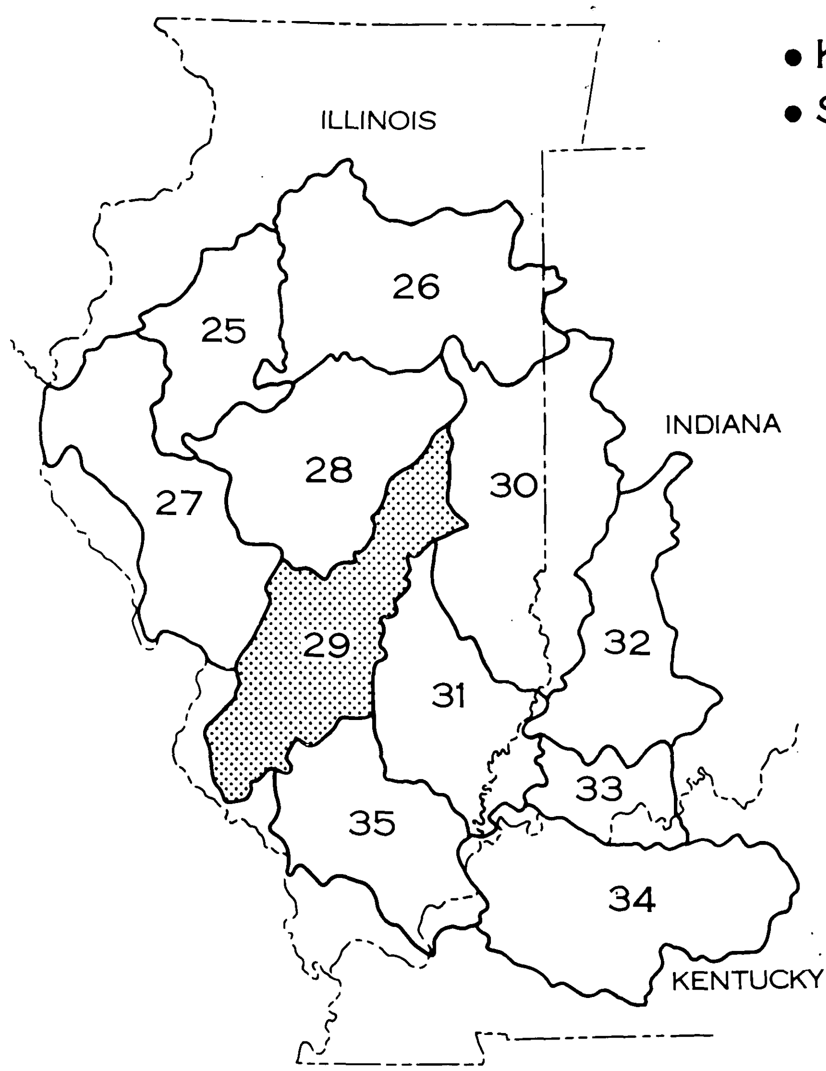
HYDROLOGY OF AREA 29, EASTERN REGION, INTERIOR COAL PROVINCE, ILLINOIS



- KASKASKIA RIVER
- SHOAL CREEK

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

WATER RESOURCES INVESTIGATIONS
OPEN FILE REPORT 82-858

HYDROLOGY OF AREA 29, EASTERN REGION, INTERIOR COAL PROVINCE, ILLINOIS

BY
K.K. FITZGERALD, C.A. PETERS, AND E.E. ZUEHLS

U. S. GEOLOGICAL SURVEY

WATER RESOURCES INVESTIGATIONS
OPEN FILE REPORT 82-858

URBANA, ILLINOIS
SEPTEMBER, 1983

UNITED STATES DEPARTMENT OF THE INTERIOR

JAMES G. WATT, *SECRETARY*

GEOLOGICAL SURVEY

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Urbana, Illinois 61801

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

For 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
inches (in)	25.40	millimeters (mm)
inches per hour (in/h)	25.4	millimeters per hour (mm/h)
	2.54	centimeters per hour (cm/h)
feet (ft)	0.3048	meters (m)
feet per mile (ft/mi)	0.1894	meters per kilometer (m/km)
miles (mi)	1.609	kilometers (km)
square miles (mi^2)	2.590	square kilometers (km^2)
gallons per minute (gal/min)	0.06309	liters per second (L/s)
million gallons per day (mgal/d)	0.04381	cubic meters per second (m^3/s)
	3785	cubic meters per day (m^3/d)
cubic feet per second (ft^3/s)	0.02832	cubic meters per second (m^3/s)/km^2
cubic feet per second per square mile [(ft^3/s)/mi^2]	0.01093	cubic meters per second per square kilometer [(m^3/s)km^2]
tons per square mile per year [(tons/mi^2)/yr]	0.3503	metric tons per square kilometer per year [(t/km^2)/a]
micromhos per centimeter at 25° Celsius (μmhos/cm)	1.000	microsiemens per centimeter at 25° Celsius (μS/cm)

National Geodetic Vertical Datum of 1929 (NGVD of 1929): A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called mean sea level. NGVD of 1929 is referred to as sea level in this report.

HYDROLOGY OF AREA 29, EASTERN REGION, INTERIOR COAL PROVINCE, ILLINOIS

BY K.K. FITZGERALD, C.A. PETERS, AND E.E. ZUEHLS

Abstract

The enactment of the "Surface Mining Control and Reclamation Act of 1977" initiated a national need for hydrologic information and analysis in coal-mining areas. This need is partially met by this report which broadly characterizes the hydrology of Area 29 in the Eastern Region of the Interior Coal Province in central Illinois. The report should be useful to surface-mine owners, mine operators, and consulting engineers in the preparation of permits and to regulatory authorities in appraising the adequacy of permit applications.

The Kaskaskia River is the major river draining Area 29. Glacial deposits cover most of the area and coal-bearing Pennsylvanian rocks underlie about 95 percent of the area. Agriculture is the dominant land use. As of June 1980, there were five active underground mines and two active surface mines in the area.

Ninety-six percent of the water used in Area 29 is obtained from surface-water sources. There are 12 reservoirs in the area that are used for water supply and 2 that are used for powerplant cooling.

Ground-water yields are low throughout most of the area. The concentration of dissolved solids tends to increase with depth, and fresh water is generally found at depths of 300 feet or less. The ground water in Area 29 is hard to very hard and has high iron concentrations.

Mean annual precipitation in the area ranges from 37 to 40 inches. Area 29 is located in a part of Illinois that experiences many forms of severe weather including drought, thunderstorms, tornadoes, hail, ice storms, and snowstorms. Drought conditions and intense short-duration, warm-season thunderstorms occur frequently.

There are 21 active streamflow gaging stations in Area 29. Equations have been developed for estimating mean annual streamflow, 7-day, 10-year low flow, 7-day, 10-year high flow, and the 10-year peak discharge. Flood-prone area maps are available for many parts of the area.

Water-quality data are available at 39 sites in Area 29. Changes in water quality and increased sedimentation are two of the major hydrologic problems related to surface mining. Water quality can be changed as a result of drainage of mine sites into the surrounding streams. Natural conditions neutralize acidic waters in the area, but increased concentrations of metals (iron, aluminum, manganese) and other elements can remain in waters. High rates of sedimentation can result from lack of soil cover and the disturbed conditions left by mining operations.

