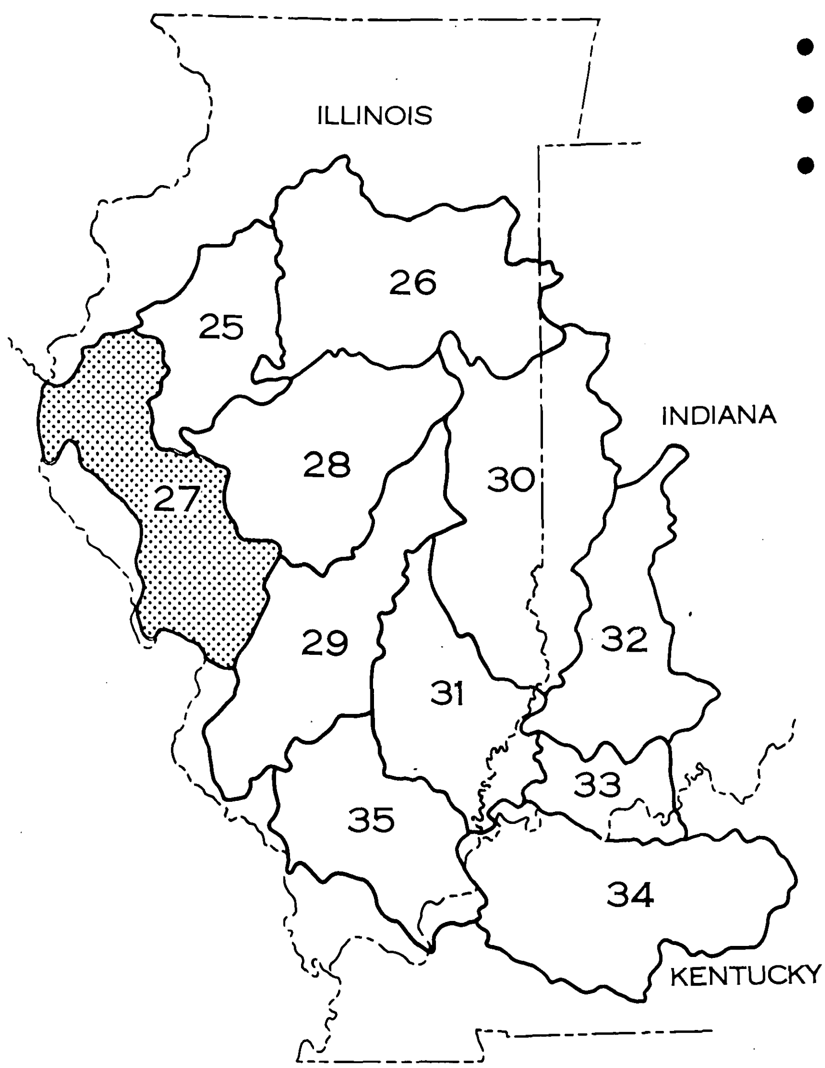
HYDROLOGY OF AREA 27, EASTERN REGION, INTERIOR COAL PROVINCE, ILLINOIS



- LA MOINE RIVER
- ILLINOIS RIVER
- MACOUPIN CREEK

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

WATER-RESOURCES INVESTIGATIONS
OPEN-FILE REPORT 84-707

HYDROLOGY OF AREA 27, EASTERN REGION, INTERIOR COAL PROVINCE, ILLINOIS

BY
E. E. ZUEHLS

U. S. GEOLOGICAL SURVEY

WATER-RESOURCES INVESTIGATIONS
OPEN-FILE REPORT 84-707

URBANA, ILLINOIS
JANUARY 1987

UNITED STATES DEPARTMENT OF THE INTERIOR

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GEOLOGICAL SURVEY

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CONTENTS

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

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

Multiply	By	To obtain
inch (in.)	25.4	millimeter (mm)
inch per hour (in/h)	25.4	millimeter per hour (mm/h)
	2.54	centimeter per hour (cm/h)
foot (ft)	0.3048	meter (m)
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
cubic yard (yd^3)	0.7646	cubic meter (m^3)
gallon per minute (gal/min)	0.06308	liter per second (L/s)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/sec)
	3,785	cubic meter per day (m^3/d)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
cubic foot per second per square mile (ft^3/s)/mi^2	0.01093	cubic meter per second per square kilometer (m^3/s)/km^2
ton, short	0.9072	megagram (Mg)
ton per square mile per year (ton/mi^2/yr)	0.3503	megagram per square kilometer per year (Mg/km^2/a)
degree Fahrenheit (°F)	°C=5/9 (°F−32)	degree Celsius (°C)
micromho per centimeter at 25° Celsius (μmho/cm)	1.000	microsiemens per centimeter at 25° Celsius (uS/m)

GLOSSARY

Alkalinity—In this report, it is the capacity of a solution to neutralize acid to pH of 4.5.

Dissolved—That material in a representative water sample which passes through a 0.45 μm membrane filter. This is a convenient operational definition used by Federal agencies that collect water data. Determinations of "dissolved" constituents are made on subsamples of the filtrate.

Dissolved solids—A measure of total concentration of dissolved minerals in water.

Flow duration—The percent of time a given discharge at a streamflow site will be equaled or exceeded.

pH—The negative logarithm to base 10 of the effective hydrogen ion activity in moles per liter.

Specific conductance—A measure of the ability of a water to conduct an electrical current. It is expressed in micromhos per centimeter at 25°C. Specific conductance is related to the type and concentration of ions in solution.

Suspended sediment—Solid material that originates mostly from disintegrated rocks and is transported by or suspended in water; it includes chemical and biochemical precipitates and decomposed organic material such as humus.

Suspended-sediment concentration—The concentration of suspended sediment in the sampled zone measured as milligrams of dry sediment per liter of the water-sediment mixture.

Suspended-sediment load—The amount of suspended sediment passing a section in a specified period.

Suspended-sediment yield—The suspended-sediment load divided by the drainage area.

Total recoverable—The amount of a given constituent that is in solution after a representative water-suspended sediment sample has been digested by a method (usually using dilute acid solution) that results in dissolution of only readily soluble substances. Complete dissolution of all particulate matter is not achieved by the digestion treatment, and thus the determination represents something less than the "total" amount (that is, less than 95 percent) of the constituent present in the dissolved and suspended phases of the sample. To achieve comparability of analytical data, equivalent digestion procedures would be required of all laboratories performing such analyses because different digestion procedures are likely to produce different analytical results.

$V_{7,10}$ *high flow*—The highest 7-day mean discharge expected to be equaled or exceeded once in a 10-year period.

$M_{7,10}$ *low flow*—The lowest 7-day mean discharge expected to be equaled or exceeded once in a 10-year period.

HYDROLOGY OF AREA 27, EASTERN REGION, INTERIOR COAL PROVINCE, ILLINOIS

BY
E. E. ZUEHLS

ABSTRACT

The "Surface Mining Control and Reclamation Act of 1977" created a need for hydrologic information and analysis related to surface mining. This report broadly characterizes the hydrology of Area 27, 1 of 11 areas in the Eastern Region of the Interior Coal Province to meet that need. Area 27 is located in west-central Illinois and includes an area of 5,805 square miles. The hydrology of Area 27 is presented in a series of independent sections, each with a brief text and accompanying illustration(s) on a single water-resource-related topic.

Major streams in Area 27 are the La Moine River and Macoupin Creek, which drain into the Illinois River, and the lower Illinois River, Bear Creek, and Cahokia Creek, which drain directly into the Mississippi River. Agriculture is the dominant land use, 59.9 percent of which is cropland and 15.6 percent pasture. Average annual precipitation ranges from 35 to 38.5 inches.

Glacial till underlies 5 to 15 feet of loess in the area. The Pennsylvanian System of rocks, which consists of sandstone, limestone, siltstone, shale, clay, and coal, underlies about two-thirds of the area. Two underground mines and one surface mine were in operation as of December 1983. Land subsidence from underground mining has been a local problem for seven communities in Macoupin and Madison Counties.

The U.S. Geological Survey operates a network of streamflow and water-quality stations in the study area. Data from this network are available from computer storage through the National Water-Data Exchange (NAWDEX) managed by the U.S. Geological Survey.

Average flow and floodflow values are available for 11 streamflow stations in the area and can be estimated at ungaged sites. Flow-duration curves indicate that for gaging stations having drainage areas less than 100 square miles, flows are less than 0.05 cubic foot per second 10 percent of the time.

Surface-water-quality samples were collected at 23 sites. Water samples were analyzed for specific conductance, pH, alkalinity, dissolved sulfate, total recoverable and dissolved iron and manganese, dissolved solids, and other properties and constituents. For area streams, specific conductance values ranged from 48 to 1,580 micromhos per centimeter at 25° Celsius, and pH ranged from 4.9 to 9.1. Average values of total-recoverable iron and manganese commonly exceeded the U.S. Environmental Protection Agency maximum criteria of 1,000 micrograms per liter and 50 micrograms per liter, respectively.

Ground water is present in unconsolidated and bedrock aquifers throughout the area. Water taken from deep bedrock aquifers is highly mineralized. All but 1 of 34 ground-water sampling sites had moderate to very hard water.

1.0 INTRODUCTION

1.1 Objective

Area 27 Report to Aid Permitting

Hydrologic information provided in this report partially meets the needs set forth by the "Surface Mining Control and Reclamation Act of 1977."

A need for hydrologic information and analysis on a scale never before required nationally, was initiated when the "Surface Mining Control and Reclamation Act of 1977" was signed into law as Public Law 95-87 on August 3, 1977. This need is partially met by this report, which broadly characterizes the hydrology of Area 27 in the Eastern Region of the Interior Coal Province in west-central Illinois (fig. 1.1-1). This report, one of a series that covers the coal provinces nationwide, contains a brief text with an accompanying map, chart, graph, or other illustration for each of a number of water-resources-related topics. The topical discussions describe the hydrology of the area.

The hydrologic information presented here, or available through sources identified in this report, may be used to describe the hydrology of the "general area" of any proposed mine. This hydrologic information, along with the lease applicant's site-specific data and data from other sources, will 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 preparing permit applications, and to regulatory authorities in appraising the adequacy of the applications.

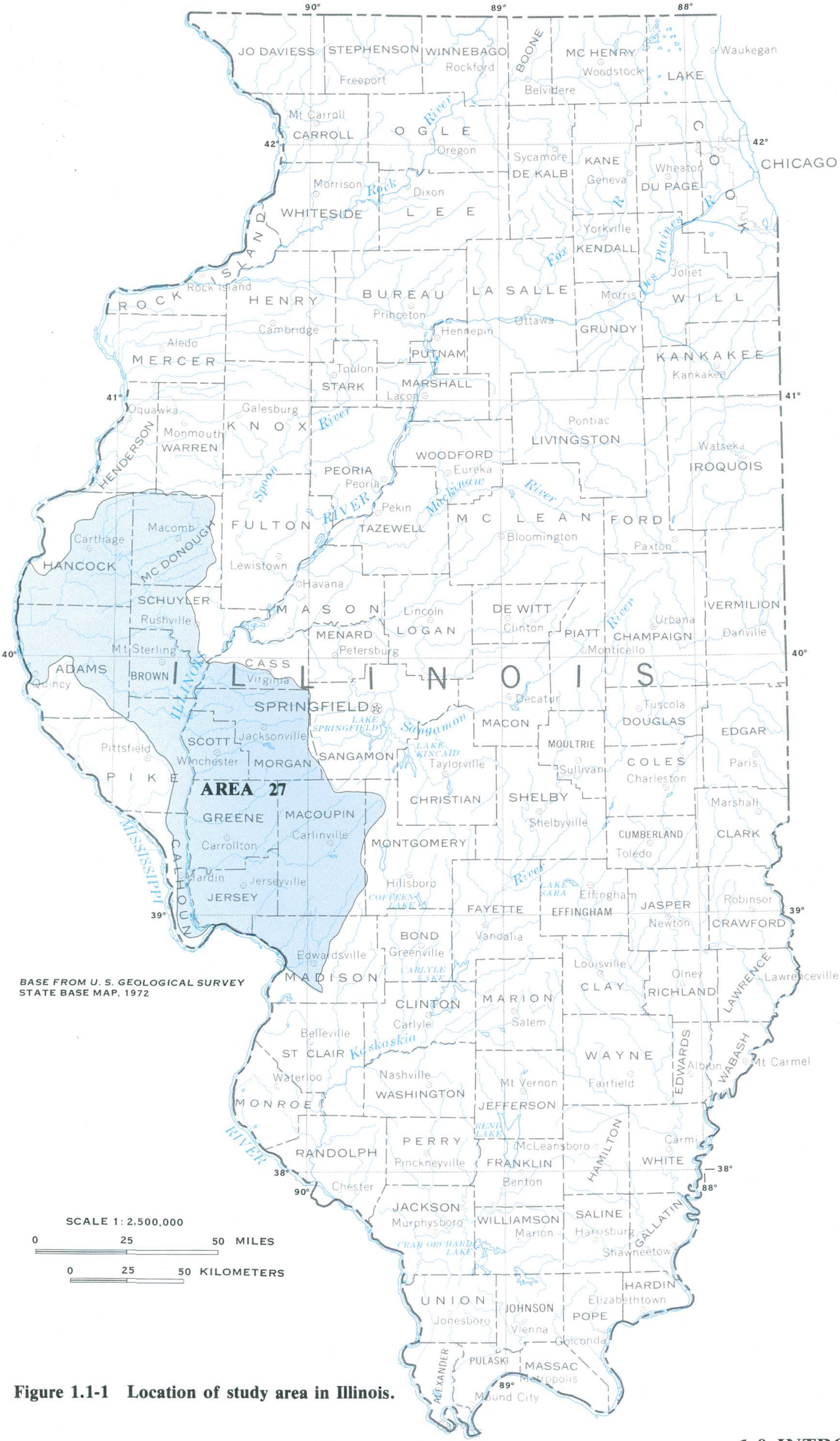


Figure 1.1-1 Location of study area in Illinois.

1.0 INTRODUCTION

1.1 Objective

Area 27 is Located in the Eastern Region of the Interior Coal Province

The area is located in west-central Illinois on the western edge of the Eastern Interior Coal Field and includes parts of two physiographic provinces.

The Eastern Region of the Interior Coal Province (fig. 1.2-1), commonly called the Eastern Interior Coal Field (Smith and Stall, 1975, second printing 1977) has been divided into 11 hydrologic study areas. The areas are delineated on the basis of hydrologic factors, location, and size. Drainage areas are combined to form each study area. The major streams included in Area 27 are the La Moine River and Macoupin Creek, which drains into the Illinois River, and the lower Illinois River, Bear Creek, and Cahokia Creek, each of which drains into the Mississippi River (fig. 1.2-2).

The area includes parts of the Central Lowlands and Ozark Plateau physiographic provinces (Willman and others, 1975) (fig. 1.2-3). The Central Lowlands Province includes the Till Plains Section including the Galesburg Plain, the Springfield Plain, and the Dissected Till Plains Section. The Ozark Plateau Province includes part of the Lincoln Hills Section, which is deeply dissected and has flat-lying rock strata.

Area 27 covers 5,805 square miles. It includes all of Scott, Greene, Jersey, and Brown Counties and parts of St. Clair, Madison, Macoupin, Montgomery, Calhoun, Pike, Morgan, Adams, Hancock, Henderson, Warren, McDonough, Schuyler, and Cass Counties. Most of the area has very little relief. However, relief is almost 200 feet along the Mississippi River and the Illinois River and 400 feet locally in Calhoun and Jersey Counties.

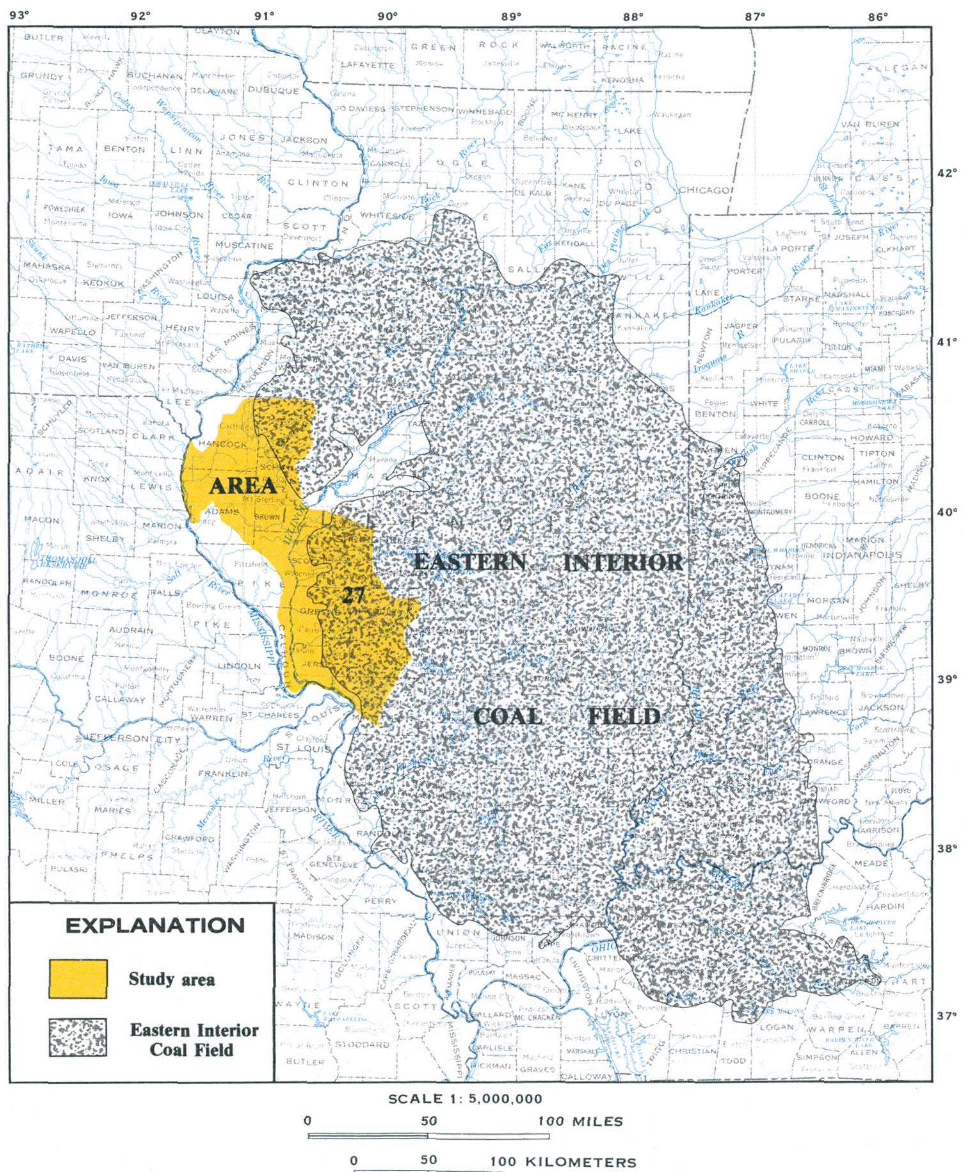


Figure 1.2-1 Location of the study area in the Eastern Interior Coal Field.

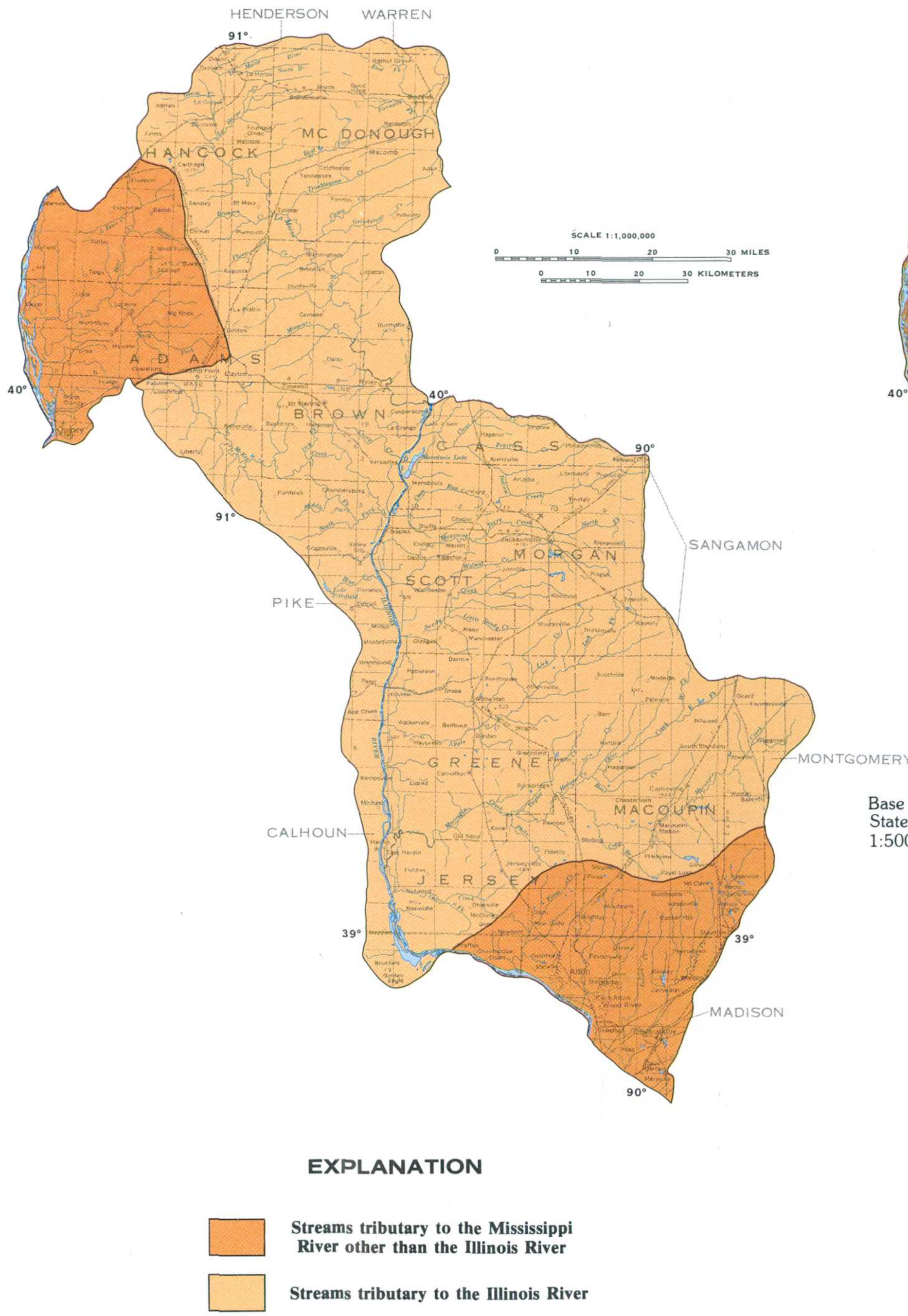


Figure 1.2-2 Major streams and drainage basins.

Base from U.S. Geological Survey
State base maps,
1:500,000; Illinois 1972

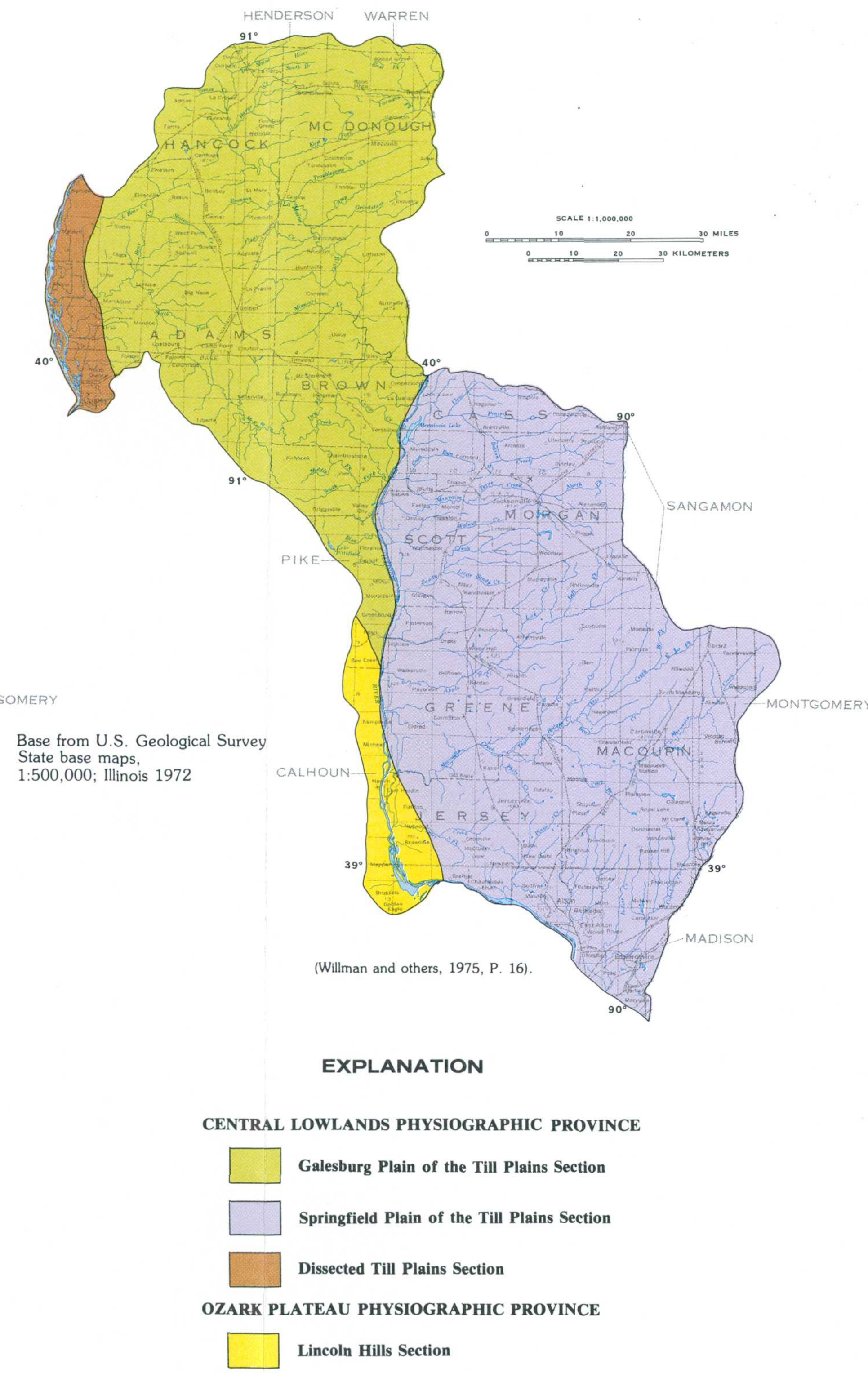


Figure 1.2-3 Physiographic divisions.

2.0 COAL MINING POTENTIAL AND HISTORY

Area 27 is Rich in Energy Resources

Two-thirds of Area 27 is underlain with coal reserves. Coal is produced by surface and undergound mining in the area. Land subsidence has been a problem in some areas.

Identifiable coal reserves in Area 27, as of January 1976, totaled about 13.4 billion tons. About 33.6 percent of these reserves could be extracted by surface mining (Smith and Stall, 1975, second printing 1977). These reserves and the active mines in the area are shown in figure 2.0-1. Two underground mines, located in Macoupin County, produced 2,308,076 tons of coal in 1982. One surface mine began operation in 1982 in McDonough County and produced 283,428 tons of coal. Area 27 produced 4.2 percent of the total coal produced in Illinois in 1982 (Illinois Department of Mines and Minerals, 1983).

Estimated coal reserves in Illinois are 161.6 billion tons; 15.1 percent of the total demonstrated coal reserves in the United States (Nawrot and others, 1980). Illinois ranks first among the States in bituminous coal reserves and second behind Montana in total coal reserves (Rickert and others, 1979). The Illinois reserves have the highest total heat content of any State's reserves. About 12.1 percent of the Illinois reserves can be extracted by surface mines (coal seams more than 18 inches thick and less than 150 feet deep); currently, however, only about 3.6 percent is economically and legally recoverable (Nawrot and others, 1980).

Rickert and others (1979) suggest that coal resources of the Eastern Interior Coal Field are among those most likely to be used for synthetic fuel production due to the large amount of coal available, plentiful water supplies, favorable geologic setting, and proximity to northeastern markets. The Nation's move toward energy independence and diminishing domestic supplies of oil and gas could also increase the demand for Midwestern coal.

Land subsidence from underground coal mining was reported in Illinois communities as early as 1914 (Young, 1916). Two communities in Macoupin County—Carlinville and Wilsonville—and five in Madison County—Alton, Bethalto, Collinsville, Edwardsville, and Maryville—have experienced property damage due to subsidence.

The first coal discovery in North America was by Marquette and Joliet in 1673 along the Illinois River, and the first commercial underground coal mine in Illinois opened in 1810 in Jackson County (Andros, 1915). Commercial surface mining began in 1866 near Danville, Illinois. Early surface mining was accomplished by removing overburden with horsedrawn scrapers and hauling coal from the mine pit in wagons and wheelbarrows. By 1886, steam shovels, made mostly of wood, were used 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 remove up to 220 cubic yards of material in a single bite (Lewis, 1972, p. 3, 4).

