, and normal to the basin length line, LE. Line MK bisects line LQ and line OF bisects line QE. The differences in elevations between points F, G, K, L, M, N, and 0 and point E are determined from the topographic map. The average of these seven elevation differences is called the average basin relief, which is expressed in feet.

Relief Ratio, RR. The relief ratio is determined by dividing the total basin relief, H, by the basin length, LB, and is expressed in feet/mile.

Basin Shape, BS. The basin shape is the ratio of the square of the basin length, LB, to drainage area, DA.

Stream Frequency, F. The stream frequency is the ratio of the total number of stream segments, NU, to the drainage area, DA. It is expressed as stream segments per square mile.

Main Stem Length, LS. The length of the main stem is measured from a topographic map. In figure 8, this will be the distance from point L to point E along the main stream, in miles.

Sinuosity, SS. The sinuosity is defined as the ratio of the stream length to the down valley length. The sinuosities for streams used in this investigation were computed from the relationships given by Bhowmik and Stall (1979).

Incision, I. The incision is defined as the difference in elevation between the top of the floodplain and the bed of the stream at the same floodplain cross section. The incision for Illinois streams was computed by following the procedure given by Bhowmik and Stall (1979). It is expressed in feet.

Circularity Ratio. CR1. The circularity ratio is obtained by dividing the drainage area by the area of a circle having the same perimeter as that of the basin. Thus in figure 8, the perimeter, P, of the basin will be the distance from point E through F, G, K, L, M, N, 0, and back to E. Once this distance, P, is measured on the topographic maps, the area of a circle with this perimeter is computed as $P^2/4\pi$ and is used in conjunction with the drainage area to compute the circularity ratio, CR1.

Circularity Ratio, CR2. This circularity ratio is obtained by dividing the drainage area by the area of a circle having a diameter equal to the basin width.

Circularity Ratio, CR3. This circularity ratio is obtained by dividing the drainage area by the area of an ellipse which is given by π (LB) (BW).

Precipitation. PRECIP. The mean annual precipitation, in inches, for each station was tabulated from figure 4.

Precipitation Volume, PRECIPV. The mean annual precipitation volume, in inch-square miles, for each station was obtained by multiplying the precipitation, PRECIP, by the drainage area, DA.

Soil Productivity, PROD. Soil productivity indexes for each station were tabulated from the Soil Conservation Service's productivity map of Illinois.

Soil Erosion, EROS. Soil erosion factors for each station were tabulated from the Soil Conservation Service's soil erosion map to estimate cropland soil loss in Illinois.

Tolerance/Erodibility Factor, TOK. Soil tolerance, T, over the soil erodibility factor, K, values were tabulated for each station from the Soil Conservation Service's map of T/K values for Illinois.

Average Water Discharge, AQW. The average water discharges, in cfs, for USGS stations were tabulated from the USGS water resources data reports. These values were tabulated for each station from the most recent USGS data available at a given site. Average water discharge values for stations which were not monitored by the USGS were estimated from the relationship between drainage areas DA and AQW at a nearby station.

Average Annual Water Volume, AQWV. Average annual water volume is obtained by converting AQW from cubic feet per second to cubic feet per year.

Discharge/Drainage Area Ratio, QWDA. This ratio is obtained by dividing the average water discharge AQW by the drainage area DA. This ratio is expressed in cubic feet per second per square mile.

Average Stream Velocity, VS. The average stream velocity, in fps, for each station was computed from the hydraulic geometry equations developed by Stall and Fok (1968). The tabulated values of VS, WS, and DS are for a discharge which is equaled or exceeded 10 percent of the time. For stations located in river basins where no equations were defined, stream velocity was estimated from an equation for a nearby river basin.

Top Width of the Stream, WS. The width of the stream at the surface, WS (ft), for each station was computed from the hydraulic geometry equations developed by Stall and Fok (1968). F6r stations located in river basins where no equations were developed, WS was estimated from an equation for a nearby river basin.

Average Depth of the Stream. DS. The average depth of the stream, DS (ft), was computed from the hydraulic geometry equations developed by Stall and Fok (1968). For stations located in river basins where no equations were developed, DS was estimated from an equation for a nearby river basin.

STATION ANALYSES

Sediment **Transport** Equations

Tributary Stations

Tributary stations are defined as those sediment stations which are not located on the main stems of the Illinois or Mississippi Rivers. Data for these stations were collected and compiled by either the USGS or the SWS.

Methods. The objective of this analysis was to develop predictive sediment transport equations for each sediment station from the available sediment record. Two types of sediment transport equations were developed for each station, both based on a least-squares linear regression analysis of the logarithms of the measured sediment discharge and the logarithms of the corresponding water discharge. It was discovered in the process of developing these equations that some of the sediment discharge and/or water discharge values were zero. In these instances the zero data pair was excluded from the analysis. Attempts to replace zero data with very small positive values (i.e., 10^{-3} through 10^{-70}) were not successful. Elimination of the zero data pairs should have very little effect on the load estimations, since a very small fraction of the total annual load is transported during low discharge periods.

The first type of equation that was developed, referred to as the annual regression equation (ARE), represents the relationship between daily sediment discharge (tons/day) and daily water discharge (cfs) on the basis of the data collected for one particular water year. The second type of equation, referred to as the period-of-record regression equation (POR), represents the relationship between daily sediment discharge (tons/day) and daily water discharge (cfs) for all the sediment data collected at the station.

Since the sediment data obtained from the USGS represent mean daily sediment and water discharges, the transport equations for stations monitored by the USGS represent the relationship between mean daily sediment and water discharges. The sediment data obtained from the SWS represent instantaneous sediment and water discharges; therefore the transport equations for stations monitored by the SWS represent the relationship between instantaneous sediment and water discharges. There were seven instances (station codes 105, 113, 119, 124, 125, 232, and 233) where sediment data were collected by the USGS in some years and by the SWS in other years. In these cases the SWS instantaneous data were treated as if they were mean daily values and were combined with the USGS data in order to develop the POR equation.

On the basis of the method described by Porterfield (1972), the resultant transport equations and the appropriate mean daily water discharge data obtained from the USGS were used to calculate daily sediment load values. These values were summed for each water year to obtain an estimate of the annual sediment load for each station for each year samples were collected.

Results. The general form of the sediment transport regression equation is:

$$Q_s = a(Q_w)^m \tag{8}$$

where Q_s is sediment load (tons/day), a is the coefficient of the regression equation, Q_w is the water discharge (cfs), and m is the slope of the regression equation.

Appendix B summarizes the regression equation parameters, including the standard error of the estimate and the correlation coefficients for all the tributary stations. The statistics are listed in ascending station code order. For each station the POR statistics are listed first and are indicated by the three-digit station code. Then the ARE statistics for that station are listed for all appropriate water years. (The fourth and fifth digits next to the three-digit station codes indicate the appropriate water year; i.e., 10181 represents station 101, Water Year 1981). Stations where the POR and ARE statistics are identical reflect the fact that data were available for only one year at those sites. The correlation coefficients were greater than or equal to 0.80 for all but 11 of the regression equations representing only five stations. Sixty-two percent of the regression equations had correlation coefficients greater than or equal to 0.90.

Figure 9 shows the four sediment transport plots for Henderson Creek near Oquawka (228). Figures 9a, b, and c show the data collected in each of the three water years. Figure 9d shows the data for the period of record. Similar plots were generated for each POR and ARE data set listed in appendix B.

These sediment transport equations were used to calculate an estimate of the annual sediment load at each station for each year samples were collected. The primary purpose of this procedure was to compare the estimated loads to the measured loads. For stations where mean daily measured loads were not available, the calculated loads are assumed to be the best estimate of the annual load for each year (Bonini et al., 1983).

Appendix C lists the calculated and measured annual loads and yields for all of the tributary stations for all years. The results are listed by station code and water year. For each water year the annual load estimated by the appropriate ARE is listed first, followed by the annual load generated by the POR and then the measured annual load, if available.

Close examination of the results in appendix C indicates a wide range of variability in the ability of the ARE and POR equations to predict the measured loads at stations where this value is known. This range of variability is less for the POR equation. The next step is to determine if the relationship between the calculated loads obtained from the POR equations and the measured loads can be quantified.

In order to do this the ratio of the calculated load (from the POR) to the measured load was determined for all appropriate stations and for all the years for which data were available. A total of 80 ratios of

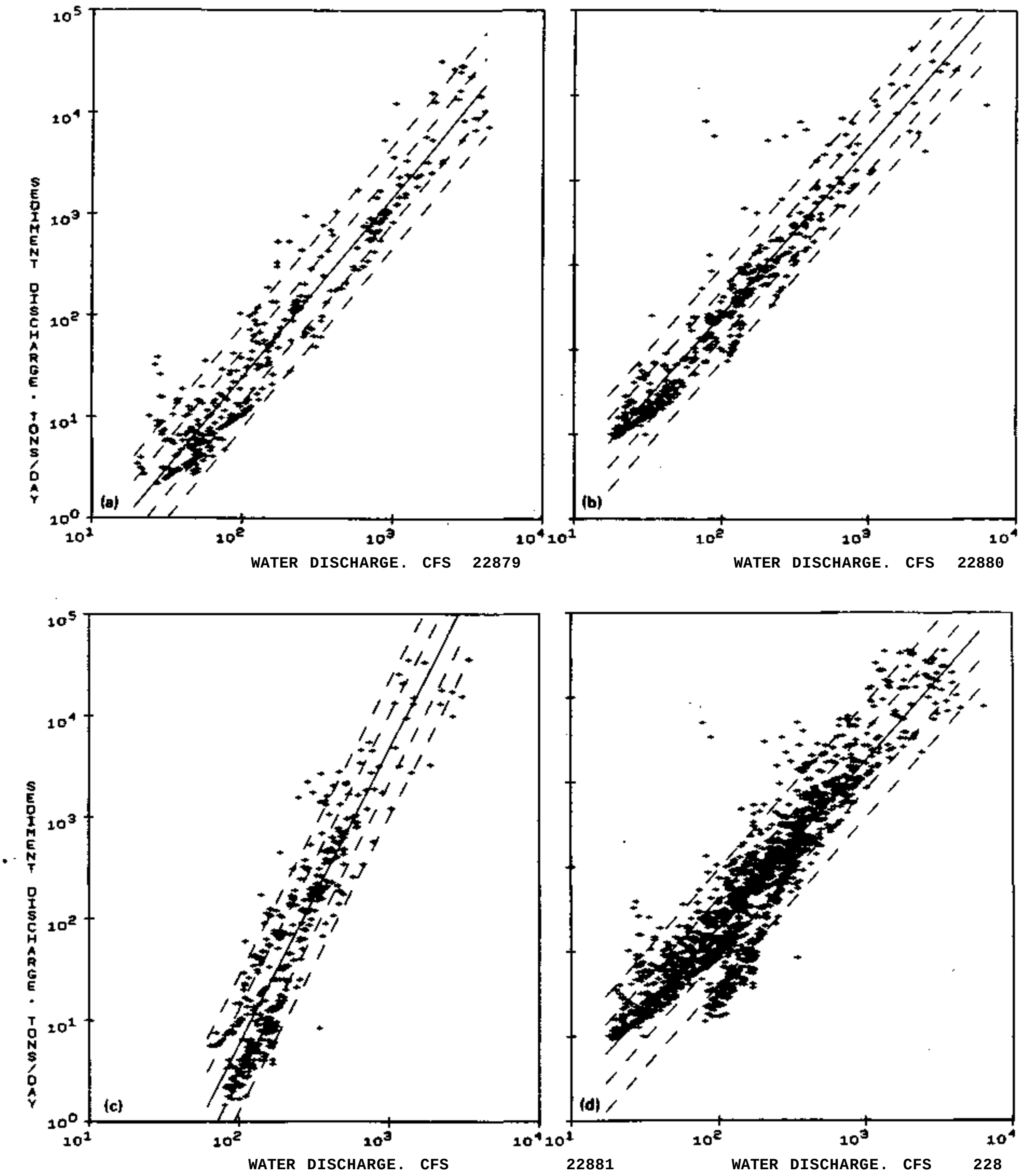


Figure 9. Suspended sediment discharge versus water discharge for Henderson Creek near Oquawka, Illinois, for a) Water Year 1979, b) Water Year 1980, c) Water Year 1981, and d) period of record

calculated to measured load were determined. These ratios ranged in value from 0.02 to 1.40. Of these 80 ratios, 54 were for stations with drainage areas greater than or equal to 50 square miles. These ratios were divided into 15 ratio classes of equal size, from 0.0-0.09 to 1.40-1.49. Figures 10 a and b show the frequency and relative frequency distribution of these ratios by ratio classes. Since these histograms are fairly symmetrical, a normal distribution may fit the data. Statistical analysis of the 80 ratios indicates that the median is equal to 0.64, the mean is equal to 0.645, and the mode is equal to 0.74. Therefore there is a slight negative skewness to the data. The standard deviation of the data is 0.29 and the variance is 0.09. Sixty-nine percent of the ratios fall within one standard deviation of the mean, while 95 percent of the ratios fall within two standard deviations of the mean. Therefore it can be assumed that the ratios are normally distributed.

If the ratio data set is separated into two subsets, one for drainage areas greater than or equal to 50 square miles and one for drainage areas less than 50 square miles, the normalcy of distribution improves for the larger drainage areas. For the smaller drainage areas, the distribution shows a strong positive skewness. For the larger drainage areas (N=54), the mean is 0.75, the median is equal to 0.73, and the mode is 0.74. The standard deviation is equal to 0.25 and the variance is 0.06. Seventy-three percent of the ratios in this subset are equal to 0.75 + 0.25 while 96 percent are equal to 0.75 ± 0.50.

These analyses indicate that the normalcy of distribution is strongest for larger drainage areas. From the analysis of these 54 ratios, it appears that the POR equation predicts 0.75 + 0.25 percent of the measured load 67 percent of the time.

The skewness of the distribution for drainage areas of less than 50 square miles suggests that POR equations may be inadequate to predict measured loads in these smaller watersheds. Further analysis of a larger data set would be necessary to confirm this observation.

When the ratio data set is segmented so that only ratios for a single water year are examined, the of distribution departs markedly from normal. This may be in part because only two years have marginally adequate data sets: Water Year 1980 with 19 data sets and Water Year 1981 with 28 data sets. It is difficult to draw any definitive conclusions from these two years. Larger data sets for more water years are needed to adequately address this issue.

The ratio data sets for 1980 and 1981 were also plotted on state maps to see if any patterns of geographic distribution could be identified. Once again the inadequate number of data points limited the usefulness of the analysis. The data that were available failed to show any discernible geographic distribution patterns.

These analyses suggest that the POR sediment transport equations may be useful under certain circumstances. if a limited amount of data is collected at a station with a drainage area greater than 50 square miles, then developing a sediment transport equation (in combination with the

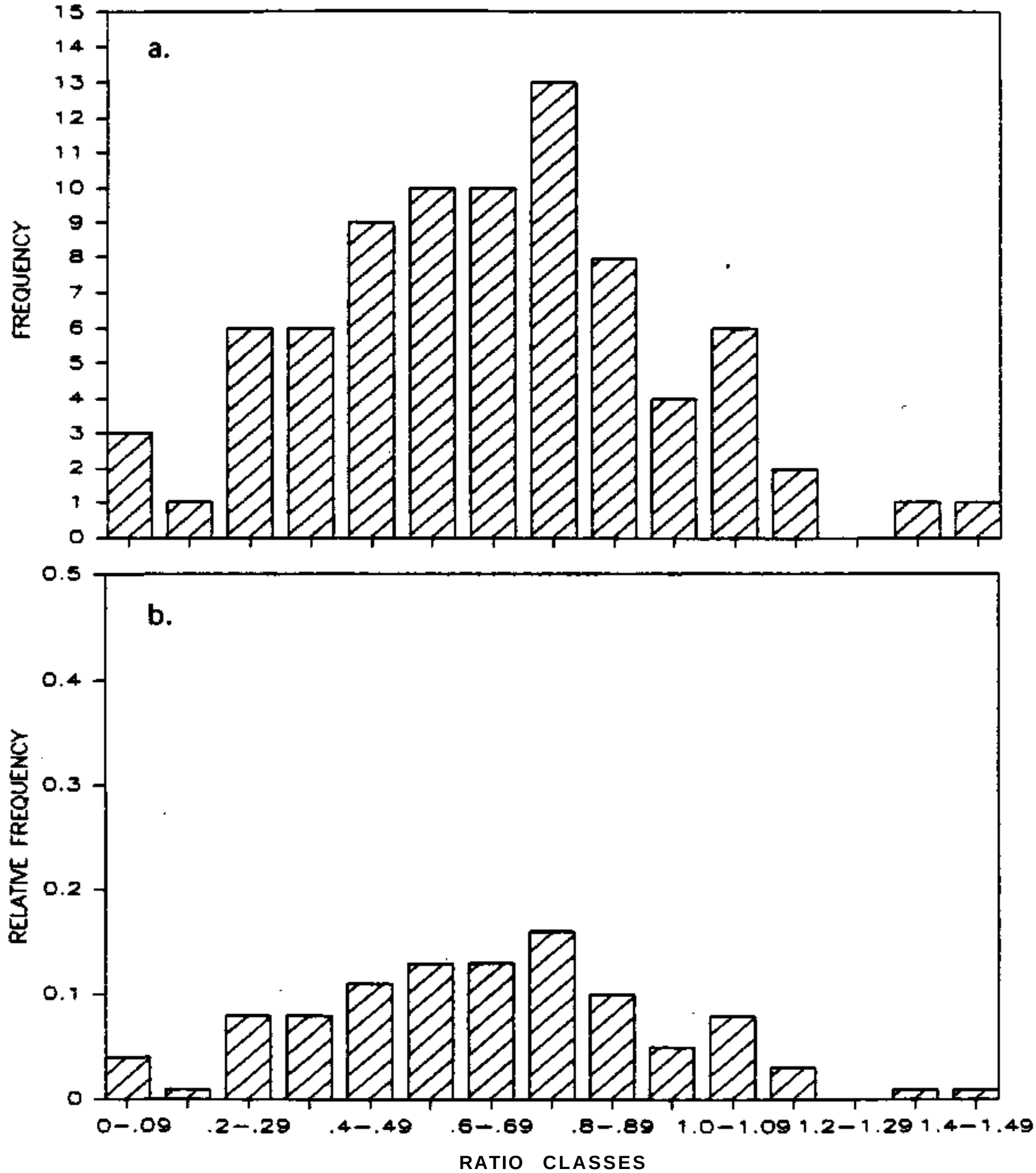


Figure 10. a) Frequency and b) relative frequency distribution of calculated to measured load ratios for POR equations of tributary stations

method referred to in the previous section) and applying the results of these analyses can yield a reasonable estimate of the annual load. If a long enough historical daily sediment record exists at the site, then the shift-control method (Colby, 1956), also referred to as the hydrograph-shifting method (Frost and Mansue, 1984), may yield a better estimate of the annual load.

The most obvious result of the ratio analysis is that the calculated loads are almost always less then the measured loads. It is important to understand why this occurs. Figures 11a and 11b show arithmetic (as opposed to log-transformed) sediment transport curve plots for two representative stations. The solid line running through each of these plots is the best fit line in the form:

$$Q_s = \text{slope}\ (Q_w) + \text{intercept} \qquad (9)$$

where Q_s is sediment load in tons/day and Q_w is water discharge in cfs. It is obvious from the degree of scatter of the data points in the higher water discharge ranges for each plot that the regression equations do a very poor job of predicting actual loads during higher flows. It is also apparent that in most cases the equations will drastically underestimate actual measured loads for higher flows. Since the greatest percentage of the total annual load tends to be transported during these high flow periods, these plots highlight the reason why the POR equations tend to underestimate the measured loads in streams.

In a recent paper, Ferguson (1986) proposed a method for determining a correction factor from the variance of the scatter of the sediment load data around the log-log regression line. This would provide a correction factor for each station. The distribution of calculated to measured load ratios discussed above yields a single correction factor for the entire data set.

Main Stem Stations

All stations on the Illinois and Mississippi Rivers are considered main stem stations. These include the Illinois River stations at Marseilles (227) and Valley City (253), and the Mississippi River stations at East Dubuque (191), Burlington (292), and Keokuk (293). Data for the Illinois River stations were provided by the USGS, while the COE collected the data for the Mississippi River stations.

The objective of this analysis was to develop predictive sediment transport equations for each main stem station, using all available sediment data. Several types of sediment transport equations of the form outlined in equation 8 were developed for all the main stem stations except Marseilles,

The Illinois River at Marseilles had very little sediment data. The USGS collected monthly data from May 1975 to February 1979, and continued to collect data intermittently from March 1979 to September 1982. The data included mean daily water and suspended sediment discharge. The period of

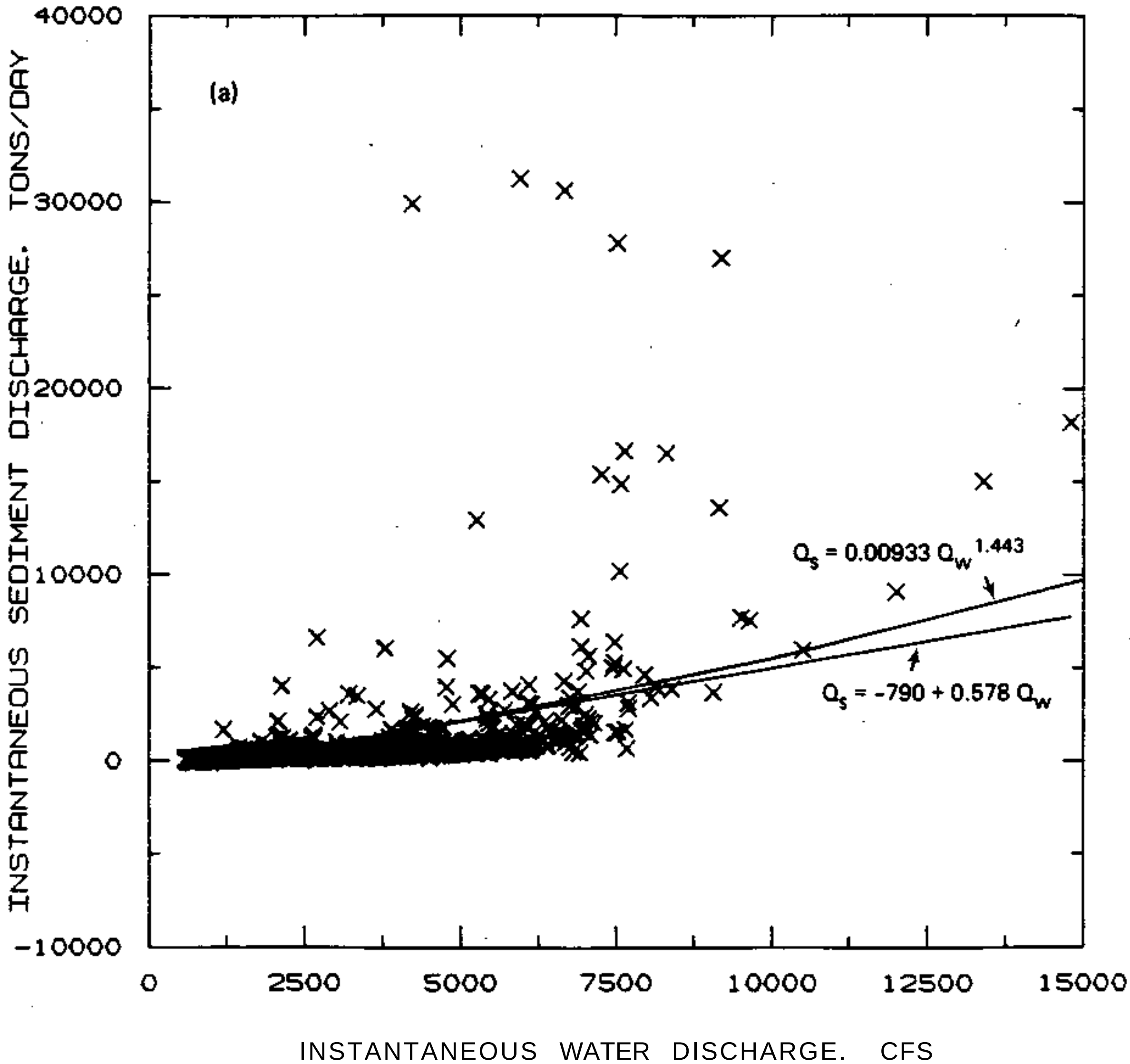


Figure 11. Arithmetic sediment transport curves for a) Kankakee River at Momence and b) Iroquois River near Chebanse

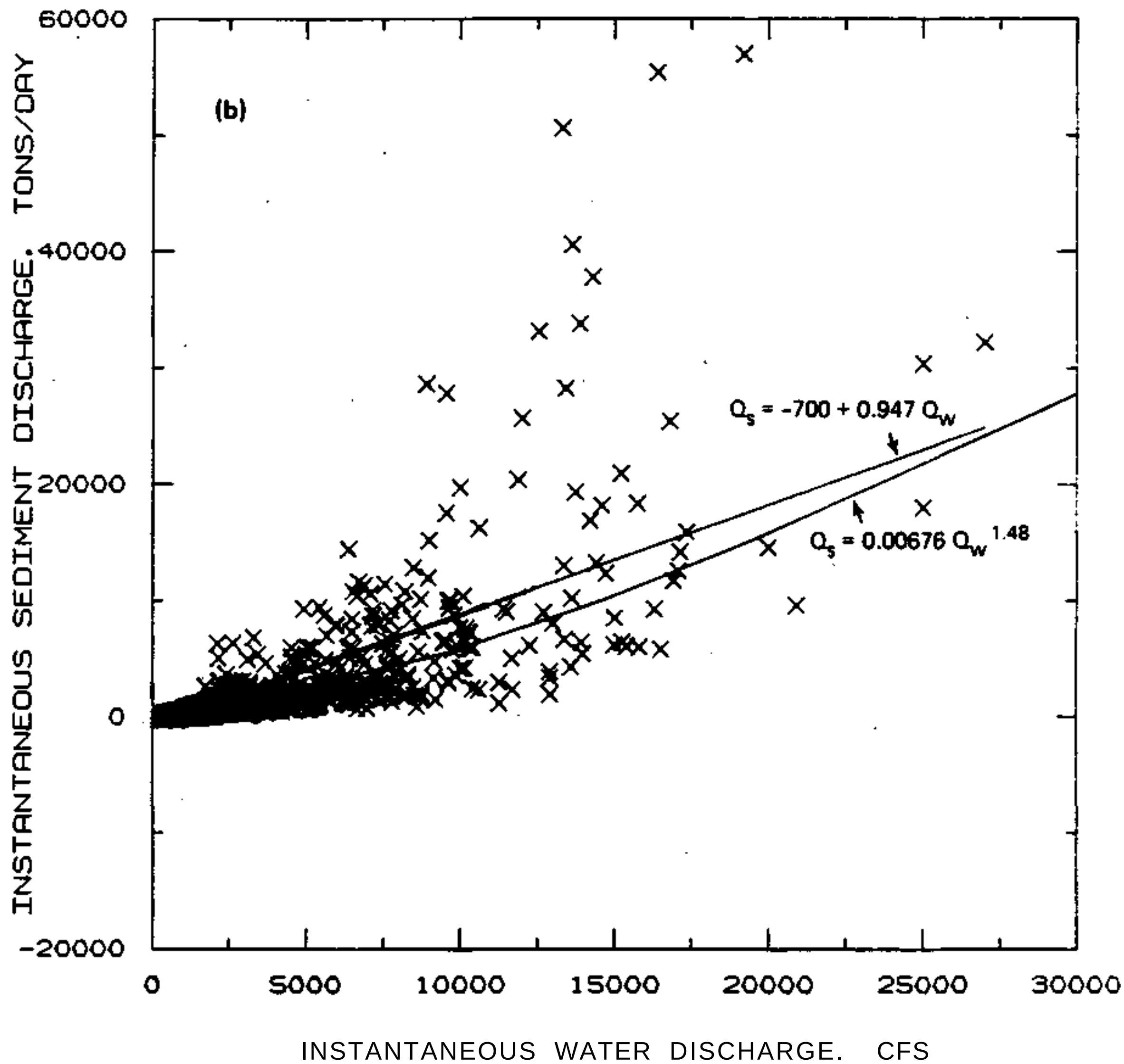


Figure 11. Concluded

record regression equation (POR) was computed and can be used to estimate a mean daily sediment load at Marseilles. The equation is:

$$Q_s = 0.678 \times 10^{-3} Q_w^{1.65} \quad (10)$$

The correlation coefficient is 0.79 and the standard error of the estimate is 0.4077. The regression plot is shown in figure 12.

Annual regression equations and a period-of-record regression equation were developed for the Illinois River at Valley City. These transport equations represent the relationship between mean daily sediment and water discharges. The equations, and appropriate mean daily water discharge records obtained by the USGS, were used to develop calculated sediment load values and to obtain an estimate of the annual sediment load for each year samples were collected. Table 5 summarizes the regression equation parameters, while table 6 lists the calculated and measured annual loads for the Valley City station. Loads based on the annual regression equation were 16 to 24 percent lower than the measured annual load. Loads based on the period-of-record equation were from 18 percent above to 28 percent below the measured annual loads. The period-of-record sediment transport plot for Valley City is shown in figure 13.

The three Mississippi River stations are the only stations on Illinois rivers for which there are 14 or 15 years of nearly continuous, daily instantaneous sediment concentration data. Consequently, these stations were analyzed in greater detail.

On a few occasions, multiple sediment concentrations were recorded on a single day. When this occurred, the daily concentration was computed as the mean value of these readings. Daily concentration and water discharge readings were used to compute daily sediment load values. The water and sediment load data were used to compute annual regression equations for each water year and to compute the period-of-record equation. These transport equations represent the relationship between instantaneous daily sediment load and daily water discharge. The period-of-record sediment transport plots for the Mississippi River stations at East Dubuque (191), Burlington (292), and Keokuk (293) are shown in figures 14, 15, and 16, respectively.

The annual regression equations were used to estimate sediment loads for days with no sediment concentrations. Measured and estimated loads were summed to obtain the annual, seasonal, and monthly measured loads for each water year. The measured loads were used' to develop four additional regression equations.

The annual load regression equation (ALRE) defines a relationship between the total measured sediment load for a water year (tons/year) and the total measured water discharge (cfs-days) for that water year. This may be used to estimate annual sediment loads. Seasonal load regression equations (SLRE) give the relationship between the total measured sediment load for a season (tons/season) and the total water discharge (cfs-days) for that season. The combined monthly regression equation (CMRE) relates the total measured sediment load for any month (tons/month) to the total

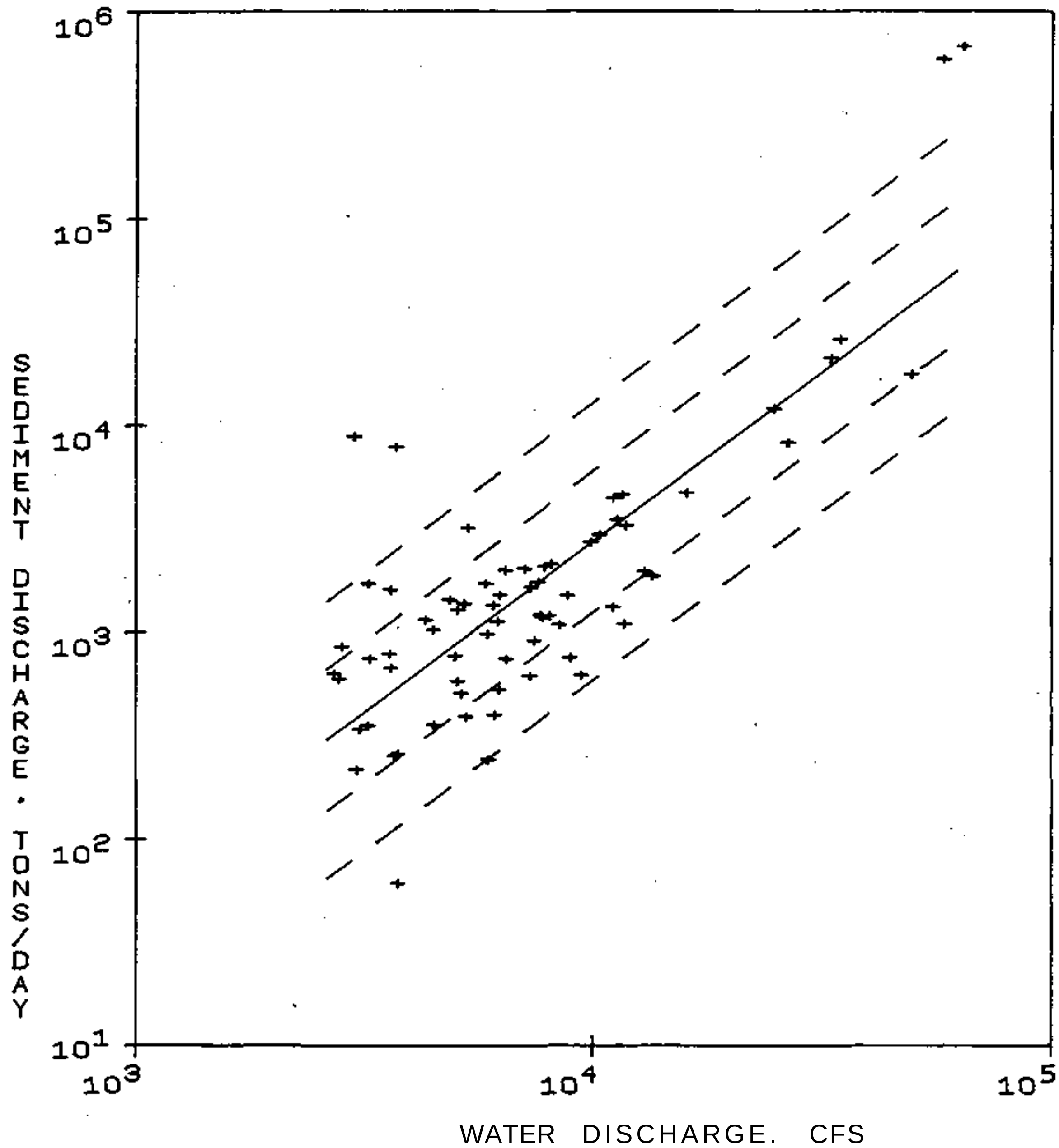


Figure 12. Suspended sediment discharge versus water discharge for Illinois River at Marseilles, Illinois

Table 5. Statistical Parameters for the Period of Record and Annual Regression Equations for the Illinois River at Valley City

STATION CODE	COEFFICIENT	SLOPE	STANDARD ERROR OF ESTIMATE	CORRELATION COEFFICIENT
25381	.0843402	1.1875286	.2513957	.8560805
25382	.2738931	1.0727617	.3352830	.6863847
25383	.5318387	.9706439	.2941112	.7719007
253	.2472944	1.0773055	.3133169	.7455299

Table 6. Calculated and Measured Annual Sediment Loads for the Illinois River at Valley City

STATION CODE	TYPE	ANNUAL LOAD (TONS)	ANNUAL YIELD (TONS/SQ MI)	ANNUAL YIELD (TONS/ACRE)
25381	ARE	6177673.	233.	.36
	POR	5675028.	214.	.33
	MEAS	7350548.	277.	.43
25382	ARE	6861236.	258.	.40
	POR	6501928.	245.	.38
	MEAS	9018570.	340.	.53
25383	ARE	4850206.	183.	.29
	POR	7100616.	267.	.42
	MEAS	5985890.	225.	.35

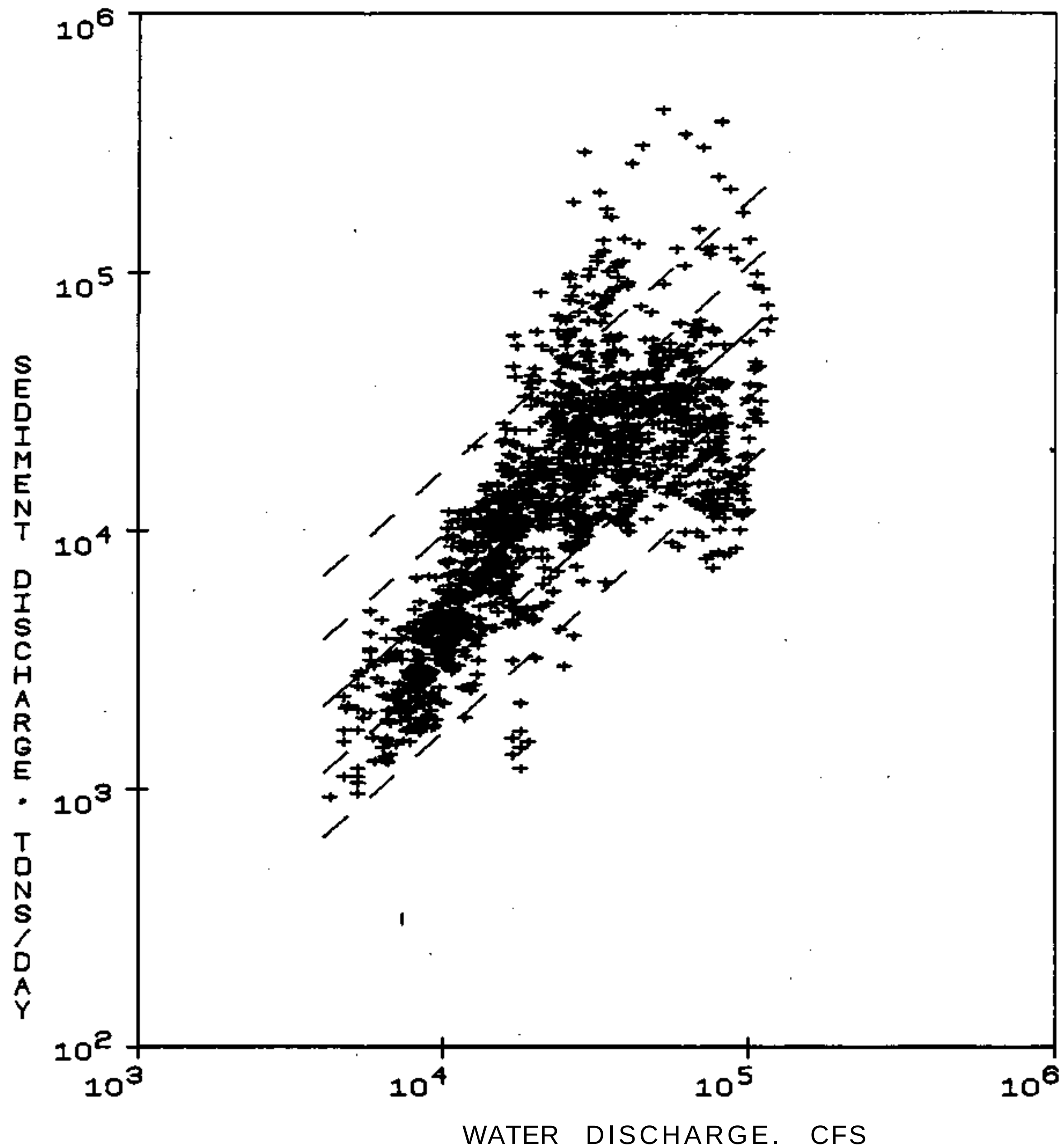


Figure 13. Suspended sediment discharge versus water discharge for Illinois River at Valley City, Illinois

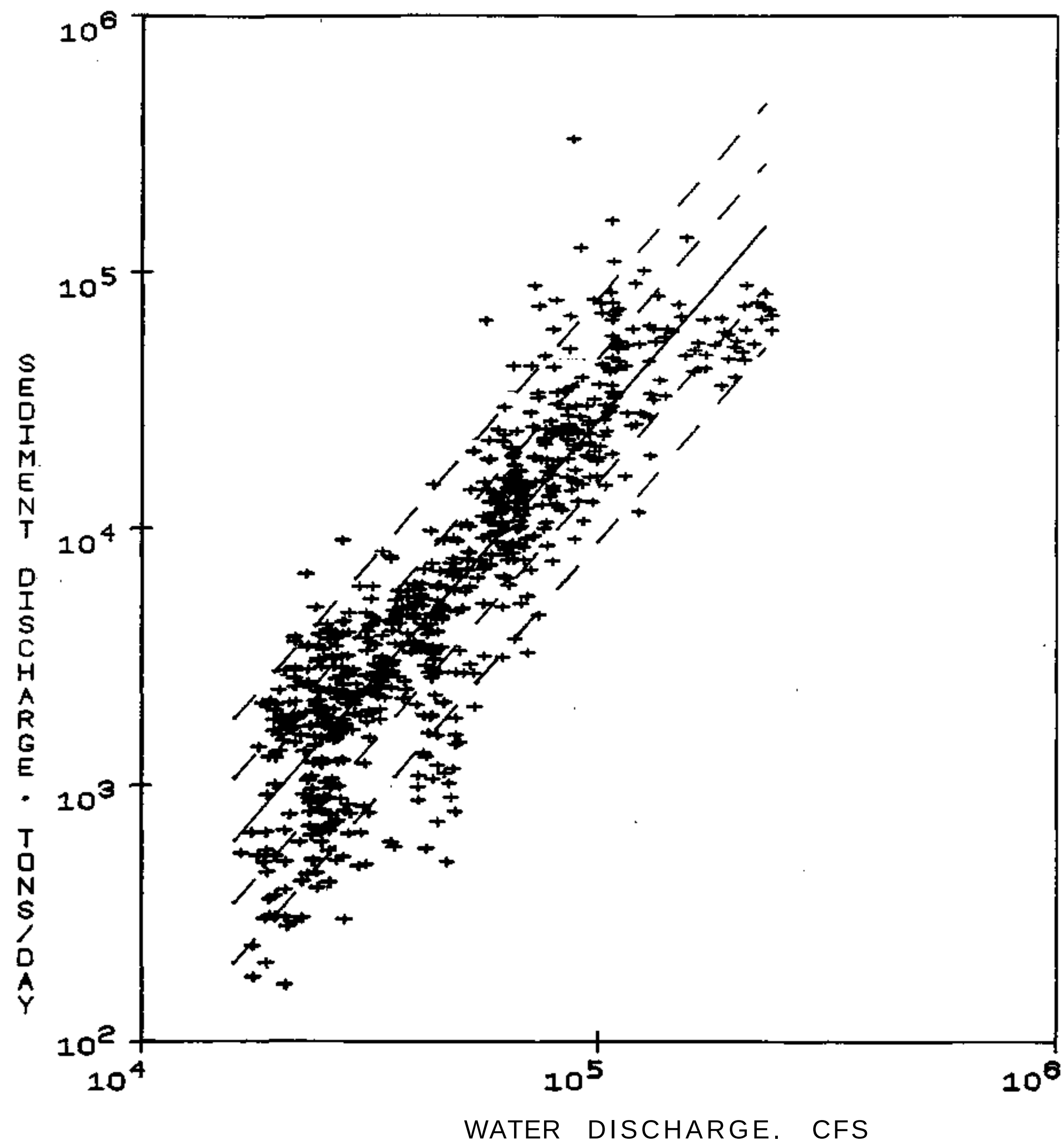


Figure 14. Suspended sediment discharge versus water discharge for Mississippi River at East Dubuque, Illinois

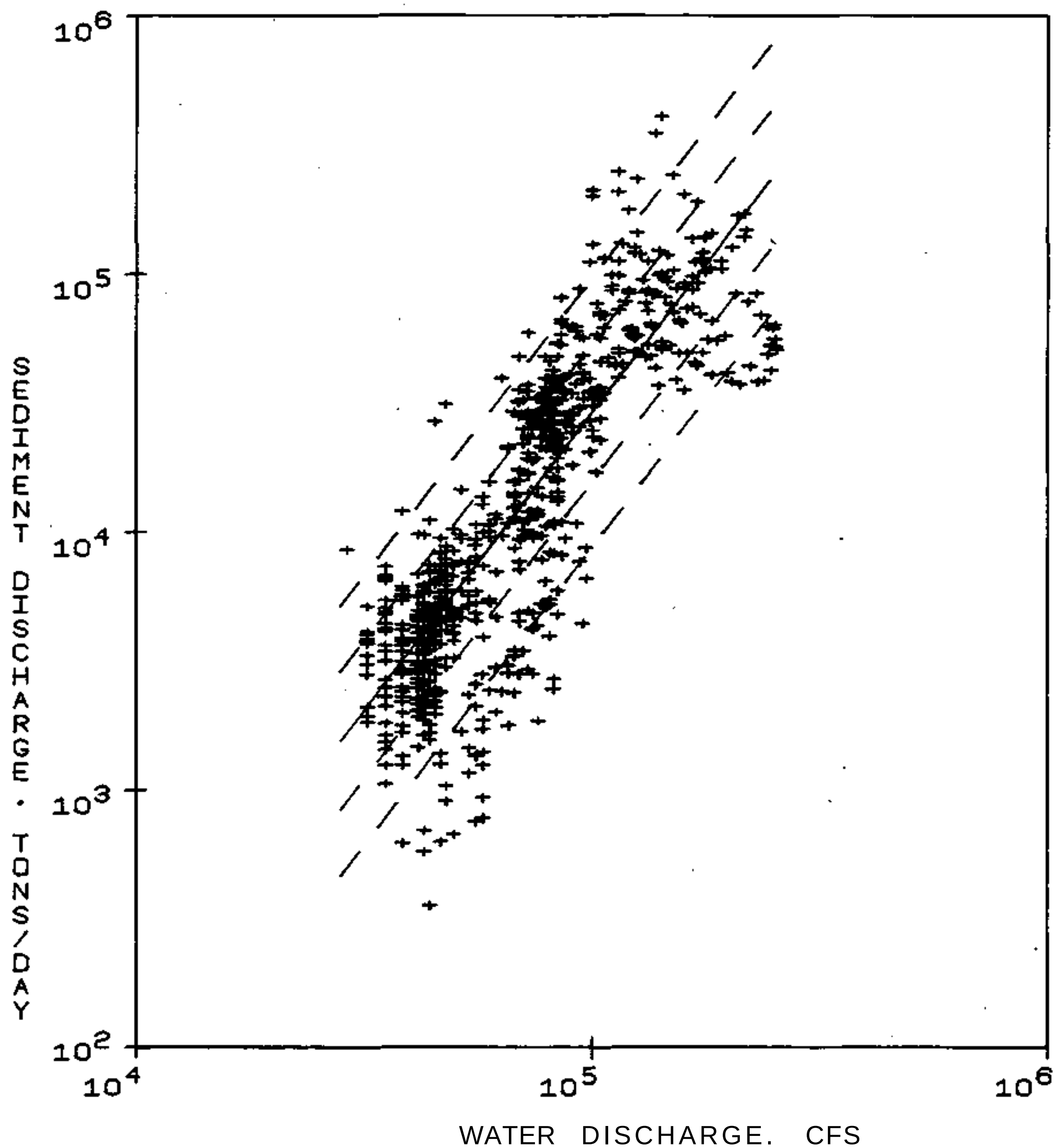


Figure 15. Suspended sediment discharge versus water discharge for Mississippi River at Burlington, Iowa

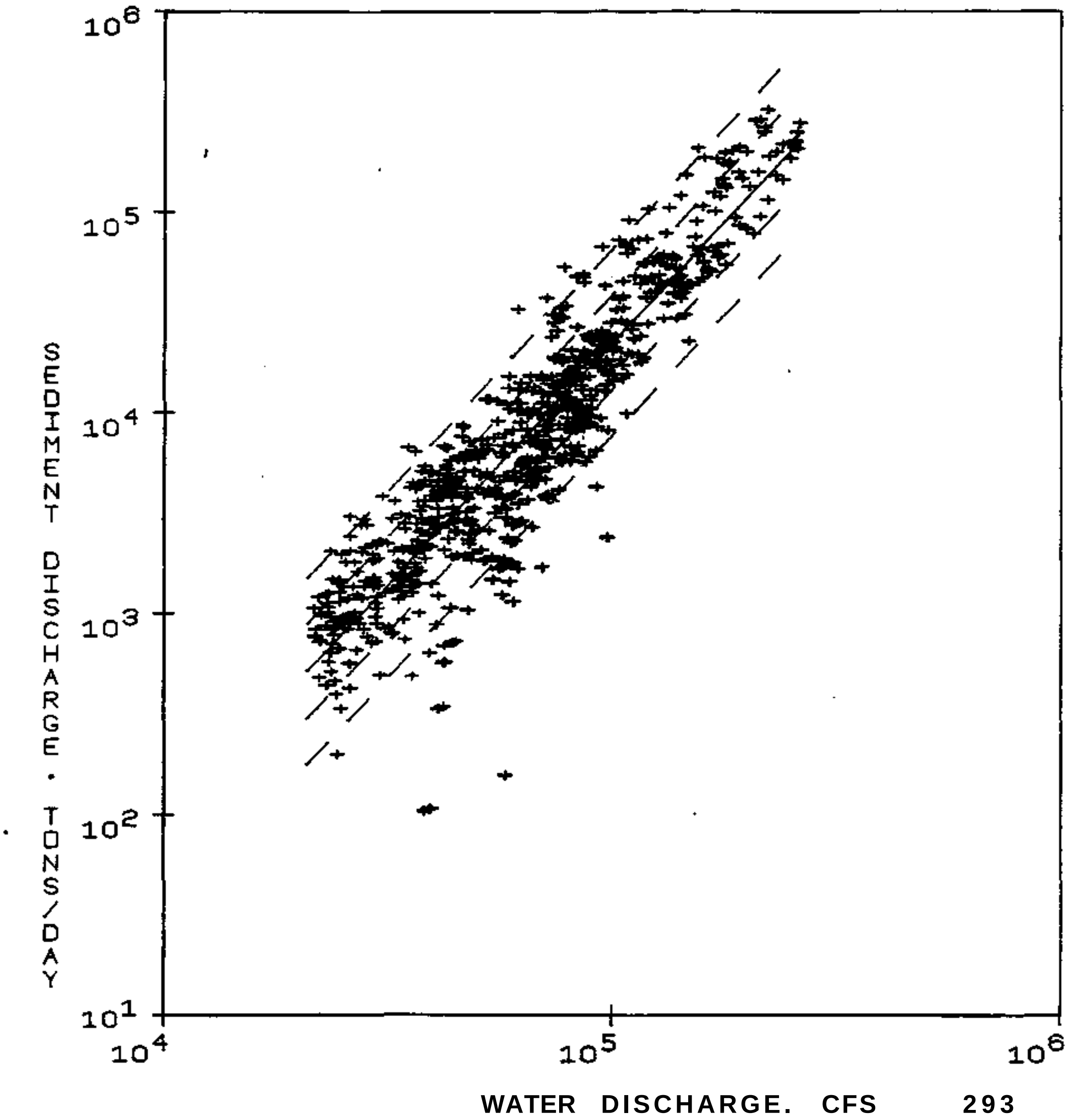


Figure 16. Suspended sediment discharge versus water discharge for Mississippi River at Keokuk, Iowa

measured water discharge (cfs-days) for that month. Individual monthly regression equations (IMRE) relate the total measured sediment load for a particular month (tons/month) to the total measured water discharge (cfs-days) for that month.