Area 29 Report to Aid in Preparing and Appraising Mine Permit Applications

Existing hydrologic conditions and sources of hydrologic information are described.

A need for hydrologic information and analysis on a scale never before required nationally, was initiated when the "Surface Mining Control and Reclamation Act of 1977" was 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 29 in the Eastern Region of the Interior Coal Province in central Illinois (fig. 1.1-1). This report is one of a series that covers the coal provinces nationwide. The report contains a brief text with an accompanying map, chart, graph, or other illustration for each of a number of water-resources related topics. The summation of the topical discussions provides a description of the hydrology of the area.

The hydrologic information presented or available through sources identified in this report may be used in describing the hydrology of the "general area" of any proposed mine. Furthermore, it is expected that this hydrologic information will be supplemented by the lease applicant's site specific data as well as data from other sources to provide a more detailed picture of the hydrology in the vicinity of the mine and the anticipated hydrologic consequences of the mining operation.

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

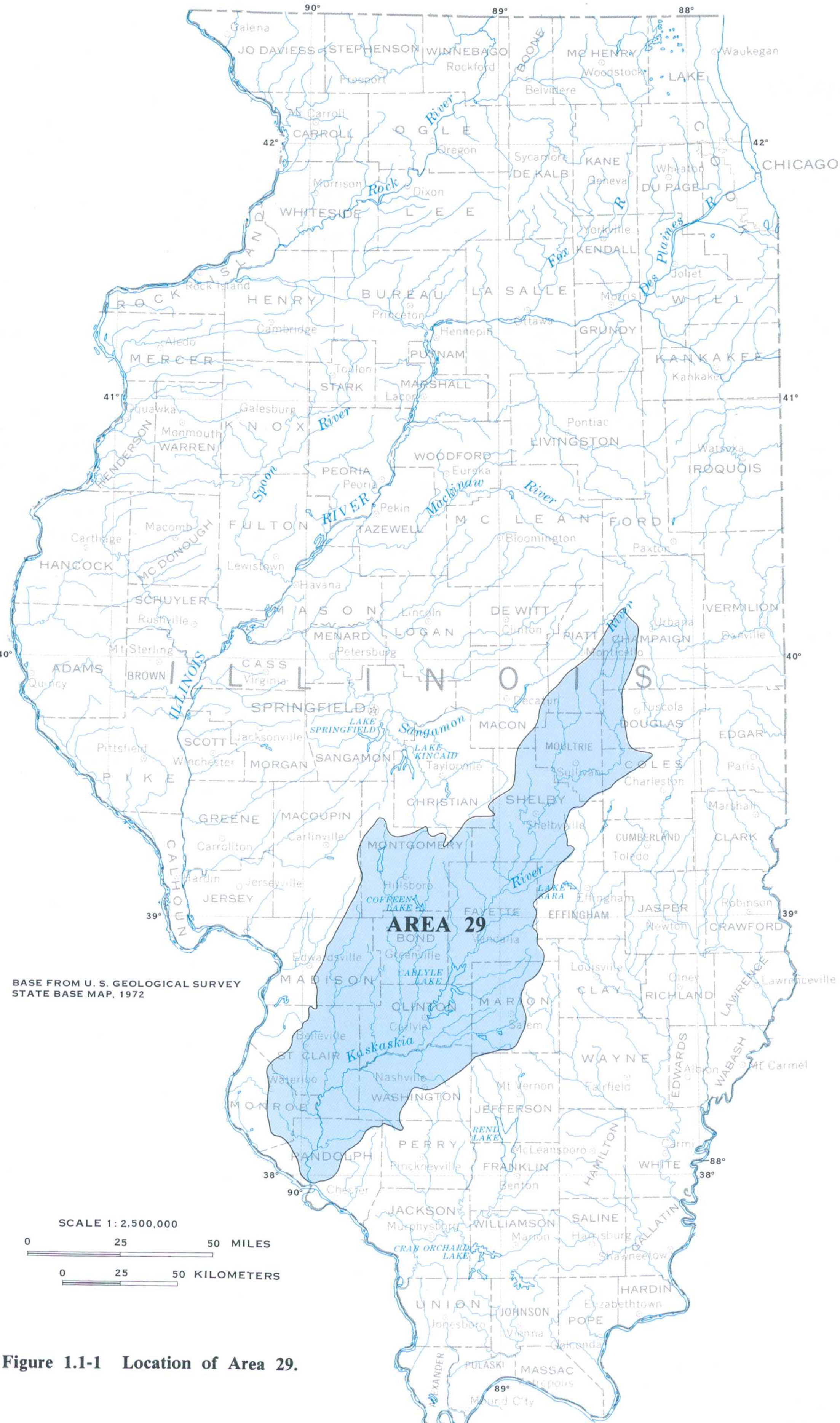


Figure 1.1-1 Location of Area 29.

1.0 INTRODUCTION

1.1 Objective

Area 29 is Located in the Eastern Region of the Interior Coal Province

Area 29 includes parts of three physiographic divisions: the Bloomington Ridged Plain, the Springfield Plain, and the Mount Vernon Hill Country.

The Eastern Region of the Interior Coal Province, commonly called the Eastern Interior Coal Field (Smith and Stall, 1975), has been divided into 11 hydrologic study areas. These are shown on the cover of this report. Hydrologic units (drainage basins) are combined to form each study area (fig. 1.2-1). These units are geographic areas that represent part or all of a surface drainage basin or distinct hydrologic feature as delineated by the Office of Water Data Coordination on State Hydrologic Unit Maps (U.S. Geological Survey, 1975). Each unit is identified by an 8-digit number.

Area 29 covers 5,801 square miles in central Illinois (fig. 1.2-2). It includes all of Bond, Clinton, Fayette, and Moultrie Counties and parts of Champaign, Coles, Douglas, Effingham, Madison, Marion, Monroe, Montgomery, Piatt, Randolph, St. Clair, Shelby, and Washington Counties.

The area, as shown in figure 1.2-3, includes parts of three physiographic divisions: the Bloomington Ridged Plain, the Springfield Plain, and the Mount Vernon Hill Country. These are all divisions of the Till Plains Section of the Central Lowland Province. The topography of the Bloomington Ridged Plain is a series of broad morainic ridges alternating with wide areas of relatively flat or gently undulating till plains. The topography of the Springfield Plain is level to gently undulating. The Mount Vernon Hill Country is rolling and hilly with many bedrock outcrops (Thornburn, 1963).

The population of the area is about 574,000. The largest cities in the area are Champaign (population 58,133), Belleville (41,580), and Centralia (15,126) (Edgar, 1982).