Coal production in Illinois from 1882 through 1982 was 4.9 billion tons of which Area 27 accounted for 7.5 percent. Peak production was reached during World War I. The Depression of the 1930's accompanied a decline in production that was reversed during World War II. Another decline in production occurred when diesel locomotives and alternative industrial fuels came into use. Increased energy consumption and declining oil and gas reserves in the early 1960's have resulted in an increase of production during the past two decades (Nawrot and others, 1980) (fig. 2.0-2). In 1982, 27 surface mines in Illinois produced 25,744,865 tons of coal, and 32 underground mines produced 35,683,305 tons (Illinois Department of Mines and Minerals, 1983).

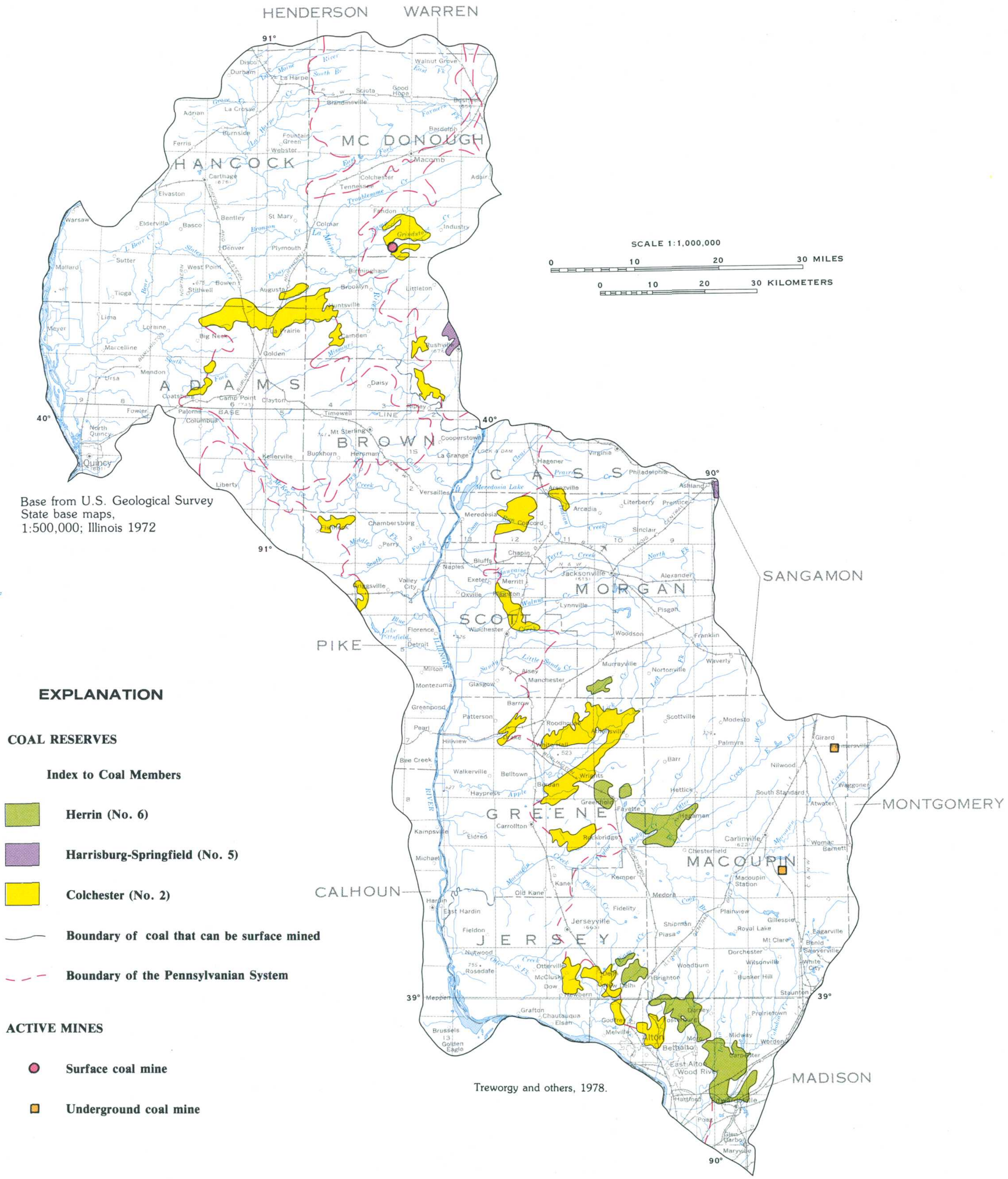
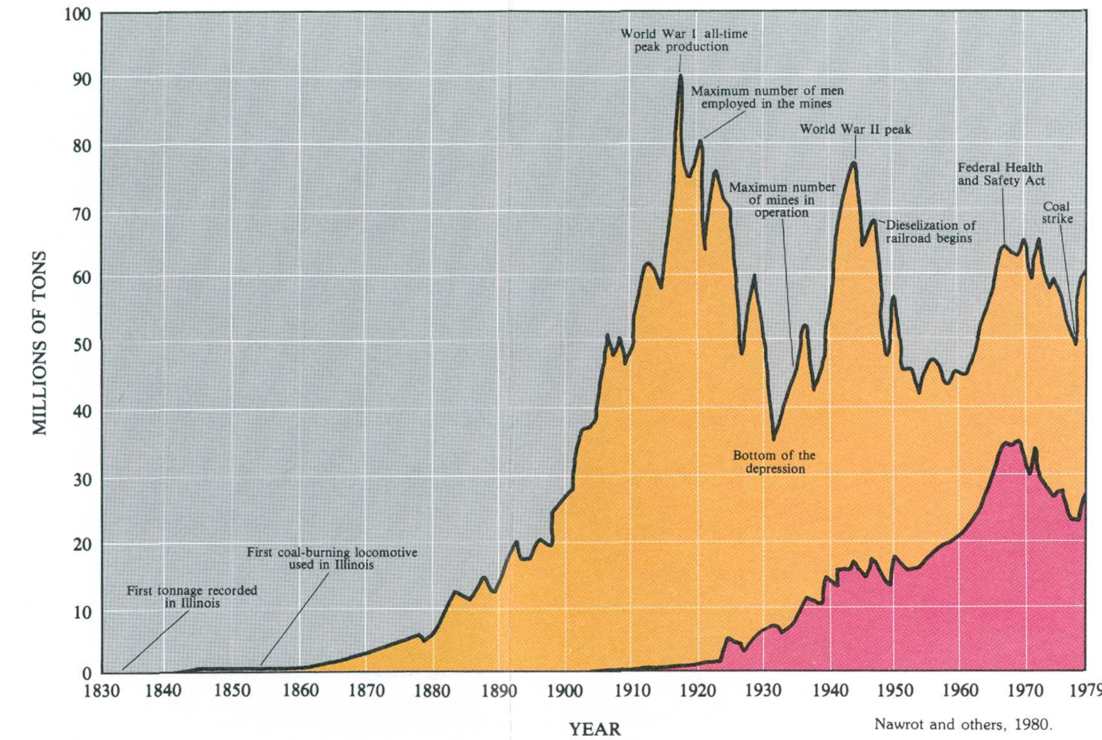


Figure 2.0-1 Coal reserves that can be surface mined, blocks of 6 million tons or more, economically and legally recoverable.



EXPLANATION

UNDERGROUND MINING

STRIP MINING

Figure 2.0-2 Illinois coal production, 1830-1979.

Glacial Deposits Cover Most of the Area

Glacial deposits cover most of the area. Loess deposits are interbedded with glacial tills and mantle the uppermost tills.

Glacial deposits cover all except the western edge of the study area (in Calhoun and Pike Counties). They overlie bedrock, form the land surface, and are parent material for most area soils. They are also important sources of building materials and ground water (Piskin and Bergstrom, 1975). Thickness ranges from less than 50 to 200 feet (Willman and others, 1975, p. 213, 216). The flood plains of major rivers are formed of alluvium, sand dunes, and gravel terraces (figs. 3.1-1 and 3.1-2). Loess, a wind-blown material, was deposited widely in Illinois during the glacial periods. The loess is mostly silt size and ranges from 50 to almost 100 feet in thickness on the river bluffs. It thins a short distance from the river valleys to a thickness of 5 to 15 feet (Piskin and Bergstrom, 1975, p. 8). Loess covers the valley walls and uplands throughout the study area (Willman and others, 1975).

Figure 3.1-1 Surficial geology.

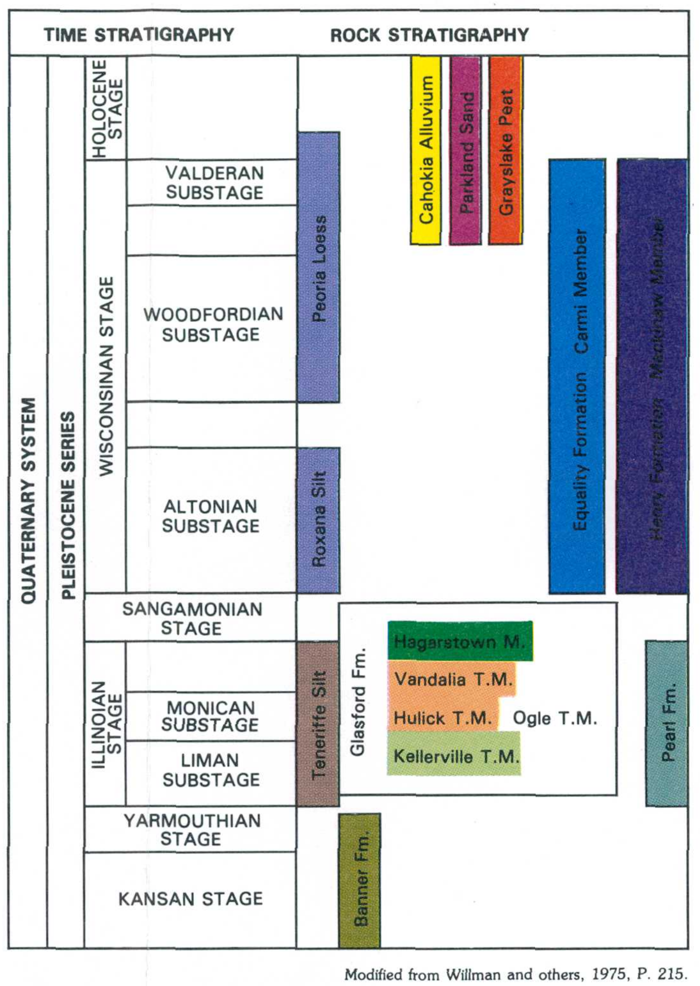


Figure 3.1-2 Stratigraphic column of Quaternary System showing locations of rock units found in Area 27 (the stratigraphic nomenclature follows the usage of the Illinois State Geological Survey and differs from the usage of the U.S. Geological Survey).

The Uppermost Bedrock is of Mississippian and Pennsylvanian Age

The uppermost bedrock in Area 27 consists mostly of rocks of Pennsylvanian and Mississippian age. Some older rocks crop out in the eroded Illinois River valley.

The uppermost bedrock in about two-thirds of the study area consists of rocks of Pennsylvanian age. Rocks of Mississippian age comprise the uppermost bedrock in almost all of the remaining one-third. The Mississippian rocks were eroded and deformed before the Pennsylvanian rocks were deposited. Therefore, the Lower Pennsylvanian rocks are discontinuous. Older rocks of Devonian, Silurian, and Ordovician age are exposed in the eroded lower Illinois River valley (Willman and others, 1967). Younger Cretaceous rocks occur along the western edge of the area in Adams and Pike Counties (fig. 3.2-1).

Rocks of Pennsylvanian age are 90 to 95 percent clastic. The upper two-thirds of these rocks, where minable coal is found, are 25 to 30 percent sandstone, 65 to 70 percent shale and underclay, and 5 to 10 percent limestone (Willman and others, 1975, p. 165-169). These rocks contain about 1 to 2 percent coal and there are 75 identified coal members in Illinois (Willman and others, 1975, p. 177). More than 99 percent of the mapped coal reserves in Illinois are in the Carbondale and Spoon Formations of Pennsylvanian age (together known as the Kewanee Group) of the Desmoinesian Series (Atherton and Palmer, 1979) (fig. 3.2-2).

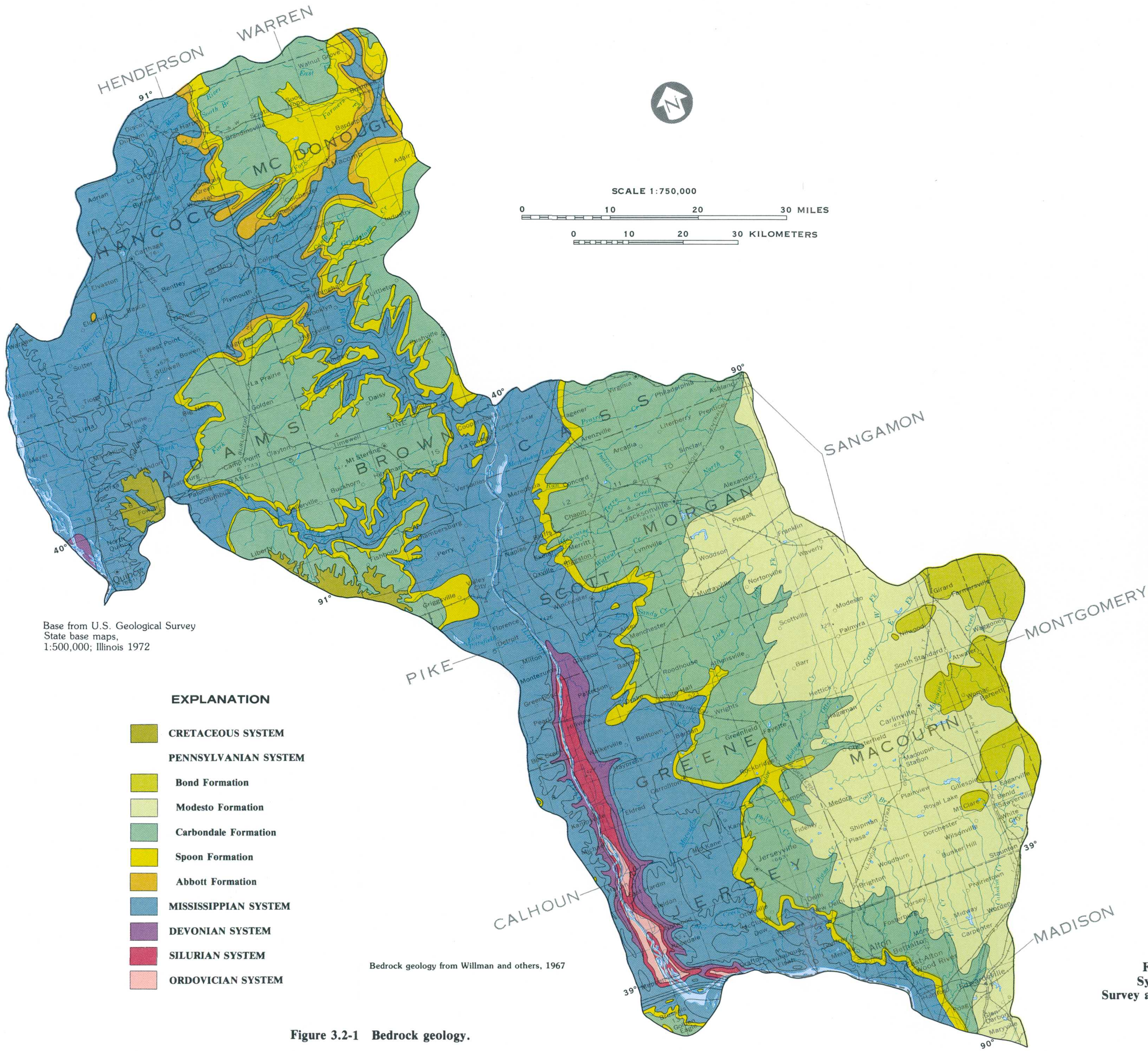


Figure 3.2-1 Bedrock geology.

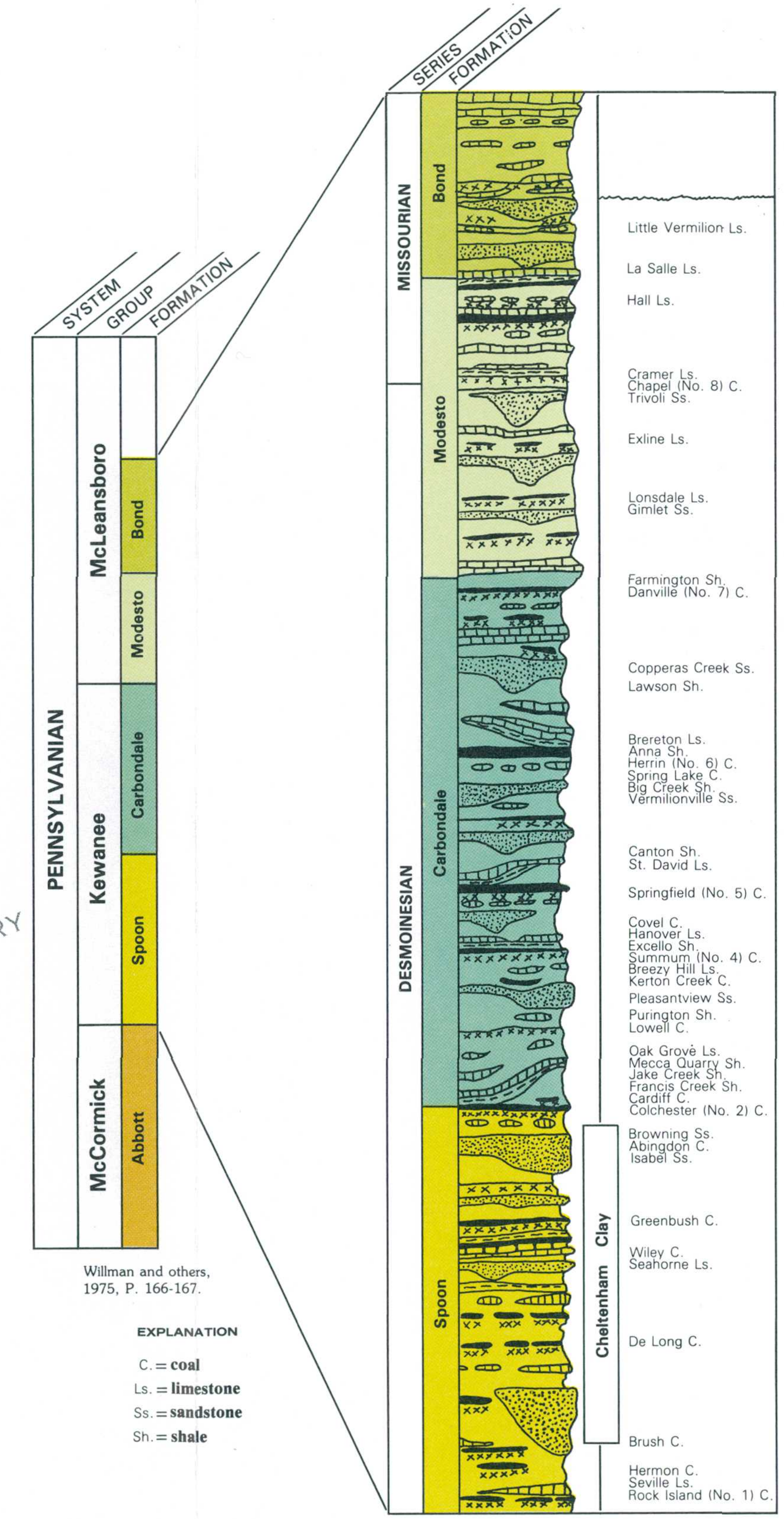


Figure 3.2-2 Stratigraphy of the major coal-bearing units in the Pennsylvanian System in Area 27. (Geologic names are those used by the Illinois State Geological Survey and are not necessarily in agreement with names used by the U.S. Geological Survey).

4.0 SOILS

Most Soils Developed from Loess

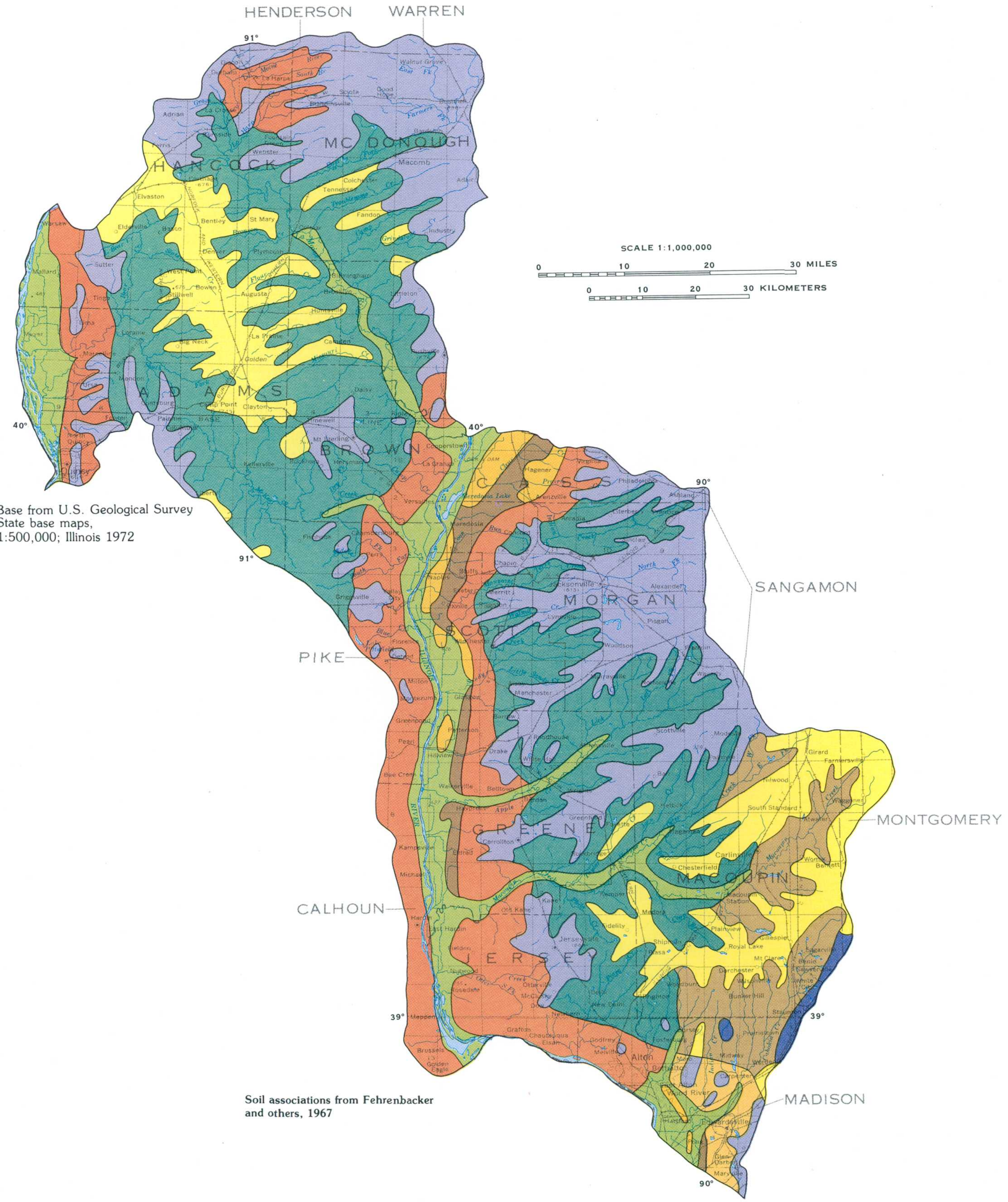
Soils of the study area are acidic, have low to moderate permeability, and, under high level of management, can have high productivity.

The soil associations in Area 27 are shown in figure 4.0-1. All soil associations, except the sandy Hagener-Ridgeville-Bloomfield-Alvin group, have low to moderate permeabilities (table 4.0-1), retain water well, and are resistant to drought (Fehrenbacher and others, 1967). Almost all soils in the area are developed from loess, a friable, medium-textured, silty loam. The loess, when deposited, was calcareous and contained many plant nutrients; however, through intense agricultural use, calcium and nutrients have been depleted (Fehrenbacher and others, 1967).

Dark-colored-loess soils developed under prairie grass in 4 to 7 feet of loess. These soils are present in level areas away from well developed drainage. Light-colored-loess soils developed under forest or forest and prairie grass in 4 to 10 feet of loess and are present on slopes that range from nearly level to very steep. Other soils were formed from outwash, alluvium, and sandy material occurring on the major stream terraces.

Management practices that include fertilization, improved drainage, and control of floods, erosion, weeds, insect pests and diseases, can achieve high agricultural productivity. All soils in Area 27 require large applications of lime and nitrogen and moderate to large applications of potash and phosphates to maintain high productivity.

Information on the engineering properties of soils in the study area and detailed soil maps are available for all counties. This information is published by the U.S. Soil Conservation Service in cooperation with the University of Illinois Agricultural Experiment Station. County soil reports are available or being prepared for all counties in the study area. A report by Wischmeier and Smith (1978) contains useful information for predicting erosional losses caused by rainfall.



Base from U.S. Geological Survey
State base maps,
1:500,000; Illinois 1972

Soil associations from Fehrenbacker
and others, 1967

Figure 4.0-1 Soil associations.

Table 4.0-1 Soil-association characteristics (Fehrenbacker and others, 1967)

Soil association	Depth to bedrock (feet)	Depth to high water table (feet)	Permeability (inches per hour)	Available water capacity (inches per inch of soil)	Soil reaction (pH)
DARK-COLORED SOILS Developed primarily from loess					
A Joy-Tama-Muscatine-Ipava-Sable	5+	0-3	0.60-2.00	0.18-0.24	5.1-8.4
D Harrison-Herrick-Virden	5+	0-5	0.20-2.00	0.10-0.24	4.5-8.4
E Oconee-Cowden-Piasa	5+	0-3	0.06-0.63	0.09-0.25	5.1-9.0
LIGHT-COLORED SOILS Developed primarily from loess					
L Seaton-Fayette-Stronghurst	5+	1-5	0.20-2.00	0.18-0.24	4.5-8.4
N Clary-Clinton-Keomah	5+	--	--	--	--
O Stookey-Alford-Muren	8+	8+	0.63-2.00	0.18-0.15	5.1-8.4
P Hosmer-Stoy-Weir	6+	0-3	0.06-2.00	0.14-0.25	4.0-6.0
DARK- AND LIGHT-COLORED SOILS Developed primarily from medium and fine-textured outwash					
W 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					
X Hagener-Ridgeville-Bloomfield-Alvin	10	10	0.63-20.0	0.02-0.18	5.1-7.3
Developed primarily from alluvium					
Z Lawson-Beaucoup-Darwin-Haymond-Belknap	0-5-10	0-4	0.06-2.00	0.11-0.25	5.1-7.8

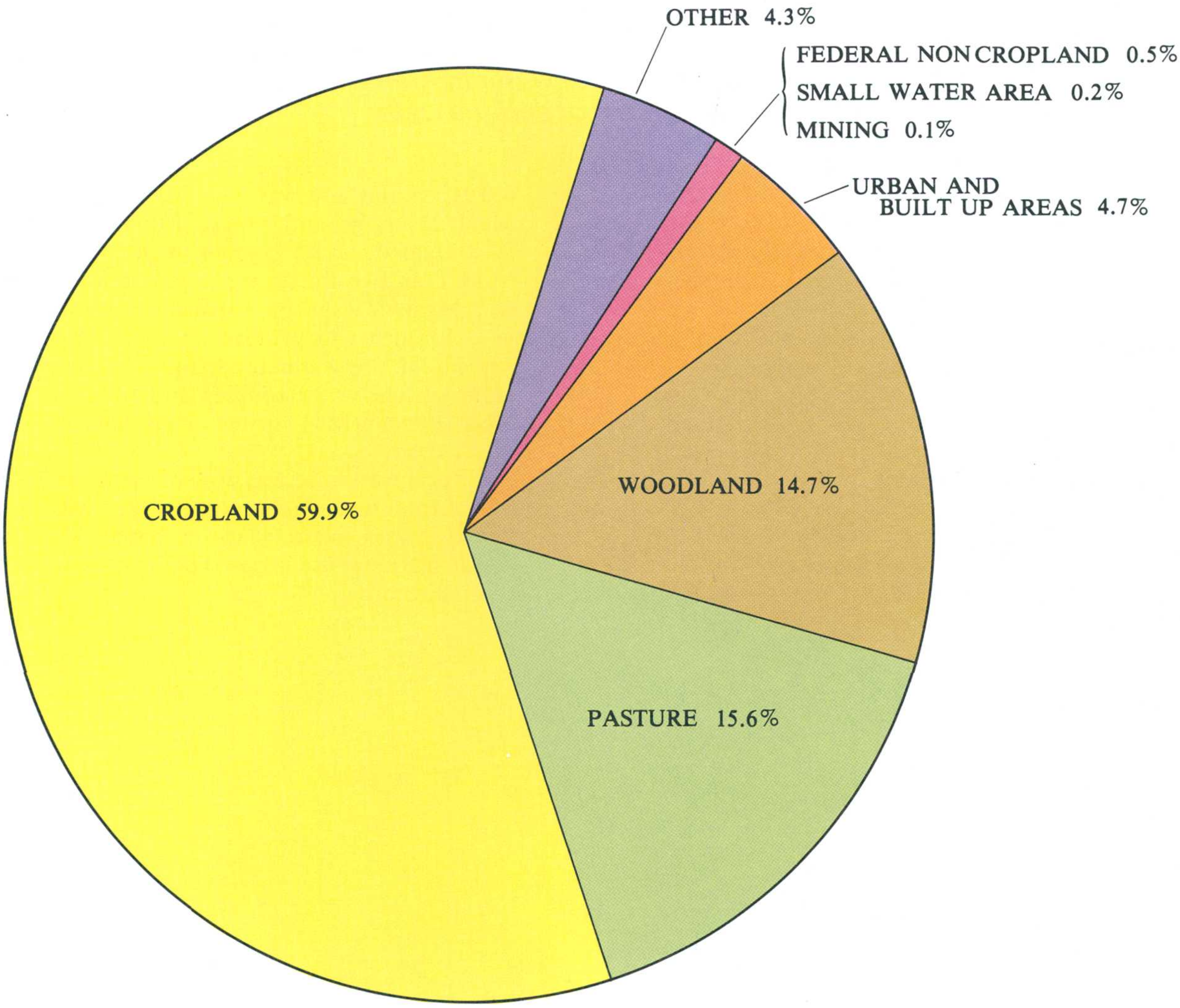
5.0 LAND USE

Agriculture is the Dominant Land Use

Agriculture is the dominant land use. Only 0.1 percent of Area 27 has been affected by mining.