Appendix D summarizes the regression equation parameters, including the standard error of the estimate and the correlation coefficient, for each of the six types of regression equations at each of the three Mississippi River stations. For each station the AREs are listed first and can be identified by a five-digit code. The first three digits indicate the station and the last two indicate the water year; i.e., AREs for Keokuk during Water Years 1968 through 1981 are given by 29368 to 29381. The POR equation is listed next and is indicated by the three-digit station code. The annual load regression equation (ALRE) is listed next and is represented by the three-digit station code followed by two zeros. The three seasonal load regression equations appear next and are indicated by the station codes followed by the numbers 21 (October-January), 22 (February-May), and 23 (June-September). The combined monthly equation is indicated by the station code followed by the number 31. Lastly, the individual monthly regression equations are indicated by the station code and the numbers 01 (January) through 12 (December). Eighty-two percent of the equations had correlation coefficients greater than 0.80, while 46 percent had correlation coefficients greater than 0.90.

The annual regression equations and the period-of-record regression equations were used with daily water discharge records obtained from the COE to calculate daily sediment loads. These daily loads were summed to obtain estimates of the annual, seasonal, and monthly loads for each water year. The annual load regression equation and the measured annual water discharge were used to estimate the annual sediment load for each water year. The three seasonal load equations were used to compute the sediment load for each season in every water year. The annual load was estimated by summing the three seasonal loads. Monthly loads were estimated from the combined monthly equation and the individual monthly equations. The monthly loads were summed to yield estimates of seasonal loads as well as annual loads for each water year.

Appendix E lists the calculated and measured annual loads for each of the Mississippi River stations during representative water years. All stations experienced low flows during Water Year 1977 and high flows during Water Year 1973. One water year representing an average annual flow for each station is also listed. None of six types of regression equations has an apparent advantage in adequately predicting annual sediment loads when these loads are compared to measured loads. However, each of these types of regression equations may be used to estimate the annual sediment load.

Seasonal Analyses

Tributary Stations

Methods. The objective of the seasonal analyses was to attempt to identify sediment transport equations which could be used to predict sediment loads on a seasonal basis. The first step in this process was to identify and define the appropriate seasons within the context of a water year calendar. An intuitive process involving an evaluation of the typical seasonal storm event patterns that occur in Illinois was used to help identify three seasons: October through January, February through May, and June through September.

Once these seasons were identified, the ARE and POR sediment transport equations were used to calculate daily sediment loads which were summed to estimate the total load for each season for all stations. For stations with three or more years of record, seasonal sediment transport equations (SREs) were developed from the relationship between the instantaneous or mean daily sediment discharge and the instantaneous or mean daily water discharge for each season for the period of record of each station. These equations were in the same form as equation 8. The regression statistics for the seasonal equations are given in appendix F. These equations were then combined with the appropriate mean daily water discharge data to obtain the calculated daily sediment loads. These were summed for each season, yielding a total seasonal sediment load.

One other method for predicting sediment loads was considered. It consisted of developing seasonal load regression equations (SLREs) from the relationship between the total measured sediment load for a season and the total measured water discharge for that season. This method was rejected for the tributary stations because of the limited size of the data set. The number of data points for each curve would be equal to the number of years of record for each station. This would mean that most of the equations would be defined by only one or two data points.

Results. Appendix G lists the calculated and measured seasonal loads and their percentages relative to their total annual load for all of the tributary stations. The seasonal loads were calculated by using the station ARE and POR equations and the daily water discharge data for the respective seasons. These values are followed by the measured loads, if available. For the 10 stations with three or more years of record, the seasonal loads estimated from the appropriate seasonal regression equations (SRE) are listed before the values derived from the ARE. There are no percentages associated with the results from the SREs since the loads from these equations do not directly relate to the other SRE-derived values listed for a particular year.

There is no apparent advantage to using the SRE, ARE, or POR to predict sediment load on a seasonal basis. However, close examination of the percentage values does yield interesting results. It appears that the relative percentages of the total load based on results generated from the AREs and PORs tend to compare favorably to the measured percentage of the total load for each of the three seasons. The percentage data also show that the February-May and June-September seasons each carries a much higher percentage of the total annual load than the October-January season. In addition, there does not appear to be a geographical pattern to the seasonal percentage load results.

This information can be useful in efforts to establish an efficient and effective sediment sampling program. It also has a potential use in evaluating and predicting the relative effects of seasonal differences in tillage practices, cropping patterns, and pesticide applications on stream sediment and water quality.

Main Stem Stations

The objective of the seasonal analysis was to define sediment transport equations which could predict seasonal loads at the following main stem stations: Illinois River at Valley City (253) and the Mississippi River at East Dubuque (191), Burlington (292), and Keokuk (293). There were not enough data to analyze the Marseilles station on a seasonal basis.

The Valley City station was analyzed according to the same procedure used to analyze the tributary stations. The seasonal regression equations for Valley City are listed in table 7, while the calculated and measured seasonal loads based on these equations and the ARE and POR equations can be found in table 8.

Seasonal loads for the Mississippi River stations were estimated from the annual regression equation, the period-of-record equation, and the seasonal load regression equations, as well as the combined monthly and the individual monthly regression equations. Seasonal regression equations were not developed for the Mississippi River stations. None of the five types of equations shows an apparent advantage in adequately predicting sediment loads on a seasonal basis. However, each may be used to estimate a seasonal load. Table 9 lists the average measured seasonal load and seasonal water discharge for each of the Mississippi River stations.

Monthly Loads. Monthly loads for the three Mississippi River stations were estimated from the annual regression equation, the period-of-record regression equation, and the combined and individual (IMRE) monthly regression equations. Again there is no apparent pattern to indicate that any one of the four types of regression equations consistently yields better estimates of monthly sediment loads than the others, but all yield reasonable estimates of these values. Table 10 summarizes the average measured monthly sediment loads and water discharges for each of the Mississippi River stations.

Table 7. Statistical Parameters for the Seasonal Regression Equations for the Illinois River at Valley City

STATION CODE	COEFFICIENT	SLOPE	STANDARD ERROR OF ESTIMATE	CORRELATION COEFFICIENT
25321	.2061403	1.0890062	.2467161	.8034880
25322	4.1929444	.7933036	.3401222	.5945857
25323	.0223573	1.3405014	.2715865	.8151413

Table 8. Calculated and Measured Seasonal Sediment Loads for the Illinois River at Valley City

STATION CODE	TYPE	OCTOBER-JANUARY (TONS)	(%)	FEBRUARY-MAY (TONS)	(%)	JUNE-SEPTEMBER (TONS)	(%)
25381	SRE	660850.		1678018.		4629092.	
	ARE	686388.	11.1	2122918.	34.4	3368366.	54.5
	POR	709843.	12.5	1944357.	34.3	3020828.	53.2
	MEAS	890950.	12.1	3249088.	44.2	3210510.	43.7
25382	SRE	920563.		2889888.		2116181.	
	ARE	1045292.	15.2	4134230.	60.3	1681715.	24.5
	POR	986180.	15.2	3925345.	60.4	1590403.	24.5
	MEAS	1291920.	14.3	3970520.	44.0	3756130.	41.6
25383	SRE	2482619.		2615626.		1294058.	
	ARE.	1770197.	36.5	2297469.	47.4	782540.	16.1
	POR	2623290.	36.9	3433317.	48.4	1044009.	14.7
	MEAS	2629000.	43.9	2130890.	35.6	1226000.	20.5

Table 9. Average Measured Seasonal Sediment Loads and Water Discharges for the Mississippi Stations

STATION CODE	SEASON	LOAD (TONS)	DISCHARGE (CFS-DAYS)
191	OCT - JAN	447912.	4164060.
	FEB - MAY	2201058.	7807606.
	JUNE - SEPT	1531107.	5730124.
292	OCT - JAN	1274440.	7859470.
	FEB - MAY	5610494.	13184598.
	JUNE - SEPT	4493946.	9135550.
293	OCT - JAN	1066304.	6167628.
	FEB - MAY	6756S18.	11865407.
	JUNE - SEPT	3075620.	8506042.

Table 10. Average Measured Monthly Sediment Loads and Water Discharges for the Mississippi River Stations

STATION CODE	MONTH	LOAD (TONS)	DISCHARGE (CFS-DAYS)
191	OCT	165540.	1182533.
	NOV	146152.	1263686.
	DEC	63793.	895420.
	JAN	72426.	822420.
	FEB	81183.	806406.
	MAR	473847.	1654753.
	APR	1029328.	2883086.
	MAY	616699.	2463360.
	JUNE	730889.	1862446.
	JULY	400918.	1577126.
	AUG	193772.	1139250.
	SEPT	205527.	1151300.
292	OCT	466323.	1857605.
	NOV	351521.	1954440.
	DEC	200515.	1864371.
	JAN	256080.	2183054.
	FEB	307631.	1900736.
	MAR	1366453.	3050648.
	APR	1938530.	4212549.
	MAY	1997879.	4020662.
	JUNE	2058210.	2866286.
	JULY	1292443.	2482500.
	AUG	625803.	1953657.
	SEPT	517490.	1833106.
293	OCT	324122.	1642628.
	NOV	332201.	1761471.
	DEC	202708.	1391307.
	JAN	207272.	1372221.
	FEB	280033.	1351300.
	MAR	1607899.	2799435.
	APR	2547473.	3978742.
	MAY	2321412.	3735928.
	JUNE	1557614.	2766757.
	JULY	872263.	2351414.
	AUG	282264.	1705685.
	SEPT	363477.	1682185.

Analysis of Long-Term Sediment Data from Other Midwestern States

It is possible that regression equations developed for sediment transport in streams on the basis of short-term records may not represent the long-term sediment transport characteristics of streams and rivers very well. The primary concern is that POR equations developed for short-term records will change significantly as the record lengths increase. This would diminish the usefulness of the POR equation for estimating sediment loads for periods outside of the available record.

In an attempt to address these issues, long-term historical sediment records for eight USGS gaging stations in three other midwestern states (Indiana, Iowa, and Ohio) were obtained (table 11). The records for these stations date as far back as 1944 with periods of record ranging from 7 to 40 years.

Two reports on sediment transport in nearby states, Fluvial Sedimentat ion in Kentucky (Flint, 1983) and Fluvial Sediment Data for Iowa (Schuetz and Matthes, 1977), are compilations of available data with little analysis or interpretation. Fluvial Sediment in Ohio (Anttila and Tobin, 1978) includes considerable analysis and discussion of the data; however, the analyses are not identical to those used in this study.

The data for each of the stations listed in table 11 were used to generate sediment transport curve plots. Figures 17 and 18 are sediment transport curve plots for stations on the Scioto River at Higby, Ohio, and Maumee River at Waterville, Ohio, and are representative of all the plots generated. POR equations were developed for all eight stations, and regression statistics are given in table 12. The slopes and intercepts for each station are obviously different, but the correlation coefficients for the POR equations range from 0.88 to 0.95. Two equations are given for station 903, Iowa River at Iowa City, because the completion of Coralville Reservoir in 1959 changed the downstream sediment loads.

Table 11. Summary of Long-Term Historical Sediment Data Available for Three Midwestern States

ID	STA. NO.	STATION NAME	PERIOD OF RECORD
901	04182000	ST MARY'S RIVER NEAR FORT WAYNE, IN	1955-67
902	03365500	E. FORK WHITE RIVER AT SEYMOUR, IN	1968-77
903	05454500	IOWA RIVER AT IOWA CITY, IA	1944-83
904	05474000	SKUNK RIVER AT AUGUSTA, IA	1977-83
905	03234500	SCIOTO RIVER AT HIGBY, OH	1954-74, 79-82
906	03265000	STILLWATER RIVER AT PLEASANT HILL, OH	1964-75
907	04193500	MAUMEE RIVER AT WATERVILLE, OH	1966-83
908	04208000	CUYAHOGA RIVER AT INDEPENDENCE, OH	1977-83

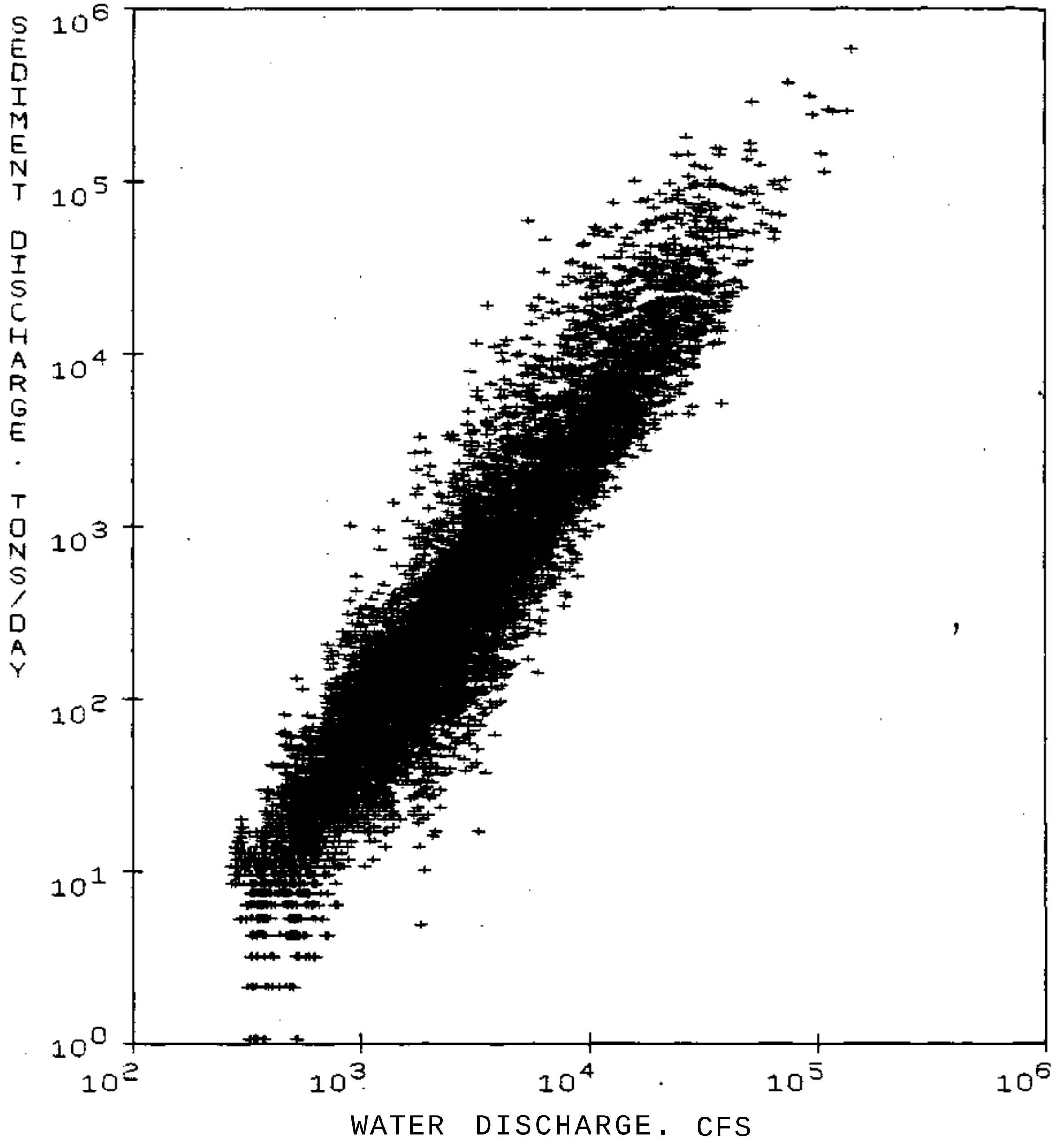


Figure 17. Period-of-record sediment transport curve plot for Scioto River at Higby, Ohio

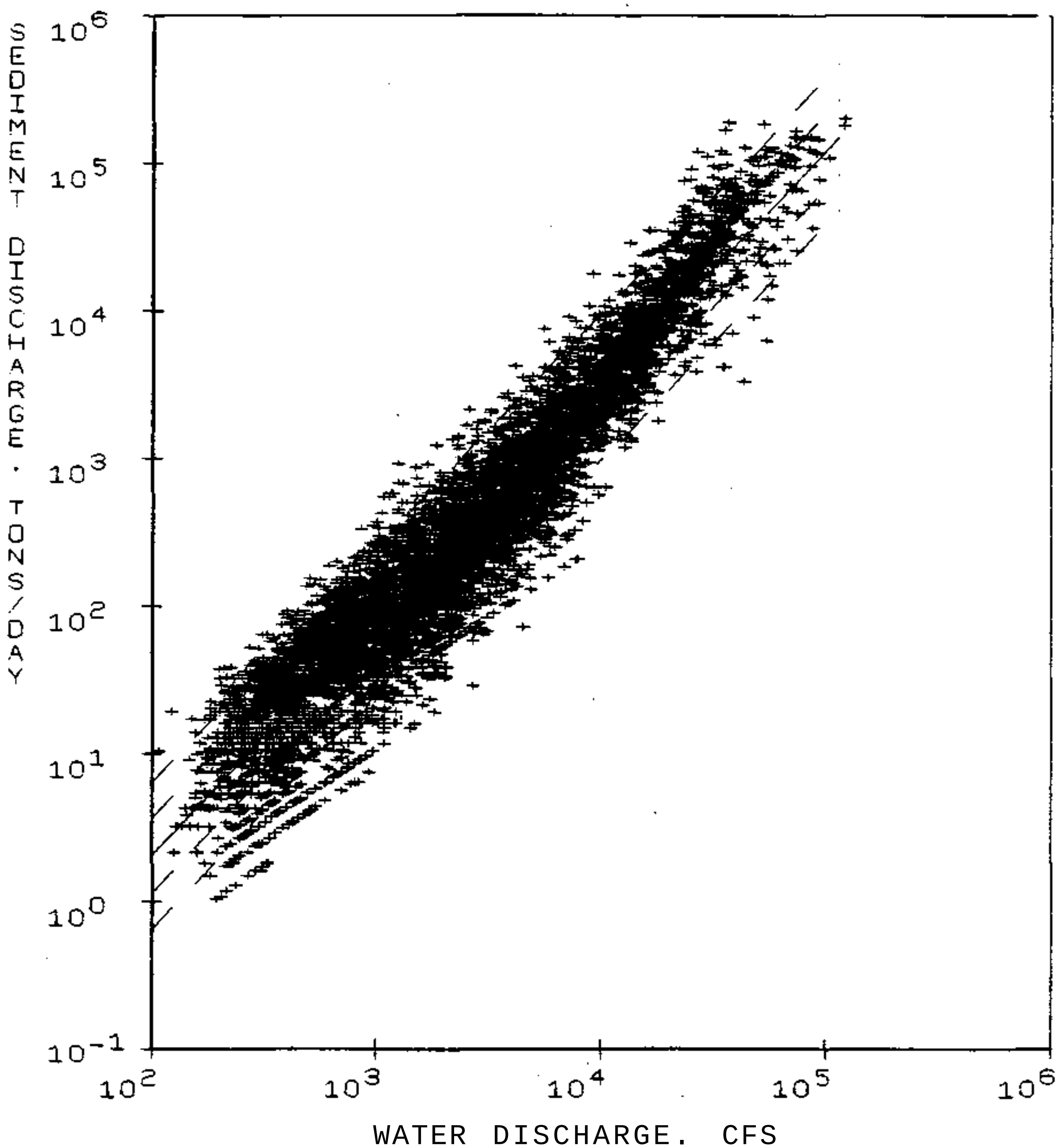


Figure 18. Period-of-record sediment transport curve plot for Maumee River at Waterville, Ohio

Table 12. Regression Coefficients for Period-of-Record Equations for Long-Term Stations in Indiana, Iowa, and Ohio

STATION CODE[1]	COEFFICIENT	SLOPE	STANDARD ERROR OF ESTIMATE	CORRELATION COEFFICIENT
901	.0306446	1.3338921	.4098017	.9199028
902	.0034606	1.5230238	.3092294	.9148842
903 A[2]	.0032471	1.6921874	.4016088	.9180911
903 B[3]	.0096616	1.3987921	.3913398	.8779000
904	.0011340	1.8190863	.4640573	.9203771
905	.0001668	1.8485173	.3285024	.9416266
906	.0044400	1.5351594	.3833038	.9184328
907	.0013271	1.5931596	.3013933	.9534992
908	.0000191	2.3245083	.3222754	.9317636

See Table 11 for station names
2 Prior to completion of Coralville Dam
Subsequent to completion of Coralville Dam

The data for each water year for each of these stations were also used to generate sediment transport curves and ARE equations. The ARE equations are similar to those for Illinois in that the slopes, intercepts, and correlation coefficients fluctuate over a wide range of values from year to year for any one station (Appendix H). This result suggests that ARE equations reliably predict sediment loads for a particular year but are very poor tools for predicting sediment loads for other years. This is identical to the findings of the analysis of the Illinois data.

Since the data for these long-term historical record stations behave in a manner similar to the short-term data available for Illinois, it seemed appropriate to investigate the evolution of the POR equations as the length of the record increased. This was done by starting with the first year of record for each station and then adding the next year's data to the data set and generating a POR equation for this incremental increase in record length. This process was continued, one year at a time for each station, until all years of record were included. This process resulted in a series of POR equations for each station reflecting an increasingly longer period of record. These equations were then plotted in sequential order on sediment transport curve plots for each station to demonstrate the fluctuation of the POR equation lines with increasingly longer records.

Figures 19 and 20 are examples of these plots for the POR equations for stations 905 (Scioto River at Higby, Ohio) and 907 (Maumee River at Waterville, Ohio). Figure 19 is a plot of 25 POR equations, and figure 20 is a plot of 18 POR equations. These plots show rather stable POR equations for these two stations. Seven of the eight stations showed similar

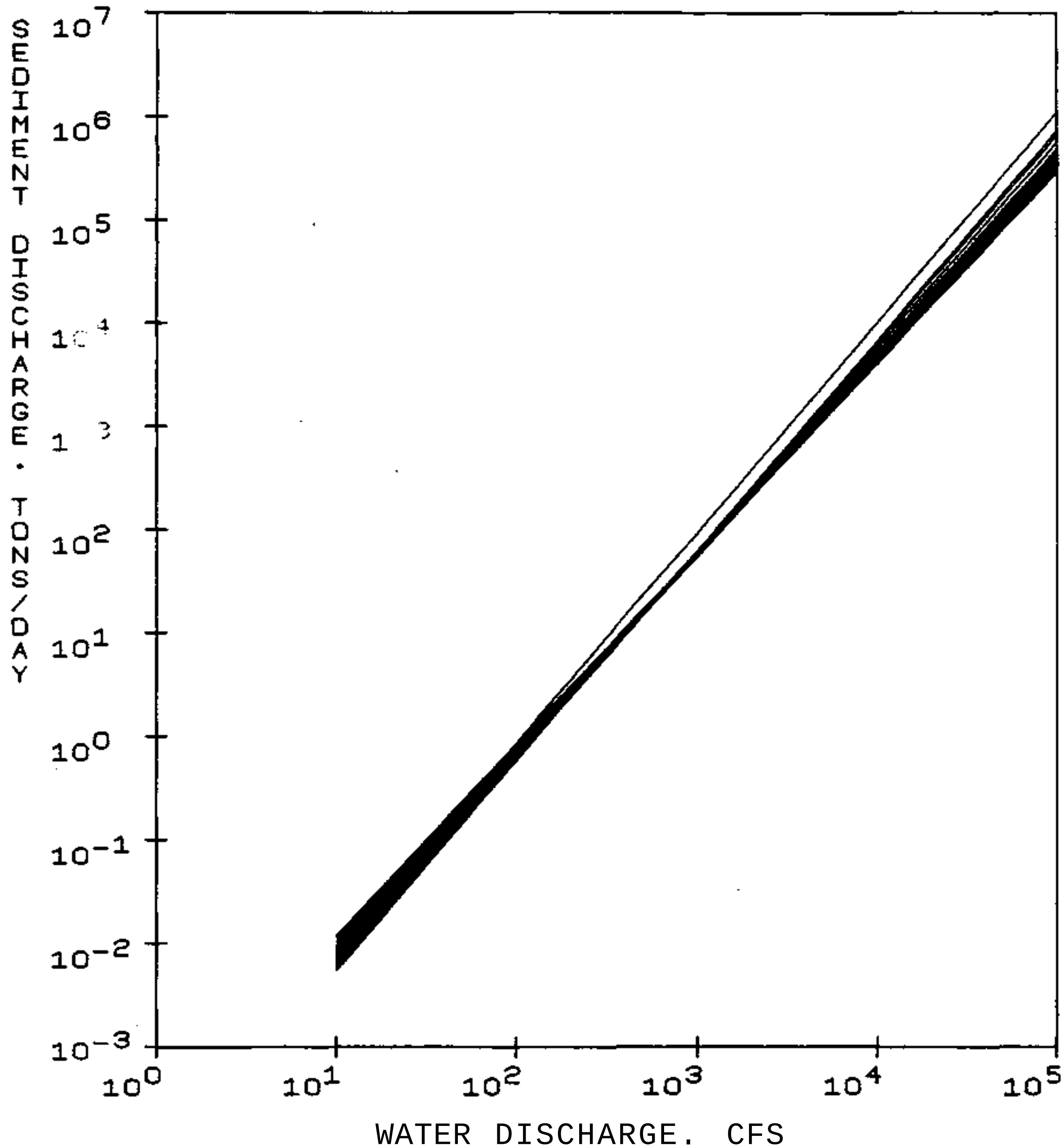


Figure 19. Cumulative period-of-record regression equation line plots for Scioto River at Higby, Ohio

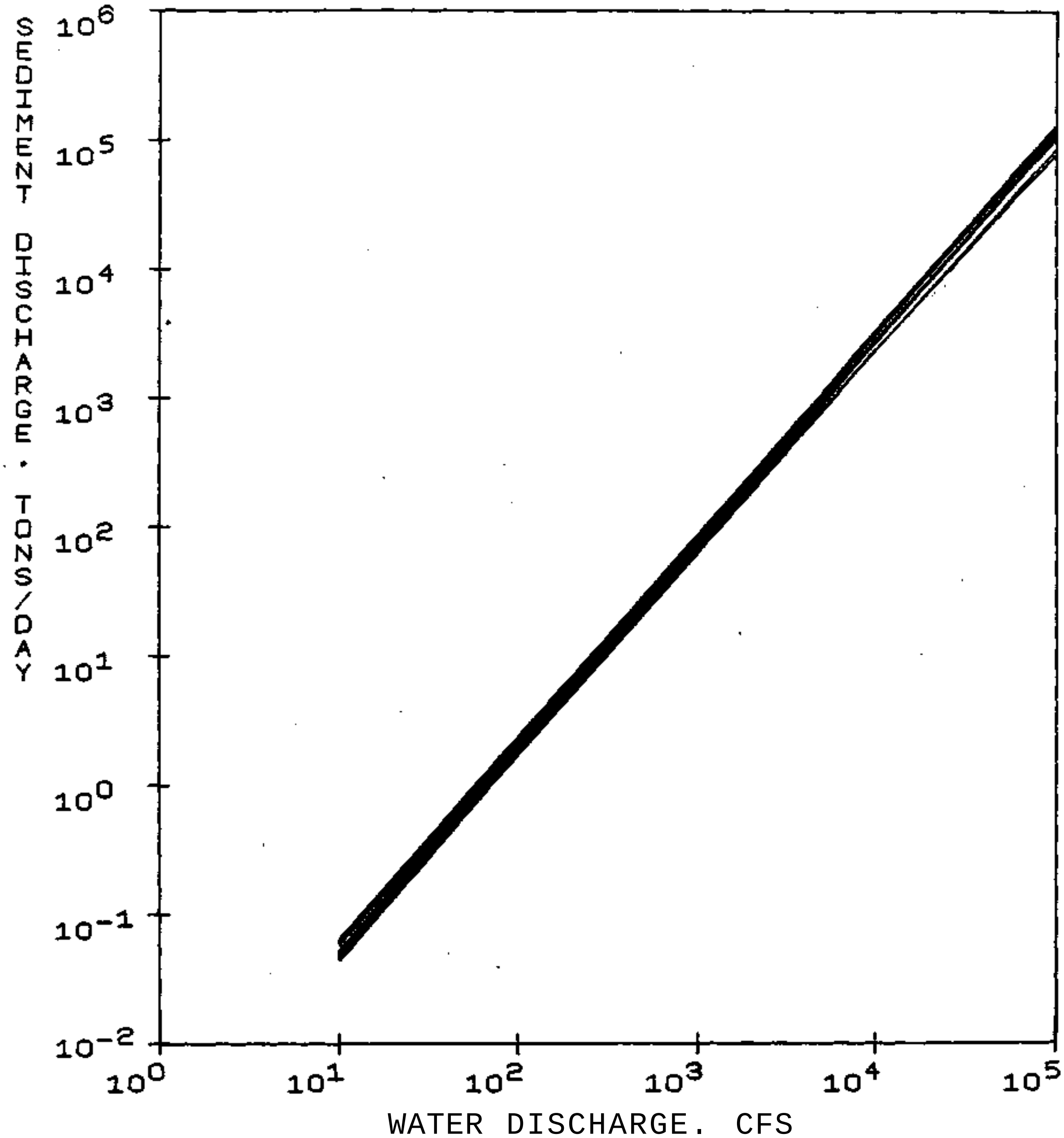


Figure 20. Cumulative period-of-record regression equation line plots for Maumee River at Waterville, Ohio

ranges of random fluctuation in the slopes and intercepts of their POR equations for increasing record length. Station 903, Iowa River at Iowa City, is the only station which showed a large range of fluctuation in slope and intercept for the POR equations over its 40 years of record. This may be because this particular station is located downstream of a reservoir that was constructed in 1959. Therefore, the results for this station are influenced by 19 years of pre-reservoir data and 21 years of post-reservoir data.

This analysis suggests that the climatological fluctuations over the past 20 to 30 years have hot significantly affected the sediment loads at the longer-term sediment stations in the midwest. This may indicate that for a general analysis, sediment rating curves developed from data of shorter duration may be used to estimate the sediment loads of streams for which these data are not available.

In order to test this observation further, the data for each of the six historical stations with at least 10 years of record were subdivided into 5-year increment data sets. POR equations were then generated for each 5-year interval. The equations were plotted for each station and the results were compared to the longest-term POR equation available for each station. The results of this analysis were inconsistent. Stations 901 (St. Mary's River near Fort Wayne, Indiana) and 907 (Maumee River at Waterville, Ohio) showed excellent consistency of slope and intercept between the 5-year interval POR equations and the long-term POR equation. Stations 903 (Iowa River at Iowa City) and 905 (Scioto River at Higby, Ohio) showed a wide range of fluctuations between the 5-year interval POR equations and the long-term POR equations. The results for station 906 (Stillwater River at Pleasant Hill, Ohio) fell in between the extremes. The results for station 902 (East Fork White River at Seymour, Indiana) were inconclusive since the 10-year record resulted in only two 5-year intervals. Figures 21 and 22 are examples of the extreme cases for this analysis: station 905, Scioto River at Higby, Ohio (which showed wide fluctuations between the two types of equations) and station 907, Maumee River at Waterville, Ohio (which showed consistency between the equations).

This seems to contradict the results of the previous analysis. However, explanations for the inconsistencies in the 5-year interval lines for stations 903 and 905 may be found by examining the annual water and sediment hydrographs for these stations. The changes in the lines for station 903 (Iowa River at Iowa City) are the easiest to explain. They are caused by the construction of the reservoir in the watershed in 1959. The effects of the reservoir on sediment loads at station 903 are represented in figure 23a. Apparently Coralville reservoir traps a significant amount of stream sediment and releases relatively clear water downstream.

An explanation of the fluctuations in 5-year interval lines for station 905 (Scioto River at Higby, Ohio) is less obvious. One possible explanation may be that the two lines that have dramatically different slopes and intercepts represent 5-year intervals with large increases in annual water discharge during those periods (figure 23b). The other three periods have fairly stable annual discharges. The dramatic increase in water discharges for these two 5-year periods may have altered the sediment

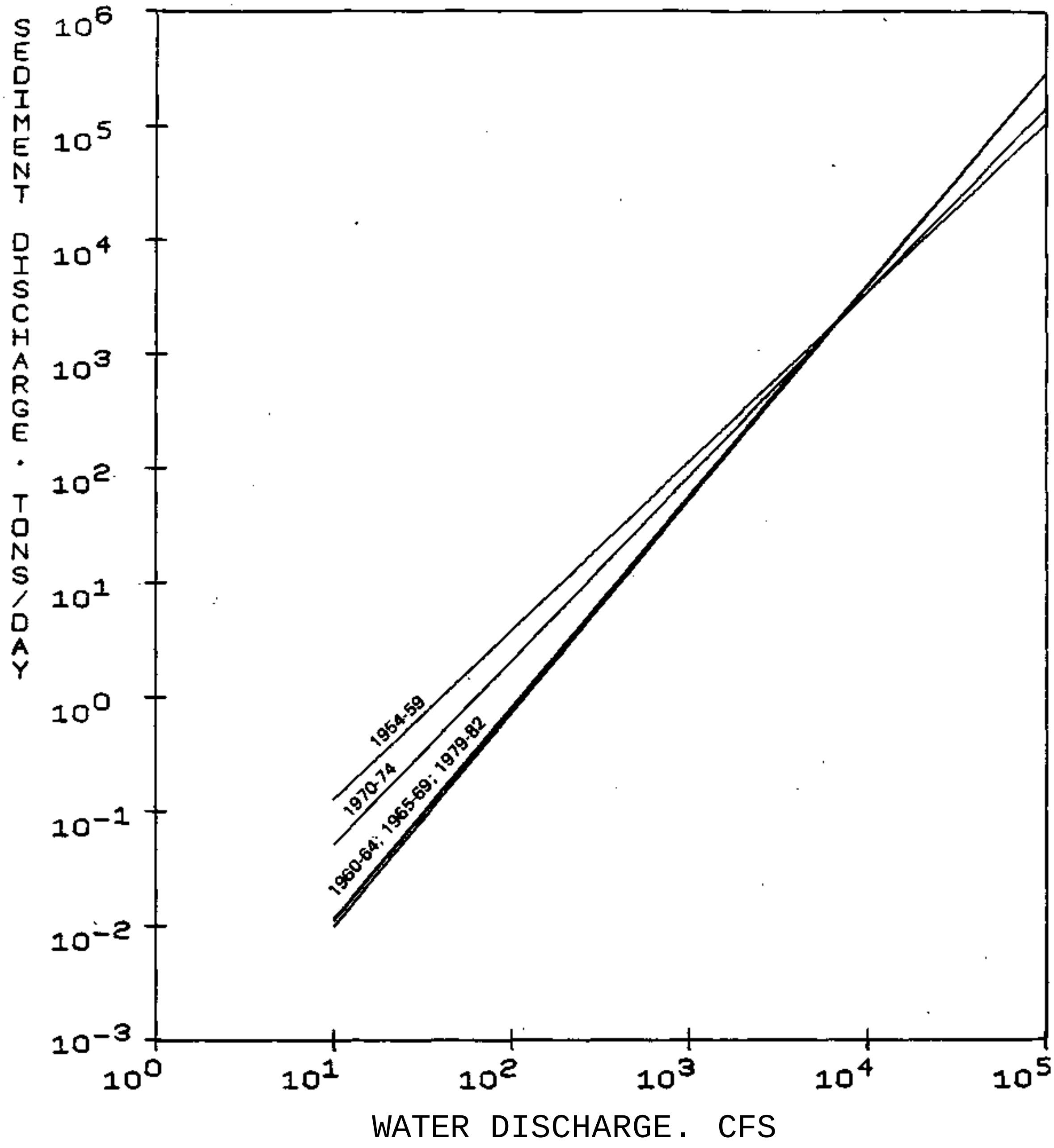


Figure 21. Five-year-interval period-of-record regression equation line plots for Scioto River at Higby, Ohio

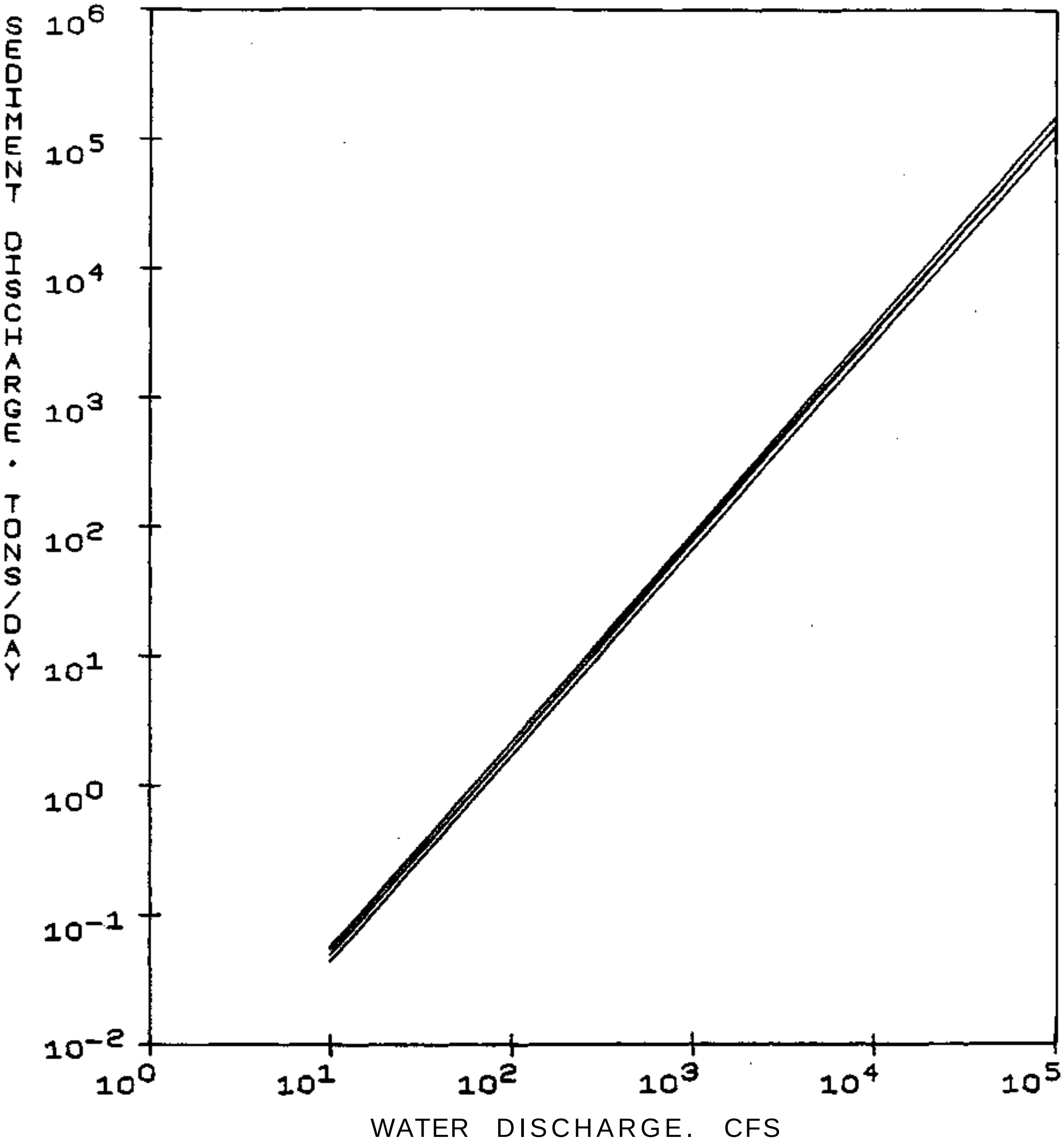


Figure 22. Five-year-interval period-of-record regression equation line plots for Maumee River at Waterville, Ohio

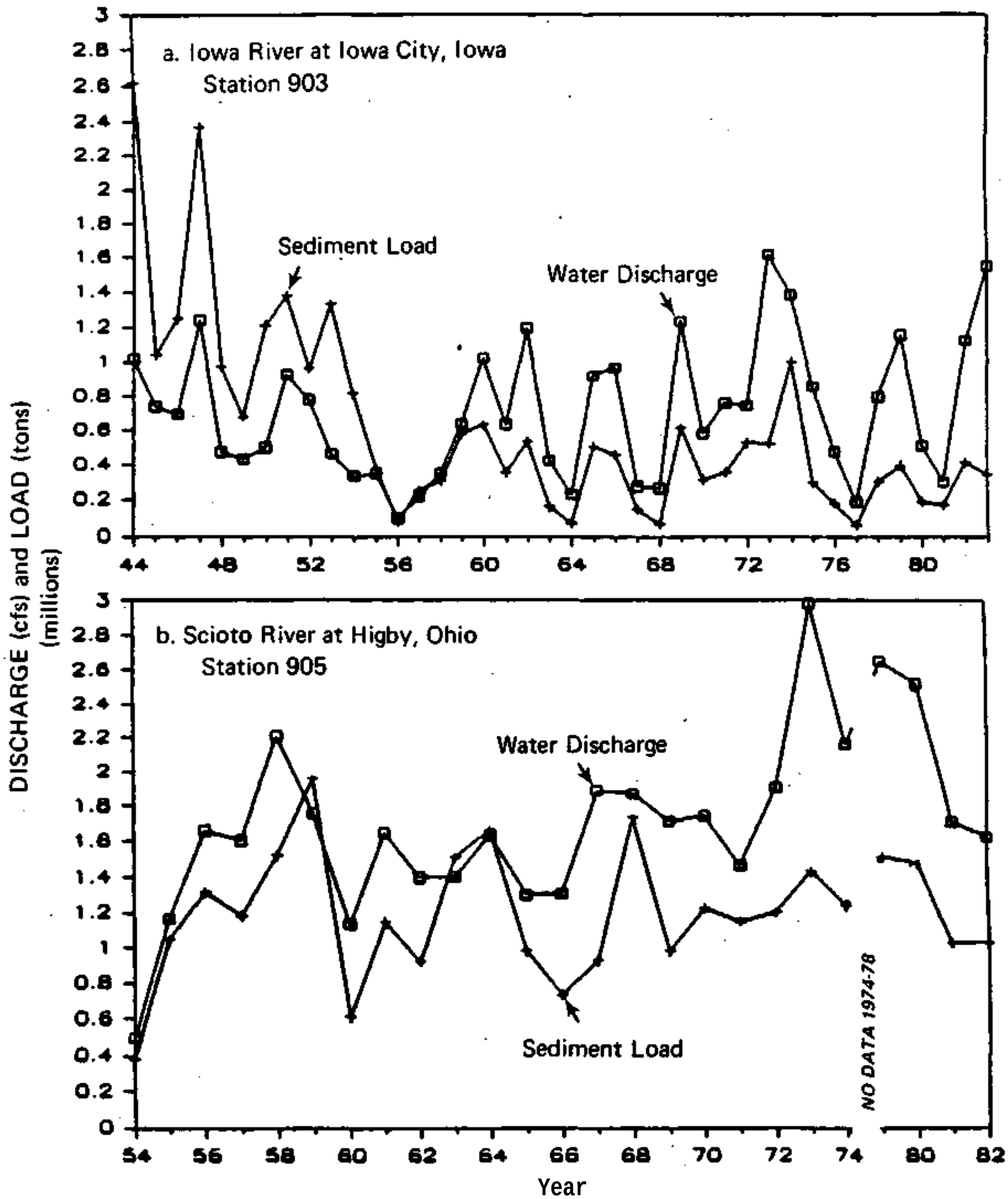


Figure 23. Hydrographs of annual water discharge and sediment load for a) Iowa River at Iowa City, Iowa, and b) Scioto River at Rigby, Ohio

transport characteristics of this river at this location and may explain why the regression lines for these two periods are different than those for the other periods.