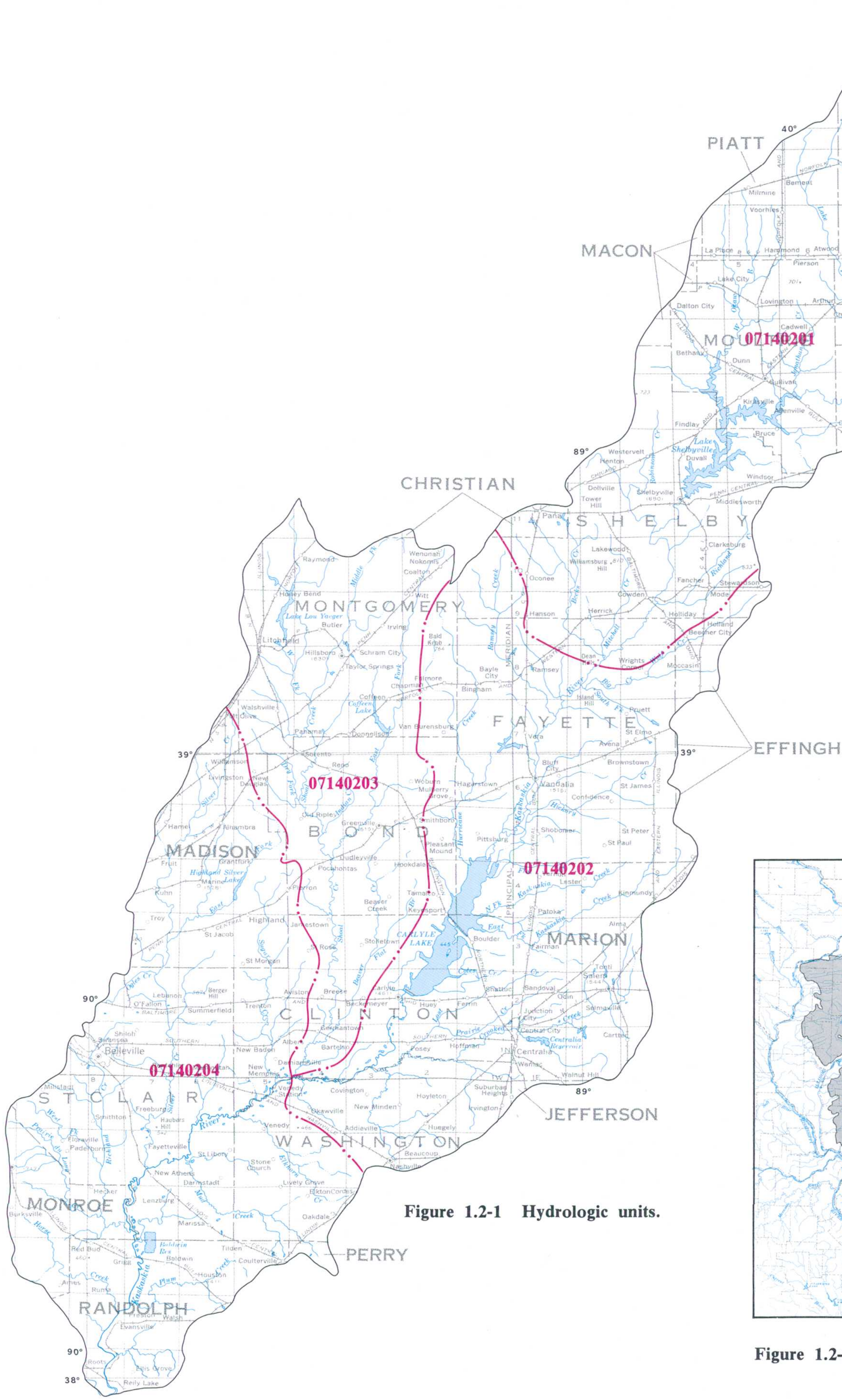


Figure 1.2-1 Hydrologic units.

BASE FROM U.S. GEOLOGICAL SURVEY
STATE BASE MAP, 1:500,000, 1972

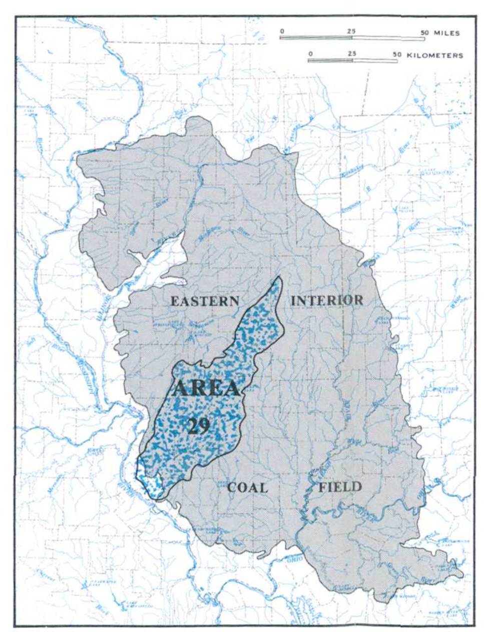


Figure 1.2-2 Eastern Interior Coal Field.

