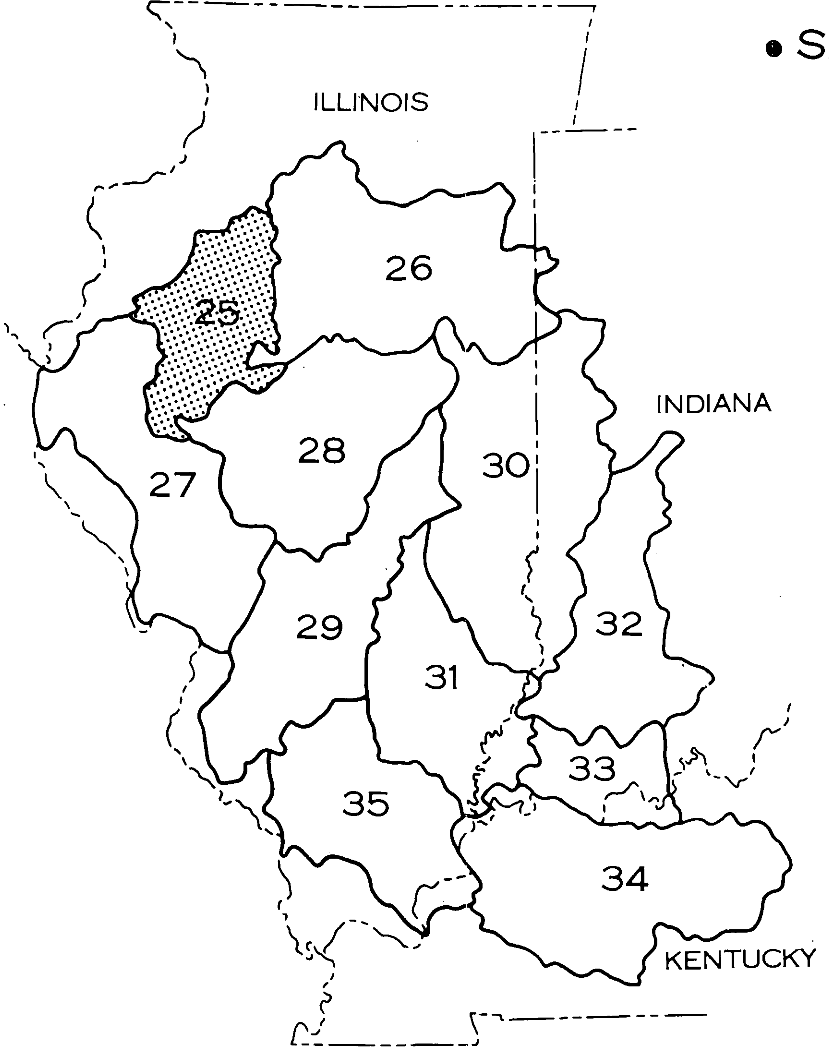
HYDROLOGY OF AREA 25, EASTERN REGION, INTERIOR COAL PROVINCE, ILLINOIS

- ILLINOIS RIVER
- SPOON RIVER



UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

WATER-RESOURCES INVESTIGATIONS
OPEN-FILE REPORT 81-636

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HYDROLOGY OF AREA 25, EASTERN REGION, INTERIOR COAL PROVINCE, ILLINOIS

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

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WATER-RESOURCES INVESTIGATIONS 81-636

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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	millimeters per hour (mm/h)
	2.54	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^2)	2.590	square kilometers (km^2)
gallons per minute (gal/min)	0.06309	liters per second (L/s)
million gallons per day (mgal/d)	0.04381	cubic meters per second (m^3/s)
	3,785	cubic meters per day (m^3/d)
cubic feet per second (ft^3/s)	0.02832	cubic meters per second (m^3/s)
cubic feet per second per square mile [$(ft^3/s)/mi^2$]	0.01093	cubic meters per second per square kilometer [$(m^3/s)/km^2$]
tons per square mile per year [$(tons/mi^2)/yr$]	0.03753	metric tons per square kilometer per year [$(t/km^2)/a$]
micromhos per centimeter at 25° Celsius (μmho/cm at 25°C)	100	microsiemens per meter at 25° Celsius (μS/m at 25°C)

HYDROLOGY OF AREA 25, EASTERN REGION, INTERIOR COAL PROVINCE, ILLINOIS

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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, mine 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 25 is located in west-central Illinois. It includes parts of three physiographic divisions: the Galesburg Plain, the Springfield Plain, and the Bloomington Ridged Plain. The drainage basins in the area are the Spoon River, Sugar Creek, Kickapoo Creek, and small tributaries to the Illinois 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. Among the 50 States, Illinois ranks first in total reserves of bituminous coal and coal reserves with the highest total heat content.

Loess soils cover most of the study area and are slowly to moderately permeable. These soils are of moderate to high productivity under a high level of management. Agriculture is the dominant land use. Water from surface-water impoundments and rivers makes up 97 percent of all the water used. Precipitation averages 34 to 35 inches across the area with about 22 inches occurring from April to September.

The U.S. Geological Survey operates a network of eight hydrologic monitoring stations in the study area. Streamflow, water levels, and water-quality data are collected. These data are available from computer storage through the National Water Data Exchange (NAWDEX) managed by the U.S. Geological Survey.

The major hydrologic problems related to surface mining are degradation of water quality and sedimentation. Water quality can be altered as a result of drainage of mine sites into the surrounding area and into the streams. Natural conditions may neutralize acidic waters but increased concentrations of dissolved trace elements can remain in the waters. High rates of sedimentation can result from the lack of soil cover and the disturbed conditions left by mining operations.

1.0 INTRODUCTION

1.1 Objective

AREA 25 REPORT TO AID PERMITTING

Existing hydrologic conditions and identification of sources of hydrologic information are described.

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 enacted as Public Law 95-87 on August 3, 1977. This need is partially met by this report which broadly characterizes the hydrology of Area 25 in the eastern region of the Interior Coal Province in west-central Illinois (fig. 1.1-1). This report is one of a series that covers the coal provinces nationwide. The report contains a brief text with an accompanying map, chart, graph, or other illustration for each of a number of water-resources-related topics. The summation of the topical discussions provides a description of the hydrology of the area.

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 with specific site data as well as data from other sources to provide a more detailed picture of the hydrology in the vicinity of the mine and the anticipated hydrologic consequences of the mining operation.

The information contained herein should be useful to surface-mine owners, mine operators, and consulting engineers in the preparation of permits and to regulatory authorities in appraising the adequacy of permit applications.

BASE FROM U. S. GEOLOGICAL SURVEY
STATE BASE MAP, 1972,

Figure 1.1-1 Location of study area in Illinois.

1.0 INTRODUCTION

1.1 OBJECTIVE

AREA 25 INCLUDES PARTS OF THREE PHYSIOGRAPHIC DIVISIONS

The study area includes parts of three physiographic divisions in west-central Illinois: the Galesburg Plain, the Springfield Plain, and the Bloomington Ridged Plain.

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 of this report. The divisions are based on hydrologic factors, location, and size. Hydrologic units (drainage basins) are combined to form each study area.

Area 25 covers about 3,400 square miles in west-central Illinois (fig. 1.2-1). It includes all of Fulton and Stark Counties and parts of Bureau, Cass, Henry, Knox, Marshall, Mason, McDonough, Peoria, Schuyler, Tazewell, and Warren Counties.

The study area, as shown in figure 1.2-2, includes parts of three physiographic divisions: the Galesburg Plain, the Springfield Plain, and the Bloomington Ridged Plain. These are all divisions of the Till Plains Section of the Central Lowland Province. The topography of the Galesburg Plain is level to gently undulating except where dissected by streams. The topography of the Springfield Plain is also level to gently undulating, but the streams are not as deeply entrenched as those in the Galesburg Plain. The topography of the Bloomington Ridged Plain is a series of low, broad, morainic ridges alternating with wide areas of relatively flat or gently undulating till plains (Thornburn, 1963). The major drainage basin wholly in Area 25 is the Spoon River basin (fig. 1.2-3). The Illinois River passes along the southeastern part of the study area and receives all the drainage.

The population of the study area as of 1970 was 463,028 (Rockford Map Publishers, 1973). Cities with populations greater than 25,000 are Bartonville, Beardstown, Canton, Pekin and Peoria.

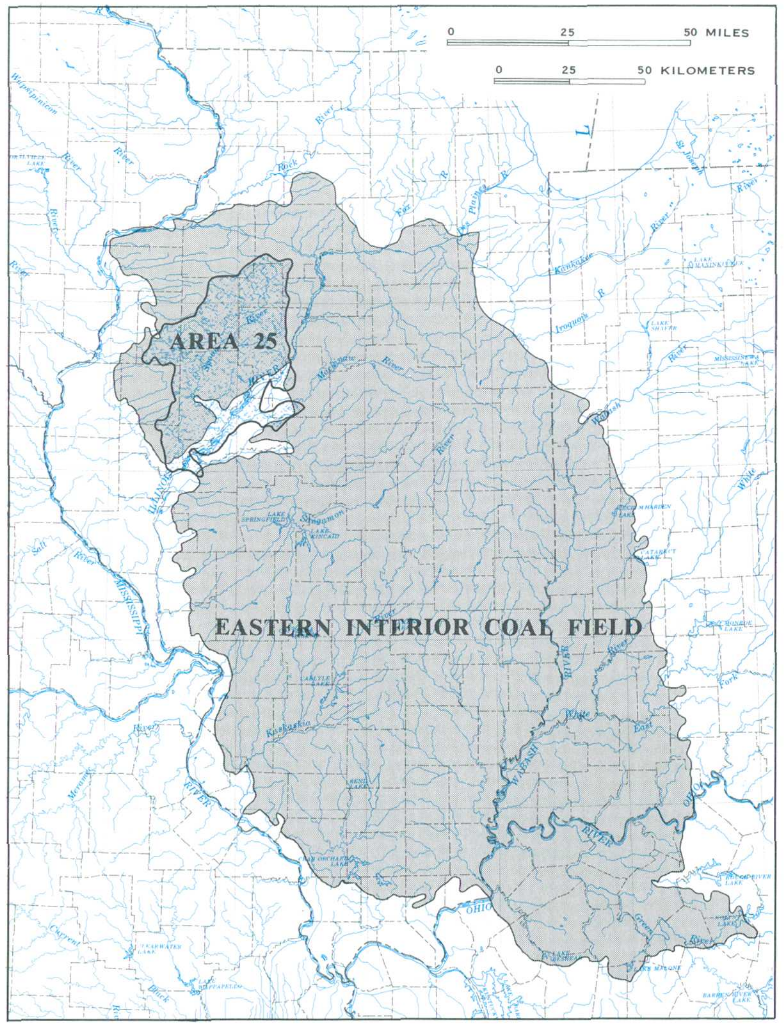


Figure 1.2-1 Location of the study area in the Eastern Interior Coal Field.

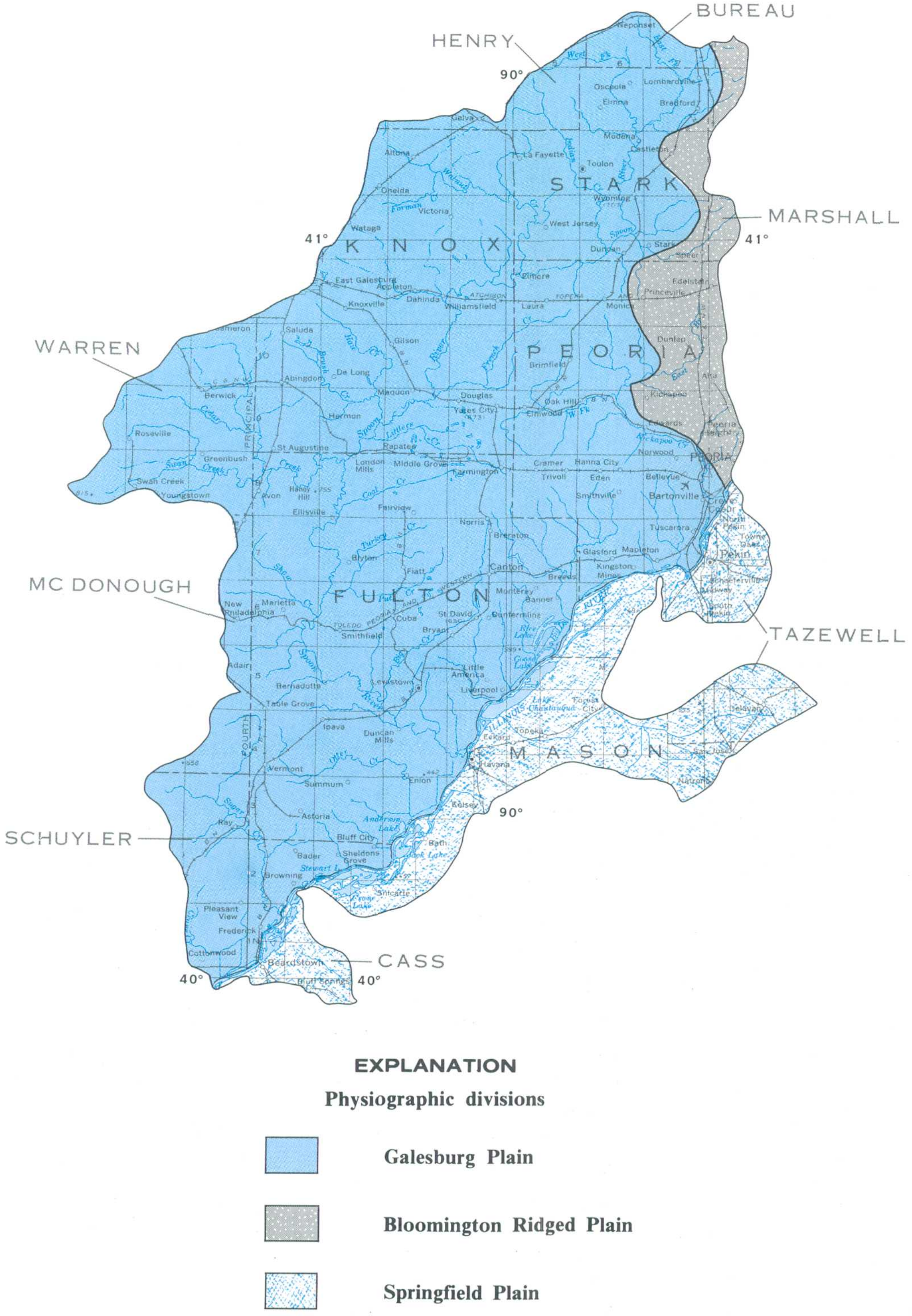


Figure 1.2-2 Physiographic divisions.

BASE FROM U. S. GEOLOGICAL SURVEY
STATE BASE MAP, 1972

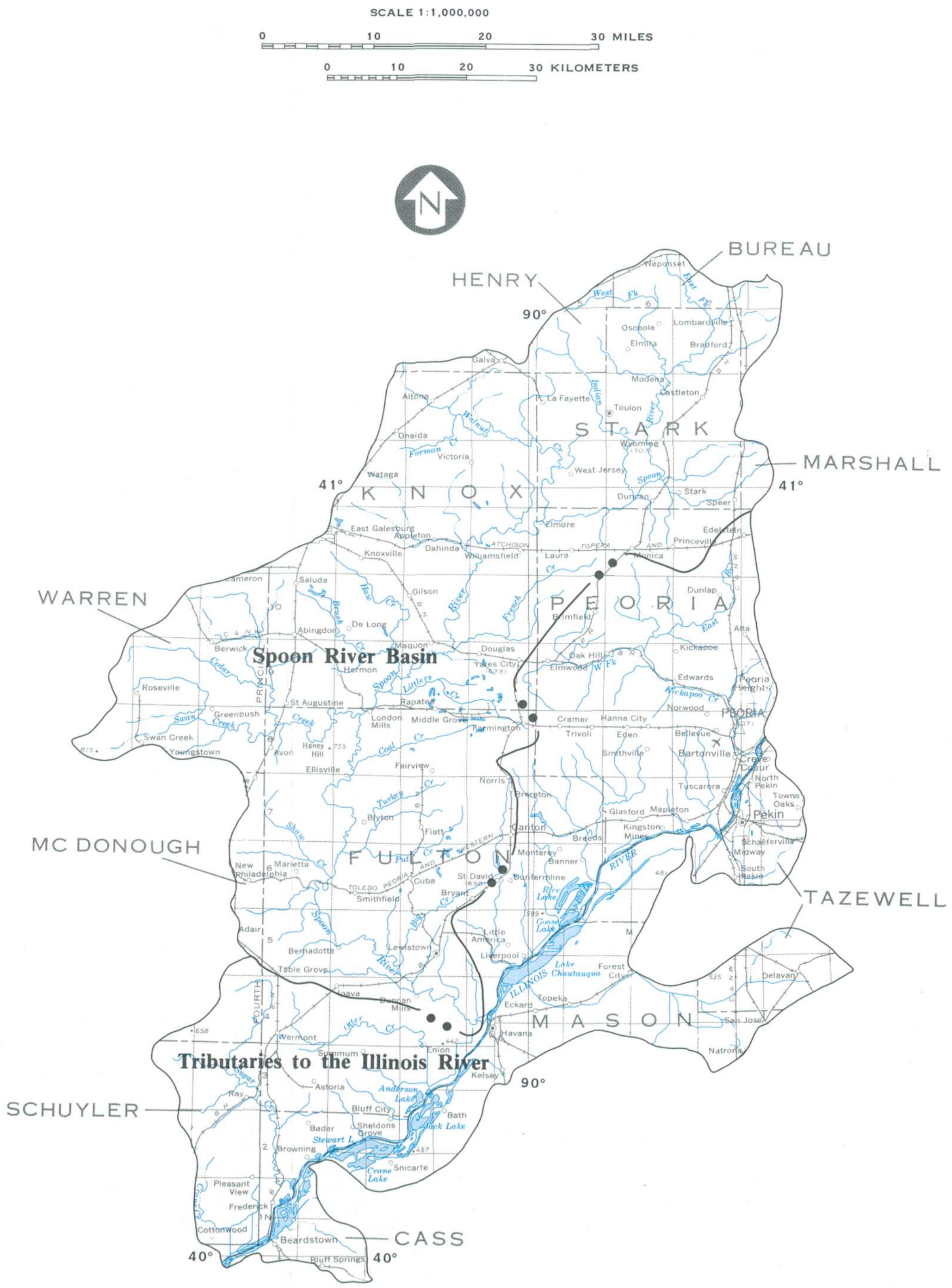


Figure 1.2-3 Drainage basins.

1.0 INTRODUCTION

1.2 STUDY AREA

ILLINOIS HAS LARGEST BITUMINOUS COAL RESERVES IN THE UNITED STATES

Illinois, second only to Montana in total coal reserves, ranks first in total reserves of bituminous coal. These reserves also have the highest total heat content. Estimated reserves of coal in Illinois are 161.6 billion tons.

Estimated coal reserves in Illinois (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. Forty-eight percent of the total United States coal reserves is bituminous. Among the 50 States, Illinois has the largest reserves of bituminous coal. Illinois coal reserves also have the highest total heat content (Btu). Only Montana has larger total coal reserves (Rickert and others, 1979). About 12.1 percent of the Illinois reserves is considered surface mineable (coal seams more than 18 inches thick and less than 150 feet deep), but currently only about 3.6 percent is economically and legally surface mineable (Nawrot and others, 1980).

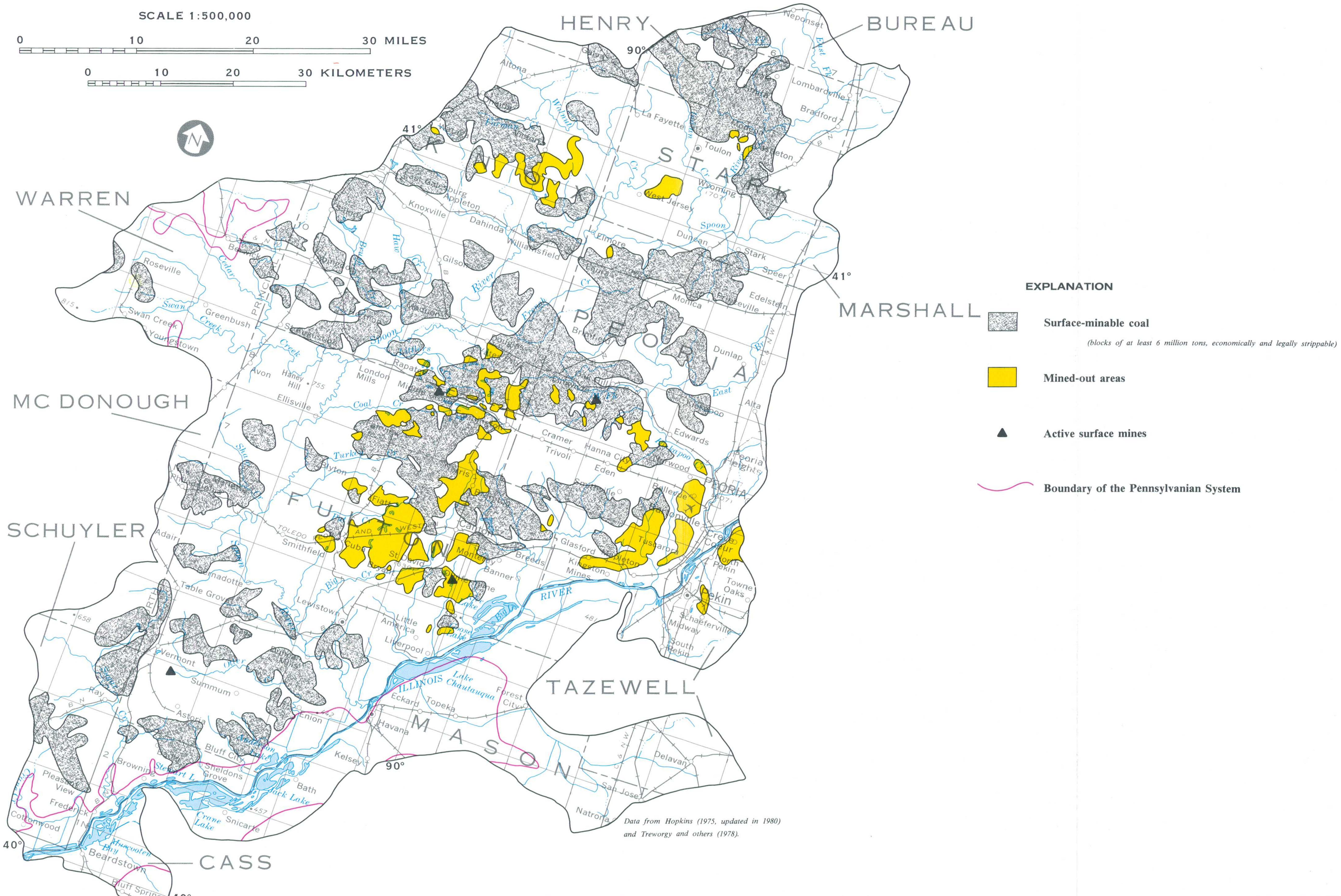
The first coal discovery in North America was by Marquette and Joliet in 1673 along the Illinois River. The first commercial underground coal mine in Illinois was opened in 1810 in Jackson County (Andros, 1915). The first commercial surface mine in the United States was opened in 1866 near Danville, Illinois. Early surface 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 up to 3 feet thick. From these beginnings, 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, 1972).

In 1979, the 40 surface mines in operation in Illinois produced 26,856,897 tons of coal and the 31 underground mines produced a total of 32,681,230 tons (Illinois Department of Mines and Minerals, 1979).

Total identified coal reserves in the study area as of January 1976 were 11.1 billion tons (figure is from values for the following counties: Fulton, Knox, Mason, Peoria, Schuyler, Stark, Tazewell, and Warren). About 64.9 percent of this reserve is considered surface-mineable (Smith and Stall, 1975, updated in 1977). The surface-mineable reserves in the study area are shown on figure 2.1-1.

Total coal production in Illinois from 1882 through 1979 was 4.7 billion tons. The study area accounted for 10.6 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 resulted in an increase in coal production through the 1960's. Production leveled off during the 1970's (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, lack of serious geologic constraints, and proximity to northeastern markets. In addition, the Nation's move toward energy independence and diminishing domestic supplies of oil and gas could increase the demand for Midwestern coal.



Data from Hopkins (1975, updated in 1980) and Treworgy and others (1978).

BASE FROM U. S. GEOLOGICAL SURVEY
STATE BASE MAP, 1972

Figure 2.1-1 Surface-mineable coal reserves and active coal mines.

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

About 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 usually fills with water to form a "final-cut lake".

Tandem use of shovels and draglines is the most common type of area mining operation in Illinois (fig. 2.2-1). State reclamation laws require that the topsoil be removed first and that it be separated into individual horizons. The topsoil 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).

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).

Figure 2.2-1 Shovel and Dragline

(view facing east of surface-mining coal near Harrisburg, Illinois)

GLACIAL DEPOSITS COVER MOST OF THE STUDY AREA

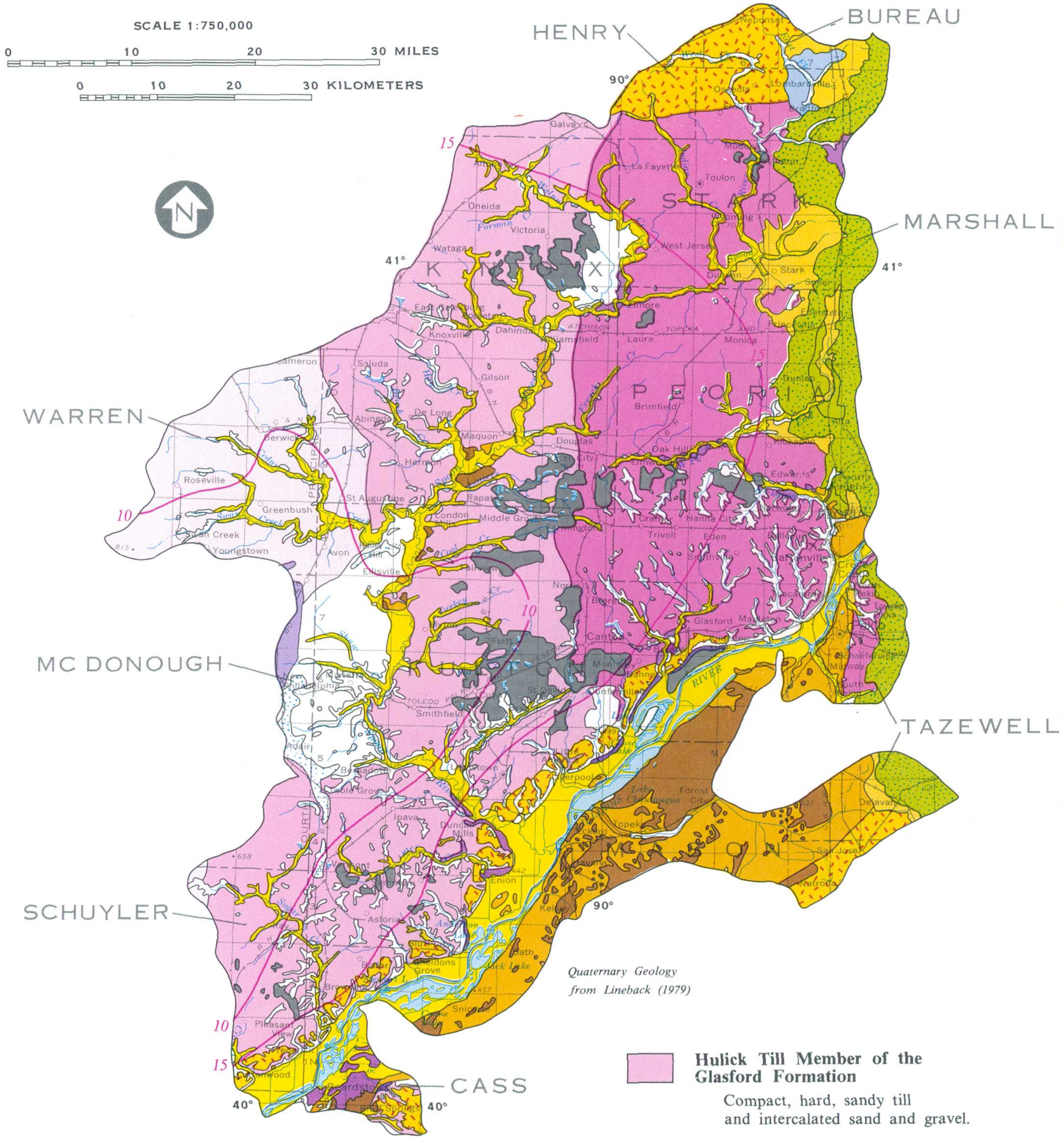
Glacial deposits cover almost all of the study area They are generally less than 50 feet thick except in bedrock valleys where they may be up to 200 feet thick.

The Quaternary System includes glacial deposits and contemporaneous sediments deposited beyond the limit of glaciation as well as all material deposited since the glacial epoch. Glacial deposits cover all of Illinois except for the northwestern corner and the southern tip. The glacial deposits in the study area are generally less than 50 feet thick except in bedrock valleys where deposits range from 50 to 200 feet in thickness. These deposits form moraines and ground moraine of Illinoian age (fig. 3.1-1 and 3.1-2) (Piskin and Bergstrom, 1975). The Illinoian glacier was the last to cover the study area. Loess of Wisconsinan age was deposited when outwash material was blown from the valleys onto the uplands. It is 10 to 15 feet thick in the study area.

Members of the Glasford Formation of Illinoian age cover most the study area. They are silty to sandy tills with interbedded sand and gravel and are generally calcareous.

The Wedron Formation of Wisconsinan age forms a moraine that extends along the eastern edge of the study area. It is a silty to sandy till with lenses of silt, sand, and gravel.

Peoria Loess blankets almost all of the study area. The thickness is shown by contour lines on the adjoining map. It is a massive, well-sorted silt and contains calcium carbonate except in the upper few feet where the carbonates have been leached. The Peoria Loess is the parent material for many of the soils in the study area (Willman and others, 1975).



Quaternary Geology from Lineback (1979)

BASE FROM U. S. GEOLOGICAL SURVEY
STATE BASE MAP, 1972

▨ **Teneriffe Silt**
Mostly silt and clayey silt with beds of sand or clay.

▨ **Radnor Till Member of the Glasford Formation**
Mostly gray compact silty till with a little gravel, sand, and silt in some places.

▨ **Hulick Till Member of the Glasford Formation**
Compact, hard, sandy till and intercalated sand and gravel.

▨ **Kellerville Till Member of the Glasford Formation**
Brown and gray silty till with discontinuous sand and gravel beds.

▨ **Banner Formation**
Mostly till with small areas of outwash sands and gravels and lacustrine silt and clay.

White areas on map indicate that rocks older than Pliocene are present at or near the surface.

Figure 3.1-1 Quaternary geology.

EXPLANATION

⬛ **Surface Mines**
Includes coal strip mines, rock quarries, sand or 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.

🟪 **Peyton Colluvium**
Narrow deposits of unsorted debris that resulted from creep and slopewash and accumulated on and at the base of river bluffs.

🟫 **Parkland Sands**
Wind-blown sand.