The analyses given for figures 21 through 23 indicate that regression equations for stream sediment that are based on shorter durations may provide representative results provided the watershed conditions remain relatively stable and annual flow conditions are representative of the average. These conditions need to be evaluated to determine the usefulness of a short-term sediment data record.

GENERALIZED ANALYSES

Though much can be learned from the study of individual station records, other methods are necessary to estimate the sediment loads at other locations or in nearby watersheds for which there are no suspended sediment data. In this section methods that might be useful on a regional basis are investigated. The transport of sediment by floods is discussed first. Next long-term average annual sediment loads are determined by using flow-duration and sediment-duration methods. Multiple regression methods are applied to the average annual loads and the geomorphic and hydraulic geometry parameters. Both regression techniques are used in performing the regional analyses in the next section.

Flood Event Transport

Although there are reasonably good relations between the annual sediment load and the annual water discharge and drainage area, the spread of the data exceeds one log cycle. Thus, it is possible to overestimate or underestimate the annual sediment load by 100 percent or more.

One important consideration in annual sediment load measurements and calculations is the realization that most of the annual sediment load is transported during flood events which take place in relatively short periods of the year (Bhowmik et al., 1980; Demissie et al., 1983; Demissie, 1984). In the Kankakee River basin in Illinois, 3 years of data from 4 gaging stations showed that 50 percent of the annual sediment load was transported in only 4 to 53 days of the year. Other studies have shown that a large percentage of the annual sediment load is generated by a few storms each year. Wischmeier (1962) estimated that 75 percent of the soil loss from a small watershed was caused by an average of four storms per year. In a similar study, Piest (1963) analyzed data from 72 small watersheds in 17 states and concluded that 3 to 46 percent of the annual sediment yield occurred during large storms; 3 to 22 percent occurred during medium storms; and 34 to 92 percent occurred during small storms. Storms were defined as follows: large storms are storms with return period greater than 2 years; medium storms are storms with return period from 1 to 2 years; and small storms are storms with return period less than 1 year. Dickinson et al. (1975) reported that about 50 percent of the annual sediment load for streams in southern Ontario, Canada, were transported in the months of March and April. In the Atlantic drainage of the U.S., Meade (1982) found that 50 percent of the annual load was discharged in 10 percent of the time.

Another important observation is the fact that there is a very good relationship between the sediment load during floods and the annual sediment load (Demissie, 1984). The existence of very good relations between the annual sediment load and the sediment load during a few floods will influence the strategy for sediment yield monitoring programs and the procedures for calculating the annual sediment loads of streams. For example, the development of equations relating annual sediment load and the sediment load during the annual flood will provide a simple procedure for estimating the total sediment yield from the sediment load during the annual flood. Such a procedure will result in significant savings of effort and money for agencies responsible for monitoring and evaluating watershed erosion, reservoir sedimentation, and conservation practices. It can also serve as an important tool in project design of reservoirs where limited or no sediment data are available.

Temporal Distribution of Sediment Load in a Year

To illustrate the importance of flood flows in the transport of sediment, the distribution of the sediment load throughout the year will be examined first. Generally there is a good correlation between water discharge and sediment load; thus it is expected that sediment load will be high when the water discharge is high. To illustrate the positive correlation between water discharge and sediment load, the daily water and sediment discharges for the Iroquois River near Chebanse (232) for Water Years 1979 and 1980 are shown in figures 24 and 25, respectively. Water Year 1979 was relatively wet, and several flood events took place in the spring and summer months. From October to February the water discharges were very low, as were the sediment loads. In general, the peak sediment discharges correspond very well to the peak water discharges even though the highest sediment load did not occur during the highest flood. Water Year 1980 (figure 25), on the other hand, was a relatively dry year. There were fewer floods in 1980 than in 1979, and the annual water discharge was also less. However, in terms of the relation between sediment load and water discharge, it is still observed that the peak sediment loads occurred during the peak water discharges. Except for very short periods of time in June (during the annual flood) and in March (early spring), the sediment load in the stream was extremely low throughout the year.

The relation between the sediment load and the water discharge for the Iroquois River near Chebanse is shown in figure 26. In general there is a very good relation between the water discharge and the sediment load; however, there is a wide scatter of the data points around the regression line in a region. This is because of the many different factors, other than water discharge, which influence the sediment discharge in a stream.

The sediment load distributions and the relations between sediment load and water discharge for other streams and even for other stations on the same river will be different from the examples shown for the Iroquois

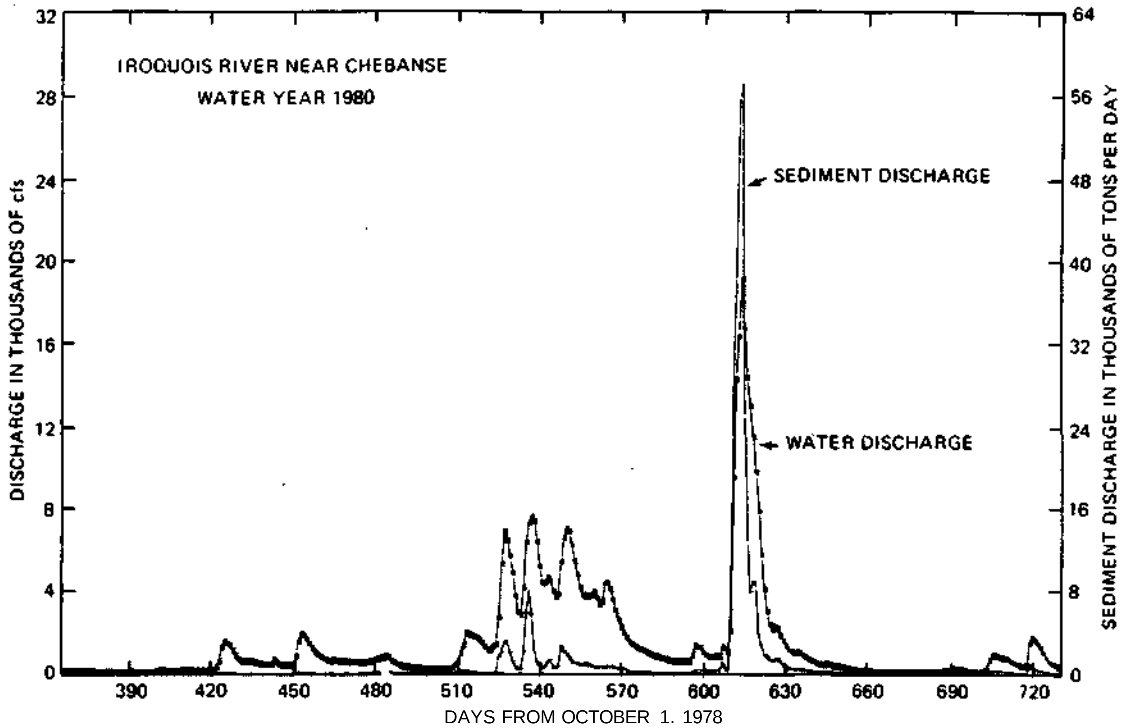


Figure 24. Daily water and suspended sediment discharge for Iroquois River near Chebanse, Water Year 1979

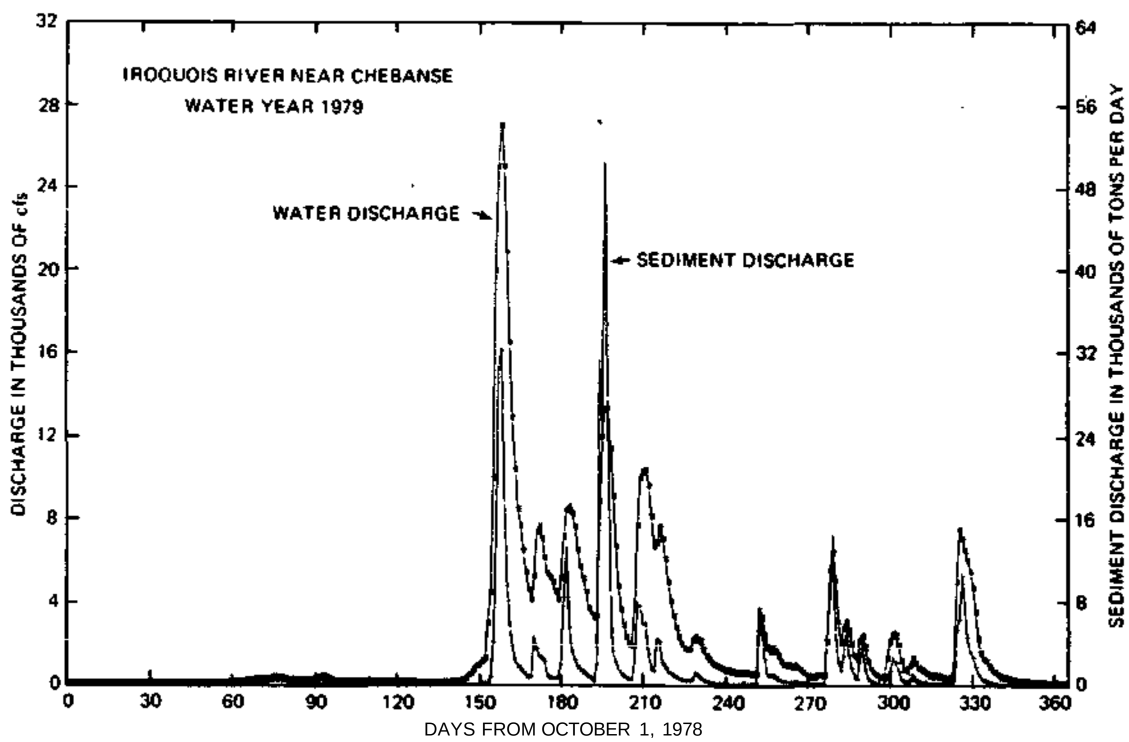


Figure 25. Daily water and suspended sediment discharge for Iroquois River near Chebanse, Water Year 1980

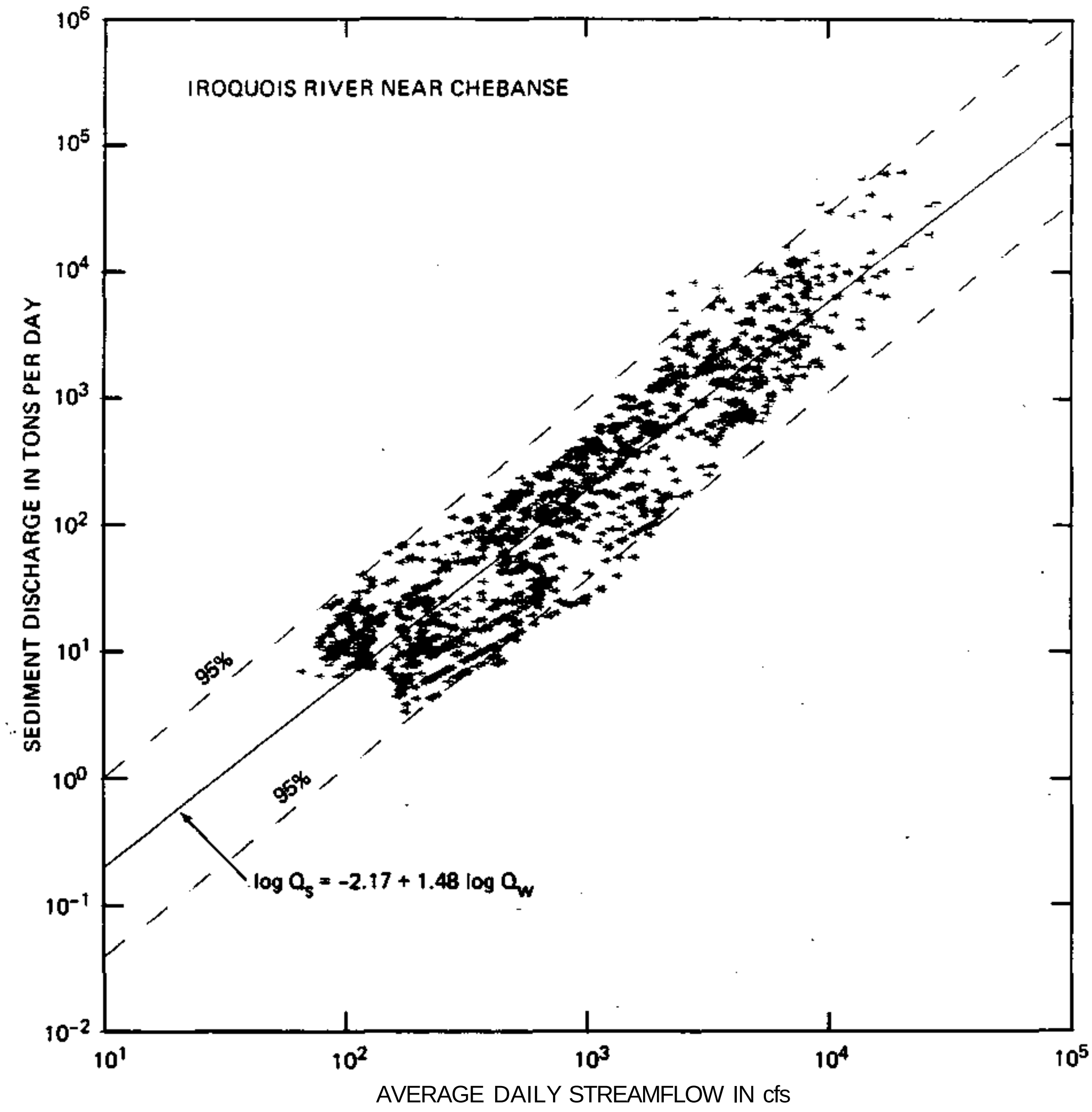


Figure 26. Daily suspended sediment load versus water discharge for Iroquois River near Chebanse

River near Chebanse. However, in general there is a good relation between the sediment load and water discharge, and furthermore the peak sediment loads for any stream occur during flood events.

Cumulative Sediment Transport

The importance of floods in the transport of a large percentage of the annual sediment load can be illustrated very clearly by constructing cumulative sediment transport curves (Demissie et al., 1983). This is shown in figure 27 for the Iroquois River near Chebanse. The curves were constructed by ranking the daily sediment loads first and then calculating the cumulative sum from the peak sediment load to the lowest in any year. The sediment loads and the time were then converted to percent sediment load and percent time by dividing them by the annual sediment load and the total number of days in a year, respectively. The general form of the curves will be similar for any stream. The main difference in the curves from stream to stream and from year to year is the slope of the curves in the initial stages. These differences are caused by differences in the sediment-carrying characteristics of the streams and in the variability of the flow in a year and from year to year. Generally the curves are steeper for very dry years than for wet years, as shown in figure 27 by the nearly vertical curve for 1980, which was the driest year among the four years considered. During dry years very few floods occur, and those few floods carry most of the annual sediment load. Table 13 shows the percent of time in a year during which 50 and 80 percent of the annual sediment load were transported in the Iroquois River. As shown in table 13, 50 percent of the annual sediment load passed the station in only 1.2 to 6.8 percent of the time (4 to 24 days).

The cumulative curves show in how many days, in percent time, a certain percent of the annual sediment load is transported by a stream. They are also useful in showing the differences in sediment transport characteristics of different streams and the variation of sediment transport from year to year. However, their predictive capability is limited unless the peak sediment loads are measured or the parameters of the curves are related to some characteristics of the watershed, discharge, precipitation, or stream.

Relations between Annual Sediment Load and Sediment Load during Flood Events

As discussed previously, a large percentage of the annual sediment load is transported during floods which occur in a relatively short period of time in a year. Development of relations between the annual sediment load and the sediment load during major floods will provide a very powerful tool for predicting annual sediment loads on the basis of the sediment loads during the floods. Such relations were developed by using data from the USGS and the SWS. Thirty gaging stations in Illinois with daily water and sediment discharge data were used to develop the relations. The period of record used was 1978 to 1982. Ten stations had only one year of data, while 20 stations had 2 to 5 years of data. A listing of the stations used in the analysis is given in table 14.

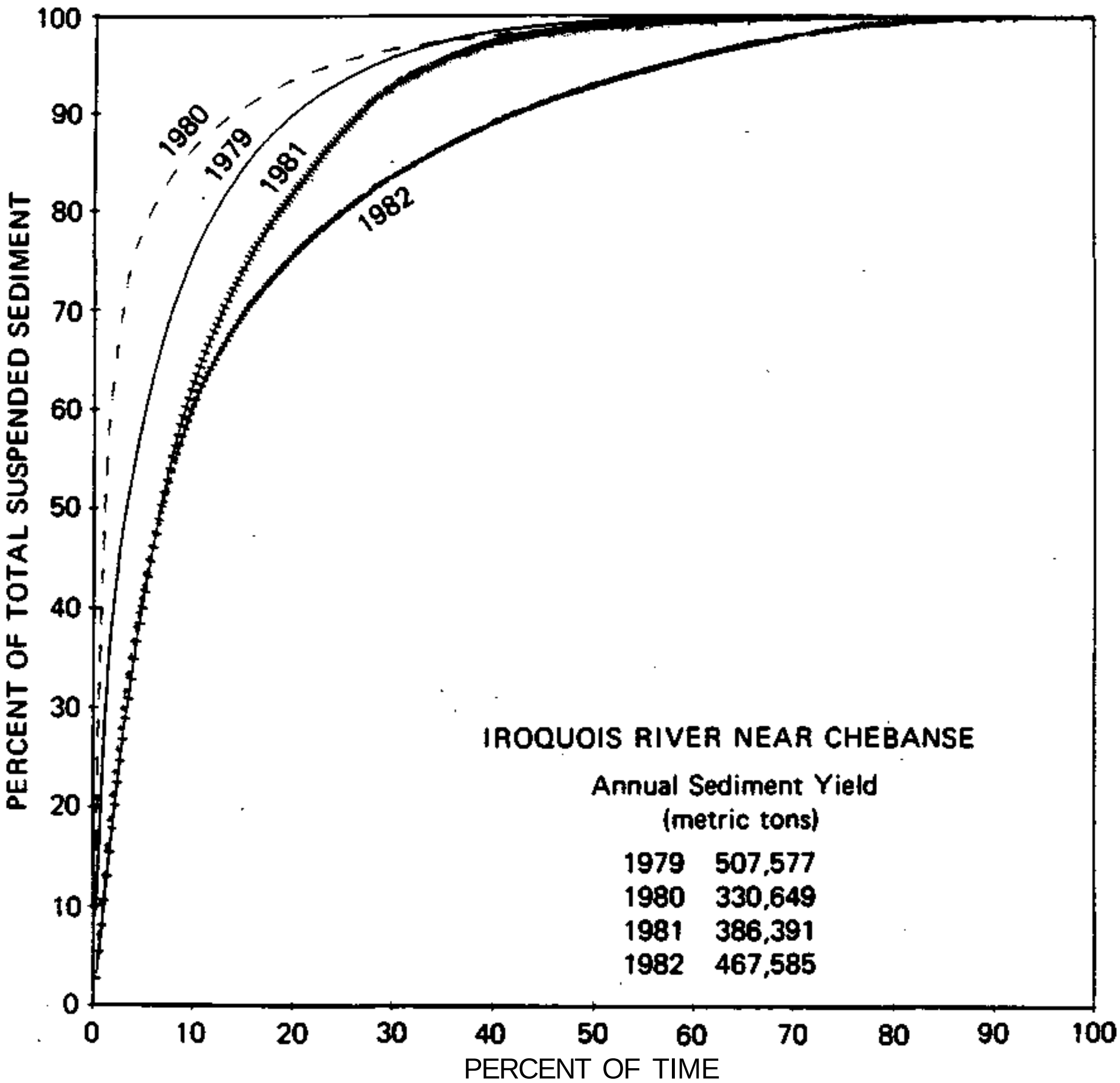


Figure 27. Cumulative sediment transport curves for Iroquois River near Chebanse

Table 13. Percent of Time during Which 50 and 80 Percent of the Annual Sediment Load Passed a Station

PERCENT OF ANNUAL LOAD	1979	1980	1981	1982
50	3.5	1.2	6.8	4.2
80	12.5	6.0	18.5	14.8

Table 14. Gaging Stations Used in Developing Relations between Annual Sediment Load and Sediment Load during Flood Events

NAME OF STREAM	DRAINAGE AREA (MI^2)
BIG MUDDY RIVER AT MURPHYSBORO, IL	2,169
BIG CREEK AT ST. DAVID, IL	26.7
DES PLAINES RIVER AT RIVERSIDE, IL	630
EDWARDS RIVER NEAR NEW BOSTON, IL	445
KASKASKIA RIVER AT COOKS MILLS, IL	473
LAMOINE RIVER AT RIPLEY, IL	1,293
SOUTH BRANCH KISHWAUKEE RIVER AT DEKALB, IL	77.7
SOUTH FORK SALINE RIVER NEAR CARRIER MILLS, IL	147
SLUG RUN NEAR BRYANT, IL	7.9
SPRING CREEK AT ROCK VALLEY COLLEGE AT ROCKFORD, IL	2.81
BIG CREEK NEAR BRYANT, IL	40.3
BRUSHY CREEK NEAR HARCO, IL	13.3
EMBARRAS RIVER AT STATE HWY. 133 NEAR OAKLAND, IL	542
GRINDSTONE CREEK NEAR BIRMINGHAM, IL	45.4
GREEN RIVER NEAR GENESEO, IL	1,003
HENDERSON CREEK NEAR OQUAWKA, IL	432
IROQUOIS RIVER NEAR CHEBANSE, IL	2,091
IROQUOIS RIVER AT IROQUOIS, IL	686
INDIAN CREEK NEAR WYOMING, IL	62.7
KANKAKEE RIVER AT MOMENCE, IL	2,294
KISHWAUKEE RIVER NEAR PERRYVILLE, IL	1,099
KASKASKIA RIVER NEAR VENEDY STATION, IL	4,393
KANKAKEE RIVER NEAR WILMINGTON, IL	5,150
LUSK CREEK NEAR EDDYVILLE, IL	42.9
LITTLE WABASH RIVER AT LOUISVILLE, IL	745
ROCK RIVER NEAR JOSLIN, IL	9,549
SPRING CREEK AT MCFARLAND RD. NEAR ROCKFORD, IL	2.44
SANGAMON RIVER NEAR OAKFORD, IL	5,093
ILLINOIS RIVER AT VALLEY CITY, IL	26,564
VERMILION RIVER NEAR LENORE, IL	1,251

The annual water hydrograph was first examined to identify the highest, the second highest, the third highest, and the fourth highest floods in any particular year. Then the total sediment discharge during those floods was calculated by summing up the daily sediment discharges during the flood periods.

The relations between the sediment load during the highest annual flood and the annual sediment load for all the stations is shown in figure 28. As may be seen in figure 28, the two sediment loads are well correlated with a correlation coefficient of 0.94. The equation which relates the two loads is:

$$\log (QSA) = 0.57 + 1.02 \log (QS1) \tag{11}$$

where QS1 is the sediment load during the highest flood, in tons, and QSA is the annual sediment load, in tons.

It is important to note that the drainage areas of the gaging stations used in this analysis range from 2.44 to 26,564 sq mi. The scatter of the data points in figure 28 can be reduced by grouping the stations. However, since the correlation with all the data points included is very good, it was felt that was not necessary. Furthermore, the results in figure 28 show that the relation is applicable for a wide range of watersheds in Illinois.

Another important observation from figure 28 and equation 11 is that the slope of the regression line is greater than 1.0. This implies that the percentage of the annual sediment load transported by the annual flood is different for small and large rivers. In general the larger the stream, the smaller the percentage. On the average, for a small stream with an annual sediment load of 1000 tons, 23 percent of the annual sediment is transported by the annual flood. On the other hand, for a large river like the Illinois River, with an annual sediment load in the range of 10 tons, the highest flood transports 20 percent of the annual load. The durations of the annual flood for all the streams considered here range from 3 to 21 days, with a mean duration of 9.2 days. This represents only 2.5 percent of the time on the average.

When the sediment transported during the two highest floods is considered, the relation between the annual sediment load and the sediment load during the floods is better than when only the annual flood is considered. The correlation coefficient improves from 0.94 to 0.97, with a corresponding reduction in the standard error of the estimate. This is shown in figure 29, where the sum of the sediment load during the highest and second highest floods is plotted against the annual sediment load. The regression equation between the two loads is:

$$\log (QSA) = 0.25 + 1.04 \log (QS2) \tag{12}$$

where QS2 is the sediment load during the two highest floods, in tons. Again the slope of the regression line is greater than 1, indicating that during floods a larger percentage of the annual sediment load is transported in smaller streams than in larger streams. The combined durations

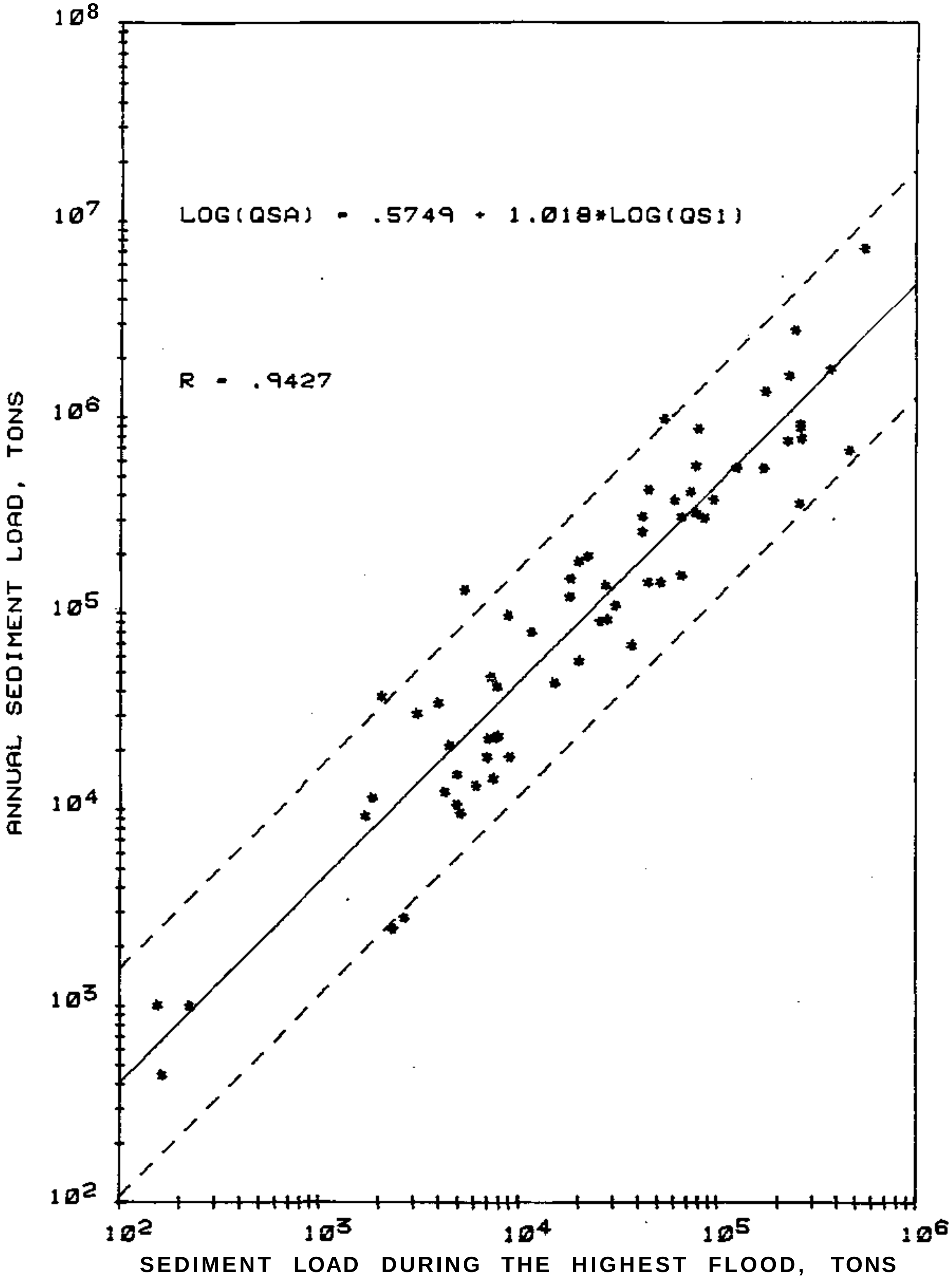


Figure 28. Annual sediment load versus the sediment load during the highest flood

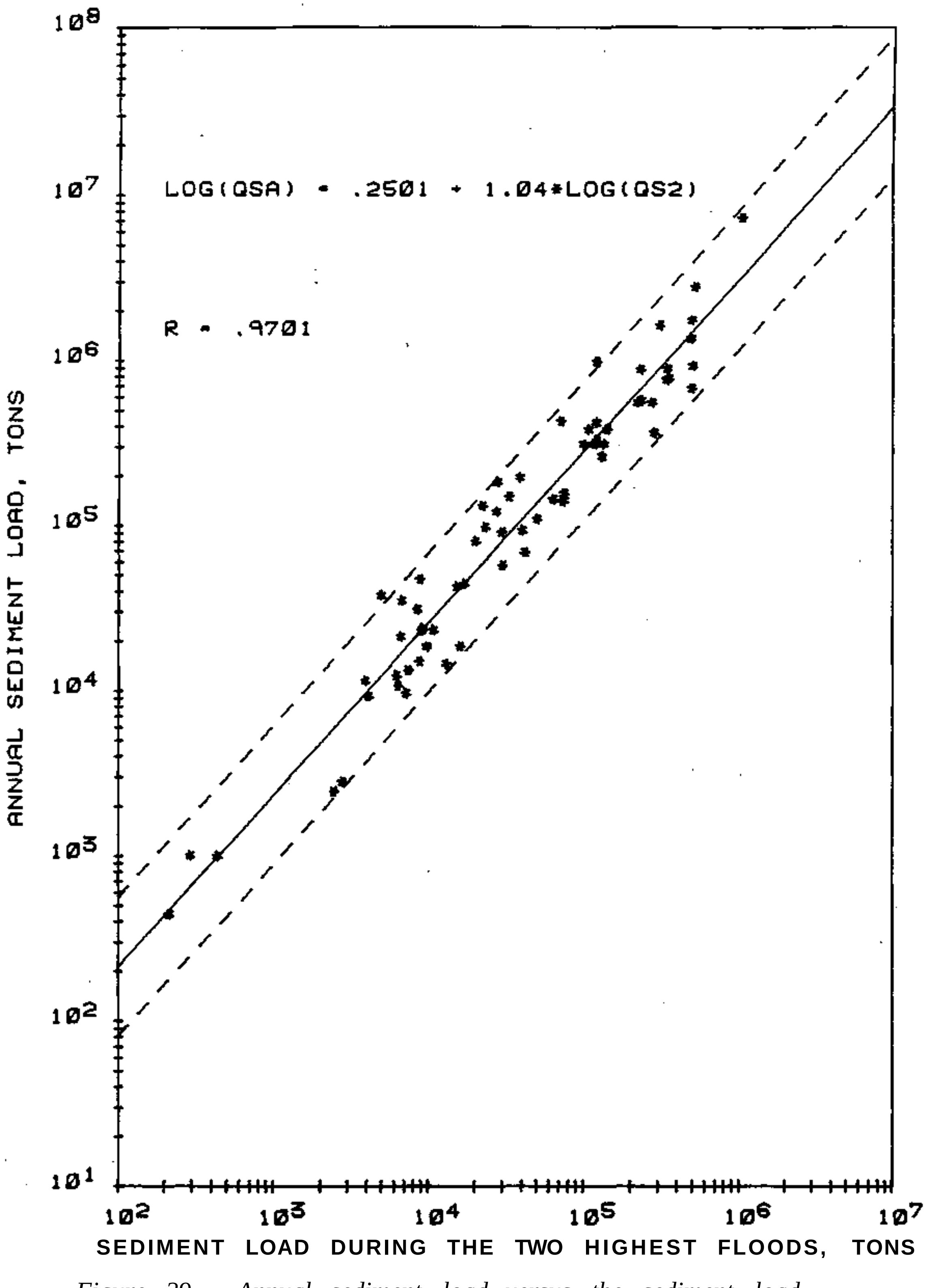


Figure 29. Annual sediment load versus the sediment load during the two highest floods

of the two floods range from 7 to 38 days with a mean duration of 17 days, which represents only 4.7 percent of the time in a year. The percentage of the annual sediment load transported by the two highest floods for a small stream with an annual sediment load of 1000 tons is 43, while for a stream with an annual load of 10^6 tons the value is 32 percent.

Further improvements in the relations between the annual sediment load and the sediment load during flood events is achieved if the third and fourth highest floods are included. The relations between the annual load and the loads carried by the three and four highest floods, respectively, are as follows:

$$\log (QSA) = 0.16 + 1.04 \log (QS3) \tag{13}$$

$$\log (QSA) = 0.12 + 1.03 \log (QS4) \tag{14}$$

The corresponding correlation coefficients are 0.98 and 0.99. QS3 and QS4 are the sediment loads during the three and four highest floods, respectively. Further reduction in the scatter of the points from the regression line is evident in figures 30 and 31 for the three and four highest floods, respectively. On the basis of equation 13 the three highest floods transport 52 percent of the annual sediment load for a small stream with an annual sediment load of 1000 tons, and 40 percent for a larger stream with an annual sediment load of 10^6 tons.

The percentages for the four highest floods increase to 62 percent for the small stream and 50 percent for the large stream. These percentages are average values; the actual percentages vary from year to year and from stream to stream.

Average Annual Sediment Load

Flow-Duration Method

One important use of suspended sediment data is to estimate the long-term average amount of sediment that will be transported by a stream. The flow-duration, sediment-rating curve method (Miller, 1951; Lee and Bhowmik, 1979) was used in this study to calculate this long-term average annual sediment load.

To use this technique, it is necessary to have a reliable, long-term flow-duration curve for the station being analyzed. Twelve of the stations in this study did not meet this criterion. Long-term flow-duration curves were not available for nine of these stations (station codes 114, 203, 204, 240, 244, 252, 356, 369, and 444). The remaining three stations (station codes 108, 109, and 116) are located in areas that are experiencing drastic changes in watershed conditions due to urbanization. The curves for these stations reflect historical watershed conditions rather than the present situation, and are not useful in this context.

The flow-duration curves for each of the remaining stations were divided into as many as 36 flow class intervals. The median flow value in

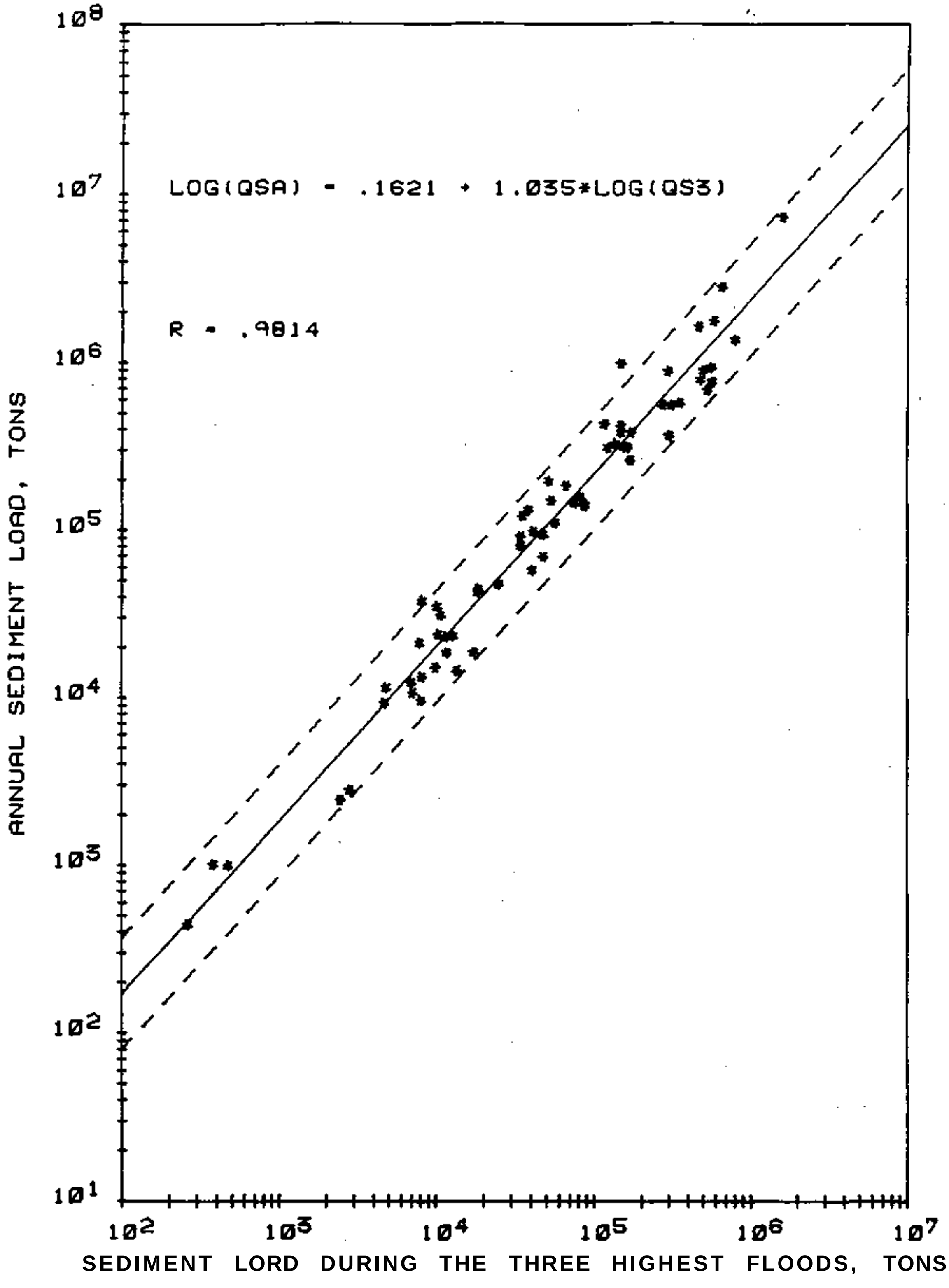


Figure 30. Annual sediment load versus the sediment load during the three highest floods

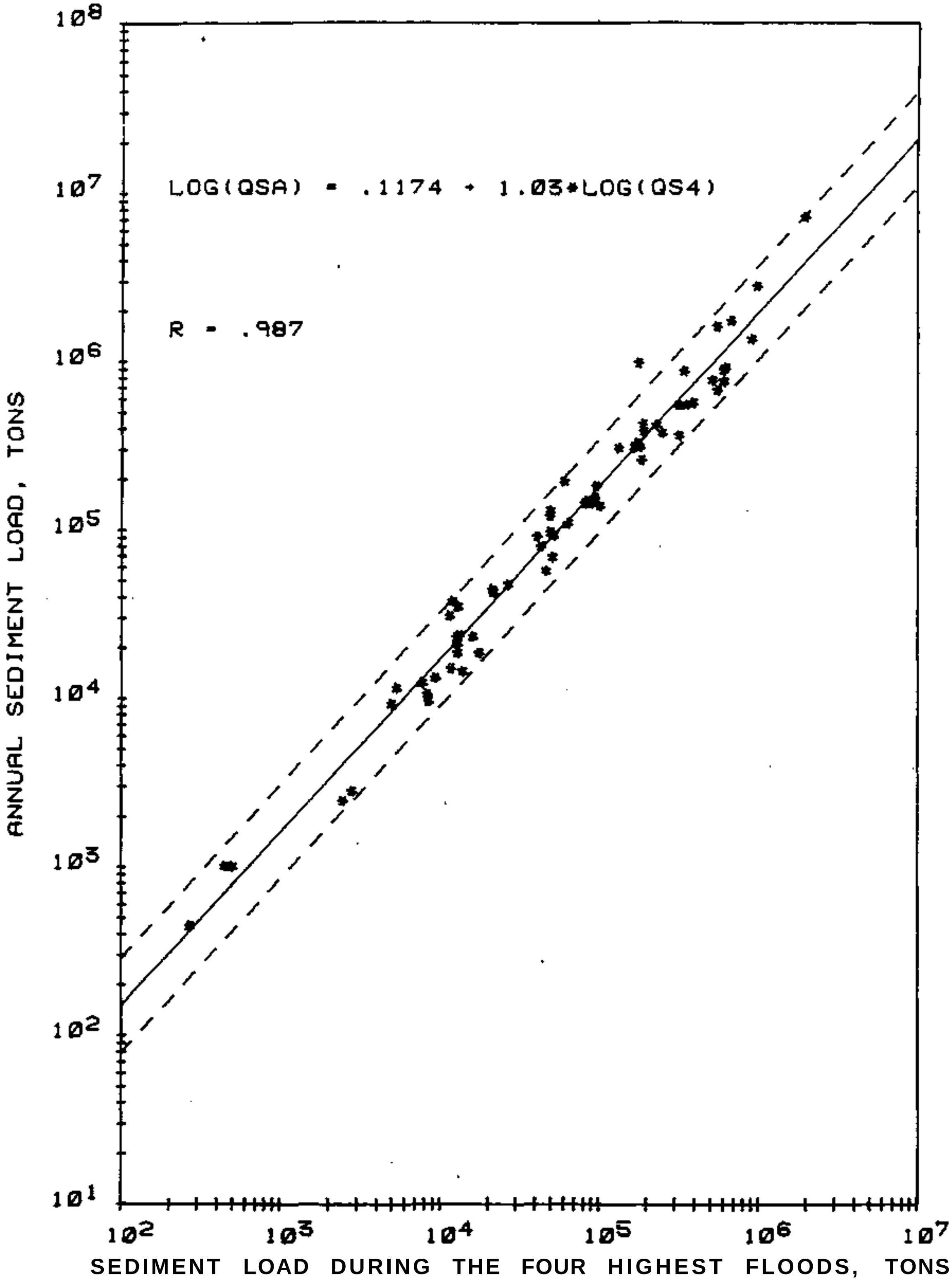


Figure 31. Annual sediment load versus the sediment load during the four highest floods

each interval was then used in the appropriate POR to calculate sediment load values for each flow class increment. Each of these sediment load values was then multiplied by the incremental difference between the appropriate two flow class intervals. This yielded up to 35 fractional total sediment loads for each station. These fractional values were summed for each station and multiplied by 365 days to get the long-term average annual sediment load.

Table 15 lists the long-term average annual sediment load for these stations. The results for six of the sediment stations (station codes 101, 122, 231, 236, 237, and 253) were based on the flow-duration tables for nearby gaging stations. The flow-duration data for these gaging stations were adjusted according to the ratio between the drainage area for the sediment site and the drainage area for the gaging station.

These long-term average annual sediment load values will be used as input for the multiple regression analyses. They will also be used in a later section to develop regional relationships.

Sediment-Duration Method

For stations with many years of continuous water discharge and sediment concentration data, long-term average annual sediment load may be estimated by either the flow-duration, sediment-rating curve method or the sediment-duration method. Both methods were used to estimate average annual sediment load for the Mississippi River stations at East Dubuque (191), Burlington (292), and Keokuk (293). These were the only stations for which there were 14 or 15 years of continuous, daily water discharge record and nearly continuous, daily instantaneous sediment concentration data. Since the methodology and results obtained by the flow-duration, sediment-rating curve method have already been presented, this discussion will be limited to explaining the sediment-duration method and comparing the results obtained by both flow-duration methods for the three Mississippi River stations.

The sediment-duration method requires a long-term flow-duration curve as well as a long-term concentration-duration curve. These curves are divided into 25 four-percent segments. The midpoint discharge and midpoint concentration of each segment are used in the following relationship to compute the long-term average annual sediment load for a particular station:

$$Q_s = [\sum_{i=1}^{25} (0.04)\ (Q_{wi})\ (C_i)\ (0.0027)]\ 365 \qquad (15)$$

where Q_s is the long-term average annual sediment load (tons), Q_{wi} is the midpoint discharge for the ith four-percent segment (cfs), and C_i is the midpoint concentration for the ith four-percent segment (mg/l). Equation 15 is based on an assumption of direct correspondence between frequencies on the flow and sediment concentration-duration curves. The concentration-duration curves for the three Mississippi River stations can be seen in figure 32.

