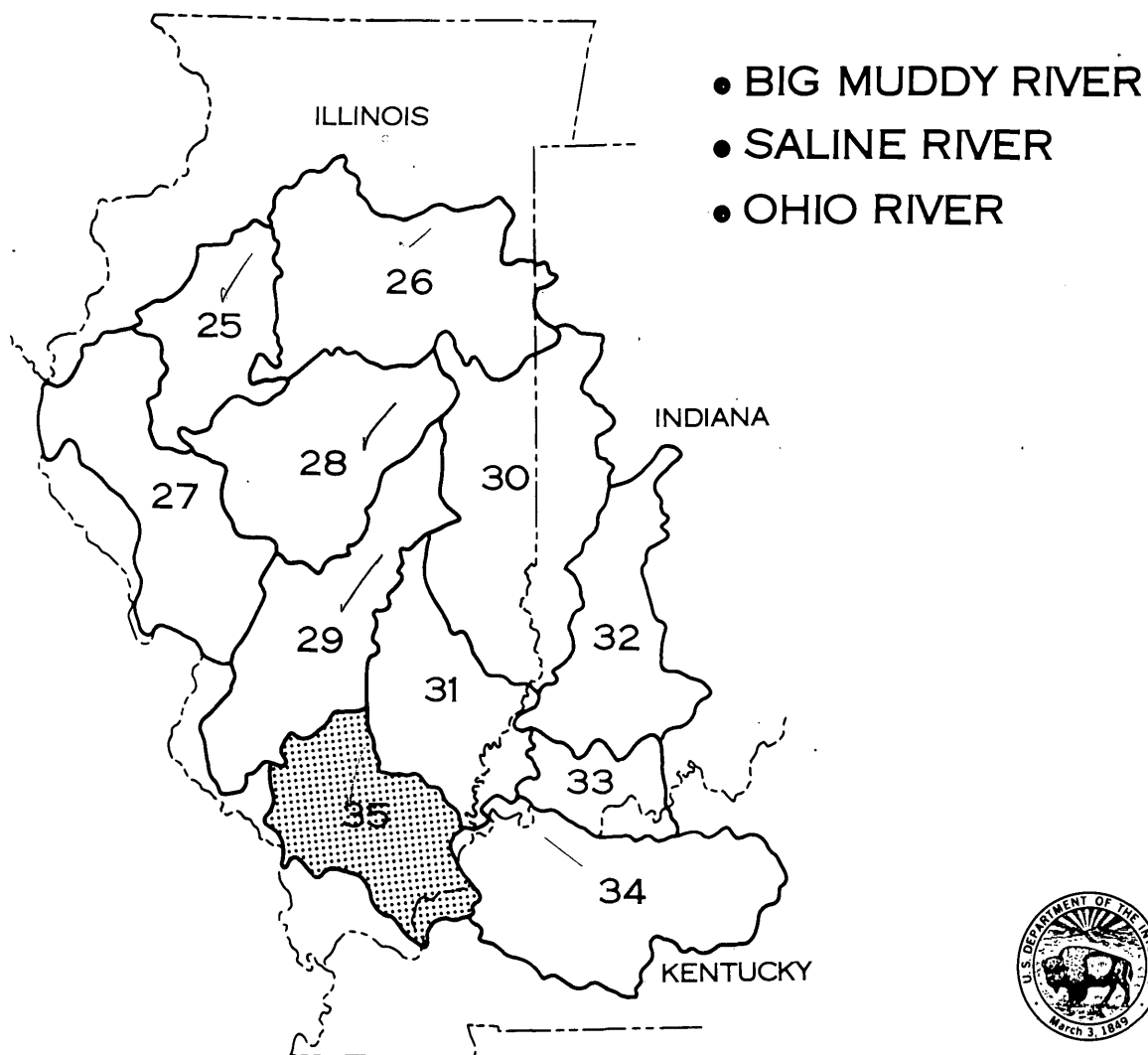


# HYDROLOGY OF AREA 35, EASTERN REGION, INTERIOR COAL PROVINCE, ILLINOIS AND KENTUCKY



UNITED STATES DEPARTMENT OF THE INTERIOR  
GEOLOGICAL SURVEY

WATER-RESOURCES INVESTIGATIONS  
OPEN-FILE REPORT 81-403



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**BY**

**E.E. ZUEHLS, G.L. RYAN, D.B. PEART, AND K.K. FITZGERALD**

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WATER-RESOURCES INVESTIGATIONS 81-403**



**URBANA, ILLINOIS  
MAY 1981**

**UNITED STATES DEPARTMENT OF THE INTERIOR**

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

For the convenience of readers who may want to use International System of Units (SI),  
the data may be converted by using the following factors:

Multiply inch-pound units	By	To obtain SI units
inches (in)	25.4	millimeters (mm)
inches per hour (in/h)	25.4 2.54	millimeters per hour (mm/h) centimeters per hour (cm/h)
feet (ft)	0.3048	meters (m)
feet per mile (ft/mi)	0.1894	meters per kilometer (m/km)
miles (mi)	1.609	kilometers (km)
square miles (mi <sup>2</sup> )	2.590	square kilometers (km <sup>2</sup> )
gallons per minute (gal/min)	0.06309	liters per second (L/s)
million gallons per day (mgal/d)	0.04381 3,785	cubic meters per second (m <sup>3</sup> /s) cubic meters per day (m <sup>3</sup> /d)
cubic feet per second (ft <sup>3</sup> /s)	0.02832	cubic meters per second (m <sup>3</sup> /s)
cubic feet per second per square mile [(ft <sup>3</sup> /s)/mi <sup>2</sup> ]	0.01093	cubic meters per second per square kilometer [(m <sup>3</sup> /s)/km <sup>2</sup> ]
tons per square mile per year [(tons/mi <sup>2</sup> )/yr]	0.03753	metric tons per square kilometer per year [(t/km <sup>2</sup> )/a]
micromhos per centimeter at 25° Celsius (μmho/cm at 25°C)	100	microsiemens per meter at 25° Celsius (μS/m at 25°C)



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BY E.E. ZUEHLS, G.L. RYAN, D.B. PEART, AND K.K. FITZGERALD

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## ABSTRACT

A nationwide need for information characterizing hydrologic conditions in mined and potential mine areas has become paramount with the enactment of the Surface Mining Control and Reclamation Act of 1977. This report is designed to be useful to the mine owners, operators, and others by presenting information about the existing hydrologic conditions and by identifying sources of hydrologic information. General hydrologic information is presented using a brief text with an accompanying map, chart, graph, or other illustration for each of a series of water-resources-related topics. The summation of the topical discussions provides a description of the hydrology of the area.

The eastern region of the Interior Coal Province has been divided into 11 hydrologic study areas. These are shown on the cover of this report. The divisions are based on hydrologic factors, location, and size. Hydrologic units (surface drainage basins) are combined to form each study area.

Study area 35 is located in southern Illinois and western Kentucky. The drainage basins in the area are the Big Muddy River, Saline River, and small tributaries to the Ohio River.

Coal is found in Pennsylvanian rocks underlying most of the study area. Seventy-five different coal members have been identified in Illinois. Commercial coal mining in Illinois began in 1810. At present, Illinois is second only to Montana in total coal reserves. It ranks first among the States in total reserves of bituminous coal and total heat content.

Loess soils cover most of the study area and are slowly to moderately permeable. These soils can be productive under a high level of management. Agriculture is the dominant land use in the study area. Most water used in the study area is taken from surface-water impoundments. Surface water makes up 87 percent of all the water used. Precipitation averages 39 to 46 inches across the study area and is distributed about equally between the summer and winter months.

The U.S. Geological Survey operates a network of 18 hydrologic monitoring stations in Area 35. Stream-flow, water level, and water-quality data are collected. These data are available from computer storage through the National Water Data Storage and Retrieval System (WATSTORE).

The major hydrologic problems related to surface mining are degradation of water quality and increased erosion and sedimentation. Degradation of water quality can result from drainage of mine sites into the surrounding area and into the streams. Natural conditions will neutralize acidic waters but increased concentrations of dissolved trace elements (aluminum, copper, manganese, iron, and so forth) remain in the waters creating bad tastes, discolorations, and possible health hazards. Increased erosion and sedimentation can result from the lack of soil cover and the disturbed conditions left by mining operations.

1.0 INTRODUCTION  
1.1 OBJECTIVE

AREA 35 REPORT SUBMITTED IN  
SUPPORT OF PUBLIC LAW 95-87

*Existing hydrologic conditions and identification of sources  
of hydrologic information are presented.*

This report provides broad hydrologic information, using a brief text with an accompanying map, chart, graph, or other illustrations for each of a series of water-resources-related topics. The summation of the topical discussions provides a description of the hydrology of the area. This information should be useful to surface-mine owners, mine operators, and consulting engineers in the preparation of permit applications and to regulatory authorities in appraising the adequacy of permit applications.

A need for hydrologic information and analysis on a scale never before required nationally was initiated when the "Surface Mining Control and Reclamation

Act of 1977" was signed into law as Public Law 95-87, August 3, 1977. As a local response to that need, this report broadly characterizes the hydrology of Area 35 in Illinois as delineated in figure 1.1-1. The hydrologic information presented or available through sources identified in this report may be used in describing the hydrology of the "general area" of any proposed mine. Furthermore, it is expected that this hydrologic information will be supplemented by the lease applicant's specific site data as well as data from other sources to provide a more detailed picture of the hydrology of the area in the vicinity of the mine and the anticipated hydrologic consequences of the mining operation.



BASE FROM U. S. GEOLOGICAL SURVEY  
STATE BASE MAP, 1970

Fig. 1.1-1 Location of study area  
in Illinois and Kentucky.

## 1.0 INTRODUCTION

### 1.1 OBJECTIVE

## 1.0 INTRODUCTION (Continued)

### 1.2 STUDY AREA

## AREA 35 IS DIVIDED INTO TWO PHYSIOGRAPHIC SECTIONS

*Area 35 is located in southern Illinois and western Kentucky. It is divided into two physiographic sections: the Mount Vernon Hill Country and the Shawnee Hills Section.*

The eastern region of the Interior Coal Province, commonly called the Eastern Interior Coal Field (Smith and Stall, 1975), has been divided into 11 hydrologic study areas. These are shown on the cover. The divisions are based on hydrologic factors, location, and size. Hydrologic units (drainage basins) are combined to form each study area.

Area 35 covers about 4,500 square miles in southern Illinois and western Kentucky (fig. 1.2-1). It includes all of Franklin, Hardin, Pope, Saline, and Williamson Counties and parts of Gallatin, Hamilton, Jackson, Jefferson, Johnson, Massac, and Washington Counties in Illinois and parts of Crittenden and Livingston Counties in Kentucky.

The study area is divided into two physiographic sections: the Mount Vernon Hill Country and the Shawnee Hills Section (fig. 1.2-2). The topography in the Mount Vernon Hill Country area is flat to gently

rolling with broad alluvial valleys along the major streams. There are many bedrock outcrops (Leighton and others, 1948). The Shawnee Hills area is unglaciated and the topography is rugged with many bluffs and ravines. An east-west trending escarpment of Pennsylvanian sandstone runs through the area (Schwegman, 1973). The major drainage basins in the study area are the Big Muddy, Saline, and part of the Ohio (fig. 1.2-3). The Ohio River separates the Illinois part of the study area from the Kentucky part.

The population of the study area (from figures for entire counties, whether partly or wholly in study area) is 298,300 (Rockford Map Publishers, 1973; and U.S. Geological Survey, 1970). Cities with populations of 5,000 or more in the study area are Benton, Mt. Vernon, Harrisburg, Carbondale, Murphysboro, Marion, and Herrin. Mt. Vernon is the largest city with a population of 16,860.



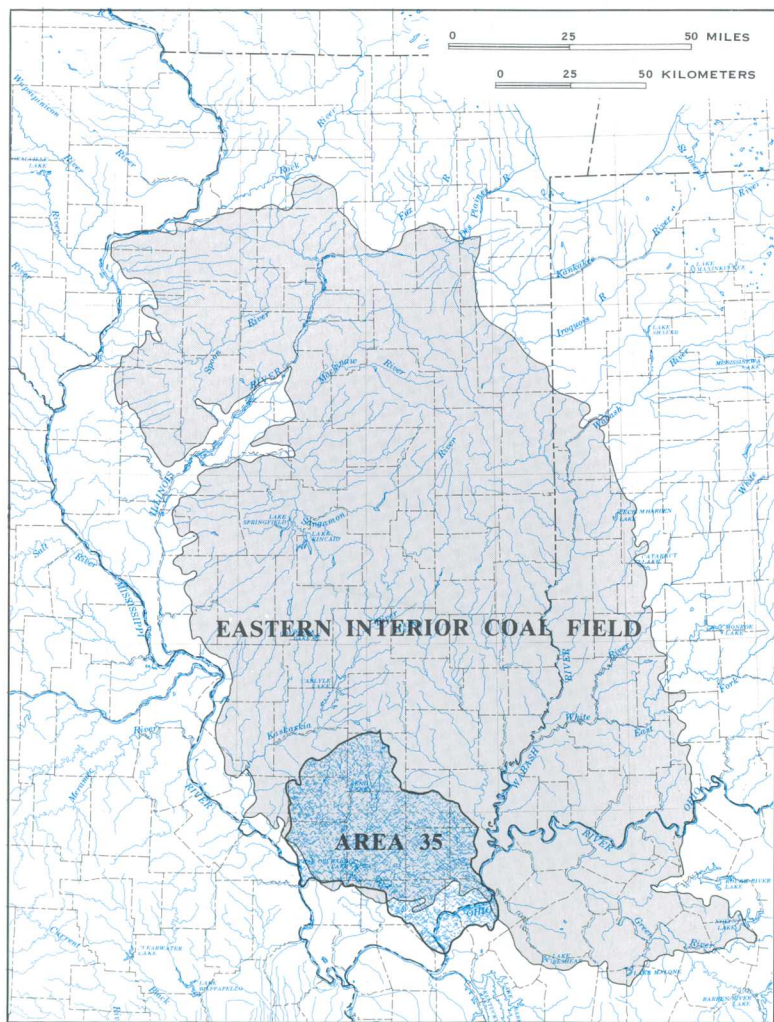
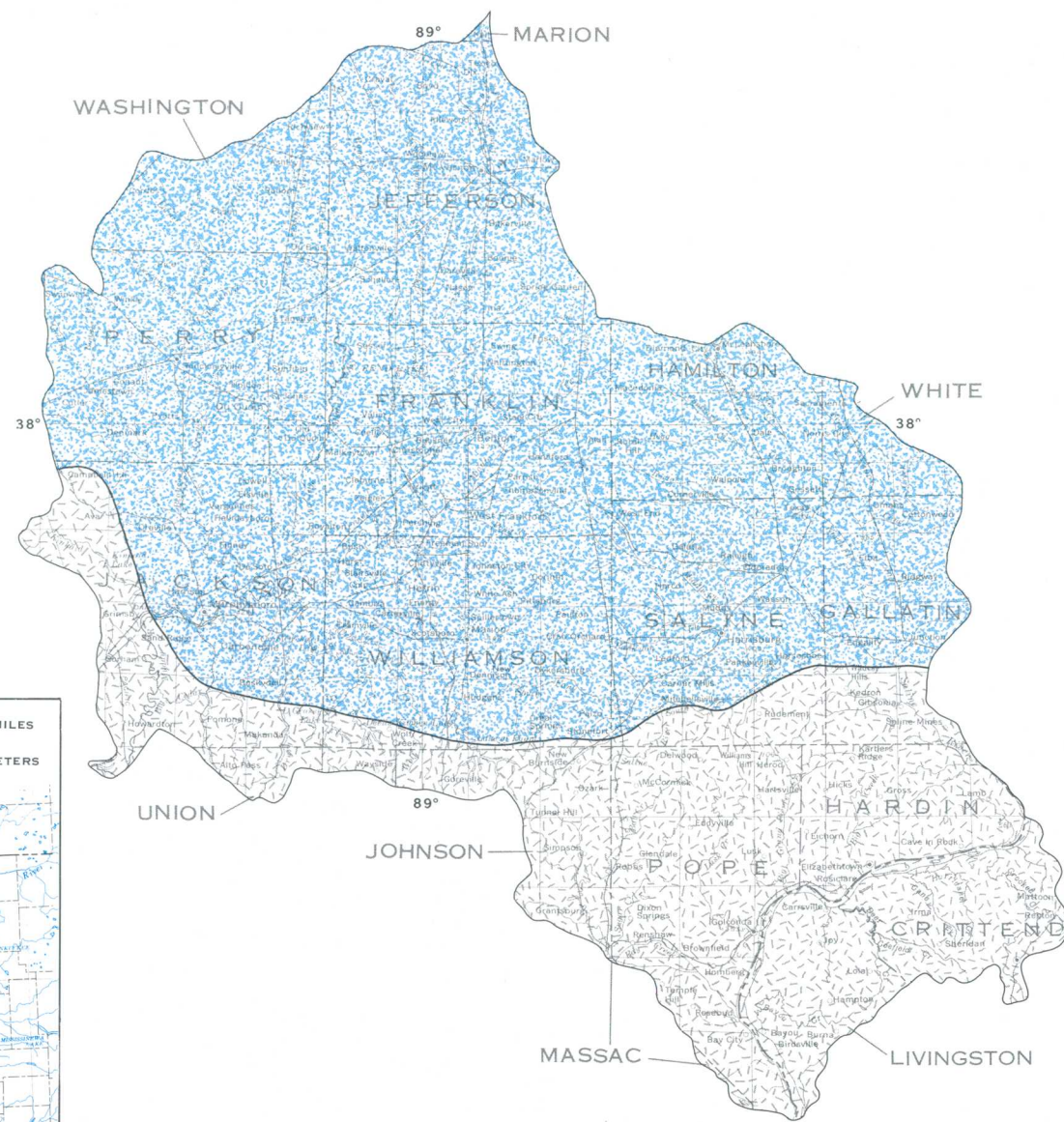


Figure 1.2-1 Location of the study area in the Eastern Interior Coal Field.



**EXPLANATION**  
Physiographic divisions



-  Mount Vernon Hill Country
-  Shawnee Hills Section

Figure 1.2-2 Physiographic divisions.

BASE FROM U. S. GEOLOGICAL SURVEY  
STATE BASE MAP, 1970

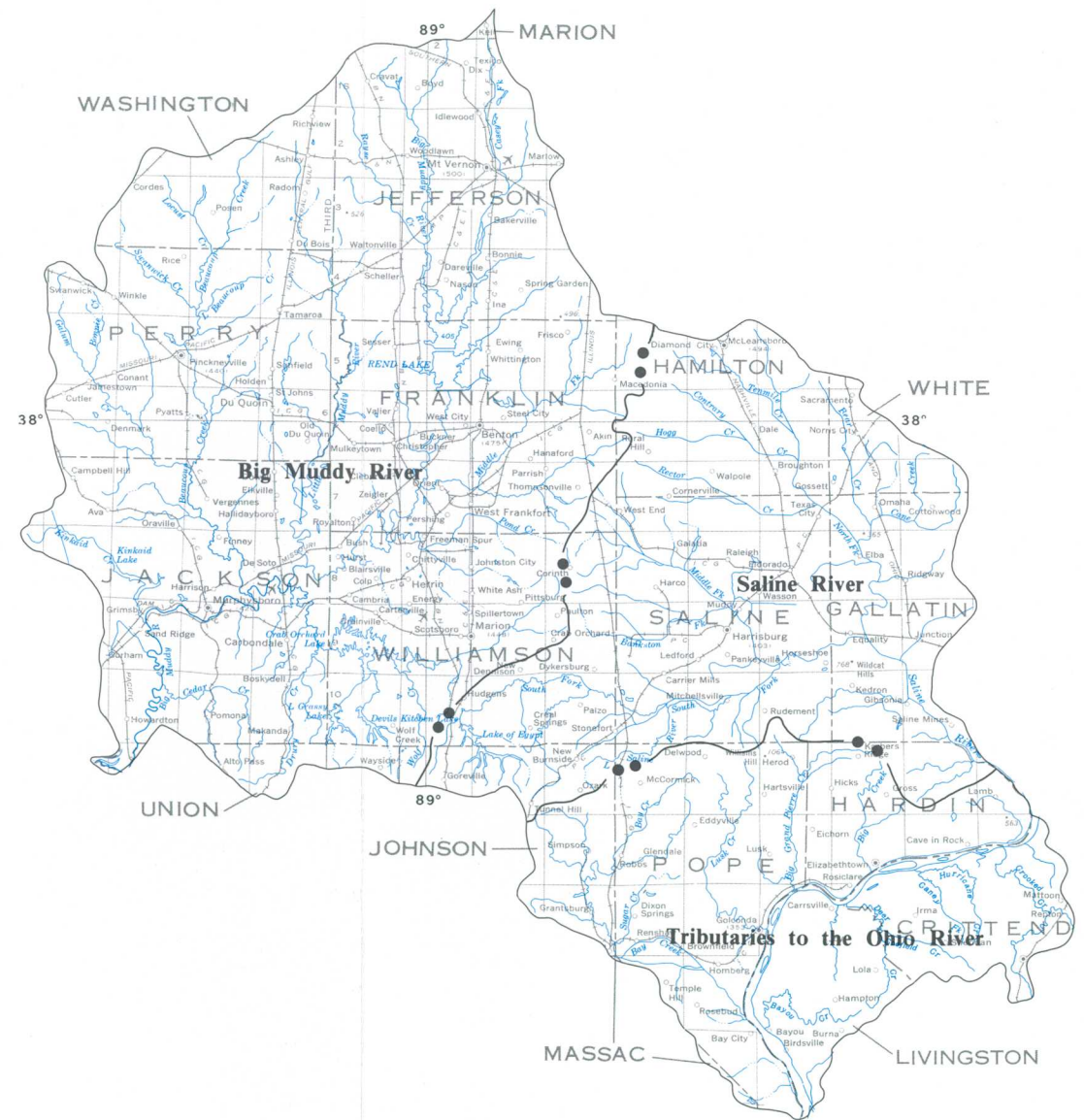


Figure 1.2-3 Drainage basins.



## 2.0 COAL MINING

### 2.1 HISTORY AND POTENTIAL

## ILLINOIS HAS LARGEST BITUMINOUS COAL RESERVES IN THE UNITED STATES

*Illinois, second only to Montana in total coal reserves, has the largest reserves of bituminous coal with the highest total heat content. Estimated reserves of coal in Illinois are 161.6 billion tons.*

The first coal discovery in North America was by Marquette and Joliet in 1673 along the Illinois River. The first commercial underground coal mine in Illinois was opened in 1810 near Brownsville in Jackson County (Andros, 1915). The first commercial strip mine in the United States was opened in 1866 near Danville, Illinois. Early strip mining was accomplished by removing overburden with horsedrawn scrapers and hauling it out of the mine pit in wagons and wheelbarrows. Within two decades, the steam shovel came into use. The first steam shovels were made mostly of wood and were able to remove 8 to 12 feet of overburden and coal seams of up to 3 feet thick. From these beginning, coal mining technology has progressed to the giant electric-powered shovels of today that can remove up to 220 cubic yards of material in a single bite (Lewis, 1971-72).

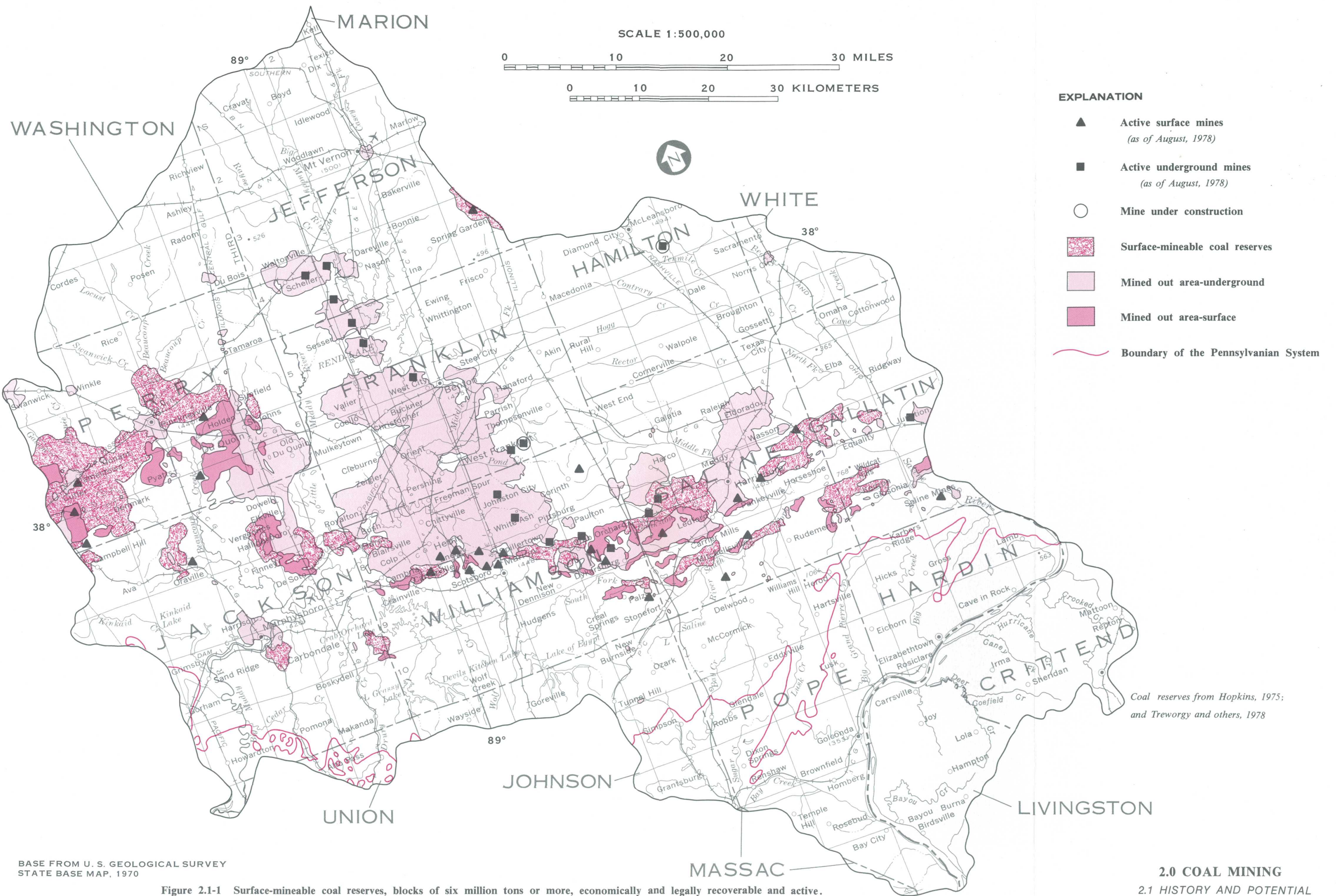
Illinois is second only to Montana in total coal reserves. Among the states, it has the largest reserves of bituminous coal with the highest total heat content (Rickert and others, 1979). Estimated reserves (as of January 1975 with revisions by Nawrot and others in 1980) are 161.6 billion tons; 15.1 percent of the total demonstrated coal reserves in the United States. Approximately 12.1 percent of the Illinois reserves is considered strippable (coal seams more than 18 inches thick and less than 150 feet deep), but currently only about 3.6 percent is economically and legally strippable (Nawrot and others, 1980).

In 1979, the 40 surface mines in operation in the State produced 26,856,897 tons of coal and 31 underground mines produced a total of 32,682,230 tons (Department of Mines and Minerals, 1979).

Total identified coal reserves in the study area are 38.2 billion tons (figure is from values for entire counties, not only the portions included in the study area). Approximately 6.7 percent of this is considered surface-minable. The surface-minable coal reserves in the study area are shown on figure 2.1-1.

Total coal production in Illinois from 1882 through 1978 was 4.7 billion tons. The study area accounted for 40.3 percent of that total. Peak production was reached during World War I. The Depression of the 1930's caused a decline in production which was reversed by World War II. Another decline in production occurred when diesel locomotives and alternate industrial fuel sources came into use. Increased energy consumption and declining oil and gas reserves have resulted in an increase and leveling off of production during the past two decades (Nawrot and others, 1980).

Rickert and others (1979) have shown that Illinois coal resources are among those most likely to be used for synthetic fuel production due to the large amount of coal available, plentiful water supplies, and lack of serious geologic constraints. In addition, the Nation's move toward energy independence and diminishing domestic supplies of oil and gas could increase the demand for midwestern coal.



BASE FROM U. S. GEOLOGICAL SURVEY  
STATE BASE MAP, 1970

Figure 2.1-1 Surface-mineable coal reserves, blocks of six million tons or more, economically and legally recoverable and active.

2.0 COAL MINING  
2.1 HISTORY AND POTENTIAL



## 2.0 COAL MINING (Continued)

### 2.2 METHODS

# **BOTH SURFACE MINING AND UNDERGROUND MINING ARE USED TO PRODUCE COAL IN ILLINOIS**

*Approximately 45 percent of the coal mined in Illinois  
is produced by surface mining. The remainder is produced  
by underground mining.*

Area mining is the most commonly used surface mining method in Illinois. Contour mining is used in only a small number of mines in the State.

In area mining a trench is made through the overburden to expose the coal deposit. The coal is removed and the spoil (overburden) from the next cut is deposited in the trench. A series of parallel cuts is made in this manner. The final cut then leaves an open trench bounded by the last spoil bank on one side and the undisturbed highwall on the other side. This trench is as deep as the thickness of the overburden plus the thickness of the coal seam (Doyle, 1976), and, in most cases, fills with water to form a "final cut lake."

Contour mining is used in hilly areas. The overburden is removed from the coal seam starting at the outcrop and proceeding around the hillside. This creates a shelf or bench on the hillside (Doyle, 1976).

Tandem use of shovels and draglines, as shown in figure 2.2-1, is the most common type of area mining operation in Illinois. State reclamation laws require that the topsoil be removed first and that it be separated into individual horizons. This will then be replaced after mining is completed so that the land can be revegetated. The wheel excavator, a piece of equipment currently used only in Illinois, is used to remove the unconsolidated overburden. It operates in advance of the power shovel or dragline which removes the consolidated overburden. The unconsolidated material is deposited on top of the consolidated material that has been removed previously. A power shovel or front end loader is then used to remove the coal. This type of operation allows for better reclamation than did past operations where the strata were not separated and replaced in their original sequence (Haynes and Klimstra, 1975).



Figure 2.2-1 Shovel and Dragline

### 3.0 GEOLOGY

#### 3.1 QUATERNARY GEOLOGY

## GLACIAL DEPOSITS COVER MOST OF THE NORTHERN TWO-THIRDS OF THE STUDY AREA

*Glacial deposits cover most of the northern two-thirds of the study area. The southern one-third is unglaciated. Glacial drift in the Ohio and Big Muddy River valleys may be as much as 200 feet thick and deposits in the valleys of the Saline and Skillet Fork Rivers and Beaucoup Creek are 50 to 100 feet thick.*

The Quaternary System includes glacial deposits and contemporaneous sediments deposited beyond the limit of glaciation as well as all material deposited through the present time. Glacial deposits cover almost all of Illinois with the southernmost extent of glaciation in central North America occurring in the study area. The southern one-third of the study area is unglaciated. Lake deposits of Wisconsinan age and ground moraine of Illinoian age cover the rest of the study area (fig. 3.1-1). These deposits are less than 50 feet thick except in river valleys. Glacial deposits in the Ohio and Big Muddy River valleys may be as much as 200 feet thick and deposits in the valleys of the Saline and Skillet Fork Rivers and Beaucoup Creek are 50 to 100 feet thick.

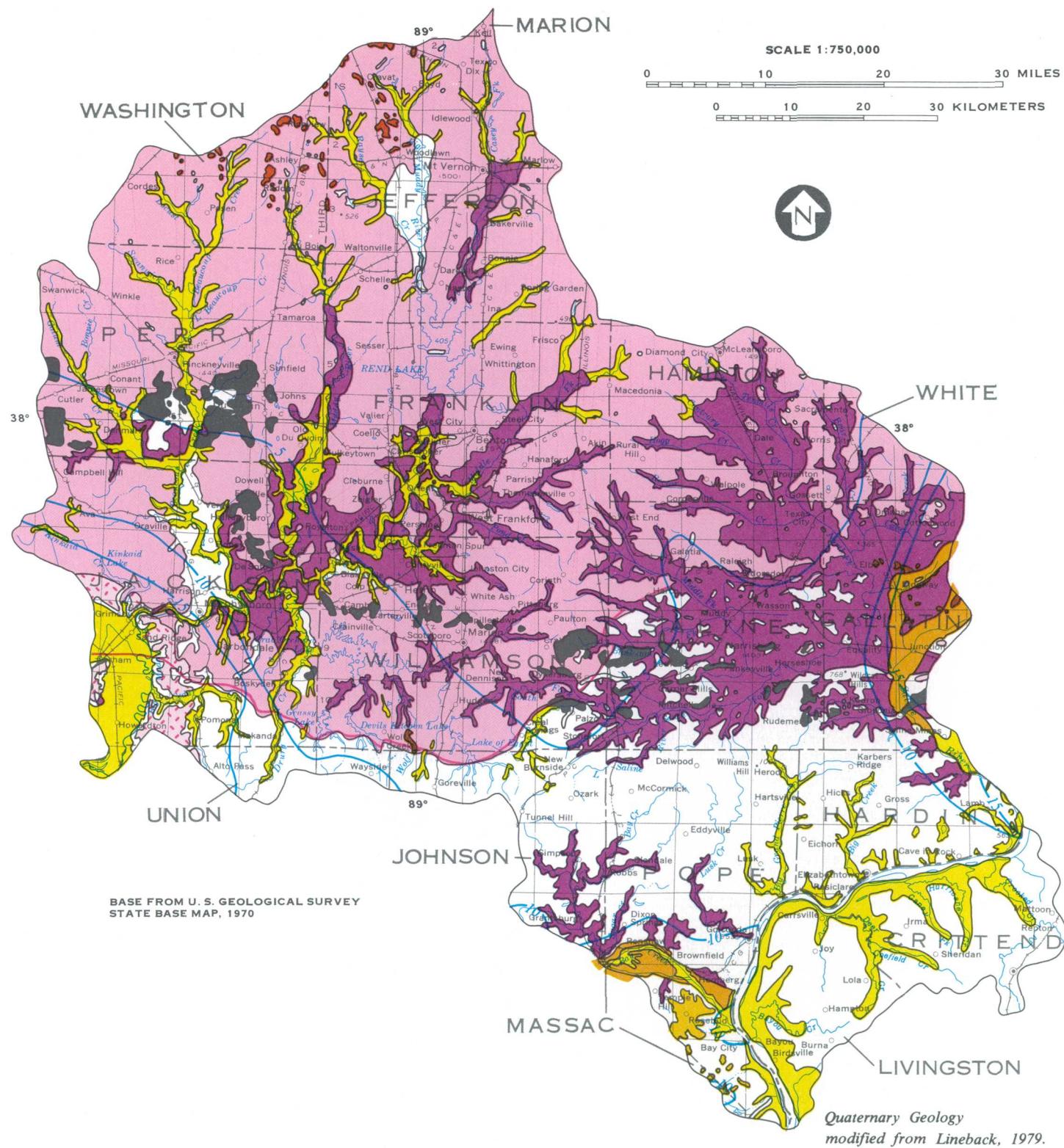
The Vandalia Till Member of the Glasford Formation is found in most of the glaciated portion of the study area. The till is sandy, with thin lenticular bodies

of silt, sand, and gravel, and is calcareous except where weathered.