Area 27 covers 5,805 square miles in west central Illinois, most of which is used for agriculture. The area has 59.9 percent cropland and 15.6 percent pasture. Corn and soybeans are the main crops. The remaining 24.5 percent of the land is used as follows (fig. 5.0-1): Forest and woodland, 14.7 percent; urban and built-up area, 4.7 percent; Federal non-cropland, 0.5 percent; small water areas, 0.2 percent; mining, 0.1 percent; and other land uses, 4.3 percent (Illinois Conservation Needs Committee, 1970).

In December 1982, one surface mine in McDonough County and two underground mines in Macoupin County were in operation. Reported problems related to mining activities include hazardous entries, acidic mine drainage, sparse vegetation, and erosion (Nawrot and others, 1980, p. 18, 19). Two percent of the area has been undermined for subsurface coal (Nawrot and others, 1980, p. 51). Subsidence has caused damage due to collapse of underground mines at Carlinville and Wilsonville in Macoupin County and at Alton, Bethalto, Collinsville, Edwardsville, and Maryville in Madison County.



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

Figure 5.0-1 Land use in Area 27.

5.0 LAND USE

Area Water Use Mainly from Surface-Water Sources

Surface water is the major source of water in Area 27. Industry is the major consumer of surface water.

Water withdrawal in Area 27 was 1,023 million gallons per day (Mgal/d) in 1980 (Kirk and others, 1982, p. 22-40) based on data for 14 of the 18 counties (table 6.0-1). St. Clair, Montgomery, Warren, and Henderson Counties have less than 1 percent of their area in the study area and were therefore omitted in the water-use analysis. Surface water was the source of 90.2 percent or 922 Mgal/d (fig. 6.0-1).

Industrial uses accounted for 886 Mgal/d or 87 percent of the total water used (table 6.0-1). Industrial uses included manufacturing (57.8 Mgal/d) and thermoelectric-power generation (828 Mgal/d). All water used for hydroelectric-power generation (20,760 Mgal/d in Hancock County) was returned to the river and was not included in figure 6.0-1 or table 6.0-1. Mining use was 13.5 Mgal/d, of which 11.6 Mgal/d was ground water. Public-supply use was 82.8 Mgal/d, or 8.1 percent of the total water used. More than two-thirds of the public water supply, or 62.3 Mgal/d, was from surface-water sources. Water used for fish and wildlife was 10.4 Mgal/d, or 1.0 percent of the water used; most of this water was from surface-water sources and was used to flood areas for waterfowl during the fall migration.

Rural water use was 30.0 Mgal/d, or 2.9 percent of the total water used. Rural water withdrawal for domestic and livestock use is based on population and irrigational use is based on acreage irrigated and rainfall records.

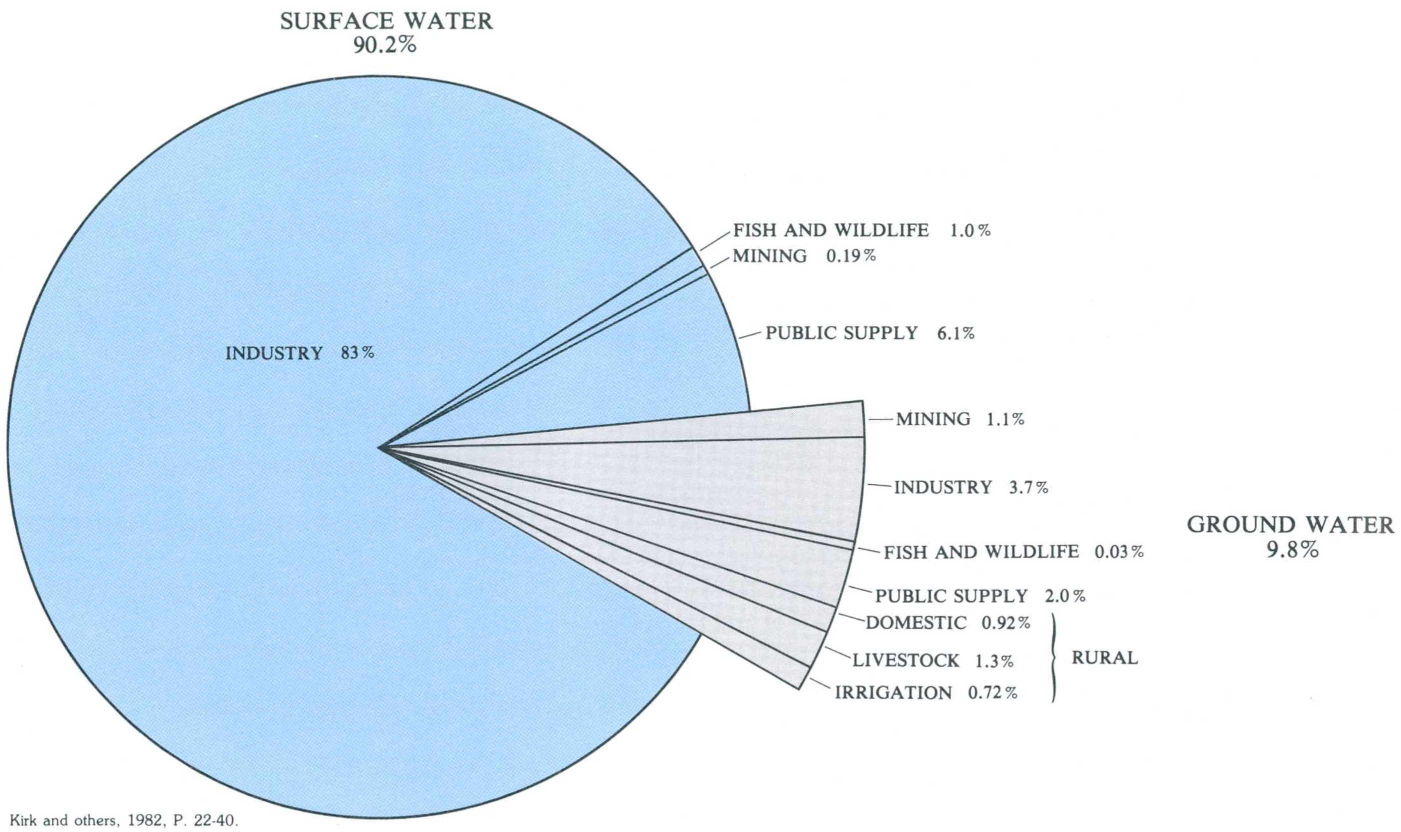


Figure 6.0-1 Distribution of water use in Area 27.

Table 6.0-1 Reported 1980 water use of Area 27 in million gallons per day (Kirk and others, 1982, p. 22-40). [St. Clair, Montgomery, Henderson, and Warren counties are not included in this table because less than one percent of each county is in the study area]

County	Public supply	Industry	Mining	Fish and wildlife	Rural: Domestic	Rural: Livestock	Rural: Irrigation	Total
Ground Water Used								
Adams	0.905	10.533	0	0	0.901	1.897	1.959	16.195
Brown	0.062	0	0	0	0.172	0.467	0	0.701
Calhoun	0.364	0	0	0.206	0.323	0.371	0	1.264
Cass	1.734	1.157	0	0	0.328	0.444	0.901	4.564
Greene	0.344	0	0.001	0	0.475	1.075	1.056	2.951
Hancock	0.195	0	0	0	0.733	1.298	0.544	2.770
Jersey	0.883	0	0	0.114	0.539	0.620	0.457	2.613
Macoupin	0.013	0	0	0	0.896	1.236	0	2.145
Madison	10.411	21.743	11.635	0	2.850	0.853	1.393	48.885
McDonough	0.633	0.014	0	0	0.725	0.890	0	2.262
Morgan	0.099	4.560	0	0	0.509	0.816	0	5.984
Pike	0.821	0.044	0	0	0.438	2.057	0.796	4.156
Schuyler	0.471	0	0	0	0.310	0.641	0.064	1.486
Scott	3.533	0	0	0	0.219	0.332	0.370	4.454
Total	20.468	38.051	11.636	0.320	9.418	12.997	7.540	100.430
Surface Water Used								
Adams	7.124	0	0	0				7.124
Brown	0.222	0	0	0				0.222
Calhoun	0	0	0	5.852				5.852
Cass	0.138	0	0	0				0.138
Greene	0.331	0	0	0				0.331
Hancock	1.025	0	0	0				1.025
Jersey	0	0	0	4.280				4.280
Macoupin	3.402	0	1.903	0				5.305
Madison	45.518	629.553	0	0				675.071
McDonough	2.993	0	0	0				2.993
Morgan	1.149	196.721	0	0				197.870
Pike	0.432	21.504	0	0				21.936
Schuyler	0	0	0	0				0
Scott	0	0	0	0				0
Total	62.334	847.778	1.903	10.132				922.147

7.0 PRECIPITATION

May and June are Wetter Months

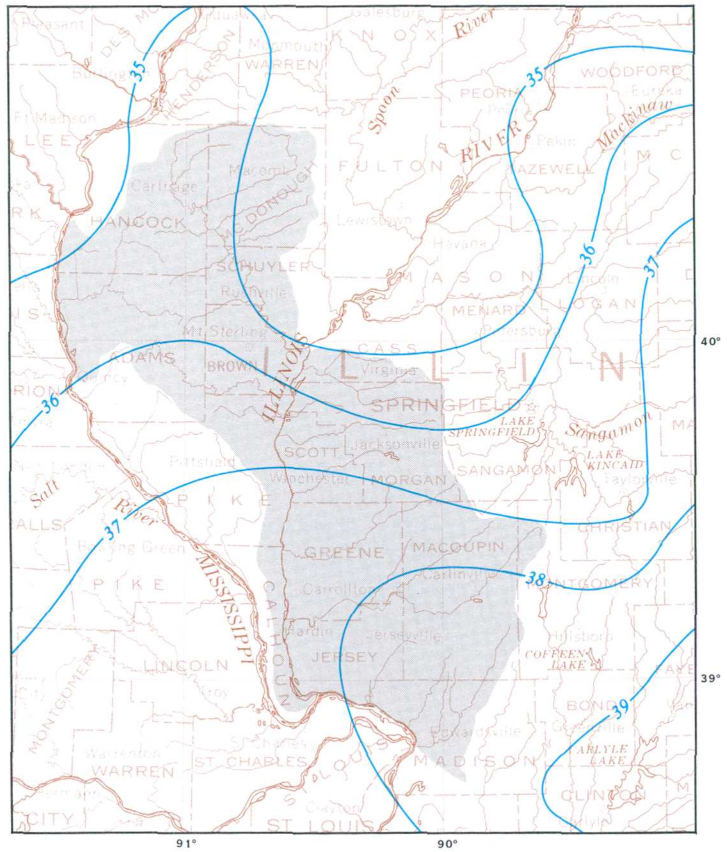
Average annual precipitation ranges from 35 to 38.5 inches. About 24 inches falls as rain from April to September. Direct runoff accounts for 37 percent of precipitation.

Average annual precipitation on Area 27 ranges from 35 to 38.5 inches (fig. 7.0-1). February and December are the driest months and May and June usually are the wettest months. About two-thirds of the annual precipitation occurs between April and September and is produced mostly by thunderstorms. Thirty-seven percent of the annual precipitation leaves the area as surface runoff. The remaining 63 percent evaporates, transpires, or infiltrates.

During October to March, the predominating cold, dry continental air inhibits heavy precipitation (Illinois Department of Registration and Education, 1958, p. 28); and an average of 12 to 14 inches of precipitation falls as rain, sleet, and snow. The average annual snowfall ranges from 16 inches along the west-central boundary of the area to 24 inches in the northernmost part of the area (fig. 7.0-2). Freezing rain and sleet occur 10 to 12 days per year on the average (Dawes and Terstriep, 1966).

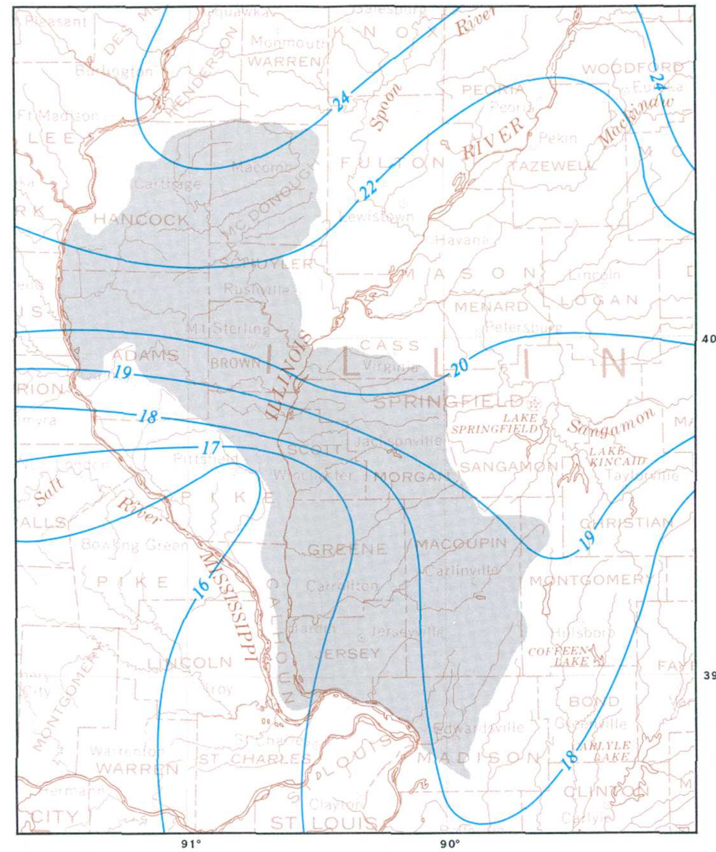
The 24-hour rainfall amount that can be expected to be equaled or exceeded on the average of once in 2 years ranges from 3.3 to 3.5 inches (fig. 7.0-3) (Herschfield, 1961). Rainfall amounts that can be expected for various frequencies and durations are given in table 7.0-1.

Daily precipitation records are published in "Climatological Data for Illinois" by the National Oceanic and Atmospheric Administration (NOAA), Environmental Data and Information Service, National Climatic Center, Asheville, North Carolina. NOAA also publishes hourly precipitation data.



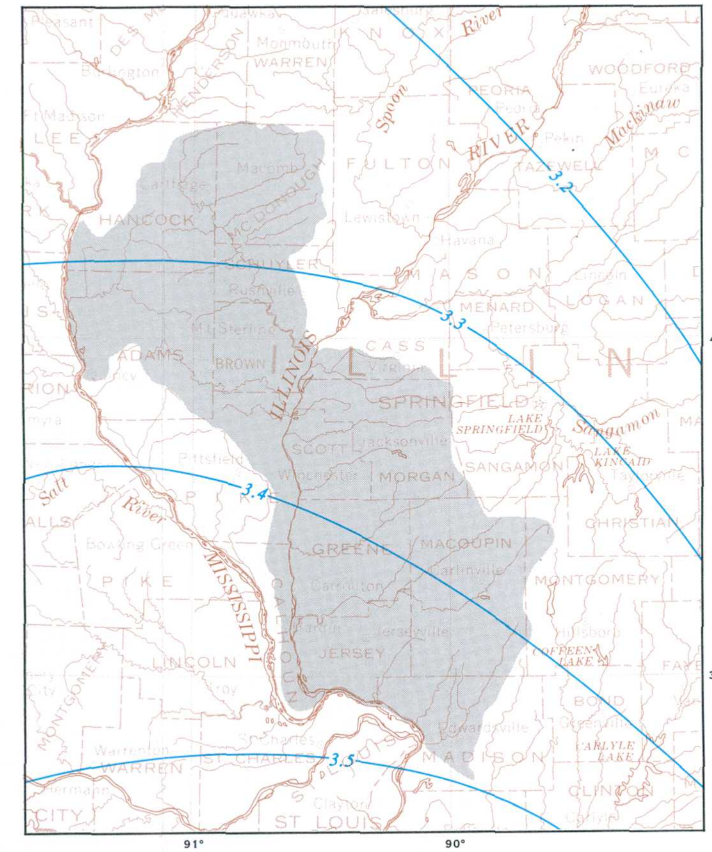
From Dawes and Terstriep, 1966.

Figure 7.0-1 Mean annual precipitation, in inches.



From Dawes and Terstriep, 1966.

Figure 7.0-2 Mean annual snowfall, in inches.



From Herschfield, 1961.

Figure 7.0-3 Two-year, 24-hour rainfall, in inches.

Table 7.0-1 Precipitation duration-frequency values in inches (30 minute, 1-, 2-, 12-, and 24-hour values from Hershfield, 1961).

Frequency in years	Duration				
	30 minute	1 hour	2 hour	12 hour	24 hour
1	1.10	1.36	1.64	2.50	2.87
2	1.28	1.58	1.90	3.00	3.40
5	1.58	1.99	2.38	3.65	4.25
10	1.80	2.25	2.75	4.25	4.80
25	2.00	2.60	3.10	4.80	5.50
50	2.30	2.90	3.45	5.30	6.20
100	2.50	3.15	3.85	6.00	6.80

7.0 PRECIPITATION

8.0 HYDROLOGIC NETWORK

Surface-Water Information Available at 38 Sites

Surface-water quantity and quality data have been collected and published annually.

The location of 38 sites in Area 27 with hydrologic information (table 8.0-1) are shown in figure 8.0-1. Streamflow data have been collected at 34 sites including continuous-recording gages, crest-stage gages, and miscellaneous measurement sites. Specific conductance, and pH values and concentrations of alkalinity, sulfate, dissolved solids, iron, manganese, and trace elements are available for 23 sites. Suspended-sediment data are available for 18 sites. All hydrologic data used in this report has been published by the U.S. Geological Survey and includes data through September 30, 1981.

Streamflow and water-quality data from network stations are useful in assessing the hydrology of an area. Data collected over a period of time can be used to derive regional equations for estimating the streamflow and water quality for ungaged sites.

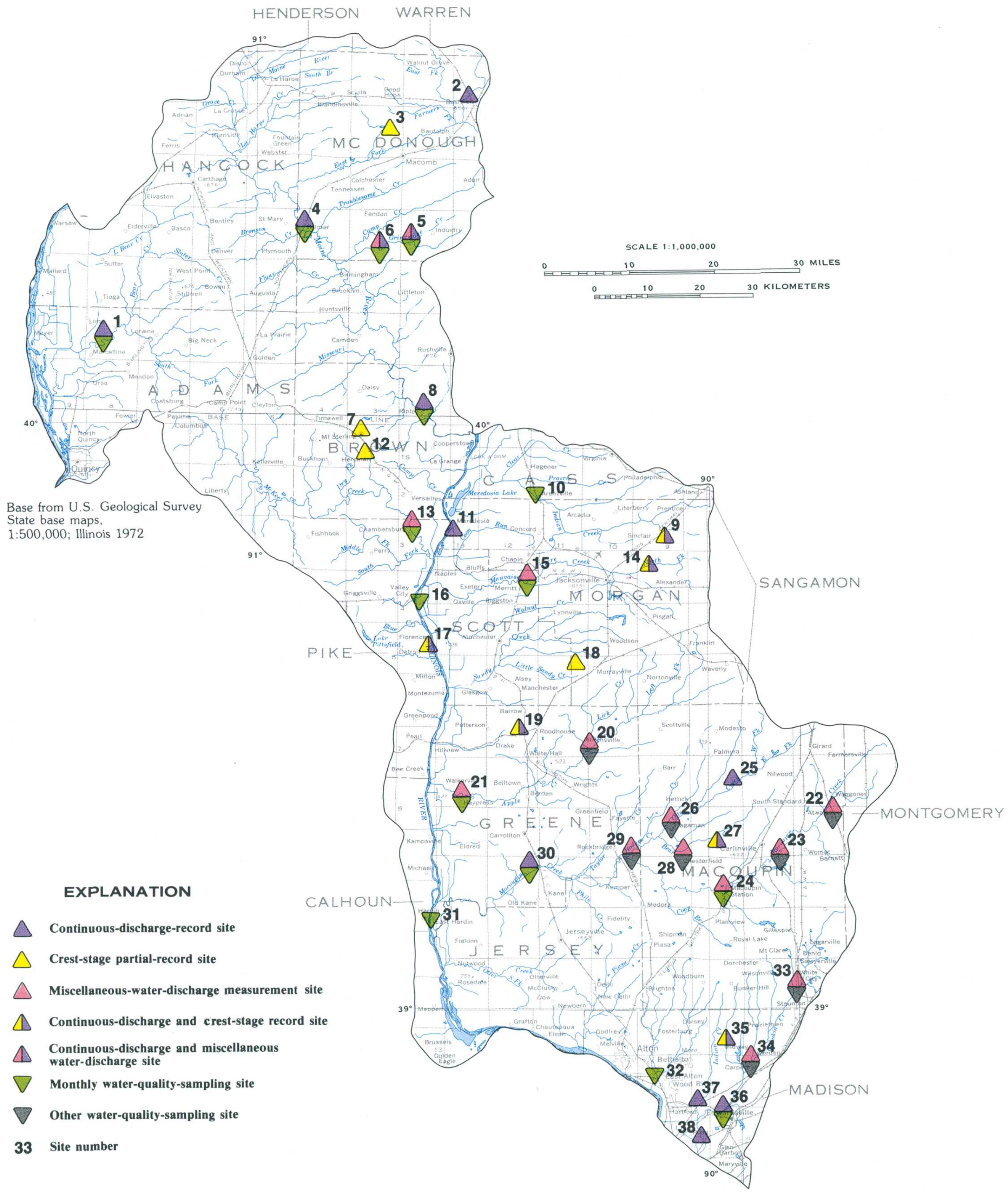


Figure 8.0-1 Location of hydrologic network sites.

Table 8.0-1 Availability of hydrologic data

Map site number	USGS station name and number		Drainage area (mi²)	Surface-water discharge: Period of record	Surface-water discharge: Type of gaging station[1]	Surface-water quality: Period of record	Surface-water quality: Collection agency[2]	Surface-water quality: Sampling frequency[3]
1	05495500	Bear Creek near Marcelline	349	1944-	D	1978-81	IEPA, USGS	M
2	05584400	Drowning Fork at Bushnell	26.3	1960-	D			
3	05584450	Wigwam Hollow Creek near Macomb	0.60	1961-76	C			
4	05584500	La Moine River at Colmar	655	1945-	D	1975-81	IEPA, USGS	M,Q
5	05584680	Grindstone Creek near Industry	35.5	1979-80 1981	S D	1980-81	USGS	M,Q
6	05584685	Grindstone Creek near Birmingham	45.4	1979-80 1981	S D	1980-81	USGS	M,Q
7	05584950	West Creek at Mount Sterling	2.16	1961-72	C			
8	05585000	La Moine River at Ripley	1,293	1921-	D	1975-81	IEPA, USGS	M
9	05585220	Indian Creek Tributary near Sinclair	3.58	1956-80	C			
10	05585275	Indian Creek at Arenzville	164			1978-81	IEPA	M
11	05585500	Illinois River at Meredosia	26,028	1939-	D			
12	05585700	Dry Fork Tributary near Mount Sterling	0.15	1956-76	C			
13	05585830	McKee Creek at Chambersburg	341	1981	S	1959, 1962-77, 1979-81	IEPA, USGS	M,Q
14	05586000	North Fork Mauvaise Terre Creek near Jacksonville	29.1	1950-75 1976-	D C			
15	05586040	Mauvaise Terre Creek near Merritt	146	1981	S	1978-81	IEPA, USGS	M,Q
16	05586100	Illinois River at Valley City	26,564			1975-81	USGS	M
17	05586200	Illinois River Tributary near Florence	0.49	1956-80	C			
18	05586350	Little Sandy Creek Tributary near Murrayville	1.82	1961-72	C			
19	05586500	Hurricane Creek near Roodhouse	2.30	1951-75 1976-	D C			
20	05586565	Birch Creek near Athensville	12.8	1981	S	1980-81	USGS	Q
21	05586600	Apple Creek near Eldred	404	1981	S	1959, 1961-81	IEPA, USGS	M,Q
22	05586630	Macoupin Creek near Standard City	73.8	1979-81	S	1980	USGS	Q
23	05586645	Macoupin Creek near Carlinville	132			1979	USGS	Q
24	05586690	Macoupin Creek near Macoupin	304	1979-80	S	1972-77, 1979-80	IEPA USGS	M Q
25	05586800	Otter Creek near Palmyra	61.1	1960-80	D			
26	05586830	Solomon Creek at Hagaman	26.2	1981	S	1980	USGS	Q
27	05586850	Bear Creek Tributary near Reeder	0.02	1956-80	C			
28	05586860	Bear Creek at Chesterfield	26.7	1979-81	S	1980	USGS	Q
29	05586890	Hodges Creek near Rockbridge	233	1979-81	S	1980	USGS	Q
30	05587000	Macoupin Creek near Kane	868	1921-33, 1940-	D D	1978-81	IEPA, USGS	M,Q
31	05587060	Illinois River at Hardin	28,690			1959-81	IEPA	M
32	05587700	Wood River at East Alton	121			1972-81	IEPA	M
33	05587740	Cahokia Creek near Staunton	71.5	1981	S	1980	USGS	Q
34	05587815	Cahokia Creek near Carpenter	151	1979-81	S	1980-81	USGS	Q
35	05587850	Cahokia Creek Tributary No. 2 near Carpenter	0.45	1956-80	C			
36	05587900	Cahokia Creek at Edwardsville	212	1969-	D	1978-81	IEPA, USGS	M,Q
37	05588000	Indian Creek at Wanda	36.7	1940-	D			
38	05588500	Cahokia Creek near Poag	259	1910-12	D			

[1] D - Continuous-discharge record
C - Crest-stage partial record
S - Miscellaneous water-discharge measurement

[2] USGS - U.S. Geological Survey
IEPA - Illinois Environmental Protection Agency

[3] M - Water-quality sampling at 4-to 6-week intervals
Q - Synoptic water-quality sampling

Average Discharge Determined at 14 Sites

Average stream discharge is determined at 14 gaging stations and can be estimated for ungaged sites.

Average stream discharges were determined from daily discharge records for 14 gaging stations located in Area 27 (fig. 9.1-1). Table 9.1-1 lists each gaging station's average discharge, drainage area, and number of years of record.

The average stream discharge is dependent on drainage area, soil characteristics, mean annual precipitation, area of lakes and ponds, area of forests, elevation, and stream length and slope as described by Sieber (1970), however, drainage area is the most significant factor. The average discharge of ungaged sites can be estimated from the drainage area using the equation:

$$Q_a = 0.72\ A^{0.98}$$

where the average discharge (Q_a) is in cubic feet per second and the drainage area (A) is in square miles (fig. 9.1-2). This relation was derived from a regression analysis of data from 10 gaging stations (table 9.1-1) having more than 10 years of discharge record. Drainage areas varied from 2.30 to 1,293 square miles. The discharge record of the Illinois River at Meredosia was not used in the analysis because water is diverted into the drainage basin from Lake Michigan at Chicago, Illinois, and because flow is regulated through many dams and reservoirs.