Table 15. Long-Term Average Annual Sediment Load
Based on the Flow-Duration, Sediment-Rating Curve Method

STA. CODE	USGS STATION NUMBER	USGS STATION NAME	AVERAGE ANNUAL SEDIMENT LOAD (TONS)	AVERAGE ANNUAL SEDIMENT YIELD (TONS/SQ MI)
101	05418950	APPLE RIVER NEAR ELIZABETH	53986	261
102	05435500	PECATONICA RIVER AT FREEP0RT	204501	154
103	05437500	ROCK RIVER AT ROCKTON	453743	71
104	05438500	KISHWAUKEE RIVER AT BELVIDERE	41026	76
105	05440000	KISHWAUKEE RIVER NEAR PERRYVILLE	109851	100
106	05439500	SOUTH BRANCH KISHWAUKEE RIVER NEAR FAIRDALE	51060	132
107	05550000	FOX RIVER AT ALGONQUIN	49425	35
110	05551200	FERSON CREEK NEAR ST. CHARLES	5411	105
111	05439000	SOUTH BRANCH KISHWAUKEE RIVER AT DEKALB	6598	85
112	05444000	ELKHORN CREEK NEAR PENROSE	43863	300
113	05446500	ROCK RIVER NEAR JOSLIN	918926	96
115	05539000	HICKORY CREEK AT JOLIET	17346	162
117	05552500	FOX RIVER AT DAYTON	182005	69
118	05556500	BIG BUREAU CREEK AT PRINCETON	73553	375
119	05447500	GREEN RIVER NEAR GENESEO	256238	255
120	05466500	EDWARDS RIVER NEAR NEW BOSTON	253985	571
121	05466000	EDWARDS RIVER NEAR ORION	103506	668
122	05555300	VERMILION RIVER NEAR LENORE	233383	187
123	05542000	MAZON RIVER NEAR COAL CITY	90822	200
124	05527500	KANKAKEE RIVER NEAR WILMINGTON	281365	55
125	05520500	KANKAKEE RIVER AT MOMENCE	102986	45
126	05568800	INDIAN CREEK NEAR WYOMING	115908	1849
127	05467000	POPE CREEK NEAR KEITHSBURG	1056581	5774
191		MISSISSIPPI RIVER AT EAST DUBUQUE	3346540	41
228	05469000	HENDERSON CREEK NEAR OQUAWKA	258684	599
229	05569500	SPOON RIVER AT LONDON MILLS	926897	873
230	05566500	EAST BRANCH PANTHER CREEK AT EL PASO	1826	60
231	05554490	VERMILION RIVER AT MCDOWELL	87934	160
232	05526000	IROQUOIS RIVER NEAR CHEBANSE	238921	114
233	05525000	IROQUOIS RIVER AT IROQUOIS	56968	83
234	05525500	SUGAR CREEK AT MILFORD	88707	199
235	05564400	MONEY CREEK NEAR TOWANDA	8056	164
236	05567510	MACKINAW RIVER BELOW CONGERVILLE	260390	336
237	05568005	MACKINAW RIVER BELOW GREEN VALLEY	595341	545
238	05570350	BIG CREEK AT ST. DAVID	5799	207
239	05570370	BIG CREEK NEAR BRYANT	13974	339

Table 15. Concluded

STA. CODE	USGS STATION NUMBER	USGS STATION NAME	AVERAGE ANNUAL SEDIMENT LOAD (TONS)	AVERAGE ANNUAL SEDIMENT YIELD (TONS/SQ MI)
241	05570000	SPOON RIVER AT SEVILLE	2158941	1320
242	05584500	LA MOINE RIVER AT COLMAR	382682	584
243	05495500	BEAR CREEK NEAR MARCELLINE	421100	1207
245	05585000	LA MOINE RIVER AT RIPLEY	938643	726
246	05583000	SANGAMON RIVER NEAR OAKFORD	1537143	302
247	05582000	SALT CREEK NEAR GREENVIEW	503968	279
248	05578500	SALT CREEK NEAR ROWELL	27320	77
249	05572000	SANGAMON RIVER AT MONTICELLO	67273	122
250	03336900	SALT FORK NEAR ST. JOSEPH	25742	192
251	03339000	VERMILION RIVER NEAR DANVILLE	434866	337
253	05586100	ILLINOIS RIVER AT VALLEY CITY	4395406	165
254	05576022	SOUTH FORK SANGAMON RIVER BELOW ROCHESTER	178481	205
255	05591200	KASKASKIA RIVER AT COOKS MILLS	31674	67
292		MISSISSIPPI RIVER AT BURLINGTON	12101837	107
293	05474500	MISSISSIPPI RIVER AT KEOKUK	7112144	60
357	03344000	EMBARRAS RIVER NEAR DIONA	299288	326
358	05592100	KASKASKIA RIVER NEAR COWDEN	314525	236
359	05587000	MACOUPIN CREEK NEAR KANE	787262	907
360	05592800	HURRICANE CREEK NEAR MULBERRY GROVE	107277	706
361	05592500	KASKASKIA RIVER AT VANDALIA	785568	413
362	03345500	EMBARRAS RIVER AT STE. MARIE	1044865	689
363	03346000	NORTH FORK EMBARRAS RIVER NEAR OBLONG	76094	239
364	03378900	LITTLE WABASH RIVER AT LOUISVILLE	148925	200
365	05593520	CROOKED CREEK NEAR HOFFMAN	80158	316
366	05594000	SHOAL CREEK NEAR BREESE	314302	428
367	05594800	SILVER CREEK NEAR FREEBURG	361183	778
368	03380500	SKILLET FORK AT WAYNE CITY	157591	340
370	03381500	LITTLE WABASH RIVER AT CARMI	577936	186
371	05597000	BIG MUDDY RIVER AT PLUMFIELD	46380	58
373	05599500	BIG MUDDY RIVER AT MURPHYSBORO	195377	90
374	05597500	CRAB ORCHARD CREEK NEAR MARION	1513	48
375	03382170	BRUSHY CREEK NEAR HARCO	2926	220
376	03382100	SOUTH FORK SALINE RIVER NEAR CARRIER MILLS	77781	529
377	03384450	LUSK CREEK NEAR EDDYVILLE	1281	30
378	03612000	CACHE RIVER AT FORMAN	70201	288
379	05594100	KASKASKIA RIVER NEAR VENEDY STATION	592191	135

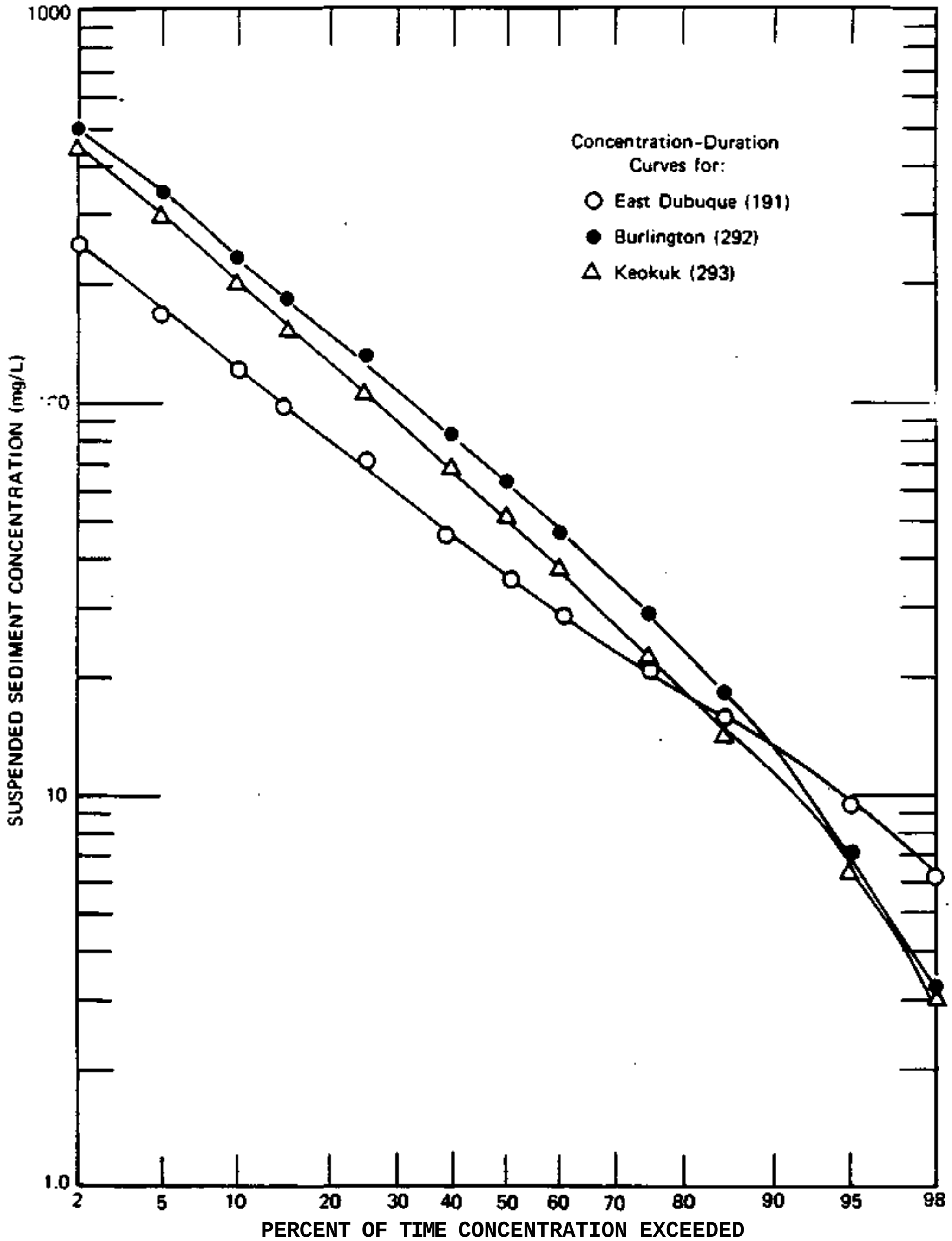


Figure 32. Concentration-duration plot- for Mississippi River stations at East Dubuque, Burlington, and Keokuk

Table 16 summarizes the results obtained by both flow-duration methods. The loads obtained by the flow-duration, sediment-rating curve method were 10 to 42 percent lower than the estimates obtained by the sediment-duration method. The flow-duration, sediment-rating curve method predicted loads which were from 6 percent above to 35 percent below the measured values, while the sediment-duration method predicted loads which were from 18 percent higher to 1 percent lower than the measured loads. The sediment-duration method gives better estimates of the average annual sediment load.

The flow-duration computations were repeated for the Keokuk station (293), using the 14-year concentration-duration curve with a flow-duration curve for these 14 years of record and a flow-duration curve for the 102 years of record at that station. The average annual water discharge for the 14-year period is 16 percent higher than that of the 102-year period. This produces a significant difference in annual load estimates. When the annual load regression equation for Keokuk was evaluated for each of the discharges, the annual load based on the 14-year discharge was 48 percent higher than the load based on the 102-year discharge. Sediment loads computed with the 14-year flow-duration curve were 13 to 28 percent higher than those computed with the 102-year flow-duration curve. Flow-duration curves based on the longest available record will more accurately reflect average conditions. Consequently the average annual sediment load based on the 102-year flow-duration curve at Keokuk is a better estimate of the long-term average annual sediment load than the one based on the 14-year curve.

Multiple Regression Analyses: Phase I

Multiple regression analysis was used to develop a statistically valid model which could easily predict long-term average annual sediment loads using the geomorphic and hydraulic parameters described earlier in this report. The multiple regression analysis was completed in two phases:

1) Selection of the most statistically significant geomorphic and hydraulic parameters.

Table 16. Average Annual Sediment Load Estimates
Obtained by the Two Flow-Duration Methods

STATION CODE	PERIOD OF RECORD: FLOW DURATION	PERIOD OF RECORD: CONCENTRATION DURATION	AVERAGE ANNUAL WATER DISCHARGE (CFS)	AVERAGE ANNUAL SEDIMENT LOAD (TONS): MEASURED	AVERAGE ANNUAL SEDIMENT LOAD (TONS): FLOW-DURATION SEDIMENT-RATING CURVE METHOD	AVERAGE ANNUAL SEDIMENT LOAD (TONS): SEDIMENT-DURATION METHOD
191	14	14	48,498	4,180,078	3,346,540	4,316,125
292	15	15	82,684	11,378,882	12,101,837	13,447,695
293	14	14	72,710	10,898,743	7,112,144	10,837,945
	102	14	62,640	NOT AVAILABLE	5,549,989	9,555,335

2) Application of these parameters to define multiple regression equations for the sediment yield areas. Phase one will be discussed in this section, while the second phase will be discussed in the regional analyses section.

All multiple regression computations were performed with the Statistical Analysis System (SAS), version FF, which was developed by and leased from SAS Institute, Inc. (1982a, 1983), for use on the University of Illinois' IBM 4341.

Several requirements had to be met in order to select a unique group of geomorphic and hydraulic parameters which yield a statistical model with the best predictive capability. The model had to be easy to use and had to include a reasonable number of parameters which are simple to obtain. Statistics require that the number of data points used to define a model must be greater than the number of parameters used in the analysis. Furthermore, since the goal of this analysis was to produce a predictive model, the correlation coefficient for the model had to be maximized and the standard estimate of error minimized, if possible.

During the analysis of individual station regressions, equation 8 was developed to describe an exponential relationship between sediment load and water discharge. Estimates of sediment load could be improved by including several variables in a similar multiplicative relationship. This technique was used to define the statistical model for estimating average annual sediment load as:

$$Q_s = b(\alpha_1)^{C_1} (\alpha\ )^{C_2} (\alpha_3)^{C_3} \ldots (\alpha_n)^{C_n} \tag{16}$$

where b and C_1 through C_n are constants, and α_1 through α_n represent geomorphic and hydraulic parameters determined by the multiple regression analysis.

The entire study area was treated as a unit to select some of the 28 geomorphic and hydraulic geometry parameters which best describe the average annual sediment load. This process began by comparing all possible combinations of parameters for 63 stations and selecting those parameters which yielded the highest correlation coefficient for each N-parameter model. The SAS Maximum R^2 procedure (SAS Institute Inc., 1982b) was used to evaluate these combinations of parameters.

Additional insight into the relative importance of the parameters was obtained from a complete cross-correlation analysis of the logarithms of the parameters as in equation 17.

$$\log (Q_s) = C_0 + C_1 \log(\alpha_1) + C_2 \log(\alpha_2) + \ldots C_n \log (\alpha_n) \tag{17}$$

where $C_0 = \log b$, and the other terms are as defined for equation 16.

Table 17 shows the correlation between each of the parameters and the average annual sediment load. The parameters are ranked by absolute value of the correlation coefficient. The complete cross-correlation table is in appendix I.

Table 17. Correlation of Parameters with Average Annual Sediment Load

RANK	PARAMETER	CORRELATION COEFFICIENT
1	LU	0.82521
2	LS	0.82081
3	DA	0.80531
4	PRECIPV	0.80195
5	LB	0.79768
6	NU	0.78182
7	AQW	0.77810
8	SO	0.71694
9	DS	0.70212
10	WS	0.65755
11	I	0.55294
12	EROS	-0.46548
13	RR	-0.45868
14	HA	0.42172
15	QWDA	-0.42096
16	H	0.33939
17	CR1	-0.30881
18	VS	0.29873
19	SS	0.26364
20	TDK	0.23520
21	PREGIP	-0.21088
22	L	0.15872
23	CR2	0.10598
24	F	-0.06310
25	PROD	0.06050
26	DD	0.05679
27	BS	0.04576
28	CR3	-0.01213

Inspection of table 17 and appendix I leads to the following observations on the relationships between some of the parameters. Only 7 parameters have correlation coefficients greater than 0.75 with the average annual sediment load. Several have low correlations with all other parameters (appendix I). The classic stream order parameters U, IC, NU, LU, LA, DD, F, LS, and SS are measured or counted on maps, and uncertainties arise because not all of Illinois has been mapped at a scale of 1/24,000 and older, smaller 1/62,500 or 1/63,360 scale maps must be used for portions of river basins. Three hydraulic geometry parameters (DS, WS, and VS) are obtained from regional equations given by Stall and Fok (1968). Thus these parameters are derived as functions of drainage area and are not measured for each station. Further inspection of the first 7 parameters finds three length terms: LU, total stream length; LS, main stem length; and LB, basin length. The main stem length is less affected by map scale than LU, and is probably the best length to use in the multiple regression analysis. All three length parameters are highly correlated with each other and with drainage area. In fact, one can question why LU and LS give higher correlation coefficients than DA. Both of these length parameters are highly correlated with drainage area and add somewhat to the relation between drainage area and sediment yield. Greater stream length for the same area provides greater opportunity for sediment to enter the stream system. The annual precipitation volume and the water discharge volume are both highly correlated with the drainage area. In fact, PRECIPV is equal to PRECIP times DA.

On the basis of this discussion, the final parameter choices might be DA and LS. However, rational analysis suggests that a parameter related to slope or elevation difference should be included. Main stem slope was not readily available, and any slope parameter will have shortcomings. A recent paper by Zecharias and Brutsaert (1985) discussed the problem of selecting a slope factor and proposed a new parameter for slope. Additional data are needed to compute their slope parameter. From the parameters determined here, the ratio of total relief, H, to basin length, LB, or relief ratio, RR, was chosen. Thus the final set of parameters to be used in Phase II of the multiple regression analysis is DA, LS, and RR, which is equivalent to DA, LS, H, and LB.

Data for the first phase of the multiple regression analysis included many geomorphic and hydraulic parameters (see appendix A) defined for each of 63 suitable sediment monitoring stations. The Illinois and Mississippi River main stem stations, in addition to Pope Creek at Keithsburg (127), Embarras River at Ste. Marie (362), Crab Orchard Creek near Marion (374), and the Big Creek stations at St. David (238) and near Bryant (239), were excluded from the multiple regression study because their sediment loads were not consistent with those of nearby stations. These will be discussed at greater length in the section on regional analyses. Stations where long-term average annual sediment loads could not be determined by the flow-duration method were also excluded. The lake stations were not included in this phase of the multiple regression analysis, because the hydraulic geometry parameters could not be determined.

REGIONAL ANALYSES

Methods of Regionalization

One of the primary objectives of this study was to identify and evaluate methods for estimating sediment loads at gaging stations with an historical sediment record. This was done in earlier sections of this report. The usefulness of this type of information is limited unless it can be transferred to other gaged or ungaged sites along a stream. A second primary objective was to expand the usefulness of the results by regionalization of the data in which areas with similar characteristics are related to one another by a simple relationship or single equation.

Four characteristics were considered for possible use in regionalizing the data. These included major river basin boundaries (see figure

1), the physiographic divisions developed by Leighton et al. (1948) (see figure 2), the Land Resource Areas (LRAs) (UMRCBS, 1970) (see figure 3), and the mean annual precipitation for the period 1951-1980 (see figure 4).

Examination of the precipitation factor failed to yield a positive relationship that could possibly be used to regionalize the data. This result was expected since precipitation was not identified by the multiple regression analysis as a significant factor in predicting sediment load.

One additional factor was developed in an attempt to establish some regionalization of the data. This factor was termed the unit area flood flow value and was equal to the ratio between the 10 percent flow duration value (the discharge value which is equaled or exceeded 10 percent of the time) and the drainage area for each station. The results of this analysis failed to reflect any pattern of regionalization. River basin boundaries, physiographic divisions, and LRAs along with the average annual sediment loads are used to derive a regional division of Illinois for instream sediment load calculation.

A review of the entire 85-station data set identified several stations which could not be included in the regional analysis. The five stations on the Mississippi and Illinois Rivers were excluded. Twelve stations (108, 109, 114, 116, 203, 204, 240, 244, 252, 356, 369, 444) did not have sufficient data or a valid flow-duration table to determine the long-term average annual sediment loads. Five stations were identified as anomalous: Pope Creek near Keithsburg (127) had one year of data with an extremely high sediment yield that is not representative of average conditions; two stations on Big Creek in Fulton County (238, 239) are in a sludge disposal study area and do not represent natural erosion and sediment transport; station 374 (Crab Orchard Creek near Marion) is in backwater from Crab Orchard Lake; and station 362 (Embarras River at Ste. Marie) has a sediment load which is inconsistent with that of other nearby stations, possibly because of site-specific activities in the watershed. Additional years of sediment data would probably allow the inclusion of some of these stations in the regional data base. This inspection of the data set yielded 63 stream stations and 24 lake stations for use in the regional analyses.

Land Resource Areas

The Upper Mississippi River Comprehensive Basin Study (1970) identified nine LRAs in Illinois (see figure 3). These LRAs were grouped into five sediment yield classes. Regression equations relating sediment yield (tons/square mile/year) to drainage area were developed for each class on the basis of the available sediment data and the assumption that all of the equations should have the same slope (-0.12). Figure 33 shows the plots of those five regression lines.

Nearly all of the sediment data for Illinois that were used by the UMRCBS to develop the regression relationships were lake sedimentation data. One question that arises from this is whether or not the previously derived equations accurately reflect the currently available instream sedi-

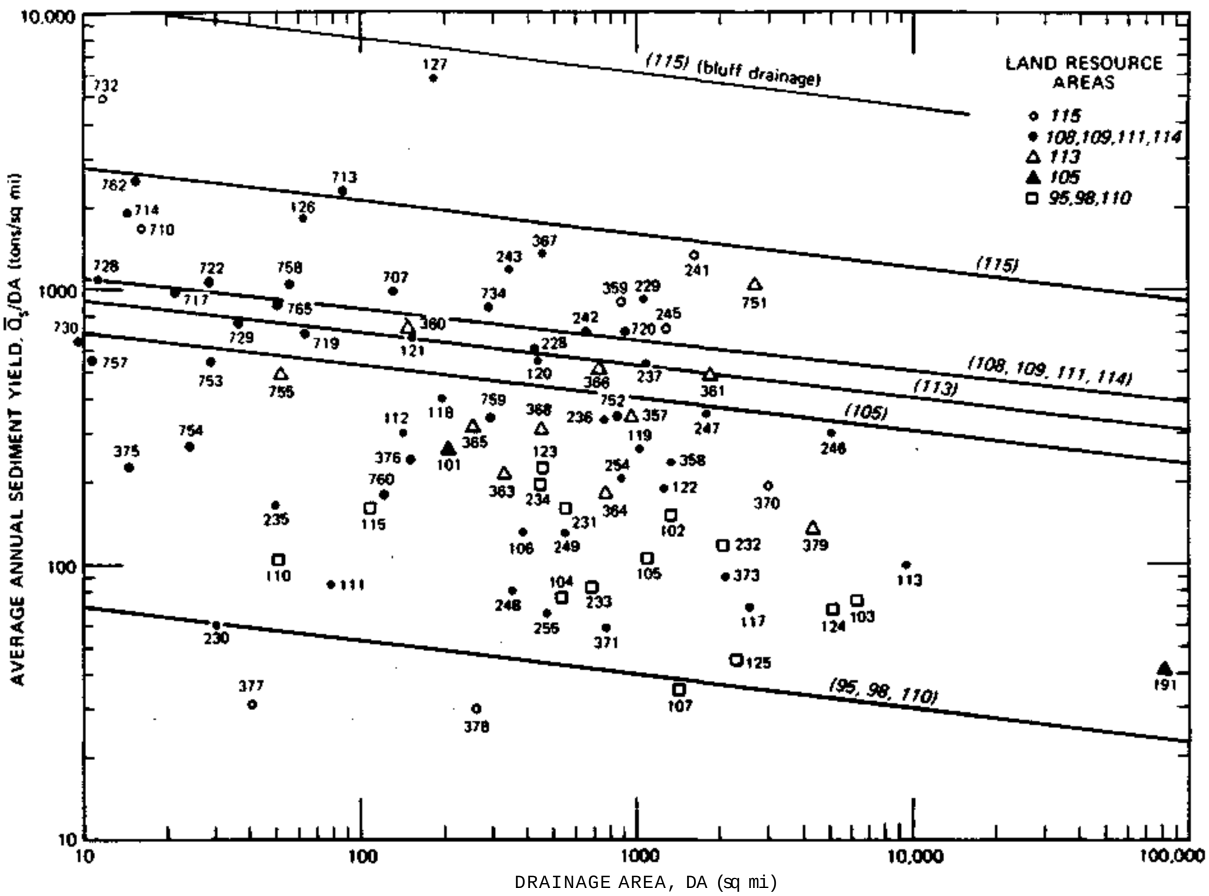


Figure 33. Average annual sediment yield versu8 drainage area for lake and suspended sediment monitoring stations in Illinois (after UMRCBS, 1970)

merit data. In order to evaluate this question, the average annual sediment yield versus drainage area for all tributary sediment stations within the LRA boundary areas for Illinois were plotted on figure 33. The number next to each data point is the station code for each station. The various symbols indicate the LRA in which the station is found. Also plotted on this figure are data points from 24 lakes with station codes in the 700s as listed in table 4.

It is difficult to decipher very much from this cluttered figure; therefore figures 34 through 38 were developed to represent the results for each of the five categories of LRAs. In these figures the original LRA regression lines are indicated by the dashed lines. It appears in figures 34 and 35 that the currently available data are not well represented by the original regression equations. This also seems to be true for figures 36,

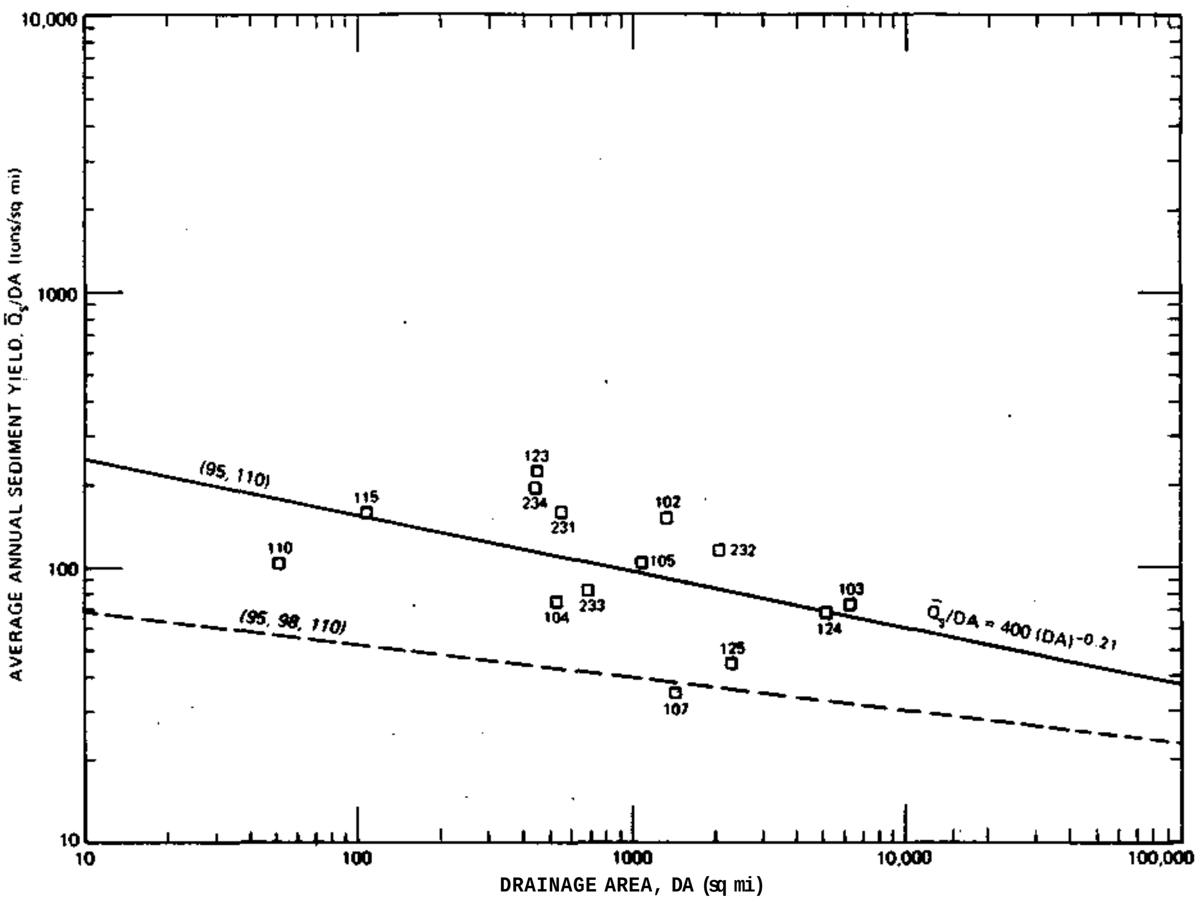


Figure 34. Average annual sediment yield versus drainage area for Land Resource Areas 95, 98, 110 in Illinois

37, and 38 although the results for these regions are less obvious because of the limited number of data points associated with each of these curves.

Close examination of the data points in figure 34 suggests some degree of linearity for LRAs 95, 110. (Although the original report includes LRA 98 in this class, this LRA does not occur in Illinois and thus is not included in the analysis.) A least-squares regression line was developed for these data and is indicated by the solid line in figure 34. The equation for this line is defined as follows:

$$Q_s/DA = 400\ (DA)^{-0.21} \tag{18}$$

where Q_s is the average annual sediment load in tons, and DA is the drainage area in square miles. The correlation coefficient for this equation is -0.51. The slope of the line is -0.21.

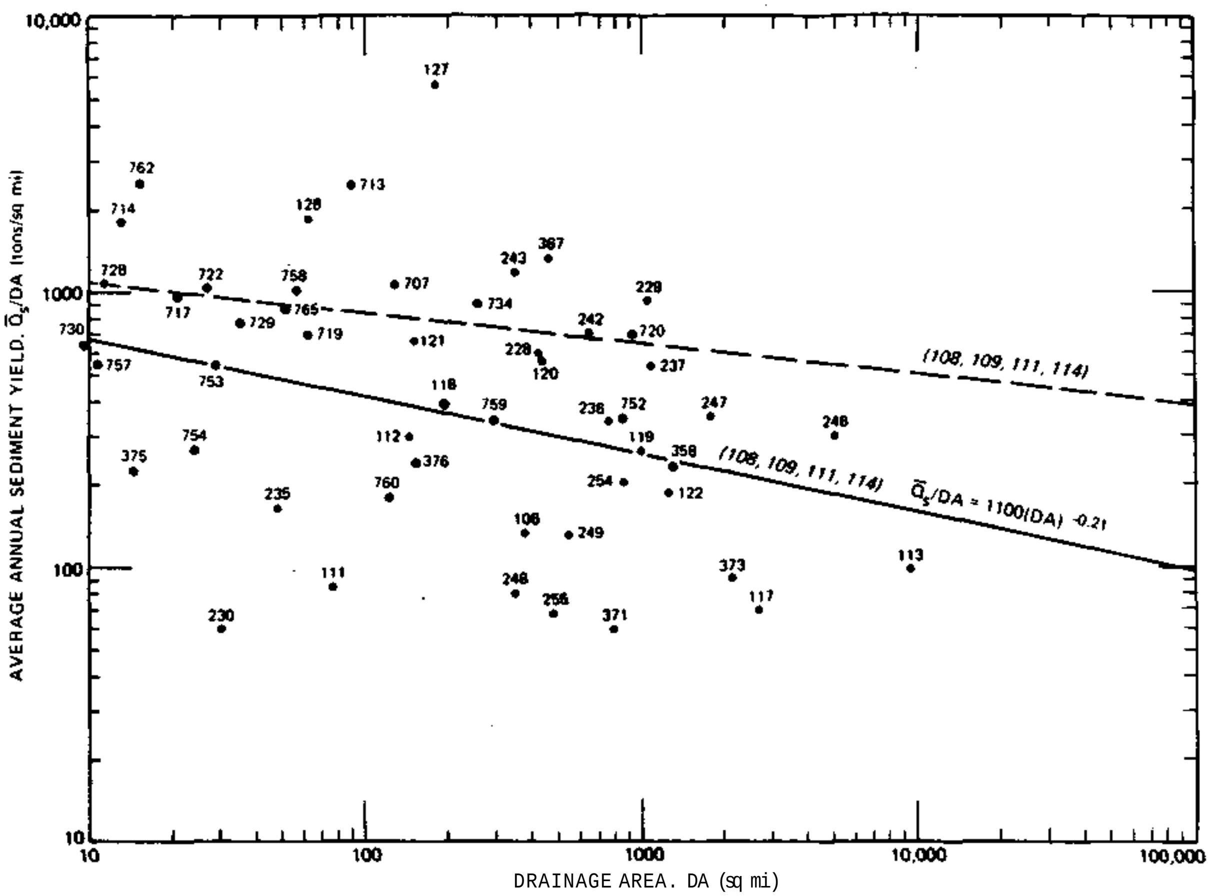


Figure 35. Average annual sediment yield versus drainage area for Land Resource Areas 108, 109, 111, 114 in Illinois

An initial least-squares analysis on the data for each of the other four LRA classes produced the following slopes and correlation coefficients. For the class which includes LRAs 108, 109, 111, and 114, the slope is -0.25 and the correlation coefficient is 0.47. For LRA 105, the slope is -0.31 and the correlation coefficient is 1.00 because there are only 2 data points in the region. LRA 113 has 11 data points; the regression slope is -0.10 and the correlation coefficient is 0.24. LRA 115 has 8 data points, and the regression slope is -0.11 and the correlation coefficient is 0.16. These regression equations could be used, but since this is a revision of a previous analysis, we chose to select a common slope for all classes of LRAs.

It appears that a slope of -0.21, based on the results for LRAs 95, 110 (figure 34), is the best choice for redefining the slope of the regression equations for the remaining four LRA categories. This decision was

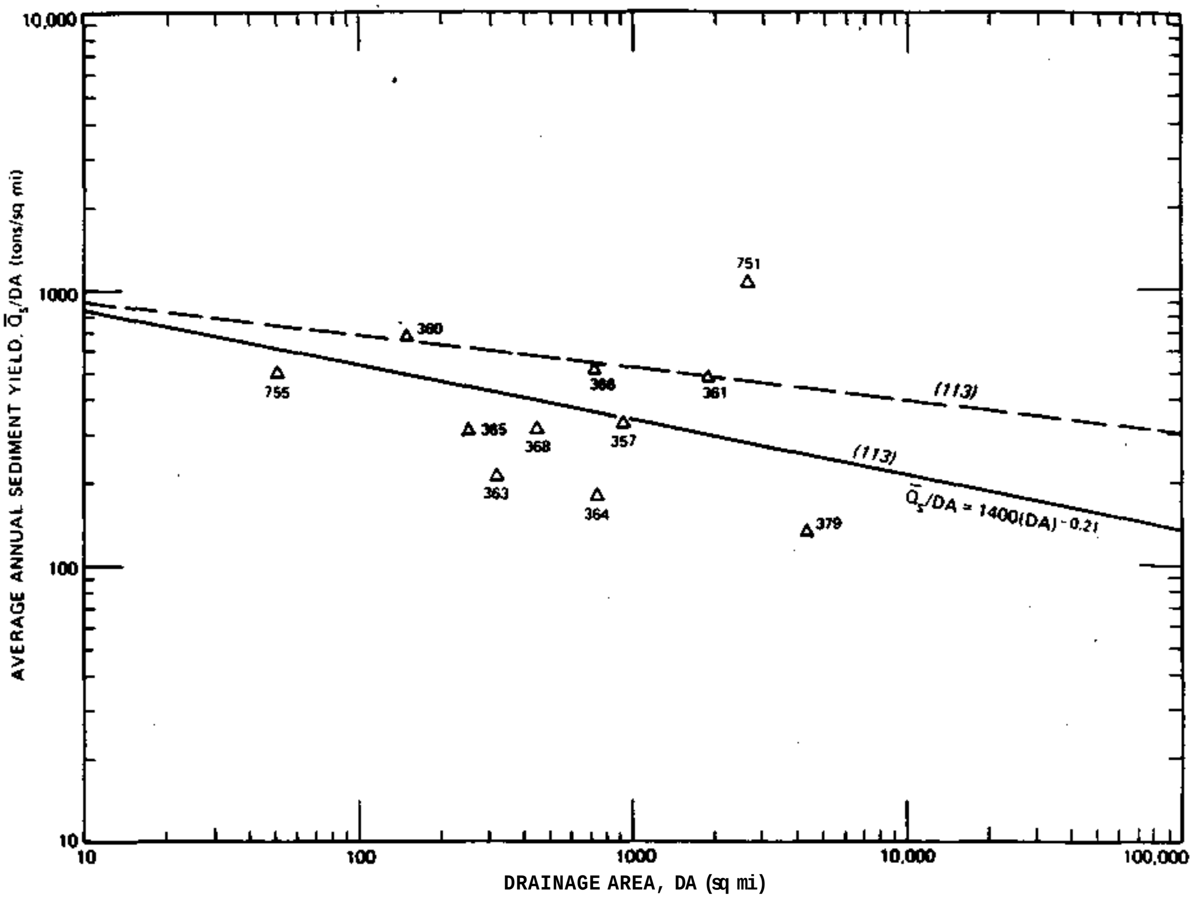


Figure 36. Average annual sediment yield versus drainage area for Land Resource Area 113 in Illinois

based on four facts: 1) the results for LRAs 115 and 105 are inconclusive due to the small size of the data sets; 2) the correlation coefficient for LRAs 95, 110 was higher than for LRAs 108, 109, 111, 114; 3) the standard error of the estimate for LRAs 95, 110 (0.21595) was much less than that for LRAs 108, 109, 111, 114 (0.3051); and 4) the new slope of -0.21 is close to the average slope for all LRA groups.

After the new slope for the five LRA classes was defined, it was necessary to compute the linear regression equation for each class so that the equations would result in parallel lines. These new equations and lines are shown in figures 34 through 38 (solid lines). The regression equation parameters and statistics are listed in table 18. The coefficients in figures 34 to 38 have been rounded to two significant figures, while table 18 gives the coefficient as obtained from the SAS procedure.

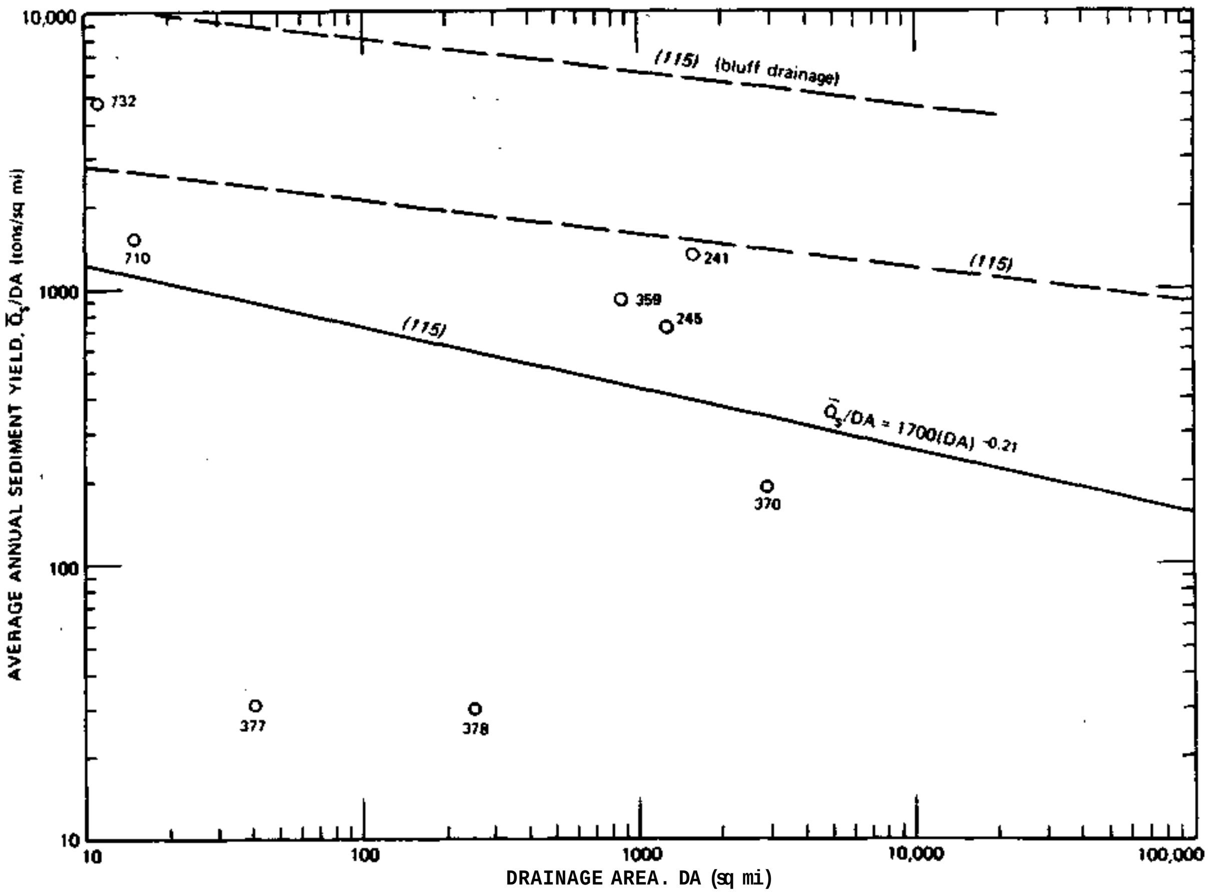


Figure 37. Average annual sediment yield versus drainage area for Land Resource Area 115 in Illinois

These redefined regression equations for the LRAs within Illinois will probably generate a better estimate of the average annual sediment yield than the equations developed by the UMRCBS for streams in Illinois.

There are several reasons why the additional data may have changed the slopes of the regression lines for the LRA classes. The original LRA analysis depended more on lake sedimentation data and the stream data were adjusted to include bed load. The recent instream data include suspended sediment load only. However, it does not appear from figures 34 - 38 that adding bed load to the instream data would significantly change the results. Also some of the boundaries between LRAs 111 and 113 have been modified on the basis of the sediment yield data.

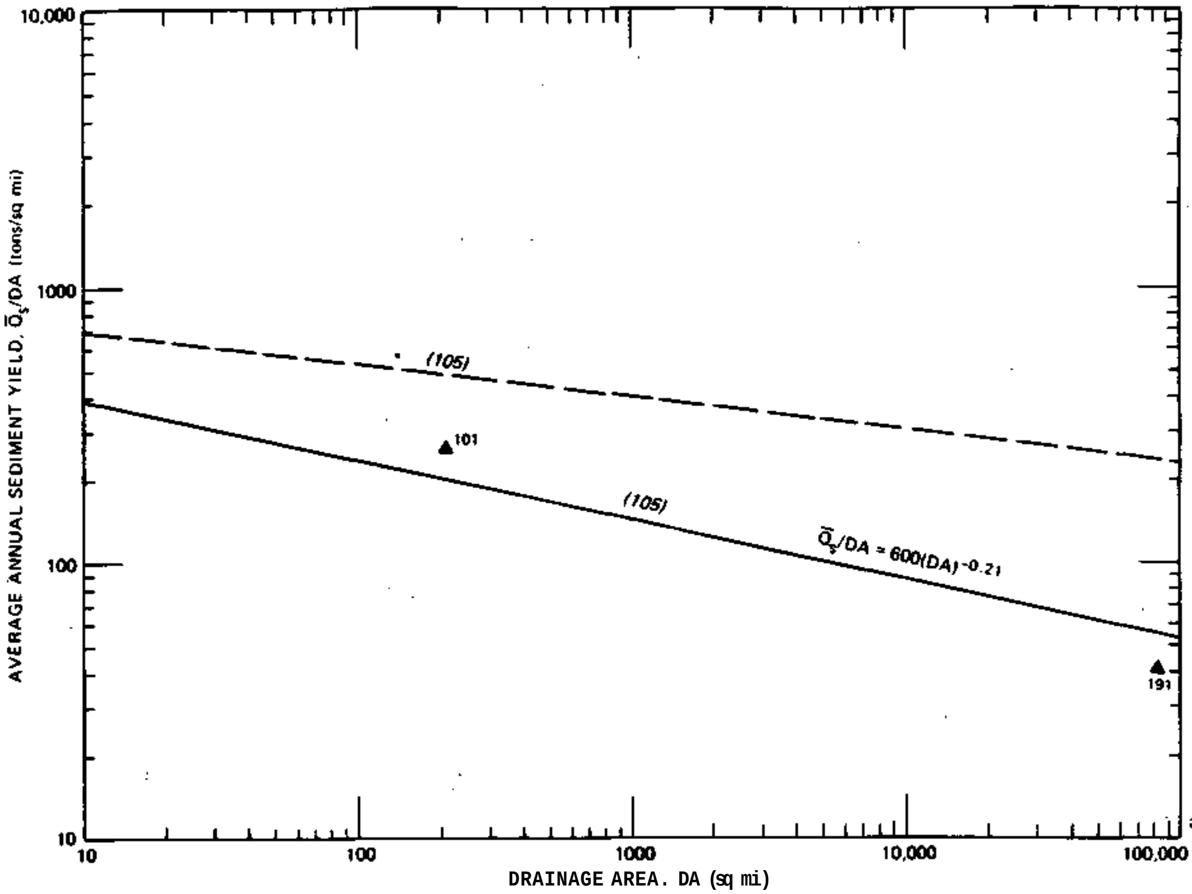


Figure 38. Average annual sediment yield versus drainage area for Land Resource Area 105 in Illinois

Table 18. Revised Land Resource Area Regression Statistics

LRA REGIONS	SAMPLE SIZE	COEFFICIENT	SLOPE	ROOT MEAN SO. ERROR	CORRELATION COEFFICIENT
95,110	14	401	-0.21	0.205406	0.51
105	2	594	-0.21	0.182648	0.95
108,109, 111,114	53	1111	-0.21	0.377513	0.46
113	11	1389	-0.21	0.246784	0.04
115	8	1734	-0.21	0.655322	0.07

Sediment Yield Areas

Regionalizing the sediment yield data on the basis of the previously defined LRAs had its limitations. Since the LRAs were a given, the larger set of sediment yield data was forced to fit within those predetermined boundaries. The question is whether or not the sediment yield data for Illinois can be grouped in a way that improves upon the relationships developed using the LRA boundaries.

Sediment Yield Area Determination

The sediment yield data in tons/square mile/year were plotted on a state map. Other maps of statewide data were also used. These included landforms of Illinois (State Geological Survey), major watershed boundaries (figure 1), physiographic divisions (figure 2), LRA boundaries (figure 3), glacial features, terrain divisions, erosion potential, soil productivity index, and annual precipitation. Sediment load was plotted as a function of drainage area on log-log graphs and the plots were examined for groupings of data.

Watershed boundaries, physiographic divisions, and sediment load variations were most useful. Terrain classes and the landform and glacial maps were also helpful but tended to support the physiographic division boundaries. A balance also had to be made between forming many small regions with few data, forming a few large regions, and the requirement for a minimum amount of data in each region for multiple regression analysis. An earlier regionalization (Adams et al., 1984) divided the state into six regions called Sediment Yield Areas (SYAs). The addition of more data from the southeastern third of the state and a desire to follow geomorphic boundaries where possible led to a redrawing of the SYA boundaries to form 11 regions. The quality of fit of the regression equations between annual average sediment load and drainage area was also considered in the location of SYA boundaries. The 11 SYAs are shown in figure 39. The DesPlaines and Chicago River basins are excluded because the rate and extent of urbanization has caused changing flow duration conditions and unstable sediment loads.

Watershed boundaries make up the largest portion of the SYA boundaries, including all of the SYA 1-3 boundary; all of the boundary between SYA 7 and SYAs 11, 8, 6, and 2; all the excluded area in SYA 9; most of the boundaries between SYAs 2 and 10; and parts of several other boundaries. The Illinois River divides SYA 2 from SYA 9, and SYA 3 from SYAs 4 and 5. The last of these segments also corresponds to a physiographic division. Physiographic boundaries also divide SYAs 4 and 8 and form parts of the SYA 6-10 and 8-11 boundaries. The east-west portion of the SYA 8-11 boundary follows a landform boundary, as does part of the SYA 6-10 boundary. The portion of the SYA 4-6 boundary paralleling the. Illinois River follows an LRA boundary. Sediment load data were used to locate the remaining boundaries. The longest of these are between SYAs 4-6, 1-9, 7-10, 2-5, 2-10, and 5-10.

In the earlier analysis (Adams et al., 1984), a single slope was fitted to the SYA regressions between annual sediment load and drainage

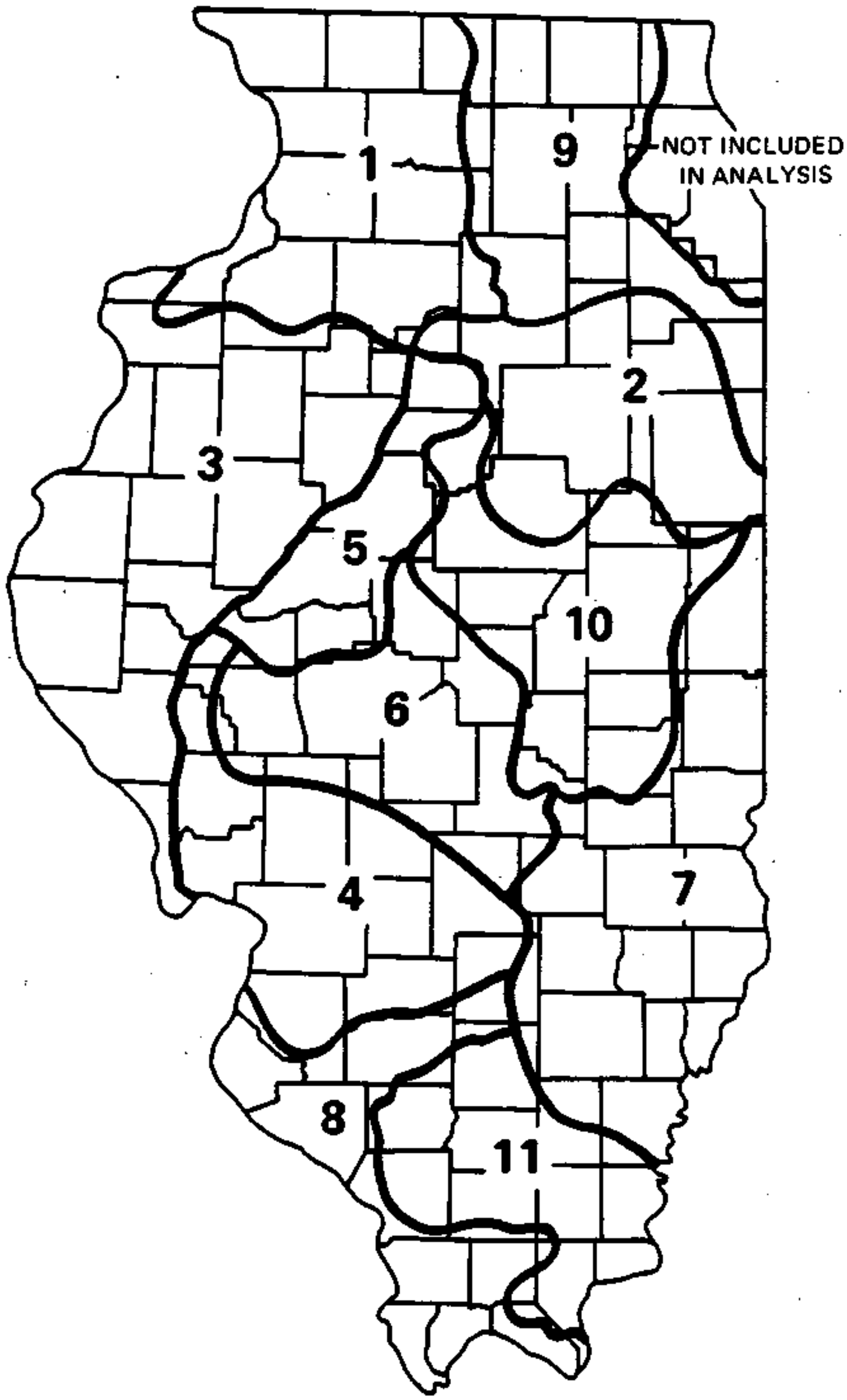


Figure 39. Sediment Held Areas in Illinois

area. The same could have been done here, but consideration that the slope of the regression equation is in effect a "delivery ratio" parameter suggests that this may vary between regions just as the sediment load from a unit area (the regression coefficient) varies.