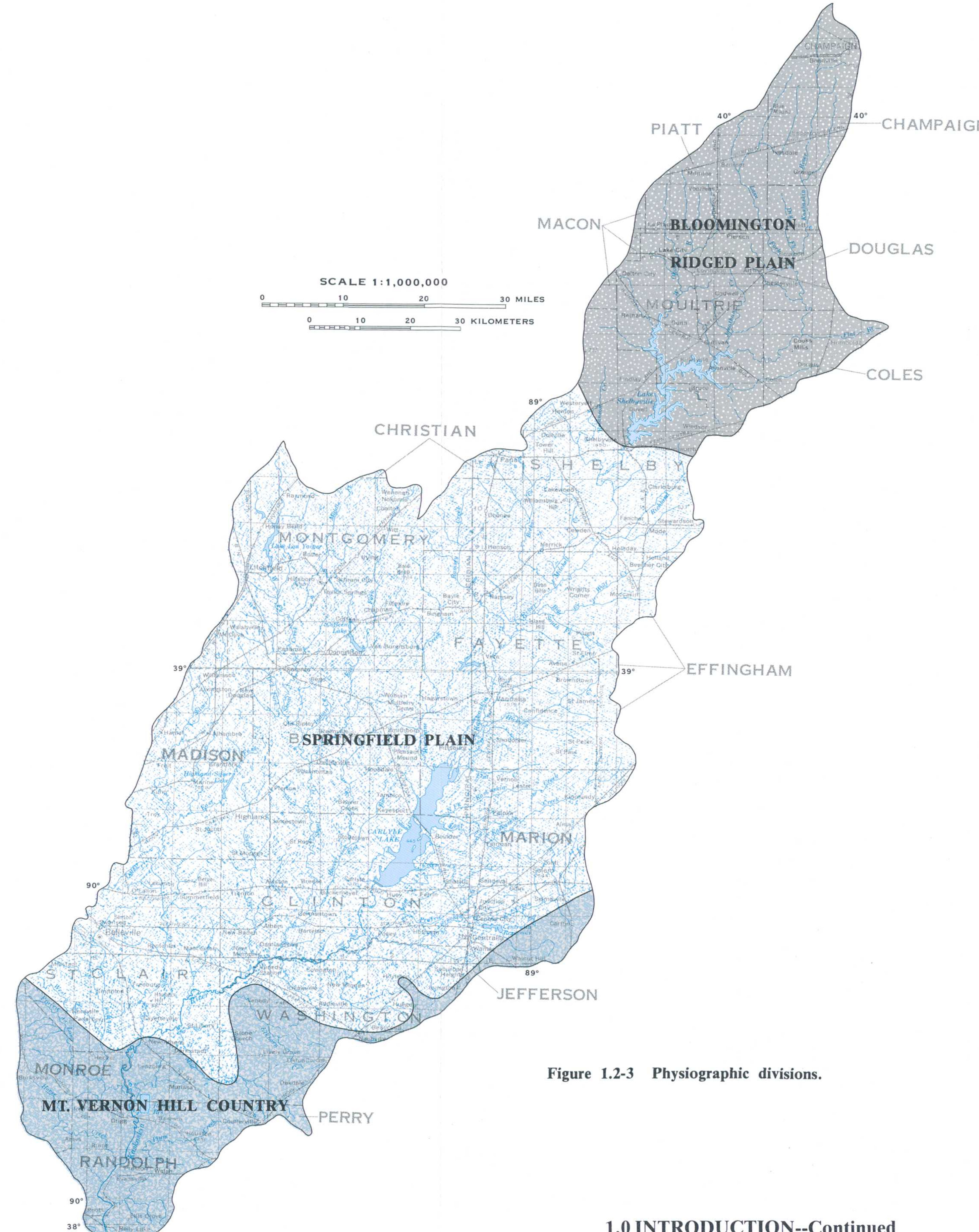


Figure 1.2-3 Physiographic divisions.

2.0 COAL MINING POTENTIAL AND HISTORY

Illinois has Largest Bituminous Coal Reserves in the United States

Estimated reserves of all coal in Illinois are 161.6 billion tons, but currently only 3.6 percent is economically and legally recoverable.

Estimated coal reserves in Illinois (as of January 1975, with revisions in 1980) are 161.6 billion tons which is 15.1 percent of the total demonstrated coal reserves in the United States (Nawrot and others, 1980). Only Montana has larger total coal reserves (Rickert and others, 1979). Illinois ranks first among the States in total bituminous coal reserves. These reserves also have the highest total heat content of any reserves in the Nation. About 12.1 percent of the Illinois reserves is considered surface-minable (coal seams more than 18 inches thick and less than 150 feet deep), but currently only about 3.6 percent is economically and legally recoverable (Nawrot and others, 1980).

Total identified coal reserves in Area 29 as of January 1976 were about 32.7 billion tons. About 4 percent of these reserves is considered surface-minable (Smith and Stall, 1975, updated in 1977). The surface-minable coal reserves, mined-out areas, and active coal mines in the area are shown in figure 2.0-1.

Rickert and others (1979) have shown that Illinois coal resources are among those most likely to be used for synthetic fuel production due to the large amount of coal available, plentiful water supplies, and lack of serious geologic constraints. In addition, the Nation's move toward energy independence and diminishing domestic supplies of oil and gas could increase the demand for Midwestern coal. Oil and gas are also produced in Area 29. Marion and Fayette Counties are among the highest oil-producing counties in Illinois, producing 10.2 percent (2,369,039 barrels) and 7.7 percent (1,803,540 barrels), respectively, of the State's total oil production in 1978 (Van Den Berg, 1980). The most heavily drilled oil- and gas-producing areas are shown in figure 2.0-1.

The first coal discovery in North America was by Marquette and Joliet in 1673 along the Illinois River. The first commercial underground coal mine in Illinois was opened in 1810 in Jackson County (Andros, 1915). The first commercial surface mine in the United States was opened in 1866 near Danville, Illinois. Early surface mining was accomplished by removing overburden with horsedrawn scrapers and hauling it out of the mine pit in wagons and wheelbarrows. Within two decades, the steam shovel came into use. The first steam shovels were made mostly of wood and were able to remove 8-12 feet of overburden and coal seams up to 3 feet thick. From these beginnings, coal mining technology has progressed to the giant electric-powered shovels of today that can remove up to 220 cubic yards of material in a single bite (Lewis, 1972).

Total coal production in Illinois from 1882 through 1979 was 4.7 billion tons. Area 29 accounted for 21.8 percent of that total. Peak production was reached during World War I. The Depression of the 1930's caused a decline in production which was reversed by World War II. Another decline in production occurred when diesel locomotives and alternate industrial fuel sources came into use. Increased energy consumption and declining oil and gas reserves have resulted in an increase and leveling off of production during the past two decades (Nawrot and others, 1980).

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

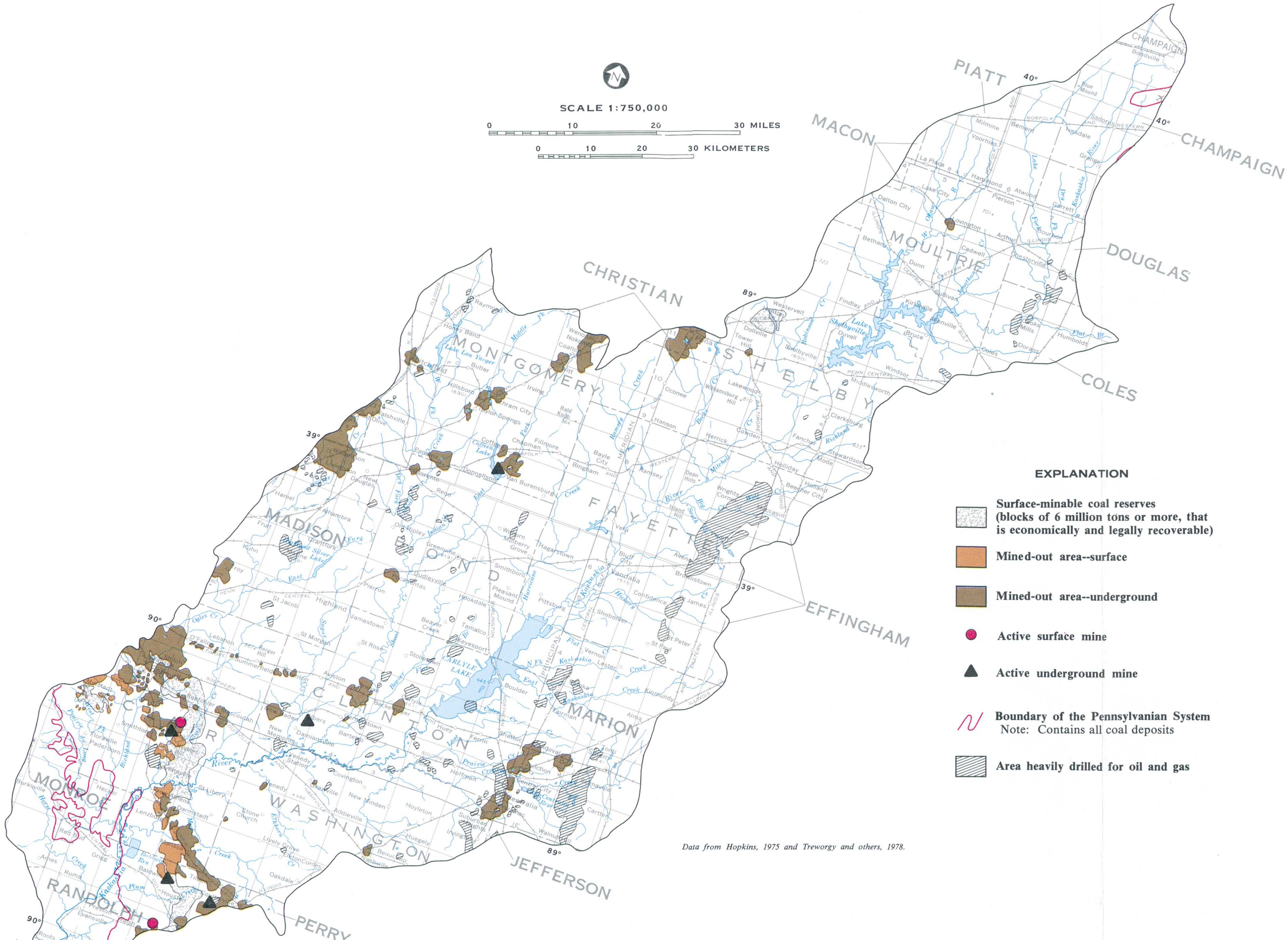


Figure 2.0-1 Surface-minable coal reserves, active coal mines, mined-out areas, and oil- and gas-producing areas.