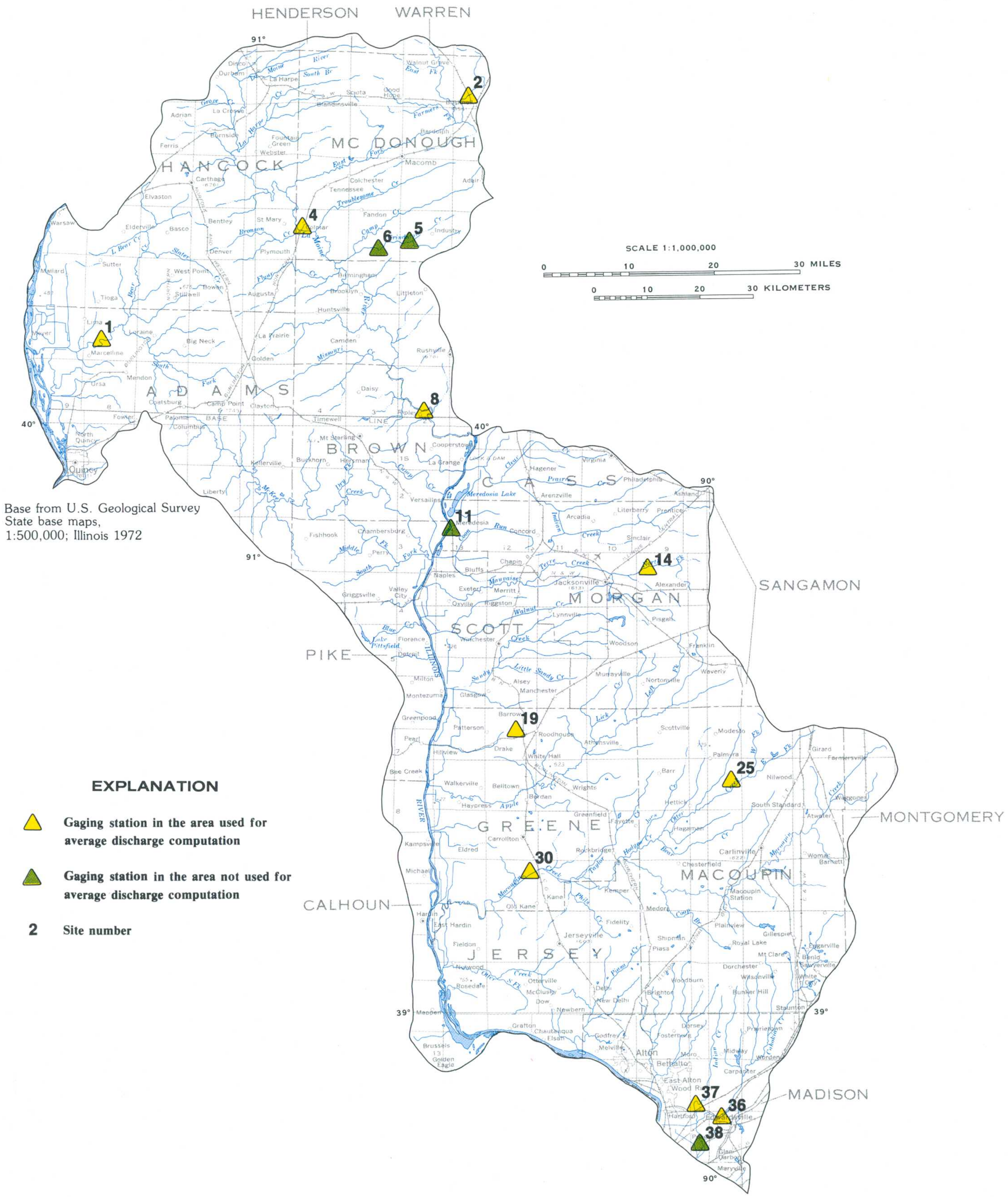


Figure 9.1-1 Surface-water gaging-station locations.

Table 9.1-1 Average discharge at gaging stations

Map site number	Station name	Drainage area (mi^2)	Average annual discharge (ft^3/s)	No. of years of record
1	Bear Creek near Marcelline	349	200	37
2	Drowning Fork at Bushnell	26.3	19.7	21
4	La Moine River at Colmar	655	433	37
5	Grindstone Creek near Industry	35.5	27.7	1
6	Grindstone Creek near Birmingham	45.4	38.3	1
8	La Moine River at Ripley	1,293	784	60
11	Illinois River at Meredosia	26,028	21,465	43
14	North Fork Mauvaise Terre Creek near Jacksonville	29.1	20.2	25
19	Hurricane Creek near Roodhouse	2.30	1.49	25
25	Otter Creek near Palmyra	61.1	40.3	20
30	Macoupin Creek near Kane	868	524	53
36	Cahokia Creek at Edwardsville	212	135	12
37	Indian Creek at Wanda	36.7	24.3	41
38	Cahokia Creek near Poag	259	162	1

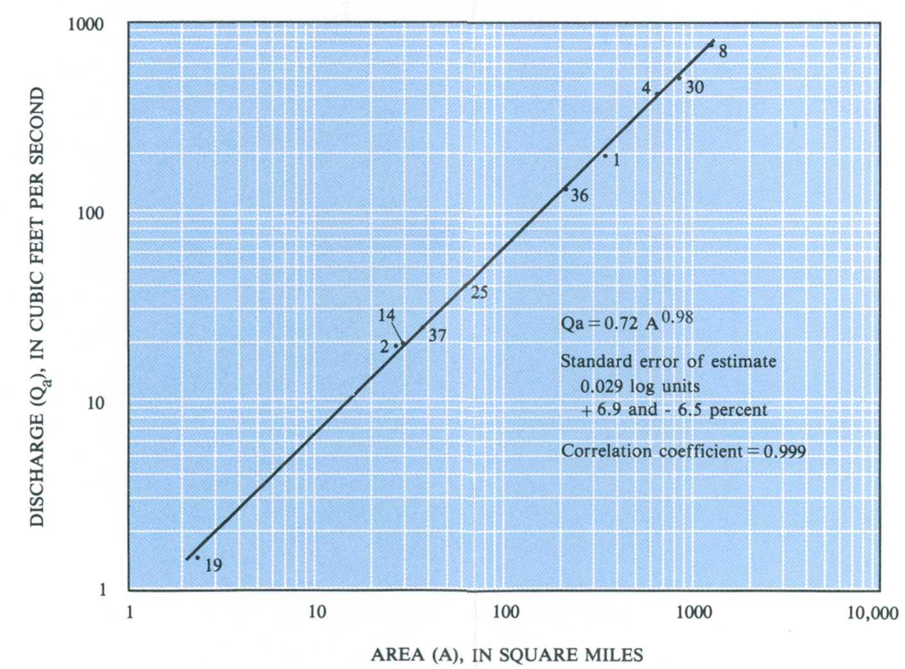


Figure 9.1-2 Relation between average discharge and drainage area in Area 27. The numbers are site numbers.

Low Flows Vary Widely Throughout Area 27

7-day, 10-year low flows range from 0 to 10 cubic feet per second for 10 gaging stations in the study area.

Low flow occurs after many days of no precipitation or snowmelt. Streamflow during these periods is mainly from ground-water inflow and industrial and municipal waste-disposal effluents.

The 7-day, 10-year low-flow ($M_{7,10}$) is the discharge below which the minimum annual 7-day average will be expected to fall once in a 10-year period, and has a probability of occurrence of 10 percent. The $M_{7,10}$ discharge at 10 continuous-record gaging stations (fig. 9.2-1) in Area 27 ranged from 0 to 10 cubic feet per second (ft^3/s) or 0 to 0.0078 cubic feet per second per square mile [$(ft^3/s)/mi^2$] of drainage area. Low flows are much greater on the Illinois River because of the regulated and diverted flow needed for river navigation requirements. Hurricane Creek at Roodhouse and Otter Creek near Palmyra had an annual average 7-day low flow of 0 during 90 percent of the period of record.

A log-Pearson Type III frequency distribution analysis (Meeks, 1977, p. G-5) was made of the daily discharge values at 11 area gaging stations. Two stations that had zero flow for all 7-day low-flow values and a third station affected by regulation are not plotted on figure 9.2-2. The computed 7-day low flows for recurrence intervals of 2, 5, 10, 20, 50, and 100 years for each station are shown in table 9.2-1. Figure 9.2-2 indicates that drainage area may be the most significant factor in estimating low flow for drainage areas greater than about 400 square miles. The best estimate of low flows at ungaged sites may be made by making discharge measurements and relating them to concurrent discharge values at nearby continuous-record gaging stations.

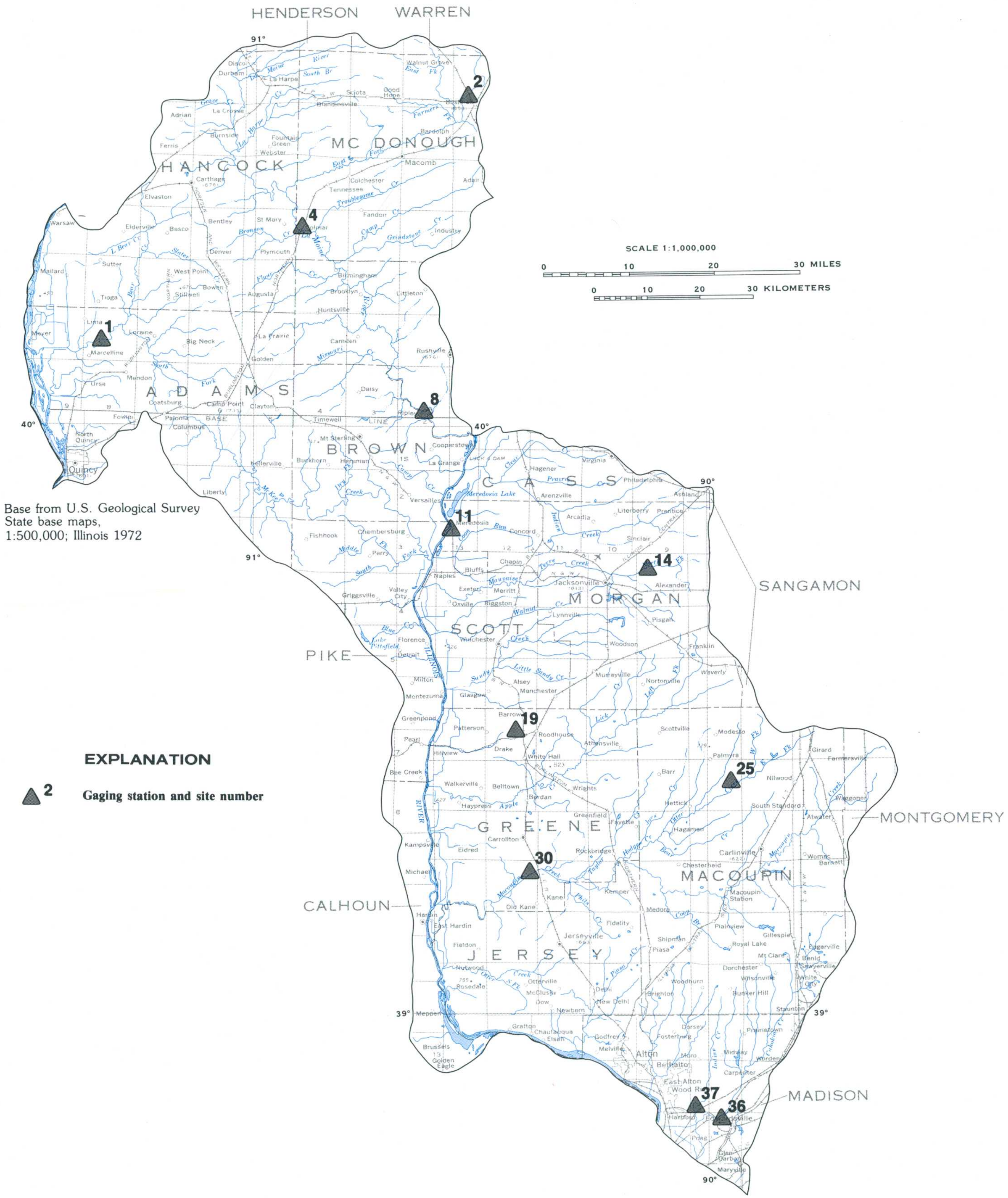


Figure 9.2-1 Location of gaging stations with calculated low-flow values.

Table 9.2-1 Calculated low-flow values for continuous-record gaging stations, in cubic feet per second

Map site number	Station name	Drainage area (mi²)	No. of years of record	Recurrence interval of 7-day low flow: 2 yr	5 yr	10 yr	20 yr	50 yr	100 yr
1	Bear Creek near Marcelline	349	37	1.03	0.23	0.09	0.04	0.01	0.005
2	Drowning Fork at Bushnell	26.3	20	0.64	0.13	0.04	0.02	0.004	0.001
4	La Moine River at Colmar	655	36	7.17	2.65	1.50	0.90	0.50	0.33
8	La Moine River at Ripley	1,293	61	23.5	13.4	10	8.06	6.30	5.37
11	Illinois River at Meredosia	26,028	43	5,020	4,020	3,600	3,320	3,040	2,880
14	North Fork Mauvaise Terre Creek near Jacksonville	29.1	25	0.92	0.17	0.05	0.02	0.004	0.001
19	Hurricane Creek near Roodhouse	2.3	24	0	0	0	0	0	0
25	Otter Creek near Palmyra	61.1	20	0	0	0	0	0	0
30	Macoupin Creek near Kane	868	52	7.89	3.55	2.30	1.53	0.96	0.70
36	Cahokia Creek at Edwardsville	212	12	1.28	0.68	0.50	0.40	0.30	0.26
37	Indian Creek at Wanda	36.7	41	0.10	0.04	0.02	0.01	0.009	0.006

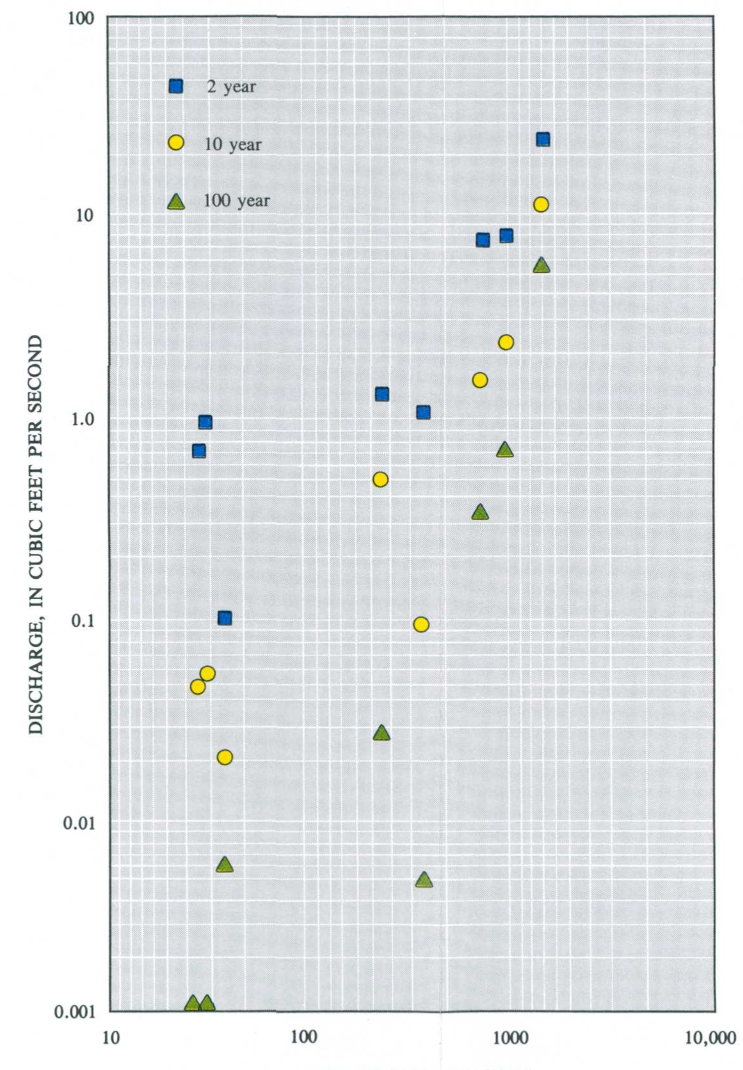


Figure 9.2-2 Relation between the 7-day, low flow at 2-, 10-, 100-year recurrence intervals and drainage area at gaging stations.

High Flow can be Estimated

Flood volumes and peak discharges were calculated from long-term daily records at gaging stations. Equations were developed for use at ungaged sites.

High flows in streams occurs when there is excessive rainfall and/or rapid snowmelt. Indices of flood volumes and peak discharges for 11 gaging stations in Area 27 (fig. 9.3-1) having more than 10 years of continuous streamflow data were calculated by using a log-Pearson Type III frequency distribution analysis for each site (Meeks, 1977, p. G-5). The computed 7-day flood-volume indices for recurrence intervals 2, 10, 50, and 100 years are shown in table 9.3-1. The relation between the 7-day, 10-year indices and the drainage areas of 10 stations is shown in figure 9.3-2.

The 7-day flood-volume indices at recurrence intervals of 2, 10, 50, and 100 years at ungaged sites in Area 27 can be estimated with equations developed from streamflow records. The equations are as follows:

$$V_{7,2} = 6.27\ A^{0.99}$$
$$V_{7,10} = 14.4\ A^{0.98}$$
$$V_{7,50} = 20.7\ A^{0.97}$$
$$V_{7,100} = 23.1\ A^{0.97}$$

The 7-day, X-year flood-volume index ($V_{7,X}$) where X is the 2-, 10-, 50-, or 100-year recurrence interval, is the annual maximum 7-consecutive-day mean flow, in cubic feet per second, expected to be exceeded at intervals averaging X years. The drainage area (A) is in square miles. Equations of the best-fit lines were derived using the least squares method. Site number 11, Illinois River at Meredosia, was not used in the analysis because water is diverted to the basin from Lake Michigan and the river flow is regulated for navigational requirements.

Peak discharge corresponding to the 2-, 10-, 50-, and 100-year recurrence interval can be estimated with the following equations developed by Curtis (1977).

$$Q_2 = 42.7\ A^{0.776} S^{0.466} (I\text{-}2.5)^{0.834}\ Af$$
$$Q_{10} = 90.8\ A^{0.767} S^{0.494} (I\text{-}2.5)^{0.833}\ Af$$
$$Q_{50} = 134\ A^{0.763} S^{0.510} (I\text{-}2.5)^{0.836}\ Af$$
$$Q_{100} = 152\ A^{0.762} S^{0.515} (I\text{-}2.5)^{0.836}\ Af$$

The peak discharge (Q_T) will be exceeded at intervals averaging T years in length where T is 2, 10, 50, or 100 years, and is in cubic feet per second. The drainage area (A) is in square miles. The slope of the river channel (S) is based on the difference of elevations divided by the distance between points 10 and 85 percent of the total distance measured along the low-water channel from the site to the basin divide, and is in units of feet of fall per mile of channel. The rainfall intensity (I) is the maximum 24-hour rainfall, in inches, expected to be exceeded at intervals averaging 2 years in length; it can be determined from figure 9.3-1. The areal factor (Af) is a dimensionless number that can also be determined from figure 9.3-1. The peak-discharge equations are based on data from daily discharge gaging stations and crest-stage gages having more than 10 years of record.

Table 9.3-1 lists the Q_2, Q_{10}, Q_{50}, and Q_{100} (2-, 10-, 50-, and 100-year peak discharges) for gaging stations in the study area, as determined by Curtis (1977).

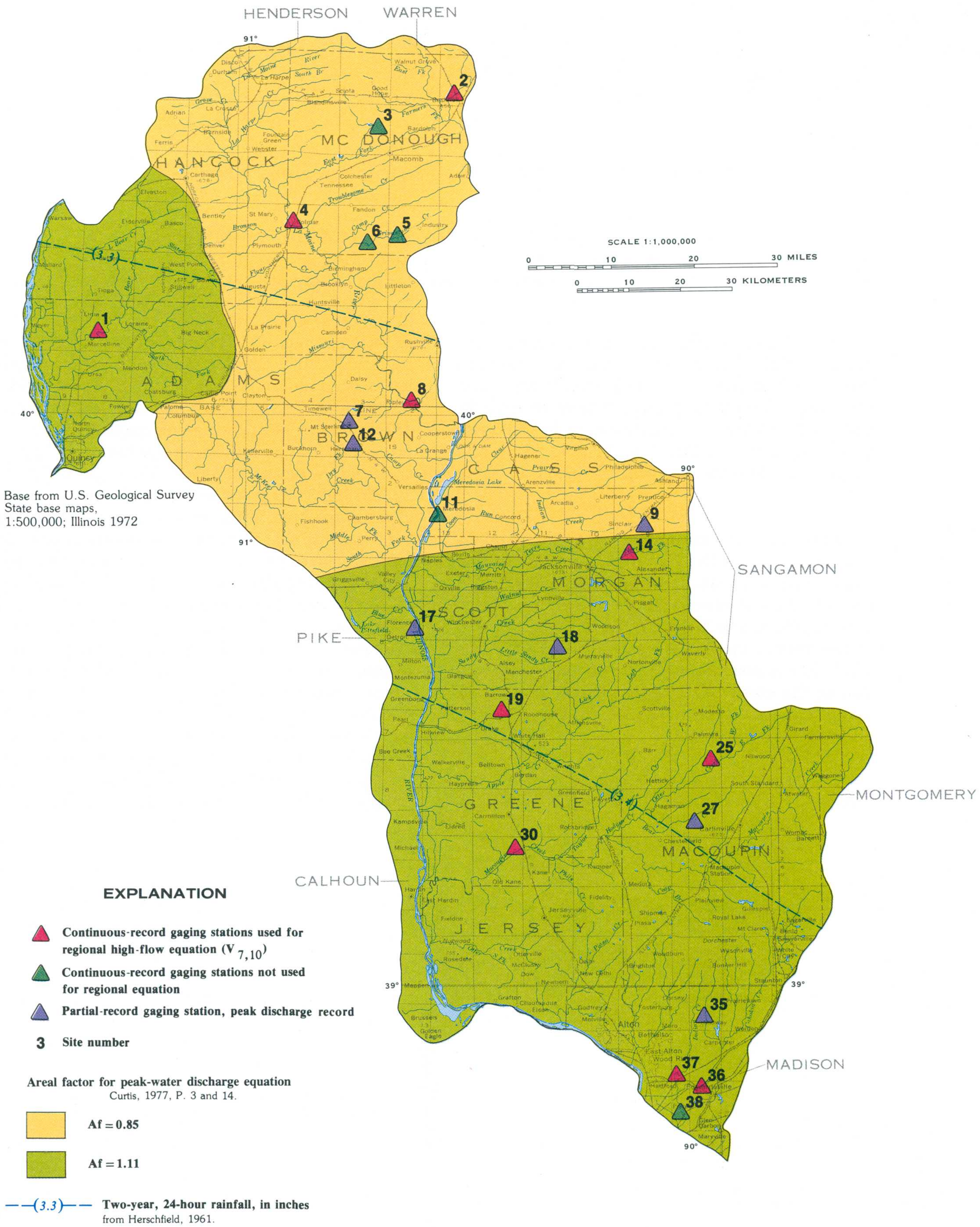


Figure 9.3-1 Location of continuous and partial-record gaging stations.

Table 9.3-1 The 2-, 10-, 50-, and 100-year 7-day high flows and peak discharges calculated for 22 daily-discharge and crest-stage gaging stations, in cubic feet per second

Map site number	Station name	Drainage area (mi^2)	Recurrence intervals, in years: 7-day high flow, 2	7-day high flow, 10	7-day high flow, 50	7-day high flow, 100	Peak discharge, 2	Peak discharge, 10	Peak discharge, 50	Peak discharge, 100
1	Bear Creek near Marcelline	349	2,120	4,620	7,130	8,260	8,230	17,400	25,600	28,900
2	Drowning Fork at Bushnell	26.3	137	294	457	532	651	1,470	2,250	2,600
3	Wigwam Hollow Creek near Macomb	.60	C	C	C	C	206	439	652	743
4	La Moine River at Colmar	655	3,650	7,960	12,000	13,700	7,890	18,000	27,600	31,700
5	Grindstone Creek near Industry	35.5	S	S	S	S	S	S	S	S
6	Grindstone Creek near Birmingham	45.4	S	S	S	S	S	S	S	S
7	West Creek at Mount Sterling	2.16	C	C	C	C	236	459	648	724
8	La Moine River at Ripley	1,293	6,020	11,200	14,600	15,700	8,420	16,200	22,800	25,500
9	Indian Creek Tributary near Sinclair	3.58	C	C	C	C	406	1,120	1,870	2,210
11	Illinois River at Meredosia	26,028	61,100	92,900	114,000	122,000	59,000	94,700	119,000	128,000
12	Dry Fork Tributary near Mount Sterling	.15	C	C	C	C	35	85	135	157
14	North Fork Mauvaise Terre Creek near Jacksonville	29.1	168	353	443	466	885	2,710	4,860	5,760
17	Illinois River Tributary near Florence	.49	C	C	C	C	297	692	1,070	1,230
18	Little Sandy Creek Tributary near Murrayville	1.82	C	C	C	C	413	1,080	1,760	2,050
19	Hurricane Creek near Roodhouse	2.30	13	28	38	41	208	577	980	1,170
25	Otter Creek near Palmyra	61.1	451	970	1,360	1,500	2,540	7,020	11,700	13,700
27	Bear Creek Tributary near Reeders	.02	C	C	C	C	14	27	38	44
30	Macoupin Creek near Kane	868	5,230	12,000	15,400	16,200	9,290	23,400	37,100	43,000
35	Cahokia Creek Tributary No. 2 near Carpenter	.45	C	C	C	C	167	356	529	601
36	Cahokia Creek at Edwardsville	212	1,470	3,070	4,210	4,620	A	A	A	A
37	Indian Creek at Wanda	36.7	262	685	1,090	1,260	1,920	4,880	6,610	9,350
38	Cahokia Creek near Poag	259	S	S	S	S	S	S	S	S

(S) No values, less than 10 years record.
(C) Crest-stage gage, peak-discharge record only.
(A) Peak-discharge value not available.

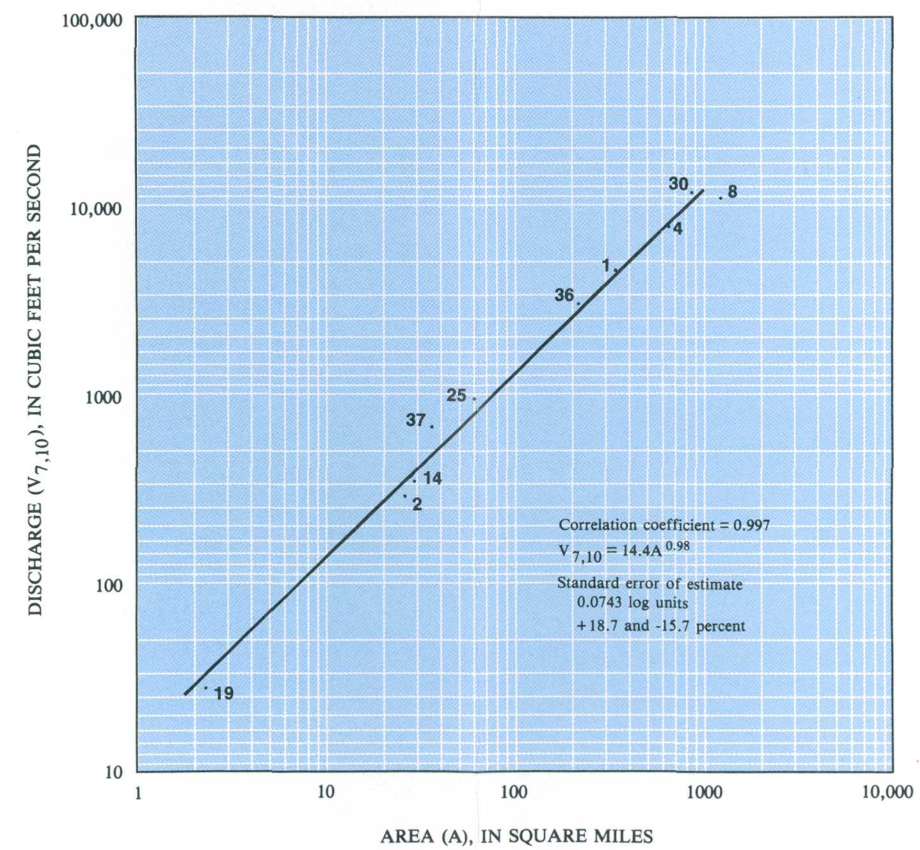


Figure 9.3-2 Relation between the 7-day, 10-year high flow and drainage area in Area 27.