🟧 **Grayslake Peat**
Peat, muck, and marl.

🟪 **Carmi Member of the Equality Formation**
Quiet-water lake sediments dominated by well-bedded silt and some clay.

🟧 **Mackinaw Member of the Henry Formation**
Sand and gravel; generally well sorted and well bedded.

🟨 **Batavia Member of the Henry Formation**
Well-sorted sand and gravel.

▨ **Peoria Loess and Roxanna Silt**
Windblown silt with local lenses of fine-grained sand; thickness shown by contour lines.

🟩 **Tiskilwa and Delavan Till Members of the Wedron Formation**
Silty and sandy till with lenses of silt, sand, and gravel in some places.

🟦 **Lee Center Till Member of the Wedron Formation**
Gray clayey till; generally thin and discontinuous.

~10~ **Thickness of Loess; contour intervals 5 feet.**

Solid colors indicate ground moraine.

▨ **Overprinted pattern indicates moraines**

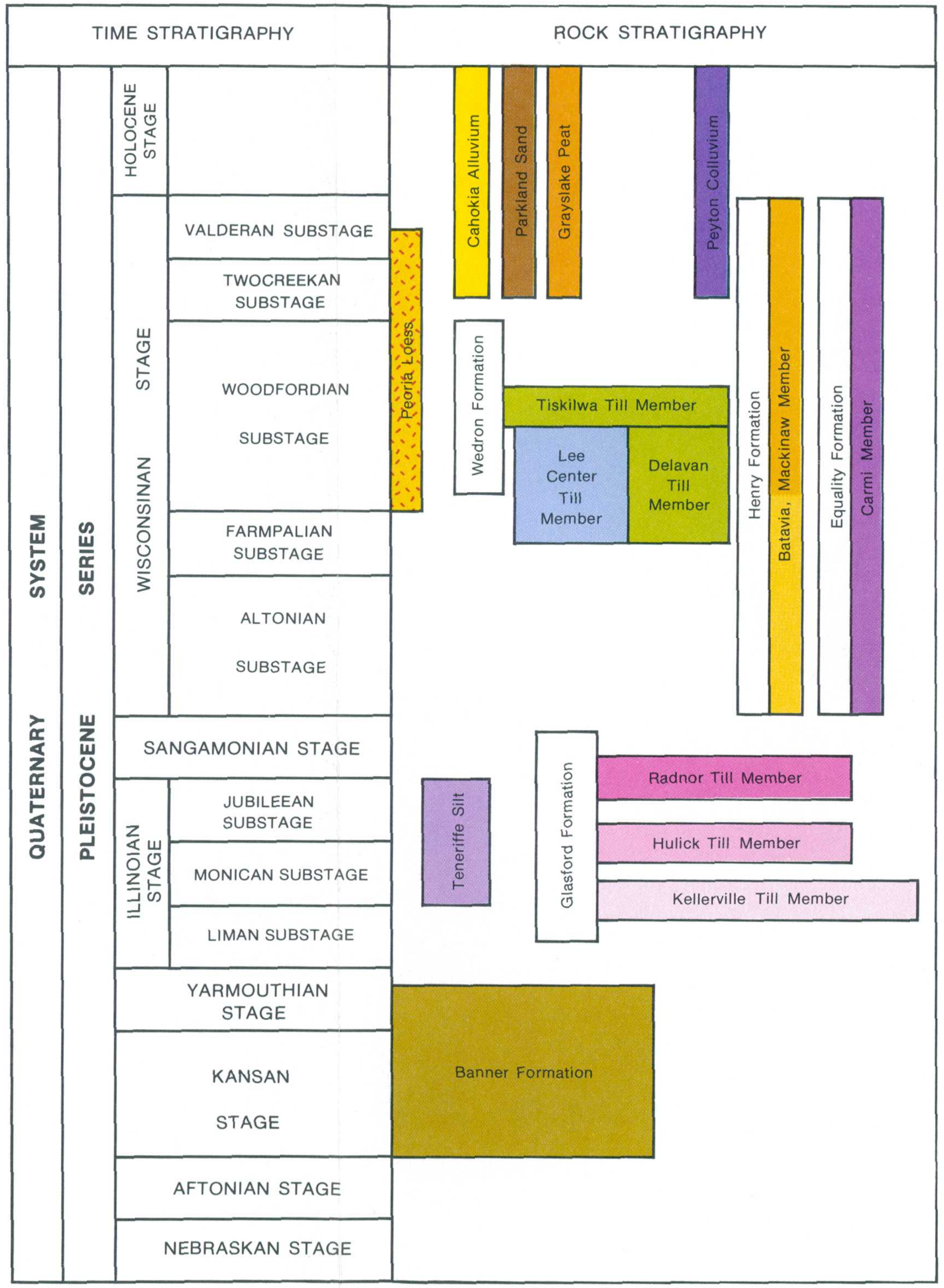


Figure 3.1-2 Stratigraphic column of Quaternary System showing locations of rock units found in Area 25 (the stratigraphic nomenclature follows the usage of the Illinois State Geological Survey and differs from the usage of the U.S. Geological Survey).

(Modified from Willman and Frye, 1970)

3.0 GEOLOGY

3.1 QUATERNARY GEOLOGY

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

The coal-bearing rocks are Pennsylvanian in age. Rocks of the Pennsylvanian System and rocks of the Mississippian System make up the bedrock surface in the study area.

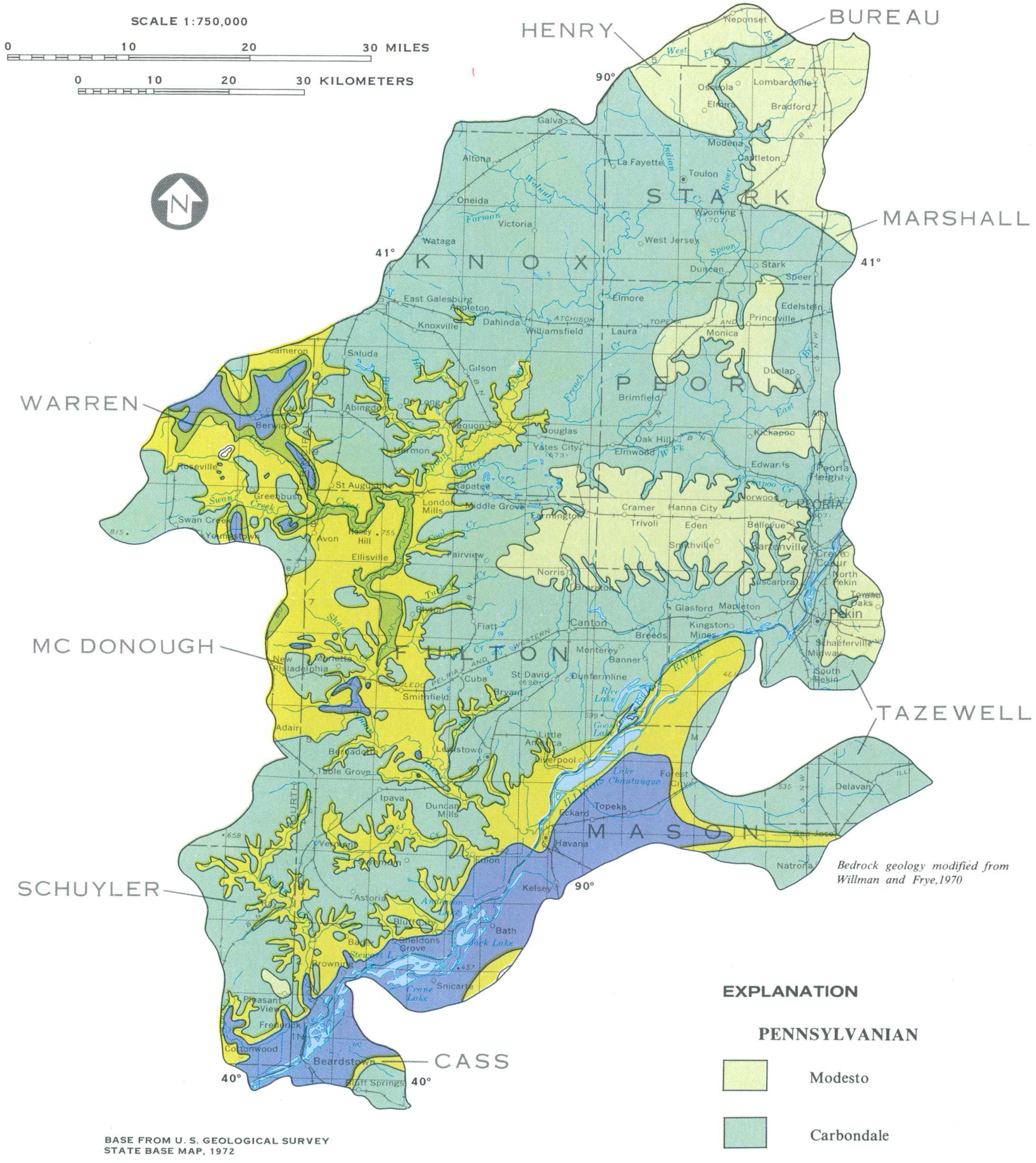
The Pennsylvanian System is the uppermost bedrock in about 90 percent of the study area (fig. 3.2-1). Rocks of the Mississippian System make up the bedrock surface in the remaining area.

The Pennsylvanian System consists of sandstones, siltstones, limestones, shales, clays, and coals. Changes in lithology within the system are generally abrupt which indicates that the depositional environment was changing rapidly. The advance of saltwater 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 swamp debris. Biochemical and physical changes took place when the partially decayed plant material (peat) was buried. These changes led to the formation of coal. There are about 75 identified coal members in Illinois.

Sixty percent of the lower section of the Pennsylvanian System in Illinois 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 (fig. 3.2-2) (Willman and others, 1975).

The coals that are mined most extensively in the study area (Willman, 1973) are the Colchester (No. 2), Harrisburg-Springfield (No. 5), Herrin (No. 6), and Danville (No. 7).

Area 25 is on the edge of the Illinois Basin which is a spoon-shaped structure oriented north-northwest to south-southeast with the deepest part in southeastern Illinois. The bedrock in the study area has a southeastward regional dip. The pre-Pennsylvanian bedrock surface was eroded, forming valleys and lowlands. Lower Pennsylvanian sediments were deposited in these low-lying areas. As sedimentation continued, the topographic differences were diminished so that by the end of the Pennsylvanian Period, deposition was occurring uniformly over the area (Smith and Berggren, 1963).



Bedrock geology modified from Willman and Frye, 1970

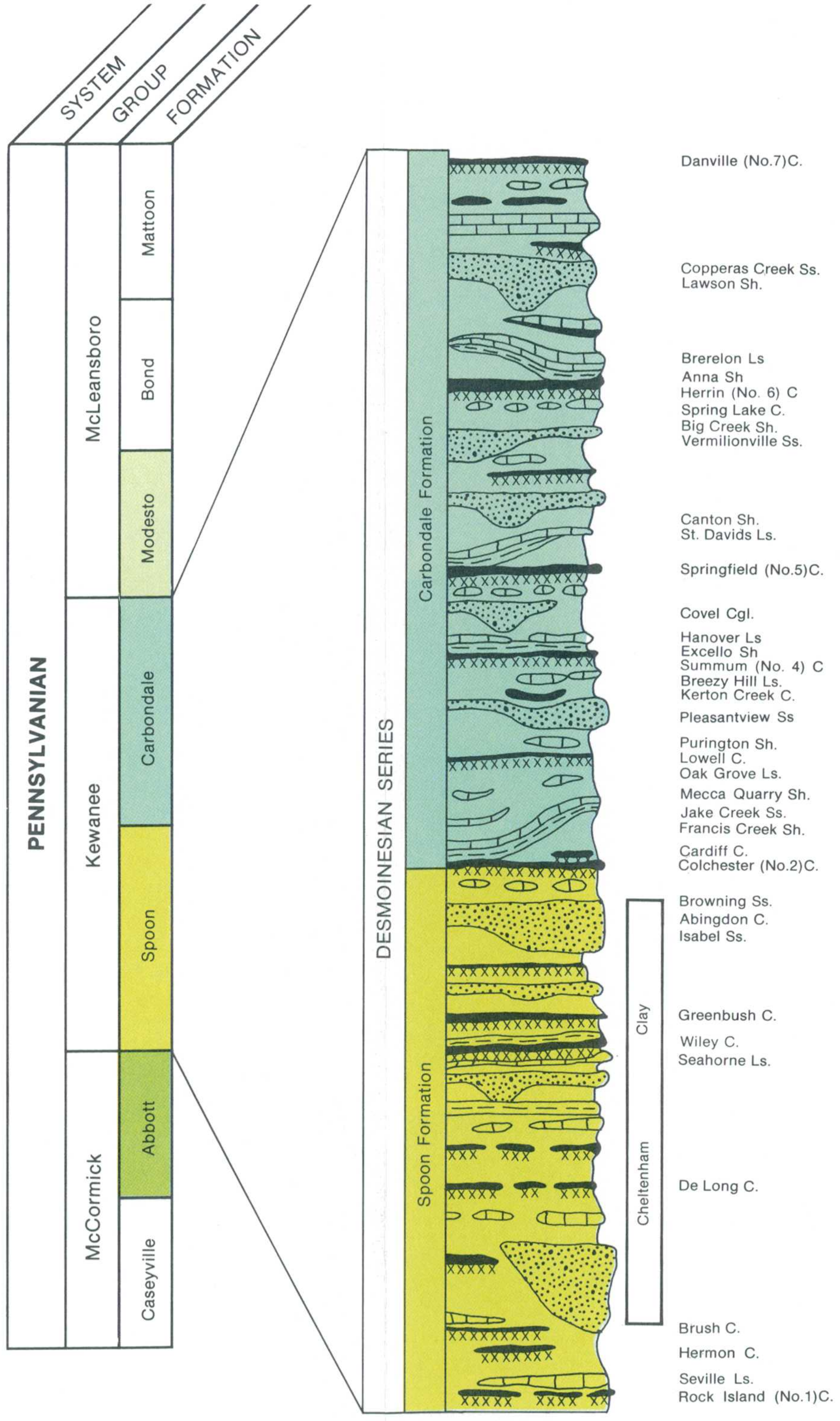
BASE FROM U. S. GEOLOGICAL SURVEY
STATE BASE MAP, 1972

EXPLANATION

PENNSYLVANIAN

▭	Modesto
▭	Carbondale
▭	Spoon
▭	Abbott
▭	**MISSISSIPPIAN**

Figure 3.2-1 Bedrock geology.



EXPLANATION

C.	coal
Ss.	sandstone
Sh.	shale
Ls.	limestone
Cgl.	conglomerate

Figure 3.2-2 Stratigraphy of the major coal-bearing units in the Pennsylvanian System.

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

Soil permeabilities range from 0.06 to 20 inches per hour and pH values range from 4.5 to 8.4. Soils are of moderate to high productivity. Erosion control is a problem, especially on slopes. Bedrock outcrops are common.

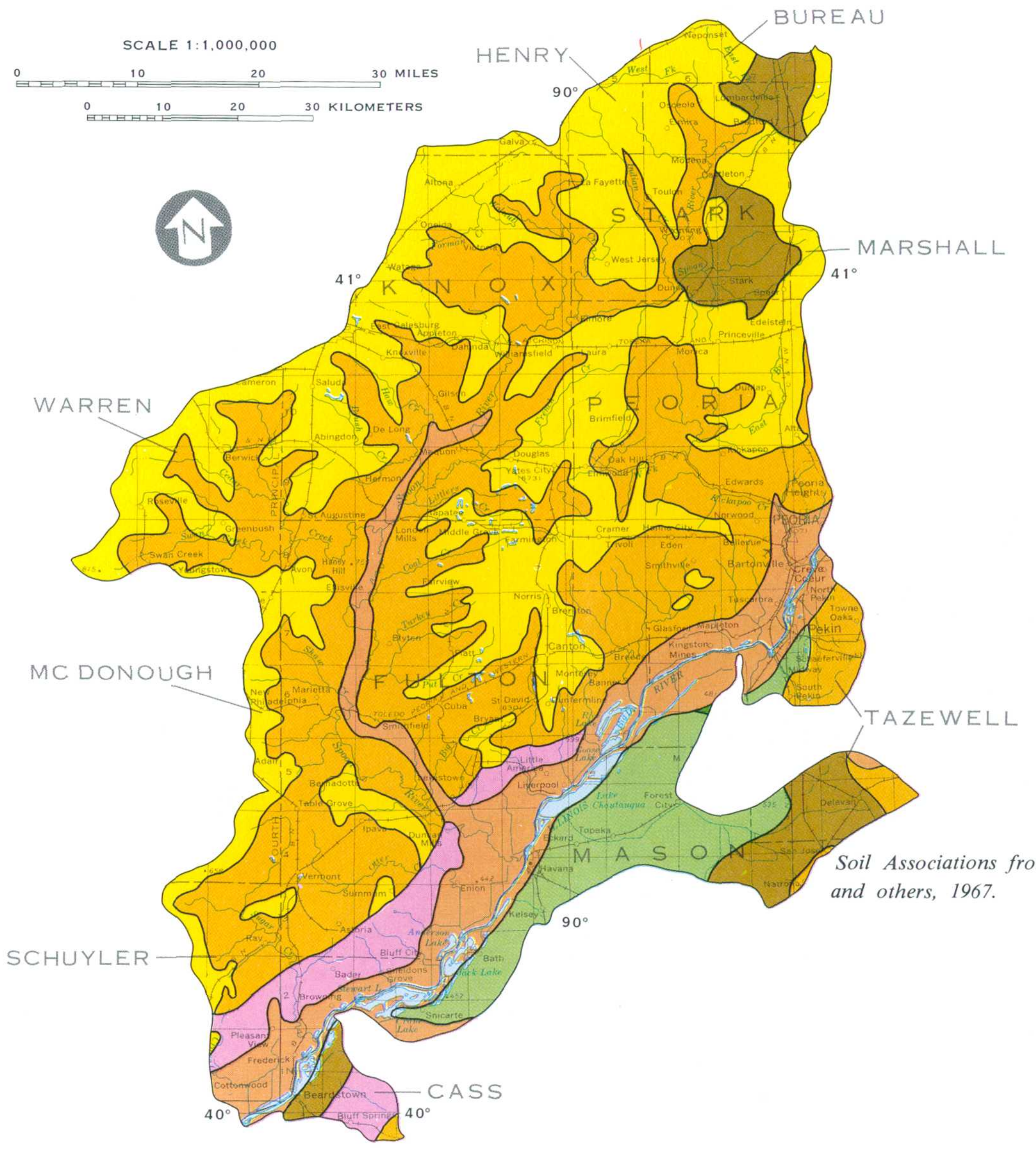
In general, soils in the study area are very slowly to moderately permeable, acidic, and of moderate to high productivity under a high level of management (application of plant nutrients, maintenance of drainage, control of flooding and erosion, and control of weeds, diseases, and insect pests). Bedrock outcrops are common. General descriptions of the soil associations are given in table 4.0-1.

The soil associations in the study area are shown in figure 4.0-1. The following associations were developed from Peoria Loess: Joy-Tama-Muscatine-Ipava-Sable, Warsaw-Carmi-Rodman, Seaton-Fayette-Stronghurst, and Clary-Clinton-Keomah. Loess is a silty wind deposit that was produced by 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 thickness in the study area ranges from 10 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 help prevent slope failure, the slopes have been benched and gutters have been used at the top of the slopes and on the benches (Thornburn, 1963).

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 and Wisconsinan Glaciations. The size of the materials ranges from gravel to clay. Alluvium is sediment that was deposited by streams in their flood plains. Alluvium in the study area is calcareous, and its size ranges from coarse gravel to sand and silt (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 published prior to 1933 are available for the following counties: Fulton, Mason, McDonough, Peoria, and Tazewell. Reports published between 1933 and 1941 are available for Schuyler and Stark Counties. Reports are being prepared for Knox and Henry Counties.

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



Soil Associations from Fehrenbacher and others, 1967.

BASE FROM U. S. GEOLOGICAL SURVEY
STATE BASE MAP, 1972

Figure 4.0-1 Soil associations.

Table 4.0-1 Soil association features.

Soil association map symbol		Depth to bedrock (ft)	Depth to high water table (ft)	Permeability (in/h)	Available water capacity (in/in) of soil	Soil reaction pH
	Dark-Colored Soils					
	Developed primarily from loess					
🟨	Joy-Tama-Muscatine-Ipava-Sable	5+	0-3	0.6-2.0	0.18-0.24	5.1-8.4
	Developed primarily from glacial drift					
🟩	Warsaw-Carmi-Rodman	5+	3+	0.6-20.0	0.02-0.24	6.1-8.4
	Light-Colored Soils					
	Developed primarily from loess					
🟪	Seaton-Fayette-Stronghurst	5+	1-5+	0.2-2.0	0.18-0.24	4.5-8.4
🟧	Clary-Clinton-Keomah	5+	--	--	--	--
	Dark- and Light Colored Soils					
	Developed primarily from medium and fine textured outwash					
🟫	Littleton-Proctor-Plano-Camden-Hurst-Ginat	10+	5-10	0.63-6.30	0.10-0.25	5.6-8.4
	Developed primarily from sandy material					
🟩	Hagener-Ridgeville-Bloomfield-Alvin	10+	10+	0.63-20.0	0.02-0.18	5.1-7.3
	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

5.0 LAND USE

AGRICULTURE IS DOMINANT LAND USE

Seventy-eight percent of the study area is used for agriculture. Coal mining uses 4.4 percent of the total land area.

Area 25 covers about 3,400 square miles in west-central Illinois. Agriculture is the dominant land use with 63.9 percent cropland and 13.7 percent pasture. The main crops are corn and soybeans. Beef cattle and hogs graze in hilly areas. The remainder of the study area is used in the following ways (fig. 5.0-1): 11.5 percent woodland, 4.6 percent urban, 4.4 percent coal mining, 0.3 percent small water areas (ponds from 2 to 40 acres in size and streams less than 1/8 mile wide), and 1.6 percent federally-owned and other lands (rural land not used as cropland, pastureland, or forest land). 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. This is mainly land that has been surface mined. Less than 0.01 percent of the total surface area has been affected by underground mining, although approximately 1.5 percent of the study area has been under-mined. There are no active underground mines in the area at the present time. The last mine closed in 1967 (Nawrot and others, 1980). There are three active surface mines; two in Fulton County and one in Peoria County (Hopkins, 1975, updated in 1980). Sand and gravel are also mined in Area 25.

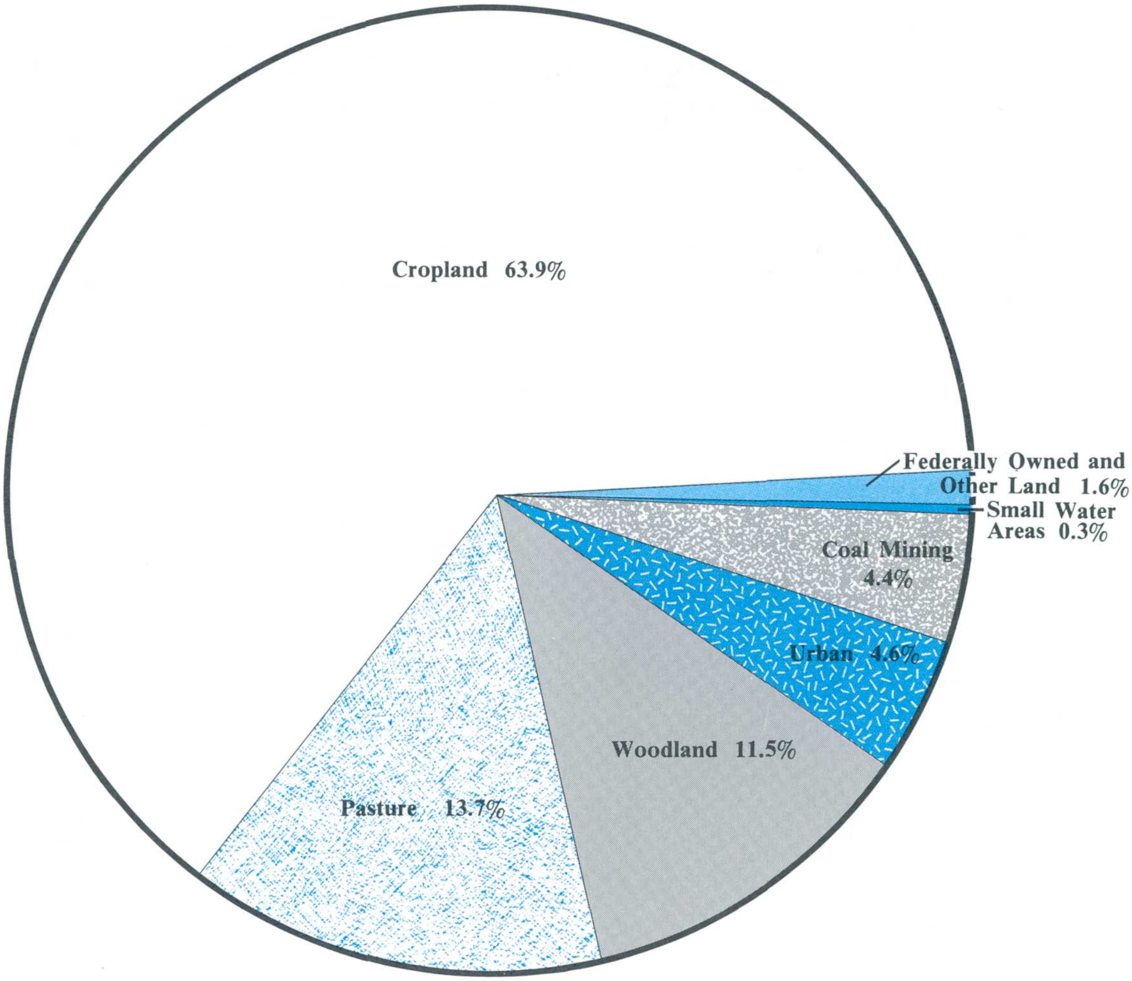


Figure 5.0-1 Land use, 1967.

(Data from Illinois Conservation Needs Committee, 1970, and Nawrot and others, 1980)

6.0 WATER USE

NINETY-SEVEN PERCENT OF THE WATER USED IS OBTAINED FROM SURFACE WATER SOURCES

Surface water is the major source of water in the study area. Only 3 percent of the total amount of water withdrawn is ground water.

Total water withdrawal in the study area was 3,378 million gallons per day (mgal/d) in 1978 (Kirk and others, 1979). About 92.7 mgal/d (3 percent) was from ground water (fig. 6.0-1).

Sixty-eight percent (2,310 mgal/d) of the total amount of water withdrawn was for industry, 29 percent (965 mgal/d) for mineral extraction, 1.5 percent (51.8 mgal/d) for public supply, 1.3 percent (43.9 mgal/d) for rural supplies (domestic, livestock, and irrigation), and 0.2 percent (6.6 mgal/d) for fish and wildlife management.

The largest users of surface water are industries along the Illinois River in the Peoria-Pekin area. Other large users are coal mines in Fulton County. The water is obtained from rivers and surface-water impoundments.

The Illinois River connects the Mississippi River with Lake Michigan and is an important commercial waterway. Coal from southern and western Illinois is moved up the Mississippi and Illinois Rivers to powerplants and docks in Chicago. Other commodities moved on the river are sand and gravel, iron and steel, grain, petroleum products, and chemicals (Illinois Technical Advisory Committee on Water Resources, 1967).

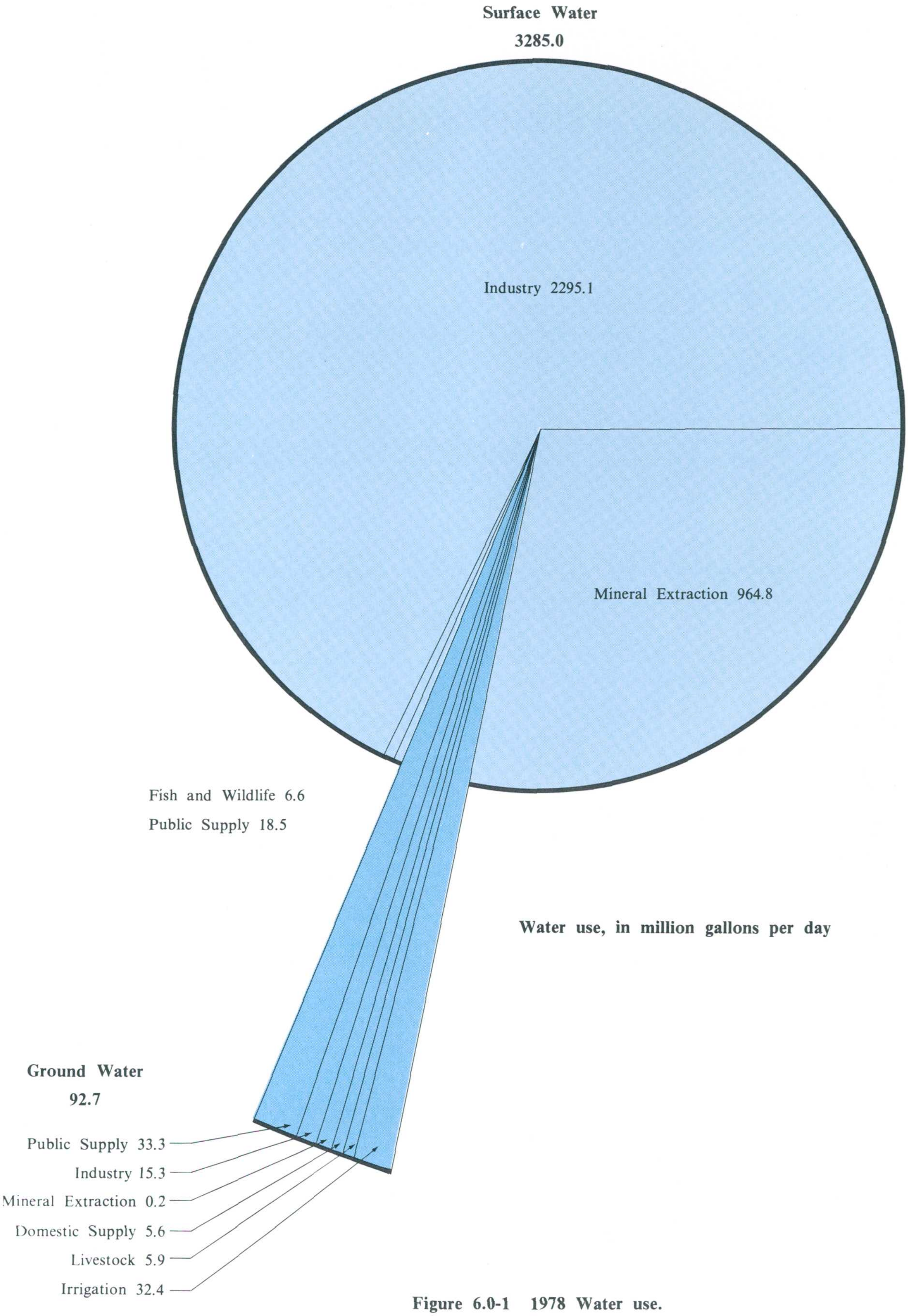


Figure 6.0-1 1978 Water use.