The Equality Formation is found in the study area in broad, poorly drained flood plains of the Big Muddy, Saline, and Skillet Fork River valleys. The lacustrine silt, clay, and sand were deposited when slackwater lakes of the Ohio and Mississippi Rivers filled these valleys.

Peoria Loess is Wisconsinan in age and blankets most of the study area. It is a massive, well-sorted silt and was calcareous when it was deposited. It was formed from outwash material that was blown from the valleys onto the uplands. The carbonates have been leached from the upper 15 to 20 feet of the formation in the southern part of Illinois. The Peoria Loess is the parent material for many of the soils in the study area (Willman and others, 1975).





### EXPLANATION

- Surface Mines**  
Includes coal strip mines, rock quarries, clay, sand, and gravel pits, and other excavated areas.
  - Cahokia Alluvium**  
Deposits in flood plains and channels of modern rivers and streams; mostly poorly sorted sand, silt, or clay.
  - Parkland Sand**  
Windblown sand; well sorted, medium sand in dunes and thick sheet deposits between dunes.
  - Carmi Member of Equality Formation**  
Quiet-water lake sediments dominated by well-bedded silt and some clay.
  - Mackinaw Member of Henry Formation**  
Sand and gravel; generally well sorted and well bedded.
  - Peoria Loess**  
Windblown silt; shown by contour lines.
  - Hagarstown Member of Glasford Formation**  
Mostly well sorted and well bedded sand gravel.
  - Vandalia Till Member of Glasford Formation**  
Hard, compact sandy till with sand and gravel.
  - Mounds Gravel**  
Mostly gravel on uplands.
- Areas not illustrated by color on map indicate that rocks older than Pliocene are present at or near the surface.
- Limitation of glaciation**
- Thickness of Loess; contour intervals 5 feet.**

TIME STRATIGRAPHY		ROCK STRATIGRAPHY	
SYSTEM	SERIES	TIME STRATIGRAPHY	
		STAGE	ROCK STRATIGRAPHY
QUATERNARY	PLEISTOCENE	HOLOCENE STAGE	
		VALDERAN SUBSTAGE	
		TWOCREEKAN SUBSTAGE	
		WOODFORDIAN SUBSTAGE	
		FARMPALIAN SUBSTAGE	
		ALTONIAN SUBSTAGE	
		SANGAMONIAN STAGE	
		JUBILEEAN SUBSTAGE	
		MONICAN SUBSTAGE	
		LIMAN SUBSTAGE	
	ILLINOIAN STAGE	YARMOUTHIAN STAGE	
		KANSAN STAGE	
		AFTONIAN STAGE	
		NEBRASKAN STAGE	

Stratigraphic column of Quaternary System showing locations of rock units found in Area 35. Stratigraphic Column from Willman and Frye, 1970.

Figure 3.1-1 Quaternary Geology

## 3.0 GEOLOGY

### 3.1 QUATERNARY GEOLOGY



### 3.0 GEOLOGY (Continued)

#### 3.2 BEDROCK GEOLOGY

## THE COAL-BEARING PENNSYLVANIAN SYSTEM IS THE UPPERMOST BEDROCK IN MOST OF THE STUDY AREA

*The coal-bearing rocks are Pennsylvanian in age. The Pennsylvanian System is the uppermost bedrock in about 80 percent of the study area. Cretaceous, Mississippian, and Devonian rocks make up the bedrock surface in the rest of the study area.*

The Illinois basin is a spoon-shaped structure that is oriented NNW to SSE with the deepest part in White County in the southeastern part of Illinois. The depth of the basin at this point is about 15,000 feet. The basin was formed by slow subsidence from Cambrian to post-Pennsylvanian times (Willman and others, 1975). This subsidence resulted in the coals being as much as 800 feet deeper in the northeastern part of the study area than in the western and southern parts of the area. Surface mining is generally restricted to areas where the coal is less than 150 feet deep.

The Pennsylvanian System is the uppermost bedrock in about 80 percent of the study area. Cretaceous, Mississippian, and Devonian rocks make up the bedrock surface in the rest of the study area (fig. 3.2-1).

The Pennsylvanian System consists of sandstones, siltstones, limestones, shales, clays, and coals. Changes in lithology within the system are often abrupt which indicates that the depositional environment was changing rapidly. The advance of salt water seas into Illinois caused transgressive marine deposition of sandstone, shale, and limestone. When the seas withdrew, large freshwater swamps developed on broad delta plains. When the seas re-advanced, marine sediments were deposited on top of the organic swamp debris which eventually became peat. As burial continued, coal was formed. There are about 75 identified coal members in Illinois.

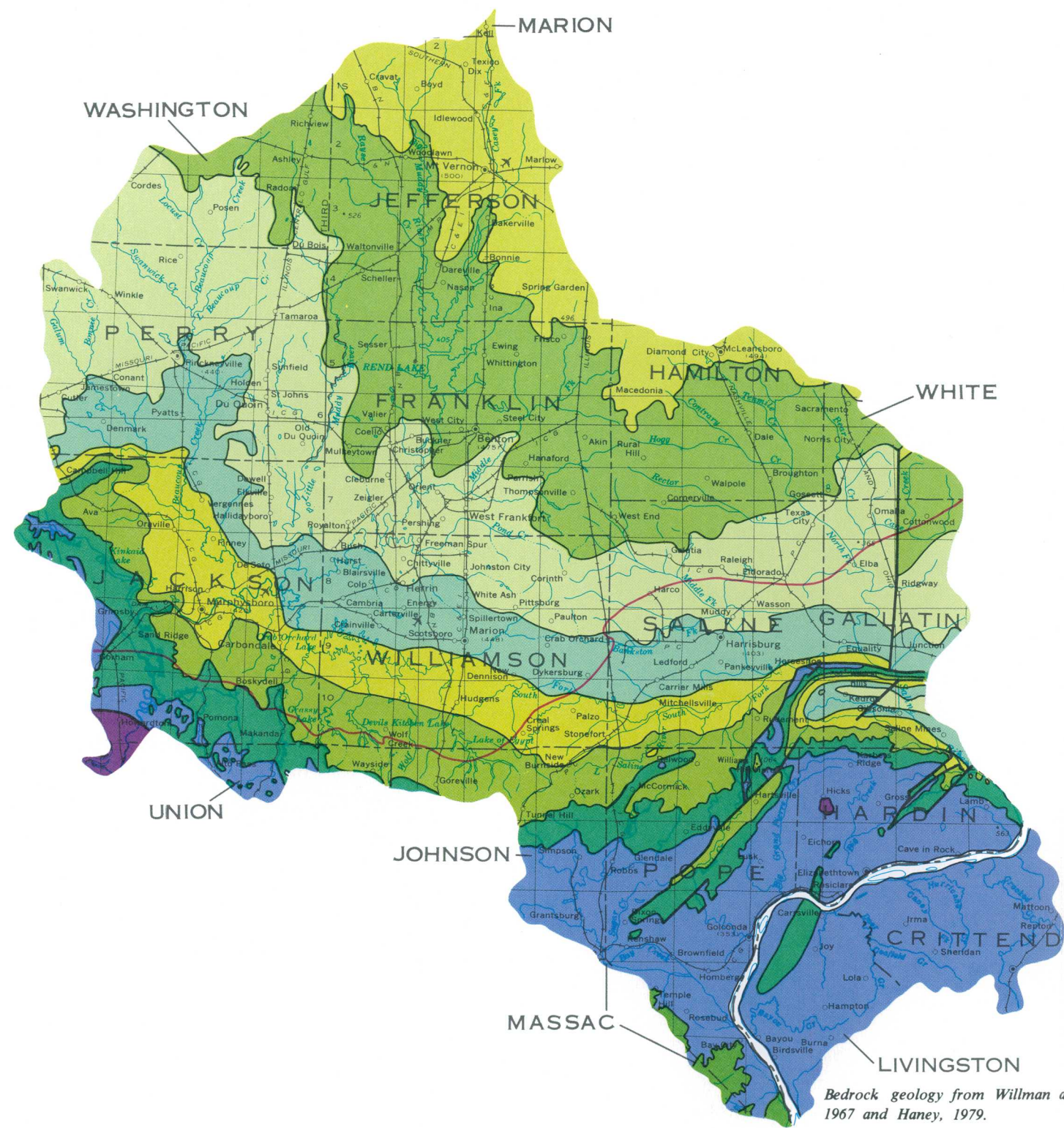
Sixty percent of the lower section of the Pennsylvanian System is sandstone with the remainder being mostly siltstone and shale. Less than 1 percent is coal and limestone. Twenty-five percent of the middle and upper sections is sandstone, 5 to 10 percent is limestone, and 65 to 70 percent is shale and clay. Coal makes up no more than 2 percent of the Pennsylvanian System and is most prominent in the middle section (Willman and others, 1975). Approximately 90 percent of the coal that is mined in the study area is from the Herrin (No. 6) and Harrisburg (No. 5) Coal Members (Smith and Stall, 1975).

The Mounds Gravel of Pliocene-Pleistocene age occurs only in a small part of the southernmost part of the study area. It is made up of chert pebbles in a matrix of coarse red sand.

Mississippian rocks in the study area are mainly limestone with some sandstones and shales. The Mississippian System reaches a thickness of over 3,200 feet in the study area. It crops out where it is the uppermost bedrock.

Devonian rocks are exposed in Hardin County in a structure called Hicks Dome. This dome probably resulted from an igneous intrusion. Devonian rocks also occur in Jackson and Union Counties near the mouth of the Big Muddy River. The Devonian System is made up mainly of limestones and shales (Willman and others, 1975).





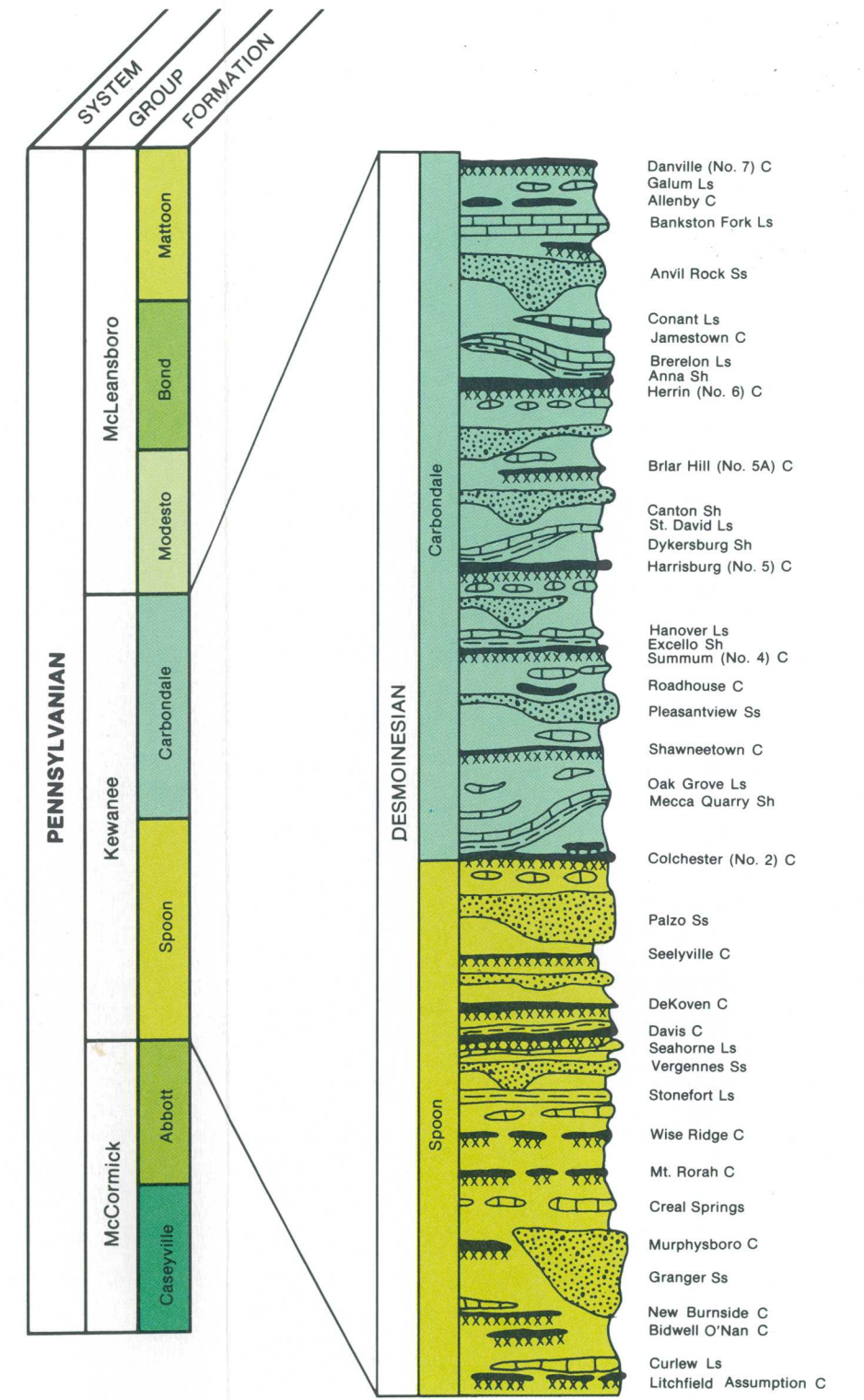
Bedrock geology from Willman and others, 1967 and Haney, 1979.

Figure 3.2-1 Bedrock Geology

EXPLANATION

- CRETACEOUS**
- Matton Formation
- Bond Formation
- Modesto Formation
- Carbondale Formation
- Spoon Formation
- Abott Formation
- Caseyville Formation
- MISSISSIPPIAN**
- DEVONIAN**
- Extent of Glaciation
- Faults

PENNSYLVANIAN





## 4.0 SOILS

### SOILS ARE SLOWLY TO MODERATELY PERMEABLE, ACIDIC, AND SUBJECT TO SLOPE EROSION

*Soil permeabilities range from 0 to 20 inches per hour, pH values range from 4.0 to 8.4, and the soils are of low to moderate productivity. Erosion control is a problem, especially on slopes, and bedrock outcrops are common.*

In general, soils in the study area are slowly to moderately permeable, acidic, and of low to moderate productivity. Erosion control is a problem, especially on slopes, and bedrock outcrops are common. General descriptions of each soil association are given in the accompanying table. This information was obtained from soil surveys for individual counties (U.S. Department of Agriculture, 1959, 1964, 1969, 1975a, 1975b, 1978, 1979). The soil associations are shown on figure 4.0-1.

Loess is a silty wind deposit that resulted from outwash material being blown from the valleys onto the uplands during glacial times. When the loess was deposited, it was calcareous and contained many important plant nutrients. It was a friable, medium-textured silt loam with high available moisture storage capacity (Fehrenbacher and others, 1967). At present, loess thicknesses in the study area range from less than 5 to 15 feet (Lineback, 1979). Loess is easily eroded unless cut in vertical slopes. In addition, seepage may occur at the boundary with the underlying drift or bedrock. To prevent slope failure, the slopes should be benched and gutters may be necessary at the top of the slope and on the benches (Thornburn, 1963). The following associations were developed from Peoria Loess: Hoyleton-

Cisne-Huey, Stookey-Alford-Muren, Hosmer-Stoy-Weir, Ava-Bluford-Wynoose, and Grantsburg-Robbs-Wellston.

Other soil associations in the study area were developed from outwash and alluvium. Outwash materials were deposited in the major river valleys by meltwater during the Illinoian glaciation. The texture of the outwash ranges from clay to gravel. Alluvium is recent sediments that are being deposited by streams in their flood plains. Alluvium in the study area is mostly acidic and its texture ranges from fine to medium (Fehrenbacher and others, 1967).

Information on the engineering properties of soils in the study area and detailed soil maps can be found in soil surveys for individual counties. These are published by the Soil Conservation Service in cooperation with the University of Illinois Agriculture Experiment Station. Reports are available for the following counties: Saline, Pope and Hardin, Union, Gallatin, Jackson, Johnson, and Williamson. Reports are being prepared for the following counties: Perry and Hamilton.

A report by Wischmeier and Smith (1978) contains useful information on predicting rainfall erosion losses.

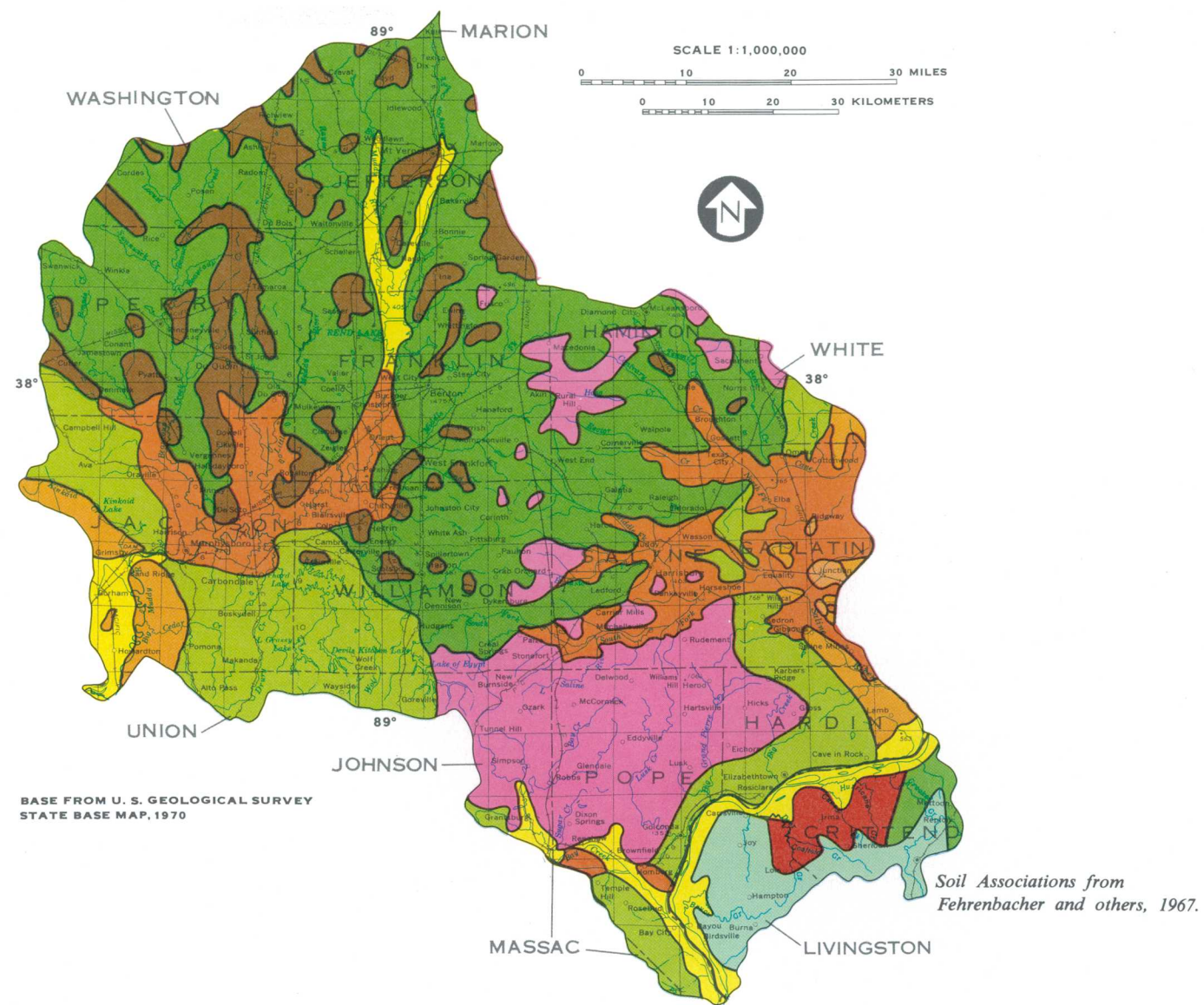


Figure 4.0-1 Soil Associations.













Soil association map symbol	Depth to bedrock (ft)	Depth to high water table (ft)	Permeability (in/h)	Available water capacity of soil (in/in)	Soil reaction pH
<b>Soils of Illinois</b>					
Dark-colored soils developed primarily from loess					
 Hoyleton-Cisne-Huey	5	0-3	0.0-2.0	0.13-0.28	4.5-6.5
Light-colored soils developed primarily from loess					
 Stookey-Alford-Muren	8	8	0.63-2.00	0.18-0.25	5.1-8.4
 Hosmer-Stoy-Weir	6	0-3	0.06-2.00	0.14-0.25	4.0-6.0
 Ava-Bluford-Wynoose	6	0-10	0.06-2.00	0.15-0.25	4.0-6.0
 Grantsburg-Robbs-Wellston	4-6	1-3	0.06-2.00	0.14-0.25	4.5-6.0
Dark- and light-colored soils developed primarily from medium and fine textured outwash					
 Littleton-Proctor-Planto-Camden-Hurst-Ginat	10	5-10	0.63-6.30	0.10-0.25	5.6-8.4
 Hagener-Ridgeville-Bloomfield-Alvin	10	10	0.63-20.0	0.02-0.18	5.1-7.3
Dark- and light-colored soils developed primarily from alluvium					
 Lawson-Beaucoup-Darwin-Haymond-Belknap	0-5-10	0-4	0.06-2.00	0.11-0.25	5.1-7.8
<b>Soils of Kentucky</b>					
Deep, well drained to poorly drained soils formed in loamy alluvium on flood plains and terraces					
 Huntington-Melvin					
Deep, moderately well drained to somewhat poorly drained soils formed in loess					
 Grenada-Loring					
Moderately deep to deep, moderately well drained to well drained soils formed in loess over residuum from sandstone, siltstone, and shale or in loamy material over interbedded sandstone, siltstone, and shale					
 Zanesville-Frondorf					
Deep, moderately well drained to well drained soils formed in clayey residuum from cherty limestone or in loess over limestone residuum					
 Baxter-Crider					

Table 4.0-1 Soil Association Features.

## 5.0 LAND USE

### AGRICULTURE IS DOMINANT LAND USE

*Sixty-six percent of the study area is used for agriculture.  
Coal mining uses 2.6 percent of the total land area.*

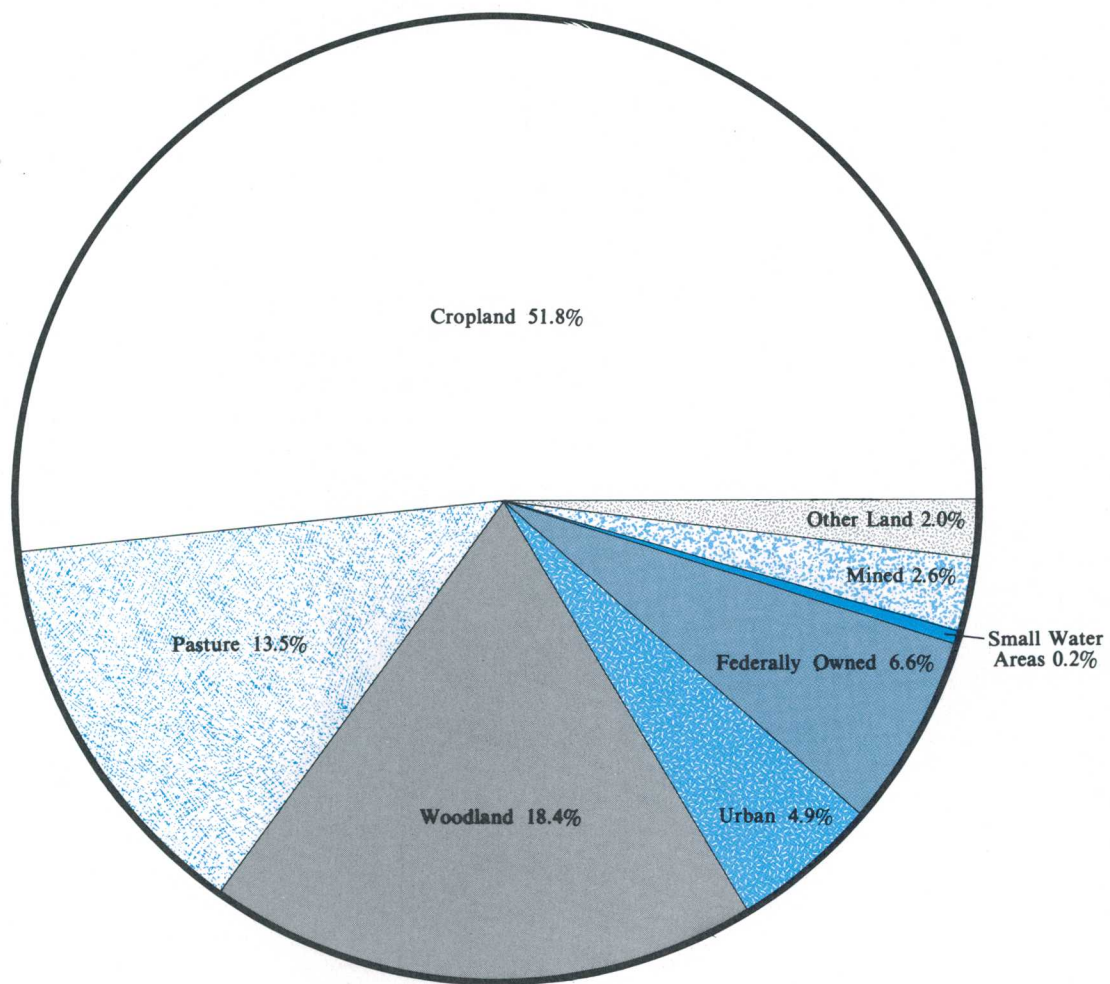
Area 35 covers 4,500 square miles. Agriculture is the dominant land use with 51.8 percent cropland and 13.5 percent pasture. The main crops are corn, soybeans, peaches, and apples. The remainder of the area is used in the following ways: 18.4 percent woodland, 4.9 percent urban, 6.6 percent federally owned (including national forest and national wildlife refuge land), 2.6 percent coal mining, 0.2 percent small water areas (ponds from 2 to 40 acres in size and streams less than 1/8 mile wide), and 2 percent other lands (fig. 5.0-1). Large water areas are excluded from the total land area (Illinois Conservation Needs Committee, 1970, Nawrot and others, 1980).

The mined land includes all land that has been affected by mining, both past and present. Surface mining has affected 2.5 percent of the land (Nawrot and others, 1980). There are 26 active surface mines in the study area (Hopkins, 1975, updated in 1978). Less than 0.1 percent of the land surface has been affected by underground mining, although approximately 7 percent of the total study area has been undermined with the

largest amounts being in Franklin County (36 percent), Williamson County (25 percent), and Saline County (19 percent) (Nawrot and others, 1980). As of August 1978, there were 15 underground mines still in operation and 2 under construction in the study area (Hopkins, 1975, updated in 1978).

There are six large surface-water impoundments in the area that occupy a total of 31,825 acres (Illinois Environmental Protection Agency, 1978). These impoundments are used for public water supply, powerplant supply, recreation and wildlife, and flood control.

The Shawnee National Forest covers 333 square miles in southern Illinois, most of which is in the study area. Crab Orchard National Wildlife Refuge is a 67 square mile area located in Williamson, Jackson, and Union Counties. It is managed for wildlife conservation and is used for recreation, agriculture, and industry (Bureau of Sport Fisheries and Wildlife, no date). No mining is allowed in the refuge (Treworgy and others, 1978).



**Figure 5.0-1 Land Use, 1967.**

## 6.0 WATER USE

### **EIGHTY-SEVEN PERCENT OF THE WATER IN THE STUDY AREA IS OBTAINED FROM SURFACE WATER SOURCES**

*The study area includes several large surface water impoundments. Although both ground water and surface water are withdrawn for industrial and domestic uses, 87 percent of the water used in the study area comes from surface water sources.*

Total water withdrawal from both surface and ground water sources is about 17 million gallons per day (mgal/d) (Kirk and others, 1979). Approximately 22.2 mgal/d (13 percent) is from ground water.

As shown in figure 6.0-1, 66 percent (112.8 mgal/d) of the total amount of water withdrawn is used for industry, 14 percent (23.5 mgal/d) is used for mineral extraction, 14 percent (23.8 mgal/d) is used for public supply, 4.5 percent (7.7 mgal/d) is used for rural supplies (domestic, livestock, and irrigation), and 1.5 percent (2.7 mgal/d) is used for fish and wildlife management.

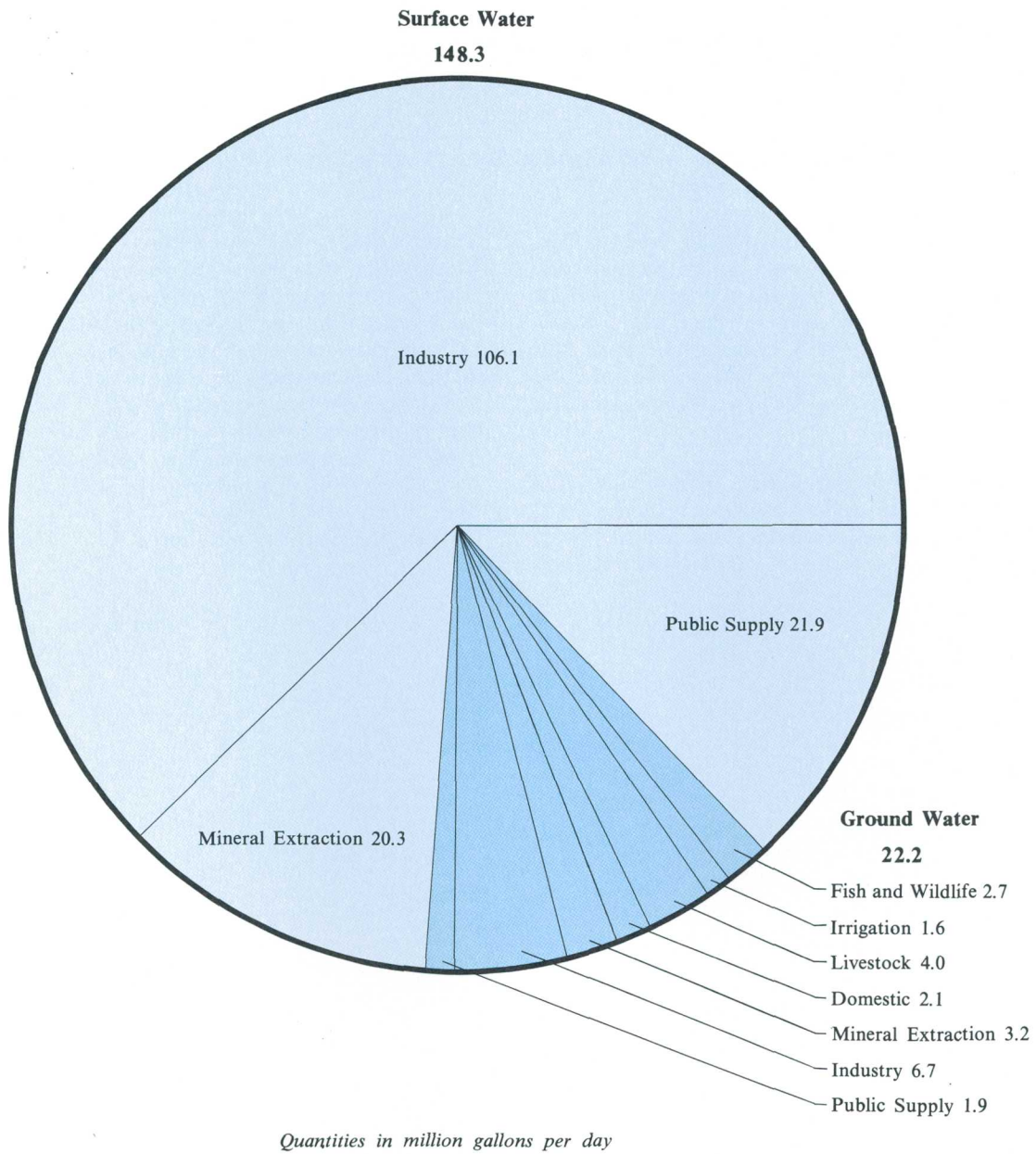
All of the larger communities in the study area use surface-water impoundments for their water supplies.

Ground water is used mainly for rural domestic supplies and small industries.

The largest surface-water impoundments in the study area are Rend Lake, Lake of Egypt, Kinkaid Lake, Crab Orchard Lake, Little Grassy Lake, and Devils Kitchen Lake. These lakes are multipurpose reservoirs that are used for public water supply, powerplant supply, flood control, and recreation and wildlife (Smith and Stall, 1975).

Water use data are available in a report entitled "Water Withdrawals in Illinois, 1978" (Kirk and others, 1980).





**Figure 6.0-1 1978 Water Use.**

## 7.0 PRECIPITATION

### PRECIPITATION

*Mean annual precipitation in the study area varies from 40 to 46 inches.*

The U.S. Weather Bureau records are used to calculate the distribution of the mean annual precipitation. Over 2,000 recording precipitation sites are operated throughout the eastern half of the United States (Frederick and others, 1977). Daily precipitation data are published monthly by the National Oceanic and Atmospheric Administration (NOAA), National Climatic Center, Asheville, N.C.

The mean annual precipitation in the study area varies from 39 to 46 inches, as shown in figure 7.0-1. A large part of the area extending from the southwest to the eastern edges receives 46 inches (Roberts and

others, 1962). The distribution and occurrence of precipitation are related to several factors including distance to primary moisture source (Gulf of Mexico), local topography, and elevation (about 300 feet elevation in the south to about 600 feet elevation in the north). Thunderstorms account for over 70 percent of the warm season precipitation (fig. 7.0-2). The cold season precipitation (fig. 7.0-3) falls as snow, general rain, and thunderstorms. The mean annual snowfall varies from 10 to 15 inches in the study area (Roberts and others, 1962). Figure 7.0-4 shows the 2-year, 24-hour precipitation varies from 3.4 to 3.6 inches.