The data points and regression lines for the entire state are shown in figures 40 (SYAs 1, 2, 3, 4), 41 (SYAs 5,6) and 42 (SYAs 7,8,9,10,11). The coefficients, exponents, root-mean-square errors, and correlation coefficients are given in table 19. Correlation coefficients are all over 0.86, which is much improved over the LRA correlations in table 18. Because of the variable slopes, line's do cross, as may be seen in figure 41. For 10 square miles, the average annual sediment loads are 8313 tons for SYA 5 and 9861 tons for SYA 6. For 1000 square miles the sediment loads are 383,500 tons/year for SYA 5 and 280,500 tons/year for SYA 6. Expressed as tons/year/square mile, these loads are 831 and 986 for 10 square miles and 384 and 281 for 1000 square miles for SYAs 5 and 6, respectively. For SYA 5 the delivery ratios are 60 percent at 10 square miles and 31 percent at 1000 square miles. For SYA 6 the delivery ratios are 53 percent at 10 square miles and 15 percent at 1000 square miles.

The highest sediment loads are in SYAs 3 and 4 and the lowest sediment loads are in SYAs 9, 10, and 11. Where data for instream sediment or lake sedimentation are available near the site at which one needs to know the sediment load, the nearby data are most useful. However, in much of Illinois, these regional equations and lines will be the best estimate of average annual sediment loads. The watershed areas range from 8 to nearly 10,000 square miles and the equations should be used outside of this range only with extreme caution.

Multiple Regression Analyses: Phase II

Phase I of the multiple regression analysis produced a set of three parameters (or four, if its components are used instead of the relief ratio) that could be used to determine multiple regression equations for average annual sediment loads. Selection of the 11 SYAs and determination of the number of data points in each region were necessary before initiating the Phase II analysis. Though more complex, requiring three additional parameters and considerably more computation, multiple regression methods are expected to improve the correlation and reduce the model error.

After the final set of parameters was selected by careful analysis of the Phase I statewide correlation analysis, they were combined with the SYAs to develop regional models for each of the selected regions. The general form of the regional model is:

$$\log(AASL) = C_0 + C_1 \log(DA) + C_2 \log(LS) + C_3 \log(H/LB) \quad (19)$$

where AASL is the average annual sediment load in tons, DA is the drainage area in square miles, LS is the main stem length in miles, H is the total basin relief in feet, LB is the basin length in miles, and C_0 through C_3 are the multiple regression coefficients. The quotient H/LB is the relief ratio (RR), which is an indicator of basin slope.

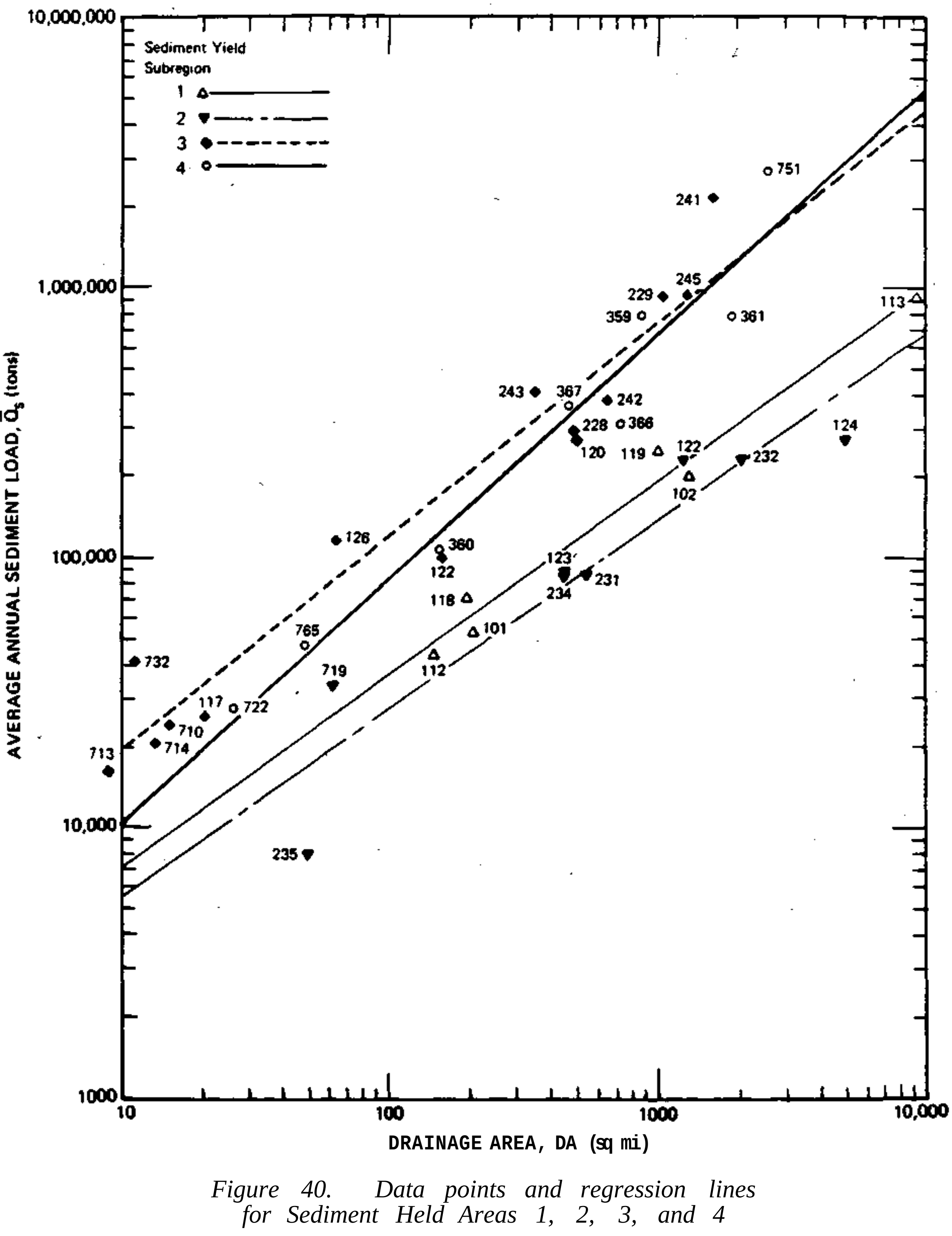


Figure 40. Data points and regression lines for Sediment Held Areas 1, 2, 3, and 4

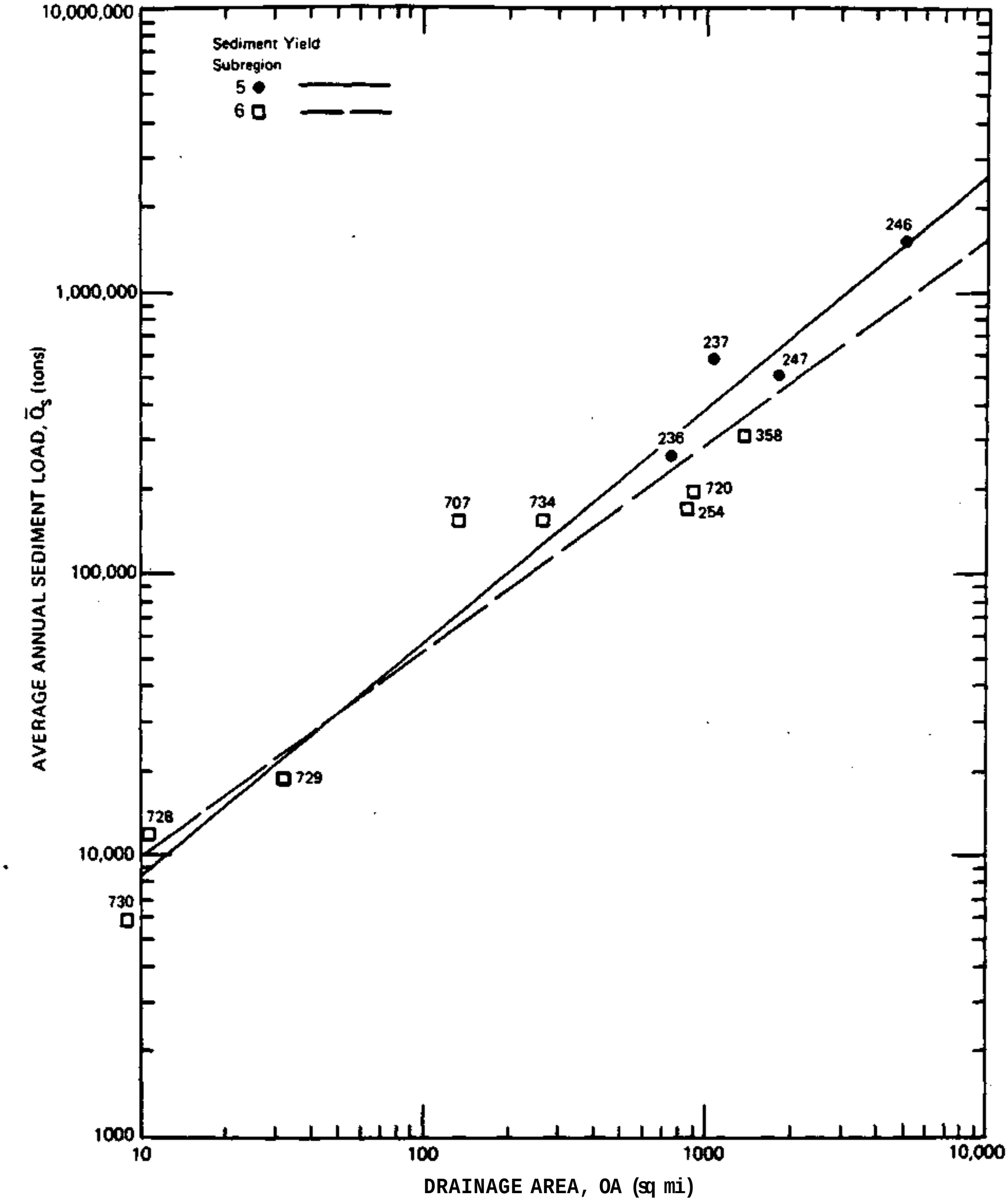


Figure 41. Data points and regression lines for Sediment Yield Areas 5 and 6

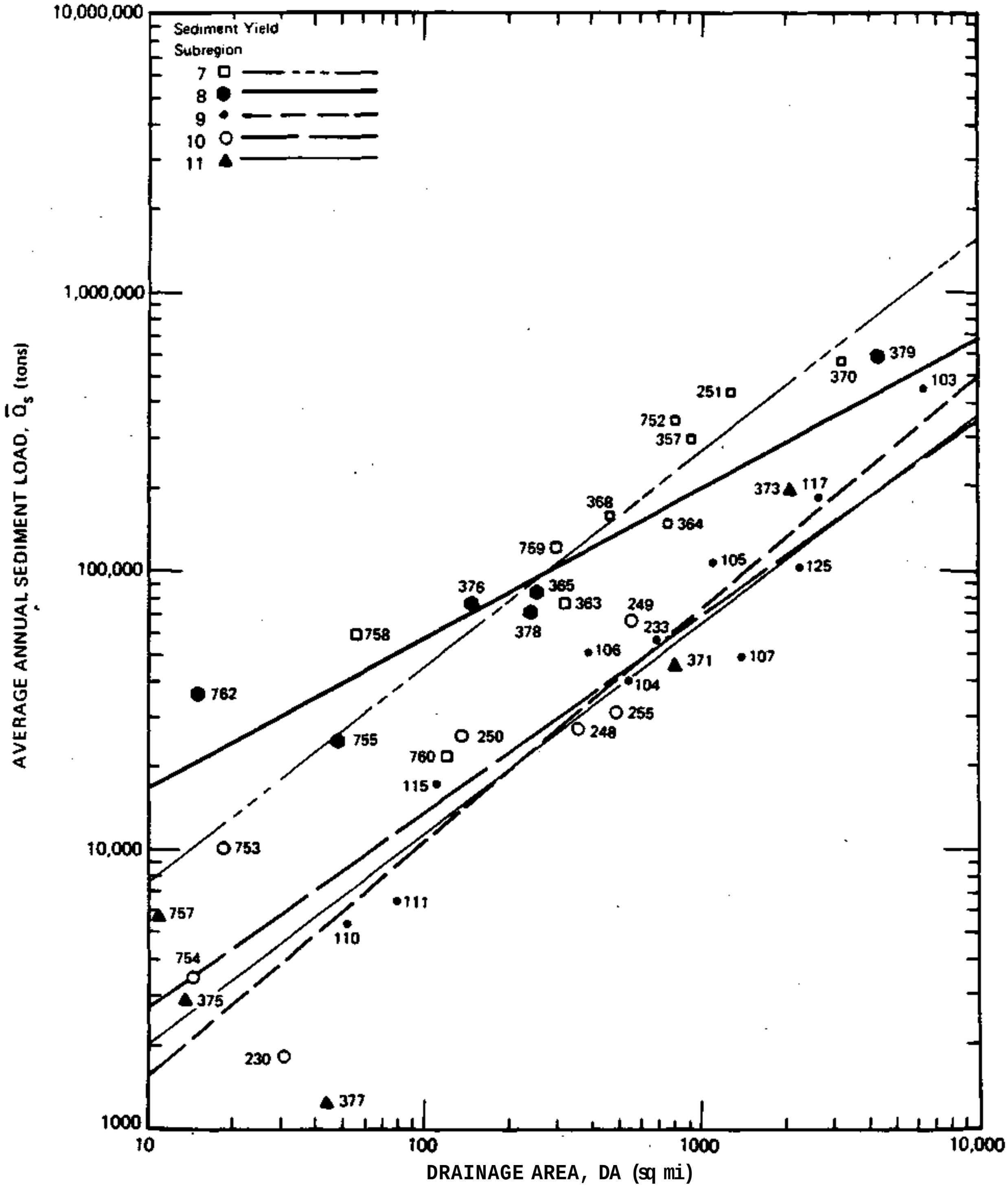


Figure 42. Data points and regression lines for Sediment Yield Areas 7, 8, 9, 10, and 11

Table 19. Sediment Yield Area Regression Statistics

SYA REGIONS	SAMPLE SIZE	COEFFICIENT	SLOPE	ROOT MEAN SO. ERROR	CORRELATION COEFFICIENT
1	6	1415	0.712	0.00828	0.987
2	8	1139	0.694	0.03736	0.938
3	14	3065	0.795	0.03066	0.970
4	8	1344	0.900	0.02519	0.976
5	4	1224	0.832	0.02018	0.931
6	8	1849	0.727	0.04412	0.956
7	10	1302	0.773	0.04369	0.893
8	6	4895	0.537	0.03401	0.938
9	11	236	0.832	0.02602	0.965
10	7	546	0.703	0.09928	0.860
11	5	366	0.753	0.23720	0.883

The Phase II multiple regression analysis used data for long-term average annual sediment load and the four geomorphic parameters in equation 19 at each of 63 instream sediment monitoring stations and 24 lakes with lake sedimentation data within Illinois. The 11 Sediment Yield Areas" (SYAs) were developed by using the results of the linear regression analysis and other information describing watersheds in Illinois. This process and the SYAs are discussed in detail in the section on SYA boundary determination. The regression coefficients and RMS errors for the logarithmic model of equation 19 are given in table 20 along with the correlation coefficient for each SYA. The lowest correlation coefficient is 0.885 for SYA 10. For SYA 5, the correlation coefficient is 1.00 and the RMS error is 0.0 because there are just 4 data points to define a 4-variable model. Except for SYA 2 the correlation coefficient is higher for the multiple regression model than for the 1-variable model. The RMS errors are similar for the 1- and 4-variable models, probably because the spread of the input data is the same and is not changed by the method of obtaining the model equation. Thus equation 19 and the coefficients in table 20 will accurately estimate the long-term average annual sediment load in Illinois streams with drainage areas greater than 8 square miles.

If LS is not known, LU may be used in its place in equation 19. It might seem that LB could also be used, but since it is already in the relief ratio, it cannot be used again without introducing spurious correlation into the results. Also, if DA is not known, but AQWV or PRECIPV is known, either of these may be used in place of DA in equation 19 with little loss in accuracy. Long-term averages are best for both of these parameters. Although individual storm precipitation is closely related to the amount of sediment transported during an event, the annual precipitation is not well correlated with annual sediment loads.

The application of the multiple regression model will be demonstrated in the section on recommended techniques, and its results will be compared

Table 20. Multiple Regression Coefficients for Equation 19

SYA	SAMPLE SIZE	C_o	C_1	C_2	C_3	ROOT MEAN SQ. ERROR	CORRELATION COEFFICIENT
1	6	4.978	0.434	-0.169	-0.755	0.00085	0.999
2	8	3.085	0.702	-0.0269	-0.0109	0.05598	0.938
3	14	2.670	0.781	0.231	0.474	0.02939	0.976
4	8	3.103	0.869	0.0556	0.0137	0.03776	0.976
5	4	2.527	-0.581	2.210	0.690	0.00000	1.00
6	8	3.645	0.761	-0.186	-0.210	0.06309	0.958
7	10	4.187	1.990	-2.353	-0.363	0.02179	0.962
8	6	2.332	1.448	-0.906	0.629	0.01143	0.990
9	11	1.362	0.902	0.251	0.506	0.02238	0.977
10	7	2.401	-0.953	2.455	0.520	0.13776	0.885
11	5	4.970	1.740	-2.369	-1.138	0.04817	0.993

with those of the linear model. Because of the additional parameters, the multiple regression model can be used only for specific locations or if specified values of the parameters are given.

RECOMMENDED TECHNIQUES

The generalized analyses performed in the last section are the bases for the recommendations made in this section. Readers must be cautioned that the analyses in this report were performed on the available data, which in most cases extended for only a 2-year period. Even though the data base was quite short, a technique was developed which will be useful for determining sediment loads in streams within Illinois.

The recommended techniques are presented in two sections. The first section discusses three techniques which were developed for the tributary streams within the study area, which flow into the Mississippi and Illinois Rivers. The second section discusses regression equations which were developed for the main stems of the Mississippi and Illinois Rivers.

Tributary Streams

Three techniques are given for tributary streams and are listed in order of preference: 1) Sediment Yield Area regional equations, 2) SYA multiple regression regional equations, and 3) Land Resource Area revised equations.

The new regional division of Illinois into Sediment Yield Areas is an improvement over the Land Resource Area regionalization for determination of instream sediment loads. Thus the SYA methods are recommended for general use in the study area. Because the drainage area is generally available or can easily be measured, the SYA linear regression method is recommended for use. The SYA multiple regression method may be used if the additional geomorphic parameters are available or can be measured or estimated. The revised LRA equations are given as an alternate method and for those who prefer to use a familiar method.

Sediment Yield Area Regional Equations

The state was divided into 11 regions (figure 39) and equations were developed to relate average annual sediment load to drainage area in each region.

The general form of these equations is

$$\bar{Q}_s = a\ DA^m \tag{20}$$

where $\bar{Q}_s$ is the average annual sediment load in tons, DA is the drainage area in square miles, m is the slope of the regression equation, and a is the coefficient. The following regression equations should be used to estimate the average annual instream sediment load of tributary streams. For the SYA regional delineation, refer to figure 39.

SYA Region 1

$$\bar{Q}_s = 1400\ DA^{0.71} \tag{21}$$

SYA Region 2

$$\bar{Q}_s = 1100\ DA^{0.69} \tag{22}$$

SYA Region 3

$$\bar{Q}_s = 3100\ DA^{0.80} \tag{23}$$

SYA Region 4

$$\bar{Q}_s = 1300\ DA^{0.90} \tag{24}$$

SYA Region 5

$$\bar{Q}_s = 1200\ DA^{0.83} \tag{25}$$

SYA Region 6

$$\bar{Q}_s = 1800\ DA^{0.73} \tag{26}$$

SYA Region 7

$$\bar{Q}_s = 1300\ DA^{0.77} \tag{27}$$

SYA Region 8

$$\bar{Q}_s = 4900\ DA^{0.54} \tag{28}$$

SYA Region 9

$$\bar{Q}_s = 240\ DA^{0.83} \tag{29}$$

SYA Region 10

$$\bar{Q}_s = 550\ DA^{0.70} \qquad (30)$$

SYA Region 11

$$\bar{Q}_s = 360\ DA^{0.75} \qquad (31)$$

The coefficients and exponents have been rounded to two significant figures, which corresponds to the confidence in the accuracy of the input data. More precise values for a (coefficient) and m (slope) are given in table 19.

The procedure for the use of these equations is:

Step 1. Locate the stream segment on a topographic map. Identify the SYA region from figure 39.

Step 2. Outline the drainage basin. Review the publication by Ogata (1975) to determine if the drainage area at the designated stream section has already been determined. Otherwise, measure the drainage area by using a planimeter or a digitizer.

Step 3. The drainage area determined in Step 2 is substituted into the appropriate SYA equation for the region determined in Step 1 to compute the average annual sediment load at the given stream segment.

Example Problem. An example is presented here to demonstrate the use of these regional equations:

Determine the instream average annual sediment load of the Sangamon River at Riverton, which is located in the NE 1/4 of Section 16, Township 16N, Range 4W, in Sangamon County, Illinois.

Note that although the data for this station were tabulated, they were not used to calibrate any of the three methods derived for the tributary stations because there were not enough data to determine long-term flows or sediment loads.

1) The basin is located in SYA 6 (figure 39) and is identified by station code 252.

2) The drainage area is 2618 square miles and is given in appendix A.

3) The drainage area is substituted into the appropriate equation for the SYA region determined in Step 1 (equation 26), and the average annual sediment load is computed as follows:

$$\bar{Q}_s = 1800(DA)^{0.73} = 1800\ (2618)^{0.73}$$

$$\bar{Q}_s = 1800\ (312.69)$$

$$\bar{Q}_s = 5.63 \times 10^5 \text{ tons}$$

The average annual sediment load for the Sangamon River at Riverton is 563,000 tons. This method may be used to determine the average annual sediment load at any stream site where the drainage area is known.

SYA Multiple Regression Regional Equations

The second recommended technique for determining average annual sediment loads for tributary streams in the study area is the SYA multiple regression regional equation method. These equations were developed for the regions delineated in figure 39. The general form of the multiple regression equation is:

$$Q_s = b(DA)^{C_1} (LS)^{C_2} (RR)^{C_3} \qquad (32)$$

where Q_s is the average annual sediment load in tons, DA is the drainage area in square miles, LS is the main stream length in miles, and RR is the dimensionless relief ratio, H/LB. The coefficients (b, C_1, C_2, C_3) for each SYA can be found in table 21. The multiple regression equations may be used to estimate the instream sediment load at a location where the values of DA, LS, LB, and H are known or can be determined from available data or maps.

The procedure for use of these equations is:

Step 1. Locate the stream site on a topographic map. Identify the SYA from figure 39.

Step 2. Outline the drainage basin on the topographic map. Review the publication by Ogata (1975) to determine if the drainage area at the stream site has already been tabulated. Otherwise, measure the drainage area with a planimeter or digitizer.

Table 21. Multiple Regression Coefficients

SYA REGION	b	C_1	C_2	C_3
1	95,000	0.434	-0.169	-0.755
2	1,200	0.702	-0.027	-0.011
3	470	0.781	0.231	0.474
4	1,300	0.869	0.056	0.014
5	340	-0.581	2.210	0.690
6	4,400	0.761	-0.186	-0.210
7	15,000	1.990	-2.350	-0.363
8	210	1.450	-0.906	0.629
9	23	0.902	0.251	0.506
10	250	-0.953	2.450	0.520
11	93,400	1.740	-2.370	-1.140

Step 3. Determine the main stem length. Healy (1979a,b) has tabulated river miles for selected points on most Illinois streams, so check these references to see if the river mile for the site has been determined. If it has, the main stem length can be determined by subtraction from the tabulated values at the point of interest and the topographic divide.

Step 4. Determine the total relief from the topographic map. Total relief is the elevation difference in feet between the highest point on the topographic divide and the point of interest. Measure the basin length in miles on the map. The relief ratio (RR) is equal to H/LB.

Step 5. The multiple regression coefficients in equation 32 are obtained from table 21 for the SYA determined in Step 1. These coefficients and the values of DA, LS, and RR determined in Steps 2, 3, and 4 are substituted into equation 32 to compute the average annual sediment load for the point of interest on the stream.

Use of this multiple regression method requires determination of the main stem length, basin length, and total relief in addition to the drainage area. In many cases these parameters will have to be determined from topographic maps. The USGS publications (Ogata, 1975; Healy, 1979a, b) will have drainage area and river mile tabulated for many points of interest on most Illinois streams. The total relief and basin length can easily be obtained from the topographic maps.

Example Problem. An example is presented here to demonstrate the multiple regression method:

Determine the average annual sediment load for the Sangamon River at Riverton. The location, SYA region, and drainage area were obtained for the linear regression example.

1) The SYA region is 6.

2) The drainage area is 2618 square miles.

3) The main stem length can be obtained from Healy (1979b). The main stem length of the Sangamon upstream of Riverton is 157.8 miles.

4) The highest point on the drainage divide on the Arrowsmith quadrangle map has an elevation of 896 ft. The stream channel elevation at Riverton, on the Springfield East map, is 505. The total basin relief is 391 feet. The basin length from Riverton to the most distant point in the basin was measured on a 1:1,000,000 scale map of landforms. It is 80 miles. The relief ratio is 391/80, which equals 4.89.

5) The coefficients for SYA 6 from table 21 and the values for DA, LS, and RR in steps 2, 3, and 4 are substituted into equation 32

to obtain the average annual sediment load for the Sangamon at Riverton.

The computation looks like this:

$$\bar{Q}_s = 4,400\ (2618)^{0.761}\ (157.8)^{-0.186}\ (4.89)^{-0.210}$$

$$\bar{Q}_s = 4,400\ (399.09)\ (0.39008)\ (0.71655)$$

$$\bar{Q}_s = 491,000 \text{ tons/year}$$

Land Resource Area Revised Equations

The Land Resource Areas of Illinois are shown in figure 3, and the regression equations were developed by following the procedure described in the Upper Mississippi River Comprehens ive Basin Study (1970). It is important to note that these are the revised LRA equations, and either these equations or the lines shown in figures 34 through 38 can be used to determine the average annual sediment yield, Q /DA.

The general form of these equations is:

$$\bar{Q}_s/DA = a(DA)^m \qquad (33)$$

where a and m are respectively the coefficient and the slope of these regression equations, and Q_s and DA have already been defined.

LRA 95, 110

$$\bar{Q}_s/DA = 400\ (DA)^{-0.21} \qquad (34)$$

LRA 105

$$\bar{Q}_s/DA = 600\ (DA)^{-0.21} \qquad (35)$$

LRA 108, 109, 111, 114

$$\bar{Q}_s/DA = 1100\ (DA)^{-0.21} \qquad (36)$$

LRA 113

$$\bar{Q}_s/DA = 1400\ (DA)^{-0.21} \qquad (37)$$

LRA 115

$$\bar{Q}_s/DA = 1700\ (DA)^{-0.21} \qquad (38)$$

The procedure for use of these equations is:

Step 1. Identify the stream segment for which the average annual sediment load is to be determined and locate it on a topographic map.

Step 2. Determine the LRA for the stream segment by using figure 3.

Step 3. Review the publication by Ogata (1975) to determine if the drainage area at the designated stream section has already been determined. Otherwise, determine the drainage area from a topographic map by using either a planimeter or a digitizer.

Step 4. On the basis of the location of the stream segment within the specific LRA region, use the appropriate equation to determine the average annual sediment load for the drainage area at the site.

Example Problem. An example problem is presented here to demonstrate the revised LRA technique:

Determine the instream average annual sediment load of the Sangamon River at Riverton. The location and drainage area were determined in the previous examples.

1) The site is indicated by station code 252.

2) According to figure 3, the site is located in LRA region 108.

3) The drainage area was determined in the previous examples and is equal to 2618 square miles.

4) Substituting the drainage area into equation 36 gives the annual sediment load as:

$$Q_s/2618 = 1100\ (2618)^{-.021}$$

$$Q_s/2618 = 210.68$$

$$Q_s = 210.68\ (2618) = 552{,}000 \text{ tons}$$

Comparison of Methods

These results indicate that any of the three methods gives a reasonable estimate of the average annual sediment load at the example location, the Sangamon River at Riverton. Other examples would demonstrate the poor correlation between the regression equations and the data for the LRA method. The multiple regression method does require some additional map work to obtain LS, LB, and H. However, the correlation coefficients are generally highest for the multiple regression equations. Thus, we recommend this method to those who have the necessary maps and references. The SYA linear regression method has good correlation coefficients and is recommended for general use. The SYAs are more appropriate regions for instream sediment loads in Illinois than the LRAs, which were defined for agricultural use.

Illinois and Mississippi Main Stems

Individual regression equations relating instream sediment load and water discharge have been developed for three gaging stations on the

Mississippi River and two on the Illinois River. These equations are recommended for determining the sediment load along the main stems of these two rivers. It is emphasized that the regional equations described above should not be used for determining the sediment load on the main stems of the Illinois and Mississippi Rivers.

Equations for specific gaging stations will now be given.

Mississippi River Main Stem

Two regression equations are recommended for estimating sediment loads at each of the Mississippi River stations. The period-of-record equation relates the daily sediment load, Q_s to the daily water discharge, Q_w. The annual load regression equation relates the annual sediment load, Q , to the annual flow, QWA. The QUA is the summation of all the individual average daily flows in cfs for each day of the water year.

The general form of the period-of-record equation is:

$$Q_s = a(Q_w)^m \qquad (39)$$

where Q_s is the daily sediment load in tons per day, Q_w is the daily water discharge in cfs, and a and m are constants which can be found in table 22a.

The general form of the annual load regression equation is:

$$Q_s = a\,(QWA)^m \qquad (40)$$

where Q_s is the annual sediment load in tons, QWA is the annual flow in cfs-days, and a and m are constants which can be found in table 22b.

Table 22. Mississippi River Regression Coefficients

	STATION	a	m
a. Period-of-record equation	East Dubuque	0.1206×10^{-5}	2.07
	Burlington	0.0843×10^{-6}	2.31
	Keokuk	0.0204×10^{-6}	2.41
b. Annual load regression equation	East Dubuque	0.1908×10^{-9}	2.11
	Burlington	0.996×10^{-3}	1.48
	Keokuk	0.2865×10^{-12}	2.63

Illinois River Main Stem

The period-of-record equations are recommended for estimating daily sediment loads for the Illinois River stations. The data base was insufficient to develop annual load regression equations.

The period-of-record equation for the Illinois River at Marseilles is:

$$Q_s = 0.678\ (10)^{-3}\ Q_w^{1.65} \qquad (41)$$

where Q_s and Q_w have already been defined.

The period-of-record equation for the Illinois River at Valley City is:

$$Q_s = 0.247\ Q_w^{1.08} \qquad (42)$$

The equations given above for the Mississippi and Illinois main stems are recommended for determining the sediment load on these two rivers.

SUMMARY AND CONCLUSIONS

Erosion and sedimentation have been identified as the main water resource problem in the state of Illinois. Soil particles eroded from the watershed are transported down ditches, streams, and rivers, and a portion of this load is ultimately delivered to the receiving stream. A quantification and estimation of the sediment thus transported by many streams and rivers of Illinois is needed for developing better management techniques for these resources, including many lakes and ponds that have been constructed throughout the state. The present research investigation was initiated to develop a technique for the estimation of sediment loads of streams and rivers at any location within the basin.

Long-term sediment data are almost nonexistent in Illinois. However, short-term data were used to estimate the long-term sediment yields at those stations for which such data are available. Data from 63 suspended sediment stations and 24 lake sedimentation surveys were used for this investigation. The average length of record for the suspended sediment stations was about 2 - 3 years. Some long-term instrearn sediment transport data from three other midwestern states were used to investigate the validity of using short-term sediment records to estimate long-term average sediment loads. Other data used included geomorphic and associated hydraulic parameters for the basin.

Analyses proceeded in three phases: station sediment load, general sediment load, and regional sediment load estimations. Analysis of each station's suspended sediment data produced yearly and period-of-record (1 to 15 years) regression equations relating sediment load to daily discharge. For tributary stations with three or more years of suspended sediment data, seasonal regression equations covering three seasons were also derived. The seasons used were October through January, February through May, and June through September. The data from other stations were also analyzed similarly.

General analyses focused on three topics: 1) sediment transport by flood events; 2) long-term average annual suspended sediment load estimation based on short-term sediment data and on a new method for stations with relatively long records of suspended sediment data; and 3) multiple regression analysis.

A relationship between annual sediment load and sediment transported by the four largest floods of the year was developed and presented. This requires rather extensive analysis of the information. However, this concept can help in planning more cost-effective sediment measuring programs. It also provides some insight into the effect of variations in annual runoff volume and sediment load.

The period-of-record sediment load equations were used with station flow-duration tables to estimate the long-term average annual sediment loads. These sediment loads were then available for use, along with the geomorphic and hydraulic parameters, in the multiple regression analyses and in the regionalization process. *

It was found that long-term average annual sediment load for each station correlated exceptionally well with drainage area of the individual station.

Regional analyses were performed to determine regional relationships for the estimation of in-stream sediment loads. The state has been divided into 11 sediment yield areas (SYAs), each representing a homogeneous area as far as the instream sediment loads are concerned. The SYAs were delineated on the basis of drainage divides, physiographic boundaries, and uniformity in sediment load estimation. The 11 SYAs are substantially different than the Land Resources Areas (LRA) boundaries of Illinois.

For each of the SYAs, regression relationships have been developed relating average annual sediment load and drainage area, and average annual sediment load and three geomorphic parameters: drainage area, main stem length, and relief ratio. The instream suspended sediment data were also used to revise the existing regression equations for each of the LRAs. However, the techniques developed for the SYAs give much better estimates of the instream sediment loads and closely match the measured instream sediment loads. The SYA techniques are recommended for use in Illinois except for those stations located along the main stems of the Illinois and Mississippi Rivers. Sediment loads on these rivers are best estimated by using the period-of-record equation for each station.

For the three Mississippi River stations with 14 or 15 years of sediment record, suspended sediment concentration-duration curves were developed. These curves were used with the long-term discharge records to generate average annual sediment loads for each station. These sediment loads were closer to the measured sediment loads than the estimates based on the daily sediment regression equation and the flow-duration data. However, at least ten years of sediment data are needed before this method is recommended.

Multiple regression techniques made use of geomorphic and hydraulic parameters that resulted in improved estimates of the average annual sediment loads. The analysis resulted in the selection of three parameters: drainage area, main stem length, and relief ratio. Relief ratio is defined as the ratio of the total relief to the basin length. As many as 7 of the parameters could be included, but the improvements in the correlation coefficients did not justify the increased complexity of the analysis. Statistical considerations including the total number of stations in each region also required using no more than these three parameters. These three parameters were used in the regional analysis.

The recommended techniques are outlined in detail and presented in a form suitable for quick reference. The recommended methods make use of the available data and yield improved estimates of suspended sediment load in streams and rivers in Illinois.

NOTATIONS

ALRE = annual load regression equation

AQW = average annual water discharge, ft^3 /sec (cfs)

AQWV = average annual water volume, ft^3

ARE = annual regression equation

a = coefficient in linear regression equation

BS = basin shape

BW = basin width, miles

b = coefficient in multiple regression equation

C/I = capacity of lake/annual inflow to lake

$\bar{C}$ = time-averaged suspended sediment concentration, mg/l

C_i = suspended sediment concentration at midpoint of ith interval, mg/1

CMRE = combined monthly regression equation

C_n = coefficients in multiple regression equation

CR1, CR2, CR3 = circularity ratios

C_t = suspended sediment concentration, at t above bed, mg/1

D = water depth, ft

DA = drainage area, mi^2

DD = drainage density, mi^{-1}

DS = depth of stream, ft

EROS = soil erosion factor

F = stream frequency, number of stream segments per square mile

H = total basin relief, ft

HA = average basin relief, ft

I = incision, ft

IMRE = individual month regression equation

LA = mean stream length, miles

LB = basin length, miles

LS = main stem length, miles

LU = total stream length, miles

LRA = Land Resource Area

m = exponent, or slope, in linear regression equation

NU = total number of stream segments

P = basin perimeter, miles

POR = period-of-record regression equation

PRECIP = normal annual precipitation, inches

PRECIPV = annual precipitation volume, inch-square miles

PROD = soil productivity index

Q_s = suspended sediment load, tons/day

$\overline{Q}_s$ = average annual sediment load, tons

Q_{sb} = bed load, tons/day

QSA = annual sediment load, tons

QSN = sediment load transported during the N largest floods, tons

Q_w = water discharge, cfs

Q_{wi} = water discharge at midpoint of ith segment

QWA = annual water volume, cfs-days

QWDA = AQW/DA, cfs/mi^2

q_s = unit sediment load, pounds/ft width/sec

R = correlation coefficient

RR = relief ratio, ft/mi

SLRE = seasonal load regression equation

SO = stream order

SRE = seasonal regression equation

SS = sinuosity

SYA = Sediment Yield Area

TOK = soil tolerance/erodibility factor

t = thickness of bed layer, or unmeasured layer, ft

$\overline{V}$ = time-averaged point velocity, ft/sec

VS = average stream velocity, ft/sec

V_* = shear velocity, ft/sec

WS = stream top width, ft

y = vertical coordinate, ft

z = exponent in suspended sediment equation

α_n = geomorphic parameters in multiple regression analysis

β = constant in expression for z

γ_s = unit weight of sediment, pounds/ft^3

k = von Karman constant

ω = sediment particle fall velocity, ft/sec

REFERENCES

Adams, J. Rodger. 1984. LTER and management of the Upper Mississippi River. In Water for Resource Development, D.L. Schreiber, ASCE, New York.

Adams, J. Rodger, and Nani G. Bhowmik. 1983. Sediment transport in Pool 19, Mississippi River. In Frontiers in Hydraulic Engineering, H.T. Shen, Editor, ASCE, New York.

Adams, J. Rodger, Nani G. Bhowmik, Allen P. Bonini, Anne M. Klock, and Misganaw Demissie. 1984. Sediment yield of streams in northern and central Illinois. Illinois State Water Survey, Contract Report 353, Champaign, Illinois..

Allen, P.B. 1981. Measurement and prediction of erosion and sediment yield. Agricultural Reviews and Manuals, S-15, U.S. Department of Agriculture, New Orleans, LA, 1981.

Anttila, Peter W., and Robert L. Tobin. 1978. Fluvial sediment in Ohio. Geological Survey Water-Supply Paper 2045, U.S. Government Printing Office, Washington, D.C.

Bagnold, R.A. 1966. An approach to the sediment transport problem from general physics. U.S. Geological Survey Professional Paper 422-J.

Bellrose, Frank C, Stephan P. Havera, Fred L. Paveglio, Jr., and Donald W. Steffeck. 1983. The fate of lakes in the Illinois River Valley. Illinois Natural History Survey, Biological Notes No. 119, Urbana, Illinois.

Bhowmik, Nani G., J. Rodger Adams, Allen P. Bonini, Chwen-Yuan Guo, David J. Kisser, and Margaret A. Sexton. 1981a. Resuspension and lateral movement of sediment by tow traffic on the Upper Mississippi and Illinois Rivers. Illinois State Water Survey, Contract Report 269, Champaign, Illinois.

Bhowmik, Nani G., and William C. Bogner. 1981. Sediment transport and hydraulics of flow in the Kankakee River. Illinois - Phase II. Illinois State Water Survey, Contract Report 282, Champaign, Illinois.

Bhowmik, Nani G., Allen P. Bonini, William C. Bogner, and Richard P. Byrne. 1980. Hydraulics of flow and sediment transport in the Kankakee River in Illinois. Illinois State Water Survey, Report of Investigation 98, Champaign, Illinois.

Bhowmik, Nani G., Ming T. Lee, William C. Bogner, and William Fitzpatrick. 1981b. The effects of Illinois river traffic on water and sediment input to a side channel. Illinois State Water Survey, Contract Report 270, Champaign, Illinois.

Bhowmik, Nani G., and Richard J. Schicht. 1980. Bank erosion of the Illinois River. Illinois State Water Survey, Report of Investigation 92, Champaign, Illinois.

Bhowmik, Nani G., and John B. Stall. 1979. Hydraulic geometry and carrying capacity of floodplains. University of Illinois Water Resources Center, Research Report 145, Urbana, Illinois'.

Bogner, William C., William P. Fitzpatrick, and Nani G. Bhowmik. 1984. Sedimentation survey of Lake Decatur. Decatur. Illinois. Illinois State Water Survey, Contract Report 342, Champaign, Illinois.

Bonini, Allen P., Nani G. Bhowmik, Richard L. Allgire, and D. Kevin Davie. 1983. Statewide instream sediment monitoring program for Illinois: annual report - Water Year 1981. Illinois State Water Survey, Contract Report 318, Champaign, Illinois.

Brune, G.M. 1953. Trap efficiency of reservoirs. Transactions American Geophysical Union, v. 34:407-418.

Chow, V.T., Editor. 1964. Handbook of applied hydrology. McGraw Hill Book Co., New York.

Colby, B.R. 1956. Relationship of sediment discharge to streamflow. U.S. Geological Survey, Open File Report.

Demissie, Misganaw. 1984. Sediment load during flood events (abstract). EOS, Trans. AGU. vol. 65(16).

Demissie, Misganaw, Nani G. Bhowmik, and J. Rodger Adams. 1983. Hydrology, hydraulics, and sediment transport. Kankakee and Iroquois Rivers. Illinois State Water Survey, Report of Investigation 103, Champaign, Illinois.

Dickinson, W.T., A. Scott, and G. Wall. 1975. Fluvial sedimentation in southern Ontario. Canadian Journal of Earth Sciences, 12(11), pp. 1813-1819.

Einstein, H.A. 1950. The bed-load function for sediment transportation in open channel flows. U.S. Department of Agriculture, Soil Conservation Service, Technical Bulletin 1026.

Ferguson, R.I. 1986. River loads underestimated by rating curves. Water Resources Research, vol. 22, no. 1, January.

Flint, Russell F. 1983. Fluvial sedimentation in Kentucky. U.S. Geological Survey, Water Resources Investigations Report 83-4152.

Frost, Leonard R., Jr., and Lawrence J. Mansue. 1984. Evaluation of a hvdrograph-shifting method for estimating suspended sediment loads in Illinois streams. U.S. Geological Survey, Water Resources Investigations Report 84-4037, Urbana, Illinois.

Graf, Julia B. 1983. Measurement of bedload discharge in nine Illinois streams with the Hellev-Smith sampler. U.S. Geological Survey, Water Resources Investigations Report 83-4136, Urbana, Illinois.

Graf, Walter H. 1971. Hydraulics of sediment transport. McGraw-Hill Book Company, New York.

Griffiths, George A. 1982. Spatial and temporal variability in suspended sediment yields of North Island basins, New Zealand. Water Resources Bulletin Paper No. 81109, vol. 18, no. 4, August 1982.

Guy, Harold P., and Vernon W. Norman. 1970. Field methods for measurement of fluvial sediment. Book 3, Chapter C2 in Techniques of Water Resources Investigations of the United States Geological Survey, United States Government Printing Office, Washington, D.C.

Healy, R.W. 1979a. River mileages and drainage areas for Illinois streams Volume 1. Illinois except Illinois River basin. U.S. Geological Survey, Water Resources Investigations 79-110.

Healy, R.W. 1979b. River mileages and drainage areas for Illinois streams - Volume 2. Illinois River basin. U.S. Geological Survey, Water Resources Investigations 79-111.

Helley, E.J., and W. Smith. 1971. Development and calibration of a pressure-difference bed load sampler. U.S. Geological Survey, Water Resources Division, Open File Report, Menlo Park,. California.

Hubbell, D.W. 1964. Apparatus and techniques for measuring bedload. U.S. Geological Survey, Water Supply Paper 1748, U.S. Government Printing Office, Washington, D.C.

Illinois State Water Plan Task Force. 1984. Illinois state water plan: critical issues, cross-cutting topics, operating issues. Springfield, Illinois.

Keown, Malcolm P., Elba A. Dardeau, Jr., and Etta M. Cursey. 1981. Characterization of the suspended-sediment regime and bed-material gradation of the Mississippi River Basin. U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

Knox, J.C., P.J. Bartlein, K.K. Hirschboeck, and R.J. Muckenhirn. 1975. The response of floods and sediment yields to climatic variation and land use in the Upper Mississippi Valley. University of Wisconsin-Madison, Institute for Environmental Studies Report 52.

Lane, E.W., and A.A. Kalinske. 1941. Engineering calculations of suspended sediment. Transactions American Geophysical Union, v. 20.

Laursen, E.M. 1958. The total sediment load of streams. Proceedings ASCE, Journal of the Hydraulics Division, v. 84(HY1).

Lazaro, Timothy R., Kathleen K. Fitzgerald, and Leonard R. Frost, Jr. 1984. Estimates of long-term suspended sediment loads in Bay Creek at Nebo. Pike County. Illinois. 1940-80. U.S. Geological Survey, Water Resources Investigations Report 84-4003.

Lee, Ming T., and Nani G. Bhowmik. 1979. Sediment transport in the Illinois River. Illinois State Water Survey, Contract Report 218, Champaign, Illinois.

Lee, Ming T., and John B. Stall. 1976. Sediment conditions in backwater lakes along the Illinois River - Phase I. Illinois State Water Survey, Contract Report 176A, Champaign, Illinois.