7.0 PRECIPITATION

PRECIPITATION

Warm season cold fronts and thunderstorms produce about two-thirds of the mean annual precipitation.

The mean annual precipitation in the study area varies from 34 to 35 inches (fig. 7.0-1). A maximum of 47 inches and minimum of 21 inches of annual precipitation have been observed.

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 Atmosphere Administration (NOAA), National Climatic Center, Asheville, N.C.

About two-thirds of the annual precipitation falls in the warmer half of the year (April to September) as shown in figure 7.0-2. May has the highest average monthly precipitation. Cold fronts and thunderstorms contribute as much as 70 percent of the average precipitation for June, July, and August. During the colder half of the year (October to March), an average of 12.5 to 14 inches of precipitation falls as rain, sleet, and snow (fig. 7.0-3). More than 70 percent of the mean annual snowfall occurs during December, January, and February. Annual snowfall amounts from 3 to 68 inches have been recorded. The average annual snowfall varies from 21 inches in the southwest to 26 inches in the northwestern part of the study area. The 24-hour precipitation in the study area expected to be exceeded at intervals averaging 2 years varies from 3.1 inches in the northeast to 3.3 inches in the southwest (fig. 7.0-4). Table 7.0-1 lists the precipitation expected for various rainfall durations and frequencies.

Table 7.0-1 Rainfall duration-frequency.

Frequency (years)	Duration (time)				
	10 min.	30 min.	60 min.	12 hour	24 hour
2	0.70	1.18	1.50	2.8	3.2
5	.86	1.48	1.91	3.5	4.0
10	.96	1.70	2.20	4.0	4.6
25	1.12	2.00	2.61	4.5	5.3
50	1.25	2.24	2.93	5.0	5.9
100	1.37	2.48	3.25	5.6	6.5

10, 30, and 60 minute from Frederick and others, 1977
12 and 24 hour from Herschfield, 1961

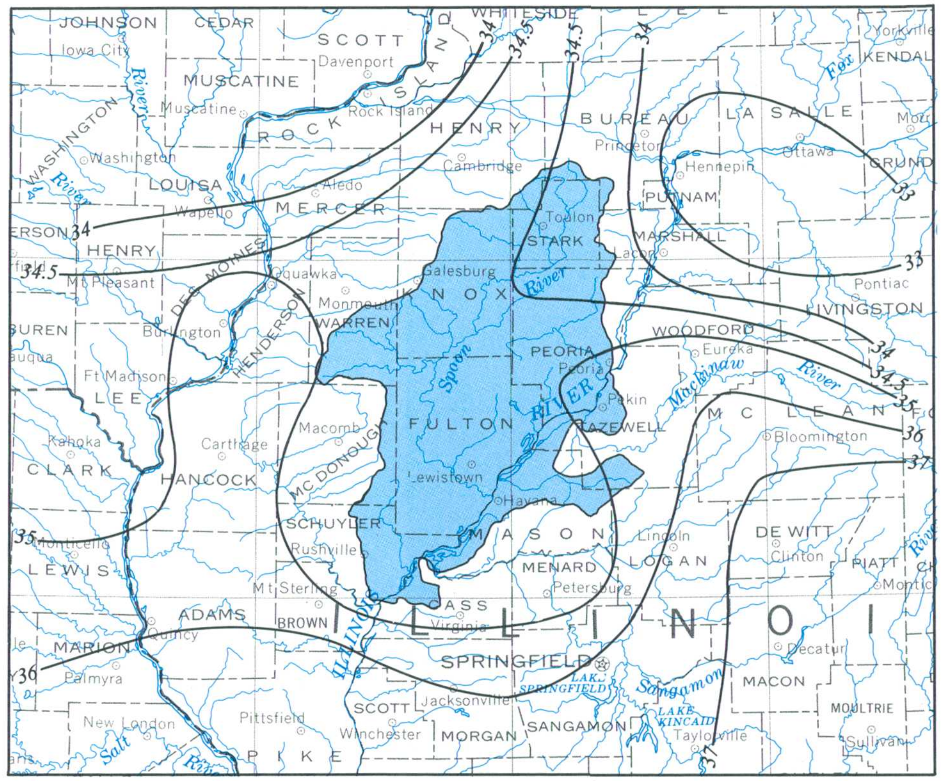


Figure 7.0-1 Distribution of mean annual precipitation.

EXPLANATION

Lines of equal precipitation in inches.

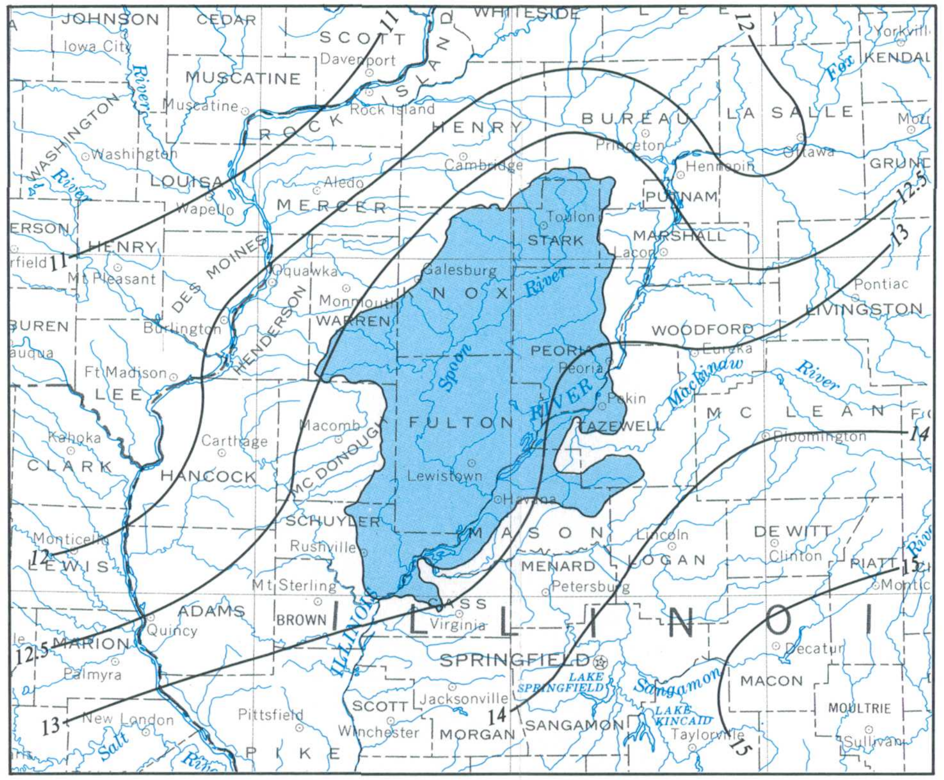


Figure 7.0-3 Distribution of colder half-year precipitation (October-March).

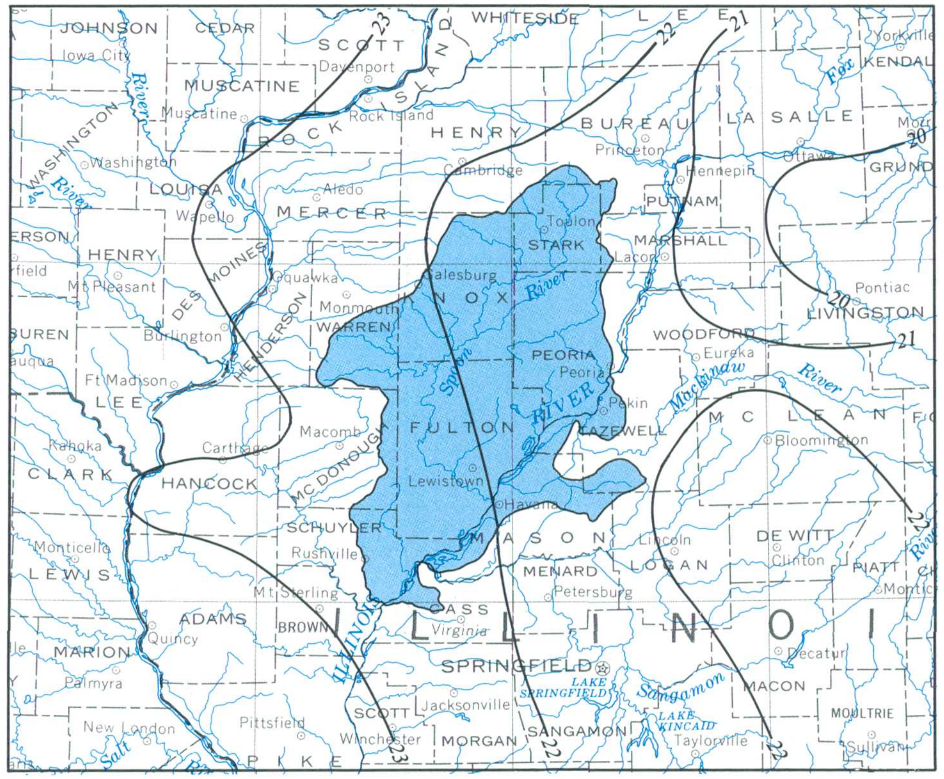


Figure 7.0-2 Distribution of warmer half-year precipitation (April-September).

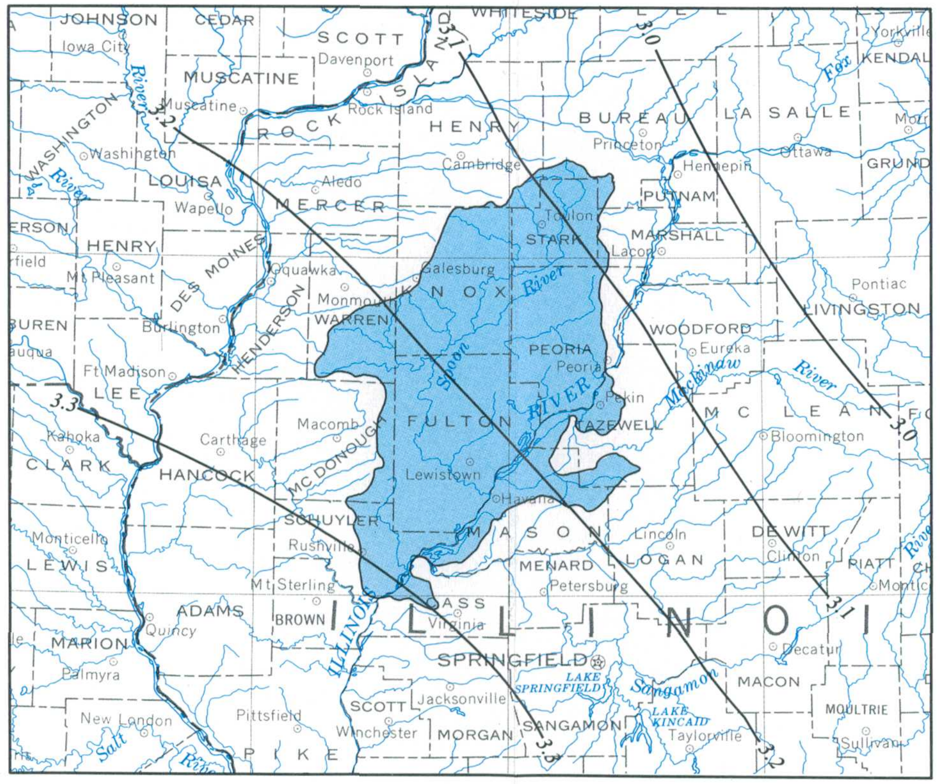


Figure 7.0-4 Distribution of 2 year-24 hour precipitation.

PRECIPITATION PATTERNS OVER THE STUDY AREA

Precipitation data from Illinois State Water Survey, 1962.

Source: Dawes and Terstriep, 1966

ESTIMATING MEAN ANNUAL STREAMFLOW

Mean annual streamflow estimates for the study area are based on stream-gaging records at 23 stations.

The mean annual streamflow depends on drainage area, soil characteristics, 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). In the study area, drainage area is the most significant and only variable needed to adequately estimate the mean annual streamflow.

Mean annual streamflow is estimated from the drainage area using the equation $Q_a = 0.72 A^{0.98}$. The mean annual streamflow (Q_a) is in cubic feet per second, and the drainage area (A) is in square miles. Figure 8.1.1-1 shows this relation based on 23 gaging stations having an average of 38 years of streamflow records each and drainage areas from 5.54 to 9,549 square miles. The Illinois River at Kingston Mines streamflow record was not used to define the relationship because additional water is being added to its drainage basin from Lake Michigan via the Chicago Sanitary and Ship Canal. Six other gaging station records were also disregarded because of their short period of record, less than 14 years. Tables 8.1.1-1 and 8.1.1-2 list the 30 gaging stations in and near the study area, and figure 8.1.1-2 shows their locations. See appendices 12.1 and 12.2 for a more detailed list of stations.

Spoon River drains into the Illinois River and has the largest drainage basin in the study area. Kickapoo Creek, in the eastern part and Sugar Creek in the southwestern part of the study area, along with other various small creeks, also drain into the Illinois River (fig. 8.1.1-2).

Table 8.1.1-1 Gaging stations in the study area.

Site No.	Station No.	Station name	Drainage area (mi^2)	Mean annual flow (ft^3/s)	Years of record
4	05568500	Illinois River at Kingston Mines	15,819	14,632	55
5	05568660	Duck Creek near Liverpool	20.0	–	3
12	05568800	Indian Creek near Wyoming	62.7	45.5	19
21	05569500	Spoon River at London Mills	1,062	693	36
28	05570000	Spoon River at Seville	1,636	1,030	64
30	05570350	Big Creek at St. David	26.7	28.9	8
31	05570360	Evelyn Branch near Bryant	6.20	5.52	8
32	05570370	Big Creek near Bryant	40.3	42.2	8
33	05570380	Slug Run near Bryant	7.90	–	5
34	05570500	Illinois River at Havana	18,299	–	6

8.0 SURFACE WATER

8.1 SURFACE WATER QUANTITY

8.1.1 GAGING STATIONS AND MEAN ANNUAL STREAMFLOW

Table 8.1.1-2 List of gaging stations outside of the study area used for mean annual flow computation.

Site No.	Station No.	Station name	Drainage area (mi^2)	Mean annual flow (ft^3/s)	Years of record
36	05443500	Rock River at Como	8,753	5,071	58
37	05445500	Rock Creek near Morrison	158	91.4	15
38	05446500	Rock River near Joslin	9,549	5,870	39
39	05447500	Green River near Geneseo	1,003	586	42
40	05448000	Mill Creek at Milan	62.4	42.0	39
41	05466000	Edwards River near Orion	155	103	39
42	05466500	Edwards River near New Boston	445	271	45
43	05467000	Pope Creek near Keithsburg	183	103	44
44	05469000	Henderson Creek near Oquawka	432	279	44
45	05556500	Big Bureau Creek at Princeton	196	128	42
46	05560500	Farm Creek at Farmdale	27.4	17.9	30
47	05561000	Ackerman Creek at Farmdale	11.2	6.2	25
48	05561500	Fondulac Creek near East Peoria	5.5	4.3	30
49	05562000	Farm Creek at East Peoria	61.2	43.3	36
50	05564400	Money Creek near Towanda	49.0	33.5	20
51	05566500	East Branch Panther Creek at El Paso	30.5	18.8	29
52	05567500	Mackinaw River near Congerville	767	485	34
53	05584400	Drowning Fork at Bushnell	26.3	20.0	18
54	05584500	La Moine River at Colmar	655	435	34
55	05585000	La Moine River at Ripley	1,293	781	57

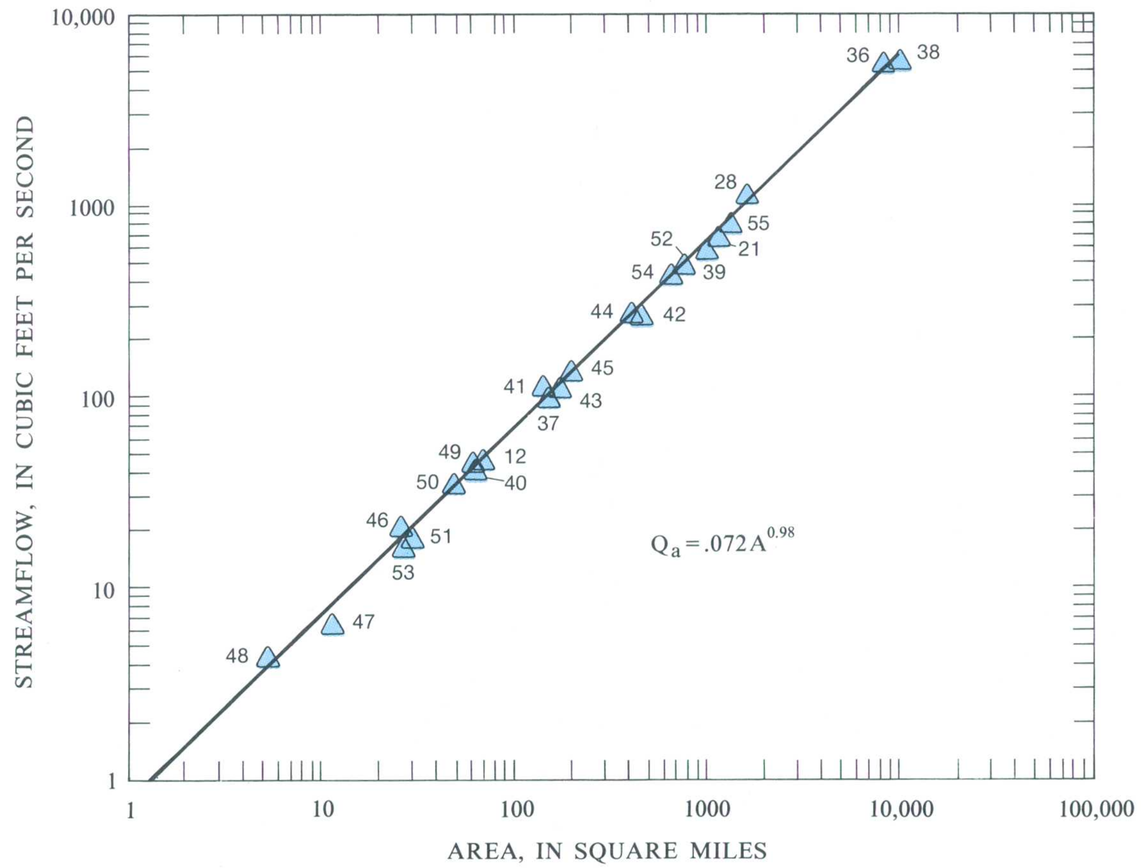
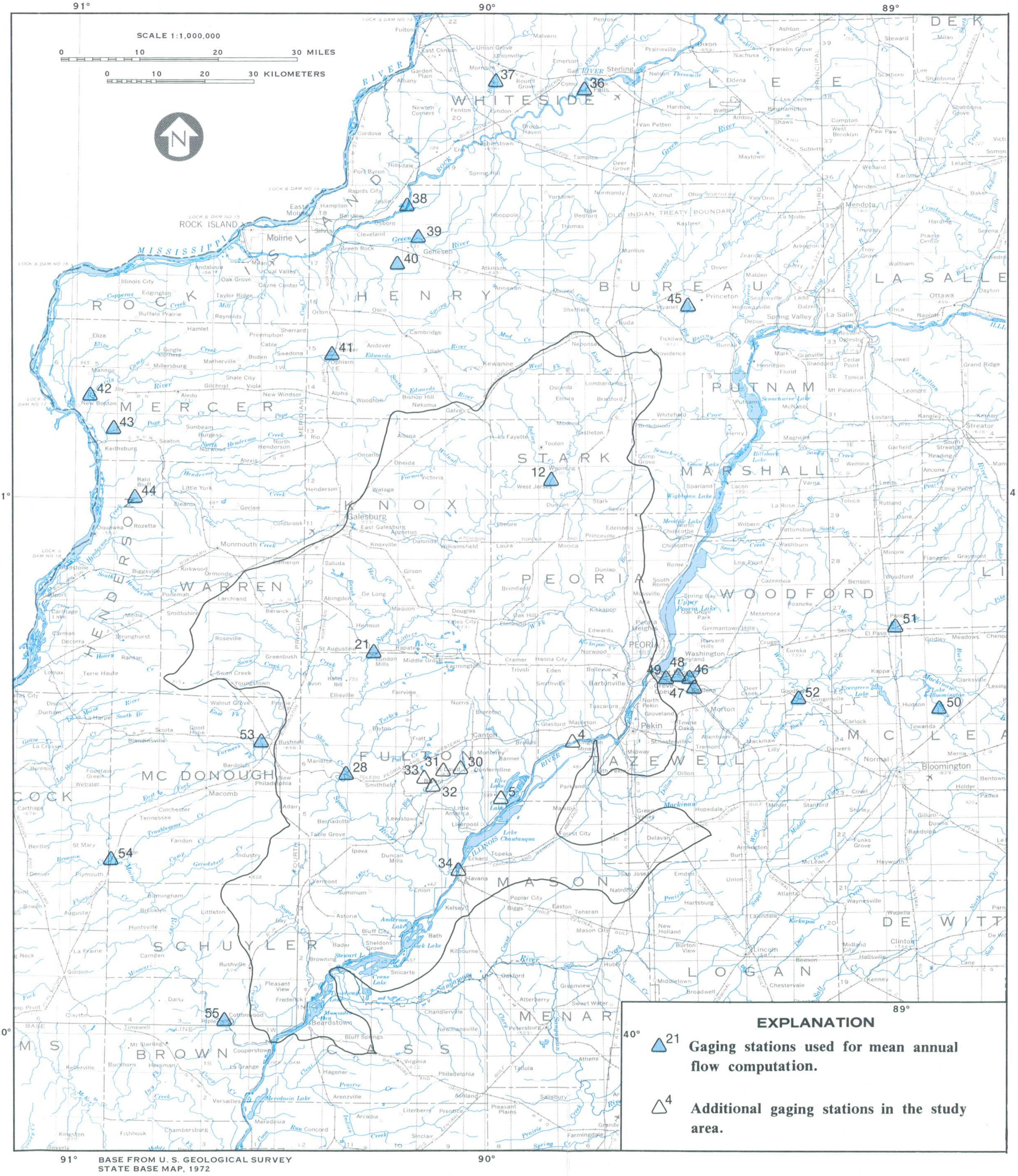


Figure 8.1.1-1 Mean annual streamflow.



BASE FROM U. S. GEOLOGICAL SURVEY STATE BASE MAP, 1972

Figure 8.1.1-2 Gaging-station locations.

ESTIMATING STREAMFLOW EXTREMES

Streamflow extremes can be estimated by using equations developed from many years of streamflow records.

The 10-year peak discharge can be estimated using the flood-frequency equation:

$$Q_{10} = 57.4\, A^{0.767}\, S^{0.494}.$$

The 7-day, 10-year high flow can be estimated using:

$$V_{7,10} = 12.8\, A^{0.95}.$$

The 7-day, 10-year low flow can be estimated using the equation:

$$M_{7,10} = 0.0011\, A^{1.33}.$$

Floodflows in a stream occur when there is excessive rainfall and/or rapid snowmelt. The peak discharge for the 10-year recurrence interval (Q_{10}) can be estimated using the equation:

$$Q_{10} = 57.4\, A^{0.767}\, S^{0.494}.$$

The 10-year peak discharge (Q_{10}), in cubic feet per second, will be exceeded at intervals averaging 10 years in length. The area (A) is the drainage area in square miles. The slope (S) is the river channel slope measured from the 10 to 85 percent points on the low-water channel as measured from the site to the basin divide (Curtis, 1977).

Table 8.1.2-1 shows the Q_2, Q_{10}, and Q_{50} (2-, 10-, and 50-year recurrence interval peak discharges) for seven gaging stations in and near the study area. Flood-frequency equations for floods of these and other recurrence intervals are available in Curtis (1977). Figure 8.1.2-1 shows the locations of the gaging stations.

For sustained high flow, the equation:

$$V_{7,10} = 12.8\, A^{0.95}$$

is used. $V_{7,10}$ is the highest 7-day mean discharge, in cubic feet per second, expected to be exceeded at intervals averaging 10 years. The drainage area (A) is measured in square miles.

Low flows occur after many days of no precipitation or snowmelt. Almost all streamflow then comes from springs and seeps along the stream. Low flow is commonly characterized by the 7-day, 10-year low flow ($M_{7,10}$). $M_{7,10}$ is the lowest 7-day mean discharge, in cubic feet per second, expected to be exceeded at intervals averaging 10-years. It can be estimated using the drainage area (A), in square miles, in the equation:

$$M_{7,10} = 0.0011\, A^{1.33}.$$

These 7-day, 10-year high and low flows and the flood-flow equations are based on records from seven USGS gaging stations having an average of 36 years of record. For each gaging station, the annual 7-day, 10-year high- and low-flow discharges are plotted against their drainage areas as shown in figures 8.1.2-2 and 8.1.2-3.

Table 8.1.2-1 Gaging stations and streamflows.

Map No.	USGS No.	Name	Drainage area (mi²)	Peak discharge (ft³/s)			Streamflow	
				Q_2	Q_{10}	Q_{50}	$M_{7,10}$	$V_{7,10}$
43	05467000	Pope Creek	183	2,190	4,280	6,140	2.19	1,510
44	05469000	Henderson Creek	432	4,940	9,950	14,500	3.87	3,820
12	05568800	Indian Creek	62.7	1,460	3,010	4,400	.40	683
21	05569500	Spoon River	1,092	10,800	22,300	32,800	10.1	10,200
28	05570000	Spoon River	1,636	12,100	23,100	33,300	19.4	14,100
53	05584400	Drowning Fork	26.3	651	1,470	2,250	.04	297
55	05585000	La Moine River	1,293	8,420	16,200	22,800	10.1	11,000

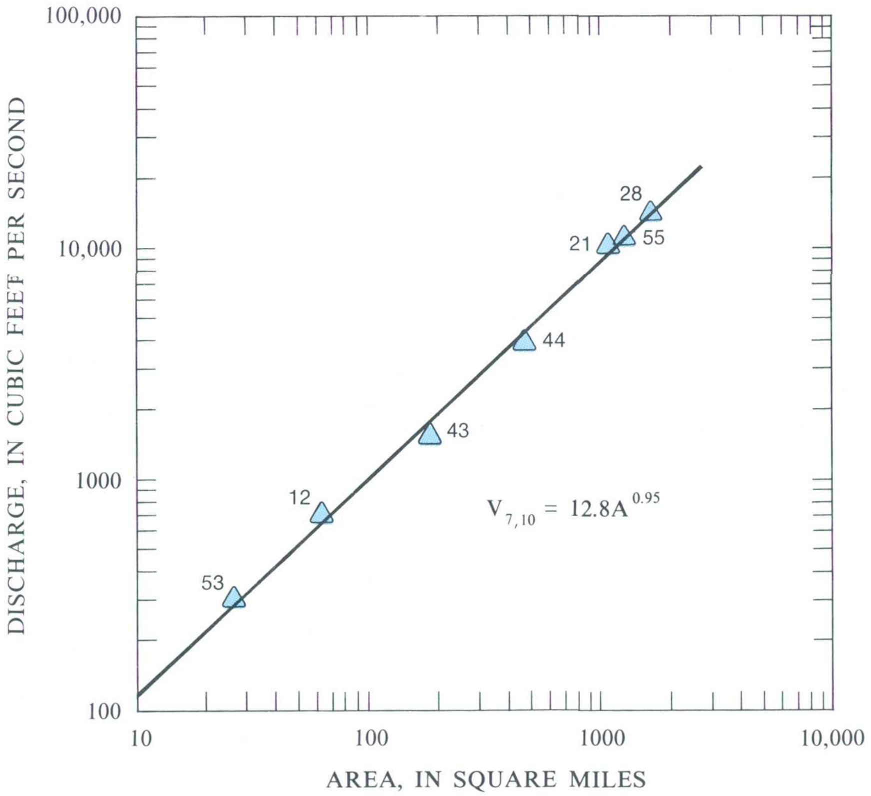


Figure 8.1.2-2 7-day, 10-year high flow

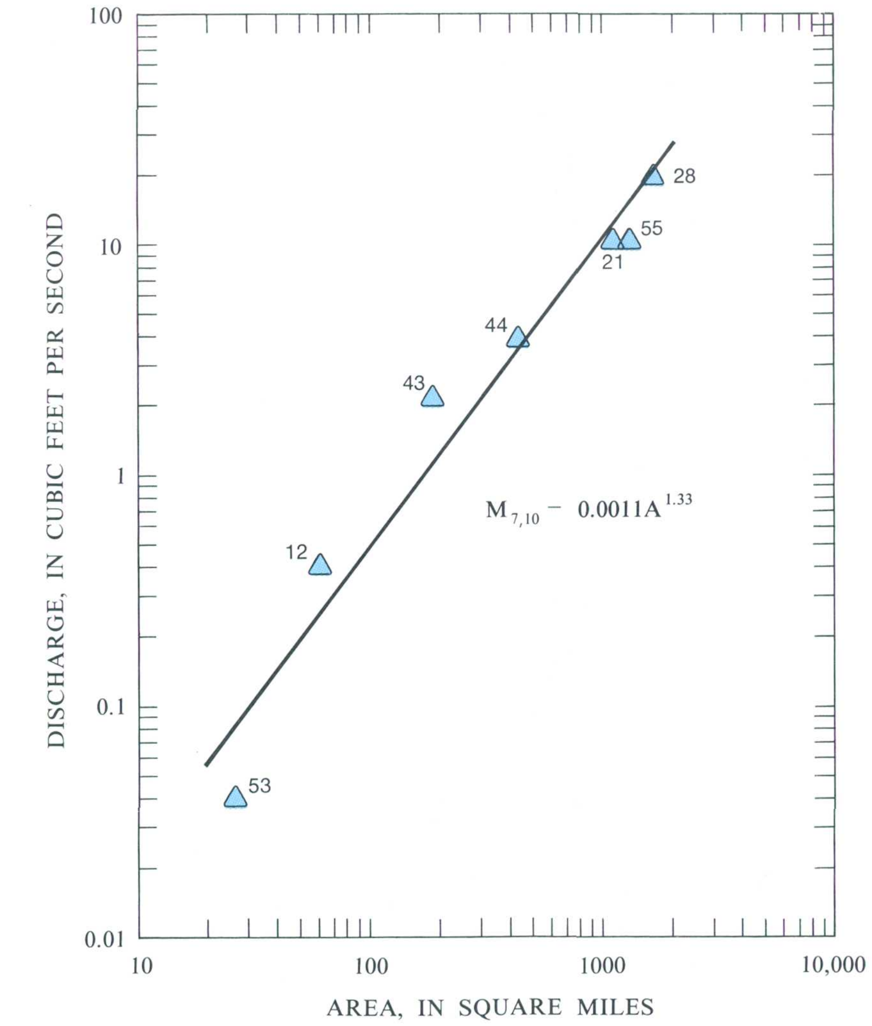
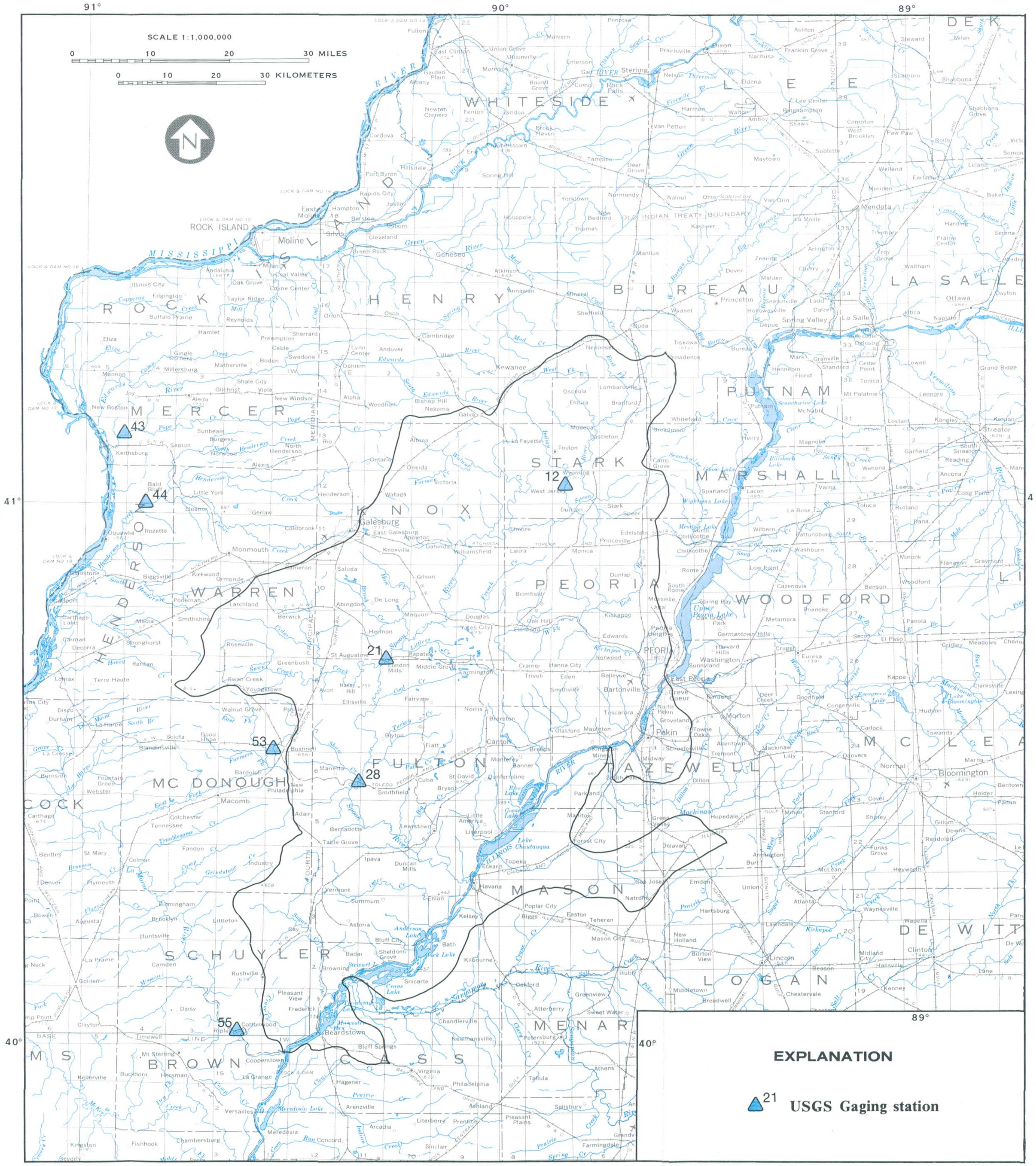


Figure 8.1.2-3 7-day, 10-year low flow



BASE FROM U. S. GEOLOGICAL SURVEY
STATE BASE MAP, 1972

Figure 8.1.2-1 Gaging station locations.