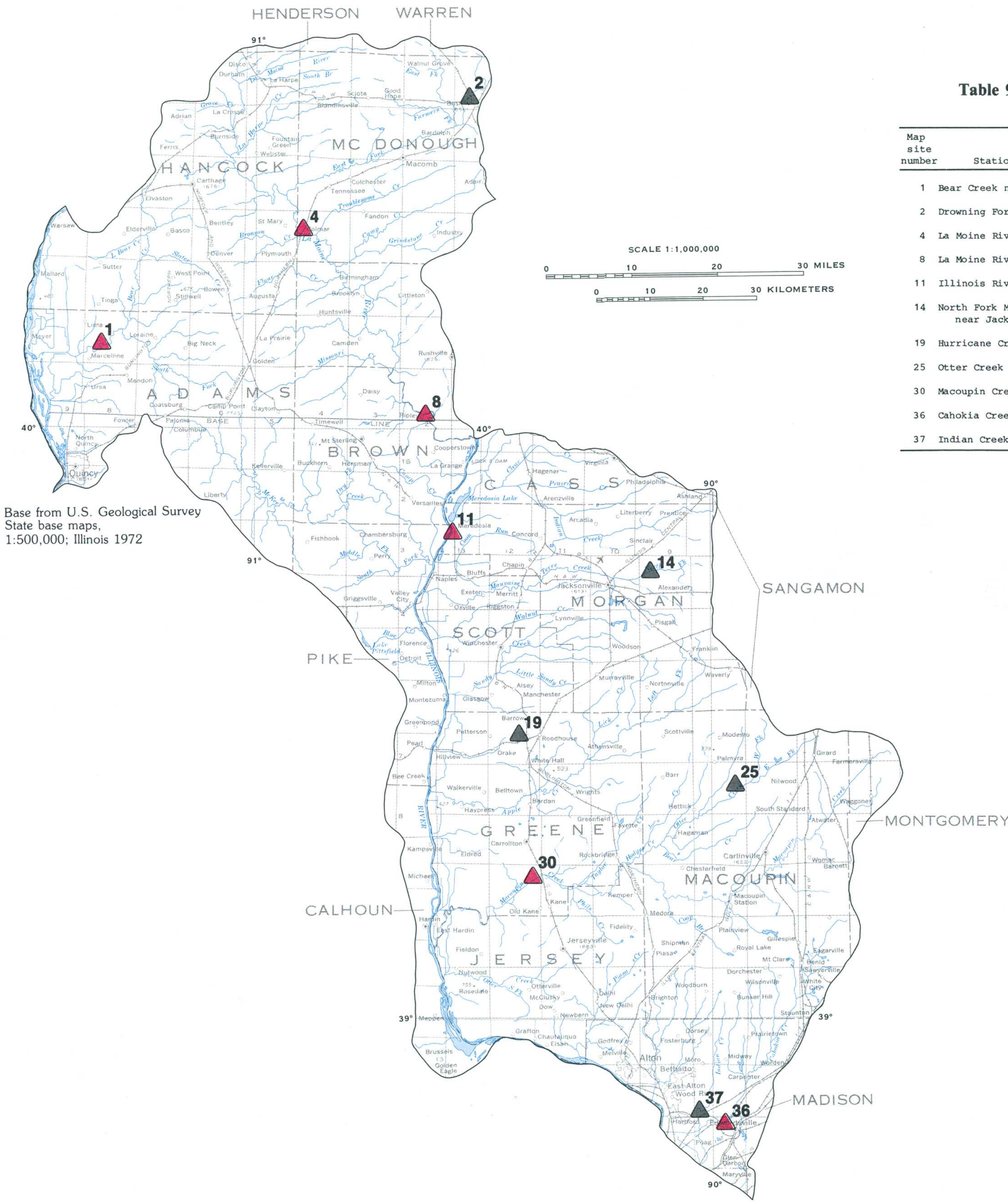
Flow-Duration Curves Reflect Streamflow Variability

Flow-duration curves for Area 27 indicate that streamflow is not well sustained during periods of no rainfall with the exceptions of the La Moine River and Lower Illinois River.

Flow duration refers to the percentage of time a specific daily discharge was equaled or exceeded during a given period of time (Searcy, 1959). Daily-discharge data for 11 gaging stations in Area 27 (fig. 9.4-1) were used in the flow-duration analyses to obtain the 95-, 90-, 75-, 70-, 50-, 25-, and 10-percent flow-duration values listed in table 9.4-1.

Low flow is associated with the higher-percentage end of the flow-duration curve and is the sustained streamflow during periods of little precipitation. It represents mostly ground water entering the stream through seeps and springs, and industrial and municipal waste-disposal effluents. High flow is associated with the lower-percentage end of the curve. It occurs as a result of direct runoff from precipitation, melting snow, and/or streamflow regulation.

The flow-duration curves in figure 9.4-2 are almost parallel for the 10 to 50 percent flow-duration range, which indicates that medium to high-flow runoff characteristics of streams in the basin are similar. In the 70 to 90 percent flow-duration range, the curves indicate that there are differences in low flow among gaged sites. It appears that the larger the drainage basin, the higher the low flow per square mile. Sites number 2, 14, 19, 25, and 37 all have less than 100 square miles of drainage area. Flow-duration curves in figure 9.4-2 indicate that flows at these sites are less than 0.05 cubic foot per second 10 percent of the time. The remaining sites, number 1, 4, 8, 30, and 36, all have more than 200 square miles of drainage area and a higher sustained low flow. The downstream reaches of large streams are in deep bedrock valleys that contain alluvial deposits. These deposits gradually release water to maintain low flow in streams during periods of no rainfall which decreases the slope of the flow-duration curve. Site number 11, Illinois River at Meredosia, includes flow diversions from Lake Michigan that flattens the shape of the flow-duration curve.



EXPLANATION

▲ (red)	Gaging stations with more than 100 square miles drainage area
▲ (gray)	Gaging stations with less than 100 square miles drainage area
14	Site number

Figure 9.4-1 Location of gaging stations with flow-duration statistics.

Table 9.4-1 Discharge at area gaging stations for various flow durations, in cubic feet per second per square mile.

Map site number	Station name	Drainage area (mi^2)	Percent of time discharge is equaled or exceeded						
			95	90	75	70	50	25	10
1	Bear Creek near Marcelline	349	0.0009	0.0026	0.0106	0.0152	0.0530	0.2381	1.063
2	Drowning Fork at Bushnell	26.3	.0004	.0019	.0418	.0646	.2700	.8441	1.768
4	La Moine River at Colmar	655	.0079	.0154	.0456	.0600	.1695	.5603	1.492
8	La Moine River at Ripley	1,293	.0148	.0214	.0523	.0682	.1748	.5584	1.671
11	Illinois River at Meredosia	26,028	.2075	.2420	.3339	.3738	.5840	1.164	1.710
14	North Fork Mauvaise Terre Creek near Jacksonville	29.1	0	.0003	.0213	.0447	.2371	.6976	1.646
19	Hurricane Creek near Roodhouse	2.30	0	0	.0026	.0060	.1304	.6522	1.522
25	Otter Creek near Palmyra	61.1	0	0	.0039	.0101	.0687	.3552	1.162
30	Macoupin Creek near Kane	868	.0052	.0084	.0264	.0358	.1054	.3698	1.302
36	Cahokia Creek at Edwardsville	212	.0057	.0094	.0288	.0382	.1090	.3877	1.170
37	Indian Creek at Wanda	36.7	0	.0003	.0082	.0155	.0763	.3270	1.011

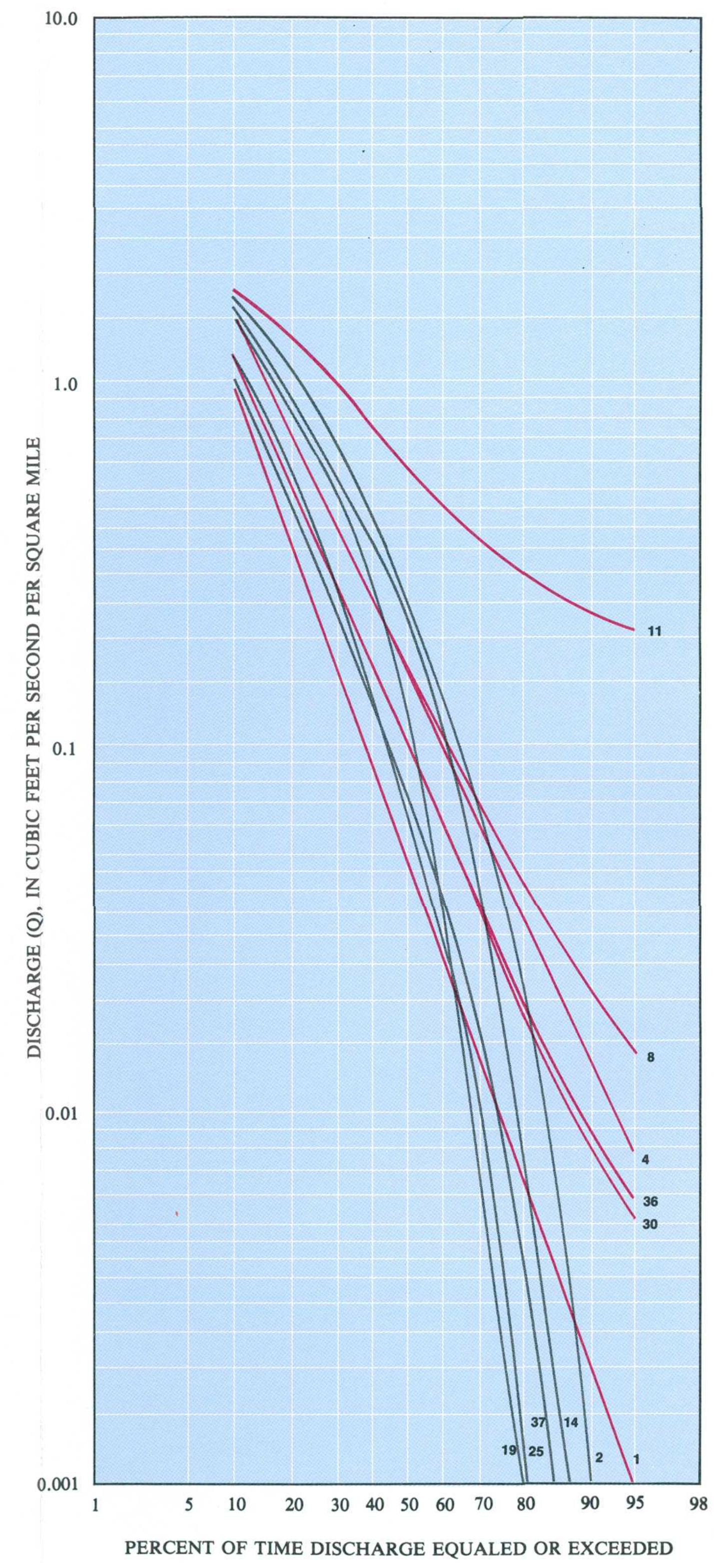


Figure 9.4-2 Flow-duration curves for study-area gaging stations. Numbers refer to sites in table 9.4-1.

Specific Conductance can be Used to Estimate Dissolved-Solids Concentrations

An equation to estimate dissolved-solids concentrations from specific conductance measurements was determined for Area 27 streams. The relation is typical of natural stream water.

Specific conductance ranged from 48 to 1,580 micromhos per centimeter at 25° Celsius (μmhos) at 23 sites (fig. 10.1-1). Average values ranged from 476 to 858 μmhos, with the exception of one value of 1,540 μmhos measured at site number 20. Eight sites had maximum measured values greater than 1,000 μmhos (table 10.1-1).

Dissolved-solids concentrations ranged from 102 to 1,310 milligrams per liter (mg/L). Average concentrations ranged from 240 to 652 mg/L. One sample at site number 20 had a concentration of 1,310 mg/L (table 10.1-2).

For Illinois streams, there is a linear relation between specific conductance and dissolved-solids concentration in the water. An equation of the form $KA = S$ (Hem, 1970, p. 99) can be used to estimate dissolved-solids concentrations. Specific conductance (K) is in micromhos per centimeter at 25° Celsius, the dissolved-solids concentration (S) is in milligrams per liter, and the regression coefficient (A) is a dimensionless constant. Hem (1970, p. 99) states that the coefficient, A, is usually between 0.55 and 0.75 for natural waters. Higher values generally are associated with high sulfate concentrations. Data from 18 sites in Area 27 were used to determine an A value of 0.66 (fig. 10.1-2).

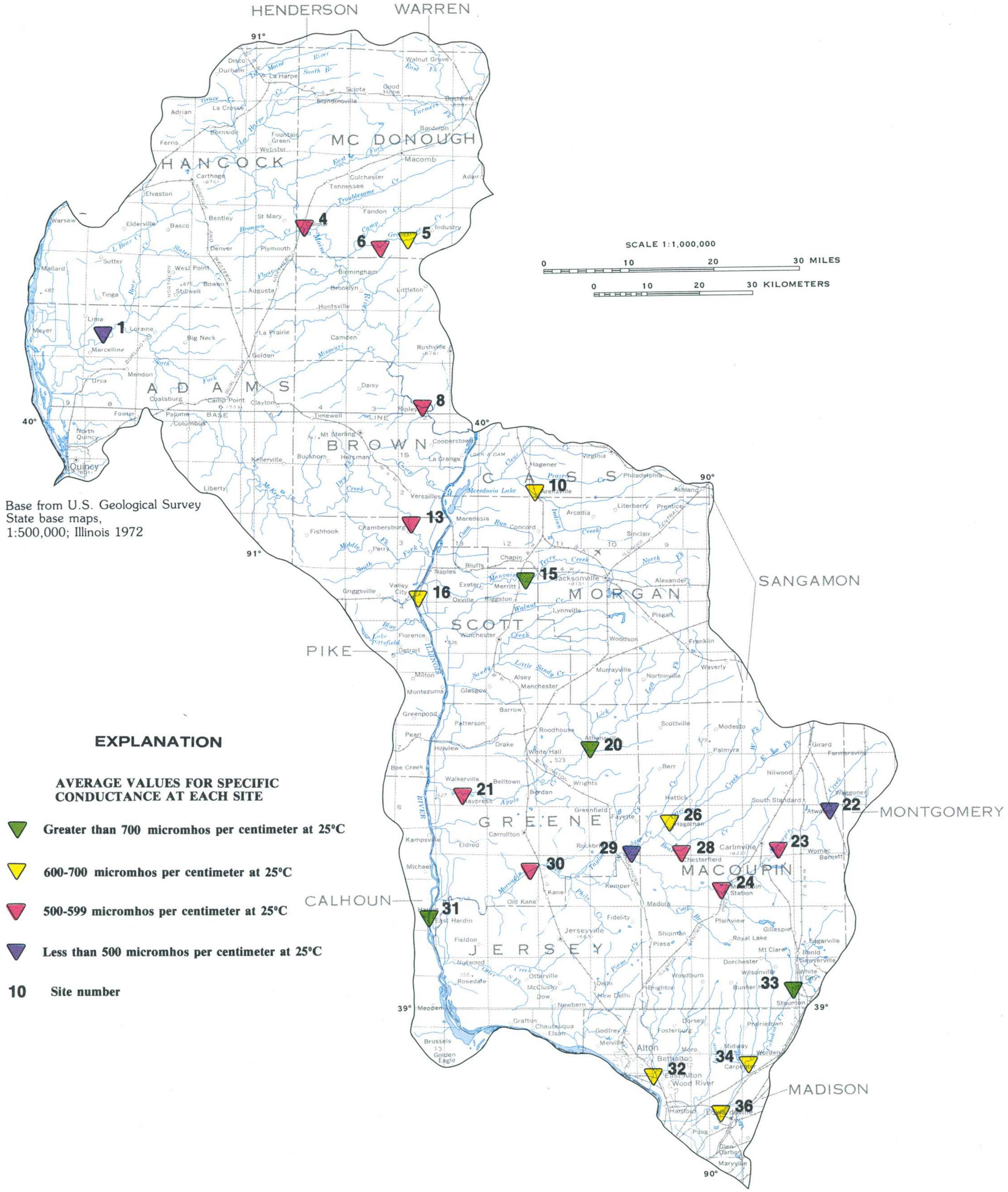


Figure 10.1-1 Average values of specific conductance measured at sites in the area.

Table 10.1-1 Specific conductance values at 23 stream sites in Area 27

Map site number	Number of samples	Specific conductance, in micromhos per centimeter at 25 degrees Celsius		
		Minimum	Average	Maximum
1	49	230	494	815
4	125	120	534	980
5	17	48	682	1,380
6	17	166	565	880
8	125	142	512	870
10	40	139	631	940
13	34	150	546	1,020
15	40	150	783	1,580
16	76	365	692	1,150
20	1	1,540	1,540	1,540
21	40	170	518	765
22	5	220	476	858
23	1	540	540	540
24	38	144	592	1,150
26	1	632	632	632
28	4	285	576	890
29	7	210	483	622
30	50	137	553	865
31	46	315	701	1,100
32	29	58	653	990
33	2	855	858	862
34	5	470	699	870
36	33	78	643	1,060

Table 10.1-2 Dissolved solids concentrations at 18 stream sites in Area 27

Map site number	Number of samples	Dissolved-solids concentration, in milligrams per liter		
		Minimum	Average	Maximum
4	95	102	335	823
5	15	325	462	875
6	15	163	368	560
8	90	143	327	486
13	1	256	256	256
15	1	409	409	409
16	68	220	424	640
20	1	1,310	1,310	1,310
22	3	164	332	489
24	2	277	279	281
26	1	424	424	424
28	2	350	384	418
29	4	246	302	428
30	1	240	240	240
32	9	430	652	815
33	2	580	598	616
34	2	432	460	487
36	10	335	489	660

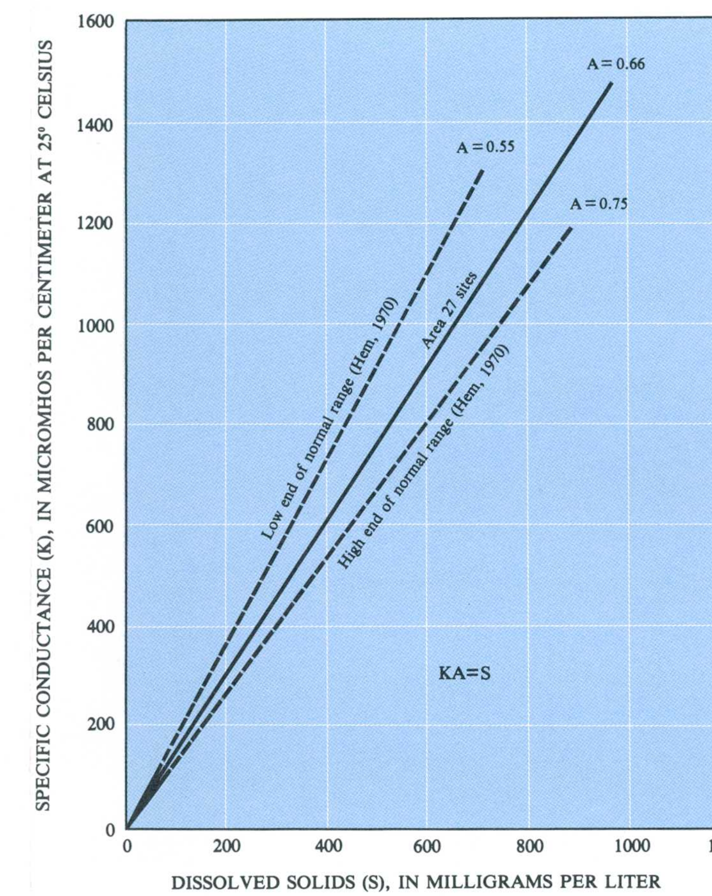


Figure 10.1-2 Relation between specific conductance and dissolved solids in Area 27.

Area Waters are Neutral to Slightly Basic

Measurements of pH for area streams are in a range of values common to natural waters.

Measured pH at 23 sites (fig. 10.2-1) ranged from 4.9 to 9.1 (fig. 10.2-2) for 812 measurements. Only two sites (4 and 8 on the La Moine River) had pH values less than 6.7 (table 10.2-1). From 1976 through 1978, four pH measurements at site number 4 ranged from 5.1 to 6.4, and 10 measurements at site number 8 ranged from 4.9 to 6.4. From 1979 through 1981, all measurements were above 6.5. Maximum values at 23 sites ranged from 6.8 to 9.1.

A pH of 7.0 indicates neutral water; lower values indicate acidic water and higher values indicate basic water. Generally, the surface waters of Area 27 can be classified as neutral to slightly basic. With the exception of the La Moine River, all streams had pH ranges similar to that of natural waters as described by Hem (1970, p. 93). For the survival of freshwater aquatic life, a pH range of 6.5 to 9.0 is recommended (U.S. Environmental Protection Agency, 1976, p. 178).

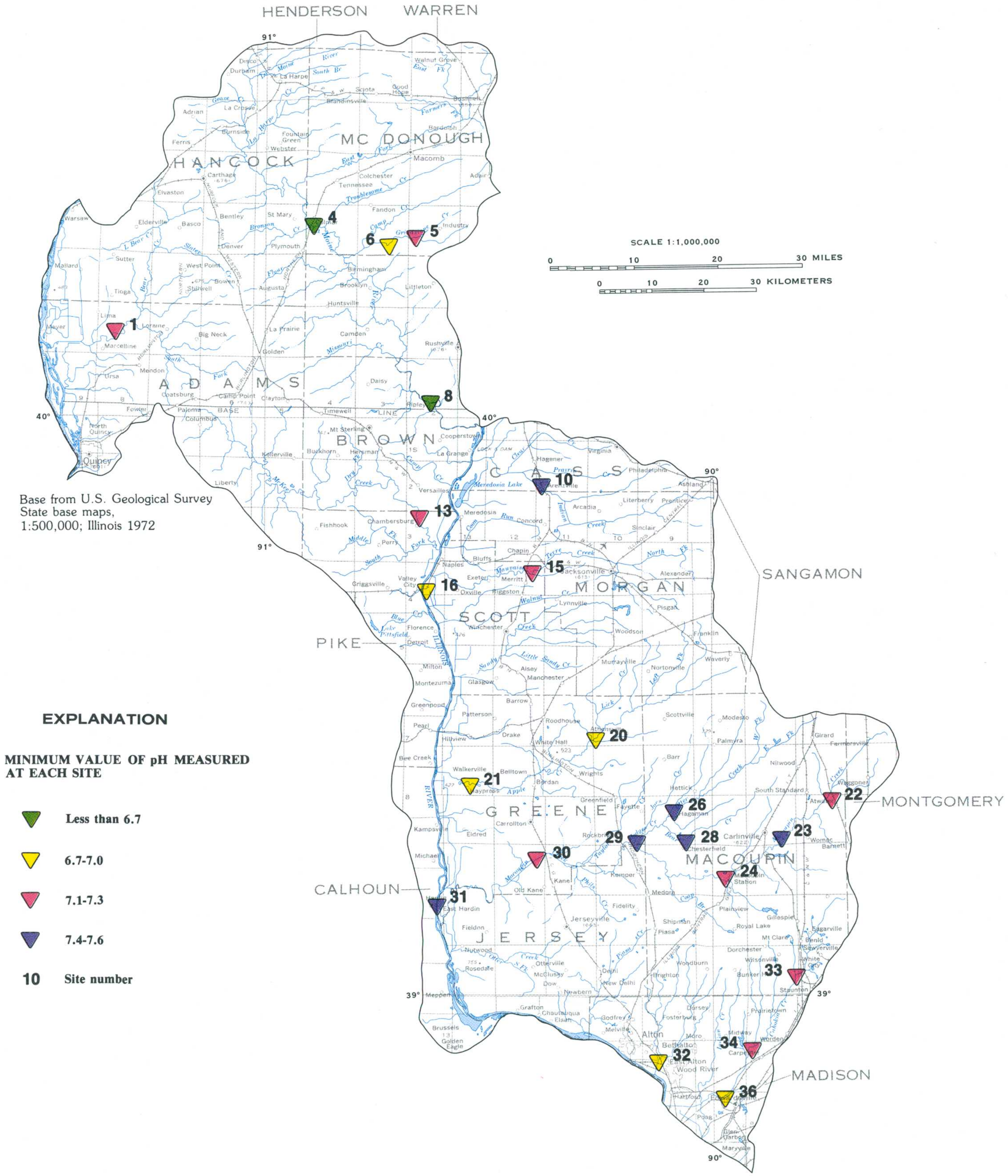


Figure 10.2-1 Minimum value of pH measured at stream sites in the area.

Table 10.2-1 Minimum and maximum pH at 23 stream sites in Area 27.

Map site number	Station name	Number of samples	pH values Minimum	pH values Maximum
1	Bear Creek near Marcelline	48	7.3	8.6
4	La Moine River at Colmar	123	5.1	8.8
5	Grindstone Creek near Industry	17	7.1	8.0
6	Grindstone Creek near Birmingham	17	6.7	9.1
8	La Moine River at Ripley	124	4.9	9.0
10	Indian Creek at Arenzville	40	7.5	8.6
13	McKee Creek at Chambersburg	34	7.3	8.4
15	Mauvaise Terre Creek near Merritt	40	7.1	8.1
16	Illinois River at Valley City	79	6.9	8.6
20	Birch Creek near Athensville	1	6.8	6.8
21	Apple Creek near Eldred	44	7.0	8.4
22	Macoupin Creek near Standard City	5	7.1	7.4
23	Macoupin Creek near Carlinville	1	7.4	7.4
24	Macoupin Creek near Macoupin	38	7.2	8.7
26	Solomon Creek at Hagaman	1	7.4	7.4
28	Bear Creek near Chesterfield	4	7.5	7.8
29	Hodges Creek near Rockbridge	7	7.4	8.1
30	Macoupin Creek near Kane	50	7.2	8.9
31	Illinois River at Hardin	46	7.6	8.6
32	Wood River at East Alton	42	6.9	8.9
33	Cahokia Creek near Staunton	2	7.2	7.5
34	Cahokia Creek near Carpenter	5	7.1	8.1
36	Cahokia Creek at Edwardsville	44	7.0	8.5

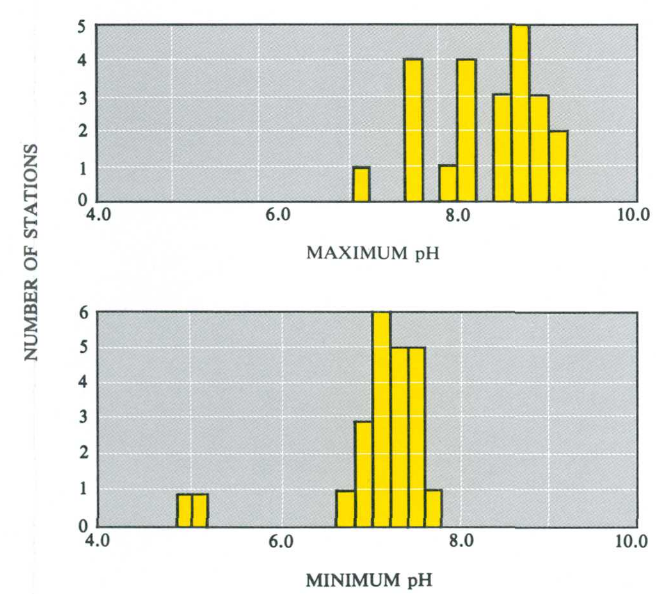


Figure 10.2-2 Range and distribution of pH values at water-quality sites.

Iron Concentrations Commonly Exceed Recommended Limits

Concentrations of dissolved iron plus suspended iron commonly exceed limits of 1,000 micrograms per liter recommended for the survival of aquatic life.

Total-recoverable-iron (dissolved plus suspended iron) concentrations in streams ranged from 10 to 69,700 micrograms per liter (μg/L) in Area 27. The average concentrations of total-recoverable-iron at sites in the area ranged from 360 to 6,400 μg/L (table 10.3-1). Ranges of average concentrations of total-recoverable-iron are shown in figure 10.3-1. The average concentration for 774 samples at 23 stream sites was 4,300 μg/L.

Dissolved-iron concentrations ranged from 10 to 2,600 μg/L and averaged 100 μg/L for 110 samples at 23 sites. Average dissolved-iron concentrations at sites in the area ranged from 14 to 280 μg/L (table 10.3-2). Ranges of average concentrations of dissolved iron are shown in figure 10.3-2.

Iron is a common constituent of most surface waters. The dissolution of iron is inversely related to pH. Surface mining can increase the amount of iron available to waters downstream by exposing iron-bearing minerals to weathering. The ferrous form (Fe^{+2}) is commonly associated with coals of the Pennsylvanian System. This soluble form of iron is easily oxidized to the less soluble ferric form (Fe^{+3}) when it is exposed to air. In streams, iron can occur as dissolved iron or precipitated iron in bed material or moving in suspension with sediment. Less than 3 percent of the iron in area streams was in the dissolved form.

Iron is an essential element to plants and animals. It is vital to the oxygen transport mechanism in the blood of all vertebrate animals, and it can be a limiting growth factor in plants. Concentrations of total recoverable iron commonly exceeded the maximum concentration of 1,000 μg/L for freshwater aquatic life recommended by the U.S. Environmental Protection Agency (1976, p. 78). Only two observed dissolved-iron concentrations exceeded the recommended limit.