Leighton, M.M., George E. Ekblaw, and Leland Horberg. 1948. Physiographic divisions of Illinois. Illinois State Geological Survey, Report of Investigation 129, Urbana, Illinois.

McNown, John S., Chairman. 1982. Classic papers in hydraulics. American Society of Civil Engineers, Task Committee of the Hydraulics Division to develop a volume of classics in hydraulics, New York.

Meade, R.H. 1982. Sources, sinks, and storage of river sediment in the Atlantic drainage of the United States. The Journal of Geology, 90(3), pp. 235-252.

Miller, Carl R. 1951. Analysis of flow-duration, sediment rating curve method of computing sediment yield. Bureau of Reclamation, U.S. Department of Interior, Denver, Colorado.

Nakato, Tatsuaki. 1981. Sediment-budget study for the Upper Mississippi River. GREAT-II reach. Iowa Institute of Hydraulic Research Report 227, Iowa City, Iowa.

Ogata, K.M. 1975. Drainage areas for Illinois streams. U.S. Geological Survey, Water Resources Investigation 13-75, Champaign, Illinois.

Piest, R.F. 1963. The role of the large storm as a sediment contributor. Miscellaneous Publication 970, Paper No. 15, U.S. Dept. of Agriculture, pp. 98-108.

Porterfield, George. 1972. Computation of fluvial-sediment discharge. Book 3, Chapter C3, Techniques of Water-Resources Investigations of the United States Geological Survey, United States Government Printing Office, Washington, D.C.

Rouse, Hunter. 1938. Fluid mechanics for hydraulic engineers. Dover Publications, Inc., New York.

Rouse, Hunter, and Simon Ince. 1957. History of hydraulics. Dover Publications, Inc., New York.

SAS Institute Inc. 1982a. SAS user's guide: basics. Cary, North Carolina.

SAS Institute Inc. 1982b. SAS user's guide: statistics. Cary, North Carolina.

SAS Institute Inc. 1983. SAS introductory guide, revised edition. Cary, North Carolina.

Schuetz, Joel R., and Wilbur J. Matthes, Jr. 1977. Fluvial sediment data for Iowa: Suspended-sediment concentrations, loads and sizes: bed-material sizes: and reservoir siltation. Iowa Geological Survey Technical Information Series No. 6, Des Moines, Iowa.

Shen, H.W., and C.S. Hung. 1971. An engineering approach to total bed material load bv regression analysis. Proceedings Sedimentation Symposium, Berkeley, California, June 17-19. Available from P.O. Box 606, Fort Collins, Colorado 80521.

Shulits, S. 1935. The Schoklitsch bedload formula. Engineering, p. 644-646. London, England.

Simons, Daryl B., and Fuat Senturk. 1977. Sediment transport technology. Water Resources Publications, Fort Collins, Colorado.

Stall, John B., and Yu-Si Fok. 1968. Hydraulic geometry of Illinois streams. University of Illinois Water Resources Center, Research Report 15, Urbana, Illinois.

Strahler, A.N. 1957. Quantitative analyses of watershed geomorphology. Transactions American Geophysical Union, v. 38(6): 913-920.

Terstriep, Michael L., Misganaw Demissie, Douglas C. Noel, and H. Vernon Knapp. 1982. Hvdrologic design of impounding reservoirs in Illinois. Illinois State Water Survey, Bulletin 67, Champaign, Illinois.

Toffaleti, F.B. 1969. Definitive computations of sand discharge in rivers. Proceedings ASCE, Journal of the Hydraulics Division, v. 95(HY1).

Upper Mississippi River Basin Commission. 1982. Comprehensive master plan for the management of the Upper Mississippi River system.

Upper Mississippi River Comprehensive Basin Study. 1970. Volumes III and VI. Prepared for the UMRCBS Coordinating Committee by the U.S. Army Corps of Engineers and the Environmental Science Services Administration.

U.S. Geological Survey. 1981. Water resources data for Illinois. Volume 2. Illinois River Basin. Water Data Report IL 81-2, Urbana, Illinois.

Vanoni, Vito A., Editor. 1975. Seidmentation engineering. American Society of Civil Engineers, Manuals and Reports on Engineering Practice, No. 54, New York.

Vanoni, V.A. 1984. Fifty years of sedimentation. Journal of Hydraulic Engineering, ASCE, 110(8), pp. 1022-1057.

Vanoni, V., and G. Nomicos. 1960. Resistance properties of sediment-laden streams. Transactions ASCE, 125/I.

Wischmeier, W.H. 1962. Storms and soil conservation. Journal of Soil and Water Conservation, pp. 55-59.

Zecharias, Yemane B., and Wilfried Brutsaert. 1985. Ground surface slope as a basin scale parameter. Water Resources Research, vol. 21, no. 12, December.

APPENDIX A: GEOMORPHIC AND HYDRAULIC GEOMETRY PARAMETERS

CODE DA AQW PRECIP SO NU LA LU DD

CODE	DA.	AQW	PRECIP	SO	NU	LA	LU	DD
101	207.0	159.	34.9	6	836	.64	537.8	2.60
102	1326.0	895.0	33.8	6	3008	.80	2408.1	1.82
103	6363.0	3940.0	35.6	7	7167	1.05	7535.9	1.18
104	538.0	340.0	36.3	6	343	1.45	495.7	.92
105	1099.0	697.0	36.4	6	759	1.39	1051.3	.96
106	387.0	256.0	36.5	4	236	1.37	323.8	.84
107	1403.0	830.0	35.0	6	741	1.07	795.5	.57
110	51.7	39.3	36.0	4	39	1.21	47.3	.91
111	77.7	55.5	36.3	3	53	1.37	72.5	.93
112	146.0	97.6	35.4	5	163	1.10	178.8	1.22
113	9549.0	5948.0	35.9	7	10523	1.08	11326.0	1.19
115	107.0	84.6	36.0	3	162	.84	135.9	1.27
117	2642.0	1680.0	33.8	6	1265	1.40	1769.4	.67
118	196.0	133.0	35.5	5	451	.67	302.4	1.54
119	1003.	604.	35.5	4	842	1.1	911.5	.91
120	445.	282.	34.2	4	1547	.59	930.3	2.09
121	155.	106.	36.0	4	349	.09	303.0	1.95
122	1251.	807.	34.4	4	575	1.8	1030.6	0.98
123	455.	329.	34.4	5	198	1.79	354.6	.78
124	5150.	4130.	35.4	7	8903	.75	6641.8	1.29
125	2294.	1942.	37.8	6	5683	.61	3467.2	1.51
126	62.7	44.9	35.6	3	57	1.39	79.4	1.27
228	432.	286.	34.5	6	681	.94	641.	1.48
229	1062.0	688.0	35.5	6	1470	1.06	1552.3	1.46
230	30.5	19.8	35.0	4	26	1.14	29.5	0.97
231	551.	385.	33.8	4	287	1.7	480.3	.87
232	2091.	1611.	38.2	6	2794	.89	2480.4	1.19
233	686.	537.	38.4	5	1408	.66	921.6	1.34
234	446.	352.	37.5	4	336	1.46	492.2	1.10
235	49.	35.2	35.2	3	70	.28	19.4	.4
236	776.	499.0	36.0	6	650	1.27	828.1	1.07
237	1092.	782.	36.4	6	999	.89	885.7	.81

APPENDIX A: CONTINUED

CODE	DA	AQW	PRECIP	SO	NU	LA	LU	DD
241	1636.0	1026.0	36.2	6	2952	.88	2585.6	1.58
242	655.0	433.	35.5	5	1689	.71	1203.1	1.84
243	349.0	203.0	35.4	5	1241	.61	756.2	2.17
245	1293.0	784.	38.0	6	3448	.72	2474.3	1.91
246	5093.	3261. •	35.0	7	3819	1.37	5221.6	1.03
247	1804.	1245.	35.5	6	1284	1.41	1811.3	1.00
248	355.	237.	38.0	5	256	1.35	344.5	0.97
249	550.	401.	38.1	5	420	1.36	570.9	1.04
250	134.	113.	35.9	3	80	1.48	118.6	.89
251	1290.	954.	35.9	6	795	1.33	1060.3	.82
252	2618.	1685.	34.7	5	1895	1.43	2704.8	1.03
254	870.	558.	34.2	5	607	1.59	966.1	1.11
255	473.0	484.	37.7	4	169	1.63	41.3	.09
357	919.	852.	38.4	6	704	.98	692.6	.75
358	1330.	1215.	39.2	5	600	1.69	1011.9	.76
359	868.	529.0	35.0	5	1124	1.04	1171.6	1.35
360	152.	128.	38.0	4	182	.80	146.4	.96
361	1904.	1412.	39.0	6	1164	1.45	1687.4	.89
363	318.	252.	39.2	5	361	1.27	458.5	1.44
364	745.	601.	40.2	5	505	1.62	817.6	1.1
365	254.	172.	39.2	6	344	.82	282.9	1.11
366	735.	507.	38.0	5	570	1.34	761.0	1.04
367	464.	306.	37.6	6	517	1.02	528.2	1.14
368	464.	392.	41.0	5	449	1.38	619.9	1.34
370	3102.	2521.	41.0	7	2724	1.27	3466.0	1.12
371	794.	699.	37.1	6	1191	.91	1084.7	1.37
373	2169.	1778.	37.1	7	3490	.91	3158.2	1.46
375	13.3	13.9	41.4	3	39	.72	28.0	2.10
•376	147.	158.	42.0	4	346	.87	301.8	2.05
377	42.9	57.6	44.7	3	160	.43	68.6	1.60
378	244.	295.	45.8	4	267	.98	262.0	1.07
379	4393.	3480.	37.6	7	3499	1.21	4237.5	.96

APPENDIX A: CONTINUED

CODE	H	HA	RR	BS	LB	LS	F	CR1	CR2
101	500	387	20.0	.12	25.0	47.0	4.0	.45	1.35
102	476	390	7.7	2.86	61.6	127.3	2.3	.59	1.30
103	314	345	3.3	1.39	94.0	146.8	1.1	.50	.87
104	210	110	8.1	1.26	26.0	36.5	.6	.56	.51
105	240	250	7.1	1.03	33.6	47.3	.7	.56	.67
106	273	181	10.3	1.80	26.4	52.3	.6	.51	.63
107	200	190	2.8	3.69	72.0	93.4	.5	.39	2.36
110	180	146	20.2	1.53	8.9	10.8	.8	.67	1.77
111	131	81	10.0	2.21	13.1	17.5	.7	.64	1.47
112	330	217	21.3	1.65	15.5	32.1	1.1	.61	1.82
113	452	400	2.6	3.11	172.4	272.8	1.1	.4	.90
115	235	183	13.4	2.89	17.6	24.1	1.5	.56	1.68
117	440	438	3.3	6.92	135.2	175.1	.5	.28	2.36
118	371	225	12.0	4.90	31.0	42.0	2.3	.46	3.71
119	350	139	5.8	3.7	60.6	78.6	.8	.32	1.86
120	310	225	5.8	6.43	53.5	68.7	3.5	.38	3.35
121	200	161	9.0	3.18	22.2	25.3	2.3	0.62	1.97
122	120	205	2.8	1.8	43.0	87.8	.5	.48	2.16
123.	173	697	7.0	1.32	24.9	26.8	.4	.91	1.10
124	327	266	2.9	2.48	113.0	156.9	1.7	.31	1.56
125	220	176	2.4	3.53	90.0	115.4	2.5	.32	1.66
126	238	153	14.9	4.08	16.0	21.9	0.9	.50	2.95
228	270	214	8.5	2.3	31.6	41.7	1.6	.74	1.56
229	450	308	8.5	2.63	52.8	93.0	1.4	.54	1.94
230	70	45	10.3	1.5	6.8	8.1	.9	1.6	.43
231	20	107	.7	1.45	28.3	39.0	.5	.64	.99
232	170	120	4.0	.86	42.4	104.2	1.3	.46	.68
233	95	99	2.2	2.72	43.2	59.0	2.1	.92	1.38
234	160	114	3.8	4.03	42.4	29.6	.8	.51	1.75
235	139	97	9.2	4.7	15.1	20.0	1.4	.31	.77
236	215	191	4.5	3.0	48.0	72.9	.8	.51	1.7
237	345	307	4.9	4.6	71.0	112.9	.9	2.0	2.6

APPENDIX A: CONTINUED

CODE	H	HA	RR	BS	LB	LS	F	CR1	CR2
241	490	362	7.3	2.74	67.0	113.9	1.8	.45	2.22
242	295	191	13.9	.69	21.2	61.0	2.6	.56	.71
243	170	145	10.6	.73	16.0	30.2	3.6	.65	.55
245	307	228	6.4	1.78	48.0	108.4	2.7	.63	1.24
246	370	278	3.7	1.93	99.2	283.8	.8	.54	1.12
247	415	270	6.2	2.49	67.0	111.0	.7	.60	1.68
248	282	188	8.1	3.62	34.8	50.0	.7	.50	1.26
249	265	190	6.8	3.15	39.0	73.8	.8	.39	.96
250	150	76	7.5	3.02	20.1	22.5	.6	.63	.86
251	320	255	5.9	2.29	54.4	77.4	.6	.42	.63
252	374	170	4.1	3.16	91.0	227.4	.7	.29	2.31
254	207	135	4.4	2.56	47.2	78.7	.7	.50	1.86
255	197	81	4.8	3.6	41.3	52.9	.4	.38	2.77
357	170	165	3.3	2.93	51.9	84.4	.8	.47	2.07
358	280	173	3.8	4.1	73.5	118.7	.5	.19	1.65
359	170	179	3.6	2.54	47.0	73.8	1.3	.56	1.57
360	230	162	8.9	4.5	26.0	28.3	1.2	.51	2.39
361	350	293	3.7	4.6	94.5	153.8	.6	.40	2.41
363	247	124	6.8	4.14	36.3	44.5	1.1	.53	2.40
364	290	179	5.8	3.36	50.0	64.7	.7	.48	1.92
365	180	152	5.8	3.8	31.0	36.8	1.4	.58	2.67
366	160	148	2.9	4.1	55.0	74.5	.8	.42	1.38
367	220	171	4.7	4.8	47.0	66.0	1.1	.46	2.63
368	208	147	6.3	2.36	33.1	46.5	1.0	.66	1.48
370	353	194	3.6	3.1	98.	1*82.6	.9	.52	1.71
371	240	178	5.9	. 2.12	40.8	65.5	1.5	.64	1.76
373	255	206	4.8	1.32	53.6	111.1	1.6	.66	1.16
375	110	129	15.1	4.0	7.3	8.0	3.0	.52	2.71
376	500	232	25.0	2.7	20.0	30.6	2.4	.46	.83
377	650	396	81.3	1.30	8.0	11.7	3.7	3.65	1.74
378	300	287	15.0	1.64	20.0	75.0	1.1	.63	1.59
379	440	256	3.1	4.5	140.0	253.6	.8	.38	1.37

APPENDIX A: CONTINUED

CODE	CR3	SS	I	WS	DS	VS	TOK	PROD	EROS
101	.19	1.25	38.1	78.1	1.62	1.20	13	100	8
102	.19	1.34	50.3	178.0	3.09	2.68	18	136	8
103	.22	1.36	63.7	485.6	4.65	3.28	18	119	2
104	.18	1.33	44.0	99.9	2.44	2.38	18	136	8
105	.23	1.34	48.9	157.8	2.95	2.61	15	125	8
106	.17	1.32	41.8	80.9	2.25	2.28	15	125	8
107	.23	1.12	34.8	173.9	3.78	3.10	15	107	2
110	.30	1.16	23.4	21.0	1.27	1.83	13	125	8
111	.23	1.30	32.9	28.9	1.48	1.85	18	136	8
112	.30	1.31	36.1	43.4	1.74	2.01	13	107	15
113	.15	1.37	67.7	629.6	5.17	3.46	18	119	2
115	.22	1.19	25.6	66.8	2.19	1.65	8	107	15
117	.23	1.16	37.5	260.8	4.64	3.43	8	113	15
118	.25	1.43	37.8	48.0	2.73	2.18	13	107	15
119	.20	1.33	48.3	70.4	10.63	1.60	18	136	8
120	.20	1.32	42.7	88.5	2.33	2.32	18	125	2
121	.22	1.31	36.5	45.1	1.77	2.02	18	119	2
122	.31	1.32	25.9	192.8	3.83	2.15	8	119	15
123	.25	1.87	23.4	117.3	4.81	2.02	18	136	8
124	.22	1.34	31.4	329.7	10.49	2.60	15	136	5
125	.19	1.33	28.5	229.1	7.97	2.26	18	107	2
126	.24	1.22	38.1	28.7	1.60	1.99	13	113	8
228	.23	1.44	44.5	56.3	6.36	1.59	15	113	2
229	.24	1.53	47.8	102.7	6.05	2.50	15	119	5
230	1.5	1.16	36.0	25.8	1.41	1.59	18	136	8
231	.73	1.31	24.0	140.4	3.06	1.92	18	136	8
232	.25	1.33	28.1	219.7	7.72	2.23	11	125	8
233	.20	1.32	24.6	133.1	5.29	1.84	18	119	5
234	.19	1.31	23.4	109.6	4.57	1.71	13	125	8
235	.11	1.16	37.4	33.7	1.66	1.66	15	125	8
236	.67	1.36	46.6	157.1	4.36	2.12	13	119	5
237	.67	1.36	47.9	191.5	4.93	2.19	18	125	8

APPENDIX A: CONCLUDED

CODE	CR3	SS	I	WS	DS	VS	TOK	PROD	EROS
241	.25	1.59	49.5	124.7	7.41	2.58	18	100	2
242	.29	1.34	46.0	75.6	5.17	1.60	15	107	2
243	.24	1.40	43.7	56.9	4.12	1.49	13	107	15
245	.23	1.32	48.6	102.6	6.61	1.72	15	119	2
246	.21	1.10	50.5	331.3	7.62	3.05	18	119	2
247	.23	1.13	42.3	195.2	5.82	2.33	18	119	2
248	.17	1.17	31.8	82.7	5.39	1.50	15	125	8
249	.17	1.15	34.6	106.5	4.27	1.71	13	119	8
250	.15	1.30	20.2	68.5	2.22	1.48	18	136	8
251	.15	1.32	26.6	158.4	4.58	2.85	13	119	8
252	.24	1.12	45.1	236.0	6.41	2.56	18	119	8
254	.24	1.14	37.4	134.5	4.82	1.92	13	86	8
255	.71	1.49	35.9	82.3	5.81	1.61	15	125	8
357	.74	1.30	28.4	123.0	7.08	2.00	8	107	15
358	.57	1.61	38.6	138.0	8.6	3.12	13	119	8
359	.22	1.14	37.4	222.4	4.59	3.46	15	119	15
360	.65	1.38	23.3	46.7	3.8	1.37	8	86	15
361	.64	1.65	39.6	166.7	9.9	1.96	18	119	2
363	.67	1.23	28.1	66.5	4.99	1.52	8	100	15
364	.21	1.42	34.9	129.1	8.35	1.63	8	125	8
365	.74	1.43	34.4	60.3	4.6	1.47	8	100	8
366	.51	1.54	37.0	102.6	6.7	1.7	13	119	2
367	.66	1.49	35.9	81.5	5.8	1.6	13	119	2
368	.22	1.37	31.8	109.9	7.18	1.41	13	119	2
370	.22	1.52	46.4	209.7	13.18	2.49	13	107	10
371	.26	2.00	51.9	180.2	8.93	1.36	13	136	10
373	.26	2.32	64.7	2.80.4	14.32	1.63	15	113	10
375	.24	1.16	15.6	32.8	2.30	1.67	8	86	20
376	.16	1.31	25.2	74.3	4.96	1.00	8	136	25
377	.33	1.24	20.3	51.2	.72	3.50	8	86	25
378	.28	1.67	40.0	107.2	5.18	1.10	18	125	2
379	.49	1.74	42.0	250.9	13.5	2.2	18	125	2

APPENDIX B. STATISTICAL PARAMETERS FOR THE PERIOD OF RECORD AND ANNUAL REGRESSION EQUATIONS

STATION CODE*	COEFFICIENT**	SLOPE**	STANDARD ERROR OF ESTIMATE	CORRELATION COEFFICIENT
101	.0095669	1.7095811	.2174954	.9261604
10181	.0051883	1.8477509	.1818888	.9589321
10182	.0174123	1.5831136	.2352428	.8707545
102	.3093833	1.0947876	.2516492	.6907199
10281	.0727841	1.3032804	.2842973	.7076517
10282	7.1102672	.6640126	.1898754	.5280962
103	13.7107497	.5530893	.2635490	.4262566
10381	7.2561918	.6380759	.2653885	.4288265
10382	1.7364514	.7805398	.2207319	.5773580
10383	3.4150764	.6727112	.2328732	.5456811
104	.0920060	1.1942641	.1949269	.8565768
10481	.0377275	1.3267879	.2392235	.7951311
10482	.2652231	1.0373471	.1139103	.9331901
105	.0040668	1.6125331	.2825845	.8775909
10580	.0017186	1.7531087	.2641672	.8997018
10581	.0035678	1.6190137	.2730881	.8105532
10583	.0936997	1.1269730	.2374717	.9201514
106	.0635758	1.3258246	.2046584	.9181496
10681	.0646505	1.3255252	.1773788	.9369229
10682	.0607883	1.3181074	.3165426	.8250717
107	1.0509069	.7328766	.2639013	.5348272
10781	1.0527243	.7329018	.2673513	.5333170
108	.0673405	1.1760446	.2293593	.7651015
10881	.0673405	1.1760446	.2293593	.7651015
109	.0003824	1.8613530	.2267081	.9422178
10980	.0003123	1.9050925	.2145256	.9518695
10981	.0001299	2.0272065	.1876854	.9438376
10982	.0002946	1.8960352	.2505351	.9313797
110	.1122406	1.2664227	.2169929	.8700597
11081	.0387253	1.5215503	.2337556	.8891267
11082	.2252573	1.0868476	.1751894	.8708976
111	.0749495	1.2616653	.2880960	.9205655
11180	.0975790	1.1897001	.2980313	.9218490
11181	.0492383	1.3777872	.2685058	.9245287
112	.0323031	1.6103716	.2288553	.9084150
11281	.0169081	1.7719837	.2088683	.9214222

STATION CODE*	COEFFICIENT**	SLOPE**	STANDARD ERROR OF ESTIMATE	CORRELATION COEFFICIENT
113	.0000957	1.9080063	.2500876	.8504840
11381	.0000135	2.1199164	.2698826	.8106618
11382	.0000148	2.1124223	.2083343	.9178468
11383	.2007140	1.0596408	.2670052	.6994617
114	.0306390	1.2251604	.2089348	.8573667
11481	.0239003	1.2835044	.2658331	.7079295
11482	.0143150	1.3264614	.1635912	.9173780
11483	.0373327	1.1768407	.1638406	.9238738
115	.0198697	1.5455081	.4439457	.8789010
11581	.0198697	1.5455081	.4439457	.8789010
116	.0000744	2.3668288	.3270546	.9067669
11681	.0000744	2.3668288	.3270546	.9067669
117	.0021105	1.6040301	.2822722	.7995452
11781	.0021105	1.6040301	.2822722	.7995452
118	.0069192	1.8081287	.3837575	.8928497
11881	.0069328	1.8340922	.3728346	.8897051
11882	.0105909	1.7043446	.2807798	.9594565
11883	.0023053	1.8829582	.3950442	.8594577
119	.0006800	1.9948054	.2876335	.9229489
11979	.0002849	2.0933735	.2549334	.9584732
11980	.0008714	1.9924234	.2800949	.8888911
11981	.0001672	2.2182639	.2988945	.9132492
11983	.0135351	1.5578492	.2145479	.9564880
120	.0069346	1.8275035	.3964421	.9262427
12080	.0184208	1.7190239	.3363540	.9407792
12081	.0001566	2.4509152	.3317034	.9453754
121	.0166221	1.7851557	.2767679	.9299352
12181	.0039629	2.0943242	.2940864	.9367055
12182	.0537906	1.5309409	.2080293	.9485902
122	.0006779	1.8825675	.4431390	.9369586
12281	.0001179	2.1148785	.3539014	.9624565
123	.0257019	1.4503580	.2331570	.9650632
12381	.0168633	1.5263604	.2110281	.9686139
12382	.0550296	1.3314045	.1664863	.9785189
12383	.0702410	1.1695168	.2651471	.9664997

APPENDIX B. CONTINUED

STATION CODE*	COEFFICIENT**	SLOPE**	STANDARD ERROR OF ESTIMATE	CORRELATION COEFFICIENT
124	.0013626	1.5428851	.3501874	.8898137
12479	.0005594	1.6724708	.3626162	.9043286
12480	.0010022	1.6085965	.2584068	.9143865
12481	.0000169	2.0798347	.2821986	.9335447
12482	.0011743	1.5457980	.3394374	.8453806
12483	.0000005	2.2641067	.2788263	.8946367
125	.0029213	1.4871599	.2885442	.8376368
12579	.0051273	1.3909369	.2592535	.8796625
12580	.0056130	1.4152265	.2491577	.8068261
12581	.0001055	1.8887967	.2976960	.8590567
12582	.0642893	1.1451356	.1991937	.8357079
12583	.0192876	1.2485206	.3108595	.6939590
126	.0044951	2.2527845	.2630790	.9630189
12681	.0044951	2.2527845	.2630790	.9630189
127	.0003639	2.6137933	.2787339	.9487831
12781	.0003701	2.6163078	.2717919	.9521633
203	.0544002	1.1048858	.3283990	.8102199
20380	.0540148	1.0541437	.3178579	.8048677
20381	.0468578	1.2278379	.3164333	.8390742
204	.0529983	1.2152692	.3513098	.8224574
20480	.0641672	1.1506834	.3410745	.8009460
20481	.0394198	1.3996660	.3154497	.8728178
228	.0023581	1.9608138	.4129258	.9235629
22879	.0068665	1.7773090	.3054924	.9580129
22880	.0028534	1.9816339	.3390167	.9511929
22881	.0000094	2.8968052	.4049790	.9220726
229	.0031943	1.8661138	.3665578	.9109418
22981	.0027654	1.8942202	.3804194	.8731114
22982	.0072436	1.7189012	.2701294	.9345553
22983	.0103739	1.6299127	.2725368	.9629765
230	.1867003	1.0734278	.2953718	.8884907
23081	.1142139	1.1919426	.3075792	.8990543
231	.0510144	1.3541986	.2328496	.9493009
23181	.0313944	1.4246308	.2404438	.9520136

STATION CODE*	COEFFICIENT**	SLOPE**	STANDARD ERROR OF ESTIMATE	CORRELATION COEFFICIENT
232	.0093325	1.4433836	.3569168	.9300155
23279	.0074225	1.4896787	.3462906	.9461182
23280	.0228776	1.2844067	.3727088	.8922117
23281	.0010782	1.7326973	.3197963	.9455559
23282	.2510017	1.0538550	.2250470	.9292567
23283	.0222284	1.3314374	.2699018	.9541075
233	.0696682	1.1943522	.4141211	.8655637
23379	.0230281	1.3704184	.4482183	.8920509
23380	.0760472	1.1079805	.4426737	.7993093
23381	.4728528	.9509043	.2547929	.8676973
23382	.8350650	.8400814	.2438232	.8734177
23383	.3134486	.9907978	.3297597	.8780548
234	.0955720	1.2727606	.2379484	.9611401
23481	.0955720	1.2727606	.2379484	.9611401
235	.2028041	1.2315447	.3635132	.9318707
23581	.2028041	1.2315447	.3635132	.9318707
236	.0228777	1.5404081	.2207728	.9723241
23681	.0169097	1.5819526	.2429309	.9617114
237	.0016027	1.9154967	.2921226	.9518449
23781	.0016027	1.9154967	.2921226	.9518449
238	.0241086	1.6856562	.4058260	.8583112
23876	.0629952	1.5603764	.3653930	.8436259
23877	.0339176	1.8429354	.2967654	.9221096
23878	.0080452	1.8864579	.3141132	.9119815
23879	.0207933	1.5831160	.3152334	.9148013
23880	.0080568	1.9945602	.3274537	.9049784
239	.0092671	1.9209093	.3932140	.8978627
23976	.0158503	1.9206946	.4244449	.8478291
23977	.0166833	1.9295911	.4052016	.8787329
23978	.0022291	2.2002392	.3563002	.9117793
23979	.0085745	1.8915974	.3632976	.9156264
23980	.0052096	2.0825105	.3009366	.9335690
23981	.0020113	2.3561328	.3342254	.9404172
23982	.0046665	2.0393738	.2671381	.9531519
23983	.0497792	1.4850978	.2739988	.9180591

STATION CODE*	COEFFICIENT**	SLOPE**	STANDARD ERROR OF ESTIMATE	CORRELATION COEFFICIENT
240	.1854862	1.1670239	.3803887	.8248933
24076	.2346525	1.0534478	.3516587	.8002238
24077	.3656750	1.1399218	.2565714	.9013702
24078	.1008677	1.4959408	.3620065	.8370841
24079	.0830543	1.5317667	.3218749	.9025051
24080	.1103510	1.5785123	.3143752	.8739432
241	.0000917	2.2841227	.2463319	.9725338
24181	.0000917	2.2841227	.2463319	.9725338
242	.0254059	1.5762017	.3729186	.9335585
24281	.0258565	1.5948455	.3205374	.9329609
24282	.0031457	1.8436209	.3769089	.8684936
24283	.1164970	1.1769240	.3479821	.9525159
243	.0190378	1.7114194	.3158764	.9744613
24381	.0190530	1.7125056	.3117993	.9749673
244	.0112846	1.9441503	.3920645	.9621231
24481	.0112846	1.9441503	.3920645	.9621231
245	.0013223	1.9389026	.3598209	.9641545
24581	.0013223	1.9389026	.3598209	.9641545
246	.0002352	1.9260384.	.3334468	.9659538
24681	.0002352	1.9260384	.3334468	.9659538
247	.0141446	1.5273288	.3124186	.9441010
24781	.0072967	1.6430043	.3149158	.9537057
24782	.0238227	1.4733974	.1666724	.9710865
24783	.0162941	1.4692480	.3557432	.9349388
248	.0332132	1.3249490	.3285374	.9107453
24881	.0561398	1.2626739	.2943454	.8815824
24882	.0677657	1.1235596	.2504235	.9309517
24883	.0382904	1.2040564	.4180200	.8853163
249	.1081745	1.1997800	.2846074	.9455882
24981	.0702815	1.3051594	.2739152	.9529862
24982	.3740508	.9838065	.1170908	.9808835
24983	.0700068	1.2365155	.3338176	.9389227
250	.0070545	1.7128805	.3029015	.9498931
25081	.0067986	1.7208573	.3017128	.9507359
25082	.0108176	1.6099448	.3072643	.9199360
251.	.0010182	1.8430580	.3861876	.9503706
25181	.0010182	1.8430580	.3861876	.9503706

STATION CODE*	COEFFICIENT**	SLOPE**	STANDARD ERROR OF ESTIMATE	CORRELATION COEFFICIENT
252	.0086885	1.4850359	.3730862	.8815854
25281	.0173216	1.4136123	.3585951	.8524043
25282	.0127241	1.3825897	.2879582	.9223911
25283	.0049479	1.4953644	.4019875	.9216116
254	.1372268	1.2377548	.3416150	.9549253
25481	.1431749	1.2425513	.3399717	.9562108
25482	.1454119	1.1358226	.2506823	.9659697
255	.0317442	1.2483000	.4535141	.8765890
25580	.0243311	1.2921250	.4421832	.8510634
25581	.0035323	1.6216163	.5443240	.8787489
25582	.0726330	1.0471514	.2967140	.9087857
25583	.1146657	1.0535597	.3518540	.9094123
356	.0176648	1.4180565	.4396080	.9069658
35680	.0133907	1.4844969	.5989477	.8482150
35681	.0065902	1.5761635	.3690993	.9482279
35682	.1198646	1.1235264	.2449324	.9314880
357	.0203497	1.4858514	.2253859	.9763789
35781	.0185286	1.5137248	.1971090	.9687753
35782	.0473737	1.3354992	.2495870	.9720502
35783	.0165294	1.4549021	.2067387	.9894677
358	.0106726	1.5309094	.2779282	.8309283
35881	.0133986	1.5046001	.2751790	.8335027
359	.0425531	1.5643615	.3665608	.9631371
35981	.0425531	1.5643615	.3665608	.9631371
360	.2292317	1.3091050	.3155134	.9623267
36081	.2292317	1.3091050	.3155134	.9623267
361	.0056791	1.6501488	.3165751	.9059885
36181	.0024690	1.7908201	.2701086	.9348539
36182	.0127602	1.4764474	.2817195	.9083405
36183	.0527527	1.2498778	.2972537	.9012843
362	.0065774	1.6934492	.2985681	.9243903
36281	.0044263	1.7758041	.2720330	.9312913
36282	.0152944	1.4951905	.2250503	.9546123
36283	.0153115	1.4926489	.2545465	.9546182

STATION CODE*	COEFFICIENT**	SLOPE**	STANDARD ERROR OF ESTIMATE	CORRELATION COEFFICIENT
363	.0315008	1.3118487	.3139240	.9476299
36381	.0764408	1.3796937	.2147311	.9775397
36382	.0771338	1.3179364	.3426515	.9213289
36383	.0859809	1.2455181	.3153424	.9562503
364	.0562238	1.3136878	.4222863	.9222432
36478	.0702102	1.2351111	.3386035	.9357379
36479	.0917248	1.2092375	.6173461	.8720484
36480	.0254899	1.4713589	.3737877	.9408014
36481	.0235648	1.5246175	.2617821	.9712285
365	.1783933	1.2833075	.3733321	.9137976
36581	.1827685	1.2932370	.3626182	.9168735
366	.0185569	1.5642289	.3213322	.9518540
36681	.0111854	1.7260207	.3576259	.9401899
36682	.0171349	1.5715361	.2549071	.9687121
36683	.0168983	1.5239095	.3133992	.9538307
367	.0704999	1.4973172	.4120987	.9270564
36781	.0506721	1.6679788	.2828869	.9661175
36782	.0221833	1.6430348	.3397339	.9442718
36783	.0348842	1.3641548	.3728912	.9506898
368	.0361249	1.4359549	.2662722	.9644544
36881	.0361249	1.4359549	.2662722	.9644544
369	.1361874	1.1818035	.3487139	.9195699
36981	.2421050	1.1522250	.3815071	.8796298
36982	.0931746	1.2081672	.2844259	.9515646
370	.0276621	1.3469818	.2639916	.9642861
37081	.0293450	1.3456433	.2466335	.9687098
37082	.0408661	1.2883934	.2847911	.9533651
37083	.0092264	1.4654491	.2658497	.9705283
371	.1413878	1.0330358	.3739443	.8522694
37181-	.1294561	1.0941114	.2871726	.9112683
37182	.1044982	1.0552153	.4063797	.8267149
373	.0310935	1.2624739	.3585059	.9163749
37381	.0068845	1.5045737	.3728989	.9304151
37382	.0582152	1.2022300	.3434241	.8760033
37383	.0993762	1.0855595	.3450387	.9109463
374	.0687299	1.1608435	.3021318	.8794506
37481	.0687299	1.1608435	.3021318	.8794506

APPENDIX B. CONCLUDED

STATION CODE*	COEFFICIENT**	SLOPE**	STANDARD ERROR OF ESTIMATE	CORRELATION COEFFICIENT
375	.0830732	1.4015216	.6339868	.8609411
37581	.0878462	1.4015684	.6829902	.8519120
376	.0020398	1.9149197	.4729058	.9291677
37680	.0017177	1.9439013	.3826805	.9524241
37681	.0029743	1.8448201	.2587196	.9756380
377	.0037737	1.4321196	.5484419	.8666771
37781	.0054326	1.4441122	.5441766	.8823135
378	.0586610	1.3329384	.3389316	.9544845
37881	.0711564	1.3338443	.2540575	.9678372
37882	.0261844	1.4925479	.2957210	.9705839
37883	.0515692	1.1589694	.4110444	.9523747
379	.0243772	1.3287406	.3820708	.9081340
37981	.0025805	1.6342665	.3921818	.9284856
37982	.1355524	1.1202080	.3745814	.3415783
37983	.0377218	1.2579001	.3060917	.9168667
444	.0177114	1.8472971	.4066572	.9567327
44481	.0177114	1.8472971	.4066572	.9567327

* THE THREE-DIGIT STATION CODE IDENTIFIES THE LINE WITH THE STATION'S PERIOD OF RECORD STATISTICS; THE FIVE-DIGIT STATION CODE INDICATES THE APPROPRIATE WATER YEAR STATISTICS (I.E. 10181 REPRESENTS STATION 101, WATER YEAR 1981)

** THE GENERAL FORM OF THE REGRESSION EQUATION IS:
QS=COEFFICIENT*QW**SLOPE

APPENDIX C. CALCULATED AND MEASURED ANNUAL LOADS AND YIELDS FOR ALL STATIONS (EXCEPT IL AND MISSISSIPPI RIVER MAINSTEM)

STATION CODE*	TYPE**	ANNUAL LOAD (TONS)	ANNUAL (TONS/SQ MI)	YIELD (TONS/ACRE)
101.81	ARE	81260.	393.	.61
	POR	57697.	279.	.44
101.82	ARE	66744.	322.	.50
	POR	86161.	416.	.65
102.82	ARE	303485.	229.	.36
	POR	310'868.	234.	.37
103.81	ARE	526405.	83.	.13
	POR	489107.	77.	.12
103.82	ARE	543643.	85.	.13
	POR	588678.	93.	.14
103.83	ARE	420863.	66.	.10
	POR	594782.	93.	.15
104.81	ARE	33136.	62.	.10
	POR	36225.	67.	.11
104.82	ARE	54160.	101.	.16
	POR	52244.	97.	.15
105.80	ARE	108693.	99.	.15
	POR	90814.	83.	.13
	MEAS	144785.	132.	.21
105.81	ARE	62685.	57.	.09
	POR	68301.	62.	.10
	MEAS	91755.	83.	.13
105.83	ARE	129014.	117.	.18
	POR	265798.	242.	.38
106.81	ARE	45651.	118.	.18
	POR	44977.	116.	.18
106.82	ARE	55169.	143.	.22
	POR	60747.	157.	.25
108.81	ARE	21079.	59.	.09
	POR	21079.	59.	.09
109.80	ARE	32492.	52.	.08
	POR	29218.	46.	.07
	MEAS	37629.	60.	.09

APPENDIX C. CONTINUED

STATION CODE*	TYPE**	ANNUAL LOAD (TONS)	ANNUAL (TONS/SQ MI)	YIELD (TONS/ACRE)
109.81	ARE	30059.	48.	.07
	POR	27860.	44.	.07
	MEAS	34886.	55.	.09
109.82	ARE	43122.	68.	.11
	POR	43298.	69.	.11
	MEAS	4 2360.	67.	.11
110.81	ARE	6010.	116.	.18
	POR	5502.	106.	.17
110.82	ARE	4706.	91.	.14
	POR	5220.	101.	.16
111.80	ARE	7221.	93.	.15
	POR	8257.	106.	.17
	MEAS	9248.	119.	.19
111.81	ARE	6567.	85.	.13
	POR	5545.	71.	.11
	MEAS	13222.	170.	.27
112.81	ARE	59521.	408.	.64
	POR	41071.	281.	.44
113.81	ARE	682997.	72.	.11
	POR	721520.	76.	.12
	MEAS	885856.	93.	.14
113.82	ARE	1545079.	162.	.25
	POR	1438480.	151.	.24
	MEAS	1642588.	172.	.27
113.83	ARE	1164475.	122.	.19
	POR	1598170.	167.	.26
115.81	ARE	45402.	424.	.66
	POR	45402.	424.	.66
116.81	ARE	79079.	244.	.38
	POR	79079.	244.	.38
117.81	ARE	194501.	74.	.12
	POR	194501.	74.	.12
118.81	ARE	104778.	535.	.84
	POR	86809.	443.	.69
118.82	ARE	76804.	392.	.61
	POR	102238.	522.	.82

STATION CODE*	TYPE**	ANNUAL LOAD (TONS)	ANNUAL (TONS/SQ MI)	YIELD (TONS/ACRE)
118.83	ARE	70802.	361.	.56
	POR	123420.	630.	.98
119.79	ARE	693555.	691.	1.08
	POR	719509.	717.	1.12
	MEAS	766286.	764.	1.19
119.80	ARE	134751.	134.	.21
	POR	106900.	107.	.17
	MEAS	196507.	196.	.31
119.81	ARE	386609.	385.	.60
	POR	274996.	274.	.43
	MEAS	568555.	567.	.89
119.83	ARE	277002.	276.	.43
	POR	421383.	420.	.66
120.80	ARE	182936.	411.	.64
	POR	147030.	330.	.52
	MEAS	313403.	704.	1.10
120.81	ARE	1496897.	3364.	5.26
	POR	440176.	989.	1.55
	MEAS	552742.	1242.	1.94
121.81	ARE	256597.	1655.	2.59
	POR	122837.	792.	1.24
121.82	ARE	104255.	673.	1.05
	POR	186562.	1204.	1.88
122.81	ARE	680835.	544.	.85
	POR	499977.	400.	.62
	MEAS	893028.	714.	1.12
123.81	ARE	138670.	305.	.48
	POR	117525.	258.	.40
123.82	ARE	134289.	295.	.46
	POR	157472.	346.	.54
123.83	ARE	55344.	122.	.19
	POR	205726.	452.	.71
124.79	ARE	611233.	119.	.19
	POR	423461.	82.	.13
	MEAS	932767.	181.	.28

STATION CODE*	TYPE**	ANNUAL LOAD (TONS)	ANNUAL (TONS/SQ MI)	YIELD (TONS/ACRE)
124.80	ARE	322262.	63.	.10
	POR	241638.	47.	.07
	MEAS	678084.	132.	.21
124.81	ARE	945868.	184.	.29
	POR	452074.	88.	.14
	MEAS	1365482.	265.	.41
124.82	ARE	491380.	95.	.15
	POR	554428.	108.	.17
	MEAS	785748.	153.	.24
124.83	ARE	217945.	42.	.07
	POR	533780.	104.	.16
125.79	ARE	101505.	44.	.07
	POR	129734.	57.	.09
	MEAS	157708.	69.	.11
125.80	ARE	95811.	42.	.07
	POR	87361.	38.	.06
	MEAS	121280.	53.	.08
125.81	ARE	177564.	77.	.12
	POR	170333.	74.	.12
	MEAS	326491.	142.	.22
125.82	ARE	232142.	101.	.16
	POR	184188.	80.	.13
125.83	ARE	151725.	66.	.10
	POR	165896.	72.	.11
126.81	ARE	134769.	2149.	3.36
	POR	134769.	2149.	3.36
	MEAS	138840.	2214.	3.46
127.81	ARE	363896.	1989.	3.11
	POR	351745.	1922.	3.00
203.80	ARE	17.	7.	.01
	POR	17.	7.	,01
	MEAS	36.	15.	.02
203.81	ARE	48.	20.	.03
	POR	39.	16.	.03
	MEAS	2449.	1004.	1.57

STATION CODE*	TYPE**	ANNUAL LOAD (TONS)	ANNUAL (TONS/SQ MI)	YIELD (TONS/ACRE)
204.80	ARE	26.	9.	.01
	POR	23.	8.	.01
	MEAS	65.	23.	.04
204.81	ARE	93.	33.	.05
	POR	65.	23.	.04
	MEAS	2814.	1001.	1.56
228.79	ARE	264053.	611.	.96
	POR	368985.	854.	1.33
	MEAS	379096.	878.	1.37
228.80	ARE	300446.	695.	1.09
	POR	211069.	489.	.76
	MEAS	268805.	622.	.97
228.81	ARE	654655.	1515.	2.37
	POR	159753.	370.	.58
	MEAS	385798.	893.	1.40
229.81	ARE	935962.	881.	1.38
	POR	861936.	812.	1.27
229.82	ARE	970001.	913.	1.43
	POR	1488658.	1402.	2.19
229.83	ARE	629644.	593.	.93
	POR	1474566.	1388.	2.17
230.81	ARE	3462.	114.	.18
	POR	3216.	105.	.16
231.81	ARE	131362.	238.	.37
	POR	124289.	226.	.35
232.79	ARE	453789.	217.	.34
	POR	374451.	179.	.28
	MEAS	558533.	267.	.42
232.80	ARE	134754.	64.	.10
	POR	215699.	103.	.16
	MEAS	364410.	174.	.27
232.81	ARE	399348.	191.	.30
	POR	280400.	134.	.21
	MEAS	425707.	204.	.32
232.82	ARE	435750.	208.	.33
	POR	529913.	253.	.40

STATION CODE*	TYPE**	ANNUAL LOAD (TONS)	ANNUAL (TONS/SQ MI)	YIELD (TONS/ACRE)
232.83	ARE	315889.	151.	.24
	POR	349719.	167.	.26
233.79	ARE	78581.	115.	.18
	POR	62659.	91.	.14
	MEAS	93130.	136.	.21
233.80	ARE	30857.	45.	.07
	POR	52192.	76.	.12
	MEAS	68666.	100.	.16
233.81	ARE	73709.	107.	.17
	POR	60730.	89.	.14
233.82	ARE	78191.	114.	.18
	POR	92990.	136.	.21
233.83	ARE	75051.	109.	.17
	POR	73068.	107.	.17
234.81	ARE	89251.	200.	.31
	POR	89251.	200.	.31
235.81	ARE	20513.	419.	.65
	POR	20513.	419.	.65
236.81	ARE	528727.	681.	1.06
	POR	509130.	656.	1.03
238.76	ARE	5062.	181.	.28
	POR	3411.	122.	.19
	MEAS	15531.	555.	.87
238.77	ARE	8469.	302.	.47
	POR	2736.	98.	.15
	MEAS	11866.	424.	.66
238.78	ARE	4544.	162.	.25
	POR	5104.	182.	.28
	MEAS	10598.	379.	.59
238.79	ARE	2962.	106.	.17
	POR	5789.	207.	.32
	MEAS	9571.	342.	.53
238.80	ARE	7609.	272.	.42
	POR	3922.	140.	.22
	MEAS	14407.	515.	.80

STATION CODE*	TYPE**	ANNUAL LOAD (TONS)	ANNUAL (TONS/SQ MI)	YIELD (TONS/ACRE)
239.76	ARE	10930.	265.	.41
	POR	6397.	155.	.24
	MEAS	24 912.	605.	.94
239.77	ARE	11418.	277.	.43
	POR	6057.	147.	.23
	MEAS	25408.	617.	.96
239.78	ARE	12619.	306.	.48
	POR	12049.	292.	.46
	MEAS	18551.	450.	.70
239.79	ARE	10023.	243.	.38
	POR	12719.	309.	.48
	MEAS	15141.	367.	.57
239.80	ARE	15129.	367.	.57
	POR	10078.	245.	.38
	MEAS	18655.	453.	.71
239.81	ARE	16124.	391.	.61
	POR	7972.	193.	.30
	MEAS	21090.	512.	.80
239.82	ARE	16725.	406.	.63
	POR	16884.	410.	.64
	MEAS	23709.	575.	.90
239.83	ARE	12122.	294.	.46
	POR	25955.	630.	.98
	MEAS	24712.	600.	.94
240.76	ARE	434.	61.	.10
	POR	439.	62.	.10
	MEAS	779.	109.	.17
240.77	ARE	365.	51.	.08
	POR	196.	27.	.04
	MEAS	736.	103.	.16
240.78	ARE	782.	110.	.17
	POR	613.	86.	.13
	MEAS	1006.	141.	.22
240.79	ARE	642.	90.	.14
	POR	56 3.	79.	.12
	MEAS	995.	140.	.22