8.0 SURFACE WATER

8.1 SURFACE WATER QUANTITY

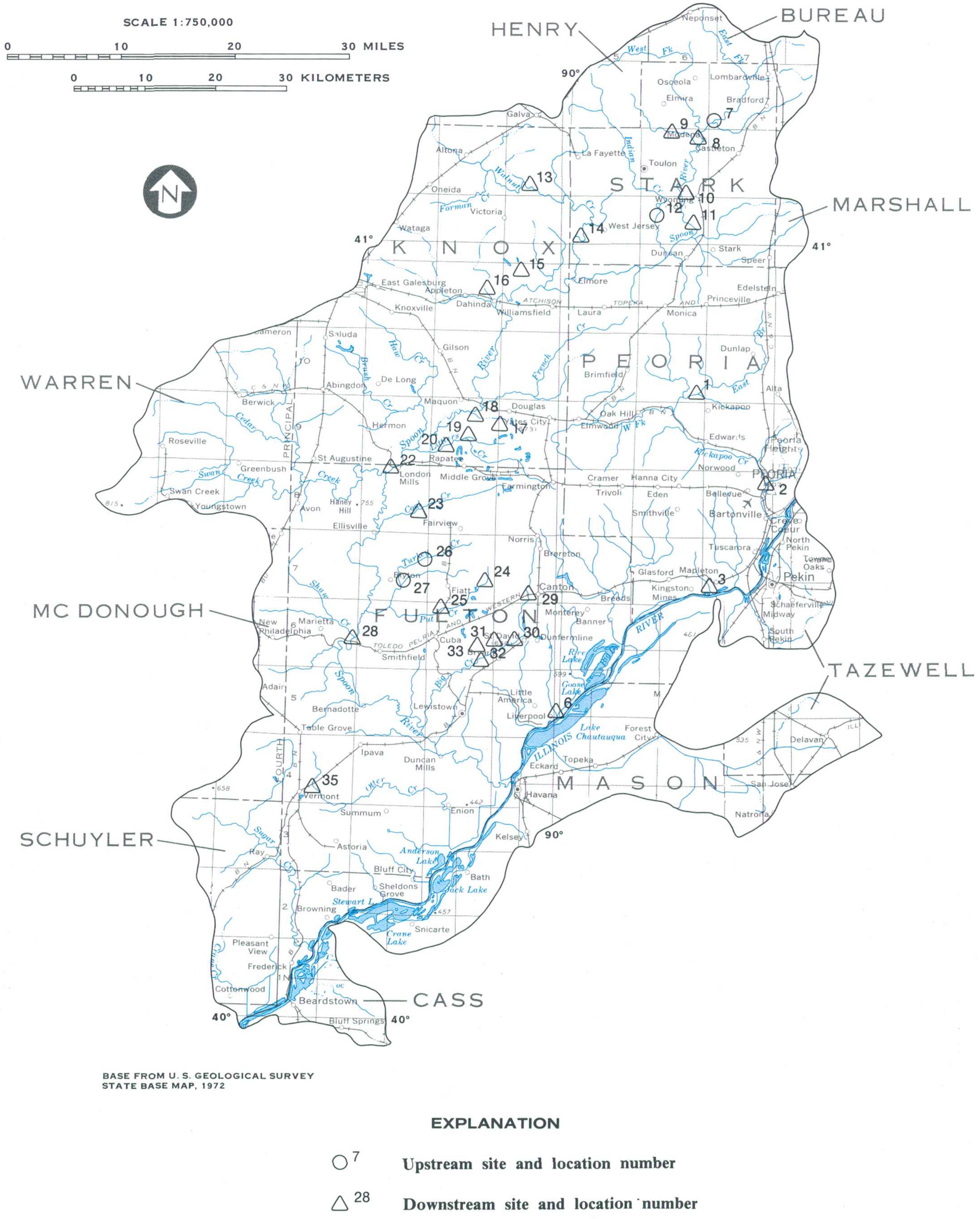
8.1.2 ESTIMATING STREAMFLOW

WATER QUALITY DATA ARE AVAILABLE FOR SITES UPSTREAM AND DOWNSTREAM OF SURFACE MINING

Measurements of specific conductance, pH, alkalinity, iron, manganese, sulfate, and other constituents are available at 31 sites.

Thirty-one surface-water-quality sites are located in the study area (fig. 8.2.1-1), either in the Spoon River basin or smaller basins that drain directly into the Illinois River. Twenty-seven sites are downstream of past or present surface-mining activities and four sites are upstream of mining activities (table 8.2.1-1). Insufficient numbers of analyses at the upstream sites preclude comparisons between them and sites downstream of mining activity. For more complete information on site locations, refer to appendix 12.1.

Specific conductance, pH, alkalinity, acidity, sulfate, iron, manganese, several trace elements, and suspended sediment were considered in the assessment of water quality in areas influenced by surface mining. The type of data measured and frequency of collection varied at each site.



BASE FROM U. S. GEOLOGICAL SURVEY STATE BASE MAP, 1972

Figure 8.2.1-1 Locations of water quality sites.

Table 8.2.1-1 Water quality sites in study area.

Site No.	Station No.	Name	Drainage area (mi^2)	Number of observations	Period of record (years)
1	05563000	Kickapoo Creek near Kickapoo	119	6	1979
2	05563500	Kickapoo Creek at Peoria	297	3	1979
3	05568450	Little Lamarsh Creek at Mapleton	8.06	4	1975, 1979
6	05568675	Buckheart Creek near Liverpool	16.8	2	1979
7*	05568765	East Fork Spoon River at Modena	92.5	3	1979
8	05568770	Spoon River at Modena	154	2	1975
9	05568772	Jack Creek at Modena	15.7	5	1975-79
10	05568775	Spoon River near Wyoming	197	6	1979
11	05568778	Spoon River near Stark	209	3	1979
12*	05568800	Indian Creek near Wyoming	62.7	25	1977-79
13	05568855	Walnut Creek near Victoria	102	3	1979
14	05568860	Walnut Creek near West Jersey	161	2	1975
15	05568895	Snakeden Hollow near Dahinda	9.82	5	1975, 1979
16	05568910	Sugar Creek at Dahinda	21.6	5	1975, 1979
17	05568935	Hickory Creek near Douglas	5.38	2	1979
18	05568940	Hickory Creek near Maquon	8.99	2	1975
19	05569450	Littlers Creek near Rapatee	33.3	2	1975
20	05569455	Littlers Creek near Maquon	36.2	2	1979
22	05569520	Spoon River at Route 116 at London Mills	1,072	17	1978-79
23	05569920	Coal Creek near Fairview	28.2	4	1975, 1979
24	05569953	Put Creek near Canton	6.06	2	1979
25	05569960	Put Creek near Cuba	24.3	2	1975
26*	05569968	Turkey Creek near Fiatt	11.5	22	1978-79
27*	05569970	Turkey Creek near Blyton	35.6	2	1975
28	05570000	Spoon River at Seville	1,636	36	1977-79
29	05570330	West Branch Big Creek near Canton	4.20	18	1978-79
30	05570350	Big Creek at St. David	26.7	60	1975-79
31	05570360	Evelyn Branch near Bryant	6.20	51	1975-79
32	05570370	Big Creek near Bryant	40.3	63	1975-79
33	05570380	Slug Run near Bryant	7.90	59	1975-79
35	05570570	Otter Creek near Vermont	14.3	2	1979

* Sites upstream of mining.

SPECIFIC CONDUCTANCE CAN BE USED TO ESTIMATE DISSOLVED-SOLIDS CONCENTRATIONS

An equation for estimating dissolved solids concentrations from specific conductance measurements was developed from analyses of surface water. Measured values of specific conductance ranged from 360 to 2,900 micromhos.

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 specific conductance is reported as micromhos per centimeter at 25°C (μmho/cm at 25°C).

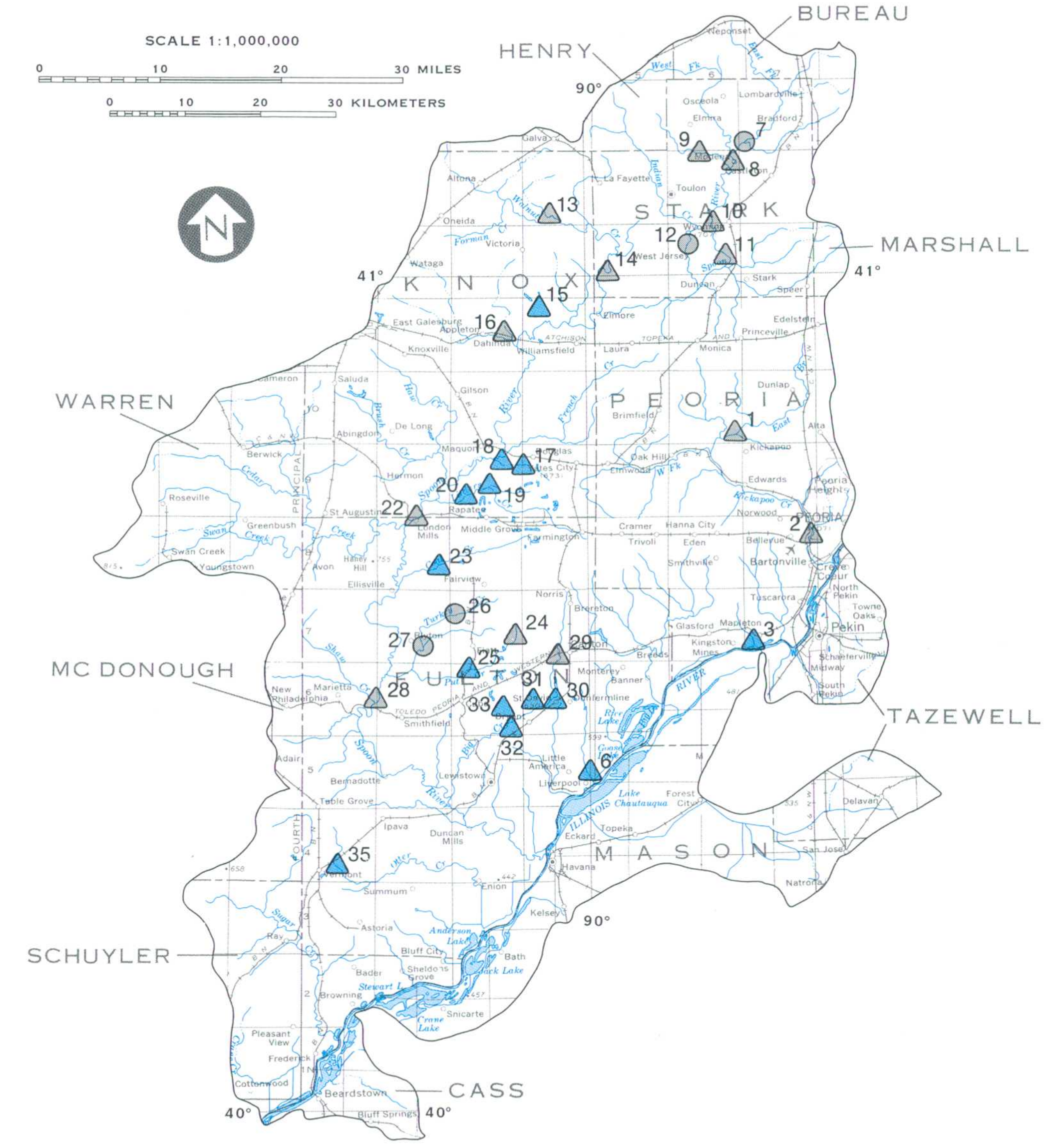
In the dilute solutions of Illinois streams, the relation between specific conductance and dissolved solids is nearly linear. Specific conductance can be a useful tool for estimating dissolved solids concentrations. Equations relating specific conductance and dissolved solids are commonly of the form $KA = S$ (Hem, 1970), where K is conductance in μmho/cm at 25°C, S is dissolved solids in milligrams per liter (mg/L), and A is a regression coefficient (slope). Hem (1970) states that usually A is between 0.55 and 0.75. The higher values in this range are associated with waters containing high sulfate concentrations. This relation was computed with data from all the sites in the study area (fig. 8.2.2-3). An equation $0.77K = S$ with a coefficient (A) of 0.77 and a standard error of 128 mg/L, was developed from 36 observations. The relatively high value for A is an indication of high sulfate concentrations.

Measured values of specific conductance ranged from 360 to 2,900 μmho/cm at 25°C with a mean value of 1,310 (table 8.2.2-1 and fig. 8.2.2-2). The range of mean specific conductance values is shown on figure 8.2.2-1.

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

Site Number	Number of Observations	Specific conductance (μmho/cm at 25°C)		
		Minimum	Mean	Maximum
1	3	680	700	720
2	3	840	890	920
3	4	940	1,290	2,250
6	2	1,220	1,590	1,960
7*	3	710	760	790
8	2	730	740	750
9	5	640	710	790
10	6	600	720	850
11	3	830	870	930
12*	20	560	740	1,000
13	3	650	710	760
14	2	530	630	730
15	5	960	1,280	1,420
16	5	560	660	740
17	2	1,610	1,800	2,000
18	2	930	1,190	1,460
19	2	1,080	1,090	1,110
20	2	1,380	1,530	1,680
22	17	600	730	880
23	4	1,000	1,140	1,280
24	2	470	530	580
25	2	1,190	1,200	1,200
26*	16	370	600	730
27*	2	610	660	700
28	22	360	690	950
29	15	800	940	1,080
30	56	540	1,230	1,890
31	51	1,160	1,950	2,900
32	61	710	1,450	1,930
33	59	990	1,920	2,600
35	2	940	1,450	1,960

* Sites upstream of mining.



BASE FROM U. S. GEOLOGICAL SURVEY
STATE BASE MAP, 1972

EXPLANATION

Mean values for specific conductance at each site

○7 Upstream site and location number

△28 Downstream site and location number

27● ▲9 0-1,000 micromohos per centimeter at 25°C.

▲3 >1,000 micromohos per centimeter at 25°C.

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

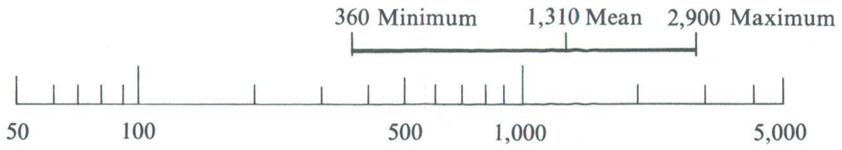


Figure 8.2.2-2 Range of specific conductance values, in micromhos, per centimeter at 25° Celsius, measured at sites in the study area.

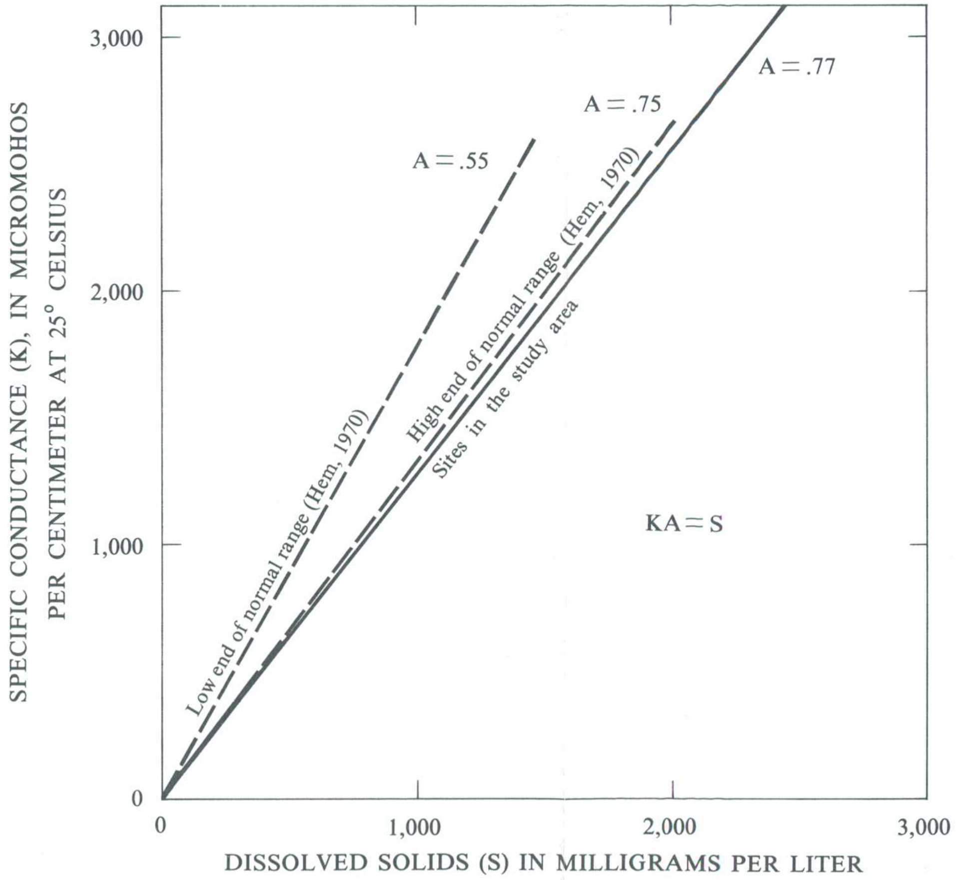


Figure 8.2.2-3 Relation between specific conductance and dissolved solids in the study area.

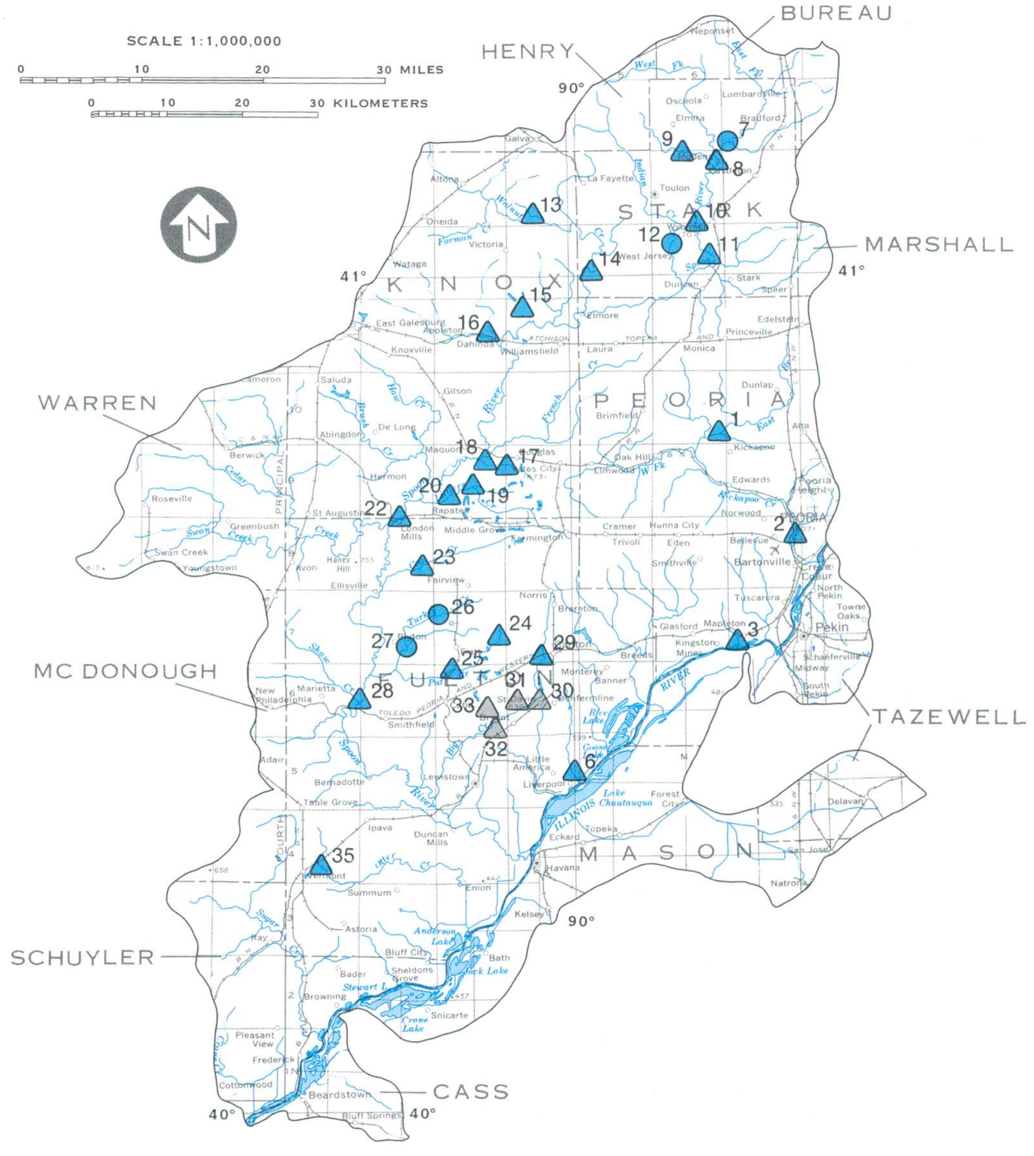
VALUES FOR pH ARE VARIABLE

Measurements of pH in the study area range from 6.3 to 9.0.

"pH" is defined as the negative base-10 logarithm of the hydrogen-ion activity in moles per liter. Most waters in the study area have a pH above 7.0 (basic solutions) and indicate the influence of carbonate-bearing sedimentary rocks. Because of surface mining, the iron sulfides (marcasite and pyrite), along with other materials, are unearthed and exposed to oxidizing conditions on the land surface. The subsequent weathering of these materials can create acidic solutions with pH values lower than 7.0. These acidic solutions can dissolve other minerals containing a wide variety of metals.

The pH in the study area ranged from 6.3 to 9.0 (fig. 8.2.3-2). This range is somewhat larger than the range given by Hem (1970) of pH 6.5 to 8.5 for "river water in areas not influenced by pollution." The lowest pH values measured were at sites downstream of mining activity (table 8.2.3-1 and fig. 8.2.3-1).

The recommended range for the pH of domestic water supplies is 5.0 to 9.0. This rather wide range is considered acceptable because pH is relatively easy to adjust during water treatment. A pH within the range of 6.5 to 9.0 is necessary to provide adequate protection for survival of freshwater fish. Outside of this range, aquatic animal life may suffer adverse physiological effects (U.S. Environmental Protection Agency, 1976, p. 178).



BASE FROM U. S. GEOLOGICAL SURVEY
STATE BASE MAP, 1972

EXPLANATION

Minimum values for pH at each site

○7 **Upstream site and location number**

△28 **Downstream site and location number**

▲31 **≤7.0**

12● ▲3 **>7.0**

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

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

Site Number	Number of Observations	pH Minimum	pH Maximum
1	3	7.9	8.3
2	3	8.2	8.5
3	4	7.9	8.0
6	2	8.1	8.2
7*	3	7.8	8.5
8	1	7.8	8.2
9	5	7.9	8.5
10	6	7.9	8.3
11	3	8.2	8.7
12*	19	7.9	8.7
13	3	7.5	8.6
14	2	7.8	7.9
15	5	7.8	8.3
16	5	8.0	8.4
17	2	7.9	8.1
18	2	7.9	8.1
19	2	7.9	8.4
20	2	8.2	8.2
22	16	7.6	8.4
23	4	8.1	8.2
24	2	8.4	8.8
25	2	7.9	8.2
26*	16	7.4	8.5
27*	2	8.2	8.2
28	19	7.6	8.6
29	15	7.7	9.0
30	52	6.3	8.4
31	48	6.4	8.8
32	55	6.9	8.4
33	55	6.3	8.4
35	2	8.1	8.2

* Sites upstream of mining.

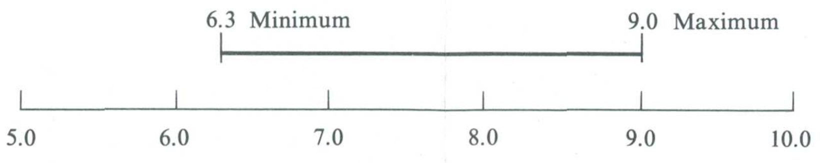


Figure 8.2.3-2 Range of pH values measured in the study area.

CONCENTRATIONS OF IRON VARY WIDELY BETWEEN SITES

Dissolved iron ranged from 0 to 1,100 micrograms per liter (μg/L) at sampling sites in the study area. Total recoverable iron ranged from 150 to 43,000 μg/L.

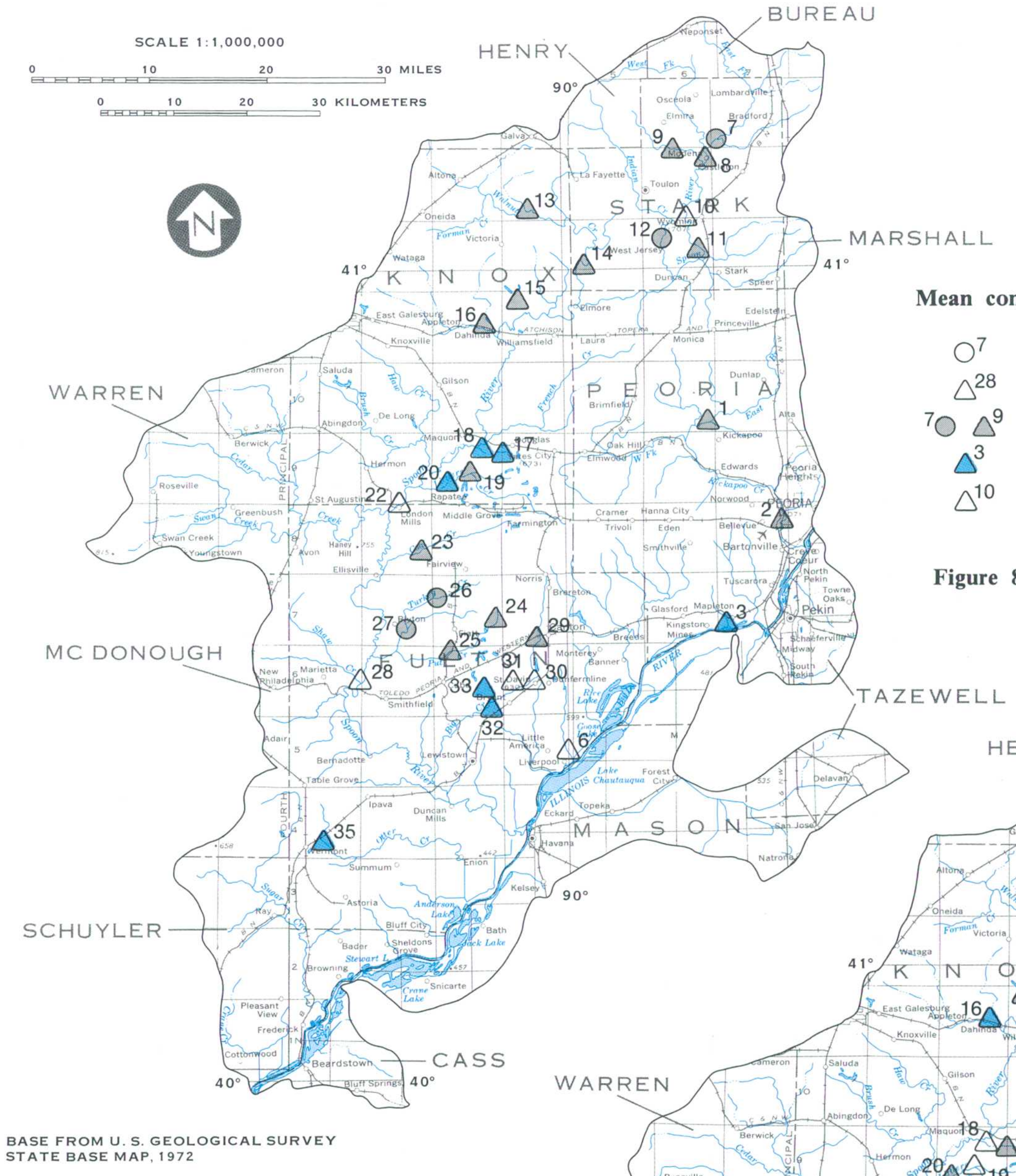
Iron is a common constituent of the surface and ground waters of the study area. It is commonly associated with coal of the Pennsylvanian System in the ferrous form (Fe^{+2}). This soluble form of iron is easily changed to the ferric form (Fe^{+3}) when it enters an oxidizing system (exposure to air). The dissolution of iron is dependent upon, and inversely related to, pH. Therefore, in streams it can occur as dissolved iron (in solution), precipitated iron (found in bed material), or suspended iron (moving in suspension). Total recoverable iron refers to the dissolved plus the suspended concentrations. Surface mining can increase the amount of iron available to waters downstream by exposing more iron-bearing minerals to weathering.