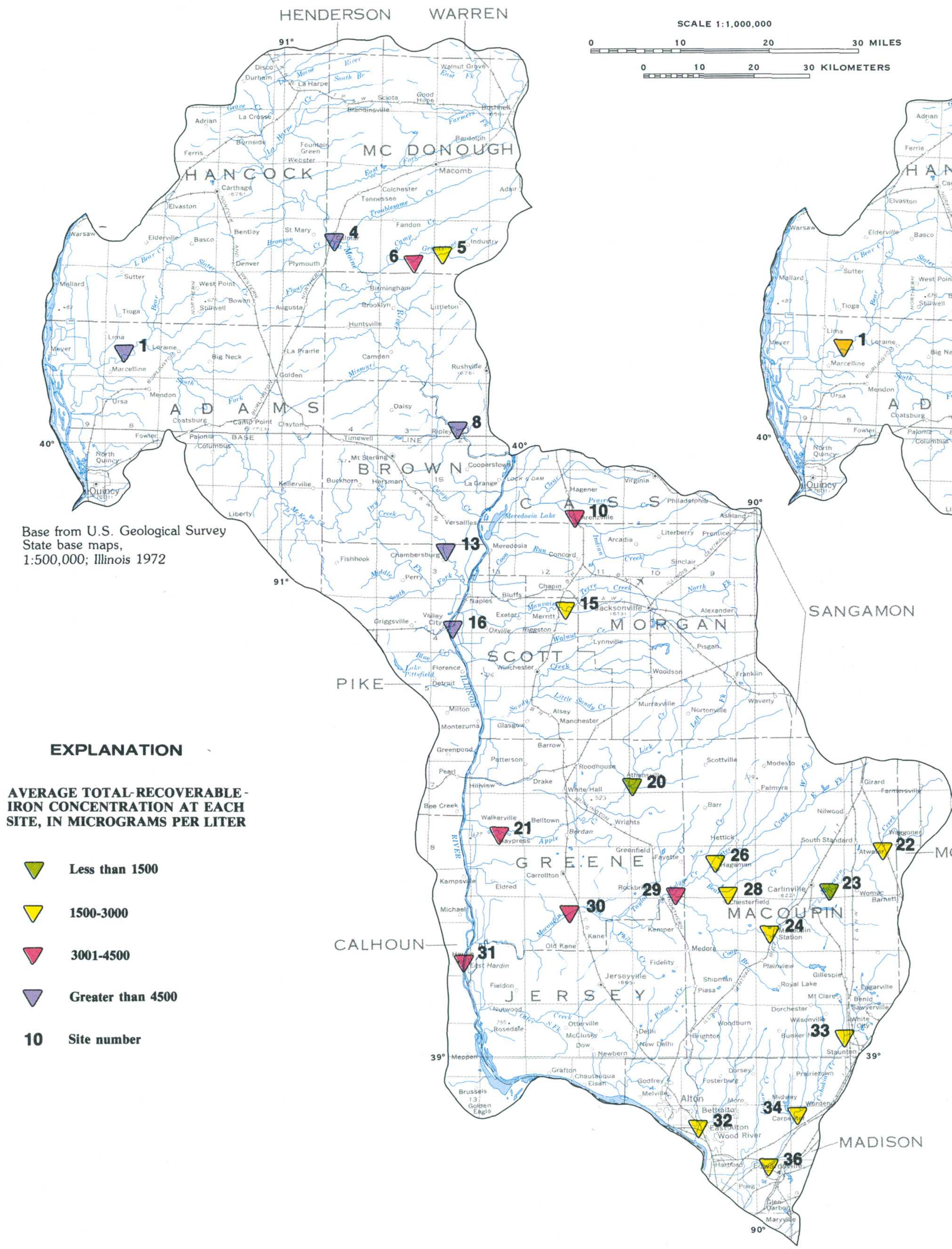


Figure 10.3-1 Average total-recoverable-iron concentrations at water-quality sites.

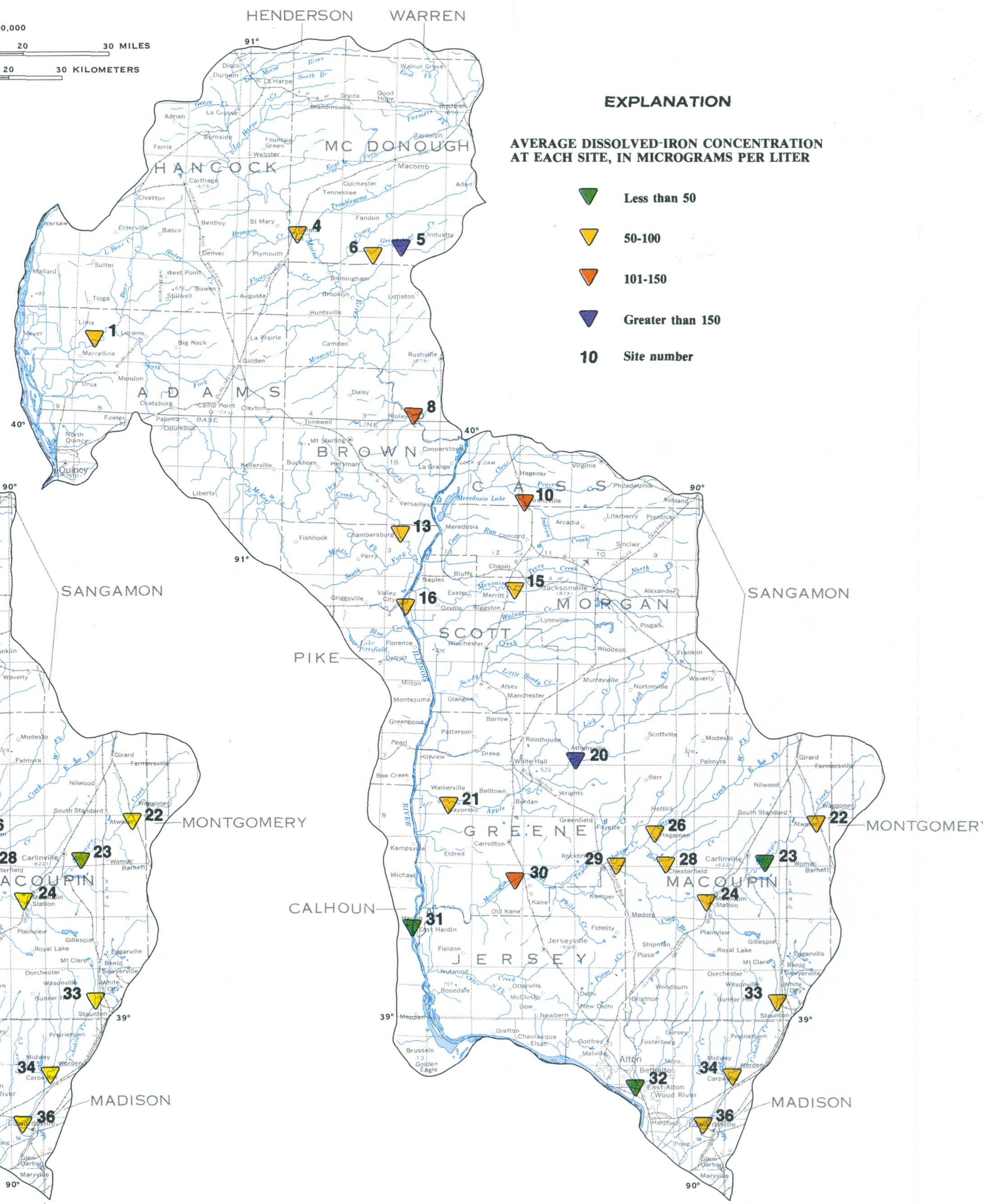


Figure 10.3-2 Average dissolved-iron concentration at water-quality sites.

Table 10.3-1 Measured total-recoverable-iron concentrations at 23 stream sites in Area 27

Map site number	Number of samples	Total recoverable iron concentration, in micrograms per liter		
		Minimum	Average	Maximum
1	27	620	4,700	50,000
4	125	10	5,000	55,000
5	17	200	1,500	6,700
6	17	50	3,600	36,000
8	127	10	6,400	69,700
10	40	200	4,400	36,000
13	33	400	5,200	34,000
15	41	50	2,500	17,000
16	58	1,000	5,900	31,000
20	1	410	410	410
21	45	350	4,500	42,000
22	5	930	3,000	11,000
23	1	360	360	360
24	37	380	2,800	26,000
26	1	1,500	1,500	1,500
28	4	500	2,500	6,000
29	7	700	3,100	12,000
30	50	400	4,400	31,000
31	46	1,000	3,600	10,700
32	40	100	1,900	37,600
33	2	700	2,900	5,000
34	5	410	2,000	4,000
36	45	340	1,700	5,800

Table 10.3-2 Measured dissolved-iron concentrations at 23 stream sites in Area 27

Map site number	Number of samples	Dissolved iron concentration, in micrograms per liter		
		Minimum	Average	Maximum
1	3	40	60	80
4	2	10	52	95
5	16	20	270	2,600
6	16	10	80	220
8	1	140	140	140
10	1	130	130	130
13	2	10	95	180
15	2	50	55	60
16	25	10	60	410
20	1	280	280	280
21	2	14	87	160
22	5	30	75	140
23	1	30	30	30
24	6	12	78	140
26	1	69	69	69
28	4	30	72	100
29	7	10	89	220
30	3	93	120	170
31	2	10	14	17
32	1	20	20	20
33	2	30	56	82
34	5	30	100	160
36	2	40	57	74

Manganese Concentrations Commonly Exceed Limits

Concentrations of total recoverable manganese exceeded the recommended limit for domestic water supply.

Average concentrations of total recoverable manganese (suspended plus the dissolved manganese) and dissolved manganese for each of 23 stream sites are shown in figures 10.4-1 and 10.4-2, respectively. Average total-recoverable manganese concentrations at sites in Area 27 ranged from 190 to 2,500 micrograms per liter (μg/L) (table 10.4-1). Average dissolved manganese concentrations ranged from 7.5 to 2,500 μg/L (table 10.4-2). The average for all measurements was 580 μg/L for total-recoverable manganese and 430 μg/L for dissolved manganese.

Manganese is an element widely distributed in igneous rocks and in soils, but its total abundance in the Earth's crust is small enough to consider it a minor element. Manganese and iron are chemically very similar. However, manganese is not as easily oxidized and will stay in the dissolved state longer than iron (Rankama and Sahama, 1950).

"Manganese is a vital micro-nutrient for both plants and animals" (U.S. Environmental Protection Agency, 1976, p. 95). 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 to prevent staining of laundry and objectionable tastes (U.S. Environmental Protection Agency, 1976, p. 96). Average concentrations of both total recoverable and dissolved manganese measured in the study area commonly exceeded 50 μg/L.

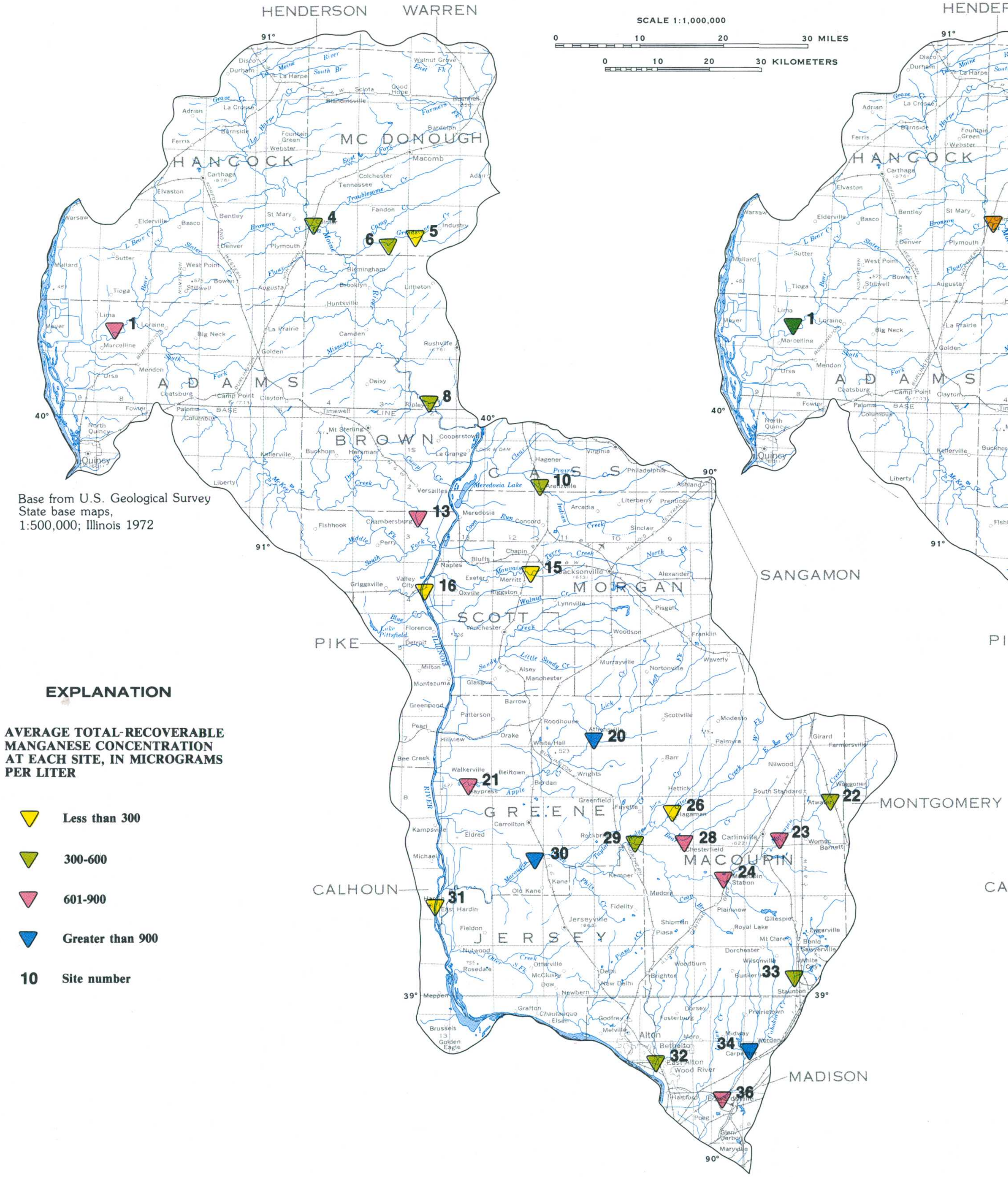


Figure 10.4-1 Average total-recoverable-manganese concentration at water-quality sites.

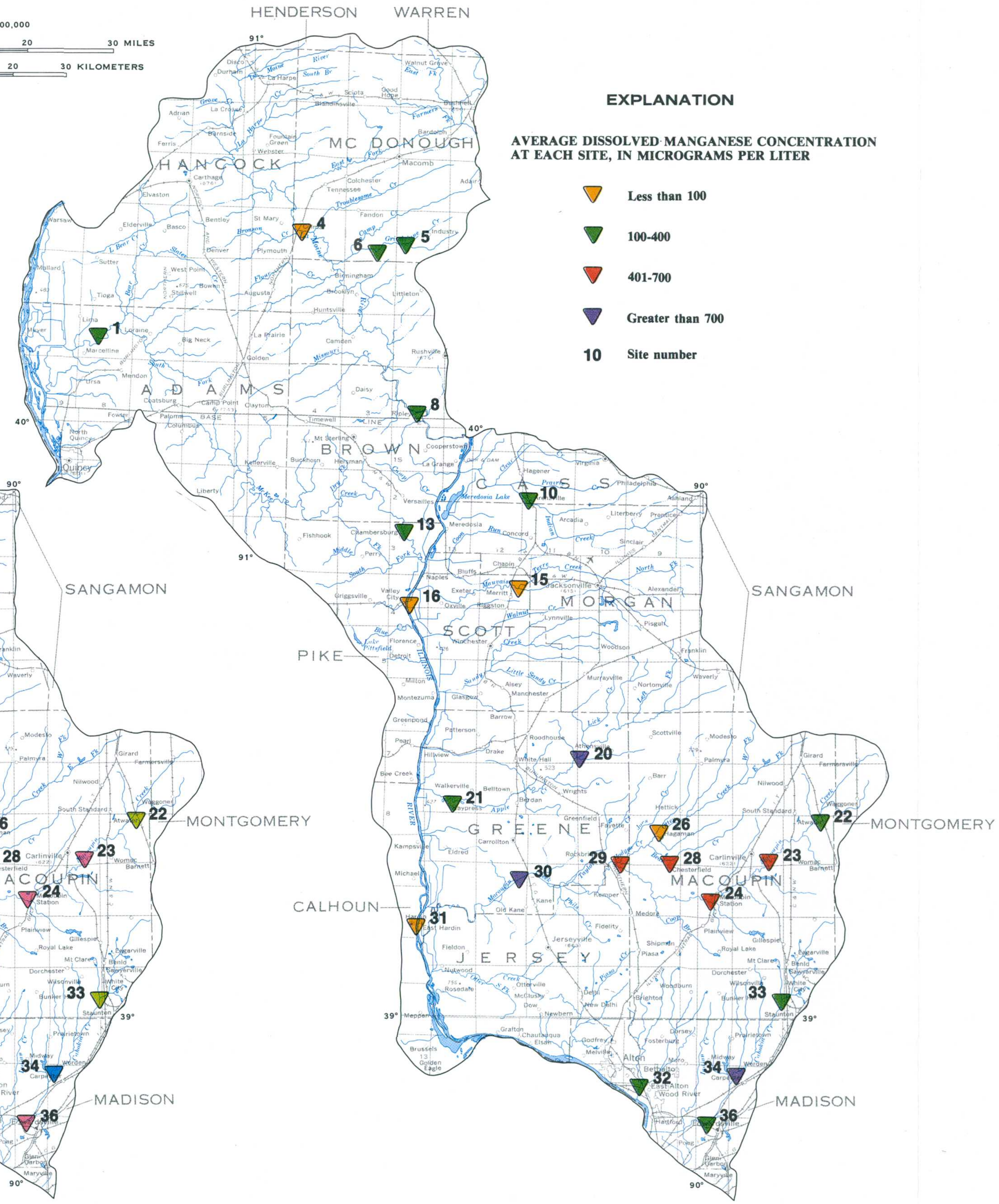


Figure 10.4-2 Average dissolved-manganese concentration at water-quality sites.

Table 10.4-1 Total-recoverable-manganese concentrations at 23 stream sites in Area 27

Map site number	Number of samples	Total-recoverable manganese concentration, in micrograms per liter		
		Minimum	Average	Maximum
1	27	180	670	3,100
4	43	100	480	2,400
5	17	110	280	760
6	17	80	400	1,600
8	44	80	500	2,450
10	23	60	550	3,400
13	25	110	710	5,300
15	22	90	280	970
16	36	60	260	890
20	1	2,500	2,500	2,500
21	27	90	630	1,600
22	5	130	460	800
23	1	780	780	780
24	37	130	620	2,900
26	1	190	190	190
28	4	290	620	1,500
29	7	190	600	1,600
30	50	150	1,100	3,200
31	29	80	230	760
32	22	120	370	1,800
33	2	250	380	500
34	5	170	1,100	4,200
36	45	110	610	1,500

Table 10.4-2 Dissolved-manganese concentrations at 23 stream sites in Area 27

Map site number	Number of samples	Dissolved-manganese concentration, in micrograms per liter		
		Minimum	Average	Maximum
1	3	70	320	540
4	2	28	54	80
5	16	35	190	740
6	16	23	240	1,200
8	1	220	220	220
10	1	390	390	390
13	2	28	110	200
15	2	67	78	90
16	25	1	34	240
20	1	2,500	2,500	2,500
21	2	120	210	300
22	5	60	310	670
23	1	680	680	680
24	6	180	640	1,700
26	1	98	98	98
28	4	150	510	1,400
29	7	70	430	1,600
30	3	120	1,500	2,700
31	2	5	7.5	10
32	1	360	360	360
33	2	250	350	450
34	5	110	970	4,000
36	2	91	360	630

Moderate Sulfate Concentrations in Area Streams

Average dissolved-sulfate concentration in Area 27 is 80 milligrams per liter. Sulfur is found in pyrite and marcasite that are present with coal in the area.

The measured concentrations of dissolved sulfate in 375 water samples from 21 sites in Area 27 ranged from 5 to 750 milligrams per liter (mg/L) and averaged 80 mg/L (table 10.5-1). The ranges of average dissolved-sulfate concentrations are shown in figure 10.5-1.

Sulfur is present in coal and associated strata as metallic sulfides, mainly in the form of pyrite (FeS_2) and marcasite (FeS_2), which also are sources of ferrous iron. During weathering, the iron sulfide produces sulfate and iron in solution. Iron is easily oxidized further and commonly precipitates as ferric hydroxide. At sites downstream of mining, sulfate concentrations may increase due to the exposure of sulfide-bearing minerals to weathering in the mined areas.

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).

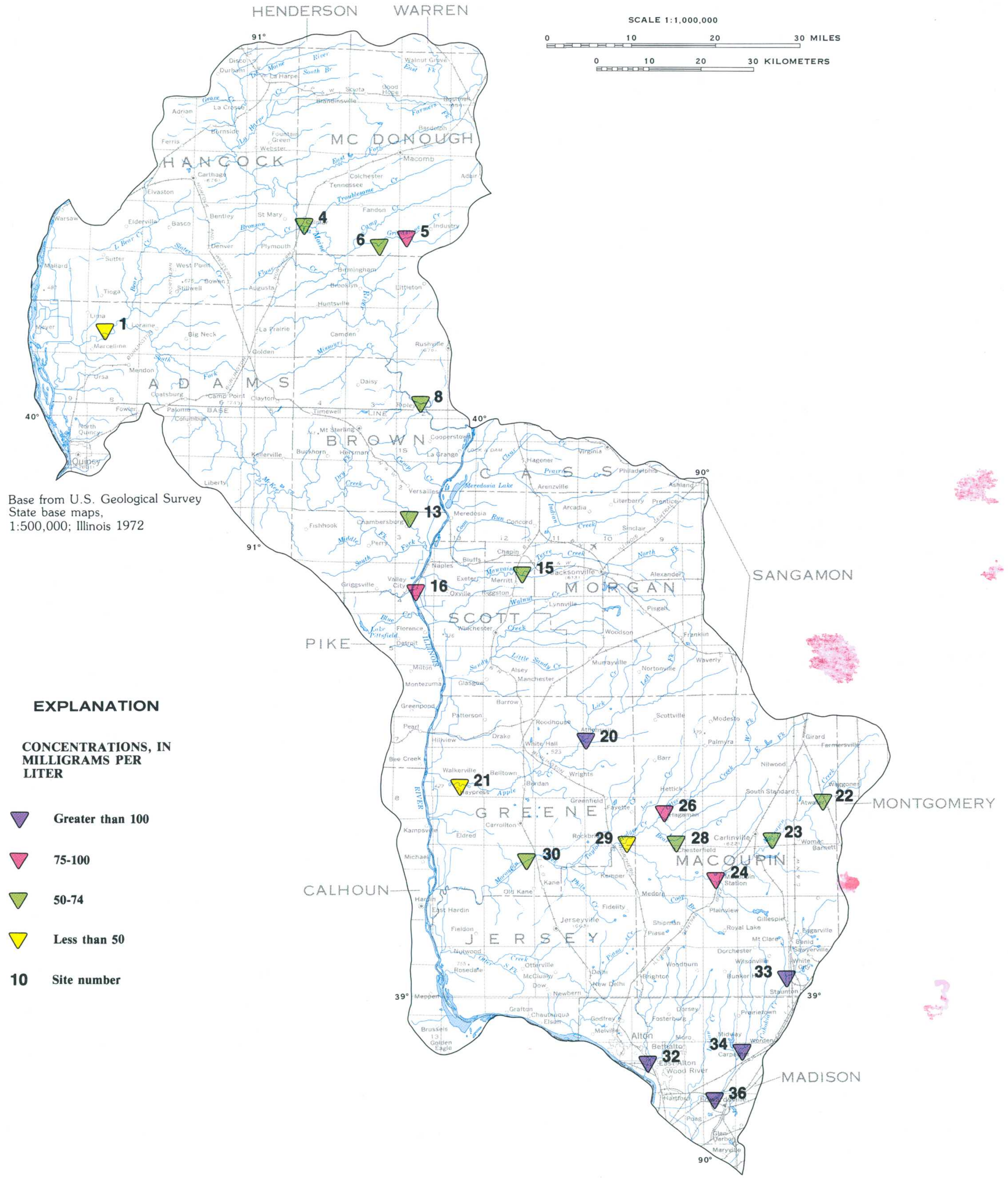


Figure 10.5-1 Average dissolved-sulfate concentrations in Area 27.

Table 10.5-1 Dissolved-sulfate concentrations at 21 stream sites in Area 27

Map site number	Station name	Number of samples	Dissolved sulfate, in milligrams per liter: Minimum	Average	Maximum
1	Bear Creek near Marcelline	1	40	40	40
4	La Moine River at Colmar	53	32	53	100
5	Grindstone Creek near Industry	16	43	83	250
6	Grindstone Creek near Birmingham	16	29	71	160
8	La Moine River at Ripley	53	24	55	98
13	McKee Creek at Chambersburg	2	48	51	53
15	Mauvaise Terre Creek near Merritt	1	51	51	51
16	Illinois River at Valley City	73	35	81	130
20	Birch Creek near Athensville	1	750	750	750
21	Apple Creek near Eldred	1	35	35	35
22	Macoupin Creek near Standard City	5	24	52	66
23	Macoupin Creek near Carlinville	1	56	56	56
24	Macoupin Creek near Macoupin	37	21	79	180
26	Solomon Creek at Hagaman	1	77	77	77
28	Bear Creek near Chesterfield	4	20	74	130
29	Hodges Creek near Rockbridge	7	17	45	78
30	Macoupin Creek near Kane	49	5	64	110
32	Wood River at East Alton	1	180	180	180
33	Cahokia Creek near Staunton	2	220	250	280
34	Cahokia Creek near Carpenter	5	96	160	200
36	Cahokia Creek at Edwardsville	46	16	140	230

Alkalinity Generally Favorable to Aquatic Life

Alkalinity concentrations in Area 27 average 180 milligrams per liter. Alkalinity values are suitable for freshwater aquatic life and are generally adequate to buffer small acid influxes.

Alkalinity concentrations commonly are reported as an equivalent amount of calcium carbonate ($CaCO_3$), in milligrams per liter (mg/L). Measurements of alkalinity ranged from 1 to 770 mg/L as $CaCO_3$ and averaged 180 mg/L as $CaCO_3$ from 350 analyses obtained at 21 sites (table 10.6-1). The average alkalinity concentrations of area streams ranged from 114 to 225 mg/L as $CaCO_3$. Areal variation is shown in figure 10.6-1.

Alkalinity values of 20 mg/L or more are generally recommended for freshwater aquatic life. Water with alkalinity less than 20 mg/L is susceptible to rapid changes in pH. Some components of alkalinity, such as carbonate and bicarbonate, can react with some toxic heavy metals and reduce their toxicity (U.S. Environmental Protection Agency, 1976, p. 7). Streams within the study area generally had alkalinities capable of maintaining a sufficient buffering capacity against small volumes of acid influx.