STATION CODE*	TYPE**	ANNUAL LOAD (TONS)	ANNUAL (TONS/SQ MI)	YIELD (TONS/ACRE)
240.80	ARE	329.	46.	.07
	POR	244.	34.	.05
	MEAS	442.	62.	.10
241.81	ARE	2166963.	1325.	2.07
	POR	2166963.	1325.	2.07
	MEAS	2049265.	1253.	1.96
242.81	ARE	692277.	1057.	1.65
	POR	582270.	889.	1.39
242.82	ARE	433922.	662.	1.04
	POR	439464.	671.	1.05
242.83	ARE	116409.	178.	.28
	POR	665407.	1016.	1.59
243.81	ARE	684866.	1962.	3.07
	POR	678116.	1943.	3.04
244.81	ARE	31294.	689.	1.08
	POR	31294.	689.	1.08
	MEAS	80041.	1763.	2.75
245.81	ARE	2050724.	1586.	2.48
	POR	2050724.	1586.	2.48
	MEAS	1771914.	1370.	2.14
246.81	ARE	2713716.	533.	.83
	POR	2713716.	533.	.83
	MEAS	2815113.	553.	.86
247.81	ARE	1771546.	982.	1.53
	POR	1210711.	671.	1.05
247.82	ARE	954323.	529.	.83
	POR	903472.	501.	.78
247.83	ARE	787719.	437.	.68
	POR	1144643.	635.	.99
248.81	ARE	60634.	171.	.27
	POR	56083.	158.	.25
248.82	ARE	27513.	78.	.12
	POR	57803.	163.	.25
248.83	ARE	21998.	62.	.10
	POR	44113.	124.	.19

APPENDIX C. CONTINUED

STATION CODE*	TYPE**	ANNUAL LOAD (TONS)	ANNUAL (TONS/SQ MI)	YIELD (TONS/ACRE)
249.31	ARE	145029.	264.	.41
	POR	102586.	187.	.29
249.82	ARE	72005.	131.	.20
	POR	100112.	182.	.28
249.83	ARE	72087.	131.	.20
	POR	85409.	155.	.24
250.81	ARE	39552.	295.	.46
	POR	38904.	290.	.45
250.82	ARE	27238.	203.	.32
	POR	34616.	258.	.40
251.81	ARE	470657.	365.	.57
	POR	470657.	365.	.57
253.81	ARE	6177673.	233.	.36
	POR	5675028.	214.	.33
	MEAS	7350548.	277.	.43
253.82	ARE	6861236.	258.	.40
	POR	6501928.	245.	.38
	MEAS	9018570.	340.	.53
253.83	ARE	4850206.	183.	.29
	POR	7100616.	267.	.42
	MEAS	5985890.	225.	.35
254.81	ARE	159467.	183.	.29
	POR	147451.	169.	.26
254.82	ARE	169630.	195.	.30
	POR	360190.	414.	.65
255.80	ARE	9864.	21.	.03
	POR	9788.	21.	.03
	MEAS	11460.	24.	.04
255.81	ARE	42899.	91.	.14
	POR	26767.	57.	.09
	MEAS	44137.	93.	.15
255.82	ARE	21765.	46.	.07
	POR	42144.	89.	.14
	MEAS	30859.	65.	.10

STATION CODE*	TYPE**	ANNUAL LOAD (TONS)	ANNUAL (TONS/SQ MI)	YIELD (TONS/ACRE)
255.83	ARE	32597.	69.	.11
	POR	36898.	78.	.12
	MEAS	70854.	150.	.23
356.80	ARE	33588.	62.	.10
	POR	28233.	52.	.08
	MEAS	47572.	88.	.14
356.81	ARE	96125.	177.	.28
	POR	77344.	143.	.22
	MEAS	110599.	204.	.32
356.82	ARE	75843.	140.	.22
	POR	105388.	194.	.30
	MEAS	97483.	180.	.28
357.81	ARE	246699.	268.	.42
	POR	218076.	237.	.37
357.82	ARE	314179.	342.	.53
	POR	459673.	500.	.78
358.81	ARE	161068.	121.	.19
	POR	155501.	117.	.18
359.81	ARE	950491.	1095.	1.71
	POR	950491.	1095.	1.71
360.81	ARE	28601.	188.	.29
	POR	28601.	188.	.29
361.81	ARE	381504.	200.	.31
	POR	297145.	156.	.24
361.82	ARE	542376.	285.	.45
	POR	1062432.	558.	.87
361.83	ARE	353696.	186.	.29
	POR	1143768.	601.	.94
362.81	ARE	739744.	488.	.76
	POR	564249,	372.	.58
362.82	ARE	701248.	463.	.72
	POR	1707396.	1126.	1.76
362.83	ARE	562379.	371.	.58
	POR	1363828.	900.	1.41

APPENDIX C. CONTINUED

STATION CODE*	TYPE**	ANNUAL LOAD (TONS)	ANNUAL (TONS/SQ MI)	YIELD (TONS/ACRE)
363.81	ARE	69495.	219.	.34
	POR	45839.	144.	.23
363.82	ARE	121897.	383.	.60
	POR	123023.	387.	.60
363.83	ARE	75953.	239.	.37
	POR	120251.	378.	.59
364.78	ARE	135728.	182.	.28
	POR	210238.	282.	.44
	MEAS	150672.	202.	.32
364.79	ARE	178847.	240.	.38
	POR	269196.	361.	.56
	MEAS	340212.	457.	.71
364.80	ARE	99235.	133.	.21
	POR	66028.	89.	.14
	MEAS	144307.	194.	.30
364.81	ARE	121885.	164.	.26
	POR	59532.	80.	.12
	MEAS	132386.	178.	.28
365.81	ARE	19348.	76.	.12
	POR	17771.	70.	.11
366.81	ARE	172043.	234.	.37
	POR	87218.	119.	.19
366.82	ARE	526882.	717.	1.12
	POR	536863.	730.	1.14
366.83	ARE	491641.	669.	1.05
	POR	761663.	1036.	1.62
367.81	ARE	174970.	377.	.59
	POR	78078.	168.	.26
367.82	ARE	375164.	809.	1.26
	POR	387312.	835.	1.30
367.83	ARE	132962.	287.	.45
	POR	783662.	1689.	2.64
368.81	ARE	18440.	40.	.06
	POR	18440.	40.	.06

APPENDIX C. CONTINUED

STATION CODE*	TYPE**	ANNUAL LOAD (TONS)	ANNUAL (TONS/SQ MI)	YIELD (TONS/ACRE)
370.81	ARE	203892.	66.	.10
	POR	194377.	63.	.10
370.82	ARE	574577.	185.	.29
	POR	657199.	212.	.33
370.83	ARE	1230703.	397.	.62
	POR	1213972.	391.	.61
371.81	ARE	33180.	42.	.07
	POR	23887.	30.	.05
371.82	ARE	47389.	60.	.09
	POR	54488.	69.	.11
373.81	ARE	224481.	103.	.16
	POR	126582.	58.	.09
	MEAS	183269.	84.	.13
373.82	ARE	245692.	113.	.18
	POR	220185.	102.	.16
	MEAS	308045.	142.	.22
373.83	ARE	305640.	141.	.22
	POR	489964.	226.	.35
	MEAS	452402.	209.	.33
375.81	ARE	2558.	192.	.30
	POR	2418.	182.	.28
	MEAS	23201.	1744.	2.73
376.80	ARE	17465.	119.	.19
	POR	17242.	117.	.18
	MEAS	22980.	156.	.24
376.81	ARE	32485.	221.	.35
	POR	36339.	247.	.39
	MEAS	57139.	389.	.61
377.81	ARE	1205.	28.	.04
	POR	777.	18.	.03
	MEAS	12267.	286.	,45
378.81	ARE	45936.	188.	.29
	POR	37638.	154.	.24

APPENDIX C. CONCLUDED

STATION CODE*	TYPE**	ANNUAL LOAD (TONS)	ANNUAL (TONS/SQ MI)	YIELD (TONS/ACRE)
378.82	ARE	103675.	425.	.66
	POR	69234.	284.	.44
378.83	ARE	38278.	157.	.25
	POR	170457.	699.	1.09
379.81	ARE	269315.	61.	.10
	POR	213957.	49.	.08
	MEAS	430589.	98.	.15
379.82	ARE	765550.	174.	.27
	POR	944242.	215.	.34
	MEAS	990789.	226.	.35
379.83	ARE	861574.	196.	.31
	POR	1076105.	245.	.38
	MEAS	1010988.	230.	.36
444.81	ARE	14187.	400.	.62
	POR	14187.	400.	.62
	MEAS	37869.	1067.	1.67

* THE FIVE-DIGIT STATION CODE CONSISTS OF THE STATION NUMBER FOLLOWED BY A DECIMAL POINT AND THEN THE WATER YEAR

** THE TYPE CODES ARE AS FOLLOWS:
ARE = ANNUAL REGRESSION EQUATION
POR = PERIOD OF RECORD REGRESSION EQUATION
MEAS = MEASURED LOAD

STATION CODE	COEFFICIENT	SLOPE	STANDARD ERROR OF ESTIMATE	CORRELATION COEFFICIENT
19167	.33935817E-05	1.9743094	.2550751	.9098291
19168	.30820747E-08	2.6206800	.2167345	.9381009
19169	.10150979E-03	1.6753119	.3245522	.8206084
19170	.24876696E-07	2.4481672	.3092203	.8258594
19171	.29620722E-05	2.0081189	.2630191	.8705975
19172	.13730179E-07	2.4749391	.3419472	.8224823
19173	.30759740E-04	1.7798004	.3326991	.7941922
19174	.27451414E-08	2.6276828	.2378198	.9235985
19175	.13518593E-05	2.0578094	.2048892	.9393429
19176	.47074040E-05	1.9361554	.3000720	.8306709
19177	.97028841E-05	1.8743294	.2768566	.7458616
19178	.57055904E-09	2.7846186	.2351683	.8882213
19179	.78523914E-06	2.1176959	.2325073	.9112548
19180	.57446709E-06	2.1533757	.2443275	.8753413
19181	.81301307E-07	2.3219449	.1849265	.8831769
191	.12064149E-05	2.0698095	.2892662	.8875765
19100	.19081324E-08	2.1127407	.0536915	.9774424
19121	.34256184E-07	1.9729429	.0951130	.9526785
19122	.37558576E-07	1.9919596	.0665198	.9765482
19123	.41593331E-08	2.1478744	.1368879	.9158629
19131	.10044859E-07	2.1665511	.1697799	.9507493
19101	.32610727E-08	2.2355273	.1450171	.9104019
19102	.16030057E-10	2.6432331	.1250576	.9225650
19103	.18524217E-09	2.4594338	.2015324	.8863954
19104	.57938424E-05	1.7359698	.1019376	.9547399
19105	.73711716E-06	1.8558495	.0909379	.9764615
19106	.79322674E-10	2.5302842	.1448367	.9472972
19107	.86820908E-07	2.0267868	.0913111	.9774208
19108	.11351825E-06	1.9994146	.1220185	.9514802
19109	.16081333E-07	2.1455903	.1033647	.9672576
19110	.23024305E-06	1.9391520	.1304610	.9338290
19111	.11990721E-06	1.9699769	.1308357	.9373364
19112	.45236022E-05	1.6952961	.1774375	.8105580
29268	.86277497E-10	2.9466698	.20,53218	.9198686
29269	.11607347E-06	2.2659398	.3896108	.7907353
29270	.61867178E-11	3.2198116	.2807527	.8938151
29271	.20946839E-06	2.2164173	.5281838	.6155165
29272	.59424177E-11	3.1585320	.4074778	.7882865
29273	.12553733E-04	1.8397274	.4204946	.7136306
29274	.89570438E-08	2.5034309	.4162006	.7719002
29275	.11054672E-08	2.6728561	.3440075	.8728357
29276	.10707708E-07	2.4769194	.4156891	.7967076
29277	.55910756E-07	2.3380927	.4438817	.4258628
29278	.55586403E-13	3.5542191	.3983037	.8007372
29279	.28948460E-06	2.1496544	.4813331	.6420168
29280	.18813495E-06	2.1919073	.4552412	.5889671
29281	.49985323E-03	1.5281631	.3499253	.6514084
292	.84281794E-07	2.3073548	.3174431	.8457348

STATION CODE	COEFFICIENT	SLOPE	STANDARD ERROR OF ESTIMATE	CORRELATION COEFFICIENT
29200	.99579645E-04	1.4753040	.1175272	.8534334
29221	.91941208E-07	1.8993759	.1068157	.9258196
29222	.37302978E-05	1.7034554	.1956597	.8316986
29223	.23619398E-07	2.0459393	.1459092	.8850544
29231	.40760830E-08	2.2150166	.3103325	.8282184
29201	.89615785E-09	2.2521056	.2876218	.7865884
29202	.16264100E-14	3.1990126	.3002325	.8113896
29203	.76798354E-06	1.8759338	.2840011	.7617127
29204	.17684135E-03	1.5095372	.1587708	.8864494
29205	.82054203E-06	1.8584396	.2854511	.8134506
29206	.23354735E-09	2.4568474	.1785436	.9253882
29207	.14458702E-06	2.0084934	.2079536	.8921592
29208	.40371553E-08	2.2382790	.1247551	.9466342
29209	.25873556E-09	2.4291323	.1554380	.9211825
29210	.26673257E-09	2.4160838	.1174757	.9572456
29211	.96283724E-04	1.5131487	.1683524	.7838341
29212	.65802745E-03	1.3415532	.2370057	.5363882
29368	.68175658E-06	2.0852897	.1986796	.9188069
29369	.10025905E-07	2.4773870	.3580457	.8670099
29370	.12357803E-07	2.4934830	.3839405	.8207969
29371	.60111209E-08	2.5313496	.3889011	.8467486
29372	.28640707E-06	2.2040086	.2795046	.8578084
29373	.38419328E-07	2.3688486	.2659291	.9168335
29374	.16750935E-09	2.8650183	.3377690	.8853785
29375	.10215777E-07	2.4818884	.2437920	.9355729
29376	.61365337E-07	2.3100135	.3466237	.8926296
29377	.43614626E-03	1.4716163	.2838423	.7327065
29378	.13426959E-09	2.8741893	.3089773	.8914173
29379	.86341697E-09	2.6890487	.3982092	.8876945
29380	.17318995E-06	2.2484516	.2689122	.8518565
29381	.43838432E-08	2.5654747	.2469343	.8977375
293	.20400035E-07	2.4092200	.2821574	.9116508
29300	.28648597E-12	2.6272633	.0970478	.9663039
29321	.27655381E-07	1.9911704	.1036335	.9567754
29322	.19211781E-11	2.6064996	.0885149	.9827587
29323	.25277498E-11	2.5947529	.1758988	.9150439
29331	.24020774E-09	2.4138941	.2050233	.9471042
29301	.25531788E-11	2.7058932	.2931730	.8601406
29302	.52078981E-12	2.8478651	.2901763	.8433595
29303	.14806981E-10	2.6199547	.1444801	.9585012
29304	.18163518E-09	2.4300178	.0967659	.9801033
29305	.13946805E-09	2.4435101	.1627968	.9619060
29306	.28566457E-13	3.0355480	.1550196	.9668691
29307	.33948693E-09	2.3843488	.1679598	.9552889
29308	.17225890E-07	2.1067313	.1095154	.9639675
29309	.16617527E-06	1.9665784	.1551273	.9388564
29310	.79032306E-07	2.0157628	.1396731	.9510828
29311	.18162377E-05	1.7934739	.1412314	.9191896
29312	.49646886E-07	2.0390765	.1439000	.9092541

APPENDIX E. MEASURED AND CALCULATED LOADS
FOR THE MISSISSIPPI STATIONS

STATION: EAST DUBUQUE
ID: 191
DRAINAGE AREA: 81600. SQ. MILES

STATION CODE	TYPE	ANNUAL LOAD (TONS)	ANNUAL YIELD (TONS/SQ MI)	(TONS/ACRE)	TOTAL QW (CFS-DAYS)
19173	MEAS	7375086.	90.381	.141	26224600.
	ARE	6136413.	75.201	.118	
	POR	6960548.	85.301	.133	
	ALRE	9003610.	110.338	.172	
	SLRE	8218661.	100.719	.157	
	CMRE	8749533.	107.225	.168	
	IMRE	9253472.	113.400	.177	
19175	MEAS	4248893.	52.070	.081	18297600.
	ARE	4018958.	49.252	.077	
	POR	4121676.	50.511	.079	
	ALRE	4208857.	51.579	.081	
	SLRE	4493198.	55.064	.086	
	CMRE	5032587.	61.674	.096	
	IMRE	4409820.	54.042	.084	
19177	MEAS	664201.	8.140	.013	7960060.
	ARE	560605.	6.870	.011	
	POR	517960.	6.348	.010	
	ALRE	725196.	8.887	.014	
	SLRE	766458.	9.393	.015	
	CMRE	589063.	7.219	.011	
	IMRE	698297.	8.558	.013	

APPENDIX E. CONTINUED

STATION: BURLINGTON
ID: 292
DRAINAGE AREA: 113600. SQ. MILES

STATION CODE	TYPE	ANNUAL LOAD (TONS)	ANNUAL YIELD (TONS/SQ MI)	ANNUAL YIELD (TONS/ACRE)	TOTAL QW (CFS-DAYS)
29273	MEAS	18223924.	160.422	.251	45738220.
	ARE	13252890.	116.663	.182	
	POR	29286924.	257.807	.403	
	ALRE	19925591.	175.401	.274	
	SLRE	19996477.	176.025	.275	
	CMRE	24015240.	211.402	.330	
	IMRE	21843307.	192.283	.300	
29277	MEAS	2668957.	23.494	.037	14724212.
	ARE	1283779.	11.301	.018	
	POR	1609625.	14.169	.022	
	ALRE	3742803.	32.947	.051	
	SLRE	2686836.	23.6-52	.037	
	CMRE	1549696.	13.642	.021	
	IMRE	2049608.	18.042	.028	
29278	MEAS	13402784.	117.982	.184	30792610.
	ARE	11323007.	99.674	.156	
	POR	9966250.	87.731	.137	
	ALRE	11114902.	97.842	.153	
	SLRE	11178661.	98.404	.154	
	CMRE	8667987.	76.303	.119	
	IMRE	10117832.	89.065	.139	

APPENDIX E. CONCLUDED

STATION: KEOKUK
ID: 293
DRAINAGE AREA: 119000. SQ. MILES

STATION CODE	TYPE	ANNUAL LOAD (TONS)	ANNUAL YIELD (TONS/SQ MI)	(TONS/ACRE)	TOTAL QW (CFS-DAYS)
29371	MEAS	8652215.	72.708	.114	26302400.
	ARE	7248096.	60.908	.095	
	POR	5919535.	49.744	.078	
	ALRE	8940975.	75.134	.117	
	SLRE	9110629.	76.560	.120	
	CMRE	8361751.	70.267	.110	
	IMRE	8818256.	74.103	.116	
29373	MEAS	28854935.	242.478	.379	43272000.
	ARE	23549354.	197.894	.309	
	POR	20448369.	171.835	.268	
	ALRE	33069656.	277.896	.434	
	SLRE	33558955.	282.008	.441	
	CMRE	29044970.	244.075	.381	
	IMRE	31866097.	267.782	.418	
29377	MEAS	859781.	7.225	.011	11090600.
	ARE	681989.	5.731	.009	
	POR	681477.	5.727	.009	
	ALRE	924816.	7.772	.012	
	SLRE	994145.	8.354	.013	
	CMRE	953006.	8.008	.013	
	IMRE	991168.	8.329	.013	

APPENDIX F. STATISTICAL PARAMETERS FOR THE SEASONAL REGRESSION EQUATIONS

STATION CODE	COEFFICIENT*	SLOPE*	STANDARD ERROR OF ESTIMATE	CORRELATION COEFFICIENT
10521**	.0094777	1.4472527	.2893205	.7543044
10522	.0029142	1.6336769	.2474220	.9160575
10523	.0047507	1.6315312	.2594656	.8980084
10921	.0003188	1.8902427	.2337015	.8987792
10922	.0002341	1.8964842	.2206782	.9525532
10923	.0002803	1.9517046	.1673304	.9670733
11321	.0000008	2.4142515	.1950087	.8992504
11322	.0000299	2.0240790	.2146918	.9170581
11323	.0012843	1.6546337	.1693344	.8911895
11921	.0014415	1.7945491	.1835254	.8987252
11922	.0007290	1.9807231	.2545500	.9434058
11923	.0029851	1.8145095	.2906614	.9021091
12421	.0347953	1.0772306	.2611835	.7670329
12422	.0002309	1.7276361	.3518869	.9007860
12423	.0038516	1.4659236	.3097349	.8706301
12521	.0019386	1.4940083	.1956016	.8328122
12522	.0005562	1.6765023	.3029723	.8109951
12523	.0205657	1.2784571	.2265248	.8137180
22821	.0237199	1.2851955	.3194083	.8095030
22822	.0019423	1.9886470	.3962842	.9346244
22823	.0043484	1.9274375	.3370152	.9324373
23221	.0289743	1.1485998	.3359287	.8344833
23222	.0032265	1.5483167	.2837727	.9442828
23223	.0220182	1.4142724	.1845484	.9719944
23321	.0300888	1.2034488	.4354960	.8076158
23322	.0595667	1.1847000	.3448844	.8615635
23323	.1652571	1.1665598	.1803262	.9583276
23821	.0173029	1.6764543	.3811329	.8096222
23822	.0102793	1.8971165	.3909557	.8975555
23823	.0453640	1.6506840	.3149173	.8820062
23921	.0066232	1.9165694	.3659570	.8797535
23922	.0046995	2.0720574	.3861882	.9145717
23923	.0201684	1.8181366	.3235707	.9033838

APPENDIX F. CONCLUDED

STATION CODE	COEFFICIENT*	SLOPE*	STANDARD ERROR OF ESTIMATE	CORRELATION COEFFICIENT
24021**	.1570540	1.0047872	.3812188	.6929277
24022	.1057710	1.4233298	.3595278	.8858484
24023	.2850175	1.1727452	.2956117	.8653247
25521	.0180593	1.2369060	.4329232	.8494607
25522	.0063074	1.4803143	.4372854	.8707582
25523	.0821520	1.2002722	.2262886	.9602848
35621	.0046316	1.5895218	.4110307	.9087891
35622	.0064805	1.5385431	.3522490	.9186549
35623	.1052224	1.2109903	.2955172	.9366702
36421	.0474389	1.2366841	.3482474	.9274016
36422	.0205973	1.4615739	.3860554	.9361646
36423	.1399310	1.2214347	.3858802	.8956405
37321	.0152987	1.3304739	.4328979	.9040426
37322	.0473223	1.1858175	.2977958	.9299188
37323	.0406274	1.2742088	.2722791	.9213935
37921	.0082899	1.4044914	.3916676	.9241173
37922	.0660116	1.1934886	.3788559	.9051599
37923	.0250251	1.3859630	.2325732	.9496562

* THE GENERAL FORM OF THE REGRESSION EQUATION IS:
QS=COEFFICIENT*QW**SLOPE

** THE TWO DIGIT SUFFIX ON THE STATION CODE REFERS TO THE SEASON: 21=OCTOBER-JANUARY; 22=FEBRUARY-MAY; 23=JUNE-SEPTEMBER

APPENDIX G. CALCULATED AND MEASURED SEASONAL LOADS FOR ALL STATIONS (EXCLUDING THE ILLINOIS AND MISSISSIPPI RIVER MAINSTEM)

STATION CODE*	TYPE**	OCTOBER-JANUARY (TONS)	(%)	FEBRUARY-MAY (TONS)	(%)	JUNE-SEPTEMBER (TONS)	(%)
101.81	ARE	3239.	4.0	18025.	22.2	59995.	73.8
	POR	3094.	5.4	13383.	23.2	41220.	71.4
101.82	ARE	21209.	31.8	39313.	58.9	6222.	9.3
	POR	27278.	31.7	52214.	60.6	6668.	7.7
102.82	ARE	87988.	29.0	120780.	39.8	94717.	31.2
	POR	78654.	25.3	144150.	46.4	88064.	28.3
103.81	ARE	178469.	33.9	185901.	35.3	162035.	30.8
	POR	165879.	33.9	171047.	35.0	152182.	31.1
103.82	ARE	150127.	27.6	231093.	42.5	162423.	29.9
	POR	173833.	29.5	231035.	39.2	183810.	31.2
103.83	ARE	144164.	34.3	176779.	42.0	99920.	23.7
	POR	203734.	34.3	240370.	40.4	150678.	25.3
104.81	ARE	10918.	33.0	11468.	34.6	10750.	32.4
	POR	11983.	33.1	12567.	34.7	11676.	32.2
104.82	ARE	11384.	21.0	28199.	52.1	14577.	26.9
	POR	9758.	18.7	28998.	55.5	13488.	25.8
105.80	SRE	7984.		19526.		77776.	
	ARE	10169.	9.4	26672.	24.5	71852.	66.1
	POR	9783.	10.8	23496.	25.9	57535.	63.4
	MEAS	18569.	12.8	27590.	19.1	98626.	68.1
105.81	SRE	15690.		19628.		32059.	
	ARE	18952.	30.2	21728.	34.7	22005.	35.1
	POR	20670.	30.3	23688.	34.7	23943.	35.1
	MEAS	16337.	17.8	26826.	29.2	48592.	53.0
105.83	SRE	59355.		102350.		63718.	
	ARE	45636.	35.4	57854.	44.8	25524.	19.8
	POR	98563.	37.1	120368.	45.3	46867.	17.6
106.81	ARE	12100.	26.5	14594.	32.0	18958.	41.5
	POR	11919.	26.5	14377.	32.0	18681.	41.5
106.82	ARE	5693.	10.3	31459.	57.0	18017.	32.7
	POR	6200.	10.2	34691.	57.1	19856.	32.7
108.81	ARE	5841.	27.7	8817.	41.8	6421.	30.5
	POR	5841.	27.7	8817.	41.8	6421.	30.5

STATION CODE*	TYPE**	OCTOBER-JANUARY (TONS)	(%)	FEBRUARY-MAY (TONS)	(%)	JUNE-SEPTEMBER (TONS)	(%)
109.80	SRE	3408.		8324.		21266.	
	ARE	3689.	11.4	11804.	36.3	16999.	52.3
	POR	3369.	11.5	10601.	36.3	15248.	52.2
	MEAS	5158.	13.7	10025.	26.6	22446.	59.7
109.81	SRE	5248.		9692.		14189.	
	ARE	5338.	17.8	13560.	45.1	11161.	37.1
	POR	5195.	18.6	12358.	44.4	10307.	37.0
	MEAS	4710.	13.5	14859.	42.6	15316.	43.9
109.82	SRE	4379.		22270.		15849.	
	ARE	4200.	9.7	27931.	64.8	10991.	25.5
	POR	4366.	10.1	27909.	64.5	11022.	25.5
	MEAS	5687.	13.4	20570.	48.6	16102.	38.0
110.81	ARE	1341.	22.3	2049.	34.1	2620.	43.6
	POR	1402.	25.5	1952.	35.5	2148.	39.0
110.82	ARE	813.	17.3	3042.	64.6	851.	18.1
	POR	740.	14.2	3657.	70.1	823.	15.8
111.80	ARE	433.	6.0	1745.	24.2	5043.	69.8
	POR	432.	5.2	1899.	23.0	5927.	71.8
	MEAS	407.	4.4	3171.	34.3	5670.	61.3
111.81	ARE	1151.	17.5	2601.	39.6	2815.	42.9
	POR	1078.	19.4	2251.	40.6	2215.	40.0
	MEAS	833.	6.3	4622.	35.0	7768.	58.8
112.81	ARE	3271.	5.5	12983.	21.8	43268.	72.7
	POR	3145.	7.7	9696.	23.6	28231.	68.7
113.81	SRE	157427.		247690.		321432.	
	ARE	' 194765.	28.5	266415.	39.0	221817.	32.5
	POR	211329.	29.3	277444.	38.5	232748.	32.3
	MEAS	138918.	15.7	282503.	31.9	464435.	52.4
113.82	SRE	209756.		823689.		433216.	
	ARE	255883.	16.6	965484.	62.5	323712.	21.0
	POR	263601.	18.3	851007.	59.2	323873.	22.5
	MEAS	270095.	16.4	897780.	54.7	474713.	28.9
113.83	SRE	523266.		820772=		312576.	
	ARE	389269.	33.4	530823.	45.6	244382.	21.0
	POR	512715.	32.1	856585.	53.6	228870.	14.3
115.81	ARE	2222.	4.9	8790.	19.4	34390.	75.7
	POR	2222.	4.9	8790.	19.4	34390.	75.7

APPENDIX G. CONTINUED

STATION CODE*	TYPE**	OCTOBER-JANUARY (TONS)	(%)	FEBRUARY-MAY (TONS)	(%)	JUNE-SEPTEMBER (TONS)	(%)
116.81	ARE	6836.	8.6	21783.	27.5	50459.	63.8
	POR	6836.	8.6	21783.	27.5	50459.	63.8
117.81	ARE	45103.	23.2	76503.	39.3	72895.	37.5
	POR	45103.	23.2	76503.	39.3	72895.	37.5
118.81	ARE	1646.	1.6	26330.	25.1	76802.	73.3
	POR	1464.	1.7	22326.	25.7	63019.	72.6
118.82	ARE	4907.	6.4	30556.	39.8	41341.	53.8
	POR	5496.	5.4	39650.	38.8	57092.	55.8
118.83	ARE	24171.	34.1	45673.	64.5	957.	1.4
	POR	42228.	34.2	79205.	64.2	1988.	1.6
119.79	SRE	6499.		514109.		165991.	
	ARE	7682.	1.1	523962.	75.5	161910.	23.3
	POR	10153.	1.4	540450.	75.1	168907.	23.5
	MEAS	6970.	.9	603089.	78.7	156227.	20.4
119.80	SRE	9680.		47067.		51973.	
	ARE	21814.	16.2	61039.	45.3	51899.	38.5
	POR	17297.	16.2	43429.	45.3	41174.	38.5
	MEAS	21890.	11.1	81853.	41.7	92764.	47.2
119.81	SRE	10347.		76977.		187817.	
	ARE	18315.	4.7	107655.	27.8	260639.	67.4
	POR	17561.	6.4	79839.	29.0	177596.	64.6
	MEAS	10010.	1.8	239566..	42.1	318979.	56.1
119.83	SRE	60465.		253475.		24935.	
	ARE	91439.	33.0	163934.	59.2	21630.	7.8
	POR	138167.	32.8	264813.	62.8	18403.	4.4
120.80	ARE	992.	.5	65770.	36.0	116174.	63.5
	POR	562.	.4	50681.	34.5	95787.	65.1
	MEAS	1383.	.4	110576.	35.3	201444.	64.3
120.81	ARE	15192.	1.0	774352.	51.7	707354.	47.3
	POR	13294.	3.0	197370.	44.8	229512.	52.1
	MEAS	12419.	2.2	244517.	44.2	295806.	53.5
121.81	ARE	10127.	3.9	108090.	42.1	138380.	53.9
	POR	7223.	5.9	49415.	40.2	66198.	53.9
121.82	ARE	3695.	3.5	43637.	41.9	56924.	54.6
	POR	3447.	1.8	70580.	37.8	112535.	60.3

APPENDIX G. CONTINUED

STATION CODE*	TYPE**	OCTOBER-JANUARY (TONS)	(%)	FEBRUARY-MAY (TONS)	(%)	JUNE-SEPTEMBER (TONS)	(%)
122.81	ARE	5028.	.7	380028.	55.8	295780.	43.4
	POR	5648.	1.1	276248.	55.3	218082.	43.6
	MEAS	8244.	.9	348264.	39.0	536520.	60.1
123.81	ARE	12999.	9.4	73153.	52.8	52518.	37.9
	POR	11812.	10.1	61871.	52.6	43842.	37.3
123.82	ARE	19949.	14.9	107261.	79.9	7080.	5.3
	POR	20409.	13.0	130308.	82.7	6755.	4.3
123.83	ARE	25579.	46.2	28639.	51.7	1126.	2.0
	POR	112100.	54.5	92096.	44.8	1530.	.7
124.79	SRE	8632.		390317.		65763.	
	ARE	9767.	1.6	546934.	89.5	54531.	8.9
	POR	9396.	2.2	369629.	87.3	44436.	10.5
	MEAS	8295.	.9	772929.	82.9	151543.	16.2
124.80	SRE	17031.		108771.		130030.	
	ARE	32852.	10.2	160823.	49.9	128586.	39.9
	POR	26466.	11.0	120830.	50.0	94343.	39.0
	MEAS	25061.	3.7	148357.	21.9	504666.	74.4
124.81	SRE	17457.		245535.		254179.	
	ARE	26176.	2.8	570210.	60.3	349482.	36.9
	POR	27426.	6.1	241145.	53.3	183502.	40.6
	MEAS	19095.	1.4	690180.	50.5	656207.	48.1
124.82	SRE	36850.		452483.		78821.	
	ARE	68082.	13.9	375700.	76.5	47598.	9.7
	POR	77048.	13.9	423511.	76.4	53868.	9.7
	MEAS	46794.	6.0	653469.	83.2	85485.	10.9
124.83	SRE	67877.		249266.		61631.	
	ARE	119379.	54.8	91432.	42.0	7134.	3.3
	POR	236405.	44.3	255758.	47.9	41617.	7.8
125.79	SRE	6421.		106654.		21064.	
	ARE	8363.	8.2	81400.	80.2	11741.	11.6
	POR	9230.	7.1	107171.	82.6	13332.	10.3
	MEAS	6298.	4.0	129463.	82.1	21947.	13.9
125.80	SRE	12996.		40203.		32839.	
	ARE	20973.	21.9	49501.	51.7	25338.	26.4
	POR	18612.	21.3	45930.	52.6	22818.	26.1
	MEAS	14113.	11.6	62466.	51.5	44701.	36.9

STATION CODE*	TYPE**	OCTOBER-JANUARY (TONS)	(%)	FEBRUARY-MAY (TONS)	(%)	JUNE-SEPTEMBER (TONS)	(%)
125.81	SRE	13797.		70809.		92042.	
	ARE	14722.	8.3	81239.	45.8	81603.	46.0
	POR	19752.	11.6	75185.	44.1	75396.	44.3
	MEAS	11357.	3.5	135114.	41.4	180020.	55.1
125.82	SRE	26254.		125670.		32039.	
	ARE	57312.	24.7	137992.	59.4	36837.	15.9
	POR	37503.	20.4	124763.	67.7	21922.	11.9
125.83	SRE	37141.		87336.		31760.	
	ARE	49014.	32.3	78958.	52.0	23753.	15.7
	POR	52888.	31.9	91015.	54.9	21993.	13.3
126.81	ARE	1432.	1.1	36676.	27.2	96661.	71.7
	POR	1432.	1.1	36676.	27.2	96661.	71.7'
	MEAS	1001.	.7	53760.	38.7	84080.	60.6
127.81	ARE	9799.	2.7	188977.	51.9	165120.	45.4
	POR	9494.	2.7	182575.	51.9	159677.	45.4
203.80	ARE	3.	19.3	7.	41.7	6.	39.0
	POR	3.	18.8	7.	42.0	7.	39.2
	MEAS	1.	4.0	9.	26.6	25.	69.4
203.81	ARE	4.	8.7	16.	34.4	27.	56.9
	POR	5.	12.0	15.	39.1	19.	48.9
	MEAS	5.	.2	84.	3.4	2359.	96.3
204.80	ARE	5.	19.8	11.	42.8	10.	37.4
	POR	4.	19.2	10.	43.3	9.	37.5
	MEAS	6.	9.4	12.	18.4	47.	72.2
204.81	ARE	5.	5.1	24.	25.5	64.	69.4
	POR	6.	9.0	22.	33.5	37.	57.5
	MEAS	7.	.3	104.	3.7	2702.	96.0
228.79	SRE	716.		368862.		9814.	
	ARE	1878.	.7	255646.	96.8	6530.	2.5
	POR	1489.	.4	361033.	97.8	6464.	1.8
	MEAS	1679.	.4	354410.	93.5	23007.	6.1
228.80	SRE	328.		22759.		265816.	
	ARE	643.	.2	31874.	10.6	267929.	89.2
	POR	488.	.2	22860.	10.8	187721.	88.9
	MEAS	495.	.2	68094.	25.3	200216.	74.5

STATION CODE*	TYPE**	OCTOBER-JANUARY (TONS)	(%)	FEBRUARY-MAY (TONS)	(%)	JUNE-SEPTEMBER (TONS)	(%)
228.81	SRE	3004.		84296.		77481.	
	ARE	75215.	11.5	384768.	58.8	194671.	29.7
	POR	23127.	14.5	83539.	52.3	53087.	33.2
	MEAS	21329.	5.5	181316.	47.0	183154.	47.5
229.81	ARE	32120.	3.4	390120.	41.7	513722.	54.9
	POR	30592.	3.5	359120.	41.7	472224.	54.8
229.82	ARE	13654.	1.4	607771.	62.7	348575.	35.9
	POR	13945.	.9	926661.	62.2	548052.	36.8
229.83	ARE	250477.	39.8	371852.	59.1	7315.	1.2
	POR	587755.	39.9	877896.	59.5	8914.	.6
230.81	ARE	111.	3.2	1489.	43.0	1862.	53.8
	POR	138.	4.3	1405.	43.7	1673.	52.0
231.81	ARE	438.	.3	73369.	55.9	57555.	43.8
	POR	536.	.4	68948.	55.5	54805.	44.1
232.79	SRE	1439.		293623.		96842.	
	ARE	2336.	.5	391415.	86.3	60038.	13.2
	POR	2282.	.6	320260.	85.5	51909.	13.9
	MEAS	1666.	.3	408817.	73.2	148050.	26.5
232.80	SRE	4521.		85878.		184195.	
	ARE	8776.	6.5	67492.	50.1	58487.	43.4
	POR	10374.	4.8	103277.	47.9	102048.	47.3
	MEAS	3789.	1.0	81281.	22.3	279340.	76.7
232.81	SRE	3418.		149522.		190629.	
	ARE	6117.	1.5	260937.	65.3	132293.	33.1
	POR	7511.	2.7	170082.	60.7	102807.	36.7
	MEAS	3314.	.8	193338.	45.4	229056.	53.8
232.82	SRE	19047.		391314.		80970.	
	ARE	78528.	18.0	304090.	69.8	53133.	12.2
	POR	64568.	12.2	421906.	79.6	43439.	8.2
232.83	SRE	31136.		175432.		33382.	
	ARE	115845.	36.7	182151.	57.7	17892.	5.7
	POR	129361.	37.0	202654.	57.9	17703.	5.1
233.79	SRE	469.		41024.		19648.	
	ARE	716.	.9	67636.	86.1	10228.	13.0
	POR	1047.	1.7	51716.	82.5	9896.	15.8
	MEAS	409.	.4	61857.	66.4	30864.	33.1
233.80	SRE	2854.		22158.		34989.	
	ARE	4100.	13.3	16331.	52.9	10426.	33.8
	POR	6260.	12.0	27776.	53.2	18156.	34.8
	MEAS	1970.	2.9	20410.	29.7	46286.	67.4

STATION CODE*	TYPE**	OCTOBER-JANUARY (TONS)	(%)	FEBRUARY-MAY (TONS)	(%)	JUNE-SEPTEMBER (TONS)	(%)
233.81	SRE	2256.		27720.		40831.	
	ARE	8808.	11.9	38550.	52.3	26351.	35.7
	POR	4965.	8.2	34868.	57.4	20897.	34.4
233.82	SRE	6262.		56796.		14871.	
	ARE	16967.	21.7	51817.	66.3	9407.	12.0
	POR	13666.	14.7	71783.	77.2	7541.	8.1
233.83	SRE	10781.		36363.		7989.	
	ARE	24579.	32.8	44957.	59.9	5515.	7.3
	POR	23376.	32.0	45731.	62.6	3961.	5.4
234.81	ARE	520.	.6	45914.	51.4	42816.	48.0
	POR	520.	.6	45914.	51.4	42816.	48.0
235.81	ARE	172.	.8	7634.	37.2	12707.	61.9
	POR	172.	.8	7634.	37.2	12707.	61.9
236.81	ARE	3148.	.6	201946.	38.2	323632.	61.2
	POR	3410.	.7	195372.	38.4	310347.	61.0
238.76	SRE	300.		2361.		1390.	
	ARE	730.	14.4	3117.	61.6	1215.	24.0
	POR	431.	12.6	2092.	61.3	887.	26.0
	MEAS	1553.	10.0	9085.	58.5	4893.	31.5
238.77	SRE	55.		1063.		2699.	
	ARE	160.	1.9	2715.	32.1	5594.	66.1
	POR	79.	2.9	935.	34.2	1722.	63.0
	MEAS	145.	1.2	4585.	38.6	7135.	60.1
238.78	SRE	869.		4194.		849.	
	ARE	1009.	22.2	3105.	68.3	430.	9.5
	POR	1260.	24.7	3320.	65.1	524.	10.3
	MEAS	1569.	14.8	8083.	76.3	947.	8.9
238.79	SRE	107.		7330.		190.	
	ARE	102.	3.5.	2787.	94.1	73.	2.5
	POR	153.	2.6	5525.	95.4	110.	1.9
	MEAS	74.	.8	9356.	97.8	141.	1.5
238.80	SRE	59.		476.		5118.	
	ARE	59.	.8	545.	7.2	7005.	92.1
	POR	84.	2.1	505.	12.9	3334.	85.0
	MEAS	57.	.4	625.	4.3	13725.	95.3
239.76	SRE	655.		4999.		1104.	
	ARE	1594.	14.6	7907.	72.3	1428.	13.1
	POR	933.	14.6	4628.	72.3	836.	13.1
	MEAS	5016.	20.1	14706.	59.0	5190.	20.8

STATION CODE*	TYPE**	OCTOBER-JANUARY (TONS)	(%)	FEBRUARY-MAY (TONS)	(%)	JUNE-SEPTEMBER (TONS)	(%)
239.77	SRE	74.		2698.		4444.	
	ARE	192.	1.7	4515.	39.5	6711.	58.8
	POR	104.	1.7	2397.	39.6	3556.	58.7
	MEAS	356.	1.4	11149.	43.9	13903.	54.7
239.78	SRE	2220.		8772.		1552.	
	ARE	3046.	24.1	8348.	66.1	1226.	9.7
	POR	3172.	26.3	7690.	63.8	1186.	9.8
	MEAS	2414.	13.0	13832.	74.6	2305.	12.4
239.79	SRE	153.		14587.		323.	
	ARE	184.	1.8	9663.	96.4	175.	1.8
	POR	216.	1.7	12293.	96.7	210.	1.6
	MEAS	120.	.8	14169.	93.6	852.	5.6
239.80	SRE	57.		943.		10412.	
	ARE	69.	.5	1095.	7.2	13965.	92.3
	POR	80.	.8	967.	9.6	9031.	89.6
	MEAS	64.	.3	1563.	8.4	17028.	91.3
239.81	SRE	148.		2910.		6353.	
	ARE	201.	1.2	4873.	30.2	11050.	68.5
	POR	209.	2.6	2811.	35.3	4952.	62.1
	MEAS	133.	.6	8177.	38.8	12780.	60.6
239.82	SRE	127.		17538.		3328.	
	ARE	127.	.8	14350.	85.8	2248.	13.4
	POR	180.	1.1	14201.	84.1	2503.	14.8
	MEAS	107.	.4	16439.	69.3	7163.	30.2
239.83	SRE	7917.		17433.		904.	
	ARE	5135.	42.4	6377.	52.6	609.	5.0
	POR	11367.	43.8	13954.	53.8	635.	2.4
	MEAS	8677.	35.1	14710.	59.5	1326.	5.4
240.76	SRE	51.		368.		63.	
	ARE	80.	18.5	307.	70.6	47.	10.9
	POR	73.	16.7	325.	74.0	41.	9.3
	MEAS	123.	15.7	568.	73.0	88.	11.3
240.77	SRE	11.		99.		144.	
	ARE	24.	6,4	170.	46.4	172.	47.1
	POR	12.	6.0	91.	46.7	93.	47.3
	MEAS	22.	3.0	383.	52.1	330.	44.9
240.78	SRE	88.		427.		168.	
	ARE	164.	20.9	504.	64.5	114.	14.6
	POR	144.	23.4	361.	58.9	108.	17.7
	MEAS	178.	17.6	626.	62.2	203.	20.2

APPENDIX G. CONTINUED

STATION CODE*	TYPE**	OCTOBER-JANUARY (TONS)	(%)	FEBRUARY-MAY (TONS)	(%)	JUNE-SEPTEMBER (TONS)	(%)
240.79	SRE	61.		487.		102.	
	ARE	63.	9.9	527.	82.0	52.	8.1
	POR	88.	15.6	409.	72.6	66.	11.7
	MEAS	61.	6.2	841.	84.5	92.	9.3
240.80	SRE	25.		85.		176.	
	ARE	24.	7.4	114.	34.8	190.	57.8
	POR	32.	13.2	98.	40.3	113.	46.4
	MEAS	40.	9.2	115.	26.1	286.	64.7
241.81	ARE	36260.	1.7	724327.	33.4	1406376.	64.9
	POR	36260.	1.7	724327.	33.4	1406376.	64.9
	MEAS	28350.	1.4	886731.	43.3	1134184.	55.3
242.81	ARE	8025.	1.2	199700.	28.8	484553.	70.0
	POR	7075.	1.2	169225.	29.1	405969.	69.7
242.82	ARE	20028.	4.6	331120.	76.3	82774.	19.1
	POR	27424.	6.2	319660.	72.7	92380.	21.0
242.83	ARE	54801.	47.1	58660.	50.4	2949.	2.5
	POR	329907.	49.6	328892.	49.4	6609.	1.0
243.81	ARE	17082.	2.5	180276.	26.3	487507.	71.2
	POR	16932.	2.5	178519.	26.3	482665.	71.2
244.81	ARE	150.	.5	18456.	59.0	12688.	40.5
	POR	150.	.5	18456.	59.0	12688.	40.5
	MEAS	269.	.3	38960.	48.7	40812.	51.0
245.81	ARE	23962.	1.2	713751.	34.8	1313010.	64.0
	POR	23962.	1.2	713751.	34.8	1313010.	64.0
	MEAS	26834.	1.5	556075.	31.4	1189005.	67.1
246.81	ARE	3275.	.1	718497.	26.5	1991944.	73.4
	POR	3275.	.1	718497.	26.5	1991944.	73.4
	MEAS	3382.	.1	834592.	29.6	1977139.	70.2
247.81	ARE	3957.	.2	388533.	21.9	1379056.	77.8
	POR	4140.	.3	281947.	23.3	924624.	76.4
247.82	ARE	43850.	4.6	786771.	82.4	123701.	13.0
	POR	37432.	4.1	754526..	83.5	111513.	12.3
247.83	ARE	367262.	46.6	359530.	45.6	60927.	7.7
	POR	547746.	47.9	514542.	45.0	82354.	7.2
248.81	ARE	401.	.7	16766.	27.7	43468.	71.7
	POR	306.	.5	15185.	27.1	40592.	72.4