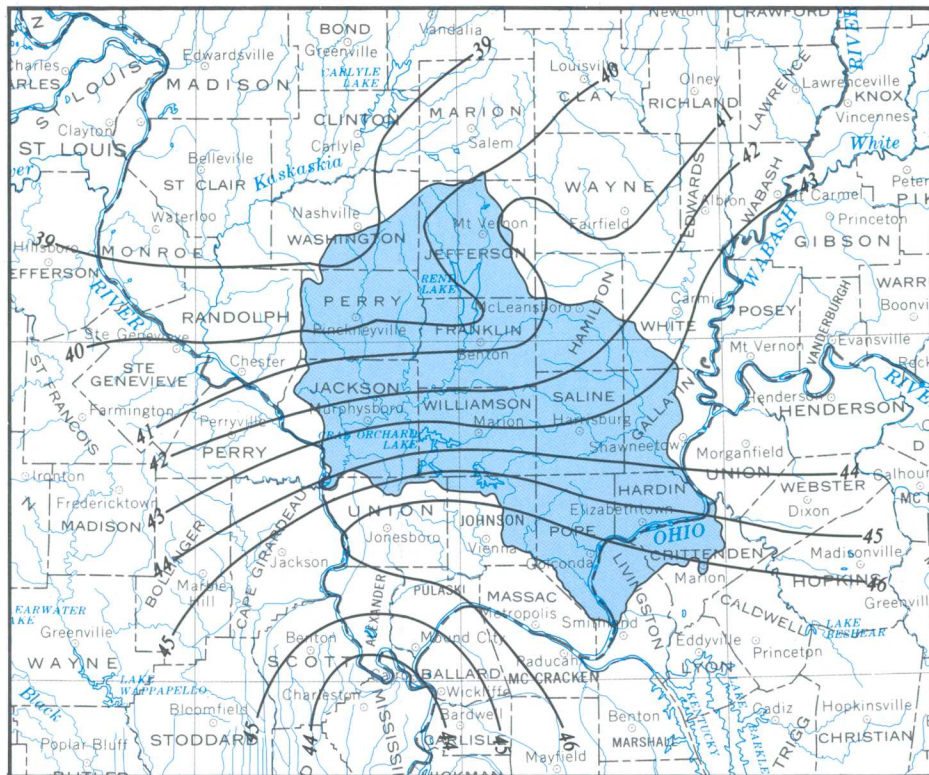


Figure 7.0-1 Distribution of mean annual precipitation.

EXPLANATION

Lines of equal precipitation,  
in inches.

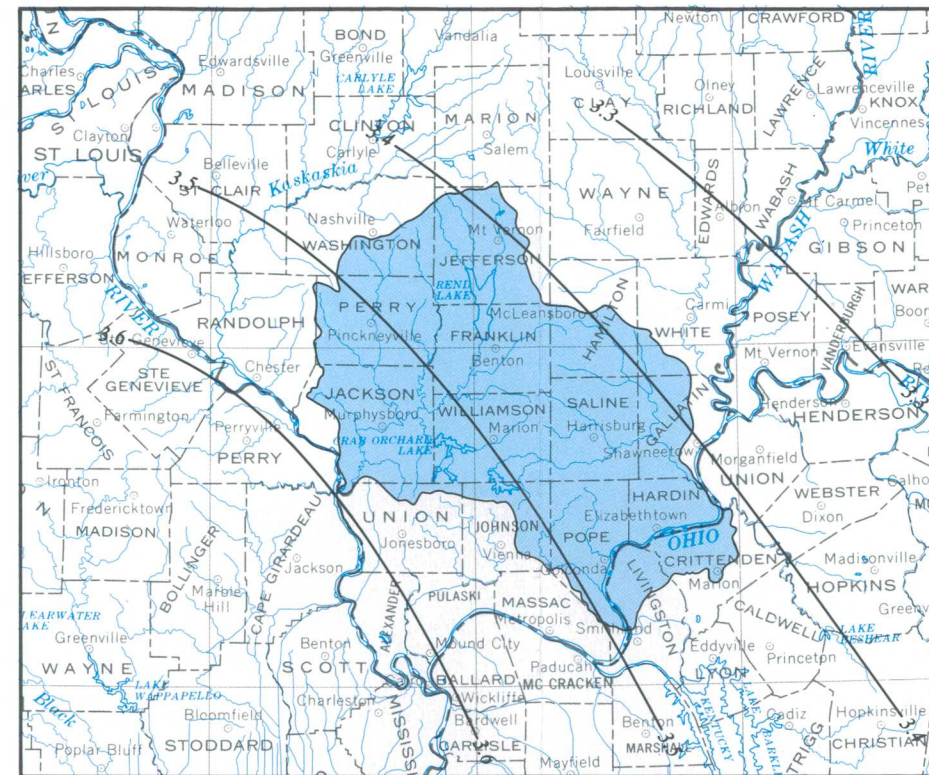


Figure 7.0-3 2 year - 24 hour precipitation.

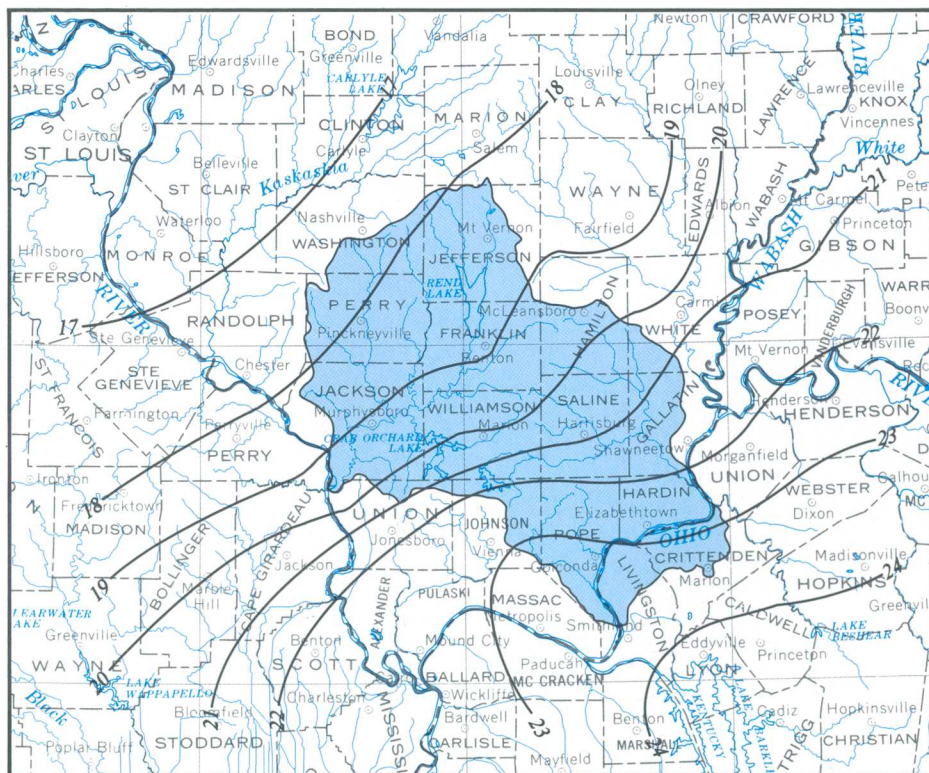


Figure 7.0-2 Distribution of colder half-year (October-March) precipitation.

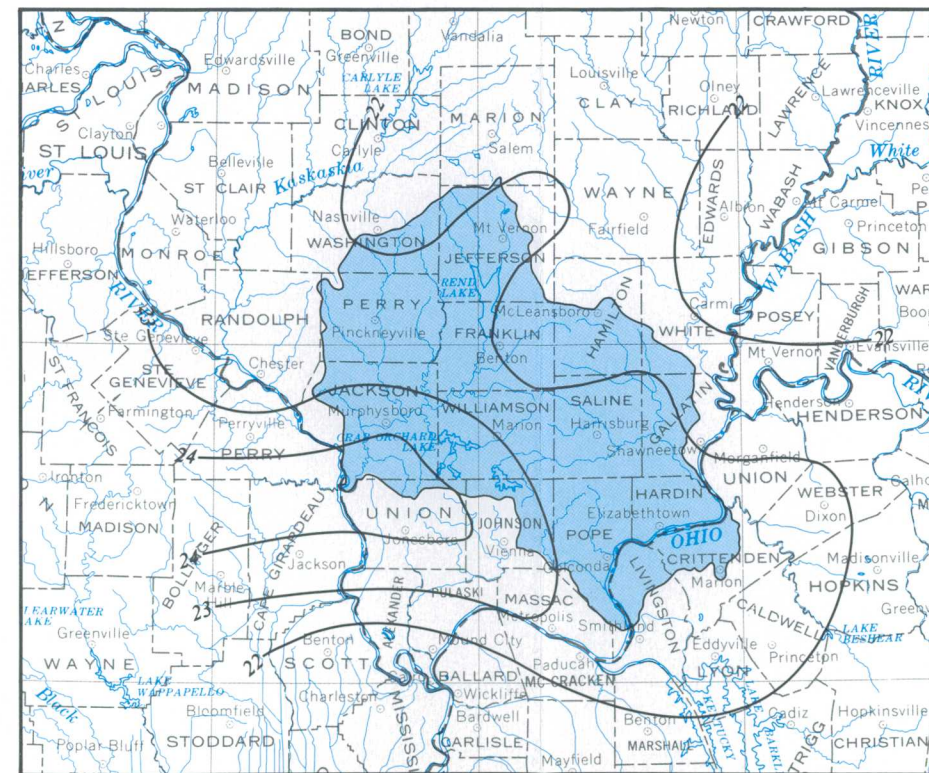


Figure 7.0-4 Distribution of warmer half-year (April-September) precipitation.



## 8.0 SURFACE WATER

### 8.1 SURFACE-WATER QUANTITY

#### 8.1.1 GAGING STATIONS AND MEAN ANNUAL FLOW

### SURFACE-WATER FLOW

*Study area streams flow into the Ohio and Mississippi Rivers. Mean annual flow is estimated from the drainage area by the equation  $Q_a = A^{0.97}$ .*

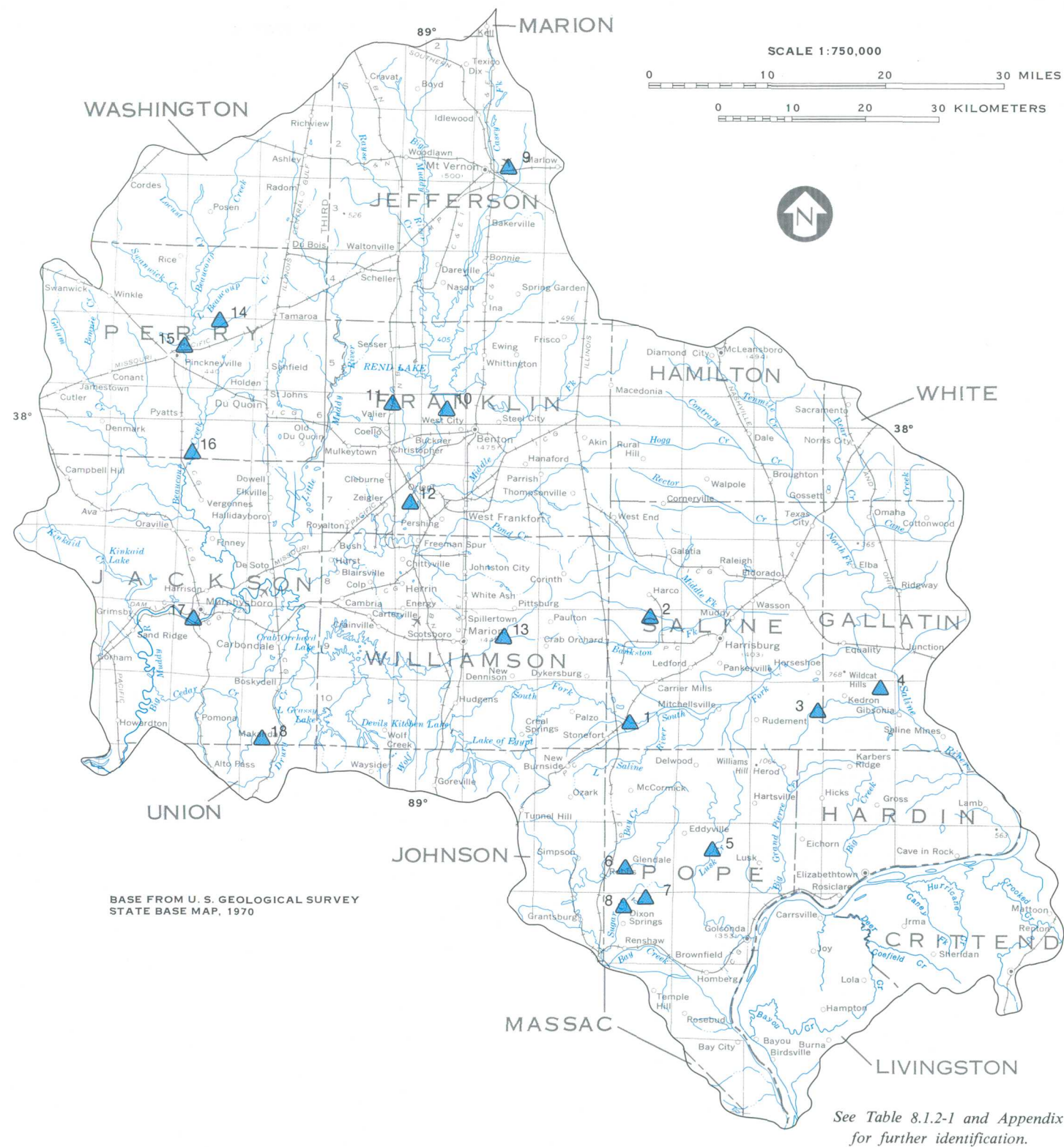
The study area drains into the Mississippi and Ohio Rivers. The Big Muddy River drains the west half of the study area into the Mississippi River. The Saline River flows into the Ohio River and is the major river draining the northeastern quarter of the study area. Many other small streams in the southeastern quarter of the study area flow directly into the Ohio River from Illinois and Kentucky.

There are 18 streamflow gaging stations in the study area (fig. 8.1.1-1). Ten gaging stations had sufficient record to establish an average flow rate. The average daily flow is given in appendix 1.

Mean annual flows of ungaged streams can be estimated from the drainage area using the equation

$Q_a = A^{0.97}$  where mean annual streamflow ( $Q_a$ ) is in cubic feet per second and the area (A) is in square miles. This equation is based on records for 10 gaging stations having record lengths averaging 17.4 years and drainage areas ranging from 8.5 to 2,169 square miles. Gage locations are shown in figure 8.1.1-2.

The mean annual streamflow is dependent on drainage area, soil index, mean annual precipitation, area of lakes and ponds, area of forest, elevation, and stream slope and length (in that order of importance) as described by Sieber (1970). Drainage area is the most significant variable and can be measured on a topographic map.



#### EXPLANATION

▲<sup>5</sup> Gaging station

Figure 8.1.1-1 Gaging station locations.

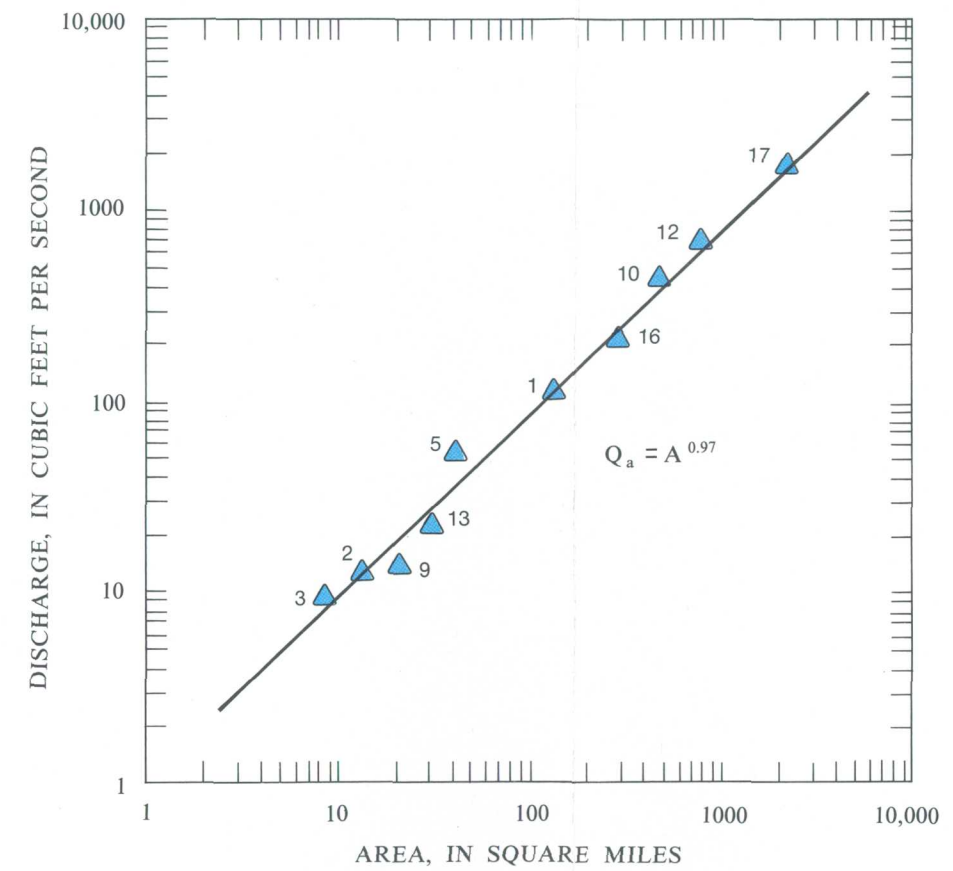


Figure 8.1.1-2 Area 35 mean annual flow.

## 8.0 SURFACE WATER

### 8.1 SURFACE WATER QUANTITY

#### 8.1.1 GAGING STATIONS AND MEAN ANNUAL FLOW

See Table 8.1.2-1 and Appendix 1 for further identification.

8.0 SURFACE WATER (Continued)  
 8.1 SURFACE-WATER QUANTITY (Continued)  
 8.1.2 ESTIMATING STREAMFLOW

## ESTIMATING STREAMFLOW EXTREMES

*The 10-year peak discharge can be estimated using the equation  $Q_{10} = 79 A^{0.767} S^{0.494} (I - 2.5)^{0.833}$ . The 7-day, 10-year high flow is estimated using the equation  $V_{7,10} = 22.9 A^{0.922}$ . The 7-day, 10-year low flow is estimated using the equation  $M_{7,10} = 0.000082 A^{1.32}$ .*

Streamflow extremes can be estimated using equations developed from streamflow records at several gaging stations in the region (fig. 8.1.2-1).

Floodflows in a stream occur when there is excessive rainfall and/or rapid snowmelt. The peak discharge for the 10-year recurrence interval can be estimated using the equation  $Q_{10} = 79 A^{0.767} S^{0.494} (I - 2.5)^{0.833}$ . The 10-year peak discharge ( $Q_{10}$ ), in cubic feet per second ( $\text{ft}^3/\text{s}$ ), will be exceeded at intervals averaging 10 years in length. The drainage area (A) is in square miles. The river channel slope (S) is measured from the 10 to 85 percent points from the site to the basin divide on the principal channel. The rainfall intensity (I) is the maximum 24-hour rainfall, in inches, expected to be exceeded at intervals averaging 2 years (Curtis, 1977).

For sustained high flow or flood volume, the equation  $V_{7,10} = 22.9 A^{0.922}$  is used (fig. 8.1.2-3).  $V_{7,10}$  is the highest average rate of flow for 7 consecutive days, in cubic feet per second, that will be exceeded on the

average of once in 10 years. The drainage area (A) is measured in square miles.

Low flows occur after many days of no precipitation or snowmelt. All surface discharge then comes from springs and seeps along the stream. The 7-day, 10-year low flow ( $M_{7,10}$ ) can be estimated from drainage area (A), in square miles, using the equation  $M_{7,10} = 0.000082 A^{1.32}$  (fig. 8.1.2-2).

The 7-day, 10-year high and low flows and the peak discharge equations are based on records from U.S. Geological Survey streamflow gaging stations having an average of 28 years of record. The drainage areas vary from 13.3 to 2,169 square miles.

Table 8.1.2-1 shows the  $Q_2$ ,  $Q_{10}$ , and  $Q_{50}$  (2-, 10-, and 50-year peak discharges) for various gaging stations calculated from their discharge records. Additional flood-frequency equations and details are available in Curtis (1977).



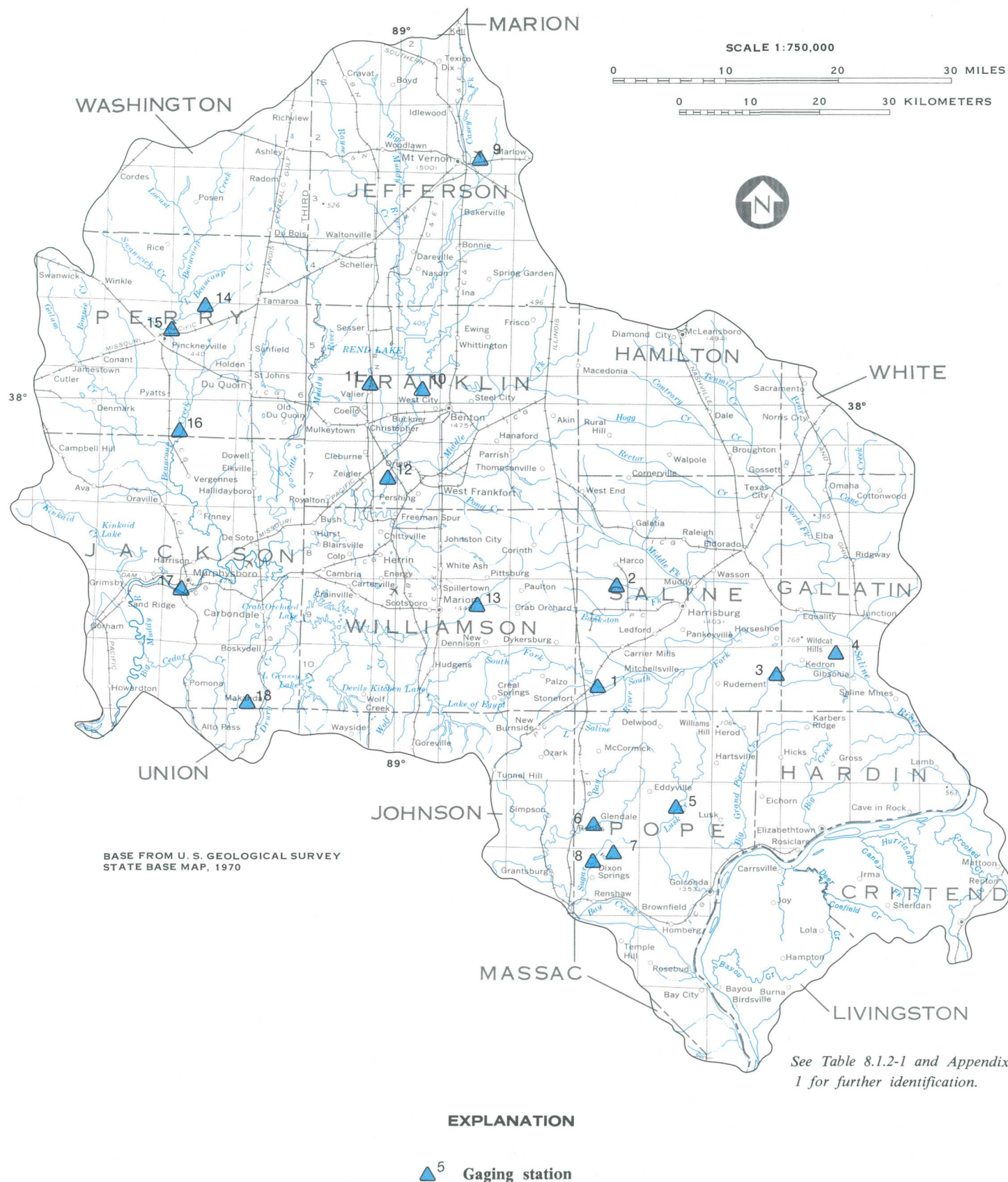


Figure 8.1.2-1 Gaging station locations.

Map No.	USGS No.	Drainage area (mi <sup>2</sup> )	Peak discharge (ft <sup>3</sup> /s)			7-day, 10-year flow (ft <sup>3</sup> /s)	
			Q <sub>2</sub>	Q <sub>10</sub>	Q <sub>50</sub>	Low, M <sub>7,10</sub>	High, V <sub>7,10</sub>
1	03382100	147	2,860	5,130	7,120	0.06	2,280
2	03382170	13.3	---	---	---	.03	249
3	03382510	8.51	---	---	---	<.01	165
4	03382520	1.10	164	415	675	<.01	25.0
5	03384450	42.9	---	---	---	.01	733
6	03385000	19.1	2,170	4,250	6,060	<.01	41.6
7	03385500	1.05	597	1,090	1,520	<.01	24.0
8	03386500	9.93	---	---	---	<.01	190
9	05595800	21.1	1,020	1,880	2,630	<.01	381
10	05596000	502	7,450	17,600	27,300	.30	7,080
11	05596100	1.03	247	570	884	<.01	23.6
12	05597000	794	7,610	16,700	24,000	.55	10,800
13	05597500	31.7	1,450	2,880	4,160	.01	554
14	05598480	16.5	---	---	---	<.01	304
15	05598500	231	---	---	---	.11	3,460
16	05599000	292	4,840	12,100	19,500	.15	4,300
17	05599500	2,169	12,600	26,900	39,200	2.08	27,300
18	05599560	1.94	730	1,530	2,250	<.01	42.2

Table 8.1.2-1 Estimating flows at study area gaging stations.

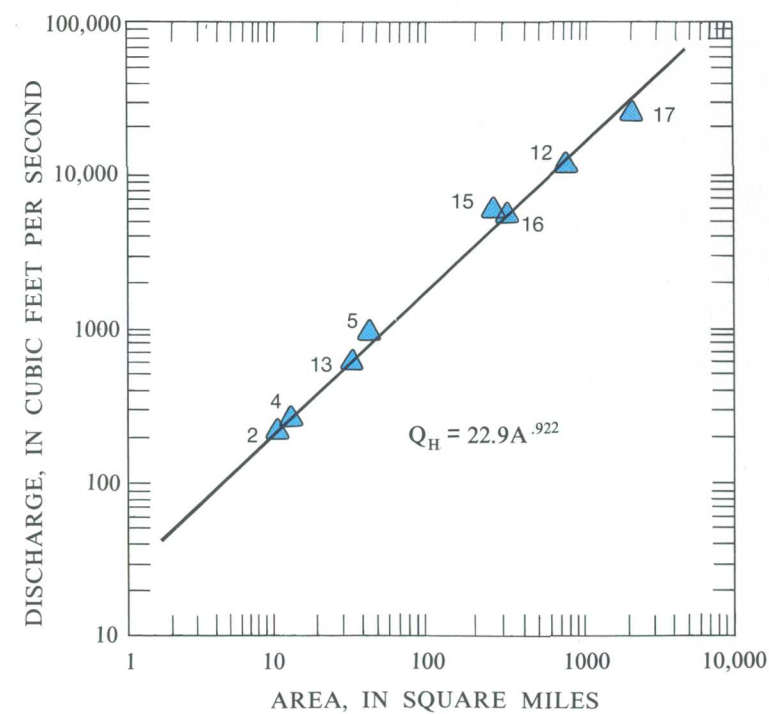


Figure 8.1.2-3 7-day 10-year high flow.

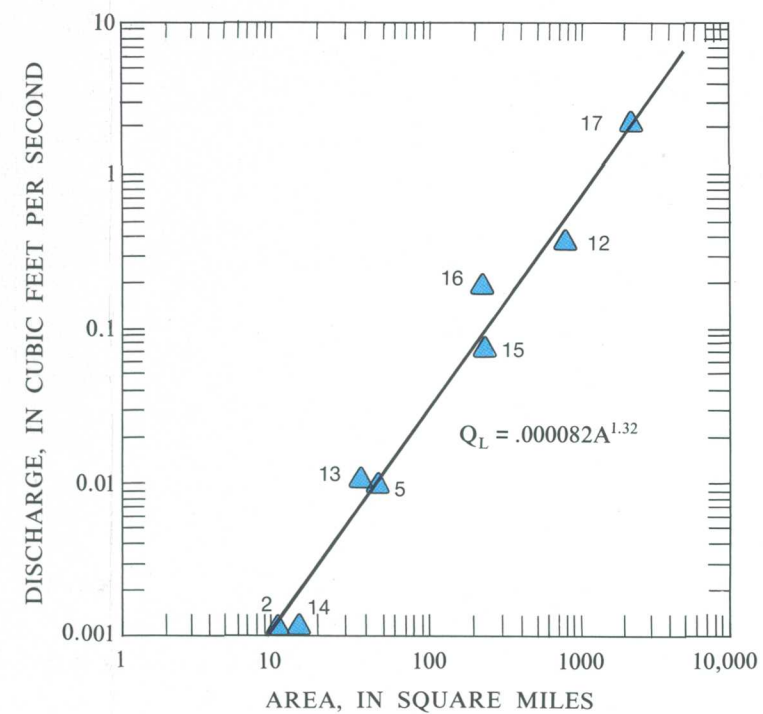


Figure 8.1.2-2 7-day 10-year low flow.

## 8.0 SURFACE WATER

### 8.1 SURFACE WATER QUANTITY

#### 8.1.2 ESTIMATING STREAMFLOW

8.0 SURFACE WATER (Continued)  
 8.2 SURFACE-WATER QUALITY  
 8.2.1 AVAILABLE DATA

**WATER QUALITY DATA ARE AVAILABLE FOR SITES UPSTREAM AND  
 DOWNSTREAM OF SURFACE MINING IN THE STUDY AREA**

*Measurements of specific conductance, pH, alkalinity, acidity, iron, manganese, sulfate, and other constituents are available at up to 63 sites in the study area.*

Specific conductance, pH, alkalinity, acidity, sulfate, dissolved and total recoverable iron, and dissolved and total recoverable manganese are important when assessing water quality of areas influenced by surface mining. These data, included in this report, have been collected in the study area by both the U.S. Geological Survey and the Illinois Environmental Protection Agency. The type of data and frequency of collection varies at each site

and often varies between sites. Six sites in the Big Muddy River basin and nine sites in the Saline River basin are upstream of (unaffected by) mining (table 8.2.1-1). Twenty-eight sites in the Big Muddy River basin and 20 sites in the Saline River basin are downstream of mining (table 8.2.1-2). For more complete information on site locations see figure 8.2.1-1 or refer to appendix 2.

Site No.	Station No.	Name	Period of record	Drainage area (mi <sup>2</sup> )	Number of observations
1	03382040	South Fork Saline River at New Dennison	1979	61.3	2
2	03382045	Little Cana Creek near Creal Springs	1978-79	1.45	12
3	03382079	Sugar Creek near Creal Springs	1979	24.5	2
6	03382119	Little Saline River near McCormick	1979	15.3	2
7	03382120	Little Saline River near Stonefort	1975	19.5	2
22	03382315	North Fork Saline River near Broughton	1979	90.0	2
23	03382320	Rector Creek near Texas City	1975-79	76.4	10
24	03382325	North Fork Saline River near Texas City	1977-79	173	20
29	03384450	Lusk Creek near Eddyville	1974-79	42.9	69
30	05595700	Big Muddy River near Mt. Vernon	1977-79	71.9	16
41	05597240	Little Muddy River at Radom	1979	14.9	2
49	05598205	Sycamore Creek near Boskydell	1979	1.56	2
52	05598400	Beaucoup Creek near Todds Mill	1979	101	2
53	05598480	White Walnut Creek near Pinckneyville	1979	16.5	1
56	05599020	Galum Creek near Jamestown	1975-79	21.4	3

**Table 8.2.1-1 Sites upstream of (unaffected by) mining.**



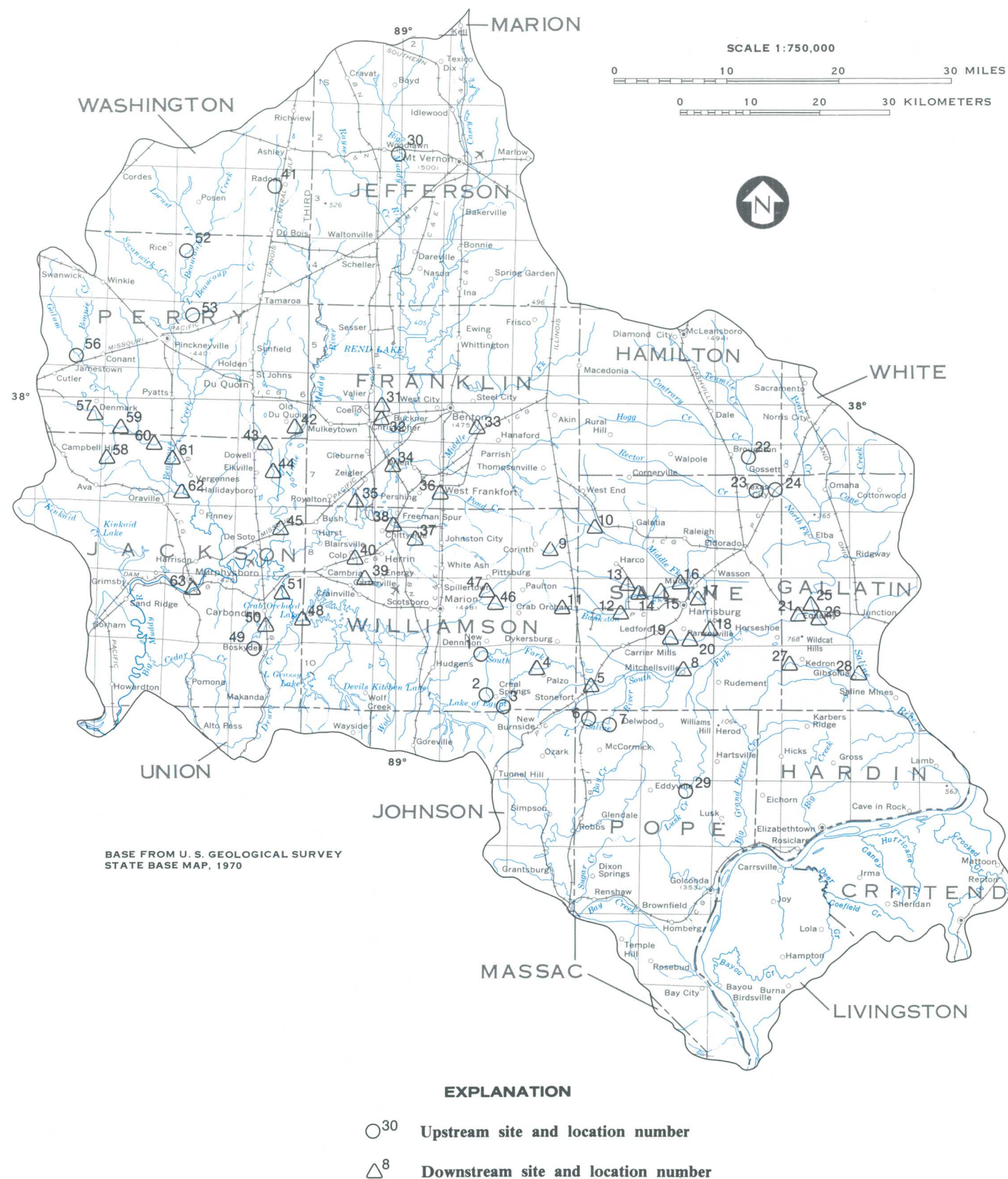


Figure 8.2.1-1 Location of water quality sites.