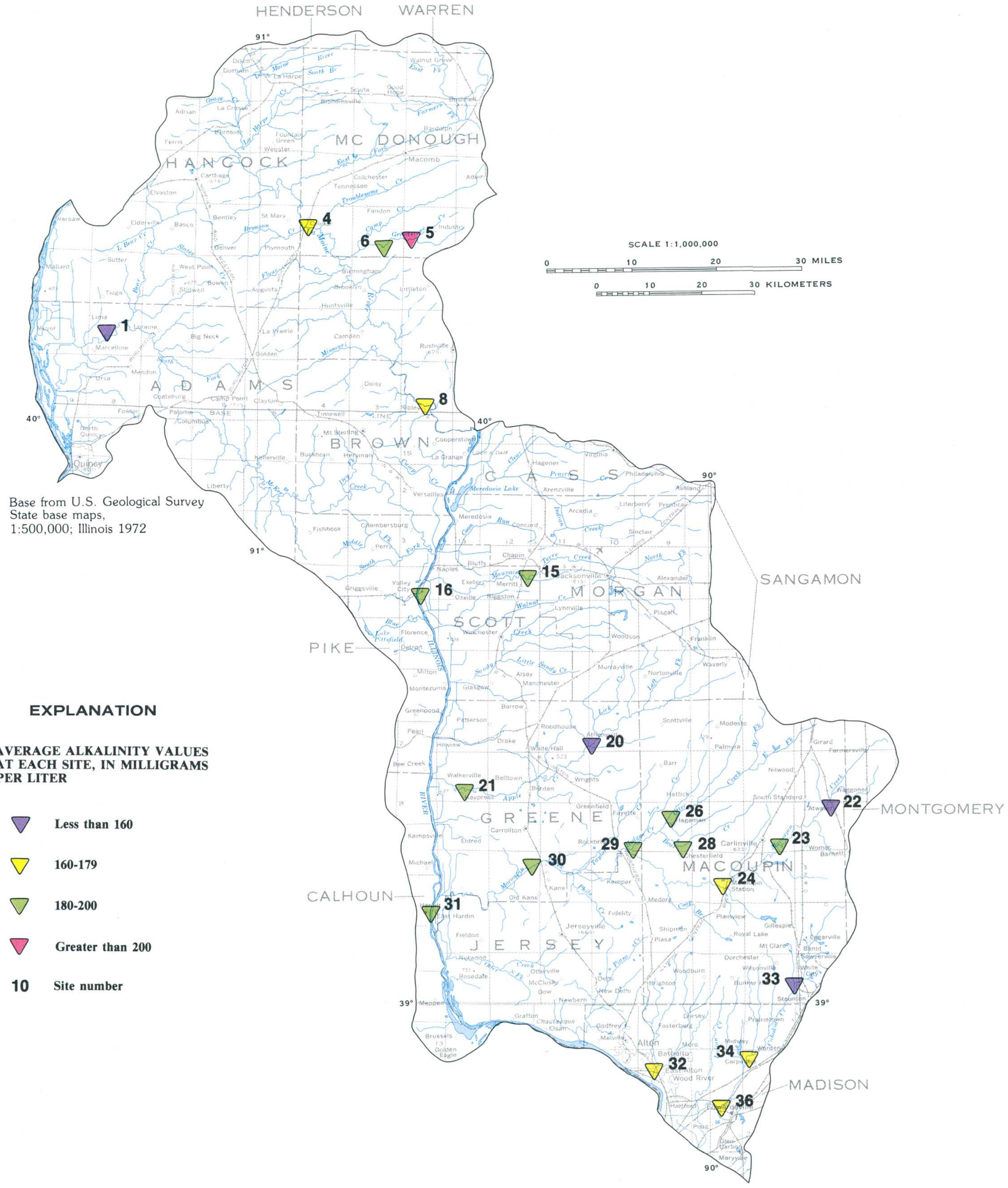


Figure 10.6-1 Average values of alkalinity measured in the area.

Table 10.6-1 Alkalinity values at 21 stream sites in Area 27

Map site number	Station name	Number of samples	Alkalinity as $CaCO_3$ in milligrams per liter		
			Minimum	Average	Maximum
1	Bear Creek near Marcelline	5	37	148	211
4	La Moine River at Colmar	44	10	172	290
5	Grindstone Creek near Industry	17	120	225	480
6	Grindstone Creek near Birmingham	17	98	192	260
8	La Moine River at Ripley	44	10	173	340
15	Mauvaise Terre Creek near Merritt	1	180	180	180
16	Illinois River at Valley City	59	90	182	253
20	Birch Creek near Athensville	1	150	150	150
21	Apple Creek near Eldred	3	120	196	240
22	Macoupin Creek near Standard City	4	55	114	170
23	Macoupin Creek near Carlinville	1	200	200	200
24	Macoupin Creek near Macoupin	34	12	169	357
26	Solomon Creek at Hagaman	1	180	180	180
28	Bear Creek near Chesterfield	4	99	187	290
29	Hodges Creek near Rockbridge	7	71	187	280
30	Macoupin Creek near Kane	49	5	190	418
31	Illinois River at Hardin	5	116	189	252
32	Wood River at East Alton	1	160	160	160
33	Cahokia Creek near Staunton	2	120	155	190
34	Cahokia Creek near Carpenter	5	26	167	250
36	Cahokia Creek at Edwardsville	46	1	160	770

Area Streams Contain Low Concentrations of Many Elements

Fourteen trace elements and other constituents measured in study area streams commonly are present in low concentrations. Sources of these elements include soils and rocks underlying the basin and atmospheric fallout.

The maximum concentration of all trace elements measured in Area 27 (table 10.7-1) was less than the maximum limit recommended by the U.S. Environmental Protection Agency (1976). The U.S. Environmental Protection Agency's (1976) recommended maximum concentrations for the following elements are:

Boron, 750 micrograms per liter (μg/L) for long term irrigation to sensitive crops;

Chloride, 250 milligrams per liter (mg/L) for domestic water supplies;

Chromium, 50 μg/L for domestic water supply, 100 μg/L for freshwater aquatic life;

Copper, 1,000 μg/L for domestic water supply;

Zinc, 5,000 μg/L for domestic water supplies.

Phosphorus promotes growth of plants and contributes to eutrophication of lakes, reservoirs, and streams. To prevent plant nuisances in natural waters, the USEPA (1976, p. 188) gives the following maximum levels for phosphate phosphorus concentrations as a desired goal:

0.025 mg/L within lakes and reservoirs,

0.050 mg/L in any stream at the point of entry to a lake or reservoir,

0.100 mg/L in any stream not discharging directly into a lake or reservoir.

In low concentrations, many elements are essential to life. However, in high concentrations, the same elements may be toxic to man, plants, or animals. Sources of these elements in streams include soils and rocks underlying the basin and atmospheric fallout. High concentrations can occur naturally; however, most high concentrations in surface waters are generally associated with industrial-waste discharge.

Number of sampling sites	Number of samples	Constituent
21	67	Boron Dissolved micrograms per liter
22	138	Calcium Dissolved milligrams per liter
22	213	Chloride Dissolved milligrams per liter
13	41	Chromium Dissolved micrograms per liter
13	40	Copper Dissolved micrograms per liter
18	124	Fluoride Dissolved milligrams per liter
22	137	Magnesium Dissolved milligrams per liter
13	23	Nickel Dissolved micrograms per liter
9	346	Phosphorus Dissolved milligrams per liter
22	137	Potassium Dissolved milligrams per liter
18	120	Silica Dissolved milligrams per liter
22	138	Sodium Dissolved milligrams per liter
3	27	Zinc Dissolved micrograms per liter

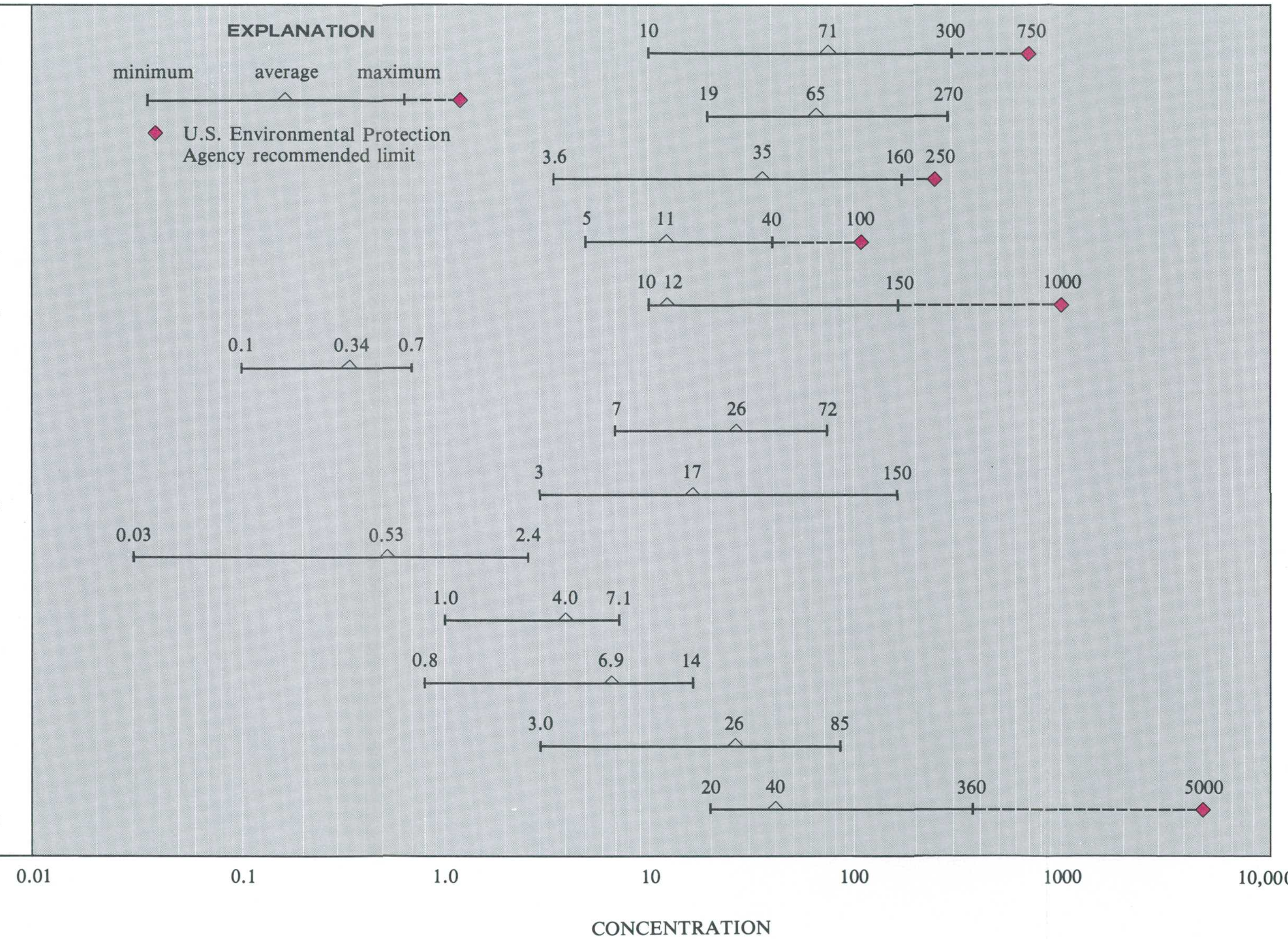


Table 10.7-1 Range of concentrations of selected constituents measured at water-quality sites in Area 27.

Suspended-Sediment Yields Vary

Suspended-sediment concentrations, loads, and yields were measured at four sites. The 1981 average annual suspended-sediment yield for three unregulated streams was 1,400 tons per square mile.

Suspended-sediment concentrations for 18 sites in Area 27 (fig. 10.8-1) ranged from 9 to 10,500 milligrams per liter (mg/L) (table 10.8-1).

Average daily suspended-sediment loads (tons of suspended-sediment passing the sampling site) for water year 1981 (October 1, 1980, to September 30, 1981). Table 10.8-2 shows the annual load and yield at the daily suspended-sediment stations. The lowest monthly loads occurred in November 1980 at all four sites and the highest monthly loads occurred between April and July of 1981 as indicated in table 10.8-2. In water year 1981, the suspended-sediment yield ranged from 277 to 1,760 tons per square mile (tons/mi^2) of drainage area. The low annual yield, 277 tons/mi^2, was for the Illinois River downstream of dams which trap part of the sediment. The average yield from the three unregulated streams was 1,400 tons/mi^2.

The energy available to transport suspended sediment increases as the stream velocity increases. The upward components of turbulent flow keeps the sediment in suspension. The size and availability of sediment along with stream velocity and discharge determine the suspended-sediment discharge. Clay-and silt-size particles (sediment particles finer than 0.062 millimeters in diameter) are held in suspension at velocities lower than those required for larger sand-size particles. In 96 of 106 samples, 90 percent or more of the suspended sediment was silt-and clay-sized particles (fig. 10.8-2).

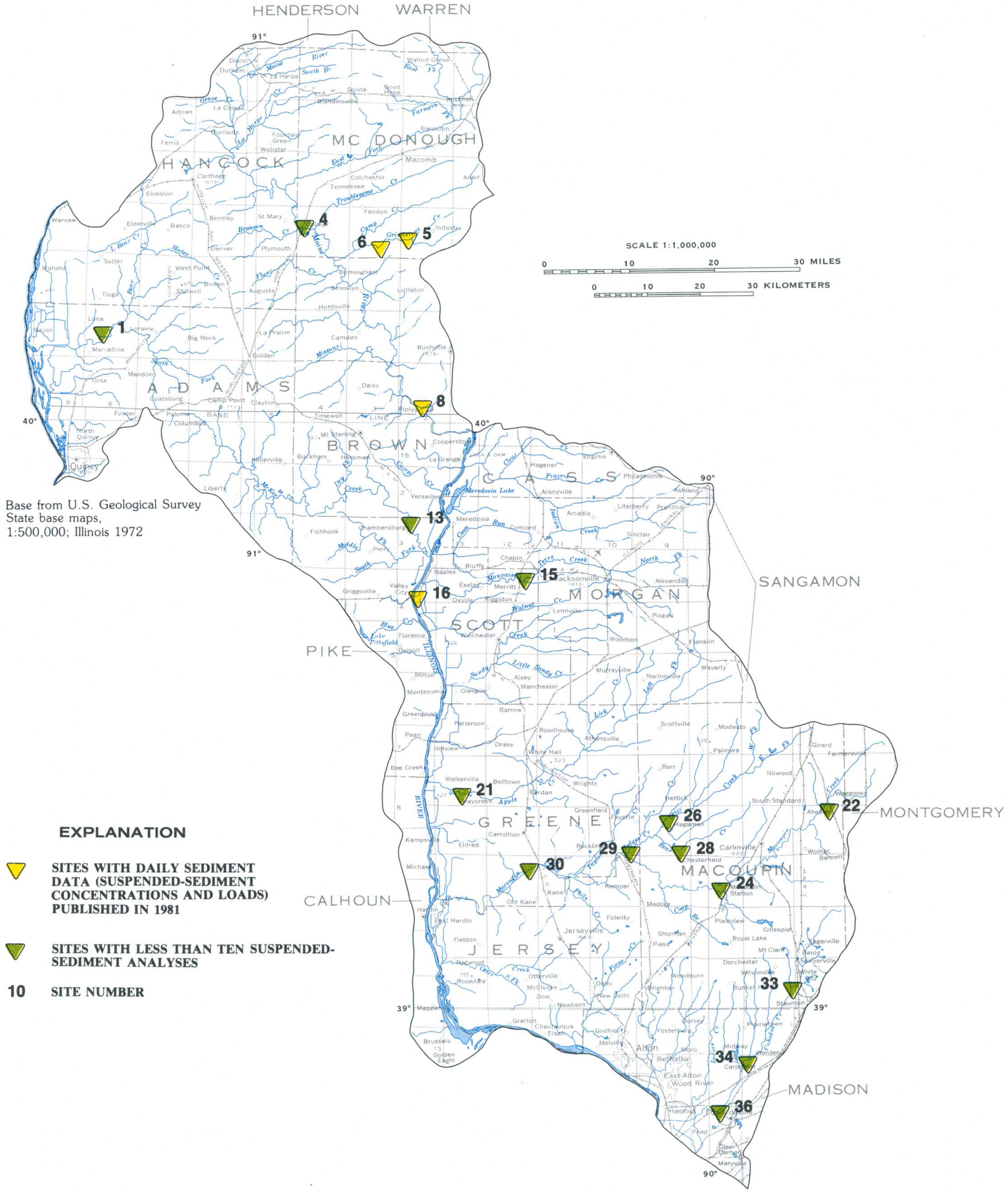


Figure 10.8-1 Suspended-sediment sampling sites.

Table 10.8-1 Suspended-sediment concentration at 18 stream sites in Area 27

Map site number	Station name	Drainage area (mi^2)	Years of record	Number of samples	Suspended-sediment concentration, in milligrams per liter: Maximum	Minimum
1	Bear Creek near Marcelline	349	1981	1	184	184
4	La Moine River at Colmar	655	1981	1	535	535
5	Grindstone Creek near Industry	35.5	1980-81	a	5,940[b]	3[b]
6	Grindstone Creek near Birmingham	45.4	1980-81	a	5,260[b]	1[b]
8	La Moine River at Ripley	1,293	1981	a	10,500	81
13	McKee Creek at Chambersburg	341	1981	1	488	488
15	Mauvaise Terre Creek near Merritt	146	1981	1	215	215
16	Illinois River at Valley City	26,564	1975-81	c	3,940	44
21	Apple Creek near Eldred	404	1981	1	648	648
22	Macoupin Creek near Standard City	73.8	1980-81	2	88	65
24	Macoupin Creek near Macoupin	304	1979-80	4	330	9
26	Solomon Creek at Hagaman	26.2	1981	1	130	130
28	Bear Creek at Chesterfield	26.7	1980-81	2	125	26
29	Hodges Creek near Rockbridge	233	1980-81	3	406	29
30	Macoupin Creek at Kane	868	1981	1	706	706
33	Cahokia Creek near Staunton	71.5	1981	1	33	33
34	Cahokia Creek near Carpenter	151	1981	2	110	21
36	Cahokia Creek near Edwardsville	212	1981	1	73	73

a Daily sediment record published in 1981.
b Maximum and minimum for average daily concentration.
c Daily sediment record published in 1980 and 1981.

Table 10.8-2 Suspended-sediment loads and yields at four daily sediment sites for October 1980 to September 1981

Map site number	Station name	Annual load (tons)	Annual yield (tons/mi^2)	Monthly suspended-sediment load: Maximum load, Month	Maximum load, tons	Minimum load, Month	Minimum load, tons
5	Grindstone Creek near Industry	37,900	1,070	June	11,300	November	0.19
	Grindstone Creek near Birmingham	80,000	1,760	May	20,600	November	.01
8	La Moine River at Ripley	1,770,000	1,370	July	617,000	November	110
16	Illinois River at Valley City	7,350,000	277	April	1,580,000	November	67,300

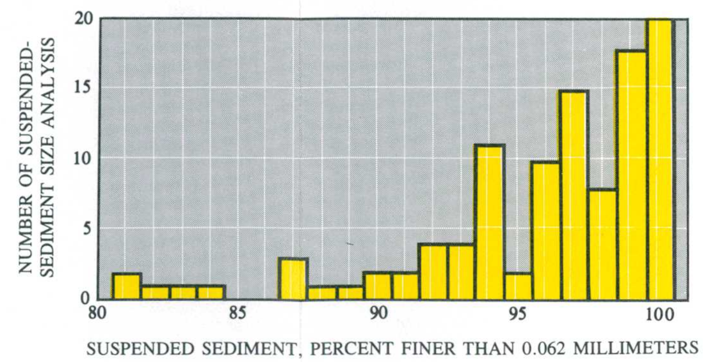


Figure 10.8-2 Area streams'sediment-size relation. Clay and silt are all sediments finer than 0.062 millimeters.

High Ground-Water Yields Obtained from Sand and Gravel Deposits

Ground-water yields are highest in the unconsolidated sand and gravel aquifers in the Mississippi and Illinois River valleys.

Ground water is obtained from unconsolidated deposits (sand and gravel) and consolidated bedrock (limestone, dolomite, and sandstone) in Area 27 (Bergstrom and Zeizel, 1957). The water is stored in fractures and solution channels in the bedrock and in pore spaces in the sand and gravel. Clays and shale can contain large quantities of water, but they do not transmit the water rapidly and, therefore, do not make good aquifers.

Yields from sand and gravel aquifers are shown in figure 11.0-1. Sand and gravel deposits are present in the stream valleys throughout the area. The Illinois River and Mississippi River valleys have the thickest deposits (nearly 100 feet) and the best potential for ground-water supply. Both areas can yield over 500 gallons per minute (gal/min). Other sand and gravel deposits are much thinner and may yield as little as 20 gal/min (Smith and Stall, 1975, second printing 1977).

Yields from wells in bedrock aquifers are shown in figure 11.0-2 and generally do not exceed 20 gal/min. Commonly, only shallow sandstone, limestone, and dolomite bedrock aquifers yield sufficient water for domestic supplies. These bedrock aquifers underlie Area 27 except along the Illinois and Mississippi Rivers where they have been removed by erosion. Deeper bedrock aquifers can yield sufficient water, but the water tends to be highly mineralized.

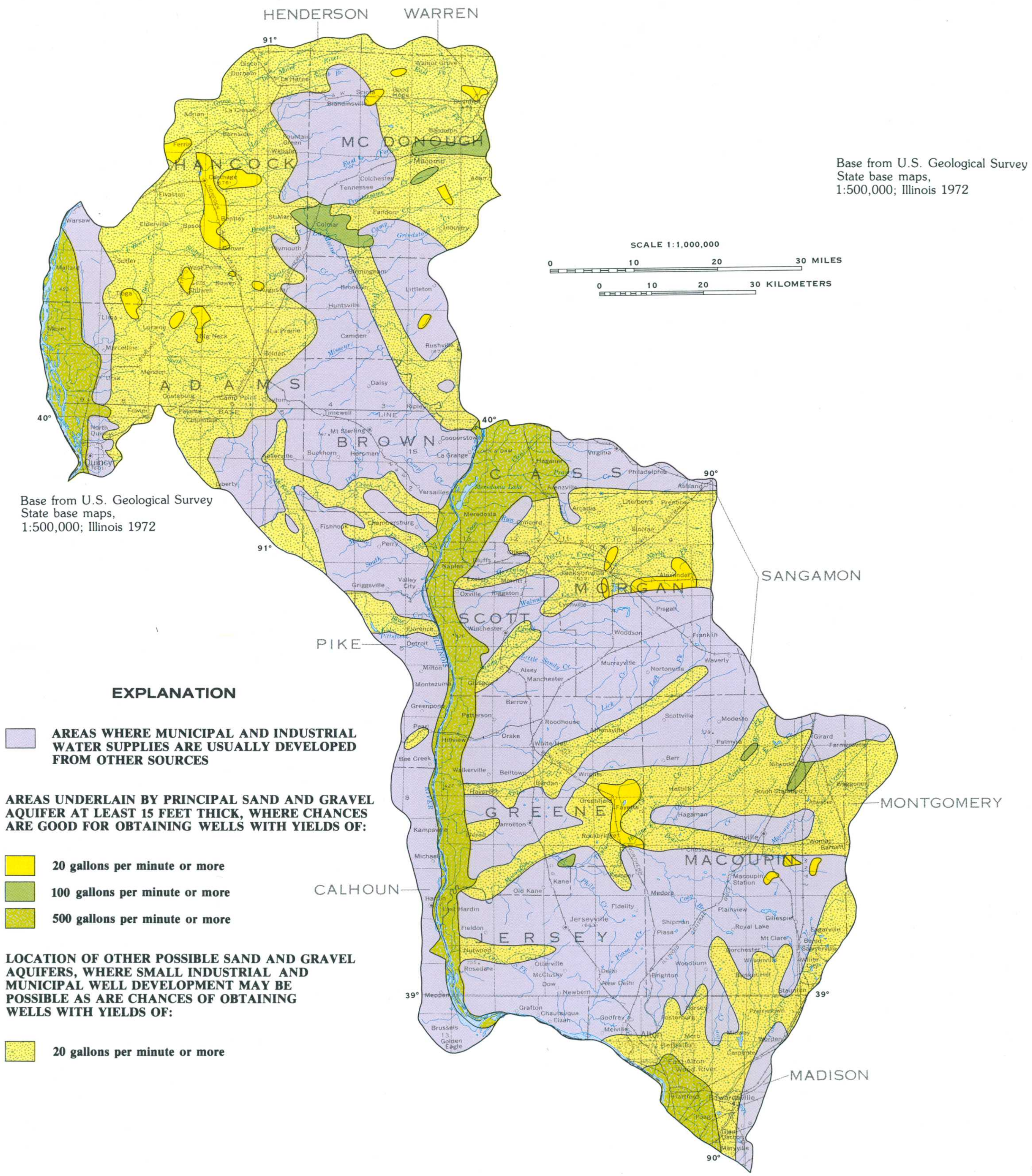


Figure 11.0-1 Yields of sand and gravel aquifers, (Smith and Stall, 1975, second printing, 1977).

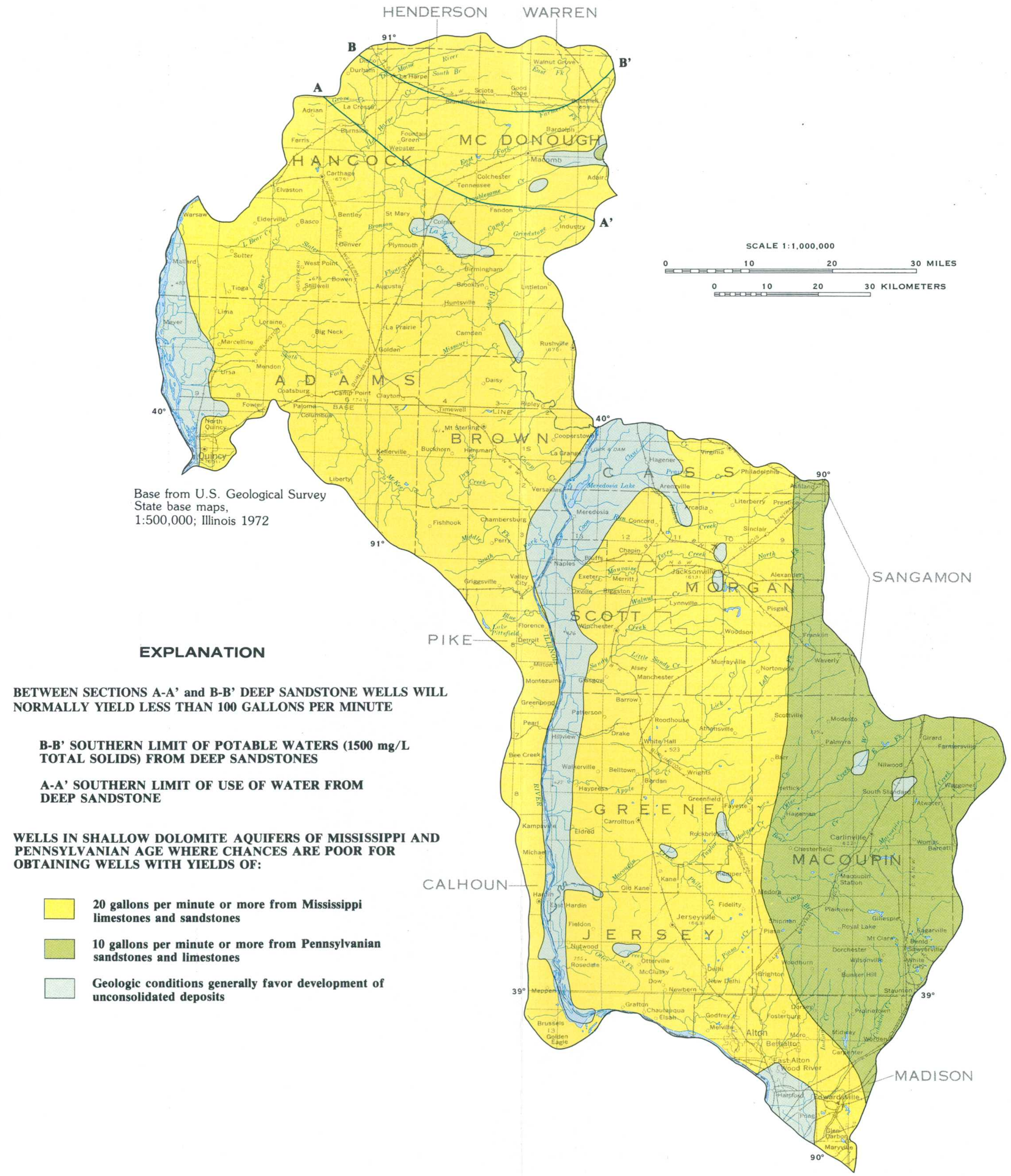


Figure 11.0-2 Yields of bedrock aquifers. (Smith and Stall, 1975, second printing, 1977).

12.0 GROUND-WATER QUALITY

Ground Water May Need Treatment

U.S. Environmental Protection Agency water-quality criteria were exceeded for iron, manganese, ammonia, chloride, sulfate, and alkalinity.

Analyses of water from 34 municipal supply wells (Larson, 1963) in the study area (fig. 12.0-1) are shown in table 12.0-1. Twenty-five wells produced water from unconsolidated material. The remaining nine wells produced water from limestone and sandstone aquifers.

The U.S. Environmental Protection Agency drinking water criteria (1976) are listed in table 12.0-1. Iron, manganese, ammonia, and alkalinity exceed the criteria in about two-thirds of the wells. The criterion for chloride was exceeded in 17 wells and for sulfate in 2 wells. Total dissolved mineral concentrations ranged from 181 to 1,870 milligrams per liter (mg/L) and the average was 512 mg/L.

Hardness values ranged from 20 to 740 mg/L as calcium carbonate ($CaCO_3$). The hardness-of-water classification (Durfor and Becker, 1964, p. 27) used in this report and the number of wells sampled with water hardness in each classification is as follows:

Classification	Number of wells observed
0 to 60 mg/L as $CaCO_3$ soft	1
61 to 120 mg/L as $CaCO_3$ moderately hard	0
121 to 180 mg/L as $CaCO_3$ hard	3
over 180 mg/L as $CaCO_3$ very hard	30

Water hardness is caused mostly by dissolved calcium and magnesium carbonates.