The measured range of concentrations for dissolved iron was from 0 to 1,100 μg/L (table 8.2.4-1) with a mean concentration of 40 μg/L (fig. 8.2.4-1) Ranges of mean dissolved iron concentrations, at each site, are displayed on figure 8.2.4-2.

Total recoverable iron concentrations ranged from 150 to 43,000 μg/L (table 8.2.4-2) with a mean of 2,650 μg/L (fig. 8.2.4-1). Ranges of mean total recoverable iron concentrations at each site are displayed on figure 8.2.4-3. The amount of iron recoverable from bottom material at sites in the study area ranged from 1,000 to 71,000 micrograms per gram (μg/g) with a mean of 12,200 μg/g.

Concentrations of dissolved iron in surface waters seldom reach 1,000 μg/L (American Public Health Association, 1976, p. 207). The range of values was generally below this level in the study area, however, one sample downstream of mining exceeded it.

Iron is an essential trace element required by plants and animals. It is a vital oxygen transport mechanism in the blood of all vertebrate animals, and its absence in plants can be a limiting growth factor. The criteria for domestic water supplies of 300 μg/L is for aesthetic rather than toxicological reasons. Concentrations greater than this can produce staining and objectionable tastes (U.S. Environmental Protection Agency, 1976, p. 79).

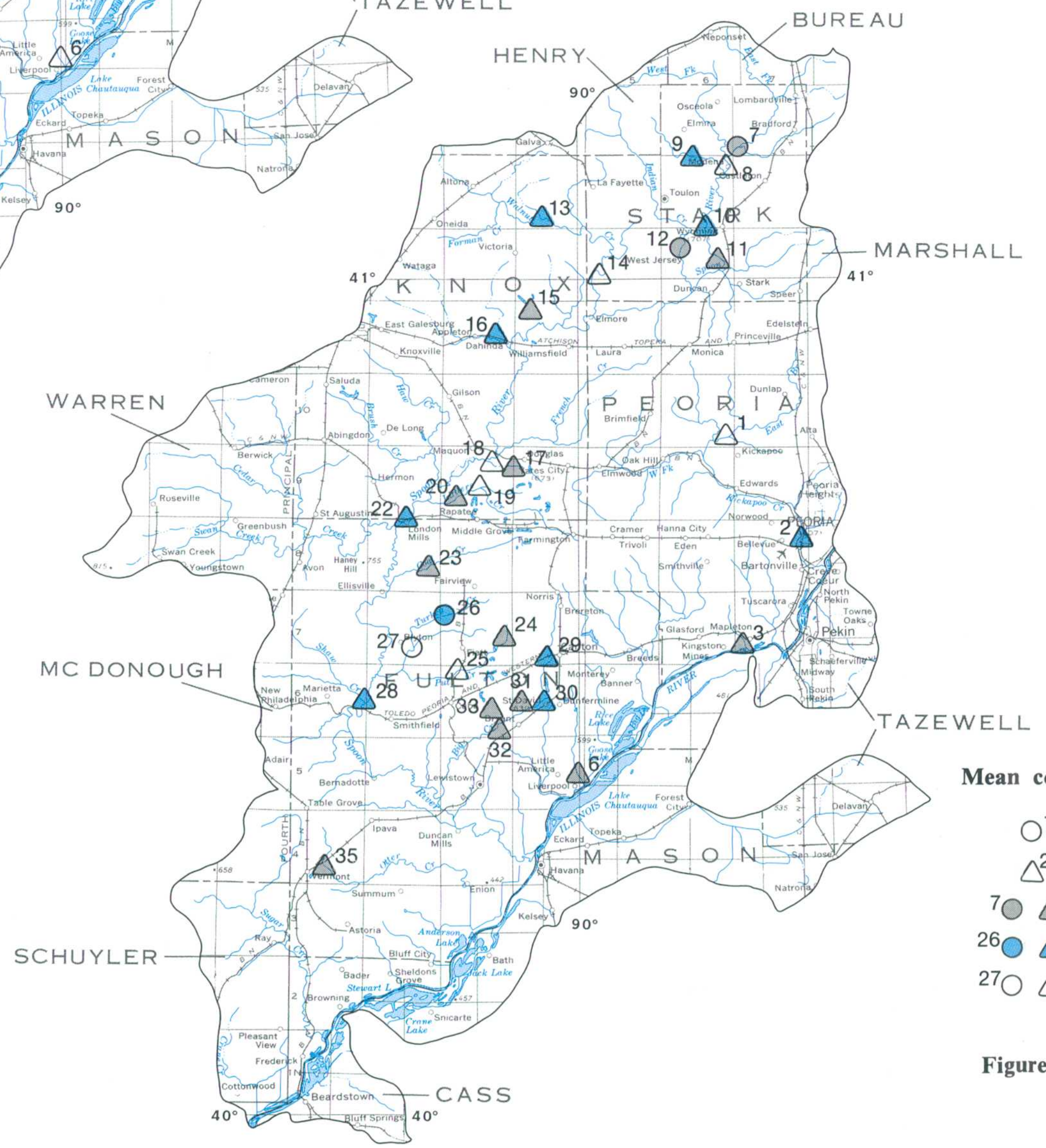


EXPLANATION

Mean concentrations of dissolved iron at each site

○7	**Upstream site and location number**
△28	**Downstream site and location number**
7● ▲9	**0-50 micrograms per liter**
▲3	**>50 micrograms per liter**
△10	**No measurements of dissolved iron**

Figure 8.2.4-2 Mean values of dissolved iron at water quality sites.



EXPLANATION

Mean concentrations of total recoverable iron at each site

○7	**Upstream site and location number**
△28	**Downstream site and location number**
7● ▲6	**0-1,500 micrograms per liter**
26● ▲2	**>1,500 micrograms per liter**
27○ △8	**No measurements of total recoverable iron**

Figure 8.2.4-3 Mean values of total recoverable iron at water quality sites.

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

Site Number	Number of Observations	Iron, dissolved (µg/L)		
		Minimum	Mean	Maximum
1	3	20	20	30
2	3	20	40	60
3	4	20	50	70
6	2	50	60	70
7*	3	10	10	20
8	2	20	20	30
9	5	10	20	50
10	0	–	–	–
11	3	20	30	30
12*	3	20	20	20
13	3	10	20	30
14	2	10	30	50
15	5	30	40	50
16	5	20	30	40
17	2	50	60	70
18	2	30	60	80
19	2	10	20	30
20	2	50	60	70
22	0	–	–	–
23	4	10	40	60
24	2	20	40	50
25	2	20	20	30
26*	16	0	50	240
27*	2	30	40	50
28	0	–	–	–
29	14	0	10	60
30	0	–	–	–
31	0	–	–	–
32	2	50	575	1,100
33	2	50	60	60
35	1	100	100	100

* Sites upstream of mining.

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

Site Number	Number of Observations	Iron, total recoverable (µg/L)		
		Minimum	Mean	Maximum
1	3	820	960	1,100
2	3	1,900	2,270	2,900
3	2	380	450	520
6	2	370	940	1,500
7*	3	1,100	1,430	2,000
8	0	–	–	–
9	3	1,400	1,970	3,000
10	5	800	1,600	4,300
11	3	320	1,380	2,900
12*	22	200	1,350	8,200
13	3	1,200	2,200	3,000
14	0	–	–	–
15	3	730	750	790
16	3	1,500	1,870	2,500
17	2	1,110	1,250	1,400
18	0	–	–	–
19	0	–	–	–
20	2	420	710	1,000
22	16	400	3,200	12,000
23	2	480	620	770
24	2	1,300	1,450	1,600
25	0	–	–	–
26*	16	200	3,550	31,000
27*	0	–	–	–
28	22	260	5,530	25,000
29	15	170	4,300	43,000
30	2	1,600	1,900	2,200
31	2	150	160	160
32	8	300	1,320	2,900
33	10	350	1,490	3,100
35	1	540	540	540

* Sites upstream of mining.

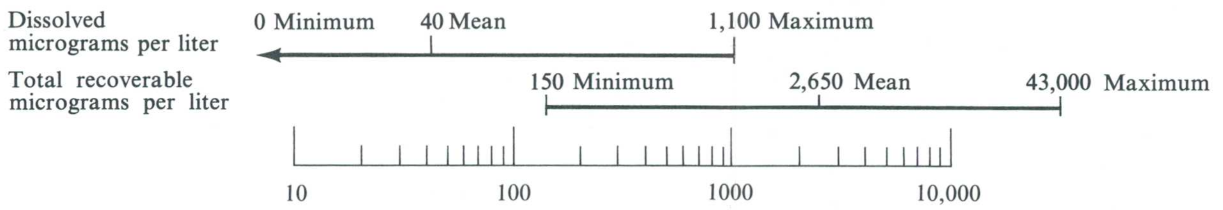


Figure 8.2.4-1 Range of dissolved and total recoverable iron concentrations measured in the study area.

CONCENTRATIONS OF DISSOLVED AND TOTAL RECOVERABLE MANGANESE VARY

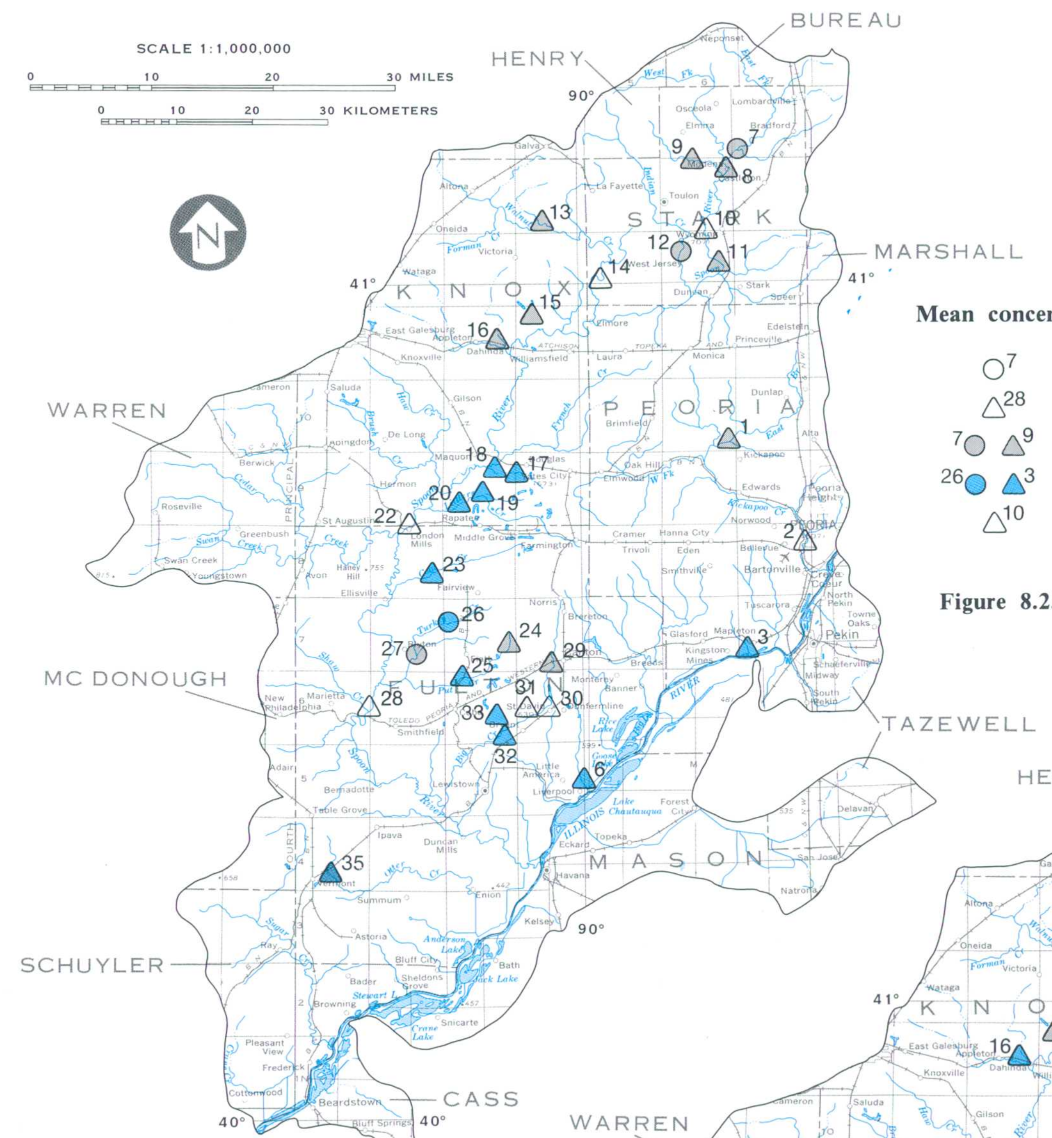
Measurements of dissolved and total recoverable manganese ranged from 0 to 830 micrograms per liter (µg/L) and 20 to 7,000 µg/L, respectively.

Manganese is an 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 are chemically similar. However, because manganese has a lower affinity for oxygen, it stays in solution longer than iron (Rankama and Sahama, 1950).

The concentrations of dissolved manganese ranged from 0 to 830 µg/L (table 8.2.5-1) with a mean of 130 µg/L in the study area. Total recoverable manganese ranged from 20 to 7,000 µg/L (table 8.2.5-2) with a mean of 340 µg/L (fig. 8.2.5-1). Ranges for mean dissolved manganese and mean total recoverable manganese concentrations are shown on figures 8.2.5-2 and 8.2.5-3, respectively.

The amount of manganese recoverable from bottom material at sites in the study area ranged from 160 to 1,700 µg/g with a mean of 800 µg/g.

"Manganese is a vital micro-nutrient for both plants and animals" (U.S. Environmental Protection Agency, 1976). Inadequate amounts can inhibit plant growth or affect animal reproductive capabilities. A concentration of less than 50 µg/L is recommended for domestic water supplies. Concentrations greater than this can cause staining of laundry and objectional tastes (U.S. Environmental Protection Agency, 1976, p. 96).



BASE FROM U. S. GEOLOGICAL SURVEY
STATE BASE MAP, 1972

EXPLANATION

Mean concentrations of dissolved manganese at each site

○7 **Upstream site and location number**
△28 **Downstream site and location number**
7● ▲9 **0-150 micrograms per liter**
26● ▲3 **>150 micrograms per liter**
△10 **No measurements of dissolved manganese**

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

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

Site Number	Number of Observations	Manganese, total recoverable (μg/L)		
		Minimum	Mean	Maximum
1	3	70	150	200
2	3	120	140	160
3	2	200	260	330
6	2	160	230	300
7*	3	90	97	100
8	0	–	–	–
9	3	80	120	180
10	5	80	160	350
11	3	60	93	120
12*	12	50	160	650
13	3	120	230	400
14	0	–	–	–
15	3	100	140	170
16	3	210	270	310
17	2	300	340	390
18	0	–	–	–
19	0	–	–	–
20	2	330	360	390
22	15	100	390	1,300
23	2	170	188	200
24	2	130	160	200
25	0	–	–	–
26*	13	40	490	600
27*	0	–	–	–
28	21	80	520	2,400
29	12	20	50	120
30	2	390	620	840
31	2	50	100	150
32	9	260	1,190	7,000
33	10	310	470	740
35	1	200	200	200

* Sites upstream of mining.

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

Site Number	Number of Observations	Manganese, dissolved (μg/L)		
		Minimum	Mean	Maximum
1	3	40	97	140
2	3	30	37	40
3	4	110	180	310
6	2	110	150	200
7*	3	30	43	50
8	2	60	80	100
9	5	40	52	80
10	0	–	–	–
11	3	30	47	60
12*	3	20	33	60
13	3	40	140	270
14	2	0	20	40
15	5	60	100	160
16	5	60	120	190
17	2	150	220	300
18	2	190	300	420
19	2	320	580	830
20	2	280	320	370
22	0	–	–	–
23	4	120	200	370
24	2	60	100	140
25	2	160	170	180
26*	16	20	180	620
27*	2	40	70	100
28	0	–	–	–
29	14	7	10	30
30	0	–	–	–
31	0	–	–	–
32	2	180	210	240
33	2	240	300	370
35	1	150	150	150

* Sites upstream of mining.

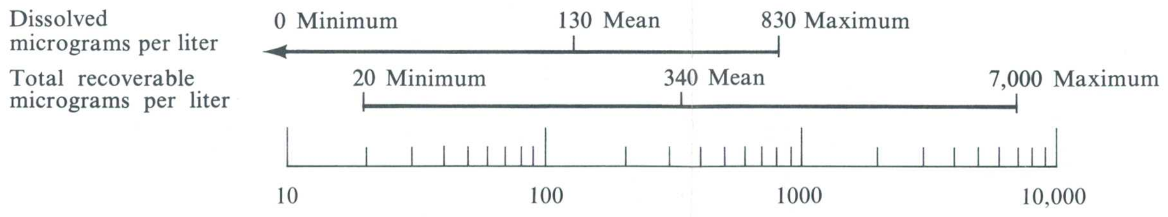
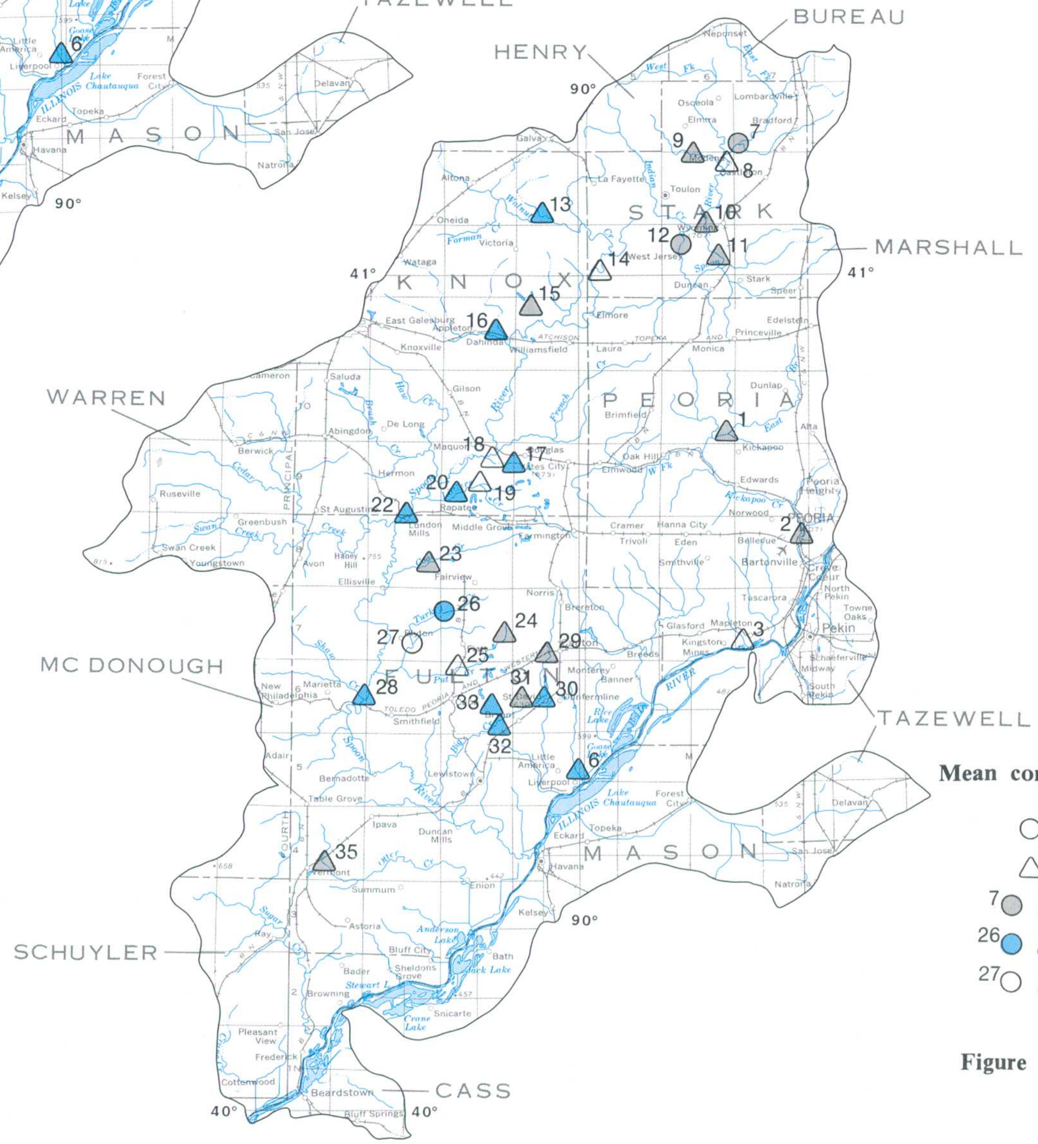


Figure 8.2.5-1 Range of dissolved and total recoverable manganese concentrations in the study area.



EXPLANATION

Mean concentrations of total recoverable manganese at each site

○7 **Upstream site and location number**
△28 **Downstream site and location number**
7● ▲2 **0-200 micrograms per liter**
26● ▲6 **>200 micrograms per liter**
27○ △8 **No measurements of total recoverable manganese**

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

SULFATE CONCENTRATIONS CAN BE ESTIMATED FROM SPECIFIC CONDUCTANCE MEASUREMENTS

Concentrations of sulfate ranged from 31 to 1,200 milligrams per liter (mg/L) in the study area. Sulfate concentrations can be estimated using the equation, SULFATE = 0.63 (SPECIFIC CONDUCTANCE) - 345.

Sulfur occurs in 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. During weathering, the iron sulfide forms sulfate and iron in solution. Iron is easily oxidized further and commonly precipitates as ferric oxide. At sites downstream of mining, higher sulfate concentrations result from the increased exposure of sulfide-bearing minerals to weathering in the mined areas. The measured concentrations of sulfate ranged from 31 to 1,200 mg/L with a mean value of 380 mg/L for all observations (fig. 8.2.6-1 and table 8.2.6-1). Ranges of mean sulfate concentrations are shown on figure 8.2.6-2.

Brabets (written commun. 1981) relates annual sulfate yields to the area of surface mines as a percentage of total drainage area. Figure 8.2.6-3 shows that in west-central Illinois sulfate can be used as an indicator of mine drainage.

Sulfate concentrations and specific conductance have a high correlation (correlation coefficient = 0.96) when the specific conductance is less than 2,500 μmho/cm at 25°C. Sulfate values within the study area can be estimated from measurements of specific conductance by the equation SULFATE = 0.63 (SPECIFIC CONDUCTANCE) - 345 or by using the graph shown in figure 8.2.6-4.

The recommended maximum concentration of sulfate in domestic water supplies is 250 mg/L. Amounts in excess of this can cause physiological effects, undesirable tastes, and can raise costs for water treatment (U.S. Environmental Protection Agency, 1976, p. 205).

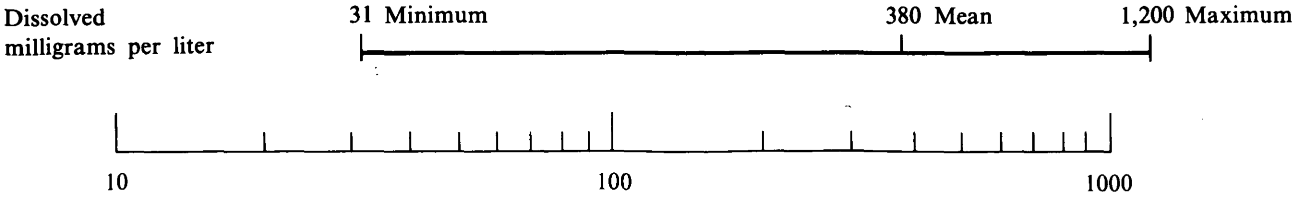
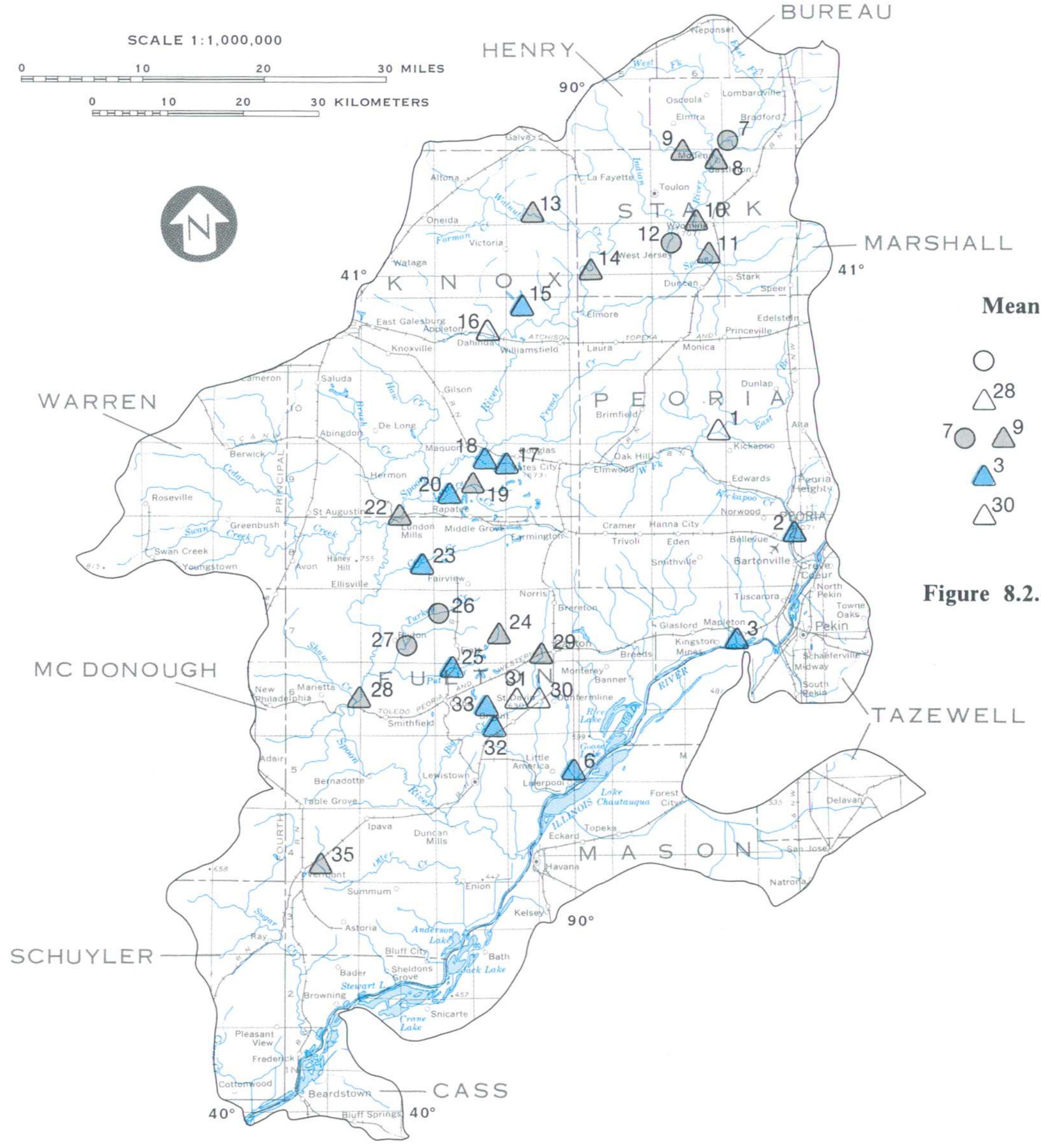


Figure 8.2.6-1 Range of sulfate concentrations measured in the study area.



BASE FROM U. S. GEOLOGICAL SURVEY
STATE BASE MAP, 1972

EXPLANATION

Mean concentrations of sulfate at each site

○ **Upstream site and location number**

△28 **Downstream site and location number**

7● ▲9 **0-400 milligrams per liter**

▲3 **>400 milligrams per liter**

△30 **No measurements of sulfate**

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

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

Site Number	Number of Observations	Sulfate as SO_4 (mg/L)		
		Minimum	Mean	Maximum
1	3	61	67	70
2	2	190	200	200
3	4	190	510	1,000
6	2	700	800	910
7*	3	45	50	57
8	2	55	60	64
9	5	47	56	64
10	6	62	68	87
11	3	70	93	130
12*	11	42	52	57
13	3	51	61	67
14	2	47	50	54
15	5	340	490	560
16	5	93	140	190
17	2	730	860	980
18	2	280	430	580
19	2	320	380	430
20	2	560	640	730
22	17	62	97	150
23	4	99	410	580
24	2	40	68	95
25	2	460	480	500
26*	16	31	45	59
27*	2	82	100	120
28	22	36	98	170
29	15	190	220	280
30	0	–	–	–
31	0	–	–	–
32	7	280	660	940
33	58	380	880	1,200
35	1	290	290	290

* Sites upstream from mining.