Site No.	Station No.	Name	Period of record	Drainage area (mi <sup>2</sup> )	Number of observations
4	03382090	Sugar Creek near Stonefort	1975-79	35.4	42
5	03382100	South Fork Saline River near Carrier Mills	1974-79	147	69
8	03382130	South Fork Saline River at Mitchellsville	1975-77	248	8
9	03382155	Prairie Creek near Cornith	1975-79	5.43	3
10	03382156	Middle Fork Saline River near Galatia	1979	47.5	2
11	03382160	Bankston Fork near Crab Orchard	1978-79	1.90	15
12	03382168	Bankston Fork near Carrier Mills	1979	35.5	2
13	03382170	Brushy Creek near Harco	1974-79	13.3	47
14	03382175	Brushy Creek tributary near Harco	1975-79	4.04	4
15	03382180	Bankston Fork at Dorris Heights	1975	73.3	2
16	03382185	Bankston Fork near Dorris Heights	1975-79	77.7	16
17	03382200	Middle Fork Saline River near Harrisburg	1979	225	2
18	03382205	Middle Fork Saline River near Pankeyville	1975-79	233	24
19	03382210	Brier Creek near Harrisburg	1975	3.22	1
20	03382211	Brier Creek near Pankeyville	1979	4.05	1
21	03382250	Saline River at Equality	1975-79	559	6
25	03382360	North Fork Saline River near Equality	1979	449	2
26	03382450	Saline River near Equality	1975-76	1,022	5
27	03382510	Eagle Creek near Equality	1974-79	8.51	48
28	03382530	Saline River near Gibsonia	1978-79	1,062	16
31	05596105	Andy Creek at Buckner	1979	17.2	2
32	05596110	Andy Creek near Christopher	1975	18.4	2
33	05596400	Middle Fork Big Muddy River near Benton	1978-79	152	19
34	05597000	Big Muddy River at Plumfield	1974-79	794	62
35	05597035	Prairie Creek near Zeigler	1975	162	2
36	05597040	Pond Creek at West Frankfort	1975-79	33.1	34
37	05597045	Lake Creek near Herrin	1975	34.0	2
38	05597050	Pond Creek near Herrin	1975-79	95.5	4
39	05597070	Hurricane Creek near Colp	1979	18.3	2
40	05597080	Hurricane Creek near Herrin	1975	23.4	2
42	05597255	Reese Creek near Old Du Quoin	1975	37.3	1
43	05597265	Sixmile Creek at Dowell	1975-79	12.7	4
44	05597280	Little Muddy River near Elkhville	1978-79	213	31
45	05597300	Little Muddy River near De Soto	1976-77	283	7
46	05597490	Little Crab Orchard Creek near Marion	1975-79	8.50	3
47	05597500	Crab Orchard Creek near Marion	1974-79	31.7	73
48	05598050	Crab Orchard Creek below Crab Orchard Lake near Carterville	1978-79	201	26
50	05598210	Sycamore Creek near Carbondale	1975-79	5.56	10
51	05598245	Crab Orchard Creek near Carbondale	1977-79	242	33
54	05598700	Panther Creek near Pyatts	1975-77	30.8	8
55	05599000	Beaucoup Creek near Matthews	1974-79	292	55
57	05599055	Pipestone Creek near Denmark	1975-79	18.7	11
58	05599060	Brushy Fork near Denmark	1975-79	11.9	4
59	05599080	Pipestone Creek near Ava	1975-77	46.1	8
60	05599100	Galum Creek near Pyatts	1975-79	162	7
61	05599200	Beaucoup Creek near Vergennes	1978-79	478	32
62	05599300	Beaucoup Creek near Oraville	1975-77	515	6
63	05599500	Big Muddy River at Murphysboro	1970-76	2,169	44

Table 8.2.1-2 Sites Downstream of mining in report area.

## 8.0 SURFACE WATER

### 8.2 SURFACE WATER QUALITY

#### 8.2.1 AVAILABLE DATA

8.0 SURFACE WATER (Continued)  
8.2 SURFACE-WATER QUALITY (Continued)  
8.2.2 SPECIFIC CONDUCTANCE

**SPECIFIC CONDUCTANCE CAN BE USED TO ESTIMATE  
DISSOLVED SOLIDS CONCENTRATIONS AT SITES IN THE STUDY AREA**

*Regression coefficients for dissolved solids versus specific conductance indicate a difference in the chemical character of the water at sites downstream of mining. Mean values of specific conductance at sites upstream and downstream of mining were 680 and 1,430  $\mu\text{mho}/\text{cm}$  at 25°C, respectively.*

Specific conductance is defined as "the reciprocal of the resistance in ohms, measured between opposite faces of a centimeter cube, of an aqueous solution at a specific temperature" (Hem, 1970). In this report (table 8.2.2-1) specific conductance is reported as micro-mhos per centimeter at 25°C ( $\mu\text{mho}/\text{cm}$  at 25°C). Measured values of specific conductance ranged from 85 to 2,720  $\mu\text{mho}/\text{cm}$  at 25°C at the sites upstream of mining and 160 to 9,200  $\mu\text{mho}/\text{cm}$  at 25°C at sites downstream of mining (fig. 8.2.2-1). The mean value of specific conductance for the downstream data (1,430  $\mu\text{mho}/\text{cm}$  at 25°C) is more than double that of upstream data (680  $\mu\text{mho}/\text{cm}$  at 25°C) as shown in figure 8.2.2-2.

In the dilute solutions of Illinois streams and rivers, the relation between specific conductance and dissolved

solids is nearly linear (fig. 8.2.2-3). Specific conductance can be a useful tool for estimating dissolved solids concentrations by using the straight-line formula  $KA = S$  (Hem, 1970), where K is specific conductance in  $\mu\text{mho}/\text{cm}$  at 25°C, S is dissolved solids in milligrams per liter (mg/L), and A is a regression coefficient. The sites upstream of mining had a regression coefficient of 0.70 with a standard error of 92 mg/L for 19 observations. The sites downstream of mining had a regression coefficient of 0.90 with a standard error of 177 mg/L for 37 observations. The different coefficients for these two data groups indicate a difference in the chemical character of the water.



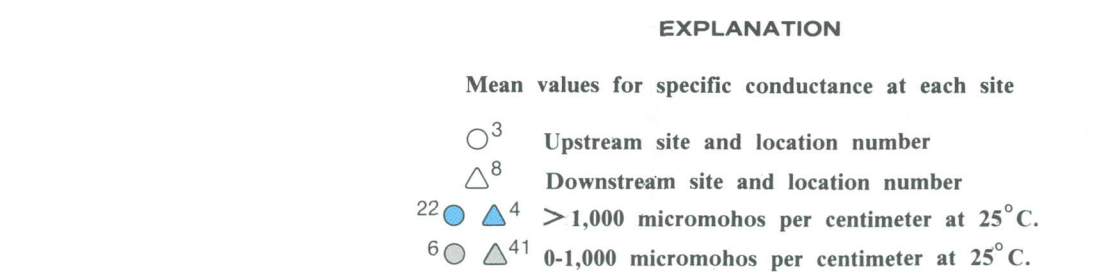
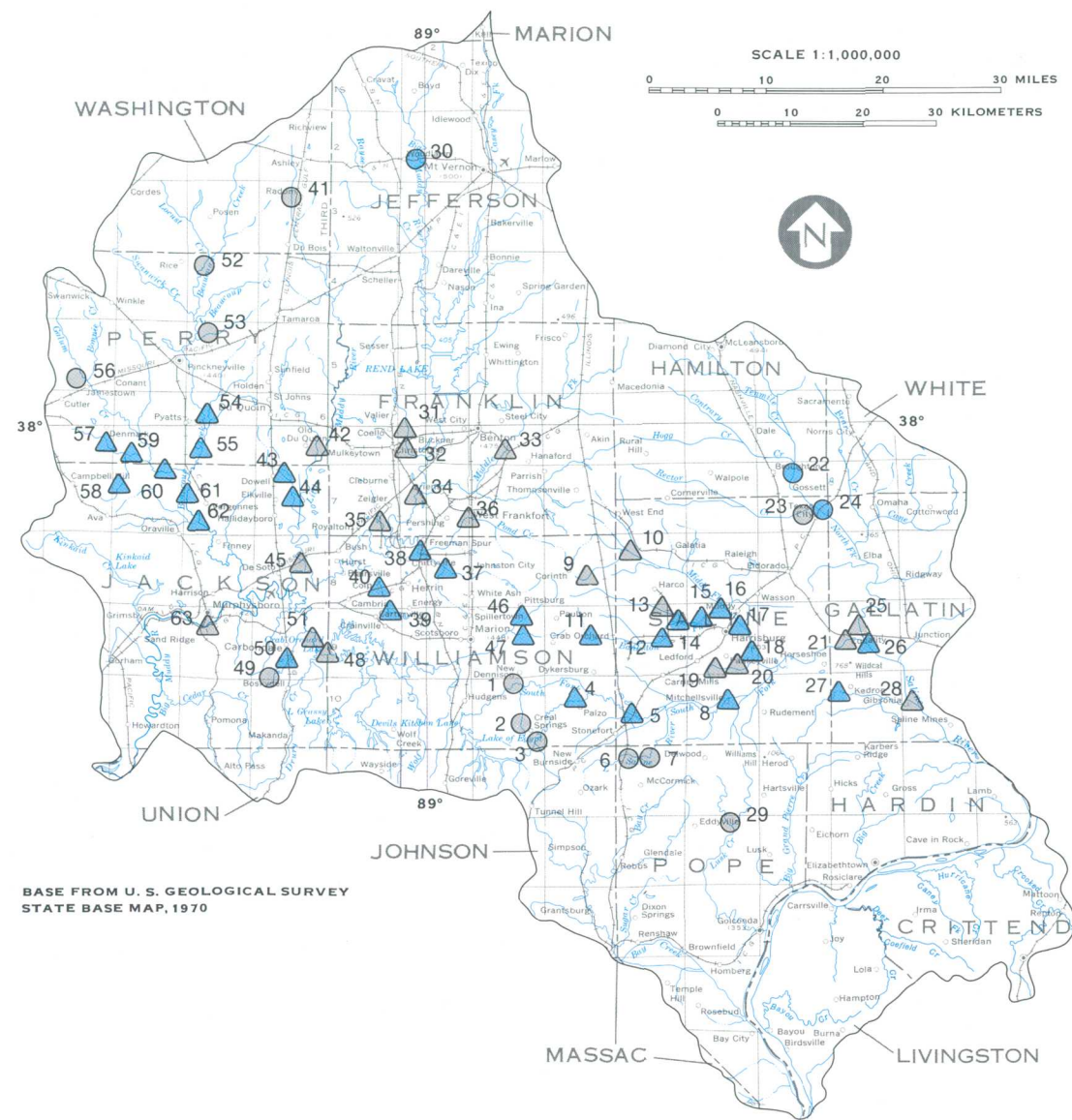


Figure 8.2.2-1 Mean values of specific conductance at water quality sites.

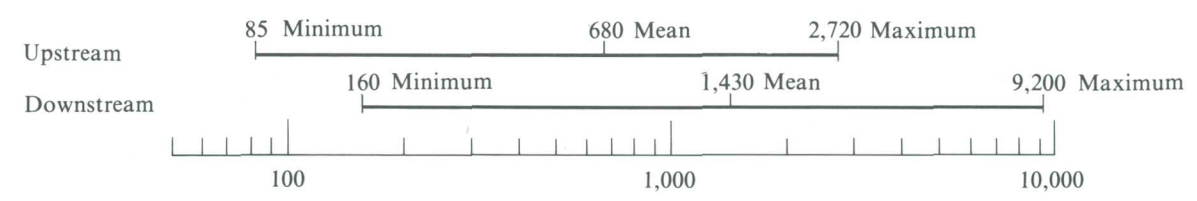


Figure 8.2.2-2 Range of specific conductance values measured at sites upstream and downstream of mining in micromhos per centimeter at 25°C measured at sites in the area.

Site Number	Number of Observations	Specific conductance (micromhos/cm at 25°C)			Site Number	Number of Observations	Specific conductance (micromhos/cm at 25°C)		
		Minimum	Mean	Maximum			Minimum	Mean	Maximum
1	2	320	345	370	33	19	225	509	810
2	11	146	462	785	34	16	267	355	480
3	2	270	330	390	35	2	200	540	880
4	31	350	2,800	9,200	36	28	161	724	1,875
5	42	220	1,220	3,000	37	1	1,080	1,080	1,080
6	2	200	202	205	38	4	1,095	1,533	1,980
7	2	120	143	167	39	2	1,220	1,240	1,270
8	8	278	1,010	2,000	40	2	970	1,090	1,210
9	3	570	709	800	41	2	439	860	1,280
10	2	560	990	1,420	42	1	680	680	680
11	15	3,050	3,990	4,300	43	4	1,120	1,960	2,750
12	2	3,200	3,240	3,270	44	22	220	1,110	2,520
13	8	300	633	1,130	45	7	260	680	1,570
14	4	2,050	4,330	5,950	46	3	1,120	1,750	2,200
15	2	2,000	2,450	2,900	47	27	375	1,480	2,750
16	15	672	2,240	3,600	48	18	195	276	375
17	2	1,900	2,200	2,500	49	2	600	628	655
18	22	500	1,420	2,560	50	10	380	1,800	3,500
19	1	586	586	586	51	20	215	352	465
20	1	655	655	655	52	2	272	648	1,025
21	6	362	984	1,380	53	2	429	695	960
22	2	620	1,670	2,720	54	8	1,700	3,200	5,000
23	10	460	770	1,200	55	8	860	1,630	2,720
24	20	179	1,060	2,610	56	3	440	770	960
25	2	635	692	750	57	11	840	4,140	6,720
26	5	369	1,080	2,030	58	4	960	1,510	2,580
27	2	635	1,100	1,570	59	8	1,300	3,460	6,050
28	17	210	905	1,660	60	7	690	3,400	5,050
29	19	85	118	158	61	21	295	2,140	4,500
30	15	433	1,050	2,130	62	6	760	1,210	2,260
31	2	530	590	650	63	65	185	694	1,480
32	2	714	772	830					

Sites upstream from mining

Table 8.2.2-1 Specific conductance values measured at water quality sites.

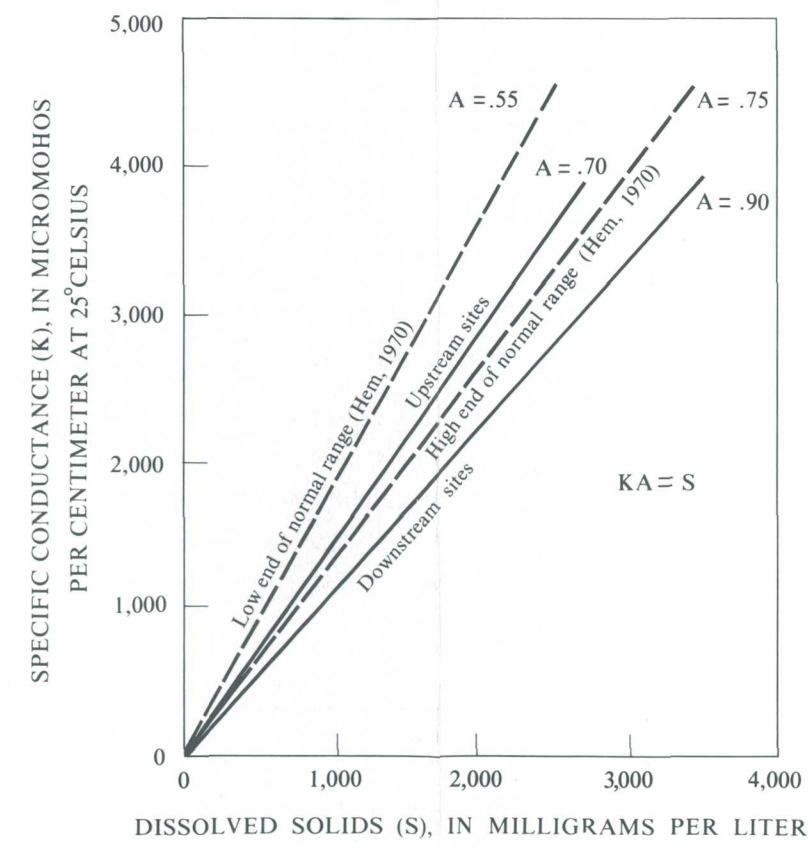


Figure 8.2.2-3 Relationship between specific conductance and dissolved solids in the study area.

8.0 SURFACE WATER (Continued)  
 8.2 SURFACE-WATER QUALITY (Continued)  
 8.2.3 pH

**VALUES FOR pH ARE AVAILABLE AT SITES  
 DOWNSTREAM OF MINING**

*Sites downstream of mining exhibit a wider range in pH (2.0 to 9.0) than sites upstream of mining (6.4 to 8.7). As a group, the downstream sites also tend to have lower pH values than the sites upstream of mining.*

“pH” is defined as the negative base 10 logarithm of the hydrogen-ion activity in moles per liter. Most waters in the study area (fig. 8.2.3-1) have a pH above seven (basic solutions) and indicate the influence of carbonate-bearing sedimentary rocks. Because of surface mining, weathering of the iron sulfides (marcasite and pyrite) is accelerated and subsequent reactions create acidic solutions with lower pH values. Iron and other metals can be dissolved from the weathered material and high

concentrations of a variety of dissolved metals may be found at sites downstream of mining.

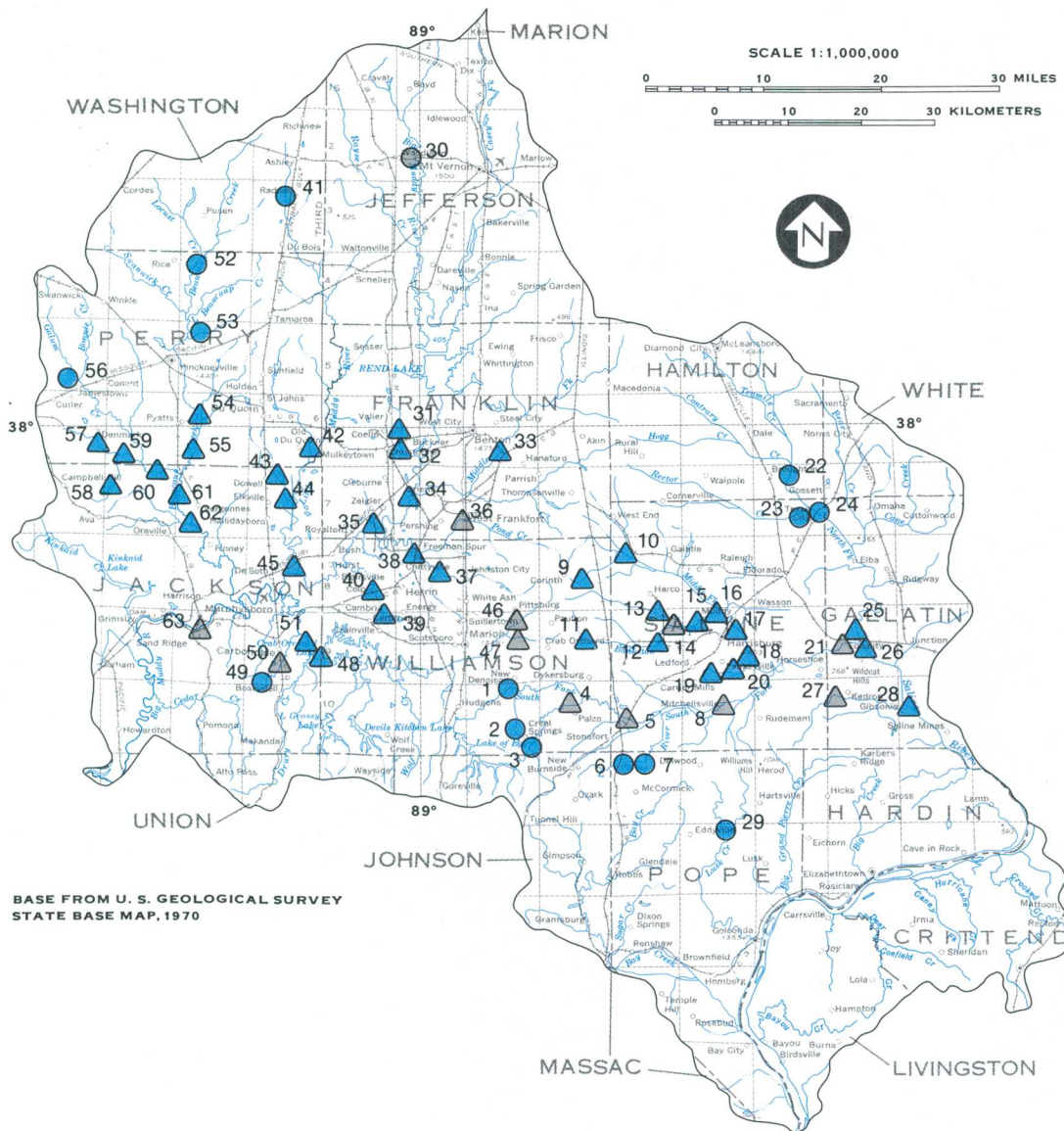
The pH measured at sites upstream of mining ranged from 6.4 to 8.7. This range is similar to the range of 6.5 to 8.5 described by Hem (1970) for “river water in areas not influenced by pollution.” The pH measured at downstream sites is much more variable ranging from 2.0 to 9.0 as shown in figure 8.2.3-2.

**Table 8.2.3-1 Minimum and maximum pH values  
 measured at water-quality sites.**

Site Number	Number of Observations	Minimum	Maximum	Site Number	Number of Observations	Minimum	Maximum
1*	2	6.5	7.2	36	28	6.4	8.1
2*	11	6.7	8.2	37	2	6.9	7.1
3*	2	7.5	7.7	38	4	6.7	7.0
4	32	2.5	5.0	39	2	7.6	8.0
5	42	2.9	6.9	40	2	7.2	7.3
6*	2	6.7	7.1	41*	2	7.4	7.5
7*	2	6.9	6.9	42	1	7.3	7.3
8	8	3.2	6.9	43	4	7.2	7.8
9	3	7.0	8.3	44	22	6.9	8.3
10	2	7.7	7.9	45	7	6.6	8.4
11	15	7.2	7.7	46	3	5.0	6.9
12	2	7.5	7.8	47	29	5.0	7.4
13	8	6.9	7.8	48	18	7.3	8.5
14	4	2.0	3.0	49*	2	8.2	8.3
15	2	6.7	7.2	50	10	2.9	7.6
16	15	6.7	8.1	51	22	7.1	8.4
17	2	7.9	8.0	52*	2	7.2	7.3
18	24	6.5	9.0	53*	3	6.9	7.2
19	1	7.3	7.3	54	8	7.6	8.6
20	1	8.1	8.1	55	8	7.5	8.3
21	6	6.1	7.6	56*	3	7.4	8.7
22*	2	7.9	8.0	57	11	7.2	8.7
23*	10	7.5	8.7	58	4	7.6	8.5
24*	20	7.5	8.8	59	8	7.8	8.7
25	2	7.5	8.1	60	7	7.3	8.4
26	5	7.3	7.7	61	21	7.0	8.4
27	2	4.9	5.3	62	6	7.3	8.3
28	17	7.0	8.0	63	67	6.4	8.9
29*	21	6.5	9.3				
30*	15	6.4	7.3				
31	2	7.1	7.3				
32	2	6.8	7.2				
33	19	6.8	7.7				
34	17	6.7	8.0				
35	2	6.7	6.9				

\* Sites upstream of mining





BASE FROM U. S. GEOLOGICAL SURVEY  
STATE BASE MAP, 1970

#### EXPLANATION

Minimum values for pH at each site

- <sup>3</sup> Upstream site and location number
- △<sup>8</sup> Downstream site and location number
- 30 ●<sup>4</sup> < 6.5
- 6 ●<sup>44</sup> ≥ 6.5

Figure 8.2.3-1 Minimum values of pH measured at water quality sites.

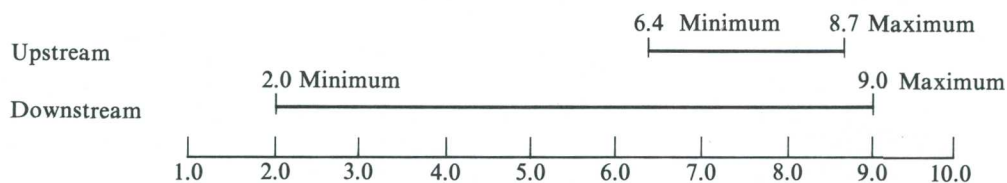


Figure 8.2.3-2 Range of pH values measured at sites upstream and downstream of mining.

## 8.0 SURFACE WATER

### 8.2 SURFACE WATER QUALITY

#### 8.2.3 pH

8.0 SURFACE WATER (Continued)  
 8.2 SURFACE-WATER QUALITY (Continued)  
 8.2.4 IRON

## IRON CONCENTRATIONS ARE HIGHER DOWNSTREAM THAN UPSTREAM OF MINING

*Dissolved iron ranged from 0 to 640 micrograms per liter ( $\mu\text{g/L}$ ) at sites upstream of mining and from 0 to 1,100,000  $\mu\text{g/L}$  at sites downstream of mining. Total recoverable iron ranged from 100 to 31,000  $\mu\text{g/L}$  at the upstream sites and from 0 to 2,100,000  $\mu\text{g/L}$  at the downstream sites.*

Iron is the fourth most abundant element in the Earth's crust with 4.7 percent (Petrucci, 1972). It is an important constituent of the surface and ground waters in this area because of its abundance in the sedimentary rocks of the Pennsylvanian System. Under natural conditions, in sedimentary rock and ground water, iron is found primarily in the ferrous form ( $\text{Fe}^{+2}$ ). It is the abundance and the instability of ferrous iron, when exposed to air, that probably influence many chemical reactions downstream of mining. Surface-mining processes increase the amount of iron available to the system by exposing more surface area of iron-bearing minerals to weathering conditions. Geologic and erosional factors at sites upstream of mining maintain fairly stable concentrations of iron in streams.

At sites upstream of mining, the measured range of concentration for dissolved iron was from 0 to 640  $\mu\text{g/L}$  with a mean of about 110  $\mu\text{g/L}$ . At sites downstream of

mining, concentrations of dissolved iron ranged from 0 to 1,100,000  $\mu\text{g/L}$  with a mean of about 20,000  $\mu\text{g/L}$  or approximately 20 milligrams per liter (mg/L) (fig. 8.2.4-1 and 8.2.4-2 and table 8.2.4-1).

Total recoverable iron for the sites upstream of mining ranged from 100 to 31,000  $\mu\text{g/L}$  with a mean of about 2,400  $\mu\text{g/L}$ . Total recoverable iron for the downstream sites ranged from 0 to 2,100,000  $\mu\text{g/L}$  with a mean of about 37,800  $\mu\text{g/L}$  or approximately 38 mg/L (fig. 8.2.4-1 and 8.2.4-3 and table 8.2.4-2).

Concentrations of dissolved iron in surface water seldom reach 1 mg/L (American Public Health Association, 1976, p. 207). For the upstream sites, the entire range of values is well below this level. The surface water of areas downstream of mining sometimes exceeded 1 mg/L of dissolved iron.

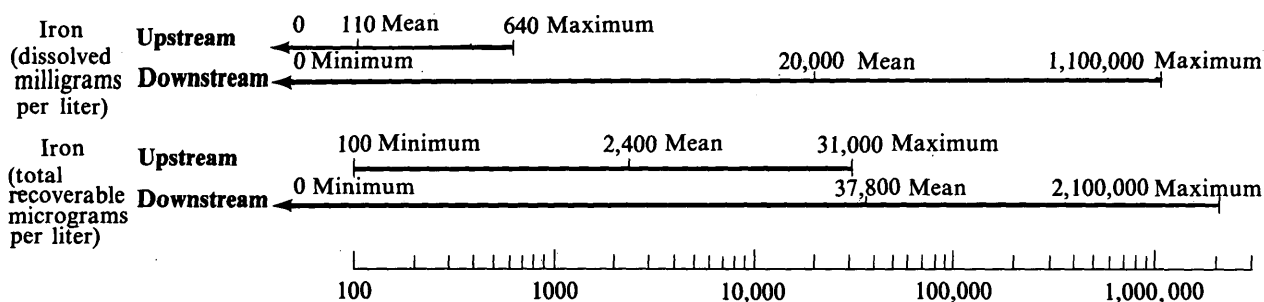
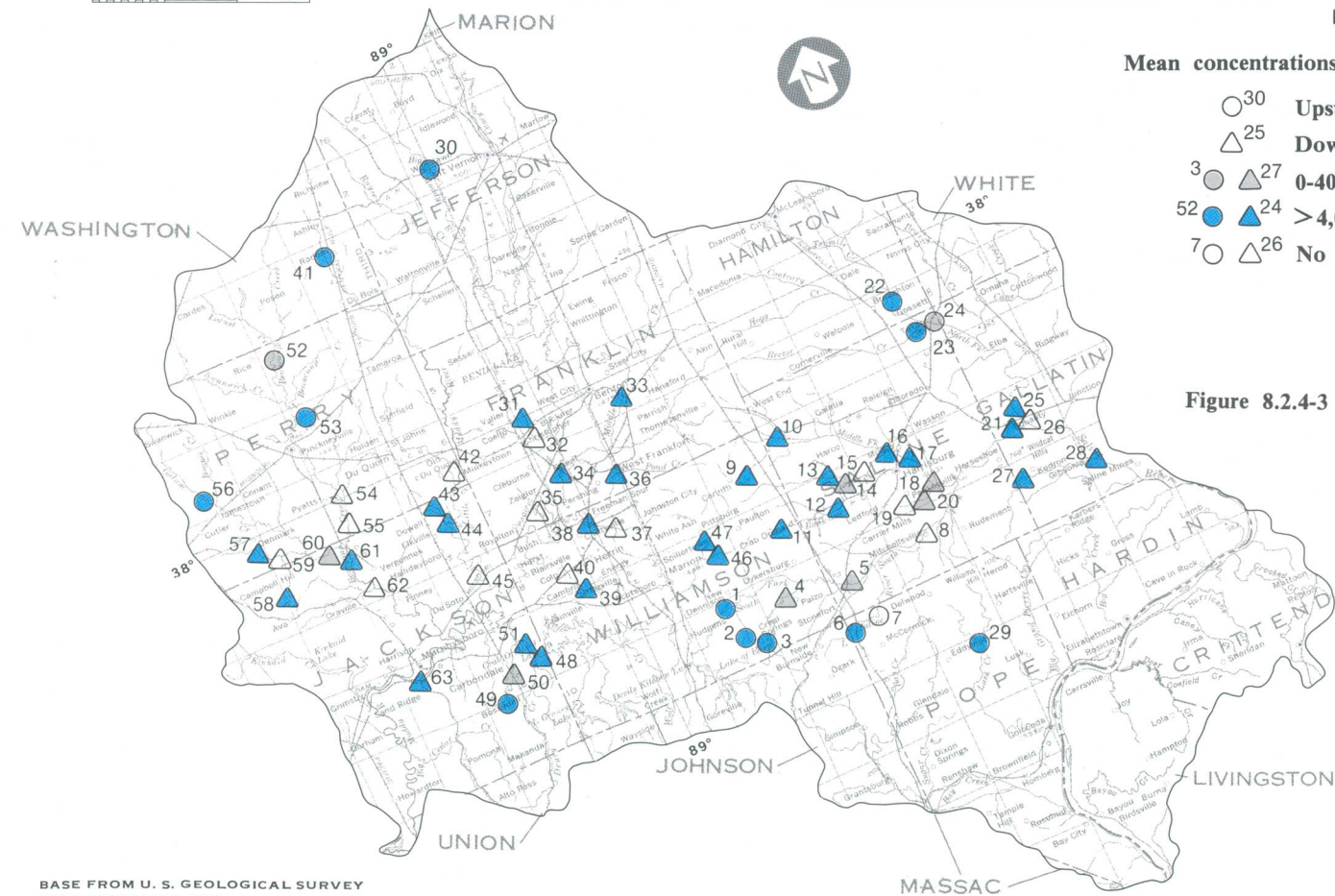
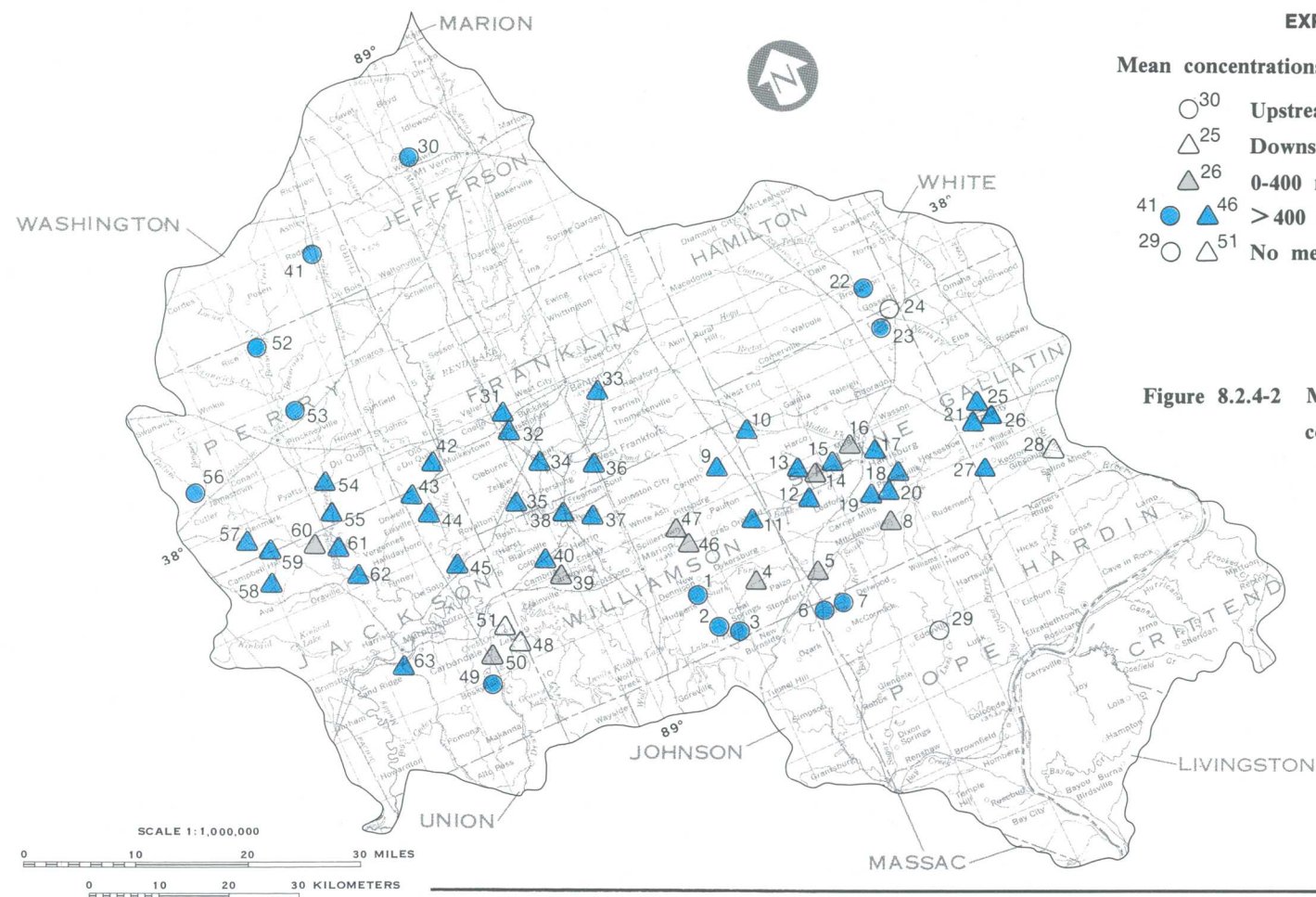