The St. Peter Sandstone of Ordovician age is the deepest consolidated aquifer considered for water use in the area. It is rarely penetrated by water wells because of its great depth (from 650 to over 1,000 feet below the land surface), and the probability of obtaining highly mineralized water (Bergstrom and Zeizel, 1957, p. 6-7). In six wells drilled deeper than 1,000 feet, dissolved-solids concentrations ranged from 3,000 to 12,200 mg/L, and chloride concentrations ranged from 1,350 to 6,400 mg/L (Bergstrom and Zeizel, 1957, p. 18-24).

As precipitation infiltrates and moves through the ground, it dissolves some minerals. In general, the deeper the water penetrates, or the farther it moves from the point of recharge (point of entry into the ground), the more mineralized the water becomes (Gibb, 1973, p. 1).

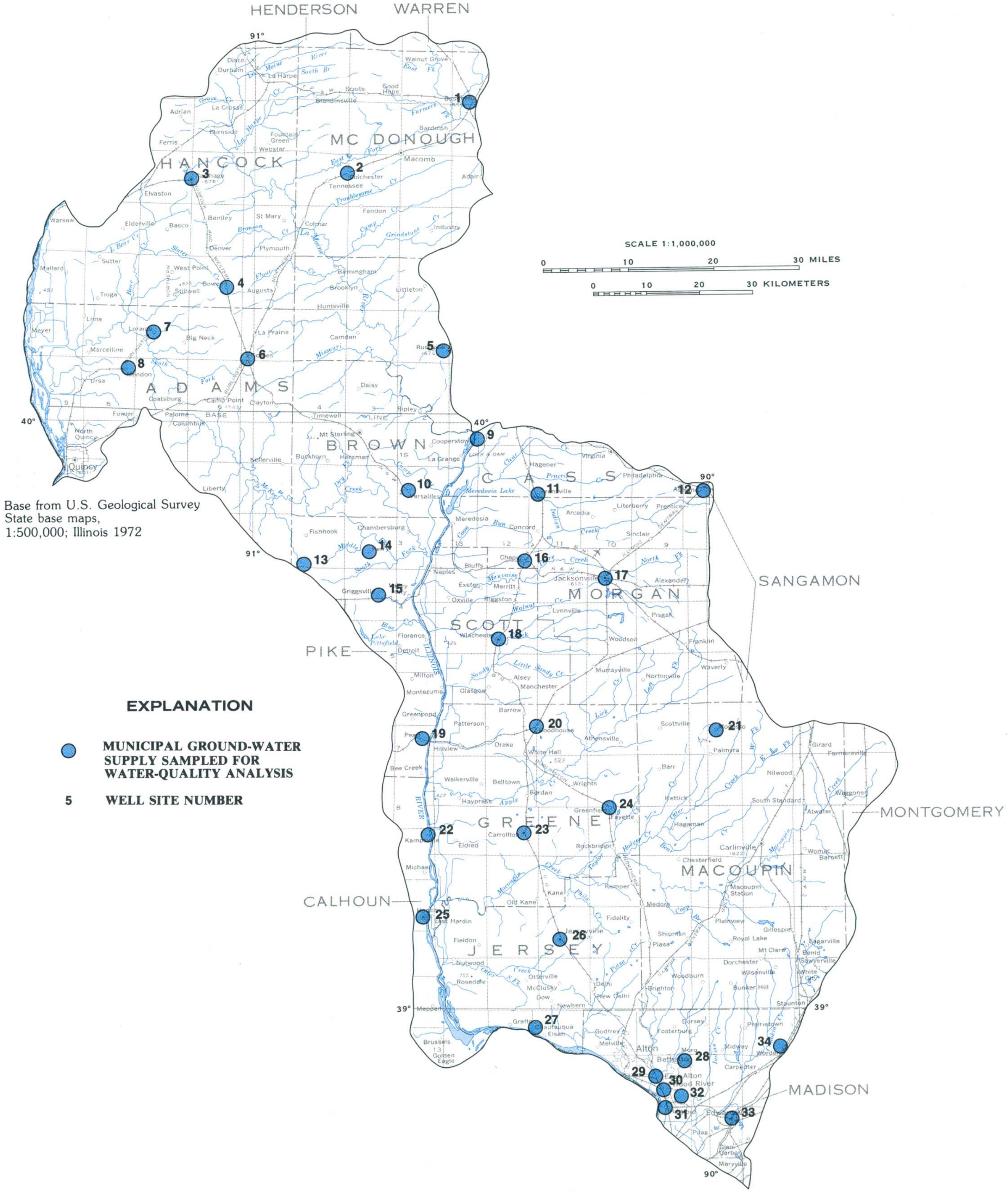


Figure 12.0-1 Ground-water-sample sites in Area 27.

Table 12.0-1 Concentrations of various constituents in 34 municipal wells in Area 27, in milligrams per liter, (Larson, 1963)

Map site number	City	Source	Treatment	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 (as $CaCO_3$)	Dissolved Solids	pH	Carbon Dioxide CO_2
USEPA criteria for domestic water supply				0.3	0.05	0.02					0.75			10	250	250			5.9	
1	Bushnell	S	Cl	.3	.0	1.3	506	100.8	41.2	14		3.5	0.2	400	649	236	422	1874		
2	Colchester	D	IZCl	2.3	.4	1.1	104	190.1	64.2	17		.1	Tr	10	480	456	740	1132		
3	Carthage	D		.7	.0	4.6	65	70.5	25.4	13	.9	.2	1.1	10	4	416	281	437		
4	Bowen	D	I	3.2								.1	.4	1		416	357	434		
5	Rushville	D	ICl	5.6	.1	Tr	6	94.8	37.2	21	.0	.2	2.1	6	25	368	390	430		
6	Golden	D		.7	.4	.2	51	84.3	26.5	36	.0	.4	.1	1	60	368	320	487	6.8	147
7	Loraine	L		.7	Tr	.1	243	31.0	17.4	9	.3	1.1	12.5	164	1	436	149	778		
8	Mendon	D	AICl	.3	.0	Tr	3	45.0	8.7	17	.0	.2	5.8	9	6	136	149	181		
9	Beardstown	D		.6	.3	Tr	26	97.4	.3	16	.3	.2	1.2	39	124	260	388	512		
10	Versailles	D		.1	.1	.1	37	84.4	45.8	18		.1	14.5	19	41	348	399	457		
11	Arenzville	D		.2	.1	Tr	1	8.8	32.5	23		.1	35.8	12	54	252	354	391		
12	Ashland	D	IZCl	1.6	.2	Tr	23	110.0	47.9	19		.2	1.7	43	89	368	472	574		
13	Baylis	L		.1	Tr	.3	136	5.6	1.5	10	.8	1.6	1.9	51	1	242	20	360		
14	Perry	D		2.7	Tr	.2	9	84.0	41.8	20	Tr	.3	.5	24	30	336	382	405		
15	Griggsville	D	Cl	.0	.0	Tr	1	92.7	31.3	20		.1	11.9	6	26	316	361	369		
16	Chapin	S	ICl	.8	Tr	.5	75	62.3	38.2	30			.4	6	8	460	315	521	7.2	
17	Jacksonville	D	LClF	3.6				88.0	19.0			Tr	.5	7		280	300	314		
18	Winchester	D	ILCl	2.9	.1	.9	8	82.2	33.9	23		.3	.3	9	20	332	345	367		
19	Pearl	L	Cl	.0	.0	Tr	1	62.5	12.0	32		.1	9.1	4	19	176	206	236		
20	Roodhouse	L	Cl	.1	Tr	Tr	10	87.1	28.2	20		.2	3.4	7	31	312	334	389		
21	Modesto	LS	AICl	4.7	.3	.5	139	74.4	23.8	20	.3	.2	.4	58	11	496	284	670		
22	Kampsville	D	I	1.9	.2	.0	9	94.6	40.2	21	.0	.2	1.0	6	42	368	402	430		
23	Carrollton	L	LCl	.1	Tr	Tr	4	82.7	25.9	20		.2	11.5	5	32	272	314	355		
24	Greenfield	D	IZCl	4.9	.4	.1	24	86.3	40.9	17	.0	.2	2.2	18	125	280	384	485		
25	Hardin	D		Tr	.1	.2	15	102.0	41.9	21	.1	.3	1.1	23	68	356	428	501		
26	Jerseyville	D		.5	Tr	Tr	8	70.9	22.4	9	.0	.2	1.2	7	42	232	269	295		
27	Chautauqua	L	Cl	.1	.0	Tr	8	84.0	16.6	23		.1	9.3	5	35	244	278	325		
28	Bethalto	D	IZ	.6	.5							.1	1.5	17		324	450	524		
29	East Alton	D	Cl	.2	.3	Tr	24	108.7	30.5	34		.4	11.5	27	171	224	398	538		
30	Wood River	D	Cl	1.1	.5	Tr	39	122.3	40.6	23	.0	.1	2.0	11	176	308	473	626		
31	Hartford	D	ILCl	10.3	.6	.3	12	131.6	32.9	36		.2	.5	13	115	352	464	566		
32	Roxana	D	IZ	4.8	.5	.1	8	87.0	25.0	31		.6	.2	19	106	200	321	410		
33	Edwardsville	D	IZCl	2.1	.2	.5	7	63.8	18.2	35	.0	.1	1.2	6	51	188	235	315		
34	Worden	D	I	.9	Tr	2.4	207	36.4	17.0	8	.1	.5	.1	90	71	416	161	715		

Symbols used in the tabulation are:

Source D-unconsolidated materials above the bedrock; L-limestone deposits; S-sandstone deposits

Treatment I-iron removal; A-aeration; L-lime or lime-soda softening; Z-zeolite; Cl-chlorination; F-fluoridation;

Constituent value Tr-trace

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 STOage 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 13.2, 13.3, 13.4, and 13.5.

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 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 at the Geological Survey National Center in Reston, Va., and a nationwide network of Assistance Centers in 45 states and Puerto Rico, which provide local and convenient access to NAWDEX facilities (fig. 13.2-1). A directory that provides names of organizations and persons to contact, as well as addresses, telephone numbers, and office hours for each of these organizations is available on request (Josefson and Blackwell, 1982).

NAWDEX can assist any organization or individual in identifying and locating water data. To accomplish this service, NAWDEX maintains a computerized Master Water-Data Index (fig. 13.2-2), which identifies sites for which water data are available, the type of data available for each site, and the organization retaining the data. NAWDEX also maintains a Water-Data Sources Directory (fig. 13.2-3) identifying organizations from which water 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 requests requiring computer cost, extensive personnel time, duplicating services, or other costs to NAWDEX providing services. 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 on request and 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 - 4:15 eastern time

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 - 4:30 central time

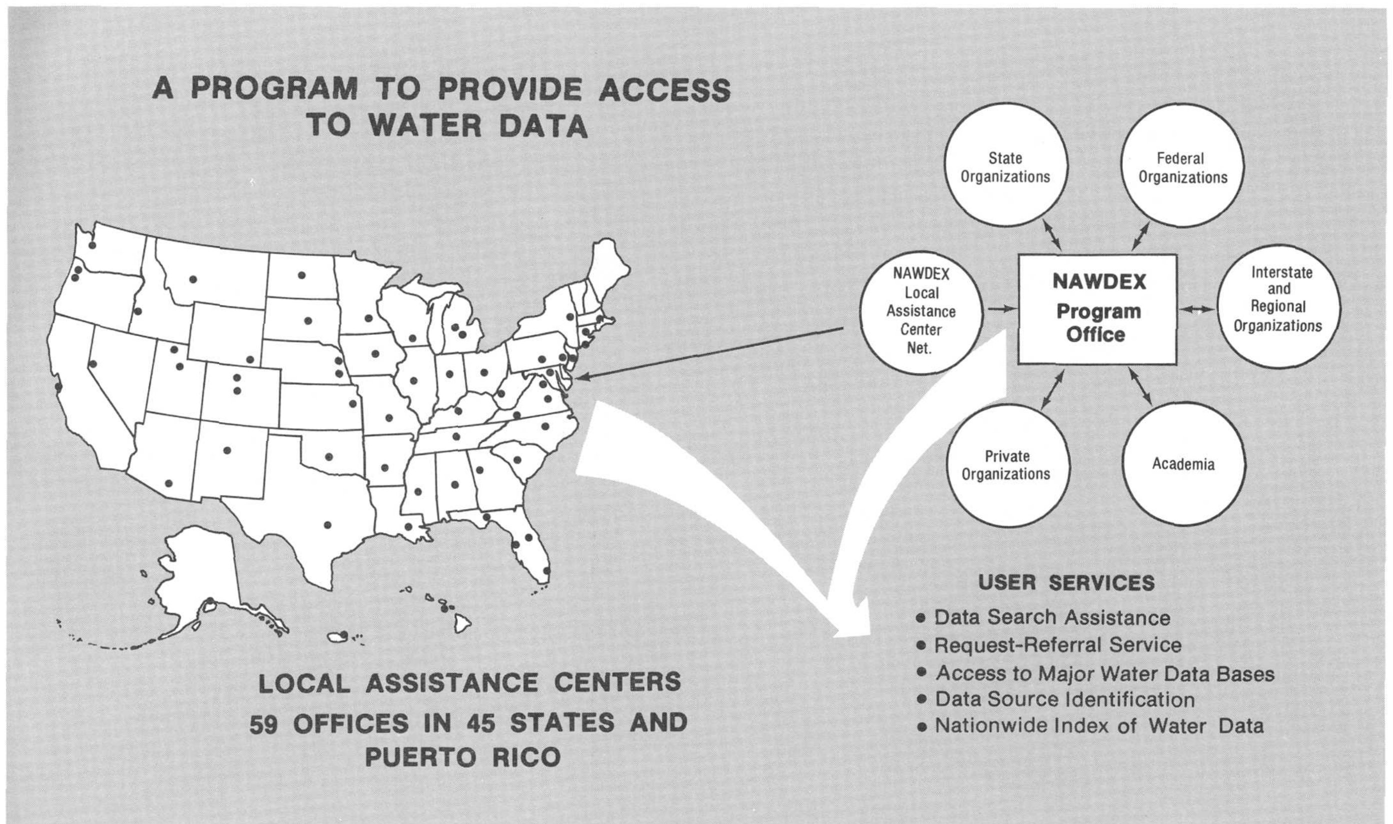


Figure 13.2-1 Access to water data.

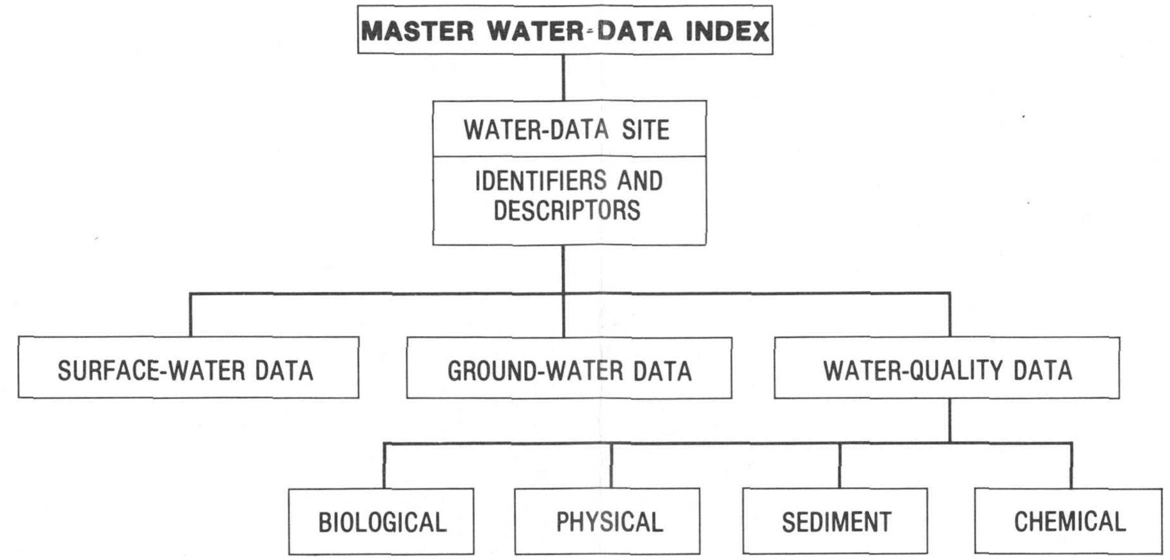


Figure 13.2-2 Master water-data index.

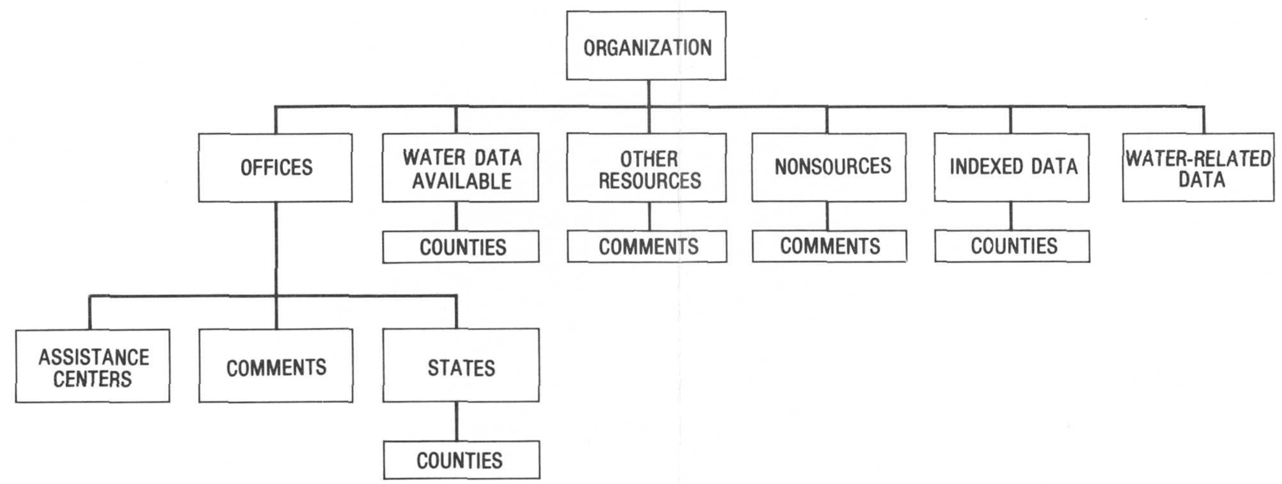


Figure 13.2-3 Water-data source directory.

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, Virginia. 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 (1983) collects data at approximately 17,000 stage-or discharge-gaging stations, 5,200 surface-water quality stations, 27,000 water-level observation wells, and 7,400 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 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. A brief description of each file (fig. 13.3-1) is as follows:

Station-Header File: Information pertinent to the identification, location, and physical description of nearly 220,000 sites are contained in this 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.

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 more than 1.4 million analyses of water samples are contained in this file. These analyses contain data for as many as 185 different constituents and physical properties that describe the chemical, physical, biological, and radiochemical characteristics of both surface and ground waters.

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 and retrieved from WATSTORE at a number of locations that are part of a nationwide telecommunication network described as follows:

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 enter data into or retrieve data from the system within an interval of 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 chloride concentration. Data are recorded on 16-channel paper tape; the tape is removed from the recorder, and the data are transmitted over telephone lines to the receiver at Reston, Va. The data are re-recorded on magnetic tape for use on the central computer. Extensive testing of satellite data-collection platforms indicates their feasibility for transmitting real-time hydrologic data on a national scale. Battery-operated radios are used as the communication link to the satellite. About 500 data-relay stations are being operated currently (1983) by the Water Resources Division.

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 substances, such as chloride, 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 tables of data to complex statistical analyses. A minimal fee, plus the actual computer cost incurred in producing a desired product, is charged to the requestor for the following products:

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 called SAS (Statistical Analysis System, 1976) to provide extensive analyses of data such as regression analyses, 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 format of the WATSTORE system or in the form of punched cards or card images on magnetic tape.

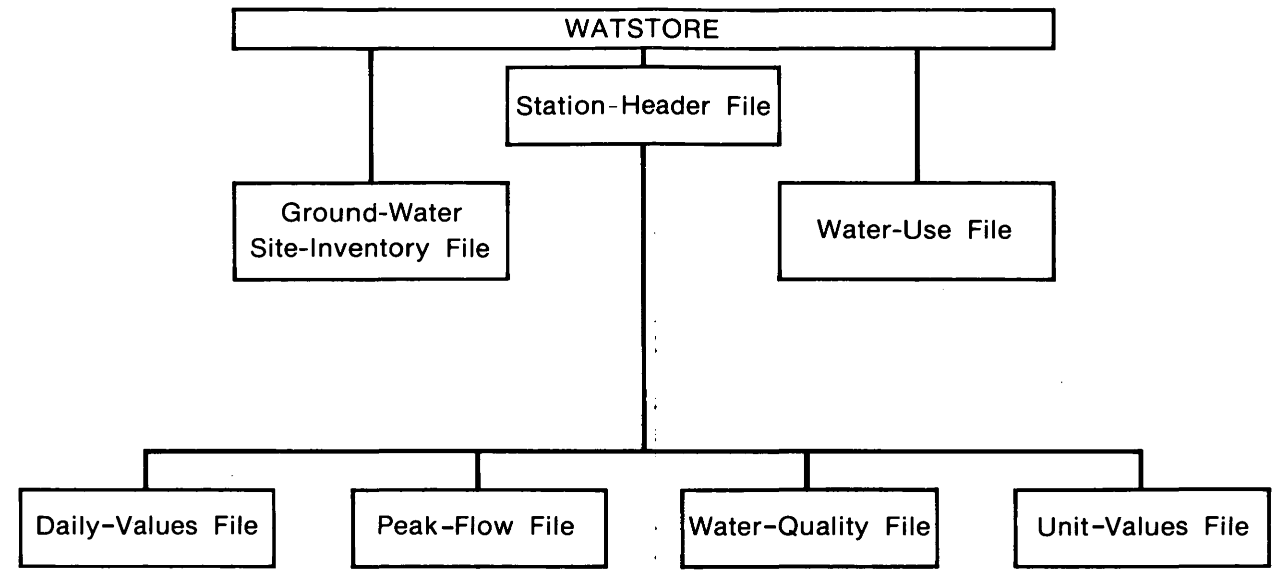


Figure 13.3-1 Index file stored data.

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 Geological Survey Office of Water Data Coordination (OWDC).

The "Index to Water-Data Activities in Coal Provinces of the United States" was prepared to provide information on the availability of water-resources data in the major coal provinces of the United States for people developing, managing, and regulating the coal resources of the Nation. It is derived from the "Catalog of Information on Water Data," a computerized information file about water-data acquisition in the United States, and some other countries. The index consists of five volumes (fig. 13.4-1): 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 volumes presented 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.

Each volume of the 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) identification and location of the station, (2) major types of data collected, (3) frequency of data collection, (4) form in which the data are stored, and (5) agency or organization reporting the activity. Part D summarizes 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.

Assistance in obtaining additional information from the Catalog file or water data is available through the National Water-Data Exchange (NAWDEX) (see section 13.2).

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 and Post Office Building
46 East Ohio Street
Indianapolis, IN 46204

Telephone: (317) 269-2631
FTS 331-2600

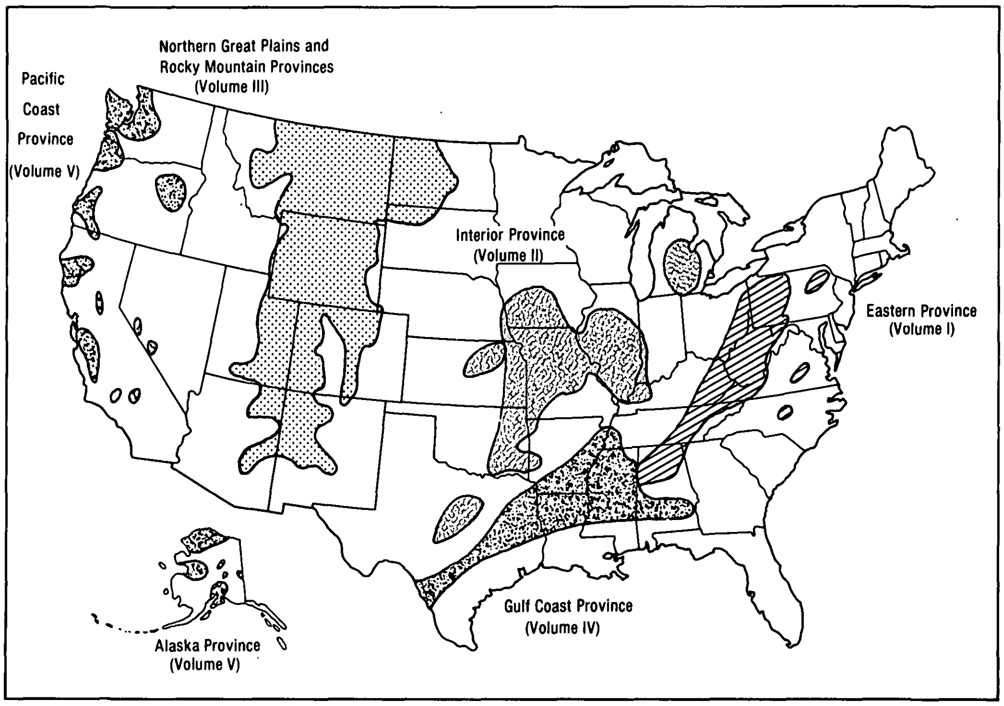


Figure 13.4-1 Index volumes and related provinces.

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 13.5-1 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

(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

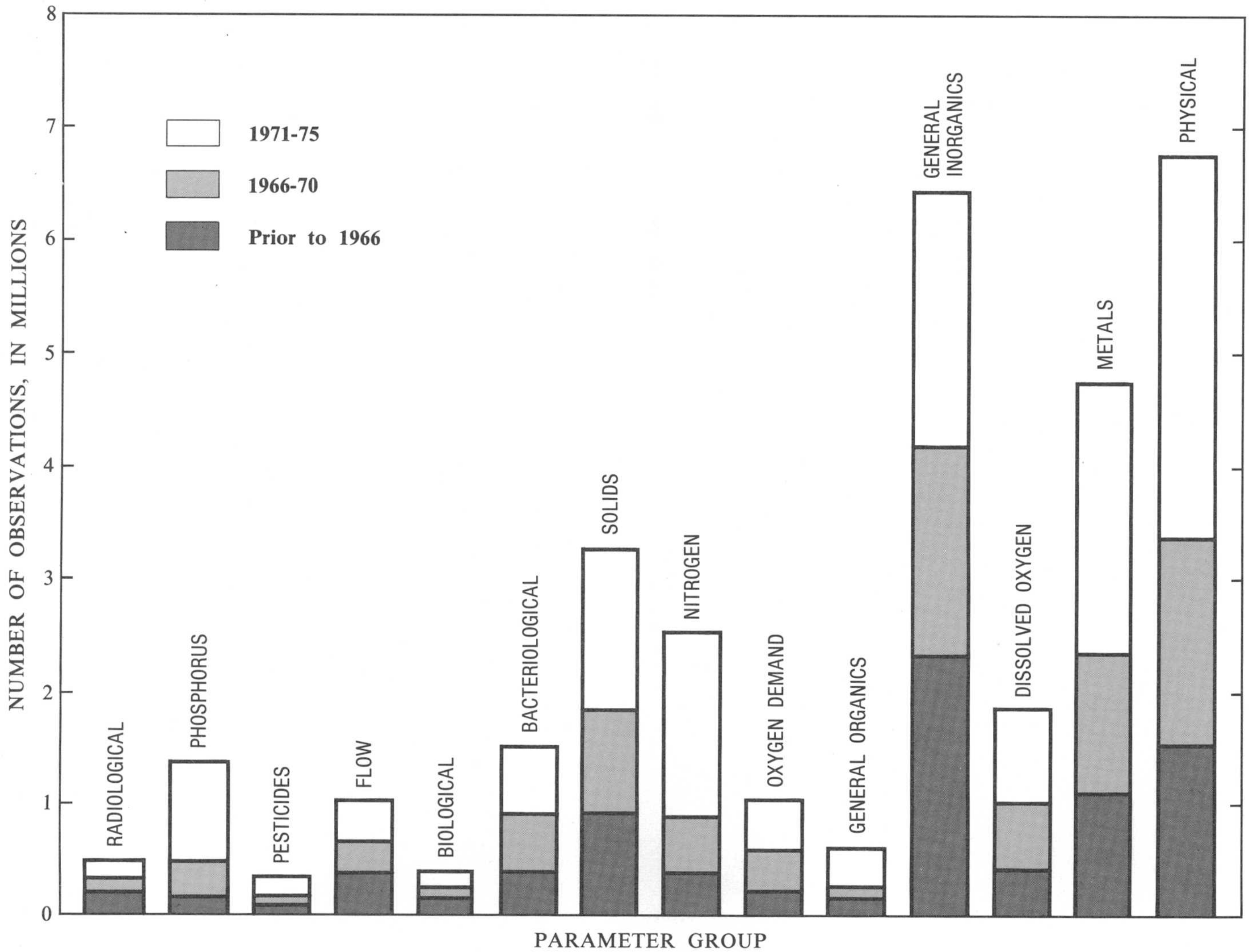


Figure 13.5-1 Parameter groups and number of observations in the Water Quality File. (from STORET User Handbook).

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