BASE FROM U.S. GEOLOGICAL SURVEY
STATE BASE MAP, 1:500,000, 1972

Glacial Deposits Cover Most of Area

Glacial deposits are less than 200 feet thick except in the northernmost end of the area where they are up to 300 feet thick.

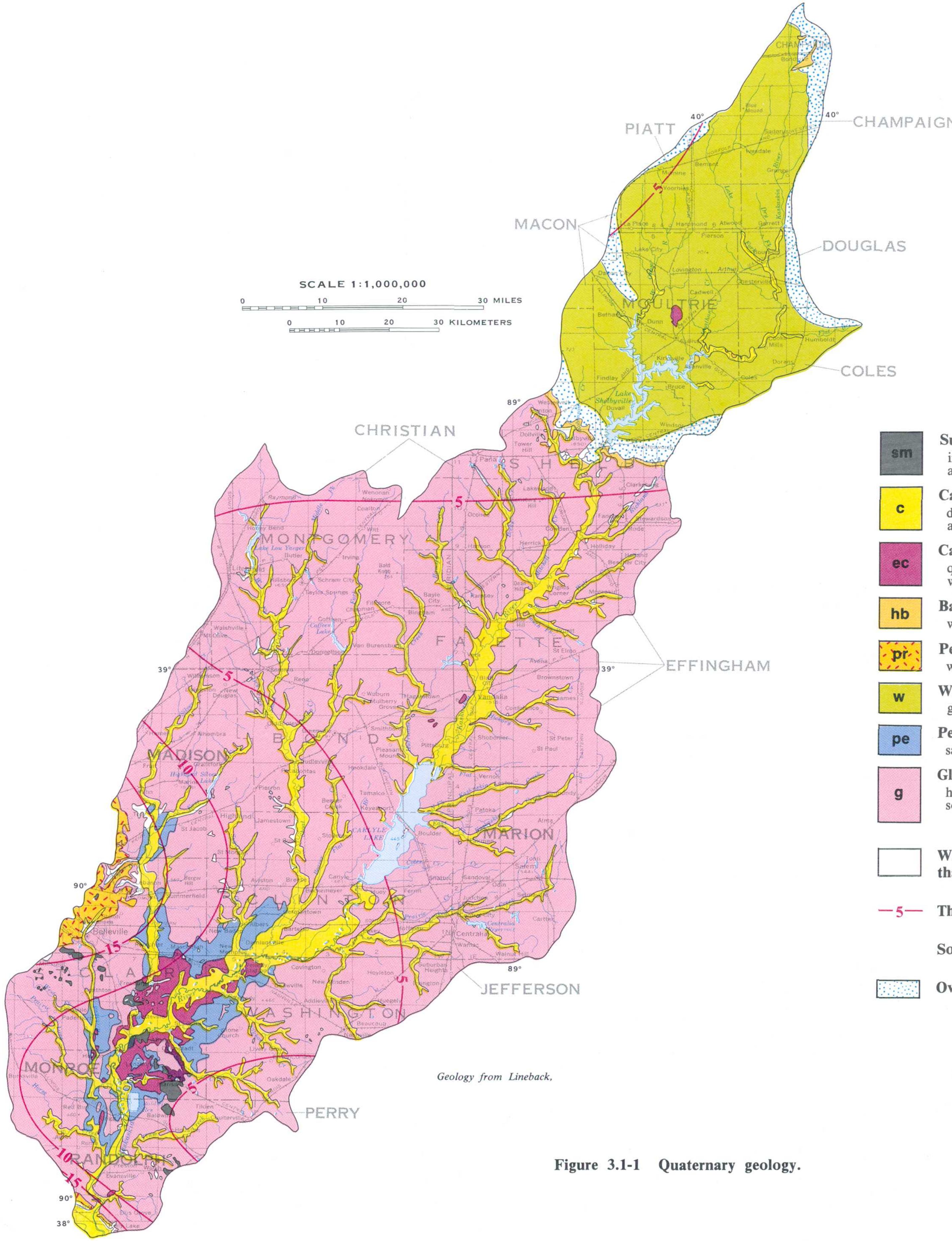
The Quaternary System, which makes up the surficial deposits in Illinois, includes glacial deposits and contemporaneous sediments deposited beyond the limit of glaciation as well as all material deposited through the present time. Glacial deposits cover all of Illinois except the northwestern corner and the southern tip. The glacial deposits in Area 29 are less than 50 feet thick on the uplands and are 50 to 200 feet thick in the valleys of the Kaskaskia River and its tributaries. The present valleys of these rivers generally conform to the bedrock valleys. The thickest deposits are in the Mahomet Bedrock Valley in the northernmost part of the area (Champaign County) (Piskin and Bergstrom, 1975). The glacial deposits form moraines and ground moraine of Illinoian and Wisconsinan age (fig. 3.1-1 and 3.1-2). The Illinoian glacier was the last to cover all of the area. The Wisconsinan glacier extended only into Shelby County. Loess of Wisconsinan age was deposited when outwash material was blown from the valleys onto the uplands. Loess is 5 to 15 feet thick in Area 29 (Lineback, 1979).

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

The Wedron Formation of Wisconsinan age covers the northern fourth of the area. It forms a moraine that runs through Shelby County. It is a silty to sandy till with lenses of silt, sand, and gravel.

Cahokia Alluvium is found in the channels and floodplains of the Kaskaskia River and its tributaries. It is poorly sorted sand, silt, and clay with local deposits of sandy gravel.

Peoria Loess blankets almost all of the area. The thickness of the loess is shown by contour lines on figure 3.1-1. It is a massive, well-sorted silt and is calcareous except in the upper few feet where the carbonates have been leached. The Peoria Loess is the parent material for many of the soils in the area (Willman and others, 1975).



BASE FROM U.S. GEOLOGICAL SURVEY
STATE BASE MAP, 1:500,000, 1972

Geology from Lineback.