Figure 8.2.4-1 Range of dissolved iron and total recoverable iron concentrations measured at sites upstream and downstream of mining





BASE FROM U. S. GEOLOGICAL SURVEY  
STATE BASE MAP, 1970

Site Number	Number of Observations	Iron, dissolved (µg/L)			Site Number	Number of Observations	Iron, total recoverable (µg/L)		
		Minimum	Mean	Maximum			Minimum	Mean	Maximum
1	2	90	360	640	1	2	1,400	1,450	1,500
2	10	10	62	210	2	10	120	1,130	5,300
3	2	40	45	50	3	2	350	360	380
4	12	3,700	20,000	240,000	4	20	8,900	530,000	2,100,000
5	42	390	8,600	46,000	5	36	900	22,000	46,000
6	2	280	300	320	6	2	1,200	1,200	1,200
7	2	170	260	360	7	0	--	--	--
8	8	170	8,200	25,000	8	0	--	--	--
9	3	30	130	260	9	1	1,200	1,200	1,200
10	2	50	50	50	10	2	150	1,800	3,400
11	15	10	230	2,200	11	15	220	1,100	3,600
12	2	40	60	80	12	2	380	540	700
13	8	30	140	390	13	2	340	3,200	6,000
14	4	180,000	570,000	1,100,000	14	2	670,000	800,000	1,100,000
15	2	20	25	30	15	0	--	--	--
16	8	40	1,020	5,000	16	7	550	3,000	5,900
17	2	60	70	80	17	2	780	1,200	1,700
18	5	0	28	50	18	17	560	7,100	7,600
19	1	150	150	150	19	0	--	--	--
20	1	30	30	30	20	1	5,000	5,000	5,000
21	6	40	260	1,000	21	2	700	1,100	1,500
22	2	40	45	50	22	2	1,300	4,000	6,800
23	10	0	81	190	23	2	920	1,900	2,900
24	0	--	--	--	24	18	200	4,900	31,000
25	2	50	120	190	25	2	880	2,300	3,800
26	5	10	120	320	26	0	--	--	--
27	2	100	170	240	27	2	290	480	670
28	0	--	--	--	28	17	600	1,200	3,700
29	0	--	--	--	29	2	100	780	4,000
30	3	5	62	130	30	4	580	1,400	2,900
31	2	220	270	320	31	2	2,000	2,100	2,200
32	2	30	55	80	32	0	--	--	--
33	2	50	60	70	33	19	590	2,800	12,000
34	2	80	95	110	34	17	480	1,600	520
35	2	60	160	260	35	0	--	--	--
36	9	50	390	1,900	36	20	400	1,400	7,500
37	2	10	55	100	37	0	--	--	--
38	4	40	65	90	38	2	1,300	1,600	2,000
39	2	300	440	580	39	2	450	1,380	2,300
40	2	50	80	110	40	0	--	--	--
41	2	70	120	160	41	2	820	840	850
42	1	40	40	40	42	0	--	--	--
43	4	20	180	600	43	2	640	1,100	1,500
44	2	40	130	220	44	22	360	2,100	4,900
45	7	50	220	510	45	0	--	--	--
46	3	80	690	1,800	46	2	440	560	690
47	7	30	440	1,600	47	20	440	1,500	3,800
48	0	--	--	--	48	18	80	370	1,530
49	2	30	75	120	49	2	310	440	580
50	10	50	38,000	160,000	50	2	110,000	130,000	150,000
51	0	--	--	--	51	20	0	1,200	2,300
52	2	50	140	230	52	2	2,500	4,350	6,200
53	2	90	140	190	53	2	630	1,100	1,500
54	8	10	51	80	54	0	--	--	--
55	8	10	62	150	55	0	--	--	--
56	3	40	100	200	56	1	1,700	1,700	1,700
57	11	10	180	1,300	57	2	1,100	1,600	2,100
58	4	0	190	660	58	2	550	690	830
59	8	20	69	220	59	0	--	--	--
60	7	500	710	920	60	2	2,100	7,600	13,000
61	2	80	160	250	61	21	480	2,900	8,800
62	6	10	100	210	62	0	--	--	--
63	27	10	160	1,500	63	36	280	3,400	14,000

Sites upstream of mining

**Table 8.2.4-1** Dissolved iron concentrations measured at water quality sites.

**Table 8.2.4-2** Total recoverable iron concentrations measured at water quality sites.

## 8.0 SURFACE WATER

### 8.2 SURFACE WATER QUALITY

#### 8.2.4 IRON

8.0 SURFACE WATER (Continued)  
 8.2 SURFACE-WATER QUALITY (Continued)  
 8.2.5 MANGANESE

**CONCENTRATIONS OF DISSOLVED AND TOTAL RECOVERABLE  
 MANGANESE ARE HIGHER DOWNSTREAM THAN UPSTREAM OF MINING**

*Mean values of dissolved and total recoverable manganese concentrations were approximately 7 to 10 times greater at the sites downstream of mining than at the upstream sites.*

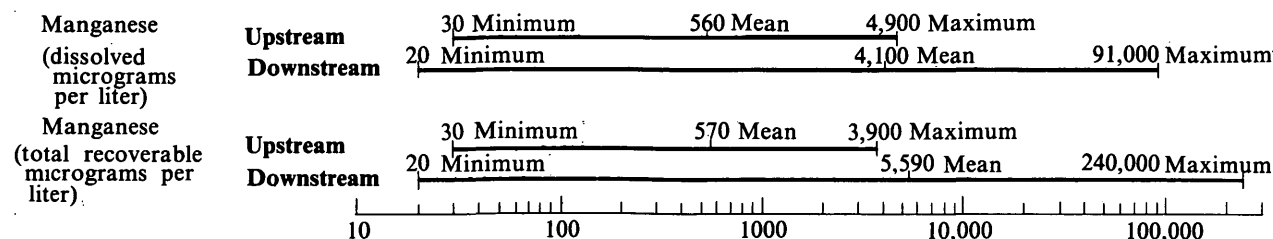
Manganese is a common element widely distributed in igneous rocks and soils, but its total abundance in the Earth's crust is small enough to put it in the list of "trace" elements. Manganese and iron have similar electronic configurations and behave similarly. Because manganese has a lower affinity for oxygen, it stays in solution longer than iron (Rankama and Sahama, 1950).

For the sites upstream of mining in the study area, the measured concentrations of dissolved manganese ranged from 30 to 4,900 micrograms per liter ( $\mu\text{g/L}$ ) with a mean of about 560  $\mu\text{g/L}$ . This compares to a measured range of 20 to 91,000  $\mu\text{g/L}$  and a mean of about 4,100  $\mu\text{g/L}$  for the sites downstream of mining (fig. 8.2.5-1 and 8.2.5-2 and table 8.2.5-1).

Total recoverable manganese for the sites upstream of mining ranged from 30 to 3,900  $\mu\text{g/L}$  with a mean of

about 570  $\mu\text{g/L}$ . Downstream of mining the measured values of total recoverable manganese ranged from 20 to 240,000  $\mu\text{g/L}$  with a mean of about 5,590  $\mu\text{g/L}$  (fig. 8.2.5-1 and 8.2.5-3 and table 8.2.5-2).

According to Rankama and Sahama (1950) the Mn:Fe ratio in natural carbonate waters is about 5:1. This ratio is approximated by the upstream data for which the mean dissolved manganese value was 560  $\mu\text{g/L}$  and the mean dissolved iron value was 110  $\mu\text{g/L}$ . The mean values of dissolved manganese and dissolved iron for the downstream sites are 4,100  $\mu\text{g/L}$  and 20,000  $\mu\text{g/L}$ , respectively, resulting in a Mn:Fe ratio of 0.21:1. This decrease in the Mn:Fe ratio reflects the relatively large upstream to downstream increase in iron concentrations compared to manganese concentrations.



**Figure 8.2.5-1 Range of dissolved and total recoverable manganese concentrations measured at sites upstream and downstream of mining**



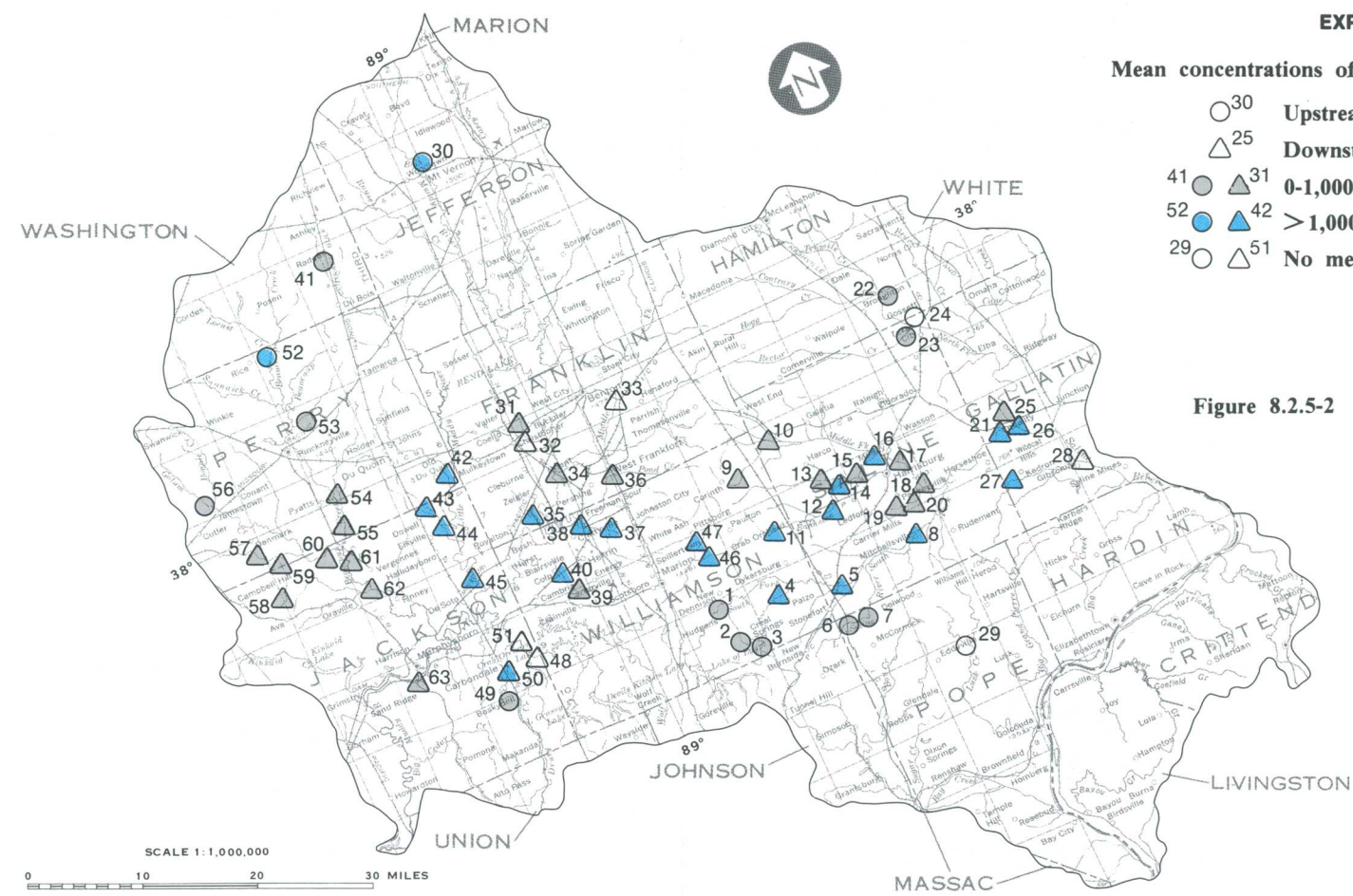


Figure 8.2.5-2 Mean values of dissolved manganese concentrations at water quality sites.

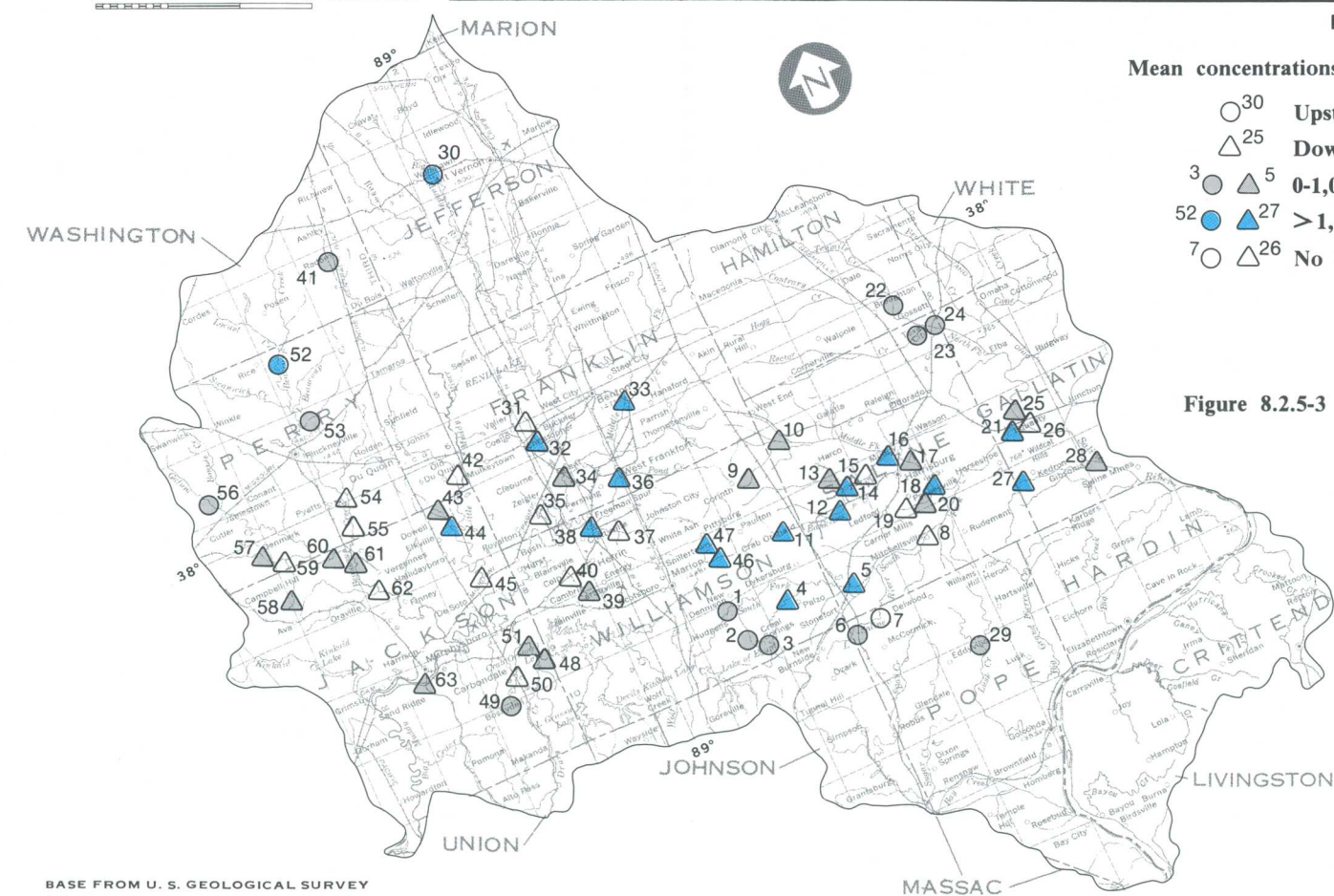


Figure 8.2.5-3 Mean values of total recoverable manganese concentrations at water quality sites.

BASE FROM U. S. GEOLOGICAL SURVEY  
STATE BASE MAP, 1970

**EXPLANATION**

Mean concentrations of dissolved manganese at each site

○<sup>30</sup> Upstream site and location number  
△<sup>25</sup> Downstream site and location number  
●<sup>41</sup> ▲<sup>31</sup> 0-1,000 micrograms per liter  
●<sup>52</sup> ▲<sup>42</sup> >1,000 micrograms per liter  
○<sup>29</sup> △<sup>51</sup> No measurements of dissolved manganese.

Site Number	Number of Observations	Manganese, dissolved (µg/L)			Site Number	Number of Observations	Manganese, total recoverable (µg/L)		
		Minimum	Mean	Maximum			Minimum	Mean	Maximum
1	2	530	700	870	1	2	590	700	800
2	10	50	200	370	2	7	60	190	390
3	2	350	360	360	3	2	330	360	400
4	12	1,900	2,300	91,000	4	20	0	5,700	240,000
5	42	610	6,000	21,000	5	36	630	7,400	22,000
6	2	510	540	570	6	2	490	520	560
7	2	150	360	560	7	0	--	--	--
8	8	830	7,100	23,000	8	0	--	--	--
9	3	40	63	90	9	1	130	130	130
10	2	90	100	110	10	2	120	180	240
11	15	210	1,200	2,100	11	11	640	1,400	2,100
12	2	890	1,600	2,400	12	2	830	1,700	2,500
13	8	200	386	510	13	2	290	420	560
14	4	7,000	17,000	26,000	14	2	16,000	16,000	16,000
15	2	510	580	640	15	0	--	--	--
16	8	860	1,500	2,200	16	7	980	1,300	2,100
17	2	470	500	730	17	2	520	620	720
18	5	230	580	860	18	17	380	1,400	5,300
19	1	210	210	210	19	0	--	--	--
20	1	60	60	60	20	1	220	220	220
21	6	350	2,800	5,400	21	2	3,400	4,300	5,200
22	2	340	410	480	22	2	570	640	720
23	10	30	75	110	23	2	280	305	330
24	0	--	--	--	24	18	170	560	2,300
25	2	180	310	440	25	2	240	380	520
26	5	160	1,600	2,700	26	0	--	--	--
27	2	5,200	9,600	14,000	27	2	5,100	9,600	14,000
28	0	--	--	--	28	17	90	1,900	3,900
29	0	--	--	--	29	12	60	180	390
30	2	430	1,360	2,300	30	4	500	1,860	3,600
31	2	1,300	1,300	1,300	31	2	1,200	1,250	1,300
32	2	690	840	980	32	0	--	--	--
33	2	710	220	3,600	33	19	190	1,800	3,900
34	2	160	220	270	34	17	150	510	960
35	2	890	2,900	4,900	35	0	--	--	--
36	9	310	520	910	36	20	160	1,200	2,700
37	2	1,600	2,400	3,200	37	0	--	--	--
38	4	1,600	2,400	2,700	38	2	2,700	2,700	2,700
39	2	350	500	640	39	2	410	510	610
40	2	570	1,040	1,500	40	0	--	--	--
41	2	210	860	1,500	41	2	230	960	1,700
42	1	1,300	1,300	1,300	42	0	--	--	--
43	4	500	1,100	2,400	43	2	540	550	560
44	2	310	1,600	2,900	44	22	220	1,880	13,000
45	7	180	2,200	13,000	45	0	--	--	--
46	3	220	1,600	3,000	46	2	1,800	2,000	2,100
47	7	580	1,900	2,800	47	20	280	2,400	7,200
48	0	--	--	--	48	18	110	420	2,300
49	2	30	105	180	49	2	30	75	120
50	10	660	22,000	72,000	50	2	48,000	48,000	49,000
51	0	--	--	--	51	20	0	730	2,200
52	2	160	2,100	4,000	52	2	400	2,150	3,900
53	2	95	150	210	53	2	150	150	150
54	8	160	680	1,100	54	0	--	--	--
55	8	330	620	1,000	55	0	--	--	--
56	3	300	700	1,300	56	1	370	370	370
57	11	110	520	1,200	57	2	380	390	400
58	4	110	200	340	58	2	100	220	340
59	8	20	370	910	59	0	--	--	--
60	7	100	440	750	60	2	500	710	920
61	2	40	460	880	61	21	380	730	1,700
62	6	200	570	910	62	0	--	--	--
63	27	20	710	1,800	63	36	20	780	1,900

Sites upstream from mining

Sites upstream from mining

Table 8.2.5-1 Dissolved manganese concentrations measured at water quality sites.

Table 8.2.5-2 Total recoverable manganese concentrations measured at water quality sites.

## 8.0 SURFACE WATER

### 8.2 SURFACE WATER QUALITY

#### 8.2.5 MANGANESE

8.0 SURFACE WATER (Continued)  
8.2 SURFACE-WATER QUALITY (Continued)  
8.2.6 SULFATE

**SULFATE CONCENTRATIONS ARE HIGHER DOWNSTREAM  
THAN UPSTREAM OF MINING**

*Concentrations of sulfate ranged from 12 to 500 milligrams per liter (mg/L) at the sites upstream of mining and from 15 to 12,000 mg/L at the downstream sites. Sulfate concentrations at downstream sites can be estimated using the equation:*  
 **$SULFATE = 0.64 (SPECIFIC\ CONDUCTANCE) - 210.$**

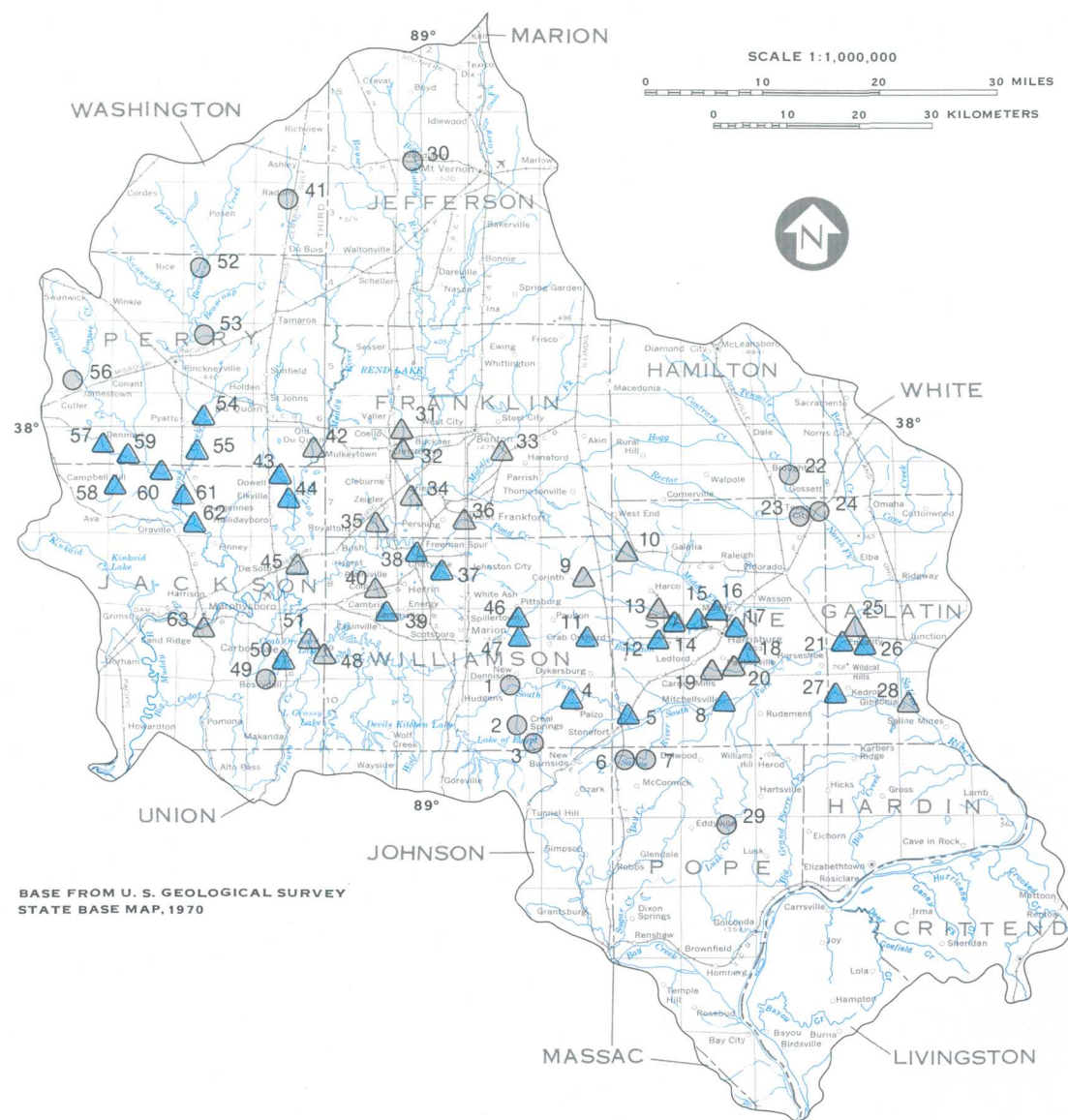
Sulfur occurs in the coal and associated strata as metallic sulfides, mainly in the form of pyrite ( $FeS_2$ ) and marcasite ( $FeS_2$ ), which are also sources of ferrous iron. When oxidized, the sulfides yield the sulfate ion and ferric oxide. At the sites upstream of mining, the sulfates are probably introduced to the water from stream cuts through exposed Pennsylvanian rocks. This would be a fairly steady source of sulfate with erosion and oxidation contributing to the dissolution of sulfate materials.

The measured concentrations of sulfate at the upstream sites range from 12 to 500 mg/L with a mean value of 140 mg/L for all the observations at all the upstream sites. The upstream sulfate data contrast sharply with sulfate data for the downstream sites (table 8.2.6-1). The mean downstream sulfate value of 760 mg/L is larger than any value at an upstream site, and the maximum value of 12,000 mg/L is 24 times that of the largest value found at an upstream site (fig. 8.2.6-1). The minimum sulfate value of 15 mg/L at the downstream sites is approximately the same as the minimum at the upstream sites.

The contrast in sulfate concentrations between the sites upstream and downstream of mining, as seen in figure 8.2.6-2, suggests the higher sulfate concentrations downstream of mining probably result from the increased exposure of sulfide-bearing minerals to weathering in the mined area. Toler (1980) related annual sulfate loads to the area of surface mines as a percentage of total drainage area and showed that in southern Illinois sulfate can be used as an indicator of mine drainage (fig. 8.2.6-3).

For the sites downstream of mining a comparison was made between sulfate concentrations and specific conductance. There is a strong correlation (correlation coefficient = 0.93) between the two variables in the range for specific conductance from 400 to 5,000  $\mu mho/cm$  at 25°C. By using the regression equation represented by the line on the accompanying illustration (fig. 8.2.6-4), sulfate concentrations can be estimated at sites in the area downstream of mining from measurements of specific conductance between 400 and 5,000  $\mu mho/cm$  at 25°C.





BASE FROM U. S. GEOLOGICAL SURVEY  
STATE BASE MAP, 1970

#### EXPLANATION

- Mean concentrations of sulfate at each site
- <sup>3</sup> Upstream site and location number
  - △<sup>8</sup> Downstream site and location number
  - <sup>22</sup> 0-400 milligrams per liter
  - ▲<sup>60</sup> > 400 milligrams per liter

Figure 8.2.6-2 Mean values of sulfate concentrations at water quality sites.

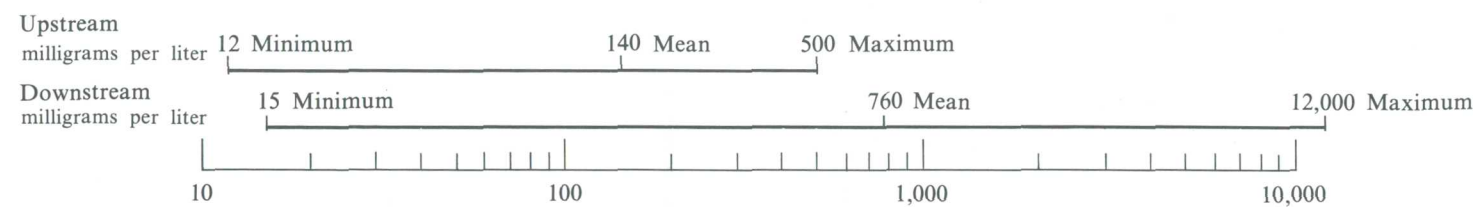


Figure 8.2.6-1 Range of sulfate concentrations measured at sites upstream and downstream of mining.

Site Number	Number of Observations	Sulfate as SO <sub>4</sub> (mg/L)			Site Number	Number of Observations	Sulfate as SO <sub>4</sub> (mg/L)		
		Minimum	Mean	Maximum			Minimum	Mean	Maximum
1	2	99	120	140	33	19	58	140	250
2	11	27	160	280	34	17	52	72	116
3	2	63	92	120	35	2	58	170	270
4	30	85	2,400	10,000	36	28	38	166	250
5	42	86	680	2,060	37	2	470	780	1,100
6	2	46	48	50	38	4	570	1,000	1,400
7	2	30	33	36	39	2	510	545	580
8	8	100	530	1,500	40	2	360	400	440
9	3	160	210	280	41	2	82	180	280
10	2	120	275	430	42	1	170	170	170
11	15	1,800	2,380	2,700	43	4	470	1,000	1,600
12	2	940	1,320	1,700	44	22	60	480	1,300
13	8	100	230	480	45	7	80	250	780
14	4	1,000	3,400	5,300	46	3	560	900	1,200
15	2	1,100	1,500	1,900	47	27	79	770	1,850
16	15	305	1,350	2,340	48	18	15	64	93
17	2	840	1,100	1,300	49	2	93	96	99
18	23	134	640	1,650	50	10	60	2,000	12,000
19	1	140	140	140	51	20	47	74	115
20	1	68	68	68	52	2	58	119	180
21	6	92	450	760	53	2	132	320	500
22	2	73	172	270	54	8	760	1,600	2,440
23	10	66	190	360	55	8	270	750	1,550
24	18	26	155	280	56	3	93	198	250
25	2	67	98	130	57	11	280	2,140	3,500
26	5	92	480	1,200	58	4	360	720	1,300
27	2	310	620	930	59	8	470	1,600	2,900
28	17	51	350	800	60	7	240	1,010	2,400
29	12	12	19	28	61	21	88	980	2,240
30	15	70	210	500	62	6	220	650	1,300
31	2	150	155	160	63	64	53	230	580
32	2	190	215	240					

Sites upstream from mining

Table 8.2.6-1 Sulfate concentrations measured at water quality sites.

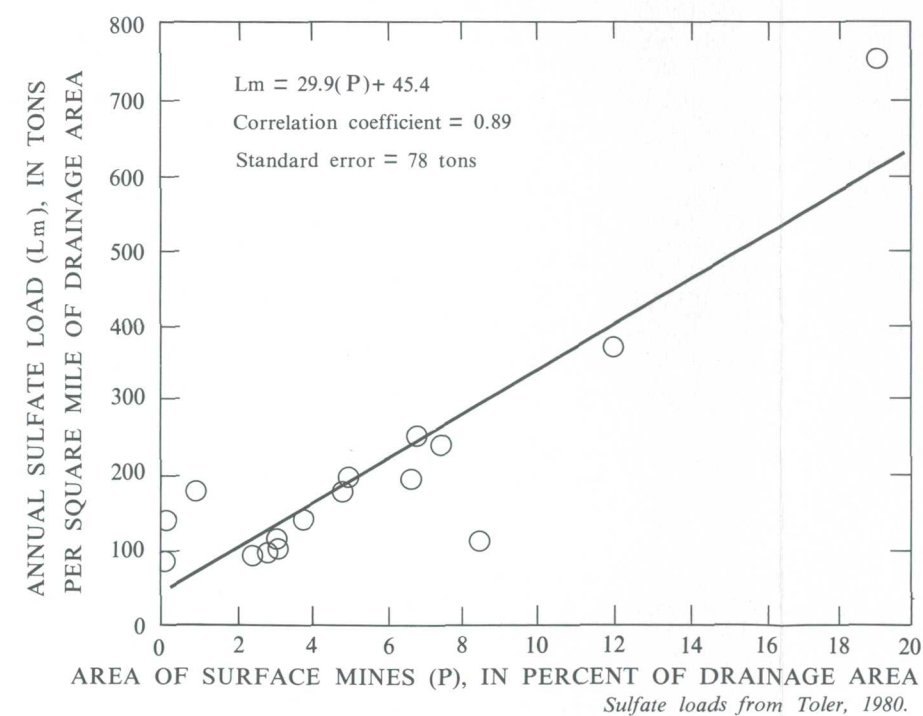


Figure 8.2.6-3 Relationship of annual sulfate load per square mile of drainage area to percent of strip mined land.