STATION CODE*	TYPE**	OCTOBER-JANUARY (TONS)	(%)	FEBRUARY-MAY (TONS)	(%)	JUNE-SEPTEMBER (TONS)	(%)
248.82	ARE	2702.	9.8	21996.	79.9	2815.	10.2
	POR	3904.	6.8	49239.	85.2	4660.	8.1
248.83	ARE	8553.	38.9	11678.	53.1	1767.	8.0
	POR	17774.	40.3	23263.	52.7	3076.	7.0
249.81	ARE	798.	.6	58355.	40.2	85876.	59.2
	POR	781.	.8	41264.	40.2	60541.	59.0
249.82	ARE	13785.	19.1	50259.	69.8	7960.	11.1
	POR	14807.	14.8	76489.	76.4	8816.	8.8
249.83	ARE	17023.	23.6	43183.	59.9	11882.	16.5
	POR	20323.	23.8	50919.	59.6	14166.	16.6
250.81	ARE	46.	.1	8336.	21.1	31169.	78.8
	POR	47.	.1	8235.	21.2	30623.	78.7
250.82	ARE	3411.	12.5	19324.	70.9	4503.	16.5
	POR	3937.	11.4	25081.	72.5	5598.	16.2
251.81	ARE	571.	.1	234874.	49.9	235212.	50.0
	POR	571.	.1	234874.	49.9	235212.	50.0
253.81	SRE	660850.		1678018.		4629092.	
	ARE	686388.	11.1	2122918.	34.4	3368366.	54.5
	POR	709843.	12.5	1944357.	34.3	3020828.	53.2
	MEAS	890950.	12.1	3249088.	44.2	3210510.	43.7
253.82	SRE	920563.		2889888.		2116181.	
	ARE	1045292.	15.2	4134230.	60.3	1681715.	24.5
	POR	986180.	15.2	3925345.	60.4	1590403.	24.5
	MEAS	1291920.	14.3	3970520.	44.0	3756130.	41.6
253.83	SRE	2482619.		2615626.		1294058.	
	ARE	1770197.	36.5	2297469.	47.4	782540.	16.1
	POR	2623290.	36.9	3433317.	48.4	1044009.	14.7
	MEAS	2629000.	43.9	2130890.	35.6	1226000.	20.5
254.81	ARE	258.	.2	58866.	36.9	100343.	62.9
	POR	244.	.2	54367.	36.9	92840.	63.0
254.82	ARE	14229.	8.4	111389.	65.7	44012.	25.9
	POR	25989.	7.2	242933.	67.4	91268.	25.3
255.80	SRE	256.		6535.		4018.	
	ARE	436.	4.4	7390.	74.9	2038.	20.7
	POR	473.	4.8	7261.	74.2	2055.	21.0
	MEAS	260.	2.3	6917.	60.4	4283.	37.4

STATION CODE*	TYPE**	OCTOBER-JANUARY (TONS)	(%)	FEBRUARY-MAY (TONS)	(%)	JUNE-SEPTEMBER (TONS)	(%)
255.81	SRE	322.		14207.		23910.	
	ARE	370.	.9	22549.	52.6	19980.	46.6
	POR	596.	2.2	13276.	49.6	12896.	48.2
	MEAS	244.	.6	23960.	54.3	19933.	45.2
255.82	SRE	2891.		33674.		18055.	
	ARE	3526.	16.2	12928.	59.4	5311.	24.4
	POR	5465.	13.0	26733.	63.6	9896.	23.5
	MEAS	3073.	10.0	11941.	38.7	15845.	51.3
255.83	SRE	6235.		25761.		5721.	
	ARE	10660.	32.7	18684.	57.3	3253.	10.0
	POR	11901.	32.3	22019.	59.7	2978.	8.1
	MEAS	7157.	10.1	55907.	78.9	7790.	11.0
356.80	SRE	1845.		17291.		8262.	
	ARE	2872.	8.5	24503.	73.0	6213.	18.5
	POR	2570.	9.1	20369.	72.1	5293.	18.7
	MEAS	1286.	2.7	21434.	45.1	24852.	52.2
356.81	SRE	384.		36299.		48165.	
	ARE	513.	.5	49424.	51.4	46189.	48.1
	POR	660.	.9	39094.	50.5	37591.	48.6
	MEAS	555.	.5	49919.	45.1	60125.	54.4
356.82	SRE	7797.		61703.		39459.	
	ARE	10701.	14.1	41844.	55.2	23298.	30.7
	POR	9956.	9.4	63252.	60.0	32180.	30.5
	MEAS	9059.	9.3	38525.	39.5	49899.	51.2
357.81	ARE	1334.	.5	133563.	54.1	111801.	45.3
	POR	1296.	.6	117536.	53.9	99244.	45.5
357.82	ARE	54260.	17.3	196990.	62.7	62929.	20.0
	POR	72871.	15.9	300963.	65.5	85839.	18.7
358.81	ARE	7340.	4.6	40271.	25.0	113457.	70.4
	POR	6875.	4.4	38695.	24.9	109931.	70.7
359.81	ARE	80.	.0	109835.	11.6	840576.	88.4
	POR	80.	.0	109835.	11.6	840576.	88.4
360.81	ARE	169.	.6	11683.	40.8	16749.	58.6
	POR	169.	.6	11683.	40.8	16749.	58.6
361.81	ARE	9299.	2.4	118176.	31.0	254030.	66.6
	POR	8901.	3.0	90828.	30.6	197416.	66.4
361.82	ARE	87621.	16.2	374542.	69.1	80214.	14.8
	POR	150318.	14.1	776724.	73.1	135390.	12.7

STATION CODE*	TYPE**	OCTOBER-JANUARY (TONS)	(%)	FEBRUARY-MAY (TONS)	(%)	JUNE-SEPTEMBER (TONS)	(%)
361.83	ARE	161208.	45.6	119425.	33.8	73062.	20.7
	POR	591698.	51.7	370120.	32.4	181950.	15.9
362.81	ARE	2814.	.4	391882.	53.0	345048.	46.6
	POR	2775.	.5	295586.	52.4	265889.	47.1
362.82	ARE	103239.	14.7	500082.	71.3	97927.	14.0
	POR	218594.	12.8	1287865.	75.4	200937.	11.8
362.83	ARE	276355.	49.1	228208.	40.6	57816.	10.3
	POR	713885.	52.3	520915.	38.2	129028.	9.5
363.81	ARE	367.	.5	38801.	55.8	30328.	43.6
	POR	321.	.7	25694.	56.1	19824.	43.2
363.82	ARE	23389.	19.2	86220.	70.7	12289.	10.1
	POR	23677.	19.2	86882.	70.6	12463.	10.1
363.83	ARE	34056.	44.8	30349.	40.0	11548.	15.2
	POR	55265.	46.0	46566.	38.7	18420.	15.3
364.78	SRE	21262.		209526.		5865.	
	ARE	31073.	22.9	101480.	74.8	3175.	2.3
	POR	46869.	22.3	159420.	75.8	3949.	1.9
	MEAS	55393.	36.8	88511.	58.7	6768.	4.5
364.79	SRE	4855.		256614.		74780.	
	ARE	7857.	4.4	126916.	71.0	44074.	24.6
	POR	9529.	3.5	192228.	71.4	67439.	25.1
	MEAS	20947.	6.2	266390.	78.3	52875.	15.5
364.80	SRE	1161.		61793.		14719.	
	ARE	2401.	2.4	82608.	83.2	14226.	14.3
	POR	2122.	3.2	53043.	80.3	10863.	16.5
	MEAS	984.	.7	112680.	78.1	30643.	21.2
364.81	SRE	230.		25859.		43620.	
	ARE	303.	.2	47105.	38.6	74477.	61.1
	POR	352.	.6	24033.	40.4	35147.	59.0
	MEAS	203.	.2	50977.	38.5	81206.	61.3
365.81	ARE	359.	1.9	8640.	44.7	10348.	53.5
	POR	343.	1.9	7939.	44.7	9488.	53.4
366.81	ARE	600.	.3	63056.	36.7	108387.	63.0
	POR	520.	.6	32084.	36.8	54614.	62.6
366.82	ARE	27103.	5.1	393001.	74.6	106778.	20.3
	POR	27855.	5.2	399688.	74.4	109320.	20.4
366.83	ARE	238437.	48.5	229662.	46.7	23543.	4.8
	POR	372902.	49i0	353564.	46.4	35197.	4.6

APPENDIX G. CONTINUED

STATION CODE*	TYPE**	OCTOBER-JANUARY (TONS)	(%)	FEBRUARY-MAY (TONS)	(%)	JUNE-SEPTEMBER (TONS)	(%)
367.81	ARE	182.	.1	33823.	19.3	140965.	80.6
	POR	175.	.2	15888.	20.3	62015.	79.4
367.82	ARE	27187.	7.2	276341.	73.7	71636.	19.1
	POR	34094.	8.8	272321.	70.3	80897.	20.9
367.83	ARE	60736.	45.7	59589.	44.8	12637.	9.5
	POR	372980.	47.6	339368.	43.3	71314.	9.1
368.81	ARE	14.	.1	11109.	60.2	7317.	39.7
	POR	14.	.1	11109.	60.2	7317.	39.7
370.81	ARE	1240.	.6	113668.	55.7	88983.	43.6
	POR	1176.	.6	108406.	55.8	84795.	43.6
370.82	ARE	112859.	19.6	390375.	67.9	71343.	12.4
	POR	126646.	19.3	452985.	68.9	77568.	11.8
370.83	ARE	514584.	41.8	639539.	52.0	76580.	6.2
	POR	499206.	41.1	632739.	52.1	82028.	6.8
371.81	ARE	1168.	3.5	11218.	33.8	20794.	62.7
	POR	1002.	4.2	7957.	33.3	14928.	62.5
371.82	ARE	7059.	14.9	32023.	67.6	8307.	17.5
	POR	8171.	15.0	36557.	67.1	9760.	17.9
373.81	SRE	995.		32583.		121432.	
	ARE	1032.	.5	73371.	32.7	150078.	66.9
	POR	1460.	1.2	41056.	32.4	84066.	66.4
	MEAS	923.	.5	68533.	37.4	113812.	62.1
373.82	SRE	30669.		120631.		38981.	
	ARE	40913.	16.7	171757.	69.9	33022.	13.4
	POR	35679.	16.2	157126.	71.4	27380.	12.4
	MEAS	100584.	32.7	134553.	43.7	72908.	23.7
373.83	SRE	160247.		218011.		30973.	
	ARE	108040.	35.3	178901.	58.5	18699.	6.1
	POR	173035.	35.3	295218.	60.3	21711.	4.4
	MEAS	154811.	34.2	250125.	55.3	47466.	10.5
375.81	ARE	8.	.3	2007.	78.5	543.	21.2
	POR	7.	.3	1897.	78.5	513.	21.2
	MEAS	46.	.2	20194.	87.0	2961.	12.8
376.80	ARE	4677.	26.8	12009.	68.8	778.	4.5
	POR	4636.	26.9	11825.	68.6	781.	4.5
	MEAS	6710.	29.2	13203.	57.5	3067.	13.3

APPENDIX G. CONCLUDED

STATION CODE*	TYPE**	OCTOBER-JANUARY (TONS)	(%)	FEBRUARY-MAY (TONS)	(%)	JUNE-SEPTEMBER (TONS)	(%)
376.81	ARE	26.	.1	21254.	65.4	11204.	34.5
	POR	22.	.1	24084.	66.3	12233.	33.7
	MEAS	43.	.1	40343.	70.6	16753.	29.3
377.81	ARE	1.	.1	877.	72.8	327.	27.2
	POR	0.	.1	565.	72.7	212.	27.2
	MEAS	1.	.0	10029.	81.3	2237.	18.2
378.81	ARE	188.	.4	18713.	40.7	27036.	58.9
	POR	154.	.4	15330.	40.7	22154.	58.9
378.82	ARE	25246.	24.4	69790.	67.3	8639.	8.3
	POR	17070.	24.7	44850.	64.8	7314.	10.6
378.83	ARE	15586.	40.7	19439.	50.8	3252.	8.5
	POR	71634.	42.0	85692.	50.3	13131.	7.7
379.81	SRE	8940.		50808.		236746.	
	ARE	15011.	5.6	66264.	24.6	188040.	69.8
	POR	15217.	7.1	54534.	25.5	144206.	67.4
	MEAS	7765.	1.8	146267.	34.0	276557.	64.2
379.82	SRE	73841.		499983.		239454.	
	ARE	116807.	15.3	506515.	66.2	142228.	18.6
	POR	116178.	12.3	683342.	72.4	144722.	15.3
	MEAS	168453.	17.0	377264.	38.1	445072.	44.9
379.83	SRE	389119.		316757.		210293.	
	ARE	428436.	49.7	325184.	37.7	107954.	12.5
	POR	548793.	51.0	400798.	37.2	126515.	11.8
	MEAS	344936.	34.1	463189.	45.8	202863.	20.1
444.81	ARE	162.	1.1	8196.	57.8	5830.	41.1
	POR	162.	1.1	8196.	57.8	5830.	41.1
	MEAS	158.	.4	12760.	33.7	24950.	65.9

* THE FIVE-DIGIT STATION CODE CONSISTS OF THE STATION NUMBER FOLLOWED BY A DECIMAL POINT AND THEN THE WATER YEAR

** THE TYPE CODES ARE AS FOLLOWS:

SRE = SEASONAL REGRESSION EQUATION
ARE = ANNUAL REGRESSION EQUATION
POR = PERIOD OF RECORD REGRESSION EQUATION
MEAS = MEASURED LOAD

APPENDIX H. STATISTICAL PARAMETERS FOR THE PERIOD OF RECORD AND ANNUAL REGRESSION EQUATIONS FOR EIGHT MIDWEST GAGING STATIONS

STATION CODE*	COEFFICIENT**	SLOPE**	STANDARD ERROR OF ESTIMATE	CORRELATION COEFFICIENT
901	.0306446	1.3338921	.4098017	.9199028
90155	. .0616438	1.1884395	.5352402	.8478441
90156	.0387336	1.3414737	.5347322	.8280392
90157	.0206596	1.4121416	.4295590	.9248472
90158	.0082736	1.5364985	.3588379	.9129175
90159	.0509302	1.2660575	.4476617	.9060954
90160	.0653155	1.2246794	.4873908	.8515943
90161	.0373840	1.2663176	.3377067	.9449325
90162	.0093478	1.4693223	.2725733	.9625443
90163	.0077827	1.5954979	.0893170	.9957859
90164	.0105220	1.5517582	.0877013	.9972684
90165	.0436662	1.2764174	.2914532	.9558447
90166	.0816133	1.1448917	.3611523	.8623734
90167	.0931883	1.1523561	.4164332	.9118380
902	.0034606	1.5230238	.3092294	.9148842
90268	.0011823	1.6711822	.2901868	.9397088
90269	.0120675	1.3761817	.2507860	.9128350
90270	.0035664	1.5069608	.3037143	.8975700
90271	.0158173	1.3511464	.2518816	.8993122
90272	.0047357	1.4818606	.2725551	.9208033
90273	.0054864	1.4507540	.3487056	.8674653
90274	.004.4863	1.4878164	.3301196	.8861909
90275	.0075788	1.4092209	.2194764	.9518615
90276	.0098955	1.3668358	.2348588	.9274206
90277	.0001160	2.0118619	.3718839	.9220999
903	.0093486	1.4494462	.4433541	.8691541
90344	.0000205	2.3521801	.3640355	.9481869
90345	.0000687	2.1854589	.3010939	.9614597
90346	.0000759	2.1653469	.4086548	.8970481
90347	.0001908	2.0108188	.3450600	.9435741
90348	.0019645	1.7756521	.3068403	.9379667
90349	.0065463	1.6061129	.3544060	.9133116
90350	.0025316	1.7675116	.2975383	.9583487
90351	.0024823	1.7182158	.2978542	.9704088
90352	.0013552	1.7639524	.4421654	.8341386
90353	.0022646	1.8019565	.3782290	.9248831
90354	.0021273	1.8176942	.3469985	.9485103
90355	.0040827	1.6527151	.3589706	.8729409
90356	.0145745	1.5576681	.3028804	.8916445
90357	.0052115	1.6791966	.2282229	.9577213

STATION CODE*	COEFFICIENT**	SLOPE**	STANDARD ERROR OF ESTIMATE	CORRELATION COEFFICIENT
90358	.0001706	2.0929053	.4099937	.8979962
90359	.0039815	1.6227168	.3836623	.9246499
90360	.0021342	1.5838492	.4197872	.8554032
90361	.0110999	1.4086808	.3516733	.8847918
90362	.0003366	1.7641971	.4331111	.7971238
90363	.0018471	1.6453599	.3322235	.8865725
90364	.0019853	1.6974498	.3615257	.8706067
90365	.0065184	1.4743556	.4433745	.8790052
90366	.0220198	1.2966675	.4344321	.7536616
90367	.0029069	1.6414242	.3800858	.8771952
90368	.0030382	1.5874142	.3823955	.7819133
90369	.0031397	1.5156552	.3736892	.9002664
90370	.0018760	1.6580653	.3054630	.8797717
90371	.0091021	1.4433271	.2744007	.9185756
90372	.0017965	1.6632950	.4112579	.8974863
90373	.0270989	1.2521864	.3089387	.8431524
90374	.0011849	1.6640642	.3930900	.8034255
90375	.0120083	1.3547335	.2428002	.9185677
90376	.0088726	1.4344596	.2788600	.9339350
90377	.0127833	1.3509719	.4296067	.8364365
90378	.0004684	1.7818906	.2986150	.9030791
90379	.0006350	1.6897408	.3830261	.8376824
90380	.0099279	1.4096680	.3623632	.7872809
90381	.0020826	1.6950790	.2770489	.9051322
90382	.0005806	1.7087857	.3757081	.8824997
90383	.0208694	1.2312980	.3041070	.8237143
904	.0011340	1.8190863	.4640573	.9203771
90477	.0102372	1.5753786	.2931166	.9564745
90478	.0000223	2.3102621	.4523506	.9158241
90479	.0000192	2.2806918	.5074134	.8846590
90480	.0000399	2.3055719	.3724399	.9181079
90481	.0000970	2.2141026	.3815004	.9419619
90482	.0000220	2.3093548	.3765958	.9571899
90483	.0005283	1.8902783	.2821650	.9430332
905	.0001668	1.8485173	.3285024	.9416266
90554	.0000721	2.0378461	.2754208	.9521688
90555	.0000115	2.1864376	.3155883	.9630364
90556	.0000687	1.9886014	.2901951	.9659940
90557	.0000670	1.9639094	.3504421	.9456901
90558	.0000414	2.0093091	.2721984	.9573210

APPENDIX H. CONTINUED

STATION CODE*	COEFFICIENT**	SLOPE**	STANDARD ERROR OF ESTIMATE	CORRELATION COEFFICIENT
90559	.0000699	1.9492551	.3105128	.9445034
90560	.0001417	1.8687922	.2647649	.9467401
90561	.0001315	1.8993915	.3207309	.9560225
90562	.0001337	1.8656627	.2487327	.9634629
90563	.0001912	1.8129699	.2729207	.9534973
90564	.0002193	1.7924096	.2972635	.9643277
90565	.0000842	1.9592360	.2691717	.9637768
90566	.0000836	1.9077762	.3189613	.9171441
90567	.0004216	1.7145722	.2461742	.9613358
90568	.0001285	1.8850399	.2999478	.9382630
90569	.0002660	1.8056640	.2975632	.9289646
90570	.0004834	1.7268300	.3049239	.9278622
90571	.0015205	1.6134060	.3332049	.8814160
90572	.0009725	1.6574153	.2799944	.9297877
90573	.0006479	1.6693163	.3254720	.8857094
90574	.0015677	1.5649323	.3800073	.8529213
90579	.0002809	1.7874776	.3735810	.8879280
90580	.0000018	2.3440604	.3977627	.8788953
90581	.0000435	1.9982750	.3354828	.9219296
90582	.0006135	1.7009366	.3350771	.9127793
906	.0044400	1.5351594	.3833038	.9184328
90664	.0060982	1.4706688	.3775053	.9348235
90665	.0024306	1.6468746	.3535260	.9423435
90666	.0135131	1.3088103	.4710552	.7716152
90667	.0087841	1.3696865	.4238969	.8876461
90668	.0023617	1.6117791	.3988020	.8953940
90669	.0032206	1.6097608	.2864226	.9324733
90670	.0066823	1.4204941	.4200528	.8634799
90671	.0076660	1.4895477	.3074294	.9221921
90672	.0024969	1.6507882	.3468800	.9295339
90673	.0035694	1.5988702	.3723599	.8932628
90674	.0033092	1.5811461	.3344901	.9298819
90675	.0018533	1.6990497	.3322795	.9367049
907	.0013271	1.5931596	.3013933	.9534992
90766	.0012956	1.5606947	.2288928	.9653124
90767	.0024784	1.4933409	.3190864	.9580802
90768	.0002673	1.7740025	.2124671	.9762947
90769	.0013105	1.5773842	.2977979	.9526616
90770	.0013241	1.5890748	.3670294	.9288633
90771	.0017766	1.5505167	.2179768	.9636953

STATION CODE*	COEFFICIENT**	SLOPE**	STANDARD ERROR OF ESTIMATE	CORRELATION COEFFICIENT
90772	.0008099	1.6874213	.2743367	.9609082
90773	.0058124	1.4307485	.2944880	.9328193
90774	.0063338	1.4397660	.2970502	.9535881
90775	.0009737	1.6823778	.2750884	.9565431
90776	.0091828	1.3653149	.2853650	.9397834
90777	.0001732	1.8394491	.3546724	.9533963
90778	.0016583	1.5431762	.2199759	.9746445
90779	.0012743	1.5986732	.2273070	.9704563
90780	.0011142	1.6211490	.2763974	.9523085
90781	.0006651	1.6675569	.3748828	.9292838
90782	.0019512	1.5393753	.1601493	.9856403
90783	.0015663	1.5709537	.2749839	.9632664
908	.0000191	2.3245083	.3222754	.9317636
90877	.0000074	2.4989932	.3520755	.9325765
90878	.0000112	2.3757537	.3052372	.9428327
90879	.0000138	2.3806372	.3130937	.9373758
90880	.0000195	2.3288567	.2704973	.9410164
90881	.0000082	2.4705465	.2757974	.9475919
90882	.0000535	2.1539091	.3461581	.9144432
90883	.0000423	2.2010575	.3444270	.9225156

* THE THREE-DIGIT STATION CODE IDENTIFIES THE LINE WITH THE STATION'S PERIOD OF RECORD STATISTICS; THE FIVE-DIGIT STATION CODE INDICATES THE APPROPRIATE WATER YEAR STATISTICS (I.E. 90155 REPRESENTS STATION 901, WATER YEAR 1955)

** THE GENERAL FORM OF THE REGRESSION EQUATION IS:

QS=COEFFICIENT*QW**SLOPE

APPENDIX I. CROSS CORRELATION COEFFICIENTS

	ID	DA	AQWV	PRECIP	PRECIPV	QWDA
ID	1.00000	-0.04590	0.02095	0.67650	-0.01427	0.52206
	0.0000	0.7210	0.8705	0.0001	0.9116	0.0001
DA	-0.04590	1.00000	0.99228	-0.19640	0.99892	-0.32339
	0.7210	0.0000	0.0001	0.1229	0.0001	0.0097
AQWV	0.02095	0.99228	1.00000	-0.10259	0.99557	-0.20350
	0.8705	0.0001	0.0000	0.4237	0.0001	0.1097
PRECIP	0.67650	-0.19640	-0.10259	1.00000	-0.15070	0.76750
	0.0001	0.1229	0.4237	0.0000	0.2384	0.0001
PRECIPV	-0.01427	0.99892	0.99557	-0.15070	1.00000	-0.28974
	0.9116	0.0001	0.0001	0.2384	0.0000	0.0213
QWDA	0.52206	-0.32339	-0.20350	0.76750	-0.28974	1.00000
	0.0001	0.0097	0.1097	0.0001	0.0213	0.0000
SO	0.04775	0.81792	0.80159	-0.14450	0.81780	-0.34089
	0.7102	0.0001	0.0001	0.2585	0.0001	0.0063
NU	-0.03353	0.90309	0.89914	-0.13458	0.90415	-0.26898
	0.7942	0.0001	0.0001	0.2930	0.0001	0.0330
LA	0.07990	0.27043	0.26889	-0.05352	0.27012	-0.08327
	0.5336	0.0321	0.0331	0.6770	0.0323	0.5164
LU	-0.03801	0.94244	0.93053	-0.16518	0.94237	-0.34009
	0.7674	0.0001	0.0001	0.1958	0.0001	0.0064
DD	0.01275	-0.07031	-0.08402	0.06753	-0.06769	-0.08601
	0.9210	0.5840	0.5127	0.5990	0.5981	0.5027
H	-0.01780	0.32188	0.34191	0.15797	0.33200	0.06767
	0.8899	0.0101	0.0061	0.2163	0.0079	0.5982
HA	-0.14077	0.44659	0.45573	-0.04463	0.44814	-0.04839
	0.2711	0.0002	0.0002	0.7284	0.0002	0.7065
RR	-0.01812	-0.69309	-0.67381	0.28373	-0.68536	0.33034
	0.8879	0.0001	0.0001	0.0242	0.0001	0.0082
BS	0.20650	0.04885	0.05328	0.10084	0.05402	0.02084
	0.1044	0.7038	0.6784	0.4317	0.6741	0.8712
LB	0.00520	0.93636	0.93211	-0.16625	0.93619	-0.28005
	0.9677	0.0001	0.0001	0.1928	0.0001	0.0262
LS	0.03600	0.94824	0.94766	-0.11334	0.95067	-0.25518
	0.7794	0.0001	0.0001	0.3764	0.0001	0.0435
F	0.04096	-0.22558	-0.21513	0.15195	-0.22024	0.13932
	0.7499	0.0755	0.0904	0.2345	0.0828	0.2762
CR1	0.11493	-0.36908	-0.35653	0.17772	-0.36370	0.19327
	0.3697	0.0029	0.0041	0.1635	0.0034	0.1291
CR2	0.13035	-0.06167	-0.04298	0.11834	-0.05658	0.15889
	0.3086	0.6311	0.7380	0.3556	0.6596	0.2136
CR3	0.38772	-0.08778	-0.07633	0.12506	-0.08259	0.11056
	0.0017	0.4939	0.5521	0.3288	0.5199	0.3883
SS	0.33389	0.28488	0.32220	0.20782	0.29705	0.20931
	0.0075	0.0236	0.0100	0.1022	0.0181	0.0997
I	-0.14833	0.55585	0.51011	-0.27972	0.54719	-0.49590
	0.2460	0.0001	0.0001	0.0264	0.0001	0.0001
WS	0.02067	0.92350	0.93652	-0.09701	0.92650	-0.14495
	0.8722	0.0001	0.0001	0.4494	0.0001	0.2570
DS	0.42064	0.75354	0.77719	0.15660	0.76714	-0.01889
	0.0006	0.0001	0.0001	0.2203	0.0001	0.8832
VS	-0.32496	0.49701	0.47495	-0.30361	0.48673	-0.29975
	0.0094	0.0001	0.0001	0.0156	0.0001	0.0170
TOK	-0.34101	0.29803	0.26021	-0.36387	0.28327	-0.36731
	0.0062	0.0177	0.0394	0.0034	0.0245	0.0031
PROD	-0.24235	0.18777	0.17234	-0.22420	0.17870	-0.16731
	0.0557	0.1406	0.1768	0.0773	0.1611	0.1900
EROS	0.07196	-0.44355	-0.41937	0.09133	-0.44287	0.30174
	0.5752	0.0003	0.0006	0.4765	0.0003	0.0162
AASL	0.08640	0.80531	0.77814	-0.21088	0.80195	-0.42024
	0.5008	0.0001	0.0001	0.0971	0.0001	0.0006

	SO	NU	LA	LU	DD	H
ID	0.04775	-0.03353	0.07990	-0.03801	0.01275	-0.01780
	0.7102	0.7942	0.5336	0.7674	0.9210	0.8899
DA	0.81792	0.90309	0.27043	0.94244	-0.07031	0.32188
	0.0001	0.0001	0.0321	0.0001	0.5840	0.0101
AQWV	0.80159	0.89914	0.26889	0.93053	-0.08402	0.34191
	0.0001	0.0001	0.0331	0.0001	0.5127	0.0061
PRECIP	-0.14450	-0.13458	-0.05352	-0.16518	0.06753	0.15797
	0.2585	0.2930	0.6770	0.1958	0.5990	0.2163
PRECIPV	0.81780	0.90415	0.27012	0.94237	-0.06769	0.33200
	0.0001	0.0001	0.0323	0.0001	0.5981	0.0079
QWDA	-0.34089	-0.26898	-0.08327	-0.34009	-0.08601	0.06767
	0.0063	0.0330	0.5164	0.0064	0.5027	0.5982
SO	1.00000	0.80564	0.15320	0.82704	0.10222	0.37205
	0.0000	0.0001	0.2306	0.0001	0.4253	0.0027
NU	0.80564	1.00000	-0.05315	0.95857	0.25546	0.43583
	0.0001	0.0000	0.6791	0.0001	0.0433	0.0004
LA	0.15320	-0.05315	1.00000	0.13309	-0.37826	-0.10545
	0.2306	0.6791	0.0000	0.2984	0.0022	0.4108
LU	0.82704	0.95857	0.13309	1.00000	0.26693	0.38595
	0.0001	0.0001	0.2984	0.0000	0.0344	0.0018
DD	0.10222	0.25546	-0.37826	0.26693	1.00000	0.21667
	0.4253	0.0433	0.0022	0.0344	0.0000	0.0881
H	0.37205	0.43583	-0.10545	0.38595	0.21667	1.00000
	0.0027	0.0004	0.4108	0.0018	0.0881	0.0000
HA	0.46712	0.51782	-0.02688	0.52171	0.26907	0.68734
	0.0001	0.0001	0.8343	0.0001	0.0330	0.0001
RR	-0.46673	-0.50531	-0.31222	-0.57234	0.28721	0.37857
	0.0001	0.0001	0.0127	0.0001	0.0225	0.0022
BS	-0.11579	-0.06328	0.04469	-0.04837	-0.29026	0.03270
	0.3662	0.6222	0.7280	0.7065	0.0210	0.7991
LB	0.74705	0.83276	0.23503	0.86268	-0.12742	0.37176
	0.0001	0.0001	0.0637	0.0001	0.3196	0.0027
LS	0.77552	0.87755	0.21847	0.89804	-0.05361	0.43492
	0.0001	0.0001	0.0854	0.0001	0.6765	0.0004
F	-0.03684	0.21385	-0.73344	0.02824	0.73145	0.25557
	0.7744	0.0924	0.0001	0.8261	0.0001	0.0432
CR1	-0.19824	-0.27586	-0.15242	-0.29227	0.19159	-0.10129
	0.1194	0.0286	0.2330	0.0201	0.1325	0.4296
CR2	-0.07183	-0.04403	-0.05842	-0.07390	-0.03876	0.17961
	0.5758	0.7318	0.6493	0.5649	0.7630	0.1590
CR3	0.06040	-0.19004	0.18503	-0.17123	-0.25828	-0.30247
	0.6382	0.1357	0.1466	0.1796	0.0410	0.0160
SS	0.31966	0.28264	0.07510	0.27767	0.00612	0.13238
	0.0107	0.0248	0.5585	0.0276	0.9620	0.3010
I	0.58474	0.57553	-0.00578	0.55574	0.04974	0.42733
	0.0001	0.0001	0.9641	0.0001	0.6987	0.0005
WS	0.72492	0.83939	0.26155	0.87646	-0.04472	0.25149
	0.0001	0.0001	0.0384	0.0001	0.7278	0.0468
DS	0.66014	0.67748	0.28687	0.70521	-0.07137	0.20378
	0.0001	0.0001	0.0226	0.0001	0.5783	0.1092
VS	0.33896	0.42019	0.06932	0.44667	-0.10102	0.23581
	0.0066	0.0006	0.5893	0.0002	0.4308	0.0628
TOK	0.21737	0.26124	-0.01997	0.26331	-0.08514	-0.03848
	0.0870	0.0386	0.8766	0.0371	0.5070	0.7646
PROD	0.03760	0.03163	0.22713	0.09810	-0.24878	-0.17708
	0.7699	0.8056	0.0734	0.4443	0.0493	0.1650
EROS	-0.39237	-0.44842	0.08739	-0.44845	-0.05212	-0.14003
	0.0015	0.0002	0.4958	0.0002	0.6850	0.2737
AASL	0.68680	0.78249	0.15598	0.82521	0.14132	0.35028
	0.0001	0.0001	0.2222	0.0001	0.2692	0.0049

APPENDIX I. CONTINUED

	HA	RR	BS	LB	LS	F
ID	-0.14077	-0.01812	0.20650	0.00520	0.03600	0.04096
	0.2711	0.8879	0.1044	0.9677	0.7794	0.7499
DA	0.44659	-0.69309	0.04885	0.93636	0.94824	-0.22558
	0.0002	0.0001	0.7038	0.0001	0.0001	0.0755
AQWV	0.45573	-0.67381	0.05328	0.93211	0.94766	-0.21513
	0.0002	0.0001	0.6784	0.0001	0.0001	0.0904
PRECIP	-0.04463	0.28373	0.10084	-0.16625	-0.11334	0.15195
	0.7284	0.0242	0.4317	0.1928	0.3764	0.2345
PRECIP	0.44814	-0.68536	0.05402	0.93619	0.95067	-0.22024
	0.0002	0.0001	0.6741	0.0001	0.0001	0.0828
QWDA	-0.04839	0.33034	0.02084	-0.28005	-0.25518	0.13932
	0.7065	0.0082	0.8712	0.0262	0.0435	0.2762
SO	0.46712	-0.46673	-0.11579	0.74705	0.77552	-0.03684
	0.0001	0.0001	0.3662	0.0001	0.0001	0.7744
NU	0.51782	-0.50531	-0.06328	0.83276	0.87755	0.21385
	0.0001	0.0001	0.6222	0.0001	0.0001	0.0924
LA	-0.02688	-0.31222	0.04469	0.23503	0.21847	-0.73344
	0.8343	0.0127	0.7280	0.0637	0.0854	0.0001
LU	0.52171	-0.57234	-0.04837	0.86268	0.89804	0.02824
	0.0001	0.0001	0.7065	0.0001	0.0001	0.8261
DD	0.26907	0.28721	-0.29026	-0.12742	-0.05361	0.73145
	0.0330	0.0225	0.0210	0.3196	0.6765	0.0001
H	0.68734	0.37857	0.03270	0.37176	0.43492	0.25557
	0.0001	0.0022	0.7991	0.0027	0.0004	0.0432
HA	1.00000	0.08893	-0.11683	0.42706	0.48543	0.14626
	0.0000	0.4883	0.3618	0.0005	0.0001	0.2527
RR	0.08893	1.00000	-0.28940	-0.71847	-0.61756	0.42688
	0.4883	0.0000	0.0214	0.0001	0.0001	0.0005
BS	-0.11683	-0.28940	1.00000	0.31651	0.14449	-0.24722
	0.3618	0.0214	0.0000	0.0115	0.2586	0.0508
LB	0.42706	-0.71847	0.31651	1.00000	0.94568	-0.23814
	0.0005	0.0001	0.0115	0.0000	0.0001	0.0602
LS	0.48543	-0.61756	0.14449	0.94568	1.00000	-0.16272
	0.0001	0.0001	0.2586	0.0001	0.0000	0.2026
F	0.14626	0.42688	-0.24722	-0.23814	-0.16272	1.00000
	0.2527	0.0005	0.0508	0.0602	0.2026	0.0000
CR1	0.00226	0.40353	-0.28749	-0.48062	-0.43032	0.20550
	0.9859	0.0010	0.0223	0.0001	0.0004	0.1062
CR2	0.15527	-0.03747	0.54174	0.17498	0.07507	0.05000
	0.2243	0.7706	0.0001	0.1702	0.5587	0.6971
CR3	-0.23141	-0.17748	0.13294	-0.04848	-0.07091	-0.22194
	0.0680	0.1641	0.2990	0.7060	0.5808	0.0804
SS	0.23894	-0.13693	-0.03075	0.23724	0.26402	-0.00906
	0.0593	0.2846	0.8109	0.0612	0.0365	0.9438
I	0.30901	-0.17311	-0.08565	0.49359	0.59231	0.03939
	0.0137	0.1749	0.5045	0.0001	0.0001	0.7592
WS	0.47885	-0.66910	0.01182	0.85958	0.87102	-0.19835
	0.0001	0.0001	0.9268	0.0001	0.0001	0.1192
DS	0.19186	-0.59299	0.21647	0.74823	0.74888	-0.17139
	0.1320	0.0001	0.0884	0.0001	0.0001	0.1792
VS	0.39788	-0.29583	0.13939	0.47291	0.43690	-0.17928
	0.0012	0.0186	0.2759	0.0001	0.0003	0.1597
TOK	0.02264	-0.26363	-0.09906	0.23331	0.25939	-0.09854
	0.8602	0.0368	0.4399	0.0657	0.0401	0.4423
PROD	-0.12720	-0.26381	0.01379	0.13130	0.11661	-0.35884
	0.3205	0.0367	0.9146	0.3050	0.3627	0.0039
EROS	-0.17834	0.33460	-0.06991	-0.43845	-0.45914	-0.00613
	0.1620	0.0074	0.5861	0.0003	0.0002	0.9620
AASL	0.45328	-0.51737	0.09767	0.78164	0.82082	-0.05587
	0.0002	0.0001	0.4463	0.0001	0.0001	0.6636

	CR1	CR2	CR3	SS	I	WS
ID	0.11493	0.13035	0.38772	0.33389	-0.14833	0.02067
	0.3697	0.3086	0.0017	0.0075	0.2460	0.8722
DA	-0.36908	-0.06167	-0.08778	0.28488	0.55585	0.92350
	0.0029	0.6311	0.4939	0.0236	0.0001	0.0001
AQWV	-0.35653	-0.04298	-0.07633	0.32220	0.51011	0.93652
	0.0041	0.7380	0.5521	0.0100	0.0001	0.0001
PRECIP	0.17772	0.11834	0.12506	0.20782	-0.27972	-0.09701
	0.1635	0.3556	0.3288	0.1022	0.0264	0.4494
PRECIPV	-0.36370	-0.05658	-0.08259	0.29705	0.54719	0.92650
	0.0034	0.6596	0.5199	0.0181	0.0001	0.0001
QWDA	0.19327	0.15889	0.11056	0.20931	-0.49590	-0.14495
	0.1291	0.2136	0.3883	0.0997	0.0001	0.2570
SO	-0.19824	-0.07183	0.06040	0.31966	0.58474	0.72492
	0.1194	0.5758	0.6382	0.0107	0.0001	0.0001
NU	-0.27586	-0.04403	-0.19004	0.28264	0.57553	0.83939
	0.0286	0.7318	0.1357	0.0248	0.0001	0.0001
LA	-0.15242	-0.05842	0.18503	0.07510	-0.00578	0.26155
	0.2330	0.6493	0.1466	0.5585	0.9641	0.0384
LU	-0.29227	-0.07390	-0.17123	0.27767	0.55574	0.87646
	0.0201	0.5649	0.1796	0.0276	0.0001	0.0001
DD	0.19159	-0.03876	-0.25828	0.00612	0.04974	-0.04472
	0.1325	0.7630	0.0410	0.9620	0.6987	0.7278
H	-0.10129	0.17961	-0.30247	0.13238	0.42733	0.25149
	0.4296	0.1590	0.0160	0.3010	0.0005	0.0468
HA	0.00226	0.15527	-0.23141	0.23894	0.30901	0.47885
	0.9859	0.2243	0.0680	0.0593	0.0137	0.0001
RR	0.40353	-0.03747	-0.17748	-0.13693	-0.17311	-0.66910
	0.0010	0.7706	0.1641	0.2846	0.1749	0.0001
BS	-0.28749	0.54174	0.13294	-0.03075	-0.08565	0.01182
	0.0223	0.0001	0.2990	0.8109	0.5045	0.9268
LB	-0.48062	0.17498	-0.04848	0.23724	0.49359	0.85958
	0.0001	0.1702	0.7060	0.0612	0.0001	0.0001
LS	-0.43032	0.07507	-0.07091	0.26402	0.59231	0.87102
	0.0004	0.5587	0.5808	0.0365	0.0001	0.0001
F	0.20550	0.05000	-0.22194	-0.00906	0.03939	-0.19835
	0.1062	0.6971	0.0804	0.9438	0.7592	0.1192
CR1	1.00000	-0.11936	0.21516	-0.02148	-0.15514	-0.24981
	0.0000	0.3515	0.0904	0.8673	0.2247	0.0483
CR2	-0.11936	1.00000	0.25768	0.06334	-0.12201	-0.09837
	0.3515	0.0000	0.0415	0.6219	0.3408	0.4431
CR3	0.21516	0.25768	1.00000	0.18775	-0.06977	-0.12840
	0.0904	0.0415	0.0000	0.1406	0.5869	0.3159
SS	-0.02148	0.06334	0.18775	1.00000	0.31982	0.24914
	0.8673	0.6219	0.1406	0.0000	0.0106	0.0489
I	-0.15514	-0.12201	-0.06977	0.31982	1.00000	0.42355
	0.2247	0.3408	0.5869	0.0106	0.0000	0.0005
WS	-0.24981	-0.09837	-0.12840	0.24914	0.42355	1.00000
	0.0483	0.4431	0.3159	0.0489	0.0005	0.0000
DS	-0.39778	0.09318	0.08223	0.51605	0.35455	0.65320
	0.0012	0.4676	0.5217	0.0001	0.0044	0.0001
VS	-0.06381	0.00816	-0.12865	-0.17025	0.24508	0.51069
	0.6193	0.9494	0.3150	0.1822	0.0529	0.0001
TOK	0.01994	-0.27962	-0.16433	0.16950	0.47020	0.21715
	0.8767	0.0265	0.1981	0.1842	0.0001	0.0874
PROD	-0.09076	-0.38268	-0.12487	0.17179	0.19290	0.16814
	0.4793	0.0020	0.3295	0.1782	0.1298	0.1878
EROS	0.18192	-0.00451	0.03641	-0.14947	-0.44319	-0.32149
	0.1536	0.9720	0.7769	0.2423	0.0003	0.0102
AASL	-0.36252	0.08415	-0.02271	0.28578	0.56127	0.65756
	0.0035	0.5120	0.8598	0.0232	0.0001	0.0001

APPENDIX I. CONCLUDED

	DS	VS	TOK	PROD	EROS	AASL
ID	0.42064	-0.32496	-0.34101	-0.24235	0.07196	0.08640
	0.0006	0.0094	0.0062	0.0557	0.5752	0.5008
DA	0.75354	0.49701	0.29803	0.18777	-0.44355	0.80531
	0.0001	0.0001	0.0177	0.1406	0.0003	0.0001
AQWV	0.77719	0.47495	0.26021	0.17234	-0.41937	0.77814
	0.0001	0.0001	0.0394	0.1768	0.0006	0.0001
PRECIP	0.15660	-0.30361	-0.36387	-0.22420	0.09133	-0.21088
	0.2203	0.0156	0.0034	0.0773	0.4765	0.0971
PRECIPV	0.76714	0.48673	0.28327	0.17870	-0.44287	0.80195
	0.0001	0.0001	0.0245	0.1611	0.0003	0.0001
QWDA	-0.01889	-0.29975	-0.36731	-0.16731	0.30174	-0.42024
	0.8832	0.0170	0.0031	0.1900	0.0162	0.0006
SO	0.66014	0.33896	0.21737	0.03760	-0.39237	0.68680
	0.0001	0.0066	0.0870	0.7699	0.0015	0.0001
NU	0.67748	0.42019	0.26124	0.03163	-0.44842	0.78249
	0.0001	0.0006	0.0386	0.8056	0.0002	0.0001
LA	0.28687	0.06932	-0.01997	0.22713	0.08739	0.15598
	0.0226	0.5893	0.8766	0.0734	0.4958	0.2222
LU	0.70521	0.44667	0.26331	0.09810	-0.44845	0.82521
	0.0001	0.0002	0.0371	0.4443	0.0002	0.0001
DD	-0.07137	-0.10102	-0.08514	-0.24878	-0.05212	0.14132
	0.5783	0.4308	0.5070	0.0493	0.6850	0.2692
H	0.20378	0.23581	-0.03848	-0.17708	-0.14003	0.35028
	0.1092	0.0628	0.7646	0.1650	0.2737	0.0049
HA	0.19186	0.39788	0.02264	-0.12720	-0.17834	0.45328
	0.1320	0.0012	0.8602	0.3205	0.1620	0.0002
RR	-0.59299	-0.29583	-0.26363	-0.26381	0.33460	-0.51737
	0.0001	0.0186	0.0368	0.0367	0.0074	0.0001
BS	0.21647	0.13939	-0.09906	0.01379	-0.06991	0.09767
	0.0884	0.2759	0.4399	0.9146	0.5861	0.4463
LB	0.74823	0.47291	0.23331	0.13130	-0.43845	0.78164
	0.0001	0.0001	0.0657	0.3050	0.0003	0.0001
LS	0.74888	0.43690	0.25939	0.11661	-0.45914	0.82082
	0.0001	0.0003	0.0401	0.3627	0.0002	0.0001
F	-0.17139	-0.17928	-0.09854	-0.35884	-0.00613	-0.05587
	0.1792	0.1597	0.4423	0.0039	0.9620	0.6636
CR1	-0.39778	-0.06381	0.01994	-0.09076	0.18192	-0.36252
	0.0012	0.6193	0.8767	0.4793	0.1536	0.0035
CR2	0.09318	0.00816	-0.27962	-0.38268	-0.00451	0.08415
	0.4676	0.9494	0.0265	0.0020	0.9720	0.5120
CR3	0.08223	-0.12865	-0.16433	-0.12487	0.03641	-0.02271
	0.5217	0.3150	0.1981	0.3295	0.7769	0.8598
SS	0.51605	-0.17025	0.16950	0.17179	-0.14947	0.28578
	0.0001	0.1822	0.1842	0.1782	0.2423	0.0232
I	0.35455	0.24508	0.47020	0.19290	-0.44319	0.56127
	0.0044	0.0529	0.0001	0.1298	0.0003	0.0001
WS	0.65320	0.51069	0.21715	0.16814	-0.32149	0.65756
	0.0001	0.0001	0.0874	0.1878	0.0102	0.0001
DS	1.00000	0.00183	0.09568	0.12291	-0.33039	0.70228
	0.0000	0.9886	0.4557	0.3372	0.0082	0.0001
VS	0.00183	1.00000	0.19270	-0.03695	-0.11978	0.29873
	0.9886	0.0000	0.1303	0.7737	0.3498	0.0174
TOK	0.09568	0.19270	1.00000	0.51023	-0.61210	0.23520
	0.4557	0.1303	0.0000	0.0001	0.0001	0.0635
PROD	0.12291	-0.03695	0.51023	1.00000	-0.17157	0.06050
	0.3372	0.7737	0.0001	0.0000	0.1788	0.6376
EROS	-0.33039	-0.11978	-0.61210	-0.17157	1.00000	-0.46548
	0.0082	0.3498	0.0001	0.1788	0.0000	0.0001
AASL	0.70228	0.29873	0.23520	0.06050	-0.46548	1.00000
	0.0001	0.0174	0.0635	0.6376	0.0001	0.0000