EXPLANATION

- **sm** — **Surface Mines**: includes coal mines, sand and gravel pits, and other excavated areas
- **c** — **Cahokia Alluvium**: deposits in floodplains and channels of modern rivers and streams; mostly poorly-sorted sand, silt, or clay
- **ec** — **Carmi Member of the Equality Formation**: quiet-water lake sediments dominated by well-bedded silt and some clay
- **hb** — **Batavia Member of the Henry Formation**: well-sorted sand and gravel
- **pr** — **Peoria Loess and Roxana Silt**: wind-blown silt with local lenses of fine-grained sand
- **w** — **Wedron Formation**: gray silty till that oxidizes to olive brown; some sandy till
- **pe** — **Pearl Formation**: sand, gravel, and some silt
- **g** — **Glasford Formation**: hard, compact sandy till with sand and gravel; some elongate, sand and gravel cored ridges

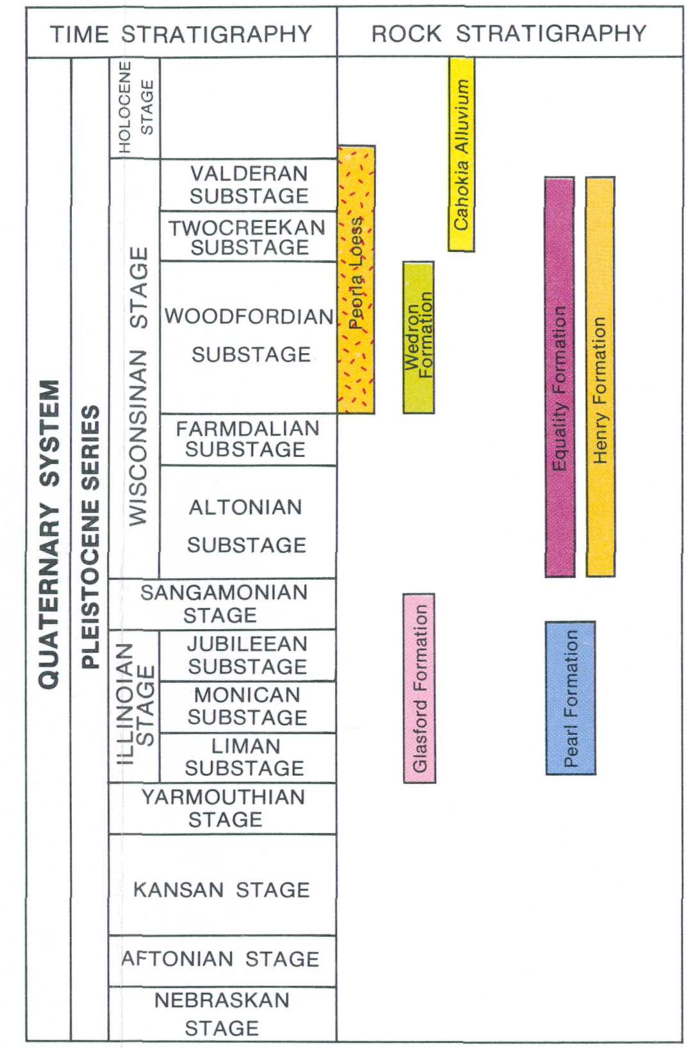
White areas on map indicate that rocks older than Pliocene are present at or near the surface

—5— Thickness of loess; contour interval, 5 feet

Solid colors indicate ground moraine

Overprinted pattern indicates moraines

Figure 3.1-1 Quaternary geology.



Modified from Willman and Frye, 1970.

Figure 3.1-2 Stratigraphy of the Quaternary System in Area 29 (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.)

Two Geologic Units Make Up the Bedrock Surface in the Area

The Pennsylvanian System, containing the coal-bearing rocks, is the uppermost bedrock in about 95 percent of Area 29 with the remainder being rocks of Mississippian age.

The Pennsylvanian System is the uppermost bedrock in about 95 percent of Area 29 (fig. 3.2-1). The Pennsylvanian System in the area ranges from 0 to 1,600 feet thick. The rocks dip gently toward the southeast. The dip is toward the center of the Illinois Basin which is a spoon-shaped structure that is oriented north-northwest to south-southeast with the deepest part in southeastern Illinois (Willman and others, 1975). Rocks of Mississippian age make up the bedrock surface in the rest of the area.

The Pennsylvanian System consists of sandstones, siltstones, limestones, shales, clays, and coals. Changes in lithology within the System are often abrupt which indicates that the depositional environment was changing rapidly. The advance of saltwater seas into Illinois caused transgressive marine deposition of sandstone, shale, and limestone. When the seas withdrew, large freshwater swamps developed on broad delta plains. When the seas readvanced, marine sediments were deposited on top of the swamp debris. Biochemical and physical changes took place as the partially decayed plant material (peat) was buried. These changes led to the formation of coal. There are about 75 identified coal members in Illinois.

Sixty percent of the lower section of the Pennsylvanian System in Illinois is sandstone with the remainder being mostly siltstone and shale. Less than 1 percent is coal and limestone. Twenty-five percent of the middle and upper sections is sandstone, 5-10 percent is limestone, and 65-70 percent is shale and clay. Coal makes up no more than 2 percent of the Pennsylvanian System and is most prominent in the middle section (fig. 3.2-2) (Willman and others, 1975). The coals that are mined most extensively in Area 29 are the Harrisburg-Springfield (No. 5) and the Herrin (No. 6) (Illinois Department of Mines and Minerals, 1979).

The depth to the Herrin coal ranges from 0 to 1,000 feet with the shallowest coal being in the southern part of the area (Randolph and St. Clair Counties). The coal is deepest in Shelby County (Smith and Stall, 1975).

The Mississippian System is composed mainly of limestone with some sandstone and shale. It is up to 2,200 feet thick in Area 29 (Willman and others, 1975).