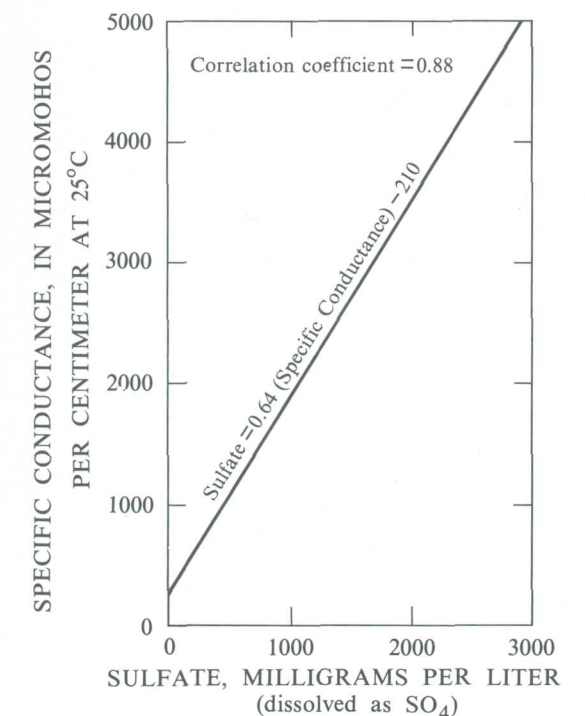


Figure 8.2.6-4 Relationship of sulfate to specific conductance at sites downstream of mining.

## 8.0 SURFACE WATER

### 8.2 SURFACE WATER QUALITY

#### 8.2.6 SULFATE

8.0 SURFACE WATER (Continued)  
 8.2 SURFACE-WATER QUALITY (Continued)  
 8.2.7 ALKALINITY AND ACIDITY

## ACIDITY VALUES ARE HIGHER DOWNSTREAM THAN UPSTREAM OF SURFACE MINING AREAS

*Only one site upstream of mining had measurable acidity. Twenty-one sites downstream of mining had acidity values ranging from 0.1 to 99 milligrams per liter (mg/L) as the hydrogen ion ( $H^+$ ). Alkalinity values ranged from 0 to 390 mg/L as calcium carbonate ( $CaCO_3$ ) at the upstream sites and from 0 to 520 mg/L as  $CaCO_3$  at the downstream sites.*

Acidity is defined as "the quantitative capacity of an aqueous media to react with hydroxyl ions" and is expressed in mg/L as the hydrogen ion ( $H^+$ ). It is an important parameter to measure in areas affected by surface mining because when present in significant amounts it is an indication that acid-forming materials are interacting with the surface water. Alkalinity is defined as the capacity of the solution to react with hydrogen ions and is commonly reported in mg/L as  $CaCO_3$  even though  $CaCO_3$  may not be the source of or be responsible for all the buffering capability.

One site upstream of mining had measurable acidity. Twenty-three of forty-eight sites downstream of mining had measurable acidity that ranged from 0.1 to 99 mg/L as  $H^+$  (fig. 8.2.7-1 and 8.2.7-2 and table 8.2.7-1).

Alkalinity at sites upstream of mining ranged from 0 to 390 mg/L as  $CaCO_3$  with a mean of 92 mg/L as  $CaCO_3$ . The sites downstream of mining had a range in alkalinity from 0 to 520 mg/L as  $CaCO_3$  with a mean of 88 mg/L (fig. 8.2.7-1 and table 8.2.7-2).

Although mean values for alkalinity at the upstream and downstream sites are similar (fig. 8.2.7-3), variations between sites, especially downstream of mining, are great. Surface mining exposes not only the pyrites and marcasites (acid-forming materials) but also the limestones (source of  $CaCO_3$ ) of the Pennsylvanian System. The variability of alkalinity values at the sites downstream of mining may depend on the amounts of limestone exposed during mining.

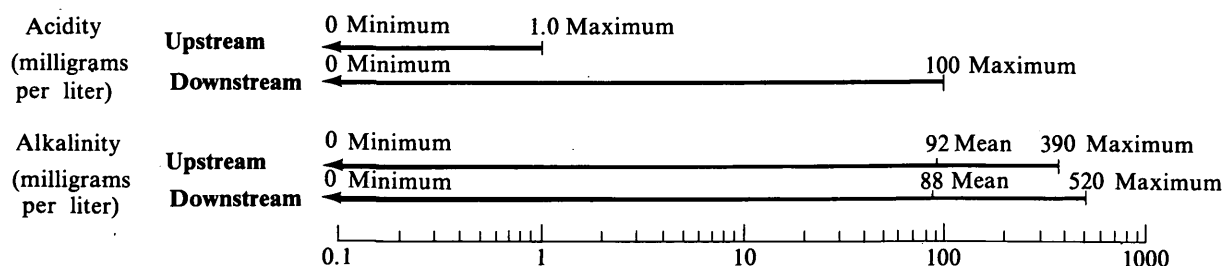
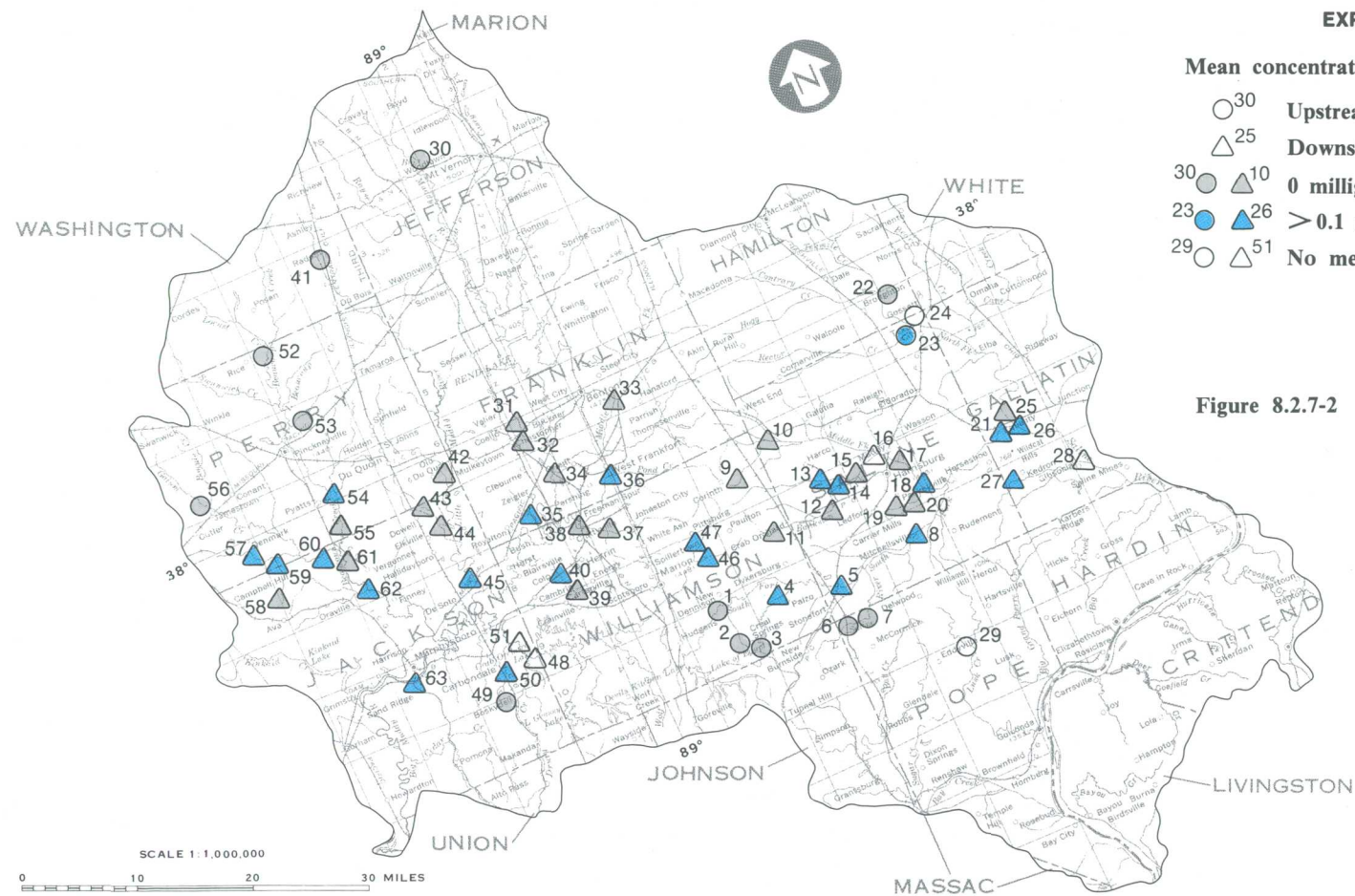


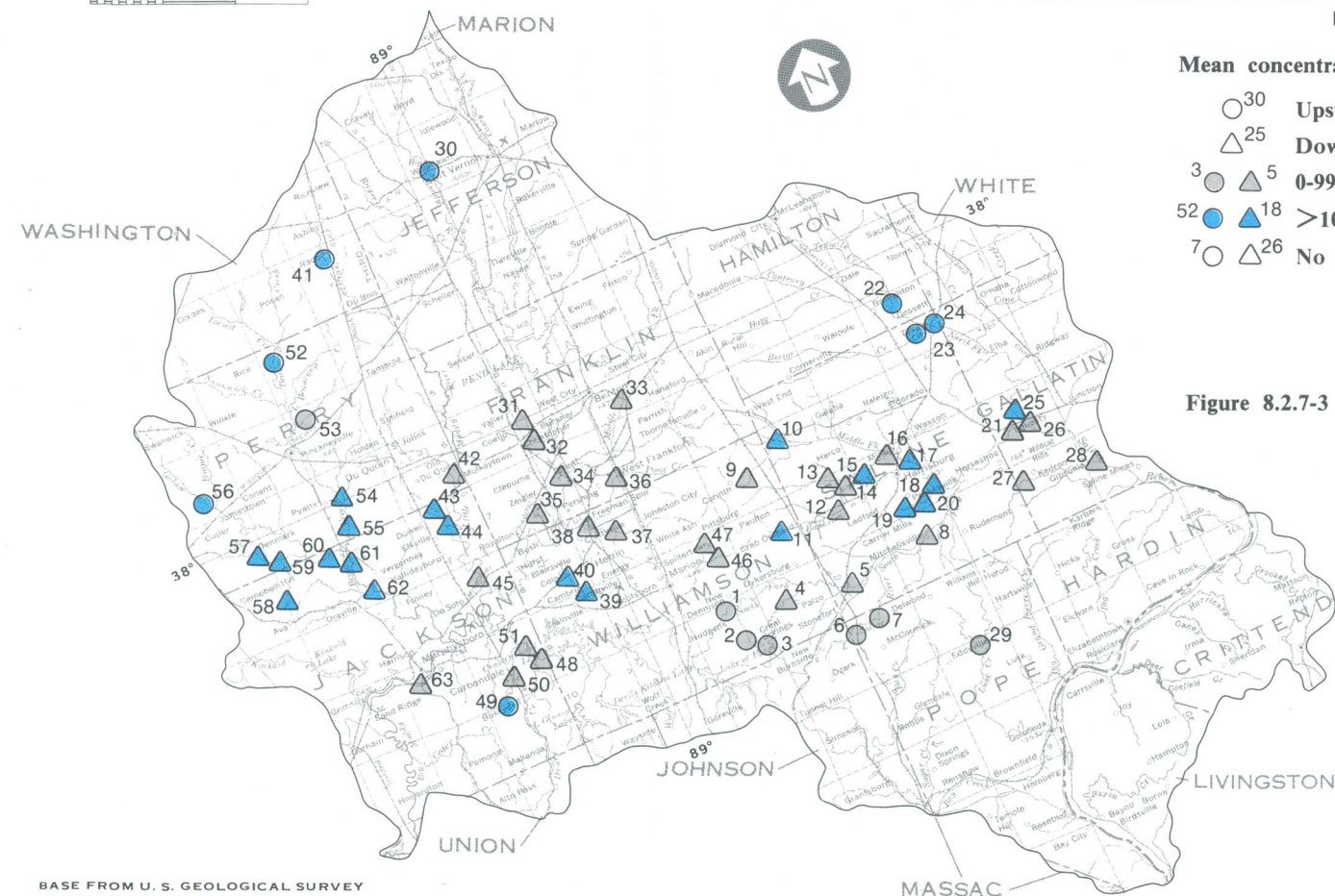
Figure 8.2.7-1 Range of acidity and alkalinity values at sites upstream and downstream of mining





- EXPLANATION**
- Mean concentrations of acidity at each site.
- 30 Upstream site and location number
  - △ 25 Downstream site and location number
  - 30 △ 10 0 milligrams per liter
  - 23 △ 26 > 0.1 milligrams per liter
  - 29 △ 51 No measurement of acidity.

Figure 8.2.7-2 Mean acidity concentrations at water quality sites.



- EXPLANATION**
- Mean concentrations of alkalinity at each site.
- 30 Upstream site and location number
  - △ 25 Downstream site and location number
  - 3 △ 5 0-99 milligrams per liter
  - 52 △ 18 > 100 milligrams per liter
  - 7 △ 26 No measurement of alkalinity

Figure 8.2.7-3 Mean alkalinity concentrations at water quality sites.

BASE FROM U. S. GEOLOGICAL SURVEY  
STATE BASE MAP, 1970

Site Number	Number of Observations	Acidity as H <sup>+</sup> (mg/L)			Site Number	Number of Observations	Acidity as H <sup>+</sup> (mg/L)		
		Minimum	Mean	Maximum			Minimum	Mean	Maximum
1	2	0	0	0	33	2	0	0	0
2	3	0	0	0	34	2	0	0	0
3	2	0	0	0	35	2	0	0.5	1.0
4	11	1.2	24	99	36	6	0	3.8	22
5	9	0.1	1.7	5.8	37	2	0	0	0
6	2	0	0	0	38	4	0	0	0
7	2	0	0	0	39	2	0	0	0
8	7	0.2	2.5	7.5	40	2	0	0.2	0.4
9	3	0	0	0	41	2	0	0	0
10	2	0	0	0	42	1	0	0	0
11	7	0	0	0	43	4	0	0	0
12	2	0	0	0	44	2	0	0	0
13	6	0	0.2	0.6	45	4	0	0.2	0.3
14	3	16	57	99	46	3	0	0.2	0.7
15	7	0	0	0	47	5	0	0.2	0.4
16	5	0.2	1.8	8.0	48	0	--	--	--
17	2	0	0	0	49	2	0	0	0
18	5	0	0.2	0.3	50	9	0.1	9.0	38
19	1	0	0	0	51	0	--	--	--
20	1	0	0	0	52	2	0	0	0
21	6	0	0.1	0.2	53	2	0	0	0
22	2	0	0	0	54	5	0.2	0.5	0.8
23	7	0	0.1	0.2	55	5	0	0	0
24	0	--	--	--	56	3	0	0	0
25	2	0	0	0	57	8	0	0.2	0.6
26	5	0.2	1.2	5.0	58	4	0	0	0
27	3	0	5.3	16	59	5	0.2	0.4	0.6
28	0	--	--	--	60	7	0	0.9	4.8
29	0	--	--	--	61	2	0	0	0
30	2	0	0	0	62	3	0.2	0.3	0.4
31	2	0	0	0	63	29	0	< 0.1	0.3
32	2	0	0	0					

Sites upstream from mining

Table 8.2.7-1 Acidity concentrations measured at water quality sites.

Site Number	Number of Observations	Alkalinity as CaCO <sub>3</sub> (mg/L)			Site Number	Number of Observations	Alkalinity as CaCO <sub>3</sub> (mg/L)		
		Minimum	Mean	Maximum			Minimum	Mean	Maximum
1	2	18	69	120	33	19	0	65	150
2	11	23	42	110	34	16	8	42	70
3	2	60	62	65	35	2	28	30	33
4	28	0	0	0	36	28	0	61	135
5	15	0	6	16	37	2	47	50	52
6	2	26	28	29	38	4	27	39	52
7	2	19	38	56	39	2	160	160	160
8	8	0	4	13	40	2	99	140	185
9	3	55	85	125	41	2	61	126	190
10	2	80	120	160	42	1	99	99	99
11	15	260	340	480	43	4	0	120	230
12	2	1	75	150	44	21	16	100	230
13	8	29	68	130	45	7	36	69	138
14	3	0	< 1	1	46	3	0	29	81
15	15	260	340	480	47	27	0	34	100
16	15	11	94	160	48	18	4	35	65
17	2	120	140	160	49	2	200	205	210
18	22	0	120	380	50	10	0	10	95
19	1	113	113	113	51	20	0	45	94
20	1	260	260	260	52	2	47	104	160
21	6	6	35	56	53	2	48	99	150
22	2	110	130	150	54	8	62	184	256
23	10	79	130	170	55	8	7	110	203
24	18	2	120	390	56	3	93	142	183
25	2	110	120	130	57	11	100	320	520
26	5	54	79	103	58	4	80	122	167
27	2	0	2	4	59	8	127	265	468
28	17	2	69	140	60	7	53	185	320
29	12	0	22	44	61	21	28	144	270
30	15	46	120	200	62	36	74	115	160
31	2	61	96	130	63	64	25	77	210
32	2	72	88	103					

Sites upstream from mining

Table 8.2.7-2 Alkalinity concentrations measured at water quality sites.

## 8.0 SURFACE WATER

### 8.2 SURFACE WATER QUALITY

#### 8.2.7 ALKALINITY AND ACIDITY

## 8.0 SURFACE WATER (Continued)

### 8.2 SURFACE-WATER QUALITY (Continued)

#### 8.2.8 TRACE ELEMENTS AND OTHER CONSTITUENTS

### CONCENTRATIONS OF TRACE ELEMENTS VARY IN THE STUDY AREA

*Concentrations of many trace elements and other water-quality constituents differed between sites upstream and downstream of surface mining.*

Concentrations of many dissolved constituents differed between sites upstream and downstream of mining as shown in figure 8.2.8-1. In water, copper, zinc, boron, calcium, nickel, magnesium, and aluminum all had higher mean concentrations downstream of mining than upstream. Concentrations of carbon dioxide in

water and total iron in the bottom material were also higher downstream of mining. Mean concentrations of total manganese in bottom material showed little difference between upstream and downstream sites. Dissolved chloride concentrations were less downstream than upstream of mining.

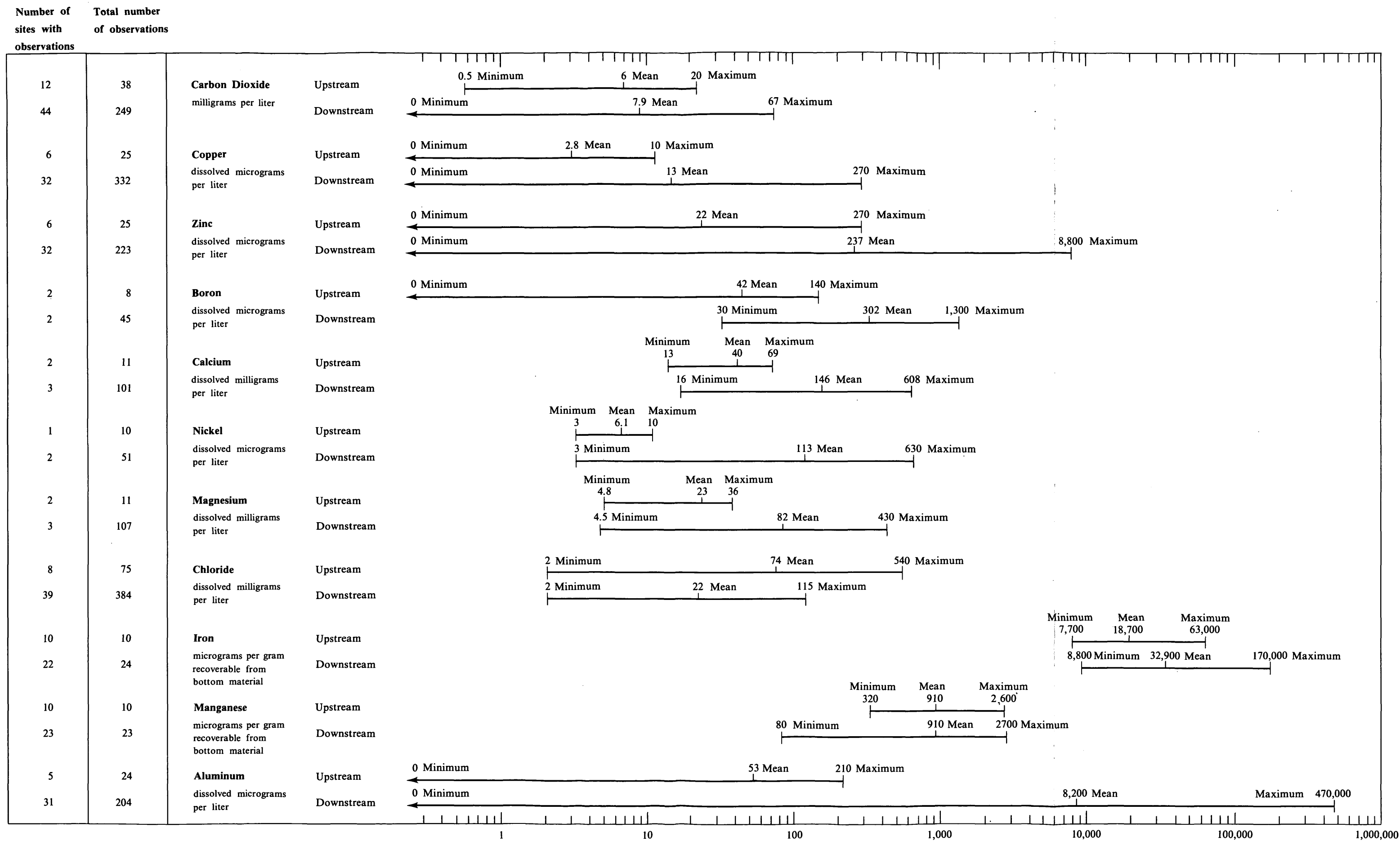


Figure 8.2.8-1 Range of concentrations for various constituents at sites upstream and downstream of mining.

8.0 SURFACE WATER (Continued)  
8.2 SURFACE-WATER QUALITY (Continued)  
8.2.9 FINAL CUT LAKES

**EIGHT STRIP MINE FINAL CUT LAKES  
WERE SAMPLED FOR WATER QUALITY**

*Acid lakes have significantly higher trace metal and sulfate content, as well as higher concentrations of most other parameters, than alkaline lakes. Stratification patterns vary widely.*

Lakes 5 and 7 (acid lakes) have measurable acidity in their epilimnia (area above the thermocline). The hypolimnia of these two lakes have measurable alkalinity. The remaining six lakes had measurable alkalinity (fig. 8.2.9-1). The mean values for specific conductance for the two acid lakes was 4,700 micromhos per centimeter at 25°C ( $\mu\text{mho}/\text{cm}$  at 25°C) versus 3,140  $\mu\text{mho}/\text{cm}$  at 25°C for the alkaline lakes. The mean measured oxidation-reduction potential for the acid lakes was one order of magnitude greater than that of the alkaline lakes (for example, 259 millivolts vs. 21 millivolts). Mean concentrations of trace metals (cobalt, copper, iron, lead, manganese, nickel, zinc, and aluminum) in the acid lakes were at least one order of magnitude greater than in the alkaline lakes. Other trace metals, excluding boron and arsenic, were also more concentrated in the acid lakes. The mean concentration of sulfate was 3,220 milligrams per liter (mg/L) for the acid lakes as compared to 1,330 mg/L for the alkaline lakes.

The accompanying depth profiles (fig. 8.2.9-2) show the various stratification patterns encountered in the lakes. The four lakes shown had strong thermoclines and

oxycelines. Lakes 1 and 8 had a narrow range of oxidation-reduction potential, and specific conductance gradually increased with depth. Lakes 5 and 7 (the acid lakes), however, have a much wider range of oxidation-reduction potential values and higher oxidation potentials in the epilimnia. Lake 7 had an extremely strong chemocline, such that the specific conductance increased by 3,000  $\mu\text{mho}/\text{cm}$  at 25°C in approximately 2 meters. A similarly strong chemocline was detected in this lake during the winter months suggesting that the lake does not completely mix. Thus, the more neutral waters of the hypolimnion cannot mix with the acidic epilimnion and temper its effects. Specific conductance values in Lake 5 indicate very little chemical stratification. This would indicate complete mixing of the lake during the fall turnover period.

These lakes are created when strip mining ceases in an area, and the abandoned pit and portions of the associated haulage roads are allowed to fill with water from precipitation, ground-, and/or surface-water runoff.



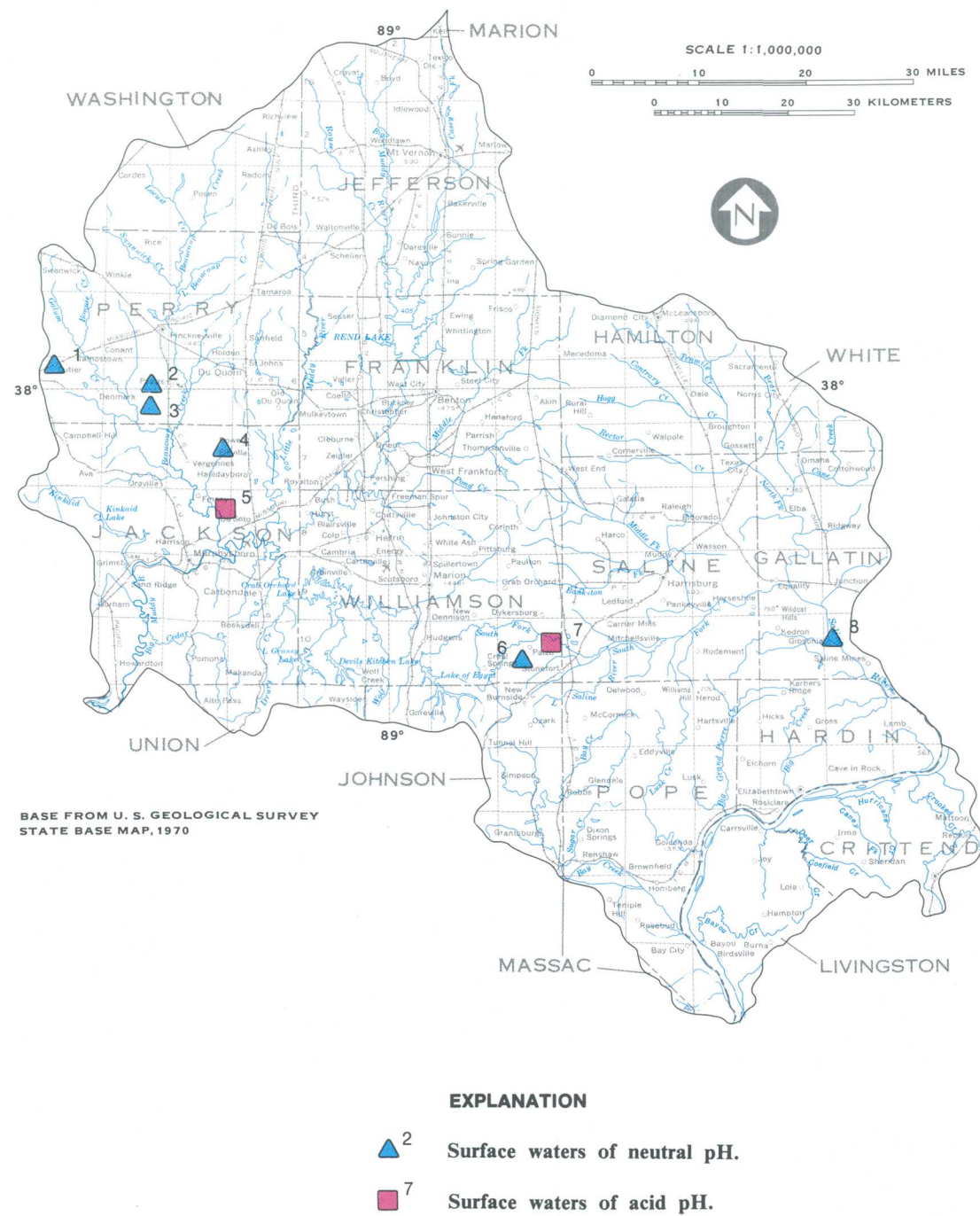
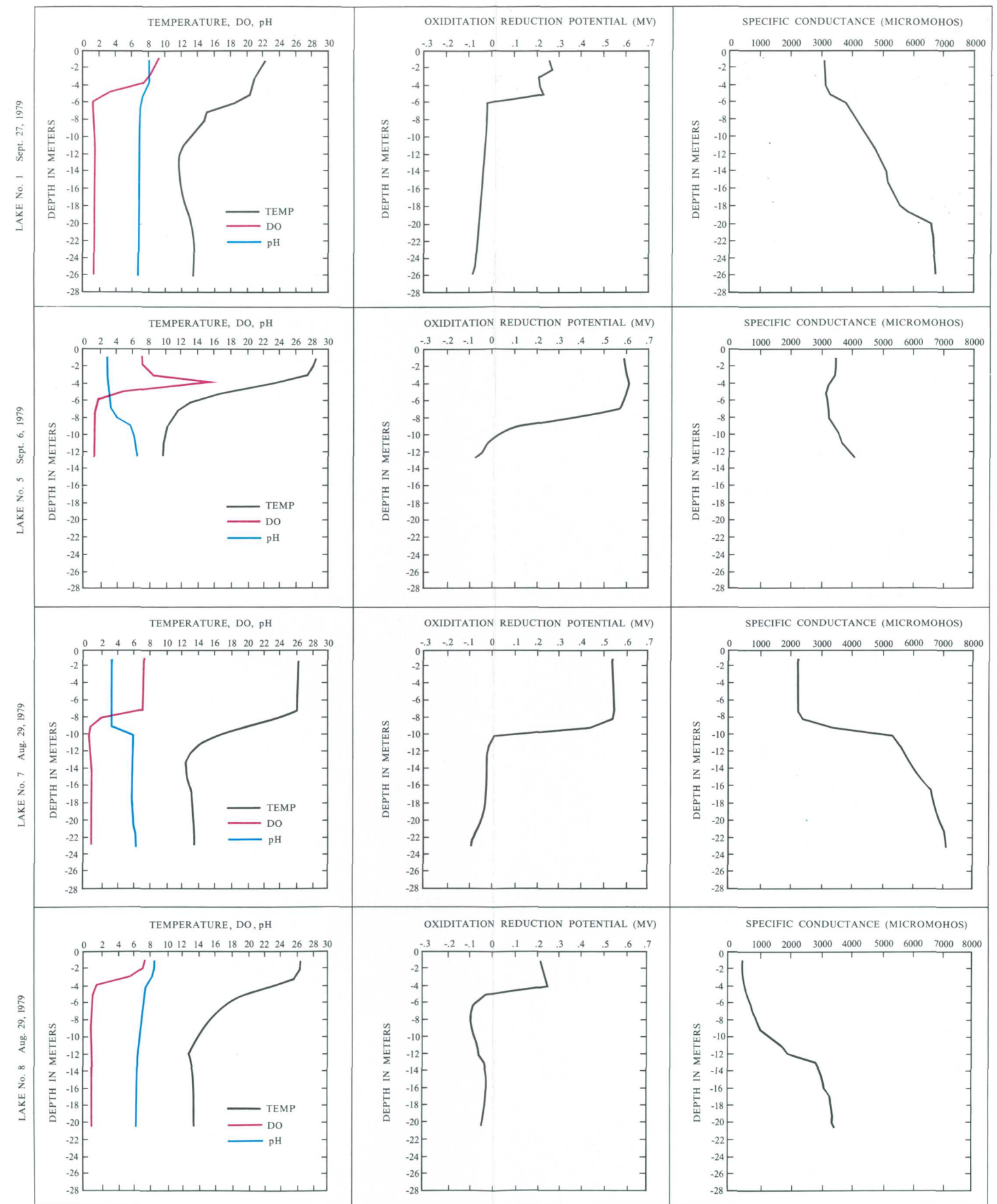


Figure 8.2.9-2 Final cut lake locations.