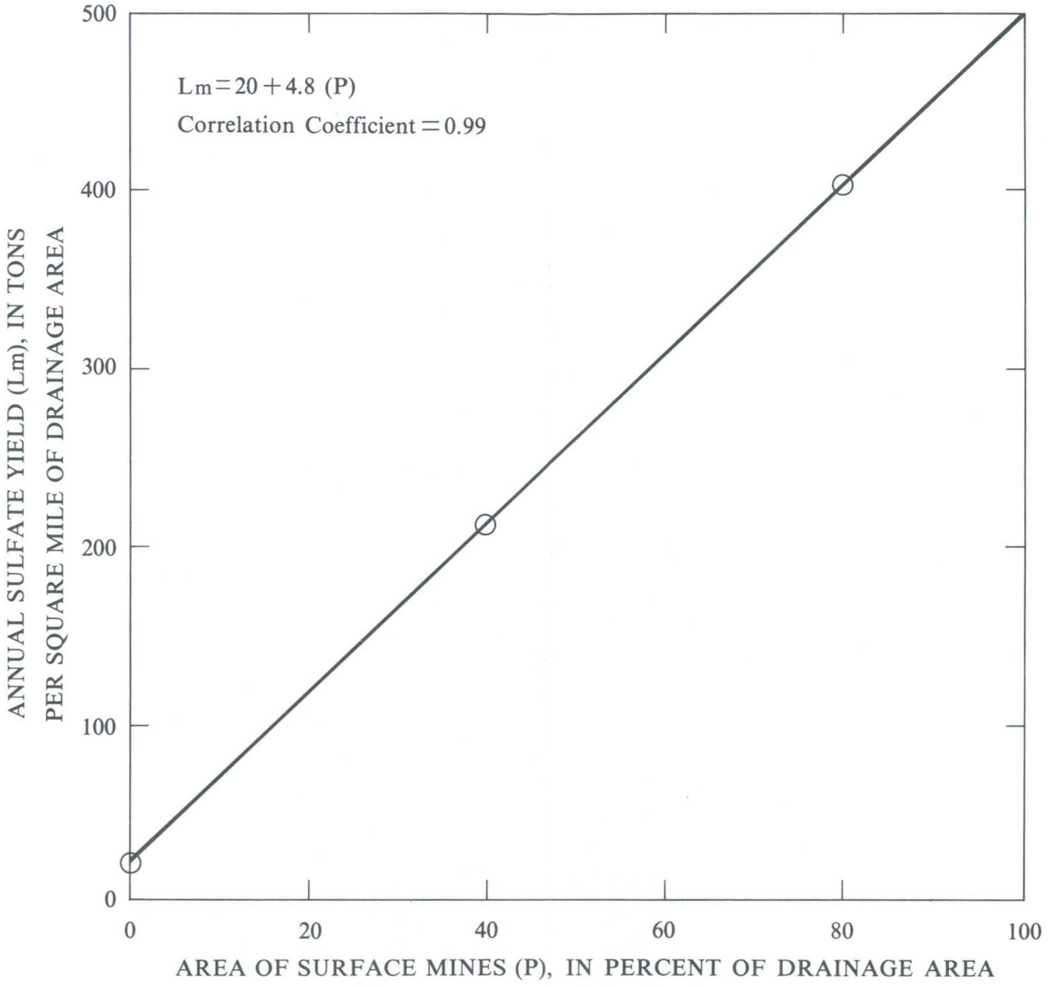


Figure 8.2.6-3 Relation between annual sulfate load and percent of drainage basin covered by surface mining.

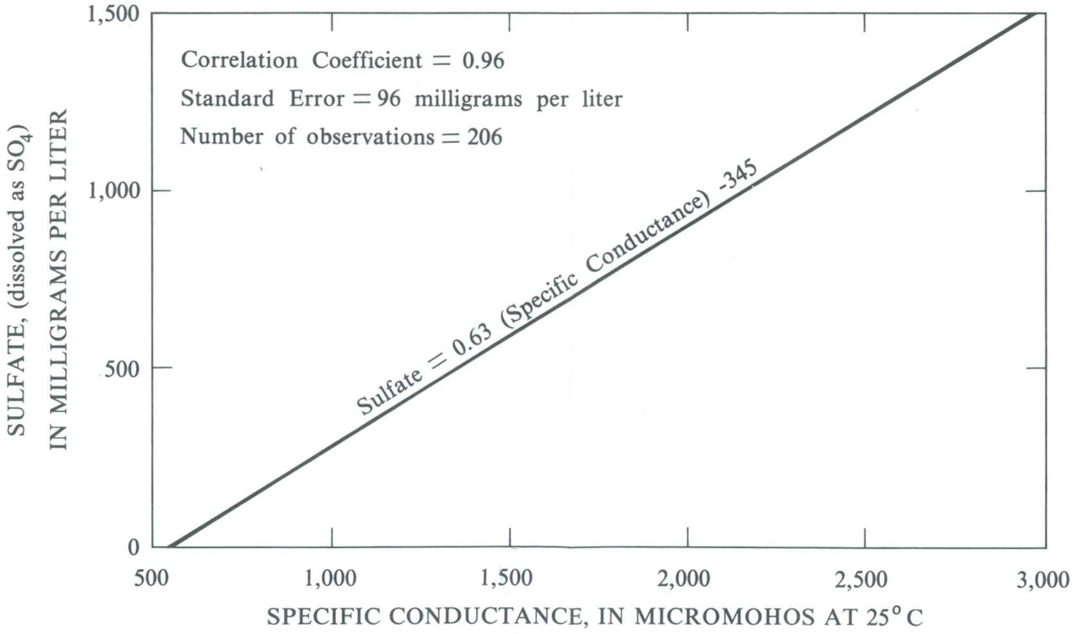


Figure 8.2.6-4 Relation between specific conductance and sulfate concentrations in the study area.

ALKALINITY VALUES VARY IN THE STUDY AREA

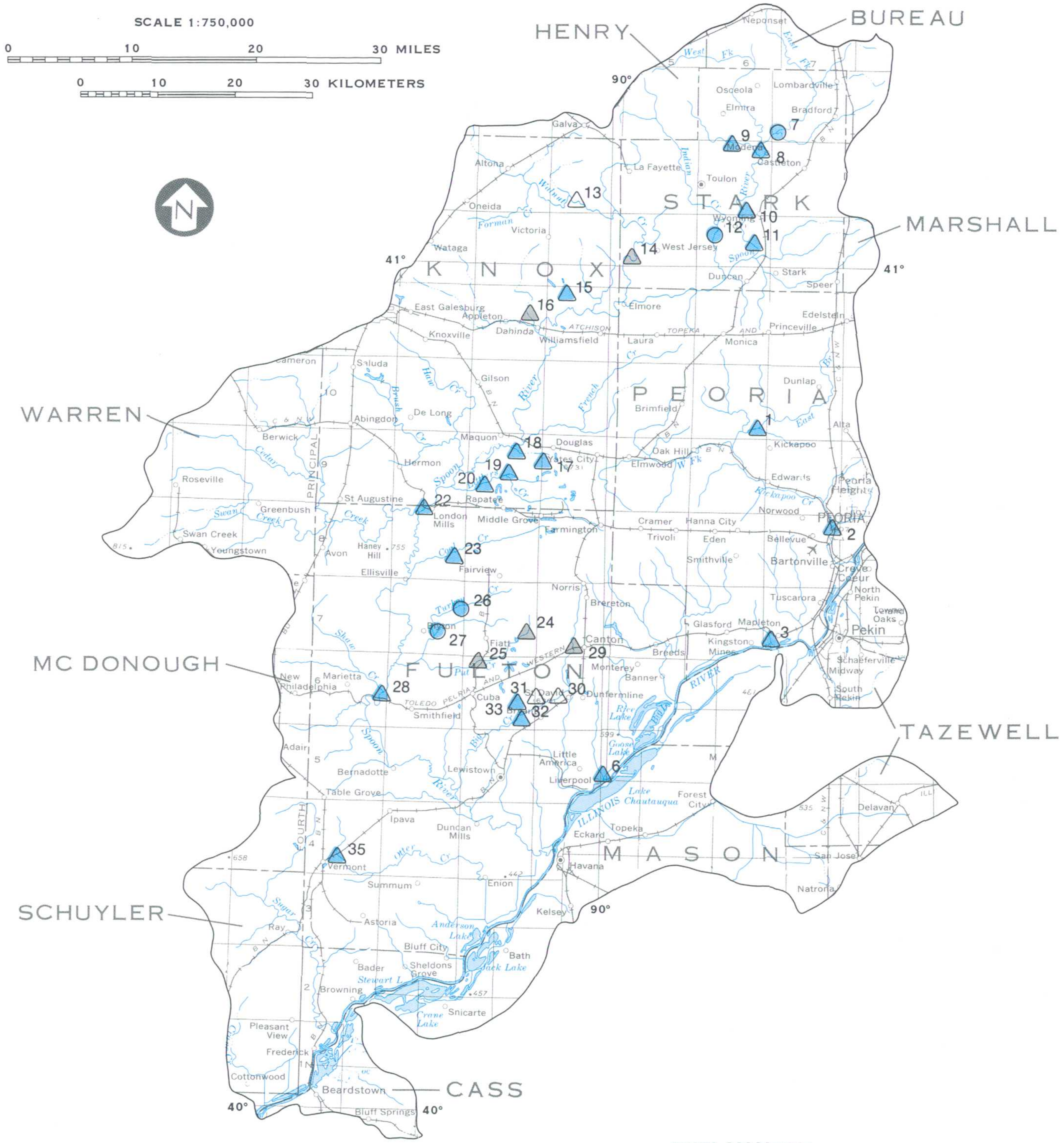
Alkalinity values ranged from 51 to 360 milligrams per liter (mg/L) as calcium carbonate ($CaCO_3$).

Alkalinity is defined as the capacity of a 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 alkalinity.

Surface waters derive their capability to react with hydrogen ions from the materials they contact. The variability of alkalinity values at sites downstream of mining depend on the soils in the unmined area and on the bedrock materials exposed by the mining.

Measurements of alkalinity ranged from 51 to 360 mg/L as $CaCO_3$ with a mean of 232 mg/L (table 8.2.7-1 and fig. 8.2.7-1). Ranges of mean alkalinity values at sampling sites are displayed on figure 8.2.7-2.

Alkalinity values of 20 mg/L or more are generally recommended for fresh-water aquatic life. Values less than this (poorly buffered) leave the water susceptible to rapid changes in pH. Some "components of alkalinity such as carbonate and bicarbonate will complex toxic heavy metals and reduce their toxicity markedly" (U.S. Environmental Protection Agency, 1976, p. 7).



BASE FROM U. S. GEOLOGICAL SURVEY
STATE BASE MAP, 1972

EXPLANATION

Mean concentrations of alkalinity at each site

○7 Upstream site and location number

△28 Downstream site and location number

▲14 *0-200 milligrams per liter*

26● ▲3 >200 milligrams per liter

△30 No measurements of alkalinity

Figure 8.2.7-2 Mean values of alkalinity at water quality sites.

Table 8.2.7-1 Alkalinity values at water quality sites.

Site Number	Number of Observa-tions	Alkalinity as $CaCO_3$ (mg/L)		
		Minimum	Mean	Maximum
1	3	260	280	300
2	3	260	260	260
3	4	280	300	320
6	2	230	230	230
7*	3	250	270	280
8	2	220	230	230
9	5	240	270	300
10	5	220	250	290
11	3	230	260	290
12*	16	180	260	320
13	3	240	250	270
14	2	170	190	220
15	5	170	200	230
16	5	160	180	190
17	2	240	250	260
18	2	160	220	270
19	2	210	230	250
20	2	230	230	230
22	17	150	230	290
23	4	210	220	240
24	2	160	200	230
25	2	170	180	180
26*	16	110	240	320
27*	2	230	230	230
28	22	51	210	360
29	15	100	140	160
30	0	–	–	–
31	0	–	–	–
32	6	120	220	260
33	58	82	250	340
35	1	220	220	220

* Sites upstream of mining.

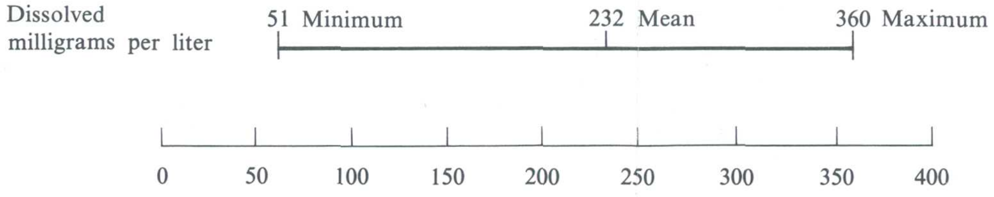


Figure 8.2.7-1 Range of alkalinity values measured in the study area.

CONCENTRATIONS OF TRACE ELEMENTS VARY

Concentrations of many trace elements and other water-quality constituents are dependent on their availability and the pH of surface waters.

Many trace elements and other water-quality constituents have been measured in the study area. The range of concentrations (fig. 8.2.8-1) are indicative of their variability. The ranges of these constituents are relatively narrow because pH values are near the neutral range in all samples. At lower pH values, many of these elements (if available) are more susceptible to dissolution.

Some of the trace constituents can be toxic at high concentrations. Recommended maximum concentrations for selected constituents in domestic water supplies are: cadmium-10 μg/L, chromium-50 μg/L, copper-1,000 μg/L, lead-50 μg/L, selenium-10 μg/L, and zinc-5,000 μg/L (U.S. Environmental Protection Agency, 1976). None of the measured concentrations exceed these levels. Many of these same constituents are necessary as micro-nutrients for plant or animal growth.

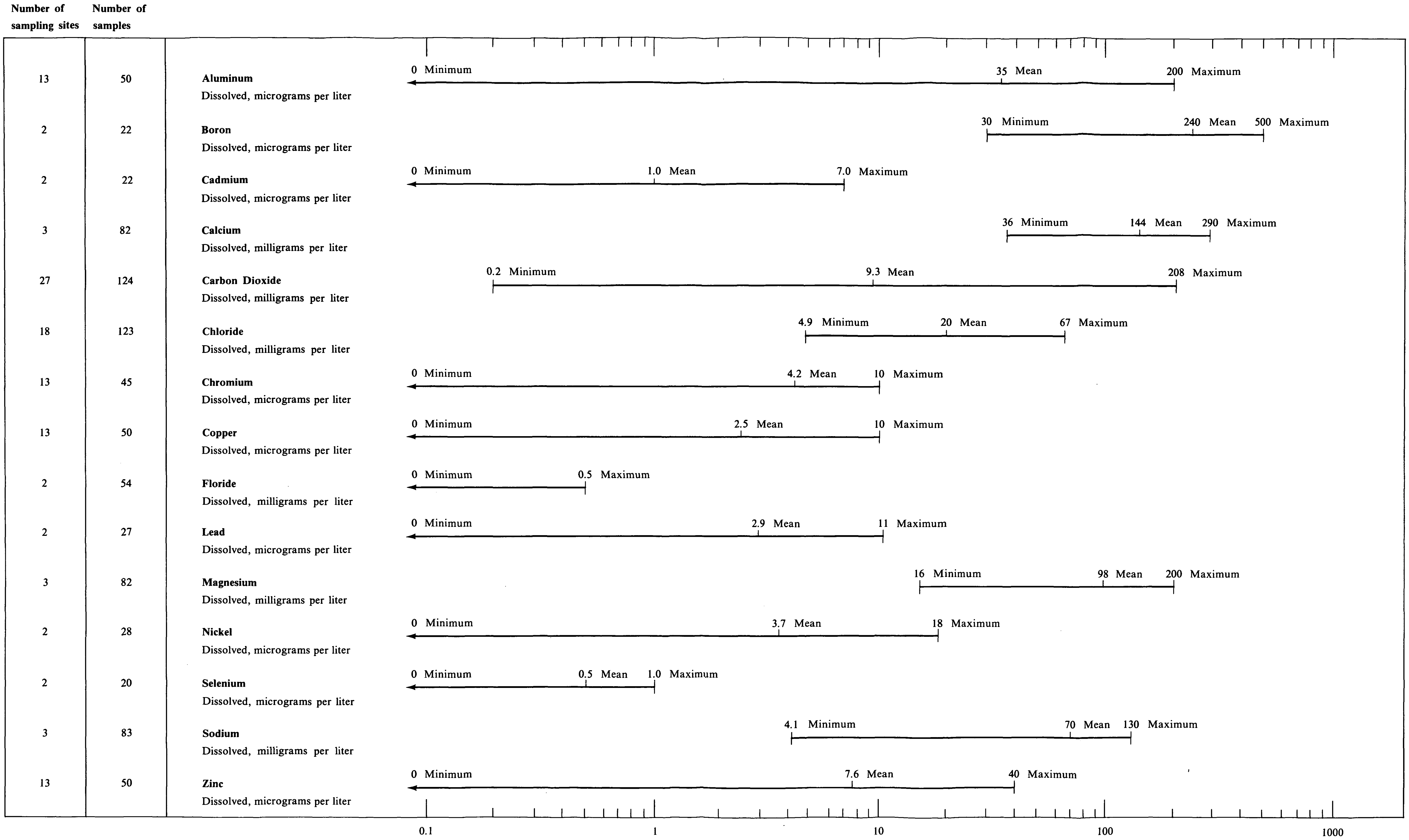


Figure 8.2.8-1 Range of concentrations of selected constituents measured at water quality sites.

QUALITY OF WATER IN FINAL-CUT LAKES

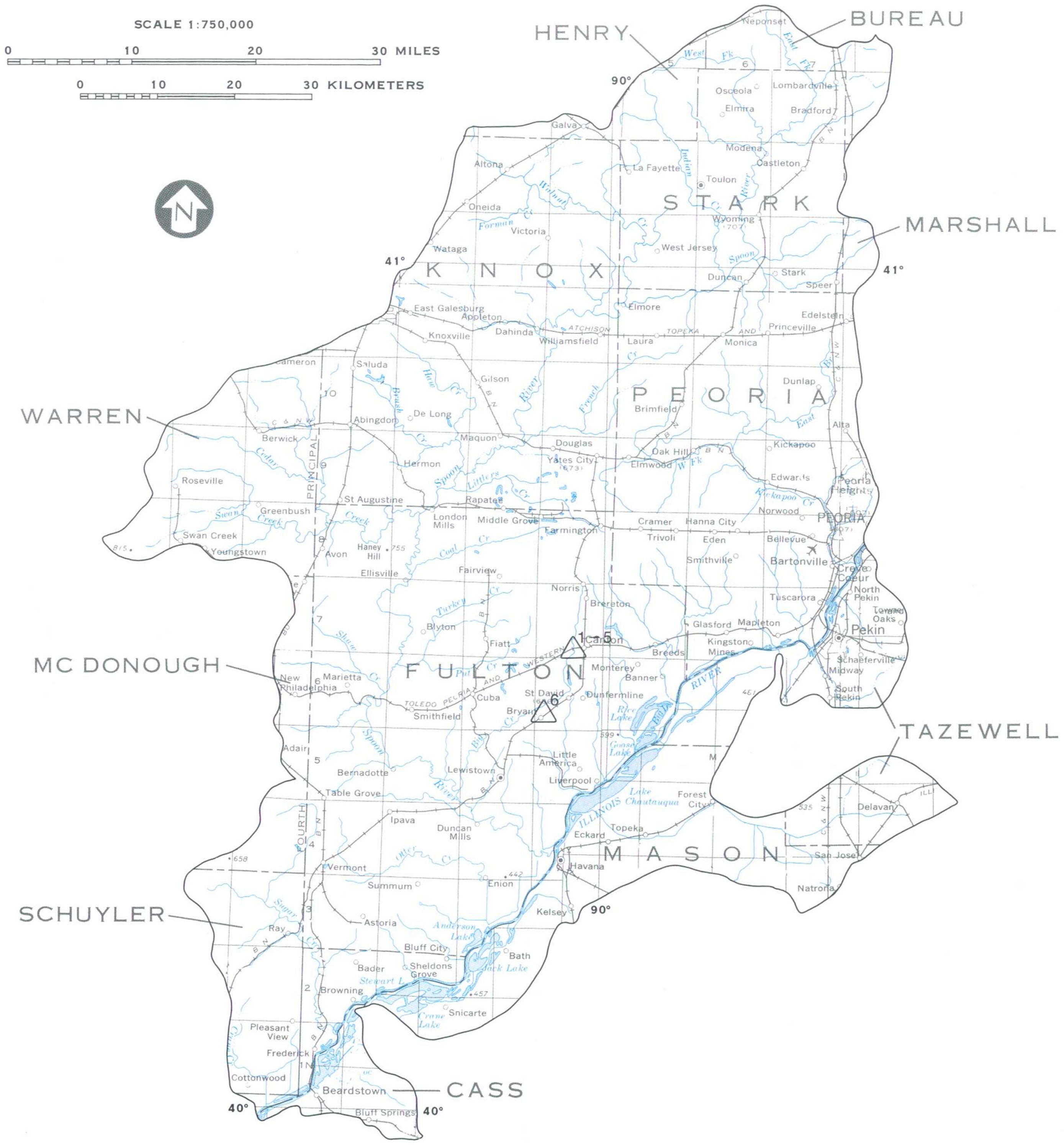
Waters of final-cut lakes are high in dissolved iron, sulfate, manganese, and other chemicals leached from the loosened surrounding material. A concentration of dissolved iron of 2,500 micrograms per liter (μg/L) was measured near the bottom of one stratified lake.

Final-cut lakes are created when surface mining ceases in an area and the abandoned pit and portions of the associated haulage roads fill with water from precipitation, ground-water inflow, and surface-water runoff.

Sixty-five water-quality constituents were either measured or calculated for six sites in three lakes sampled on October 3 and 4, 1979 (fig. 8.2.9-1). The lake waters at five sites had overturned prior to sampling and were completely mixed from the surface to the bottom. The sixth site was deeper and thermally stratified when sampled.

Limited data indicate a high positive correlation between specific conductance and dissolved sulfate ($r = 0.993$, $n = 8$). Dissolved iron concentrations ranged from 10 to 40 μg/L with the exception of one value of 2,500 μg/L from a sample taken near the bottom of the stratified lake. Total iron ranged from 80 to 210 μg/L except near the bottom of the stratified lake where it was 2,600 μg/L. Comparison of total and dissolved iron concentrations shows that 75 to 95 percent of the iron was in the suspended phase except near the bottom of the stratified lake where only 3.8 percent was in the suspended phase. Similar comparison showed that 50 to 100 percent of the manganese was in the suspended phase.

Figure 8.2.9-2 shows the locations of sites 1 through 5. The water flows from sites 1, 2, and 3 to 4 and on to site 5 during periods of high-water levels. Specific conductance ranged from 470 to 560 micromhos per centimeter at 25°C at sites 1 to 4 but was 1,060 micromhos per centimeter at 25°C at site 5. Much of this increase at site 5 may be related to renewed weathering and surface drainage runoff during recent development of this area into a city park.

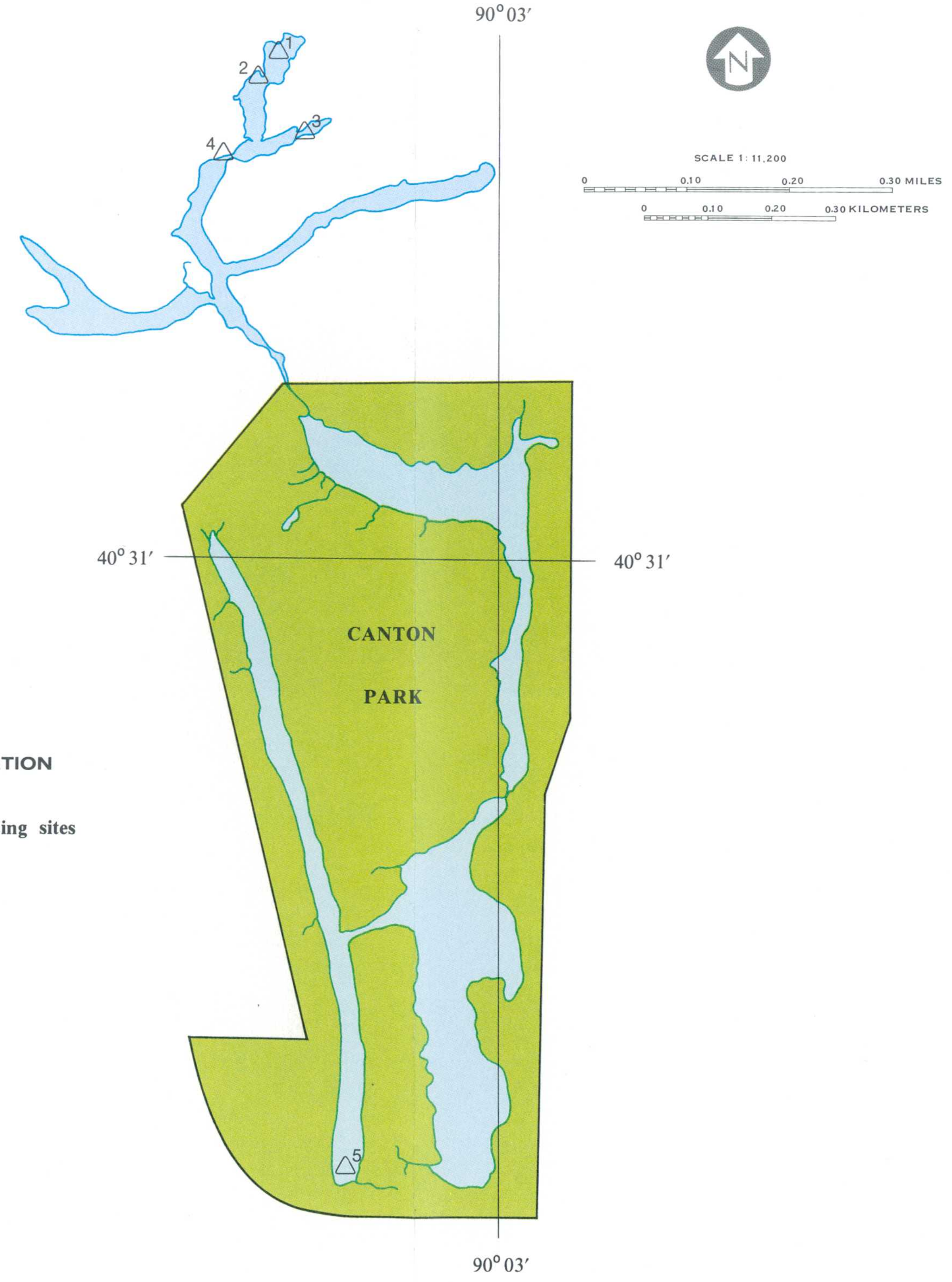


BASE FROM U. S. GEOLOGICAL SURVEY
STATE BASE MAP, 1972

EXPLANATION

△6 **Final-cut lake site and number**

Figure 8.2.9-1 Final-cut lake locations.



EXPLANATION

△2 **Sampling sites**

Figure 8.2.9-2 Locations of sampling sites one through five.

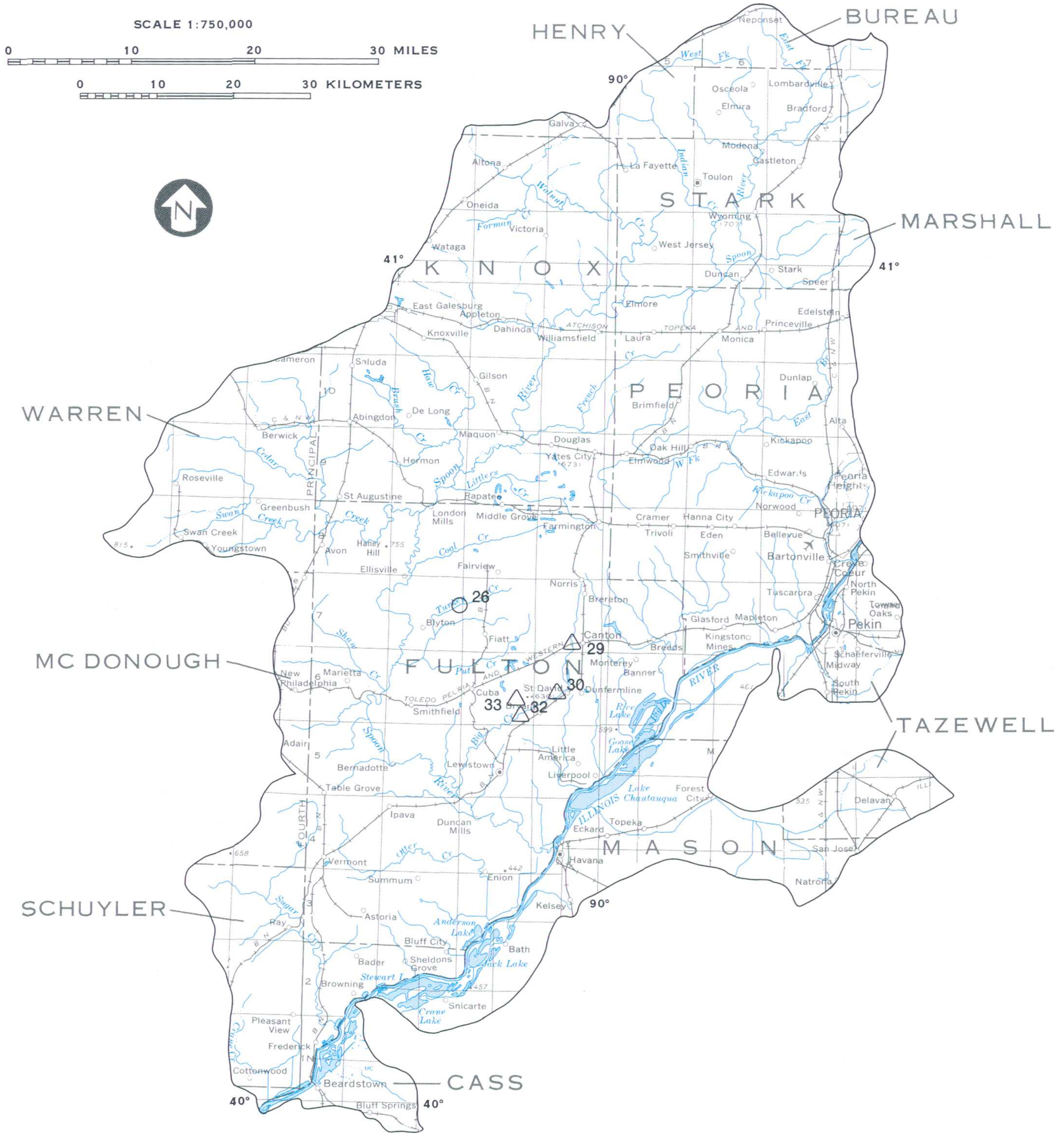
SUSPENDED-SEDIMENT YIELDS RANGE UP TO 473 TONS PER SQUARE MILE PER YEAR

Computed annual suspended-sediment yields at five sites in the study area ranged from 57.5 to 473 tons per square mile.

The smallest annual suspended-sediment yield was 57.5 tons per square mile at the West Branch Big Creek near Canton (table 8.2.10-1). It drains an area comprised almost entirely of reclaimed surface mines. The drainage area is characterized by lakes and graded land with grasses and pasture (T. P. Brabets, written commun., 1981). Slug Run drains another area of past surface mining that had no reclamation and has been left idle since mining ceased. Final-cut lakes and low parallel hills with some trees and grasses now form the landscape. Slug Run near Bryant had an annual suspended-sediment yield of 115 tons per square mile over 4 years of daily sediment records or about twice the annual yield calculated for the West Branch of Big Creek site. The yield at Turkey Creek near Fiatt, 233 tons per square mile per year, was about four times the yield calculated for West Branch of Big Creek. Turkey Creek drains land which is about 80 percent agricultural and 20 percent wooded (T. P. Brabets, written commun., 1981). From 8 years of daily sediment record, Big Creek at St. David and Big Creek near Bryant have high annual suspended-sediment yields of 400 and 473 tons per square mile per year respectively, which are about seven and eight times that calculated for West Branch Big Creek. Big Creek drains some previously surface-mined land, agricultural land, and four urban areas. It has a meandering channel with steep banks. Figure 8.2.10-1 shows the suspended-sediment sampling site locations.

Table 8.2.10-1 shows that as much as 97 percent of the annual suspended-sediment yield is transported in 36 days or 10 percent of the time. During this same 10 percent of the time, 45 to 48 percent of the total streamflow occurred, indicating that sediment is transported mostly during high flows created by storms and/or snowmelt runoff.