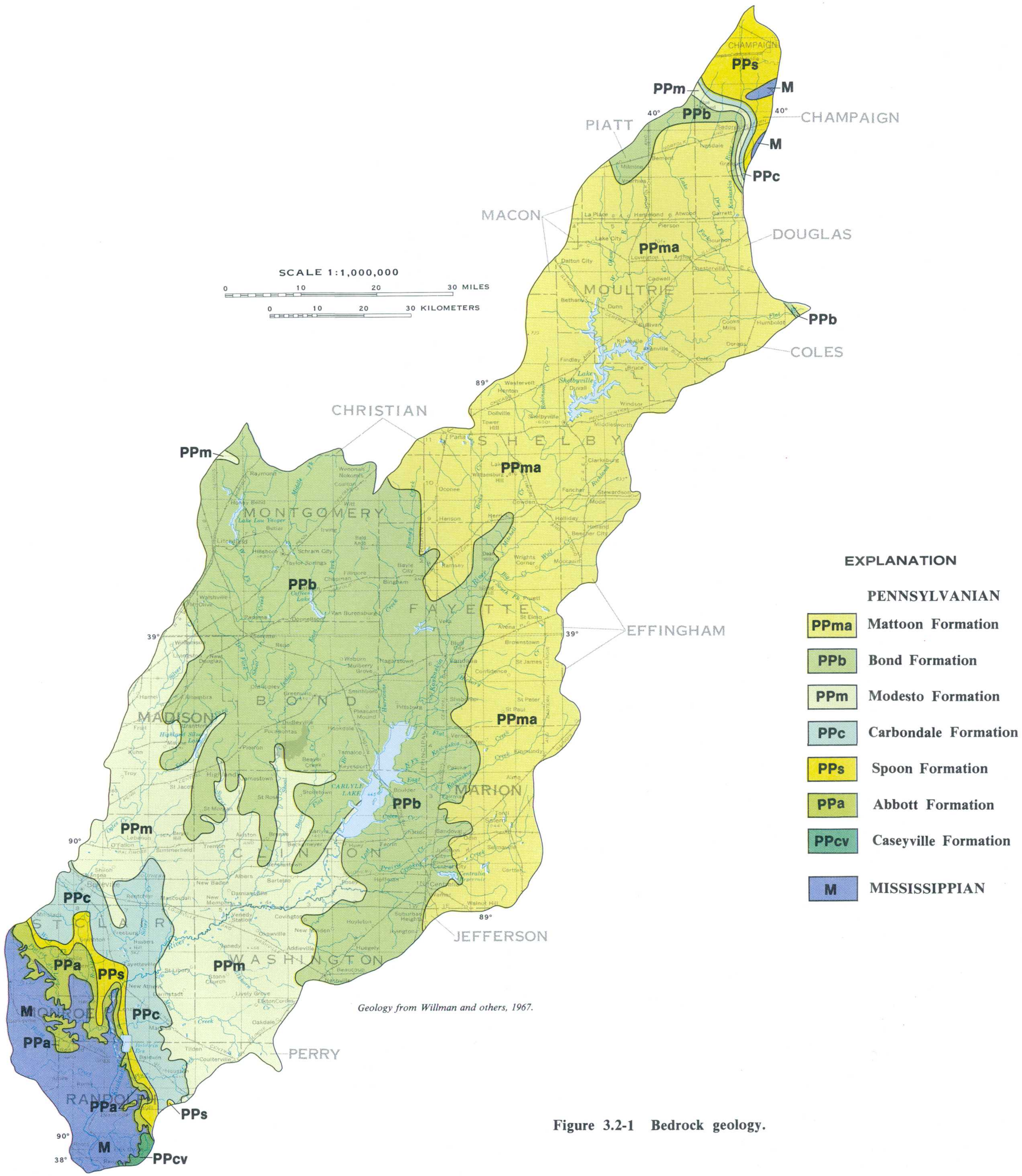


Figure 3.2-1 Bedrock geology.

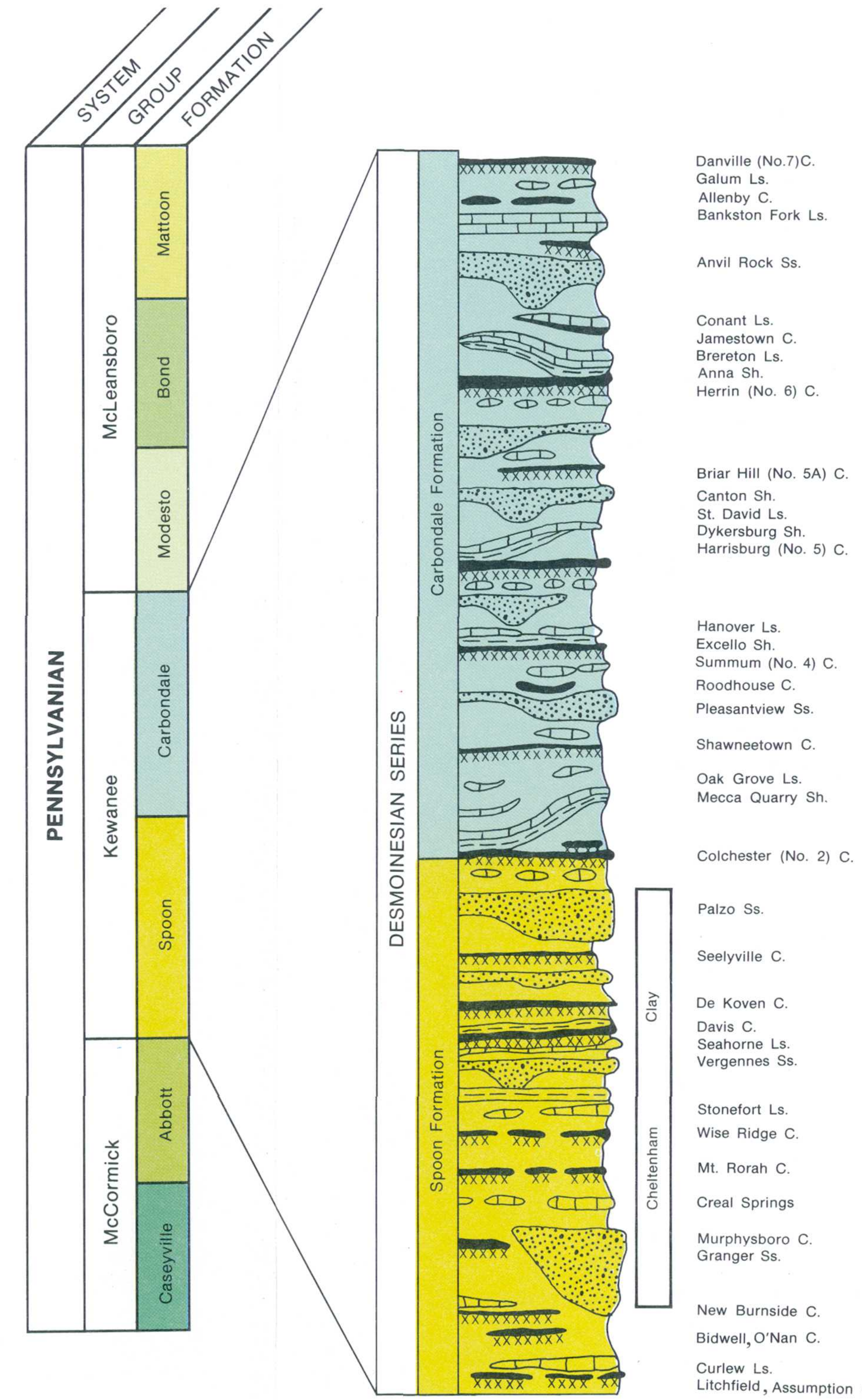


Figure 3.2-2 Stratigraphy of the major coal-bearing units in the Pennsylvanian System in Area 29 (Geologic names are those used by the Illinois State Geological Survey and are not necessarily in agreement with names used by the U.S. Geological Survey.)

Erosion Control is a Problem in Parts of Area 29

Soils are of low to moderate permeability, acidic, and subject to slope erosion.

In general, soils in Area 29 are of low to moderate permeability, acidic, and of moderate to high productivity under a high level of management (application of plant nutrients, maintenance of drainage, control of flooding and erosion, and control of weeds, diseases, and insect pests).