## 8.0 SURFACE WATER

### 8.2 SURFACE WATER QUALITY

#### 8.2.9 FINAL CUT LAKES

## 8.0 SURFACE WATER (Continued)

### 8.2 SURFACE-WATER QUALITY (Continued)

#### 8.2.10 SUSPENDED SEDIMENT

### AVERAGE SUSPENDED SEDIMENT LOAD WAS 109 TONS PER SQUARE MILE

*The average suspended-sediment load was 109 tons per square mile per year and ranged from 83.1 to 125 tons per square mile per year.*

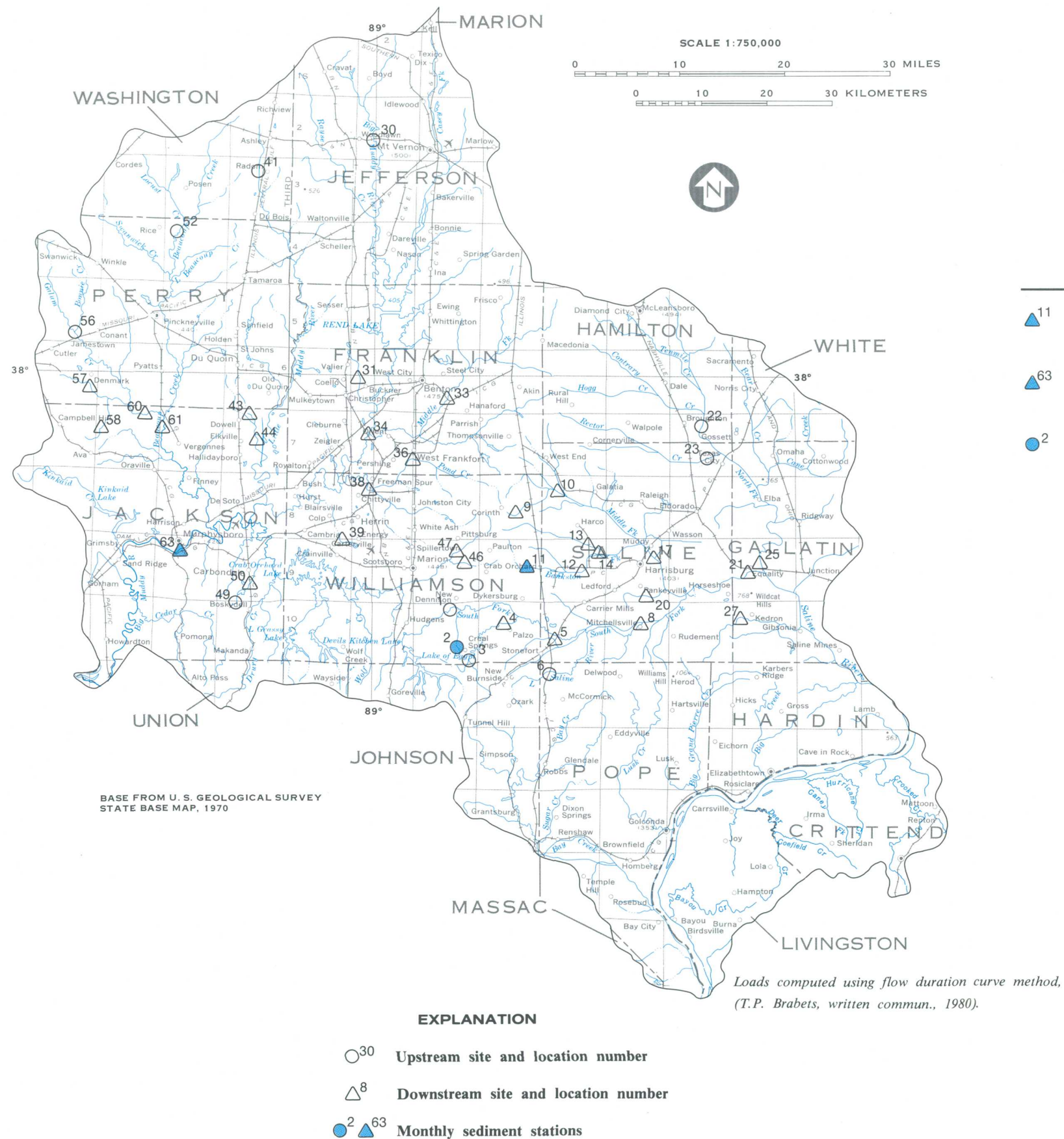
Suspended sediment in streams is the result of erosion of unprotected land and/or the degradation of stream channels. The rainfall intensity, land use, (agricultural, mining, forested, and so forth), and drainage pattern are three important factors in sediment erosion from overland flow. The rate of streamflow will affect the rate of stream-channel erosion.

Bankston Fork near Crab Orchard, Illinois, drains 1.9 square miles ( $\text{mi}^2$ ) and had the lowest annual suspended-sediment load, 83.1 tons per square mile per year  $[(\text{tons}/\text{mi}^2)/\text{yr}]$ , of three monthly sampling sites. It drains an area that was strip mined from 1944 to 1958 and has been left idle since. Little Cana Creek near Creal Springs, Illinois, also drains a small area ( $1.45 \text{ mi}^2$ ) but had the highest annual suspended-sediment load, 125  $(\text{tons}/\text{mi}^2)/\text{yr}$  (T. P. Brabets, written commun., 1980). It drains an area of rolling hills with some wooded areas and some areas used for agriculture and grazing.

The Big Muddy River drains about one-half of the study area ( $2,169 \text{ mi}^2$ ) and had an annual suspended-sediment load of 118  $(\text{tons}/\text{mi}^2)/\text{yr}$ . Discharge and suspended-sediment data used for analyses were for the period of record at each site.

Twenty suspended-sediment samples were collected at 11 synoptic sites without mining operations in their drainage basins. The concentrations ranged from 3 to 264 milligrams per liter (mg/L). From 108 miscellaneous samples at 29 synoptic sites which included some mining operations (present or past), the suspended-sediment concentrations ranged from 2 to 1,645 mg/L. Particle-size analyses of suspended sediment showed that between 90 and 95 percent of all suspended sediment was composed of material finer than sand particles (0.062 millimeters). All samples were collected at stream flows varying from low to high stream discharge.





	SITE	DRAINAGE AREA	PERCENT MINED	ANNUAL SEDIMENT	RIVER BASIN
		Square miles		LOAD Tons per square mile	
▲ <sup>11</sup>	Bankston Fork near Crab Orchard, Ill.	1.9	100	83.1	Saline
▲ <sup>63</sup>	Big Muddy River at Murphysboro, Ill.	2162	4	118	Big Muddy
● <sup>2</sup>	Little Cana Creek near Creal Springs, Ill.	1.45	0	125	Saline

Table 8.2.10-1 Suspended sediment loads in the study area.

## 9.0 GROUND WATER

### 9.1 GROUND-WATER QUANTITY

#### GROUND-WATER YIELDS ARE GENERALLY LOW

*Aquifer yields in the study area are low. Unconsolidated deposits are thin or absent in most of the area and yields from bedrock wells are generally less than 20 gallons per minute.*

The major aquifers in the area include unconsolidated glacial deposits, Pennsylvanian sandstones, coal, and limestones, and Mississippian limestones. Devonian limestone and Silurian dolomite aquifers are also used in a small part of northwestern Union and southwestern Jackson Counties. Unconsolidated aquifers are limited to a few drift-filled valleys and glacial deposits are thin or absent in the rest of the area.

Sand and gravel aquifers, where present, generally yield 20 gallons per minute (gal/min) or more. In a few areas, 100 gal/min or more may be obtained, and, in areas of thick valley fill in Jackson and Gallatin Counties, 500 gal/min or more may be obtained (fig. 9.1-1).

The Pennsylvanian System is the aquifer that is most used for rural domestic supplies in the study area (Pryor, 1956). The Pennsylvanian System is the uppermost bedrock unit in all but the southernmost part of the area. Its maximum thickness in the area is 2,200 feet in the northeast corner of Hamilton County (Willman and others, 1975). Due to the great variability in water-yielding characteristics of the strata within the Pennsylvanian System, well depths range from 50 to 800 feet (Csallany, 1966). Yields from these wells are usually less than 10 gal/min.

In the southern part of the study area, the Mississippian limestones are the principal sources of water for domestic supplies. Yields from these wells are usually less than 20 gal/min (fig. 9.1-2). For comparison, deep sandstone wells in the northern part of Illinois will yield 500 gal/min or more (Smith and Stall, 1975).

The Devonian and Silurian limestones in the study area are well-creviced and are a source of water in a small part of Union and Jackson Counties where they are near the surface (Roberts and others, 1962).

Recharge to these aquifers is primarily from precipitation and takes place at outcrop areas throughout the study area and by percolation into and through overlying unconsolidated materials. The slow movement of water through the low permeability rocks of the Pennsylvanian System causes the water in the deeper formations to become highly mineralized (Brueckman and Bergstrom, 1968). Figure 9.1-3 is a hypothetical geologic cross section that shows the relative positions of water-bearing materials in the study area.







## 9.0 GROUND WATER (Continued)

### 9.2 GROUND-WATER QUALITY

#### DISSOLVED SOLIDS CONCENTRATIONS INCREASE WITH DEPTH

*Dissolved solids concentrations in wells sampled by the Illinois State Water Survey ranged from 207 to 3,048 milligrams per liter (mg/L). Dissolved solids concentrations generally increase with depth, reaching brine levels (greater than 35,000 mg/L) at a depth of about 1,000 feet in the study area. Potential for contamination of ground water is moderate to high in most of the study area.*

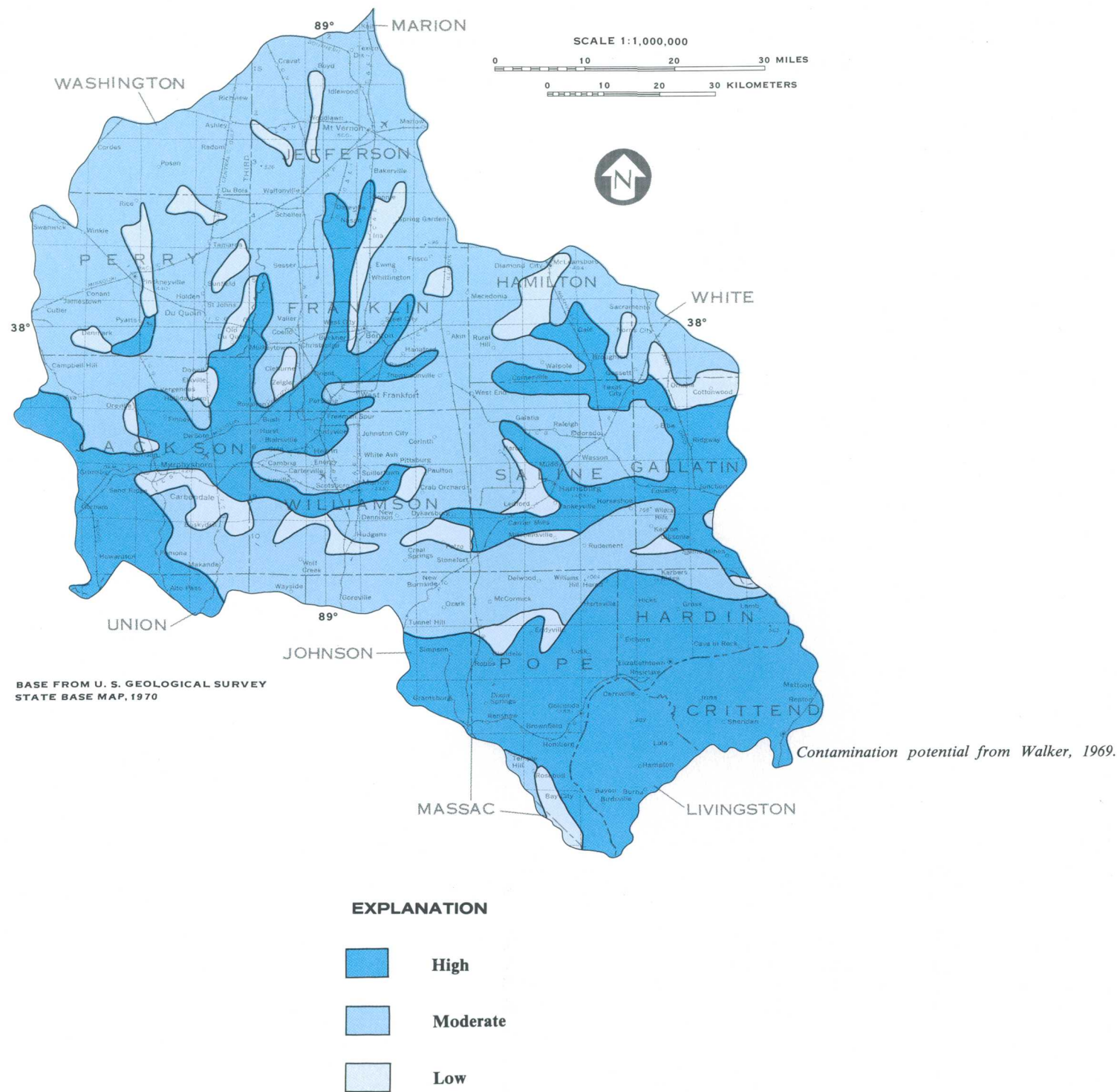
Dissolved solids concentrations in ground water in the study area tend to become higher with increasing depth. Samples from wells in or just outside the study area, shown in table 9.2-1, had total dissolved solids concentrations ranging from 207 to 3,048 mg/L (Roberts and others, 1962). Brines (greater than 35,000 mg/L dissolved solids) occur at a depth of about 1,000 feet (Meents and others, 1952). The National Secondary Drinking Water Regulations (U.S. Environmental Protection Agency, 1977) recommended a limit of 500 mg/L total dissolved solids in drinking water. Higher levels can be consumed with no harmful effects, but water containing more than 4,000 mg/L total dissolved solids is generally considered unfit for human consumption (McKee and Wolf, 1963).

The only measured constituent that exceeds recommended levels for drinking water is iron. The recommended limit for iron in drinking water is 0.3 mg/L (U.S. Environmental Protection Agency, 1976). The mean concentration of iron in wells that are receiving water from Pennsylvanian rocks is 2.3 mg/L. The mean concentration of iron in wells receiving water from unconsolidated materials is 13.1 mg/L. The mean concentration of dissolved iron in surface water in the study

area is 0.1 mg/L upstream of mining and 20 mg/L downstream of mining. Values for other constituents are given in table 9.2-1. Locations of these sites are shown in appendix 3.

A study by Gluskoter (1965) of the composition of ground water associated with coal in Illinois found that pH ranged from 7.0 to 8.6. Total dissolved mineral content increased with depth, and chloride accounted for approximately 60 percent of the total dissolved minerals. Values for other parameters are given in table 9.2-2. The samples were taken from coal in underground mines, either by collecting water dripping from freshly exposed coal or from the shale immediately overlying the coal, or by drilling a hole in the roof of the mine and collecting water in a sampling device designed to fit into the hole.

Figure 9.2-1 (Walker, 1969) shows that most of the study area has moderate to high potential for chemical or bacterial contamination of ground water. These are areas where permeability of overlying unconsolidated material is high, bedrock is at or near the surface, or the water table is shallow.



County	Owner	Source	Depth ft	Casing ft	Yield gpm	Iron Fe	Manganese Mn	Ammonia NH <sub>4</sub>	Sodium Na	Calcium Ca	Magnesium Mg	Silica SiO <sub>2</sub>	Fluoride F	Nitrate NO <sub>3</sub>	Chloride Cl	Sulfate SO <sub>4</sub>	Alkalinity (as CaCO <sub>3</sub> )	Total hardness (as CaCO <sub>3</sub> )	Total dissolved solids	pH
DRINKING WATER STANDARDS						0.3	0.05						2.0	10.0	250	250			500	6.5-8.5
Gallatin	Omaha (village)	R	130	110	18	0.5	0.0	3.6	275	14	10	15		Tr	117	2	516	76	751	7.7
Gallatin	U.S. Forest Service	R	141	40		6.0				34	7				4	54	172	113	260	
Gallatin	U.S. Forest Service	R	127			6.0				12	11				3	74	102	73	207	
Hardin	Daisy Mine	R			3,200					103	29		1.6	1.3	116	150	196	379		
Jackson	Campbell Hill	R	443	250	54	2.1	0.1	0.7	17	142	42	17		1.0	9	167	380	525	617	
Jefferson	Ill. Cent. R.R.	R	124		17	1.1	0.1	0.1	51	153	78	39	0.1	0.1	12	262	524	703	903	7.0
Perry	Cutler No. 1	R	550	495	30	0.7	Tr	0.6	53	49	15	14	0.1	0.5	25	14	252	186	313	7.5
Perry	Cutler No. 2	R	575	418		1.8	0.0	0.7	56	45	15	15	0.2	0.0	17	15	250	180	290	7.3
Perry	Willisville No. 2	R	557	278		0.8	0.01	0.6	43	50	16	12	0.1	0.0	32	7	246	192	316	7.4
Pope	Dixon Sprgs. Exp. Sta.	R	461	401	50	5.1									34	1,810	244	1,872	3,058	
Randolph	Percy No. 1	R	447	312	100	0.3									19			171	309	
Randolph	Percy No. 2	R	466	295	106	0.3	Tr	0.4	40	60	15	14	0.1	0.1	18	18	256	213	322	7.2
Randolph	Steelville No. 1	R	285	275	110	0.1	0.0	0.5	86	36	14	10		1.1	30	164	150	364		
Randolph	Steelville No. 2	R	319		93	0.1	Tr	0.6	57	48	14	15	0.1	0.1	22	13	256	176	342	7.5
Union	Giant City State Park No. 4	R	600	521	64	3.1									17	140	238	330	510	
Union	Trojan Powder Co.	R	653		45	8.5							0.2				252	268	320	
White	Enfield No. 2	R	395	285	28	0.2		0.5	493	4	1	13	3.0	0.4	149	2	876	16	1,206	
Williamson	Creal Springs No. 6	R	402	117	25	2.0							0.2	0.0	6		316	270	380	
Gallatin	Equality	U	91		145	2.8							0.3	1.6	9		432	324	437	
Jackson	Gorham (village)	U	89	89	150	26.0							0.2	0.7	9		296	296	320	
Jackson	Grand Tower	U	156	156	250	0.1	Tr	0.0	25	104	11	23	0.0	7.8	8	46	292	304	408	
Pope	Dixon Sprgs. Exp. Sta.	U	104		24	23.5	0.7	Tr	8	35	20	11	0.6	0.0	4	74	-85	169	277	

R = Rock  
U = Unconsolidated  
Table 9.2-1 Ground water quality, in milligrams per liter (from Roberts and others, 1962).

County	Depth (feet)	Coal No.	pH	Total dissolved minerals	Chloride	Sulfate	Na + K (as Na)	Fe	Mn	Ca	Mg	SiO <sub>2</sub>	Alkalinity (as CaCO <sub>3</sub> )	Hardness (as CaCO <sub>3</sub> )
Franklin	653	6	7.5	38,236	22,800	0.0	13,500	0.0	0.4	672	316	6.9	160	2,980
Franklin	653	6	8.1	37,936	22,800	0.0	13,504	0.0	0.5	664	316	8.5	168	2,960
Franklin	450	6	7.6	30,214	18,000	18.9	10,771	0.1	0.3	436	275	7.1	236	2,220
Franklin	450	6	7.6	30,376	18,200	34.6	10,905	0.1	0.3	436	275	7.1	228	2,220
Jefferson	795	6	7.4	42,466	25,750	9.9	15,155	3.3	0.8	824	360	7.4	168	3,540
Jefferson	765	6	7.4	42,788	26,000	4.9	15,292	2.2	1.0	840	367	7.7	188	3,610
Jefferson	769	6	7.0	48,306	29,250	20.6	17,059	8.7	0.9	1,008	452	6.8	200	4,380
Williamson	185	6	8.3	3,942	1,480	622.0	1,477	0.0	-	17.6	7.8	10.0	552	76
Williamson	161	6	7.7	2,320	1,030	6.6	859	0.1	0.0	36	17	13.8	568	160
Williamson	143	6	7.6	2,984	1,583	2.5	943	0.7	0.1	131	56	13.9	376	560
Williamson	143	6	7.6	1,534	595	21.4	518	0.1	0.1	44	21	22.1	460	196
Williamson	440	6	8.6	994	162	6.6	408	0.6	0.0	2	1	9.8	660	8
Williamson	440	6	8.6	1,002	150	3.3	406	0.5	0.0	2	1	9.8	676	8

Table 9.2-2 Analysis of ground water associated with coals in milligrams per liter (from Gluskoter, 1965).





## 10.0 WATER-DATA SOURCES

### 10.1 INTRODUCTION

## NAWDEX, WATSTORE, OWDC, STORET HAVE WATER DATA INFORMATION

*Water data are collected in coal areas by a large number of organizations in response to a wide variety of missions and needs.*

Three activities within the U.S. Geological Survey help to identify and improve access to the vast amount of existing water data.

(1) The National Water Data Exchange (NAWDEX) indexes the water data available from over 400 organizations and serves as a central focal point to help those in need of water data to determine what information already is available.

(2) The National Water Data Storage and Retrieval System (WATSTORE) serves as the central repository of water data collected by the U.S. Geological Survey and contains large volumes of data on the quantity and quality of both surface and ground waters.

(3) The Office of Water Data Coordination (OWDC) coordinates Federal water-data acquisition activities and

maintains a "Catalog of Information on Water Data." To assist in identifying available water-data activities in coal provinces of the United States, special indexes to the catalog are being printed and made available to the public.

In addition to U.S. Geological Survey water-data activities, the U.S. Environmental Protection Agency operates a data base called the Water Quality Control Information System (STORET). This data base is used for the STORage and RETrieval of data relating to the quality of waterways within and contiguous to the United States.

More detailed explanations of these four activities are given in sections 10.2, 10.3, 10.4, and 10.5.

## 10.0 WATER-DATA SOURCES (Continued)

### 10.2 NATIONAL WATER DATA EXCHANGE – NAWDEX

#### NAWDEX SIMPLIFIES ACCESS TO WATER DATA

*The National Water Data Exchange (NAWDEX) is a nationwide program managed by the U.S. Geological Survey to assist users of water data or water-related data in identifying, locating, and acquiring needed data.*

NAWDEX is a national confederation of water-oriented organizations working together to make their data more readily accessible and to facilitate a more efficient exchange of water data.

Services are available through a Program Office located at the U.S. Geological Survey's National Center in Reston, Virginia, and a nationwide network of Assistance Centers located in 45 States and Puerto Rico, which provide local and convenient access to NAWDEX facilities (fig. 10.2-1). A directory is available on request that provides names of organizations and persons to contact, addresses, telephone numbers, and office hours for each of these locations [Director of Assistance Centers of the National Water Data Exchange (NAWDEX), U.S. Geological Survey Open-File Report 79-423 (revised)].

NAWDEX can assist any organization or individual in identifying and locating needed water data and referring the requester to the organization that retains the data required. To accomplish this service, NAWDEX maintains a computerized Master Water Data Index (fig. 10.2-2), which identifies sites for which water data are available, the type of data available for each site, and the organization retaining the data. A Water Data Sources Directory (fig. 10.2-3) also is maintained that identifies organizations that are sources of water data and the locations within these organizations from which data may be obtained. In addition NAWDEX has direct access to some large water-data bases of its members and has reciprocal agreements for the exchange of services with others.

Charges for NAWDEX services are assessed at the option of the organization providing the requested data or data service. Search assistance services are provided free by NAWDEX to the greatest extent possible. Charges are assessed, however, for those requests requiring computer cost, extensive personnel time, duplicating

services, or other costs encountered by NAWDEX in the course of providing services. In all cases, charges assessed by NAWDEX Assistance Centers will not exceed the direct costs incurred in responding to the data request. Estimates of cost are provided by NAWDEX upon request and in all cases where costs are anticipated to be substantial.

For additional information concerning the NAWDEX program or its services contact:

Program Office  
National Water Data Exchange (NAWDEX)  
U.S. Geological Survey  
421 National Center  
12201 Sunrise Valley Drive  
Reston, VA 22092

Telephone: (703) 860-6031  
FTS 928-6031

Hours: 7:45 to 4:15 Eastern Time

or

NAWDEX ASSISTANCE CENTER

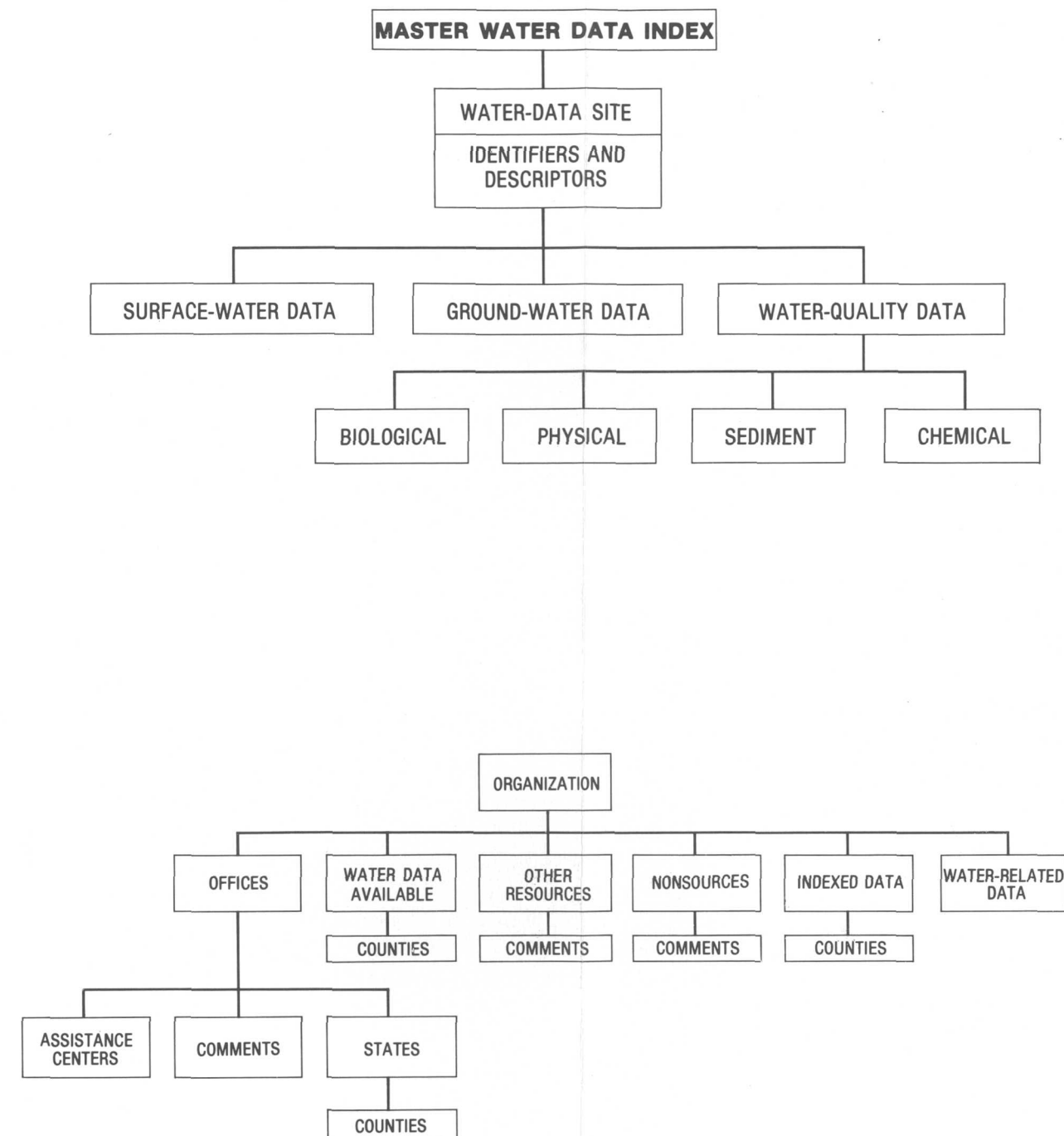
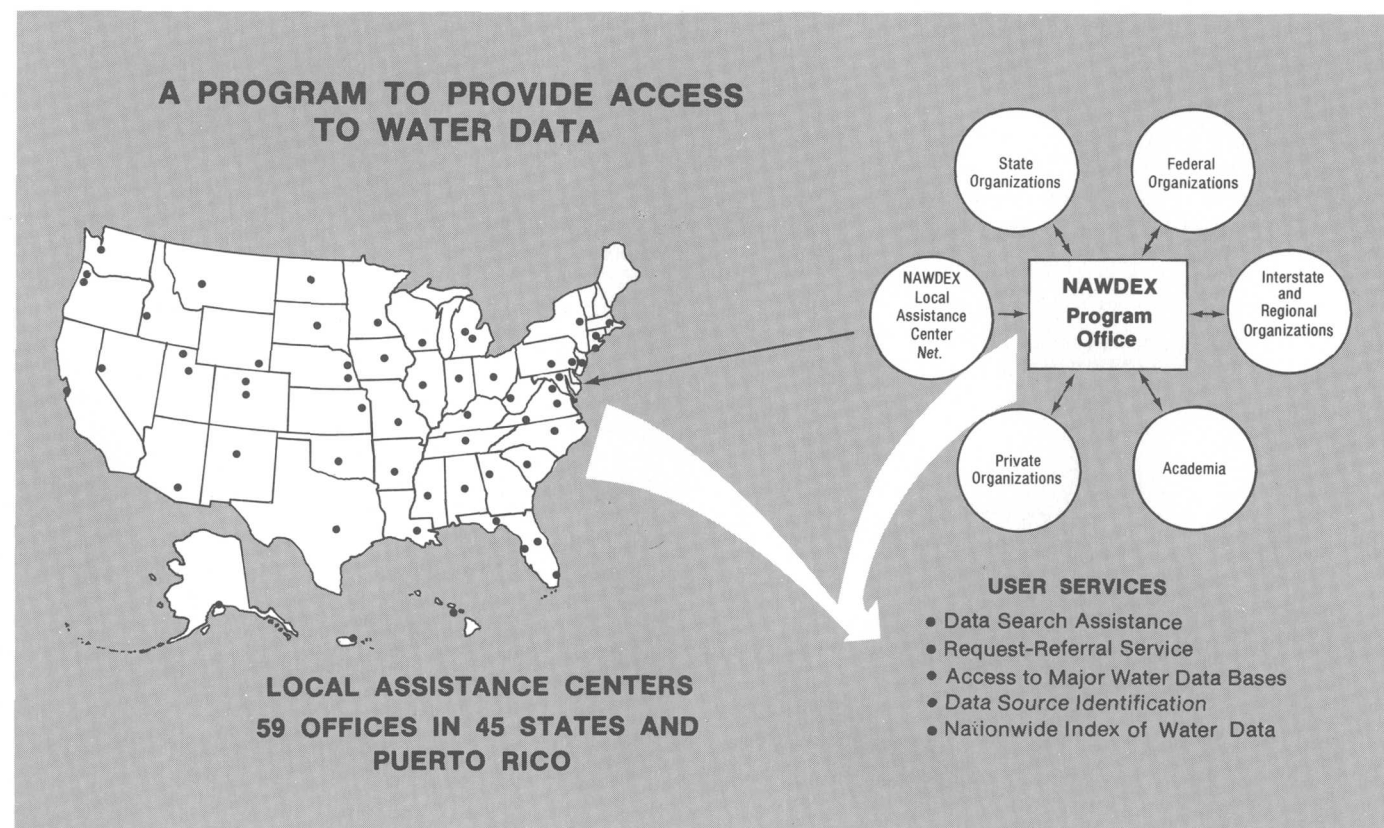
ILLINOIS

U.S. Geological Survey  
Water Resources Division  
Champaign County Bank Plaza  
4th Floor  
102 East Main Street  
Urbana, IL 61801

Telephone: (217) 398-5353  
FTS 958-5353

Hours: 8:00 to 4:00 Central Time





## 10.0 WATER-DATA SOURCES (Continued)

### 10.3 WATSTORE

## WATSTORE AUTOMATED SYSTEM

*The National Water Data Storage and Retrieval System (WATSTORE) of the U.S. Geological Survey provides computerized procedures and techniques for processing water data and provides effective and efficient management of data-releasing activities.*

The National Water Data Storage and Retrieval System (WATSTORE) was established in November 1971 to computerize the U.S. Geological Survey's existing water-data system and to provide for more effective and efficient management of its data-releasing activities. The system is operated and maintained on the central computer facilities of the Survey at its National Center in Reston, Va. Data may be obtained from WATSTORE through the Water Resources Division's 46 district offices. General inquiries about WATSTORE may be directed to:

Chief Hydrologist  
U.S. Geological Survey  
437 National Center  
Reston, VA 22092

or

U.S. Geological Survey  
Water Resources Division  
Champaign County Bank Plaza  
4th Floor  
102 East Main Street  
Urbana, IL 61801

The Geological Survey currently (1980) collects data at approximately 16,000 streamgaging stations, 1,000 lakes and reservoirs, 5,200 surface-water quality stations, 1,020 sediment stations, 30,000 water-level observation wells, and 12,500 ground-water quality wells. Each year many water-data collection sites are added and others are discontinued; thus, large amounts of diversified data, both current and historical, are amassed by the Survey's data-collection activities.

The WATSTORE system consists of several files in which data are grouped and stored by common characteristics and data-collection frequencies. The system also is designed to allow for the inclusion of additional data files as needed. Currently, files are maintained for the storage of: (1) surface-water, quality-of-water, and ground-water data measured on a daily or continuous

basis; (2) annual peak values for streamflow stations; (3) chemical analyses for surface- and ground-water sites; (4) water parameters measured more frequently than daily; and (5) geologic and inventory data for ground-water sites. In addition, an index file of sites for which data are stored in the system is also maintained (fig. 10.3-1). A brief description of each file is as follows:

**Station Header File:** All sites for which data are stored in the Daily Values, Peak Flow, Water Quality, and Unit Values files of WATSTORE are indexed in this file. It contains information pertinent to the identification, location, and physical description of nearly 220,000 sites.

**Daily Values File:** All water-data parameters measured or observed either on a daily or on a continuous basis and numerically reduced to daily values are stored in this file. Instantaneous measurements at fixed-time intervals, daily mean values, and statistics such as daily maximum and minimum values also may be stored. This file currently contains over 200 million daily values including data on streamflow, river stages, reservoir contents, water temperatures, specific conductance, sediment concentrations, sediment discharges, and ground-water levels.

**Peak Flow File:** Annual maximum (peak) streamflow (discharge) and gage height (stage) values at surface-water sites comprise this file which currently contains over 400,000 peak observations.

**Water Quality File:** Results of over 1.4 million analyses of water samples that describe the chemical, physical, biological, and radiochemical characteristics of both surface and ground waters are contained in this file. These analyses contain data for 185 million constituents.

**Unit Values File:** Water parameters measured on a schedule more frequent than daily are stored in this file. Rainfall, stream discharge, and temperature data are examples of the types of data stored in the Unit Values File.

**Ground-Water Site-Inventory File:** This file is maintained within WATSTORE independent of the files discussed above, but it is cross-referenced to the Water-Quality File and the Daily Values File. It contains inventory data about wells, springs, and other sources of ground water. The data included are site location and identification, geohydrologic characteristics, well-construction history, and one-time field measurements such as water temperature. The file is designed to accommodate 255 data elements and currently contains data for nearly 700,000 sites.

All data files of the WATSTORE system are maintained and managed on the central computer facilities of the Geological Survey at its National Center. However, data may be entered into or retrieved from WATSTORE at a number of locations that are part of a nationwide telecommunication network.

**Remote Job Entry Sites:** Almost all of the Water Resources Division's district offices are equipped with high-speed computer terminals for remote access to the WATSTORE system. These terminals allow each site to put data into or retrieve data from the system within several minutes to overnight, depending upon the priority placed on the request. The number of remote job entry sites is increased as the need arises.