As velocity of streamflow increases, the energy available to transport suspended-sediment also increases. Suspended-sediment concentrations depend on this stream energy and the availability and size of sediment, all of which are variable in the study area. The suspended-sediment particle size averaged 76 percent silt and clay (finer than 0.062 millimeters) and 24 percent sand (coarser than 0.062 millimeters). Suspended-sediment concentrations ranged from 19 to 14,400 mg/L in 86 samples collected at 31 sites during three synoptic sampling runs in the study area.



BASE FROM U. S. GEOLOGICAL SURVEY
STATE BASE MAP, 1972

EXPLANATION

○26 **USGS Upstream gaging station**

△30 **USGS Downstream gaging station**

Figure 8.2.10-1 Suspended-sediment sampling site locations.

Table 8.2.10-1 Suspended-sediment sampling site descriptions.

Site No.	Suspended sediment sampling site	Drainage area (mi²)	Drainage area surface mined	Suspended sediment load [(tons/mi²)/yr]	Mean annual percentage passing site during the 36 days of highest water flow		Description of drainage basin as related to coal mining
					Sediment	Water	
29	West Branch Big Creek near Canton	4.2	about 1/3	57.5	–	–	Abandoned surface mine with most area reclaimed; hay fields and pasture along with final cut lakes.
33	Slug Run near Bryant	7.9	Most	115	71	40	Abandoned surface mine area with no reclamation.
26	Turkey Creek near Fiatt	11.5	None	233	–	–	Natural basin with agriculture. No mining.
30	Big Creek at St. David	26.7	about 1/2	400	93	48	Abandoned surface mine and the city of Canton and some unmined agricultural areas. (Received West Branch Big Creek drainage also.)
32	Big Creek near Bryant	40.3	about 1/2	473	97	45	Passed surface mining, urban, and unmined area including effluent from St. David sewage treatment plant.

GROUND-WATER YIELDS ARE HIGH IN THE NORTHERN AND SOUTHERN REGION OF THE STUDY AREA

Aquifer yields in the middle third of the study area are low. The unconsolidated deposits of the Illinois bedrock valley and the bedrock in the northern third of the study area can yield 500 gallons per minute or more.

The major aquifers in the study area are unconsolidated glacial deposits; sandstones, coals, and limestones of Pennsylvanian age; limestone and dolomite of Mississippian through Silurian age; and sandstone of Cambrian age. The unconsolidated deposits are found in the present Illinois and Spoon River valleys and in older bedrock valleys south of the present Illinois River. The shallow aquifers are used mainly for domestic supplies. High capacity wells are generally developed in the deep sandstones. In parts of the study area (Fulton and Peoria Counties), the deep sandstone aquifers are too highly mineralized for most uses (Bergstrom, 1956).

Wells in the sand and gravel which fills the bedrock valleys can yield as much as 500 gallons per minute (gal/min). Yields from relatively thin unconsolidated deposits in much of the remaining area can be 20 gal/min or more (fig. 9.1-1).

Yields from shallow bedrock wells in the northern one-third of the study area can be 100 gal/min or more. Elsewhere in the area, the chance of obtaining yields of 20 gal/min or more from shallow bedrock wells is poor. One hundred gal/min or more can be obtained from the deeper sandstones in the northern two-thirds of the area (fig. 9.1-2) (Smith and Stall, 1975).

Recharge is primarily from precipitation and takes place at bedrock outcrops both within and outside the study area and by percolation into and through overlying unconsolidated material (Bergstrom, 1956). Figure 9.1-3 is a hypothetical geologic cross section showing ground-water occurrence.

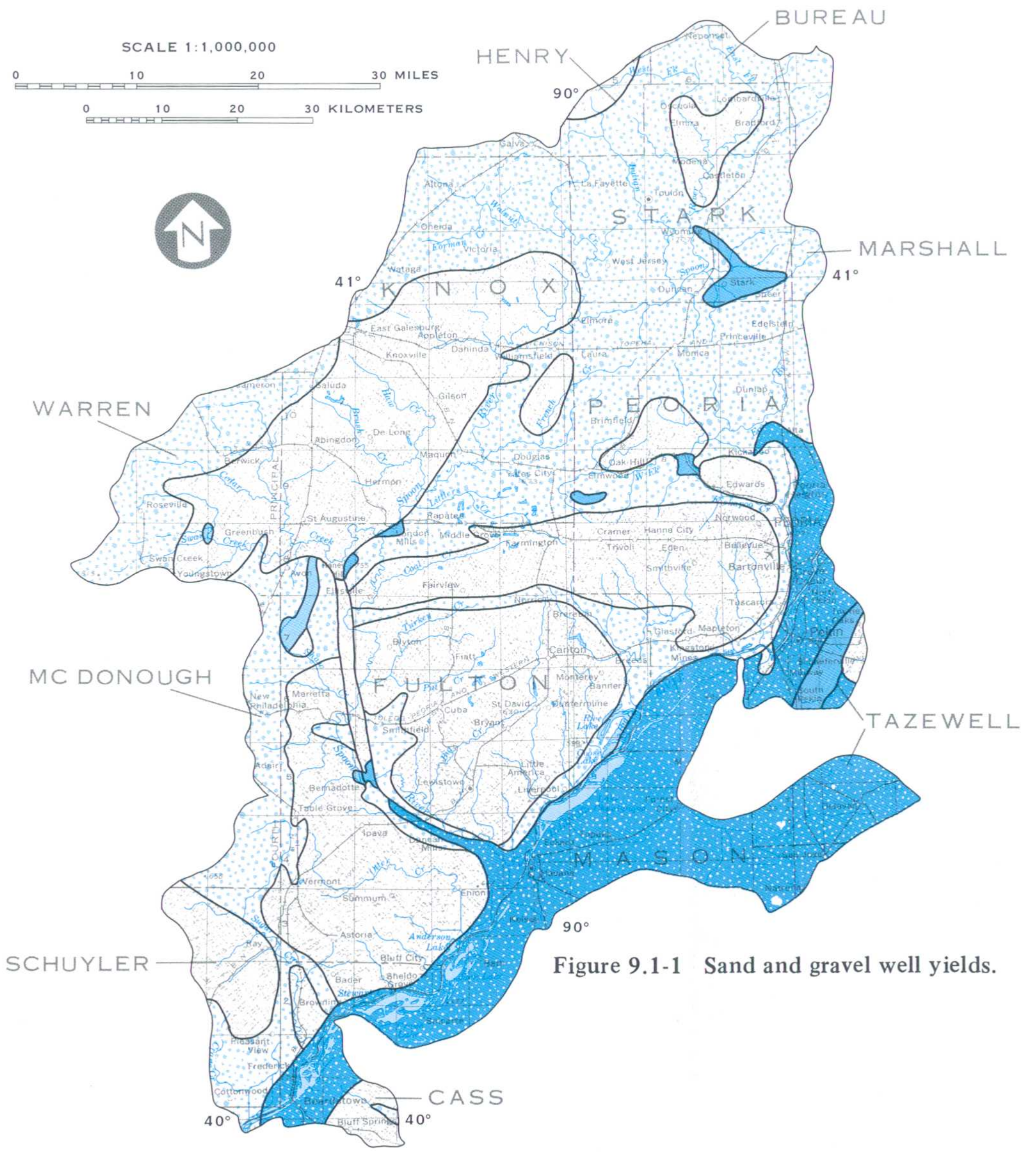


Figure 9.1-1 Sand and gravel well yields.

BASE FROM U. S. GEOLOGICAL SURVEY
STATE BASE MAP, 1972

EXPLANATION

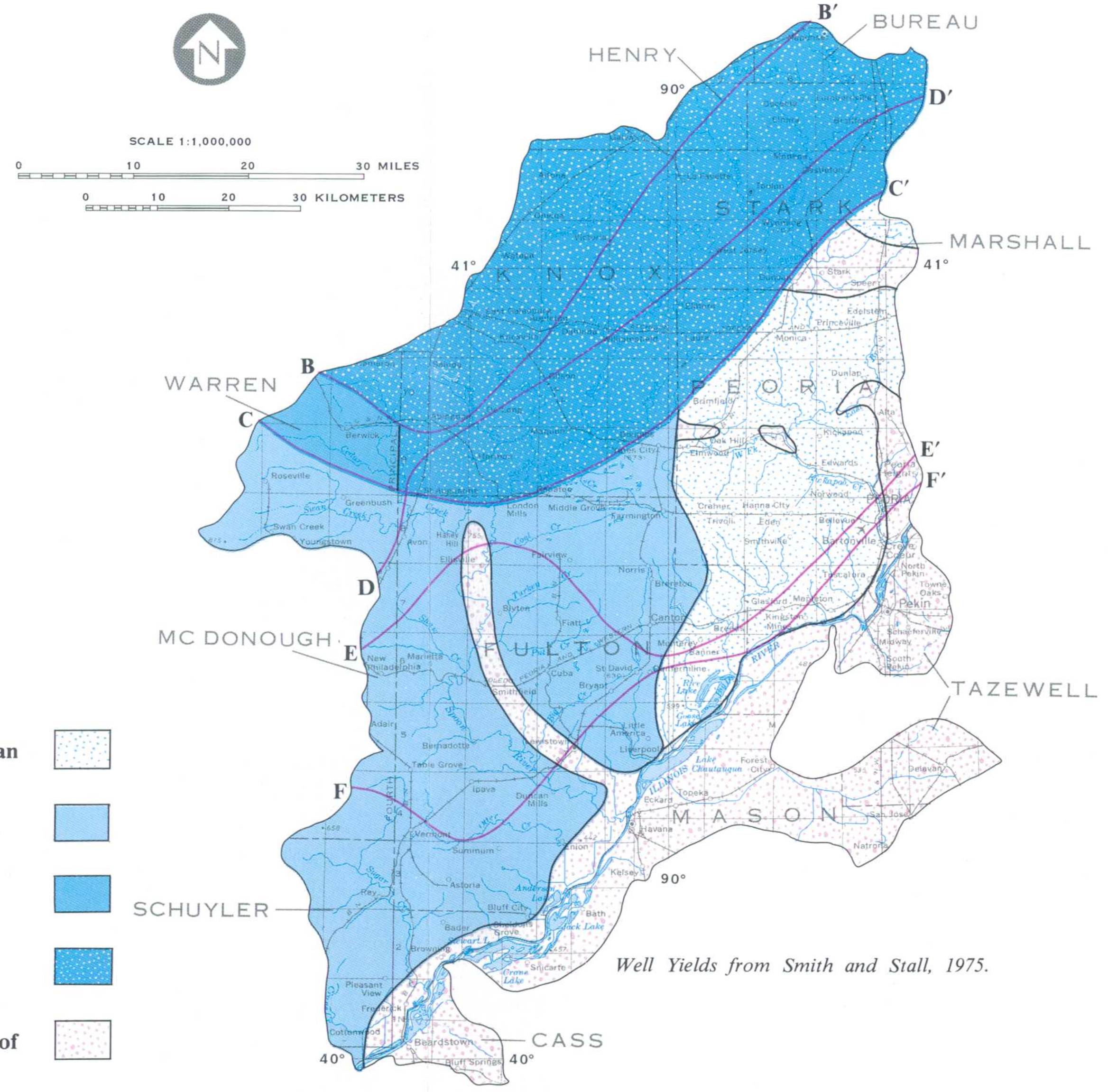
▢ Areas where municipal and industrial water supplies are generally developed from other sources.

Areas underlain by principal sand and gravel aquifer at least 15 feet thick, where chances are good for obtaining wells with yields of:

- ▢ 20 gallons per minute or more.
- ■ 100 gallons per minute or more.
- ▩ 500 gallons per minute or more.

Location of other possible sand and gravel aquifers, where small industrial and municipal well development may be possible as are chances of obtaining wells with yields of:

- ▩ 20 gallons per minute or more.



Well Yields from Smith and Stall, 1975.

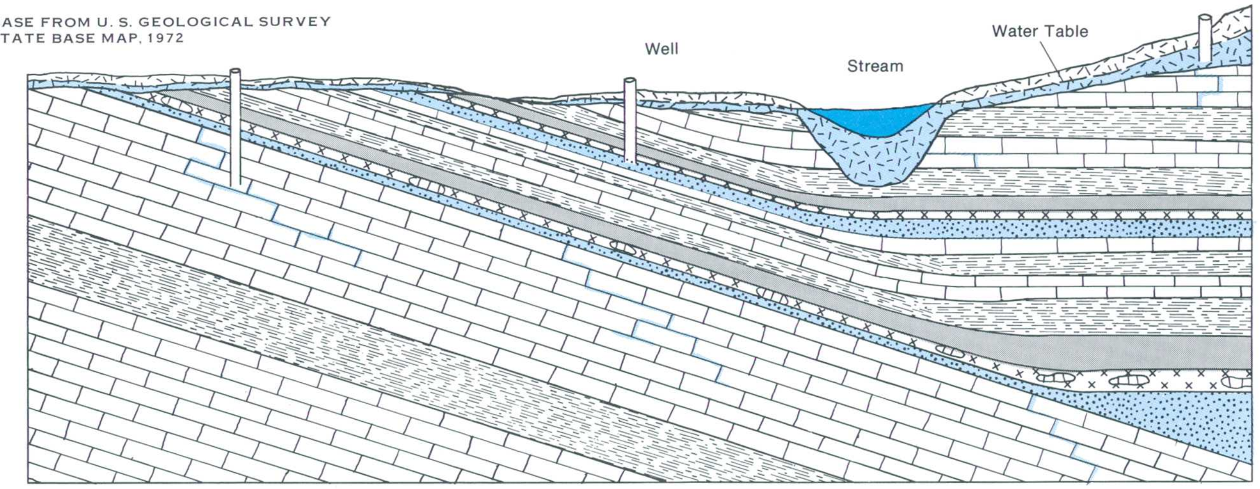
EXPLANATION

Chances of obtaining a well with yield of:

- 10 gallons per minute or more from Pennsylvanian sandstone and limestones are poor. ▩
- 20 gallons per minute or more from Mississippian limestones and sandstones are poor. ■
- 100 gallons per minute or more from shallow dolomites are good. ■
- 500 gallons per minute or more from shallow dolomites are good. ▩
- Geologic conditions generally favor development of unconsolidated deposits. ▩

Yields of wells in deep sandstone aquifers		North of line B-B′ deep sandstone wells will commonly yield 500 gallons per minute or more.
		Between lines E-E′ and B-B′ deep sandstone wells will commonly yield between 100 to 500 gallons per minute
		Between lines F-F′ and E-E′ deep sandstone wells will commonly yield less than 100 gallons per minute
	D-D′	Southern limit of potable waters (1500 milligrams per liter total solids) from deep sandstones.
	F-F′	Southern limit of use of water from deep sandstones.
Yields of wells in shallow dolomites and Mississippian and Pennsylvanian Aquifers	C-C′	Southern limit of potable waters (1500 milligrams per liter total solids) from shallow dolomites.

Figure 9.1-2 Bedrock well yields.



EXPLANATION

- ▨ Glacial Drift
- ▦ Limestone
- ■ Coal
- ▤ Shale
- ☒ Underclay
- ▩ Sandstone
- ☒ Limestone (nodular)

Figure 9.1-3 Hypothetical geologic cross-section showing ground water occurrence.

DISSOLVED-SOLIDS CONCENTRATIONS INCREASE WITH DEPTH

The mean concentration of dissolved solids is 415 milligrams per liter (mg/L) for water from wells in unconsolidated deposits and 1,600 mg/L for water from wells in bedrock. Iron concentrations exceed 0.3 mg/L in 63 percent of the wells sampled.

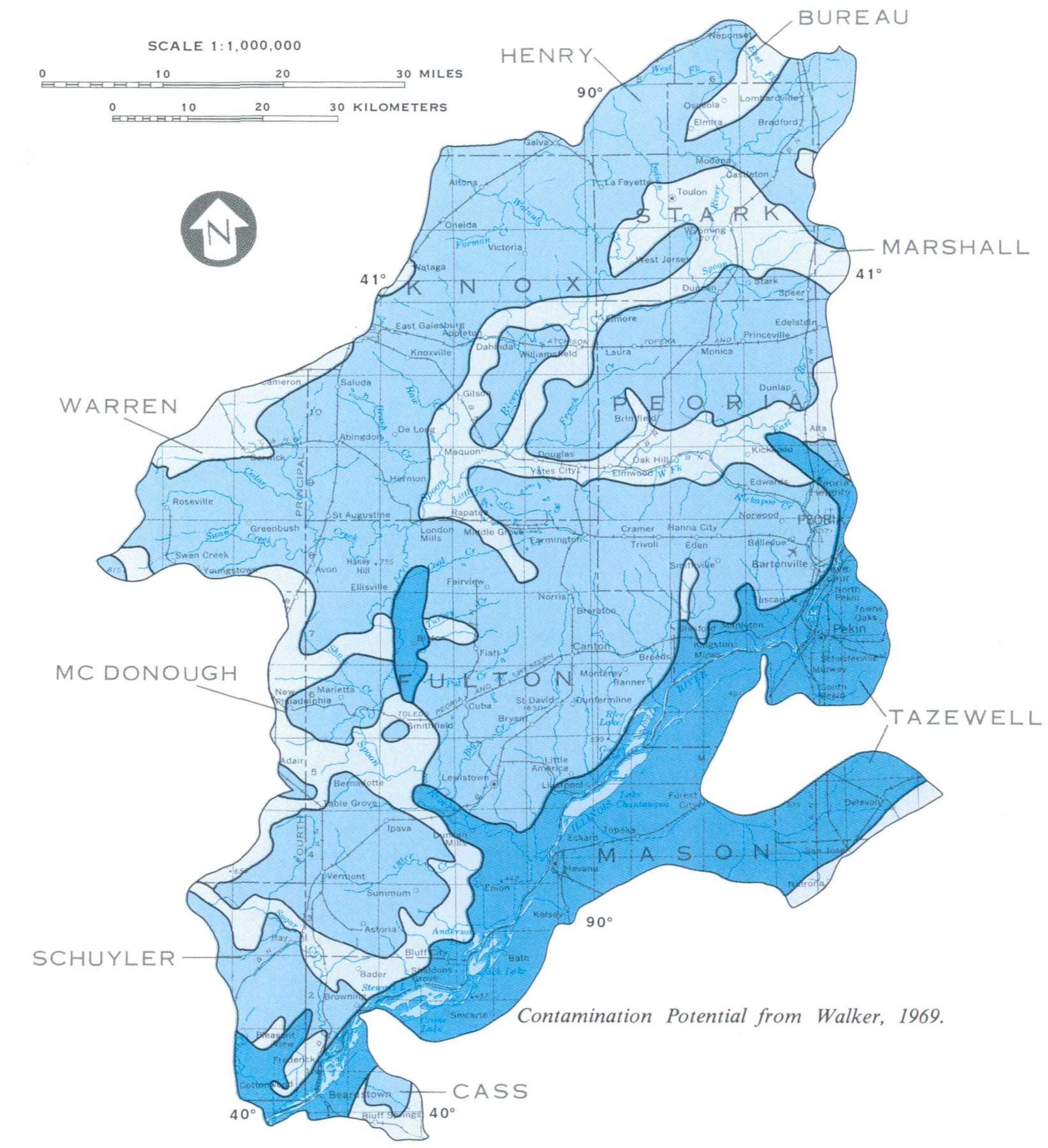
The concentration of dissolved solids in ground water of the study area tends to increase as depth increases. Dissolved solids concentrations in wells in unconsolidated deposits (drift) range from 197 to 658 milligrams per liter (mg/L) with a mean concentration of 415 mg/L. Dissolved solids concentrations in wells in bedrock range from 427 to 3,106 mg/L with a mean concentration of 1,600 mg/L (Larson, 1963). The National Secondary Drinking Water Regulations (U.S. Environmental Protection Agency, 1977) recommend 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).

In general, water in the study area ranges from hard (150 to 300 mg/L as calcium carbonate) to very hard (greater than 300 mg/L as calcium carbonate). Iron concentrations that exceed the 0.3 mg/L criterion for domestic water supplies (U.S. Environmental Protection Agency, 1976, p. 205) are common. Sixty-three percent of the municipal wells listed in table 9.2-1 had iron concentrations that exceeded 0.3 mg/L. The water from several of the wells is treated for softening and/or iron removal. Concentrations of selected constituents and corresponding U.S. Environmental Protection Agency (1976) water-quality criteria are given in table 9.2-1.

Walker (1969) (fig. 9.2-1) shows most of Area 25 has a moderate to high potential for chemical, thermal, or bacterial contamination of ground water. He considers the potential for contamination high where 1) the water table is near the land surface; 2) the permeability of material above the water table is high; or 3) bedrock is at or near the land surface.

Cartwright and others (1981, fig. 1, p. 14) have mapped geologic conditions relating to the feasibility of sanitary landfill sites in Illinois. They show favorable geologic conditions occur relating to the feasibility of sanitary landfill sites in areas which Walker (fig. 9.2-1) shows as having moderate potential for contamination.

Because both Walker and Cartwright used a regional approach in developing their maps, a detailed site-specific study would have to be made to determine the contamination potential of any specific site.



Contamination Potential from Walker, 1969.

BASE FROM U. S. GEOLOGICAL SURVEY
STATE BASE MAP, 1972

EXPLANATION

- ▇ **High potential contamination**
- ▆ **Moderate potential contamination**
- ▢ **Low potential contamination**

Figure 9.2-1 Ground water contamination potential.

Table 9.2-1 Concentrations (in milligrams per liter) of various constituents in municipal wells in Area 25 (from Larson, 1963).

City	Source	Iron Fe	Manganese Mn	Ammonium NH_4	Sodium Na	Calcium Ca	Magnesium Mg	Silica SiO_2	Boron B	Fluoride F	Nitrate NO_3	Chloride Cl	Sulfate SO_4	Alkalinity (as $CaCO_3$)	Total hardness	Total dissolved minerals	pH	Hydrogen sulfide H_2S	Temperature °F
Drinking water criteria		0.3	0.05						0.75	2.0	10.0	250	250		500				
Abingdon	S	0.7	0.0	1.1	320	84.4	33.4	14		3.5	0.9	160	566	232	349	1,324			71.5
Altona	L	0.3	0.0	0.8	348	12.1	2.8	15		2.8	0.7	159	39	536	42	920		X	61.0
Beardstown	D	0.6	0.3	Tr	26	97.4	0.3	16	0.3	0.2	1.2	39	124	260	388	512			
Bradford	LS	0.4	0.0	1.0	399	76.0	31.0	11		1.4	3.9	500	249	220	318	1,428			68.5
Creve Coeur	D	0.1	Tr	0.1	27	121.8	50.2	18	0.2	0.2	2.7	22	175	356	511	640			56.0
Cuba	L	0.6	0.0	1.8	544	169.8	68.0	10	0.7	2.8	0.8	370	1,109	216	704	2,482			
Delavan	D	0.2	Tr	1.5	3	77.0	29.6	26		0.2	0.8	2	1	320	314	328			54.5
Elmwood	LS	0.5	0.0	1.6	390	84.9	31.0	15		2.8	0.2	215	648	216	340	1,513			76.8
Fairview	S	3.5	2	1.5	388	94.1	38.5	12		3.5	2	210	670	248	394	1,584			71.8
Farmington	S	0.5	Tr	Tr	634	43.9	18.7	11	1.0	2.4	0.8	530	462	420	187	1,965			74.0
Galesburg	D	0.5	0.2	1.2	298	55.7	21.3	13		0.2	0.1	3	364	172	184	210			53.5
Galva	S	0.1	0.0	1.1	281	29.2	13.0	12		3.0	0.1	148	220	304	127	898			65.0
Glasford	S	1.0	0.0	1.6	586	57.5	18.9	14		4.0	0.1	450	565	276	222	1,866		X	70.0
Hanna City	S	2.0	0.0	1.8	420	68.9	27.8	14	1.0	3.5	0.7	233	619	232	287	1,543	6.9		76.0
Havana	D	0.4	0.1	Tr	2	44.9	15.6	19		0.1	0.2	3	25	152	177	197			
Ipava	S	0.3	0.0	1.9	771	158.4	60.8	13		4.0	Tr	780	968	220	646	2,953			69.5
Knoxville	S	0.7	0.0	1.2	307	49.0	23.0	14		2.6	0.9	190	375	228	217	1,101			68.5
London Mills	D	0.1	0.0	0.1	6	81.5	27.0	18	0.1	0.1	19.1	8	74	224	315	385			51.2
Maquon	L	0.5	0.0	0.9	694	9.5	4.5	11		3.5	0.2	490	213	640	43	1,822			61.9
North Pekin	D	Tr							0.1	0.1		27	157	300	460	585			56.0
Oneida	L	1.0	0.0	0.7	307	11.3	7.9	12		1.8	3.0	110	50	532	61	842	7.8		62.2
Pekin	D	0.3	0.0	Tr	36	104.0	37.7	17	0.3	0.1	8.9	29	151	288	415	567			57.0
Peoria	D	Tr	0.0	Tr	38	123.8	45.8	19	0.2	0.1	8.5	50	153	344	498	658			58.0
Princeville	S	0.7	0.0	1.2	412	82.3	32.2	14		2.4	2.7	185	730	216	339	1,604		X	68.0
Roseville	D	0.2	Tr	0.2	5	32.9	15.9	31		0.2	53.8	11	46	52	148	235	6.6		54.8
St. Augustine	L	9.5	0.0							0.4	0.1	1		444	304	427			54.0
St. David	D	2.6	0.1							0.3	1.3	2		364	368	394		X	54.5
San Jose	D	4.6	0.1	Tr	4	74.9	34.7	21	0.0	0.2	1.6	3	16	316	330	352			
Table Grove	S	3.0	0.0	1.5	834	156.0	69.3	9	2.1	4.0	1.2	835	1,013	260	675	3,106			68.0
Williamsfield	L	5.4	0.2	1.1	700	21.7	6.8	14		4.0	0.4	570	176	620	83	1,882		X	63.5
Wyoming	L	0.1	0.0	1.7	341	42.8	18.1	14		2.4	0.6	270	303	232	182	1,136	7.6	X	66.4
Yates City	D	Tr	0.0	Tr	1	74.8	29.2	22		0.1	16.5	6	33	252	307	329			53.8

SOURCE:
D - unconsolidated materials above the bedrock.
L - limestone deposits
S - sandstone deposits

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.

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

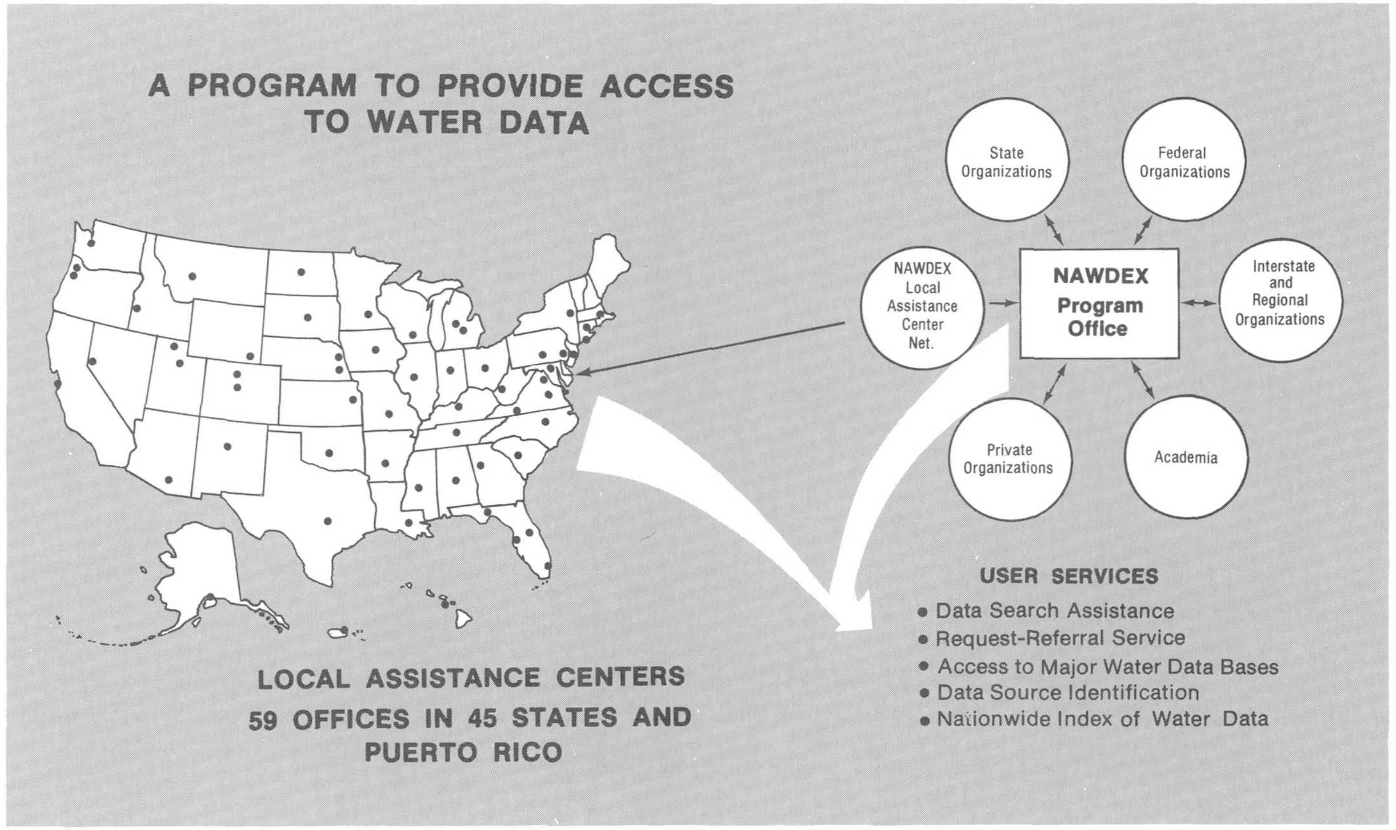


Figure 10.2-1 Access to water data.