**Digital Transmission Sites:** Digital recorders are used at many field locations to record values for parameters such as river stages, conductivity, water temperature, turbidity, wind direction, and chlorides. Data are recorded on 16-channel paper tape, which is removed from the recorder and transmitted over telephone lines to the receiver at Reston, Va. The data are recorded on magnetic tape for use on the central computer. Extensive testing of satellite data collection platforms indicates their feasibility for collecting real-time hydrologic data on a national scale. Battery-operated radios are used as the communication link to the satellite. About 200 data relay stations are being operated currently (1980).

**Central Laboratory System:** The Water Resources Division's two water-quality laboratories, located in Denver, Colo., and Atlanta, Ga., analyze more than 150,000 water samples per year. These laboratories are equipped to automatically perform chemical analyses ranging from determinations of simple inorganic compounds, such as chlorides, to complex organic compounds, such as pesticides. As each analysis is completed, the results are verified by laboratory personnel and transmitted via a computer terminal to the central computer facilities to be stored in the Water-Quality File of WATSTORE.

Water data are used in many ways by decision-makers for the management, development, and monitoring of our water resources. In addition to its data processing, storage, and retrieval capabilities, WATSTORE can provide a variety of useful products ranging from simple data tables to complex statistical analyses. A minimal fee, plus the actual computer cost incurred in producing a desired product, is charged to the requester.

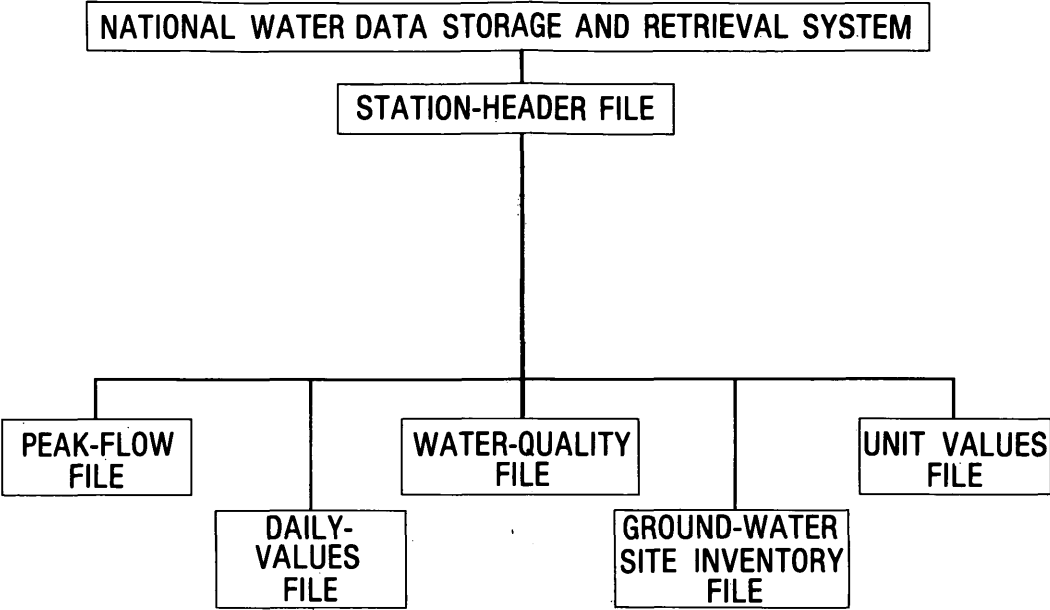
**Computer-Printed Tables:** Users most often request data from WATSTORE in the form of tables printed by the computer. These tables may contain lists of actual data or condensed indexes that indicate the availability of data stored in the files. A variety of formats is available to display the many types of data.

**Computer-Printed Graphs:** Computer-printed graphs for the rapid analysis or display of data are another capability of WATSTORE. Computer programs are available to produce bar graphs (histograms), line graphs, frequency distribution curves, X-Y point plots, site-location map plots, and other similar items by means of line printers.

**Statistical Analyses:** WATSTORE interfaces with a proprietary statistical package (SAS) to provide extensive analyses of data such as regression analyses, the analysis of variance, transformations, and correlations.

**Digital Plotting:** WATSTORE also makes use of software systems that prepare data for digital plotting on peripheral offline plotters available at the central computer site. Plots that can be obtained include hydrographs, frequency distribution curves, X-Y point plots, contour plots, and three-dimensional plots.

**Data in Machine-Readable Form:** Data stored in WATSTORE can be obtained in machine-readable form for use on other computers or for use as input to user-written computer programs. These data are available in the standard storage format of the WATSTORE system or in the form of punched cards or card images on magnetic tape.





## 10.0 WATER-DATA SOURCES (Continued)

### 10.4 INDEX TO WATER-DATA ACTIVITIES IN COAL PROVINCES

#### WATER DATA INDEXED FOR COAL PROVINCES

*A special index, "Index to Water-Data Activities in Coal Provinces of the United States," has been published by the U.S. Geological Survey's Office of Water Data Coordination (OWDC).*

The "Index to Water-Data Activities in Coal Provinces of the United States" was prepared to assist those involved in developing, managing, and regulating the Nation's coal resources by providing information on the availability of water-resources data in the major coal provinces of the United States. It is derived from the "Catalog of Information on Water Data," which is a computerized information file about water-data acquisition activities in the United States, and its territories and possessions, with some international activities included.

This special index consists of five volumes (fig. 10.4-1): volume I, Eastern Coal province; volume II, Interior Coal province; volume III, Northern Great Plains and Rocky Mountain Coal provinces; volume IV, Gulf Coast Coal province; and volume V, Pacific Coast and Alaska Coal provinces. The information presented will aid the user in obtaining data for evaluating the effects of coal mining on water resources and in developing plans for meeting additional water-data needs. The report does not contain the actual data; rather, it provides information that will enable the user to determine if needed data are available.

Each volume of this special index consists of four parts: Part A, Streamflow and Stage Stations; Part B, Quality of Surface-Water Stations; Part C, Quality of Ground-Water Stations; and Part D, Areal Investigations and Miscellaneous Activities. Information given for each activity in Parts A-C includes: (1) the identification and location of the station, (2) the major types of data collected, (3) the frequency of data collection, (4) the form in which the data are stored, and (5) the agency or organization reporting the activity. Part D summaries

areal hydrologic investigations and water-data activities not included in the other parts of the index. The agencies that submitted the information, agency codes, and the number of activities reported by type are shown in a table.

Those who need additional information from the Catalog file or who need assistance in obtaining water data should contact the National Water Data Exchange (NAWDEX) (See section 10.2).

Further information on the index volumes and their availability may be obtained from:

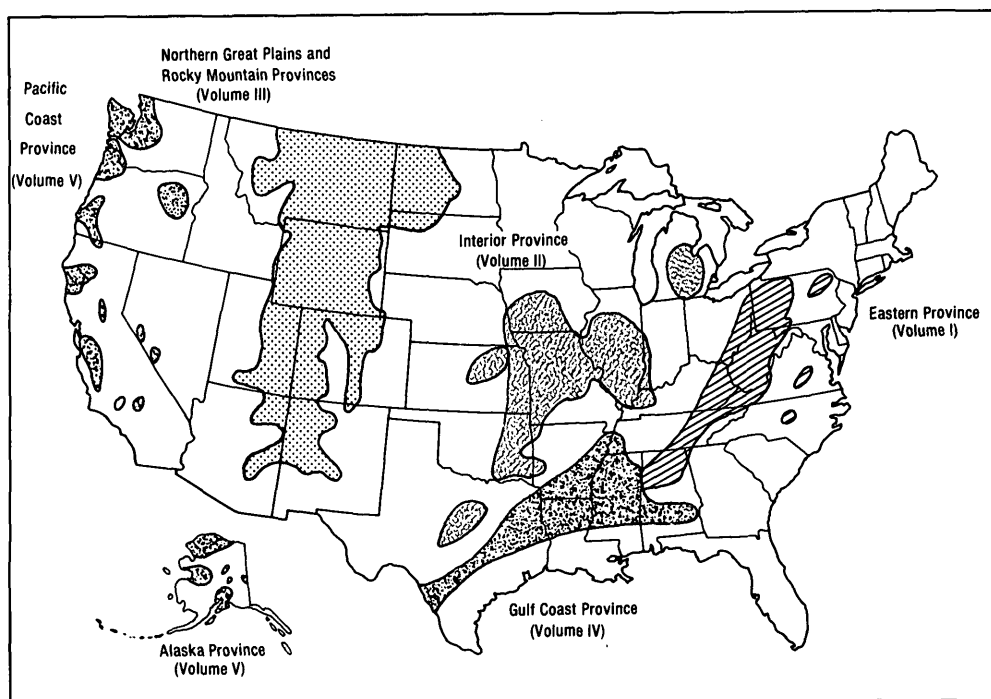
U.S. Geological Survey  
Water Resources Division  
Champaign County Bank Plaza  
4th Floor  
102 East Main Street  
Urbana, IL 61801

Telephone: (217) 398-5353  
FTS 958-5353

or

Office of Surface Mining, Region III  
U.S. Department of the Interior  
U.S. Court House and Post Office Building  
46 East Ohio Street  
Indianapolis, IN 46204

Telephone: (317) 269-2631



**10.0 WATER-DATA SOURCES (Continued)**  
**10.4 INDEX TO WATER-DATA ACTIVITIES IN**  
**COAL PROVINCES**

## 10.0 WATER-DATA SOURCES (Continued)

### 10.5 STORET

#### STORET IS U. S. ENVIRONMENTAL PROTECTION AGENCY COMPUTERIZED DATA BASE SYSTEM

*STORET is the computerized data base system that is maintained by the U.S. Environmental Protection Agency. The system is used to store many kinds of water-quality data.*

"STORET is a computerized data base system maintained by the U.S. Environmental Protection Agency (EPA) for the STOrage and RETrieval of data relating to the quality of the waterways within and contiguous to the United States." The system is used to store data on water quality, water-quality standards, point sources of pollution, pollution-caused fish kills, waste-abatement needs, implementation schedules, and other water-quality related information. The Water Quality File (WQF) is the most widely used STORET file.

The data in the Water Quality File is collected through cooperative programs involving EPA, State water pollution control authorities, and other governmental agencies. The U.S. Geological Survey, the U.S. Forest Service, the U.S. Army Corps of Engineers, the Bureau of Reclamation, and the Tennessee Valley Authority all use STORET's WQF to store and retrieve data collected through their water-quality monitoring programs.

There are 1,800 water-quality parameters defined within STORET's WQF. In 1976 there were data from

over 200,000 unique collection points in the system. Figure 10.5-1 illustrates the groups of parameters and number of observations that are in the WQF.

State, Federal, interstate, and local government agencies can become STORET users. Information on becoming a user of the system can be obtained by contacting the EPA. The point of contact for Region V is:

Director  
Surveillance and Analysis Division  
Environmental Protection Agency  
230 S. Dearborn Street  
Chicago, IL 60604

Telephone: (312) 353-6738

Source: Handbook Water Quality Control Information System (STORET), U.S. Environmental Protection Agency, Office of Water and Hazardous Materials, Washington, D.C. 20460.



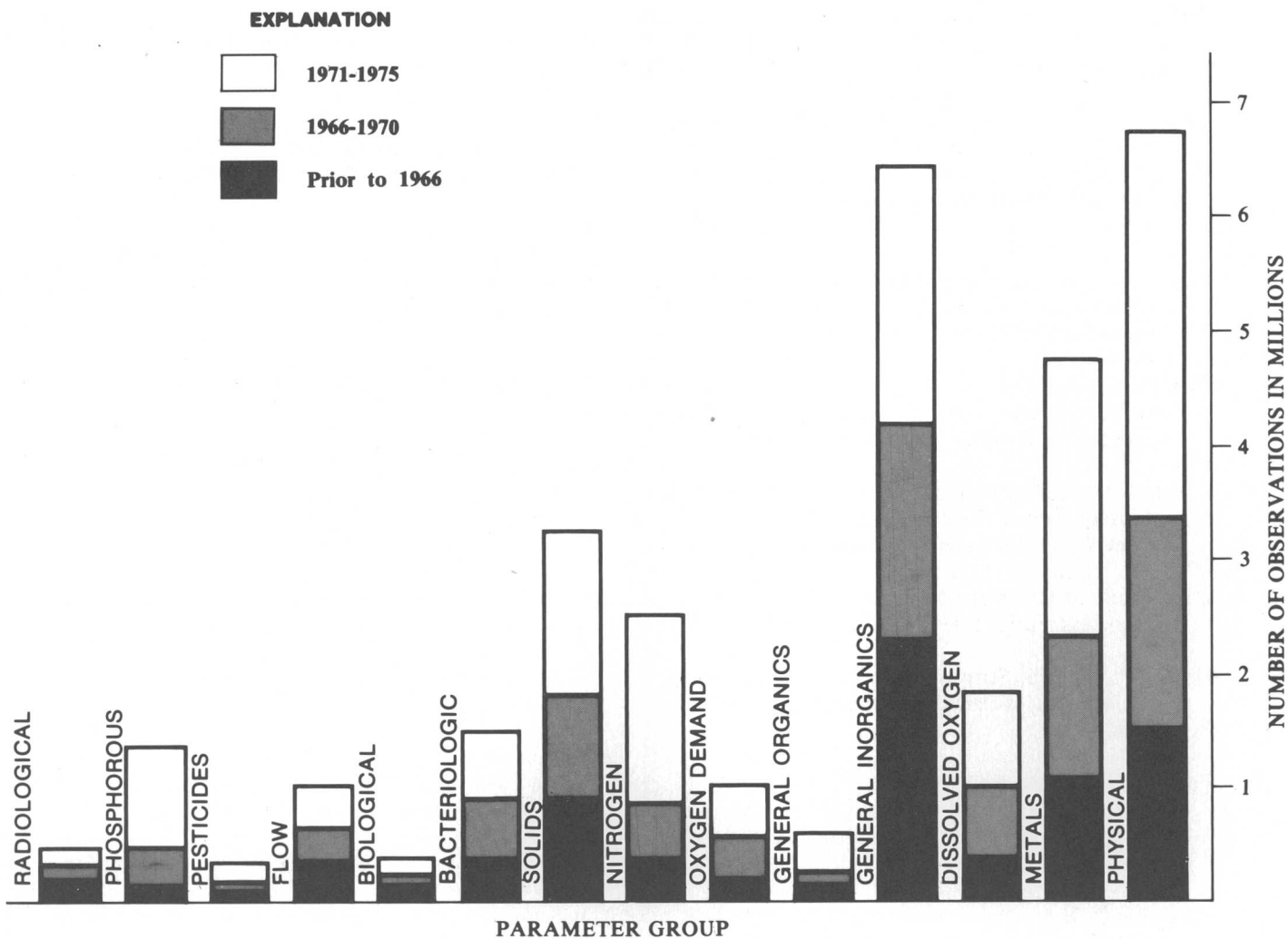


Fig. 10.5-1 Parameter groups and number of observations in the Water Quality File (from STORET User Handbook).

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## 12.0 APPENDICES

### 12.1 APPENDIX 1

Map No.	Station No.	Station name and location	Drainage area (mi <sup>2</sup> )	Average discharge (ft <sup>3</sup> /s)	Type	Years of discharge record
1	03382100	South Fork Saline River near Carrier Mills, IL Lat 37°38'16", long 88°40'40", in SW¼NE¼ sec. 20, T.10 S., R.5 E., Saline County.	147	158	D	10/65 -
2	03382170	Brushy Creek near Harco, IL Lat 37°46'30", long 88°39'08", in NW¼NW¼ sec. 3, T.9 S., R.5 E., Saline County.	13.3	13.9	D	07/68 -
3	03382510	Eagle Creek near Equality, IL Lat 37°39'03", long 88°23'28", at east boundary of sec.14, T.10 S., R.7 E., Saline County.	8.51	10.2	D	06/66 -
4	03382520	Black Branch tributary near Junction, IL Lat 37°41'13", long 88°15'55", in NE¼ sec.2, T.10 S., R.8 E., Gallatin County.	1.10	---	C	11/59 - 09/72
5	03384450	Lusk Creek near Eddyville, IL Lat 37°38'20", long 88°32'50", in SE¼ sec.16, T.12 S., R.6 E., Pope County.	42.9	60.7	D	10/67 -
6	03385000	Hayes Creek at Glendale, IL Lat 37°27'25", long 88°40'05", in SW¼SW¼ sec. 21, T.12 S., R.5 E., Pope County.	19.1	26.1	D C	05/49 - 09/75 10/75 -
7	03385500	Lake Glendale Inlet near Dixon Springs, IL Lat 37°24'55", long 88°39'00", in NE¼SW¼ sec. 3, T.13 S., R.5 E., Pope County.	1.04	1.37	D C	08/54 - 09/63 10/63 -
8	03386500	Sugar Creek near Dixon Springs, IL Lat 37°24'56", long 88°40'25", in NE¼SE¼ sec. 5, T.13 S., R.5 E., Pope County.	9.93	10.8	D C	04/50 - 09/71 10/71 -
9	05595800	Sevenmile Creek near Mt. Vernon, IL Lat 38°19'10", long 88°50'50", in NW¼SW¼ sec. 26, T.2 S., R.3 E., Jefferson County.	21.1	15.5	D	10/60 -
10	05596000	Big Muddy River near Benton, IL Lat 37°59'40", long 88°58'30", in NE¼NW¼ sec. 22, T.6 S., R.2 E., Franklin County.	498	452	D	10/45 - 09/70
11	05596100	Andy Creek tributary at Valier, IL Lat 38°01'15", long 89°02'40", in NW¼NE¼ sec. 12, T.6 S., R.1 E., Franklin County.	1.03	---	C	11/55 - 05/72

Map No.	Station No.	Station name and location	Drainage area (mi <sup>2</sup> )	Average discharge (ft <sup>3</sup> /s)	Type	Years of discharge record
12	05597000	Big Muddy River at Plumfield, IL Lat 37°54'05", long 89°00'50", in NW¼ sec.20, T.7 S., R.2 E., Franklin County.	794	635	D	06/08 - 09/10 12/10 - 12/12 08/14 -
13	05597500	Crab Orchard Creek near Marion, IL Lat 37°43'52", long 88°53'21", in SW¼SW¼ sec. 16, T.9 S., R.3 E., Williamson County.	31.7	23.6	D	10/51 -
14	05598480	White Walnut Creek near Pinckneyville, IL Lat 38°06'27", long 89°20'50", in SW¼NW¼ sec. 8, T.5 S., R.2 W., Perry County.	16.5	---	D	03/80 -
15	05598500	Beaucoup Creek near Pinckneyville, IL Lat 38°06'27", long 89°20'50", in SW¼NW¼ sec. 8, T.5 S., R.2 W., Perry County.	231	---	D	01/09 - 12/12 07/14 - 10/14
16	05599000	Beaucoup Creek near Matthews, IL Lat 37°58'00", long 89°21'00", in SW¼ sec.29, T.6 S., R.2 W., Perry County.	292	223	D	10/45 -
17	05599500	Big Muddy River at Murphysboro, IL Lat 37°44'55", long 89°20'45", in SE¼ sec.8, T.9 S., R.2 W., Jackson County.	2,169	1,823	D	10/70 -
		Prior to construction of Rend Lake	2,169	1,788	D	10/31 - 09/70
18	05599560	Clay Lick Creek near Makanda, IL Lat 37°36'00", long 89°14'25", in SW¼ sec.32, T.10 S., R.1 W., Jackson County.	1.94	---	C	10/59 -

Type

D = Discharge gage.

C = Crest-stage gage.

**12.0 APPENDICES**  
**12.2 APPENDIX 2**

Map No.	Station No.	Station name and location
1	03382040	South Fork Saline River near New Dennison, IL Lat 37°40'40", long 88°51'38", in NE¼SE¼ sec.3, T.10 S., R.3 E., Williamson County.
2	03382045	Little Cana Creek near Creal Springs, IL Lat 37°37'16", long 88°51'36", in NE¼NE¼ sec.22, T.10 S., R.3 E., Williamson County.
3	03382079	Sugar Creek near Creal Springs, IL Lat 37°37'22", long 88°48'42", in SE¼NW¼ sec.30, T.10 S., R.4 E., Williamson County.
4	03382090	Sugar Creek near Stonefort, IL Lat 37°39'19", long 88°45'48", in NE¼ sec.16, T.10 S., R.4 E., Williamson County.
5	03382100	South Fork Saline River near Carrier Mills, IL Lat 37°38'16", long 88°40'40", in SW¼NE¼ sec.20, T.10 S., R.5 E., Saline County.
6	03382119	Little Saline River near McCormick, IL Lat 37°35'19", long 88°41'53", in NW¼SE¼ sec.6, T.11 S., R.5 E., Pope County.
7	03382120	Little Saline River near Stonefort, IL Lat 37°35'04", long 88°40'09", in SW¼ sec.4, T.11 S., R.5 E., Pope County.
8	03382130	South Fork Saline River at Mitchellsville, IL Lat 37°39'30", long 88°32'14", in NW¼ sec.15, T.10 S., R.6 E., Saline County.
9	03382155	Prairie Creek near Corinth, IL Lat 37°49'37", long 88°42'36", in SE¼ sec.13, T.8 S., R.4 E., Williamson County.
10	03382156	Middle Fork Saline River near Galatia, IL Lat 37°49'48", long 88°39'06", in SW¼NW¼ sec.15, T.8 S., R.5 E., Saline County.
11	03382160	Bankston Fork near Crab Orchard, IL Lat 42°35'17", long 88°49'55", in NE¼NE¼ sec.21, T.9 S., R.4 E., Williamson County.
12	03382168	Bankston Fork near Carrier Mills, IL Lat 37°43'41", long 88°38'02", in NW¼NW¼ sec.23, T.9 S., R.5 E., Saline County.
13	03382170	Brushy Creek near Harco, IL Lat 37°46'30", long 88°39'08", in NW¼NW¼ sec.3, T.9 S., R.5 E., Saline County.
14	03382175	Brushy Creek tributary near Harco, IL Lat 37°46'33", long 88°37'09", in NW¼ sec.1, T.9 S., R.5 E., Saline County.
15	03382180	Bankston Fork at Dorris Heights, IL Lat 37°45'34", long 88°34'10", in NW¼ sec.8, T.9 S., R.6 E., Saline County.

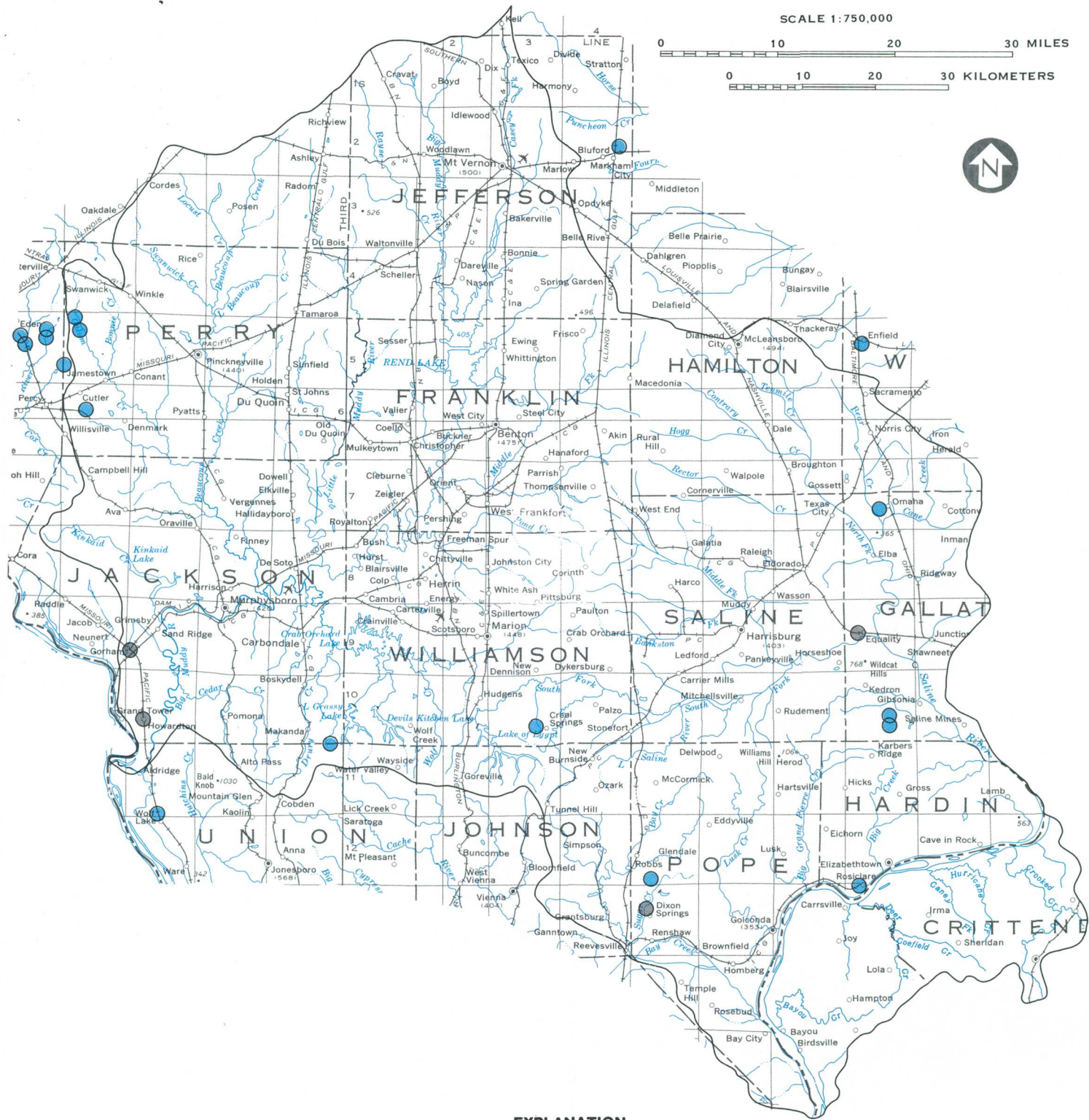


Map No.	Station No.	Station name and location
16	03382185	Bankston Fork near Dorris Heights, IL Lat 37°46'05", long 88°32'25", in SE¼NE¼ sec.4, T.9 S., R.6 E., Saline County.
17	03382200	Middle Fork Saline River near Harrisburg, IL Lat 37°44'18", long 88°30'05", in NW¼SW¼ sec.13, T.9 S., R.6 E., Saline County.
18	03382205	Middle Fork Saline River near Pankeyville, IL Lat 37°42'28", long 88°29'31", in SE¼ sec.25, T.9 S., R.6 E., Saline County.
19	03382210	Brier Creek near Harrisburg, IL Lat 37°41'40", long 88°32'10", in SW¼ sec.34, T.9 S., R.6 E., Saline County.
20	03382211	Brier Creek near Pankeyville, IL Lat 37°41'53", long 88°29'58", in SE¼NW¼ sec.36, T.9 S., R.6 E., Saline County.
21	03382250	Saline River at Equality, IL Lat 37°43'53", long 88°20'27", in NE¼NW¼ sec.20, T.9 S., R.8 E., Gallatin County.
22	03382315	North Fork Saline River near Broughton, IL Lat 37°56'12", long 88°25'34", in NW¼NW¼ sec.10, T.7 S., R.7 E., Hamilton County.
23	03382320	Rector Creek near Texas City, IL Lat 37°53'01", long 88°26'05", in SE¼ sec.28, T.7 S., R.7 E., Saline County.
24	03382325	North Fork Saline River near Texas City, IL Lat 37°53'18", long 88°23'06", in NW¼ sec.25, T.7 S., R.7 E., Saline County.
25	03382360	North Fork Saline River near Equality, IL Lat 37°44'40", long 88°19'48", in NW¼NW¼ sec.16, T.9 S., R.8 E., Gallatin County.
26	03382450	Saline River near Equality, IL Lat 37°42'14", long 88°17'14", in SE¼ sec.26, T.9 S., R.8 E., Gallatin County.
27	03382510	Eagle Creek near Equality, IL Lat 37°39'03", long 88°23'28", at east boundary of sec.14, T.10 S., R.7 E., Saline County.
28	03382530	Saline River near Gibsonia, IL Lat 37°38'53", long 88°14'30", in SW¼ sec.17, T.10 S., R.9 E., Gallatin County.
29	03384450	Lusk Creek near Eddyville, IL Lat 37°28'20", long 88°32'50", in SE¼ sec.16, T.12 S., R.6 E., Pope County.
30	05595700	Big Muddy River near Mt. Vernon, IL Lat 38°18'36", long 89°59'18", in NW¼ sec.33, T.2 S., R.2 E., Jefferson County.
31	05596105	Andy Creek at Buckner, IL Lat 37°58'46", long 89°01'42", in SW¼SE¼ sec.19, T.6 S., R.2 E., Franklin County.
32	05596110	Andy Creek near Christopher, IL Lat 37°57'53", long 89°01'37", in SE¼ sec.30, T.6 S., R.2 E., Franklin County.

Map No.	Station No.	Station name and location
33	05596400	Middle Fork Big Muddy River near Benton, IL Lat 37°56'58", long 88°54'00", in NE¼ sec.5, T.7 S., R.3 E., Franklin County.
34	05597000	Big Muddy River at Plumfield, IL Lat 37°54'05", long 89°00'50", in NW¼ sec.20, T.7 S., R.5 E., Franklin County.
35	05597035	Prairie Creek near Zeigler, IL Lat 37°51'43", long 89°04'03", in S½ sec.35, T.7 S., R.1 E., Franklin County.
36	05597040	Pond Creek at West Frankfort, IL Lat 37°53'06", long 88°55'54", in NE¼ sec.25, T.7 S., R.2 E., Franklin County.
37	05597045	Lake Creek near Herrin, IL Lat 37°50'23", long 89°00'03", in W½ sec.9, T.8 S., R.2 E., Williamson County.
38	05597050	Pond Creek near Herrin, IL Lat 37°51'10", long 89°00'37", in SE¼ sec.5, T.8 S., R.2 E., Williamson County.
39	05597070	Hurricane Creek near Colp, IL Lat 37°49'08", long 89°04'39", in SE¼SE¼ sec.15, T.8 S., R.1 E., Williamson County.
40	05597080	Hurricane Creek near Herrin, IL Lat 37°49'16", long 89°05'46", in SE¼ sec.16, T.8 S., R.1 E., Williamson County.
41	05597240	Little Muddy River at Radom, IL Lat 38°16'53", long 89°12'16", in SE¼NE¼ sec.9, T.3 S., R.1 W., Washington County.
42	05597255	Reese Creek near Old Du Quoin, IL Lat 37°58'33", long 89°10'02", in NW¼NW¼ sec.25, T.6 S., R.1 W., Perry County.
43	05597265	Sixmile Creek at Dowell, IL Lat 37°56'08", long 89°13'09", in NW¼ sec.9, T.7 S., R.1 W., Jackson County.
44	05597280	Little Muddy River near Elkhaville, IL Lat 37°54'03", long 89°12'31", in SE¼NE¼ sec.21, T.7 S., R.1 W., Jackson County.
45	05597300	Little Muddy River near De Soto, IL Lat 37°49'53", long 89°11'12", in NW¼ sec.14, T.8 S., R.1 W., Jackson County.
46	05597490	Little Crab Orchard Creek near Marion, IL Lat 37°44'22", long 88°51'21", in NE¼ sec.15, T.9 S., R.3 E., Williamson County.
47	05597500	Crab Orchard Creek near Marion, IL Lat 37°43'52", long 88°53'21", in SW¼SW¼ sec.16, T.9 S., R.3 E., Williamson County.
48	05598050	Crab Orchard Creek below Crab Orchard Lake near Carterville, IL Lat 37°42'51", long 89°09'04", in NW¼ sec.30, T.9 S., R.1 E., Williamson County.
49	05598205	Sycamore Creek near Boskydell, IL Lat 37°40'22", long 89°10'00", in NW¼NW¼ sec.12, T.10 S., R.1 W., Jackson County.

Map No.	Station No.	Station name and location
50	05598210	Sycamore Creek near Carbondale, IL Lat 37°42'30", long 89°10'20", in NE¼SE¼ sec.26, T.9 S., R.1 W., Jackson County.
51	05598245	Crab Orchard Creek near Carbondale, IL Lat 37°40'18", long 89°10'49", in NE¼ sec.2, T.9 S., R.1 W., Jackson County.
52	05598400	Beaucoup Creek near Todds Mill, IL Lat 38°11'58", long 89°20'29", in NW¼NE¼ sec.8, T.4 S., R.2 W., Perry County.
53	05598480	White Walnut Creek near Pinckneyville, IL Lat 38°06'27", long 89°20'50", in SW¼NW¼ sec.8, T.5 S., R.5 W., Perry County.
54	05598700	Panther Creek near Pyatts, IL Lat 38°00'10", long 89°20'07", in E½ sec.17, T.6 S., R.2 W., Perry County.
55	05599000	Beaucoup Creek near Matthews, IL Lat 37°58'00", long 89°21'00", in SW¼ sec.29, T.6 S., R.2 W., Perry County.
56	05599020	Galum Creek near Lost Prairie, IL Lat 38°05'13", long 89°33'14", in NW¼ sec.21, T.5 S., R.4 W., Perry County.
57	05599055	Pipestone Creek near Denmark, IL Lat 37°57'58", long 89°29'03", in NW¼ sec.31, T.6 S., R.3 W., Perry County.
58	05599060	Brushy Fork near Denmark, IL Lat 37°57'52", long 89°29'03", in NW¼ sec.31, T.6 S., R.3 W., Perry County.
59	05599080	Pipestone Creek near Ava, IL Lat 38°57'33", long 89°26'34", in SW¼ sec.33, T.6 S., R.3 W., Perry County.
60	05599100	Galum Creek near Pyatts, IL Lat 37°56'42", long 89°22'45", in E½ sec.1, T.7 S., R.3 W., Jackson County.
61	05599200	Beaucoup Creek near Vergennes, IL Lat 37°54'12", long 89°22'36", in NE¼ sec.24, T.7 S., R.3 W., Jackson County.
62	05599300	Beaucoup Creek near Oraville, IL Lat 37°51'43", long 89°19'57", in N½ sec.4, T.8S., R.2W., Jackson County
63	05599500	Big Muddy River at Murphysboro, IL Lat 37°44'55", long 89°20'45", in SE¼ sec.8, T.9S., R.2W., Jackson County





SCALE 1:750,000

0 10 20 30 MILES

0 10 20 30 KILOMETERS



# EXPLANATION

● Rock wells

● Unconsolidated deposit wells

BASE FROM U. S. GEOLOGICAL SURVEY  
STATE BASE MAP, 1970

## APPENDIX 3

### GROUND WATER QUALITY SAMPLES