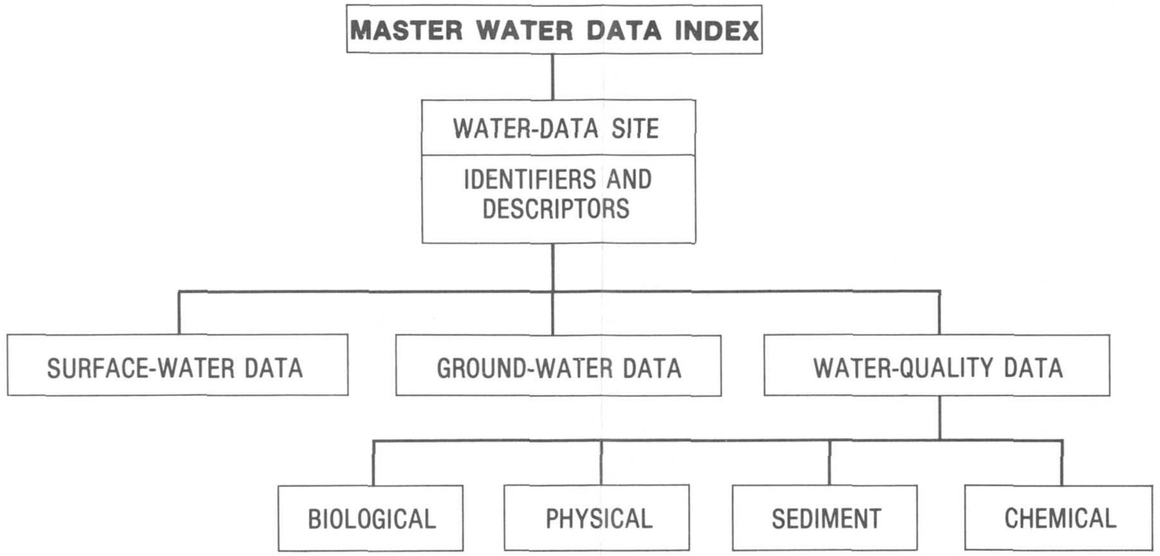


Figure 10.2-2 Master water-data index

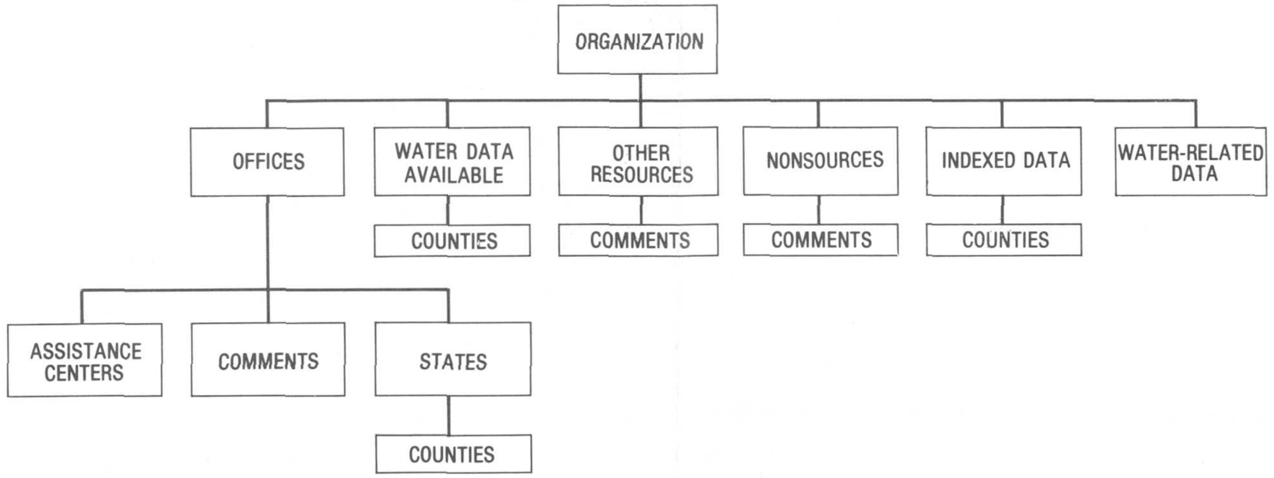


Figure 10.2-3 Water-data sources directory.

WATSTORE AUTOMATED DATA 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 accomodate 270 data elements and currently contains data for nearly 780,000 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 project, 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.

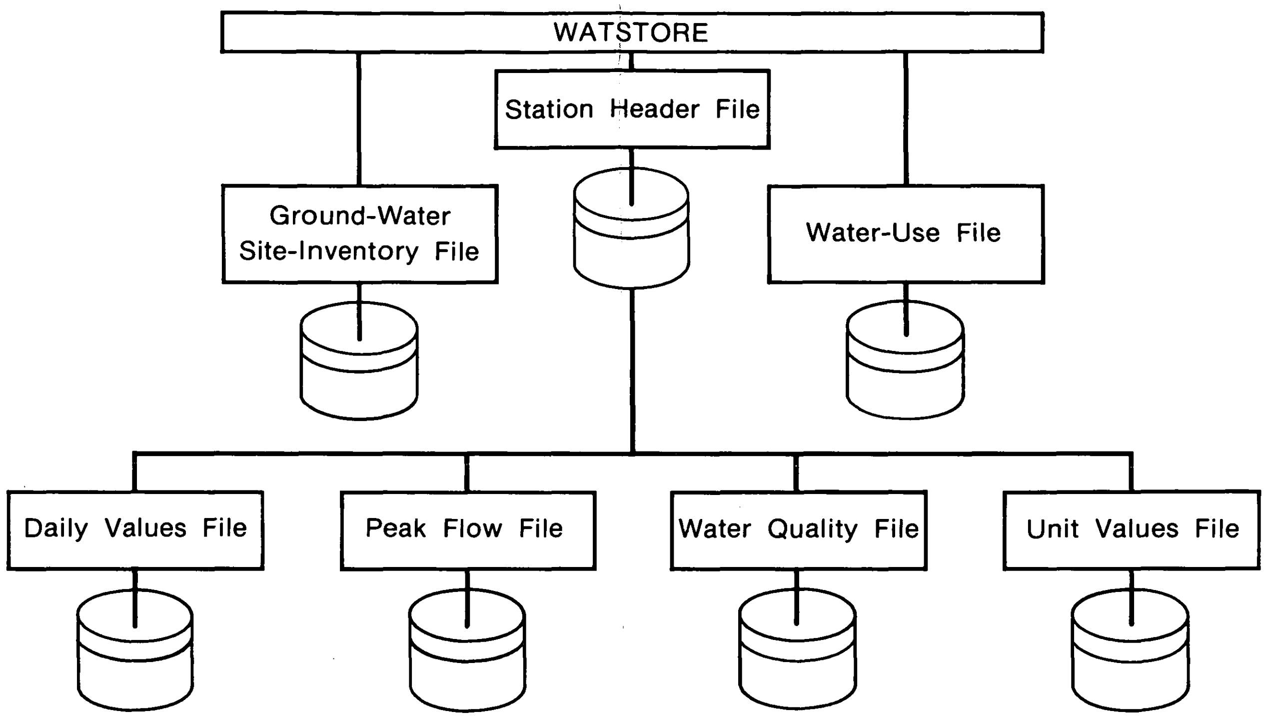


Figure 10.3-1 Files of stored data.

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

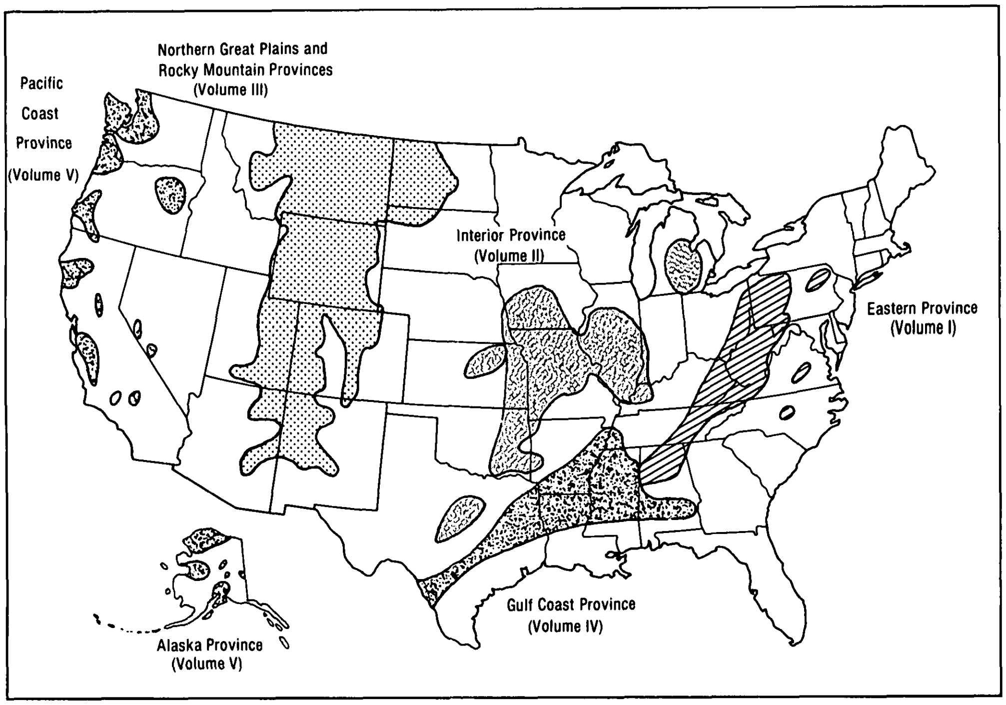


Figure 10.4-1 Index volumes and related provinces

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.

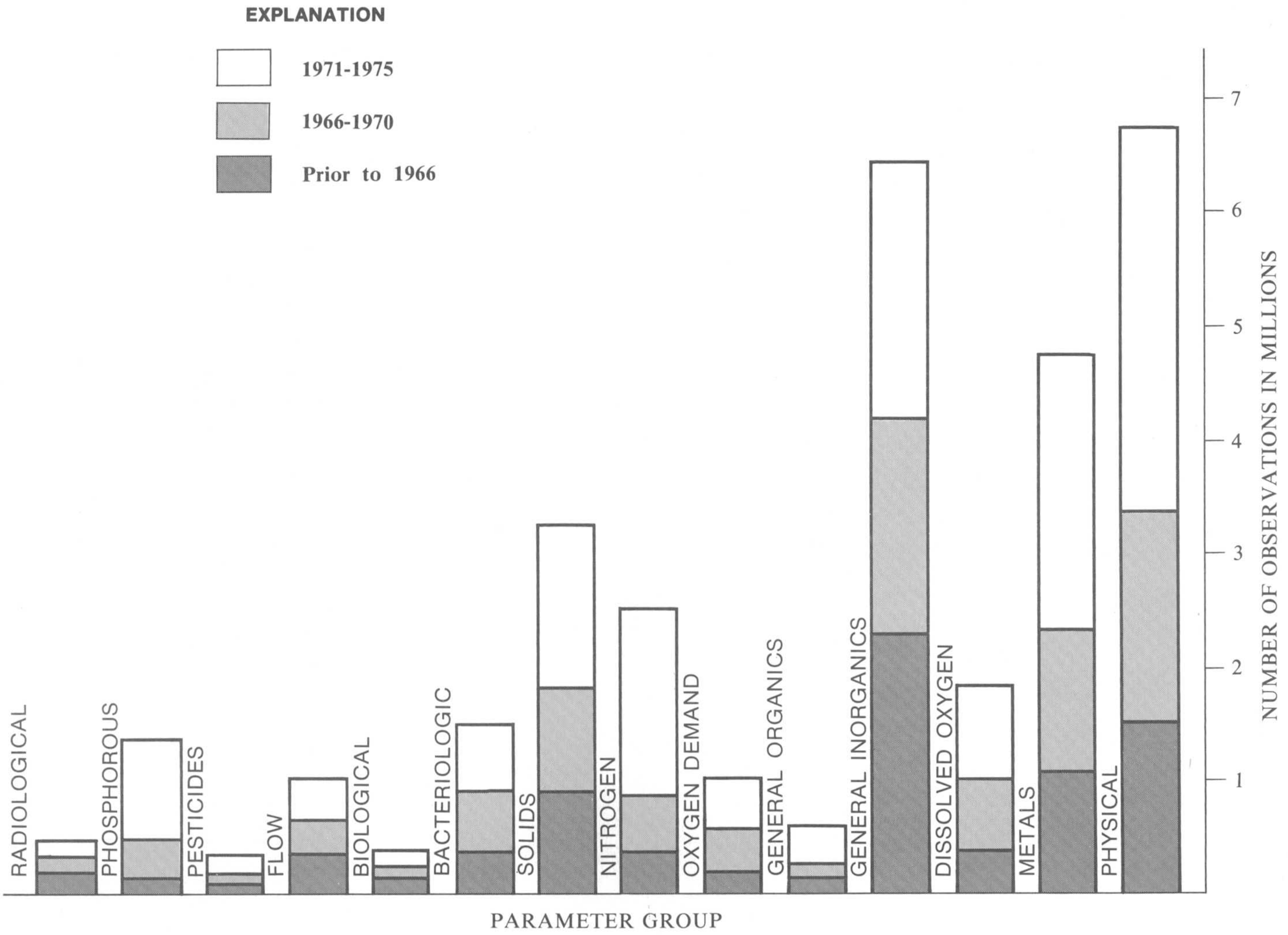


Figure 10.5-1 Parameter groups and number of observations in the Water Quality File.

11.0 LIST OF REFERENCES

American Public Health Association, 1976, Standard methods of the examination of water and wastewater: Washington, D.C. 1,193 p.

Andros, S. D., 1915, Coal mining in Illinois: Illinois State Geological Survey Coal Mining Investigation Bulletin 13, 250 p.

Atherton, Elwood and Palmer, J. E., 1979, The Mississippian and Pennsylvanian (carboniferous) systems in the United States - Illinois: Illinois State Geological Survey Reprint 1979 H, 42 p.

Bergstrom, R. E., 1956, Groundwater geology in western Illinois, north part: Illinois State Geological Survey Circular 222, 24 p.

Cartwright, Keros, Gilkeson, R. H., Griffen, R. A., Johnson, T. M., Lindorff, D. E., and DuMontelle, P. B., 1981, Hydrogeologic considerations in hazardous-waste disposal in Illinois: Illinois State Geological Survey Environmental Geology Notes 94, 20 p.

Curtis, G. W., 1977, Technique for estimating magnitude and frequency of floods in Illinois: U.S. Geological Survey Water Resources Investigations 77-117, 70 p.

Dawes, J. H., and Terstriep, M. L., 1966, Potential surface water reservoirs of north-central Illinois: Illinois State Water Survey Report of Investigation 56, 144 p.

Doyle, W. S., 1976, Strip mining of coal-- environmental solutions: Noyes Data Corporation, Park Ridge, N. J., 352 p.

Fehrenbacher, J. B., Jansen, I. J., Ray, B. W., Alexander, J. D., and Harris, T. S., 1977, Soil associations of Knox County, Illinois: University of Illinois at Urbana-Champaign College of Agriculture Special Publication 46, 27 p.

Fehrenbacher, J. B., Walker, G. O., and Wascher, H. L., 1967, Soils of Illinois: University of Illinois College of Agriculture, Agricultural Experiment Station, Urbana, IL., Bulletin 725, 47 p.

Frederick, R. H., Myers, V. A., and Auciello, E. P., 1977, Five-to-sixty minute precipitation frequency for the eastern and central United States: National Oceanic and Atmospheric Administration Technical Memorandum NWS HYDRO-35, 36 p.

Haynes, R. J., and Klimstra, W. D., 1975, Illinois lands surface mined for coal: Southern Illinois University, Cooperative Wildlife Research Laboratory, Carbondale, Ill., 201 p.

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

Herschfield, D. M., 1961, Rainfall frequency atlas of the United States, U.S. Weather Bureau Technical Paper No. 40, 115 p.

Hopkins, C. G., Mosier, J. G., Pettit, J. H., and Readhimer, J. E., 1913, Knox County soils: University of Illinois Agricultural Experiment Station, Soil Report No. 6, Urbana, Ill., 43 p.

Hopkins, M. E., 1975, updated 1980, Coal mines in Illinois map: Illinois State Geological Survey, scale, 1:500,000.

Illinois Conservation Needs Committee, 1970, Illinois soil and water conservation needs inventory: Cooperative Extension Service, College of Agriculture, University of Illinois, Urbana, Ill., 192 p.

Illinois Department of Mines and Minerals, 1979, Annual coal, oil, and gas report: 321 p.

Illinois Environmental Protection Agency, 1976, Water quality management basin plan--phase 1, Illinois River Basin: p. I-I-III-47.

Illinois Technical Advisory Committee on Water Resources, 1967, Water for Illinois - A plan for action: Illinois State Department of Business and Economic Development, 452 p.

Kirk, J. R., Jarboe, Jacquelyn, Sanderson, E. W., Sasman, R. T., and Sinclair, R. H., 1979, Water withdrawals in Illinois, 1978: Illinois State Water Survey Circular 140, 34 p.

Larson, T. E., 1963, Mineral content of public ground water supplies in Illinois: Illinois State Water Survey Circular 90, 28 p.

Lewis, J. W., ed., 1972, Illinois blue book: 856 p.

Lineback, J. A., 1979, Quaternary deposits of Illinois map: Illinois State Geological Survey, scale 1:500,000.

McKee, J. E., and Wolf, H. W., 1963, Water quality criteria, second edition: California State Water Resources Control Board Publication 3-A, 584 p.

Nawrot, J. R., Klimstra, W. D., Jenkusky, S. M., and Hickmann, T. J., 1980, Illinois State reclamation plan for abandoned mined land, resource document: Cooperative Wildlife Research Laboratory, Southern Illinois University, Carbondale, IL., 254 p.

Petrucci, R. H., 1972, General chemistry: The MacMillan Company, New York, N.Y., 637 p.

Piskin, Kemal and Bergstrom, R. E., 1975, Glacial drift in Illinois--thickness and character: Illinois State Geological Survey Circular 490, 35 p.

Rankama, Kalervo and Sahama T. G., 1950, Geochemistry: The University of Chicago Press, 912 p.

Rickert, D. A., Ulman, W. J., and Hampton, E. R., 1979, Synthetic fuels development-- Earth science considerations: U.S. Geological Survey Special Report, 45 p.

Rockford Map Publishers, Inc., 1973, Illinois State atlas: Rockford, IL., 260 p.

Seiber, C. R., 1970, A proposed streamflow data program for Illinois: U.S. Geological Survey Open-File Report 19-21, 73 p.

Smith, R. S., and Wascher, Herman, 1937, Peoria County soils-- revised descriptions and recommendations for use and management: University of Illinois Agricultural Experiment Station, Urbana, IL., 12 p.

Smith, R. S., De Turk, E. E., Bauer, F. C., and Smith, L. H., 1924, Mason County soils: University of Illinois Agricultural Experiment Station Soil Report No. 28, Urbana, IL., 62 p.

----, 1932, Fulton County soils: University of Illinois Agricultural Experiment Station Soil Report No 51, Urbana, 48 p.

Smith, W. H., and Berggren, D. J., 1963, Strippable coal reserves of Illinois, part 5A-Fulton, Henry, Knox, Peoria, Stark, Tazewell, and parts of Bureau, Marshall, Mercer, and Warren Counties: Illinois State Geological Survey Circular 348, 59 p.

Smith, W. H., and Stall, J. B., 1975, Coal and water resources for coal conversion in Illinois: Illinois State Water Survey and Illinois State Geological Survey, Cooperative Resources Report 4, 79 p.

Thornburn, T. H., 1963, Surface deposits of Illinois - a guide for soil engineers: University of Illinois Engineering Experiment Station Circular No. 80, Urbana, IL., 135 p.

Toler, L. G., 1980, Some chemical characteristics of mine drainage in Illinois: U. S. Geological Survey Open-File Report 80-416, 47 p.

Treworgy, C. G., Bengal, L. E., and Dingwell, A. G., 1978, Reserves and resources of surface-minable coal in Illinois: Illinois State Geological Survey Circular 504, 44 p.

United States Department of Agriculture, Soil Conservation Service, 1976, Soil survey of Stephenson County, Illinois: Soil Report No. 99, 133 p.

----, 1977, Soil survey of Rock Island County, Illinois: Soil Report No. 97, 140 p.

----, 1980, Soil survey of Ogle County, Illinois: Soil Reort No. 113, 242 p.

U.S. Environmental Protection Agency, 1976, Quality criteria for water: 256 p.

----, 1977, National secondary drinking water regulations: Federal Register, v. 42, no. 62, Thursday, March 31, 1977, Part I, p. 17143-17147.

U.S. Geological Survey, 1980, Water resources data for Illinois, water year 1979, volume I, Illinois except Illinois River basin: Champaign, Ill., U.S. Geological Survey Water Data Report IL-79-1, 491 p.

----, 1980, Water resources data for Illinois, water year 1979, volume 2, Illinois River basin: Champaign, Ill., U.S. Geological Survey Water Data Report IL-79-2, 401 p.

Walker, W. H., 1969, Illinois ground water pollution: Journal of the American Water Works Association, v. 61, no. 1, p. 31-40.

William, H. B., 1973, Geology along the Illinois waterway-a basis for environmental planning: Illinois State Geological Survey Circular 478, 48 p.

----, 1975, Illinois stratigraphy: Illinois State Geological Survey Bulletin 95, 261 p.

William, H. B., and Frye, J. C., 1970, Pleistocene stratigraphy of Illinois: Illinois State Geological Survey Bulletin 94, 204 p.

William, H. B., and others, 1967, Geologic map of Illinois: Illinois State Geological Survey, scale 1:500,000.

Winters, Eric, Smith, R. S., and Smith, L. H., 1939, Stark County soils: University of Illinois Agricultural Experiment Station Soil Report No. 64, Urbana, IL., 26 p.

Wischmeier, W. H. and Smith, D. D., 1978, Predicting rainfall erosion losses -a guide to conservation planning: U.S. Department of Agriculture, Agriculture Handbook Number 537, 58 p.

12.0 APPENDIX

12.1 Surface-Water Stations within the Study Area

Map No.	Station No.	Station name and location
1	05563000	Kickapoo Creek near Kickapoo, Ill. Lat 40°48'00", long 89°48'00", in SW¼SE¼ sec.34, T.10 N., R.6 E., Peoria County.
2	05563500	Kickapoo Creek at Peoria, Ill. Lat 40°40'52", long 89°39'19", in NE¼NW¼ sec.13, T.8 N., R.7 E., Peoria County.
3	05568450	Little Lamarsh Creek at Mapleton, Ill. Lat 40°33'48", long 89°44'36", in NW¼NE¼ sec.30, T.7 N., R.7 E., Peoria County.
4	05568500	Illinois River at Kingston Mines, Ill. Lat 40°33'10", long 89°46'40", in SE¼SE¼ sec.26, T.7 N., R.6 E., Peoria County.
5	05568660	Duck Creek near Liverpool, Ill. Lat 40°26'45", long 89°58'18", in SW¼NW¼ sec.5, T.5 N., R.5 E., Fulton County.
6	05568675	Buckheart Creek near Liverpool, Ill. Lat 40°25'13", long 90°00'30", in SW¼NW¼ sec.13, T.5 N., R.4 E., Fulton County.
7	05568765	East Fork Spoon River at Modena, Ill. Lat 41°08'53", long 89°45'30", in SW¼SE¼ sec.36, T.14 N., R.6 E., Stark County.
8	05568770	Spoon River at Modena, Ill. Lat 41°08'08", long 89°45'38", in SE¼ sec.1, T.13 N., R.6 E., Stark County.
9	05568772	Jack Creek at Modena, Ill. Lat 41°08'05", long 89°46'40", in NW¼NE¼ sec.11, T.13N.,R.6 E., Stark County.
10	05568775	Spoon River near Wyoming, Ill. Lat 41°03'47", long 89°47'43", in SE¼SE¼ sec.34, T.13 N., R.6 E., Stark County.
11	05568778	Spoon River near Stark, Ill. Lat 41°01'05", long 89°46'12", in NW¼NW¼ sec.24, T.12 N., R.6 E., Stark County.
12	05568800	Indian Creek near Wyoming, Ill. Lat 41°01'06", long 89°50'07", in SE¼SE¼ sec.17, T.12 N., R.6 E., Stark County.
13	05568855	Walnut Creek near Victoria, Ill. Lat 41°04'14", long 90°02'33", in SE¼NE¼ sec.33, T.13 N., R.4 E., Knox County.
14	05568860	Walnut Creek near West Jersey, Ill. Lat 41°01'05", long 89°57'43", in NW¼ sec.20, T.12 N., R.5 E., Stark County.
15	05568895	Snakeden Hollow near Dahinda, Ill. Lat 40°57'34", long 90°04'15", in NE¼NW¼ sec.8, T.11 N., R.4 E., Knox County.

12.0 APPENDIX

12.1 Surface-Water Stations within the Study Area (Continued)

Map No.	Station No.	Station name and location
16	05568910	Sugar Creek at Dahinda, Ill. Lat 40°55′40″, long 90°07′00″, in SW¼NW¼ sec.24, T.11 N., R.3 E., Knox County.
17	05568935	Hickory Creek near Douglas, Ill. Lat 40°46′36″, long 90°06′03″, in NW¼SW¼ sec.7, T.9 N., R.4 E., Knox County.
18	05568940	Hickory Creek near Maquon, Ill. Lat 40°46′43″, long 90°08′07″, in W½ sec.11, T.9 N., R.3 E., Knox County.
19	05569450	Littlers Creek near Rapatee, Ill. Lat 40°44′53″, long 90°09′28″, in SW¼ sec.22, T.9 N., R.3 E., Knox County.
20	05569455	Littlers Creek near Maquon, Ill. Lat 40°44′08″, long 90°12′00″, in NE¼SE¼ sec.30, T.9 N., R.3 E., Knox County.
21	05569500	Spoon River at London Mills, Ill. Lat 40°42′51″, long 90°16′00″, in NW¼NE¼ sec.3, T.8 N., R.2 E., Fulton County.
22	05569520	Spoon River at Route 116 bridge at London Mills, Ill. Lat 40°42′31″, long 90°16′53″, in NW¼ sec.4, T.8 N., R.2 E., Fulton County.
23	05569920	Coal Creek near Fairview, Ill. Lat 40°39′33″, long 90°14′00″, in NE¼SE¼ sec.23, T.8 N., R.2 E., Fulton County.
24	05569953	Put Creek near Canton, Ill. Lat 40°34′17″, long 90°06′51″, in NE¼SW¼ sec.24, T.7 N., R.3 E., Fulton County.
25	05569960	Put Creek near Cuba, Ill. Lat 40°31′27″, long 90°11′55″, in SW¼sec.6, T.6 N., R.2 E., Fulton County.
26	05569968	Turkey Creek near Fiatt, Ill. Lat 40°35′22″, long 90°13′50″, in SW¼NW¼ sec.13, T.7 N., R.2 E., Fulton County.
27	05569970	Turkey Creek near Blyton, Ill. Lat 40°33′26″, long 90°15′40″, in SE¼ sec.27, T.7 N., R.2 E., Fulton County.
28	05570000	Spoon River at Seville, Ill. Lat 40°29′24″, long 90°20′26″, in NW¼ sec.24, T.6 N., R.1 E., Fulton County.
29	05570330	West Branch Big Creek near Canton, Ill. Lat 40°34′53″, long 90°04′27″, in NE¼ sec.20, T.7 N., R.4 E., Fulton County.
30	05570350	Big Creek at St. David, Ill. Lat 40°29′51″, long 90°03′12″, in S½SE¼ sec.16, T.6 N., R.4 E., Fulton County.

Map No.	Station No.	Station name and location
31	05570360	Evelyn Branch near Bryant, Ill. Lat 40°29′15″, long 90°06′08″, in NW¼SW¼ sec.19, T.6 N., R.4 E., Fulton County.
32	05570370	Big Creek near Bryant, Ill. Lat 40°27′32″, long 90°08′00″, in center of sec.35, T.6 N., R.3 E., Fulton County.
33	05570380	Slug Run near Bryant, Ill. Lat 40°28′24″, long 90°08′37″, in SE¼NE¼ sec.27, T.6 N., R.3 E., Fulton County.
34	05570500	Illinois River at Havana, Ill. Lat 40°17′54″, long 90°04′04″, in SW¼ sec.1, T.21 N., R.9 W., Mason County.
35	05570570	Otter Creek near Vermont, Ill. Lat 40°17′29″, long 90°23′38″, in SE¼SE¼ sec.28, T.4 N., R.1 E., Fulton County.

12.0 APPENDIX

12.2 Surface-Water Stations near the Study Area used for Water-Discharge Analysis

Map No.	Station No.	Station name and location
36	05443500	Rock River at Como, Ill. Lat 41°47'00", long 89°44'58", in NE¼ sec.25, T.21 N., R.6 E., Whiteside County.
37	05445500	Rock Creek near Morrison, Ill. Lat 41°49'50", long 89°58'00", in SW¼SE¼ sec.6, T.21 N., R.5 E., Whiteside County.
38	05446500	Rock River near Joslin, Ill. Lat 41°33'35", long 90°10'55", in NE¼ sec.18, T.18 N., R.3 E., Rock Island County.
39	05447500	Green River near Geneseo, Ill. Lat 41°29'20", long 90°09'30", in NE¼SW¼ sec.4, T.17 N., R.3 E., Henry County.
40	05448000	Mill Creek at Milan, Ill. Lat 41°26'35", long 90°33'15", in SW¼SE¼ sec.24, T.17 N., R.2 W., Rock Island County.
41	05466000	Edwards River near Orion, Ill. Lat 41°16'20", long 90°22'40", in NE¼SE¼ sec.21, T.15 N., R.1 E., Henry County.
42	05466500	Edwards River near New Boston, Ill. Lat 41°11'15", long 90°58'05", at quarter corner between secs.21 and 28, T.14 N., R.5 W., Mercer County.
43	05467000	Pope Creek near Keithsburg, Ill. Lat 41°07'45", long 90°55'14", in SE¼ sec.11, T.13 N., R.5 W., Mercer County.
44	05469000	Henderson Creek near Oquawka, Ill. Lat 41°00'05", long 90°51'15", in NE¼SW¼ sec.28, T.12 N., R.4 W., Henderson County.
45	05556500	Big Bureau Creek at Princeton, Ill. Lat 41°21'55", long 89°29'55", in SW¼SE¼ sec.18, T.16 N., R.9 E., Bureau County.
46	05560500	Farm Creek at Farmdale, Ill. Lat 40°40'00", long 89°30'15", in NE¼SE¼ sec.36, T.26 N., R.4 W., Tazewell County.
47	05561000	Ackerman Creek at Farmdale, Ill. Lat 40°39'43", long 89°30'13", in SE¼SE¼ sec.36, T.26 N., R.4 W., Tazewell County.
48	05561500	Fondulac Creek near East Peoria, Ill. Lat 40°40'38", long 89°31'52", on line between SW¼ and SE¼ sec.26, T.26 N., R.4 W., Tazewell County.
49	05562000	Farm Creek at East Peoria, Ill. Lat 40°40'04", long 89°34'40", in SW¼NW¼ sec.33, T.26 N., R.4 W., Tazewell County.

12.0 APPENDIX

12.2 Surface-Water Stations near the Study Area used for Water-Discharge Analysis (Continued)

Map No.	Station No.	Station name and location
50	05564400	Money Creek near Towanda, Ill. Lat 40°36′19″, long 88°53′56″, in SW¼SW¼ sec.20, T.25 N., R.3 E., McLean County.
51	05566500	East Branch Panther Creek at El Paso, Ill. Lat 40°45′15″, long 89°00′20″, at line between secs.32 and 33, T.27 N., R.2 E., Woodford County.
52	05567500	Mackinaw River near Congerville, Ill. Lat 40°37′25″, long 89°14′30″, in NE¼SW¼ sec.17, T.25 N., R.1 W., Woodford County.
53	05584400	Drowning Fork at Bushnell, Ill. Lat 40°33′45″, long 90°31′23″, in NE¼SE¼ sec.29, T.7 N., R.1 W., McDonough County.
54	05584500	La Moine River at Colmar, Ill. Lat 40°19′45″, long 90°53′55″, in SE¼SW¼ sec.18, T.4 N., R.4 W., McDonough County.
55	05585000	La Moine River at Ripley, Ill. Lat 40°01′31″, long 90°37′55″, in NE¼ sec.33, T.1 N., R.2 W., Brown County.

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HYDROLOGY OF AREA 25, EASTERN REGION, INTERIOR COAL PROVINCE, ILLINOIS WRI 81-636