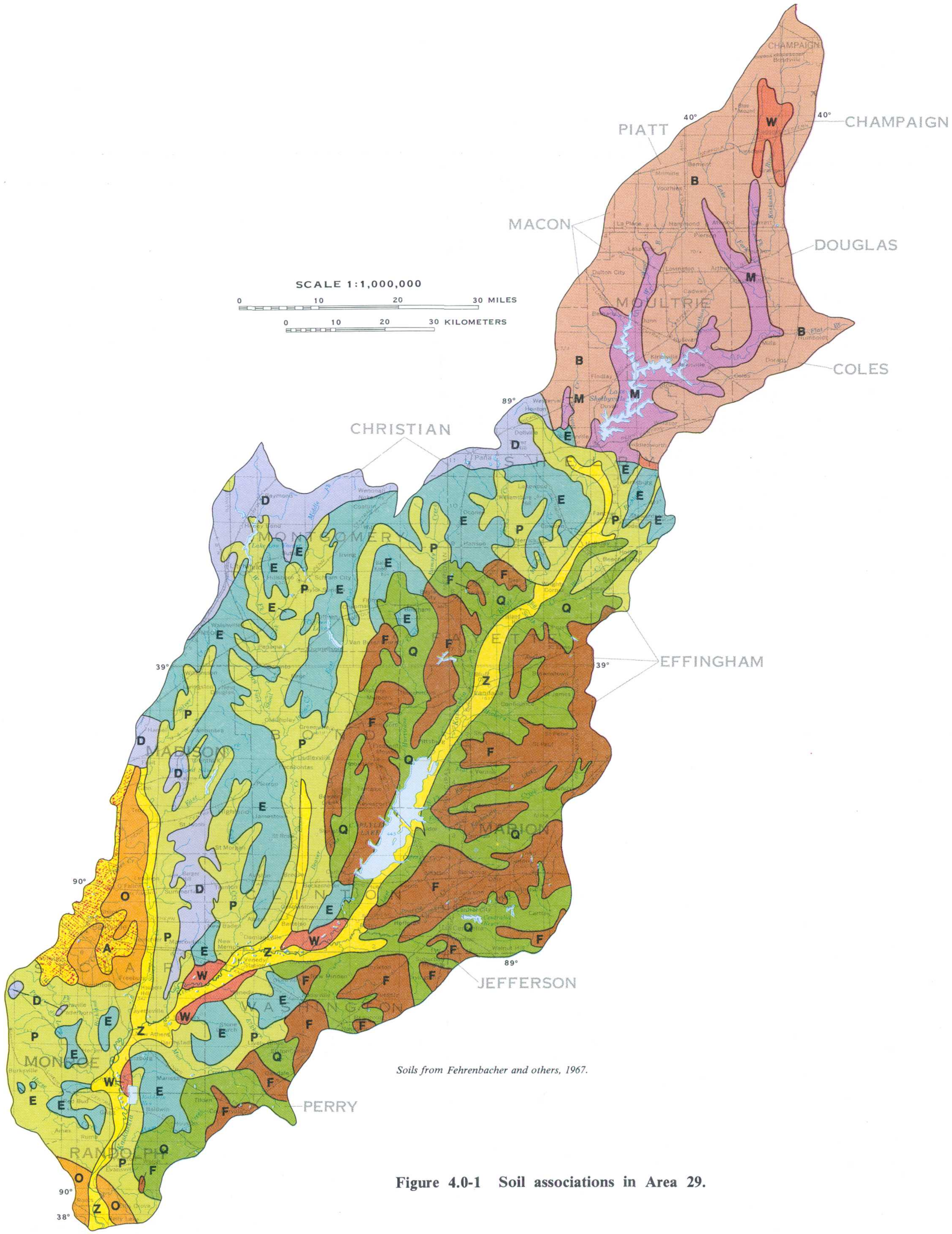
General descriptions of the soil associations in the area are given in table 4.0-1 and the soils are delineated in figure 4.0-1. The descriptions were compiled from soil surveys for individual counties (U.S. Department of Agriculture, 1969, 1971, 1978) and from Fehrenbacher and others (1967) and U.S. Department of Agriculture (1980).

Erosion control is a problem on slopes. More than 30 percent of soil association P, which makes up 23.1 percent of the area, is classified as having severe erosion problems. The percentages of each soil association that are subject to slight, moderate, or severe erosion are given in table 4.0-1. Average annual soil loss in Area 29 is 5-10 tons per acre (U.S. Department of Agriculture, 1980). Bedrock outcrops are common with depth to bedrock being up to 200 feet in the river valleys (Willman and others, 1975).

All of the soil associations in the area, except W and Z, were developed from loess. Loess is a silty wind deposit that was produced by outwash material being blown from the valleys onto the uplands during glacial times. When the loess was deposited, it was calcareous and contained many important plant nutrients. It was a friable, medium-textured silt loam with high available moisture storage capacity. Because of this, the soils that developed from loess are very productive (Fehrenbacher and others, 1967). At present, loess thickness in the area ranges from 5 to 15 feet (Lineback, 1979). Loess is easily eroded unless cut vertically. In addition, seepage may occur at the boundary with the underlying drift or bedrock. To help prevent slope failure, the slopes are benched and gutters are used at the top of the slopes and on the benches (Thornburn, 1963).

Soil associations W and Z were developed from outwash. Outwash materials were deposited in the major river valleys by meltwater during the Illinoian and Wisconsinan glaciations. The size of the materials ranges from gravel to clay (Fehrenbacher and others, 1967).

Information on the engineering properties of soils in Area 29 and detailed soil maps can be found in soil surveys for individual counties. These are published by the Soil Conservation Service in cooperation with the University of Illinois Agriculture Experiment Station. Soil surveys and other information can be obtained from the State office of the Soil Conservation Service, 200 W. Church Street, Champaign, Illinois 61820 (telephone 217-398-5265) or from county offices of the Soil Conservation Service. Recent soil surveys are available for Champaign, Douglas, Montgomery, and St. Clair Counties. A report by Wischmeier and Smith (1978) contains useful information on predicting rainfall erosion losses.



Soils from Fehrenbacher and others, 1967.

BASE FROM U.S. GEOLOGICAL SURVEY STATE BASE MAP, 1:500,000, 1972

Figure 4.0-1 Soil associations in Area 29.

Table 4.0-1 Soil association characteristics.

Soil association map symbol	Depth to bedrock (ft)	Depth to high water table (ft)	Permea-bility (in/hr)	Available water capacity (in/in of soil)	Soil reaction pH	Erosion class distribution (%) Slight 0-1	Moderate 2	Severe 3
A Joy-Tama-Muscatine-Ipava-Sable	5+	0-3	0.60-2.00	0.18-0.24	5.1-8.4	70	25	5
B Sidell-Catlin-Flanagan-Drummer	5+	0-6	0.20-2.00	0.16-0.25	5.1-8.4	99	1	0
D Harrison-Herrick-Virden	5+	0-5	0.20-2.00	0.10-0.24	4.5-8.4	99	1	0
E Oconee-Cowden-Piasa	5+	0-3	0.06-0.63	0.09-0.25	5.1-9.0	93	7	0
F Hoyleton-Cisne-Huey	5+	0-3	0.00-2.00	0.13-0.28	4.5-6.5	95	5	0
M Birkbeck-Ward-Russell	5+	3-6	0.20-2.00	0.14-0.25	5.1-8.4	57	32	11
O Stooky-Alford-Muren	8+	8+	0.63-2.00	0.18-0.25	5.1-8.4	25	49	26
P Hosmer-Stay-Weir	6+	0-3	0.06-2.00	0.14-0.25	4.0-6.0	26	38	36
Q Ava-Bluford-Wynoose	6+	0-10+	0.06-2.00	0.15-0.25	4.0-6.0	68	26	6
W Littleton-Proctor-Plano-Camden-Hurst-Ginat	10+	5-10	0.63-6.30	0.10-0.25	5.6-8.4	90	10	0
Z Lawson-Beaucoup-Darwin-Haymond-Belknap	0.5-10+	0-4	0.06-2.00	0.11-0.25	5.1-7.8	100	0	0

5.0 LAND USE

Agriculture is Dominant Land Use

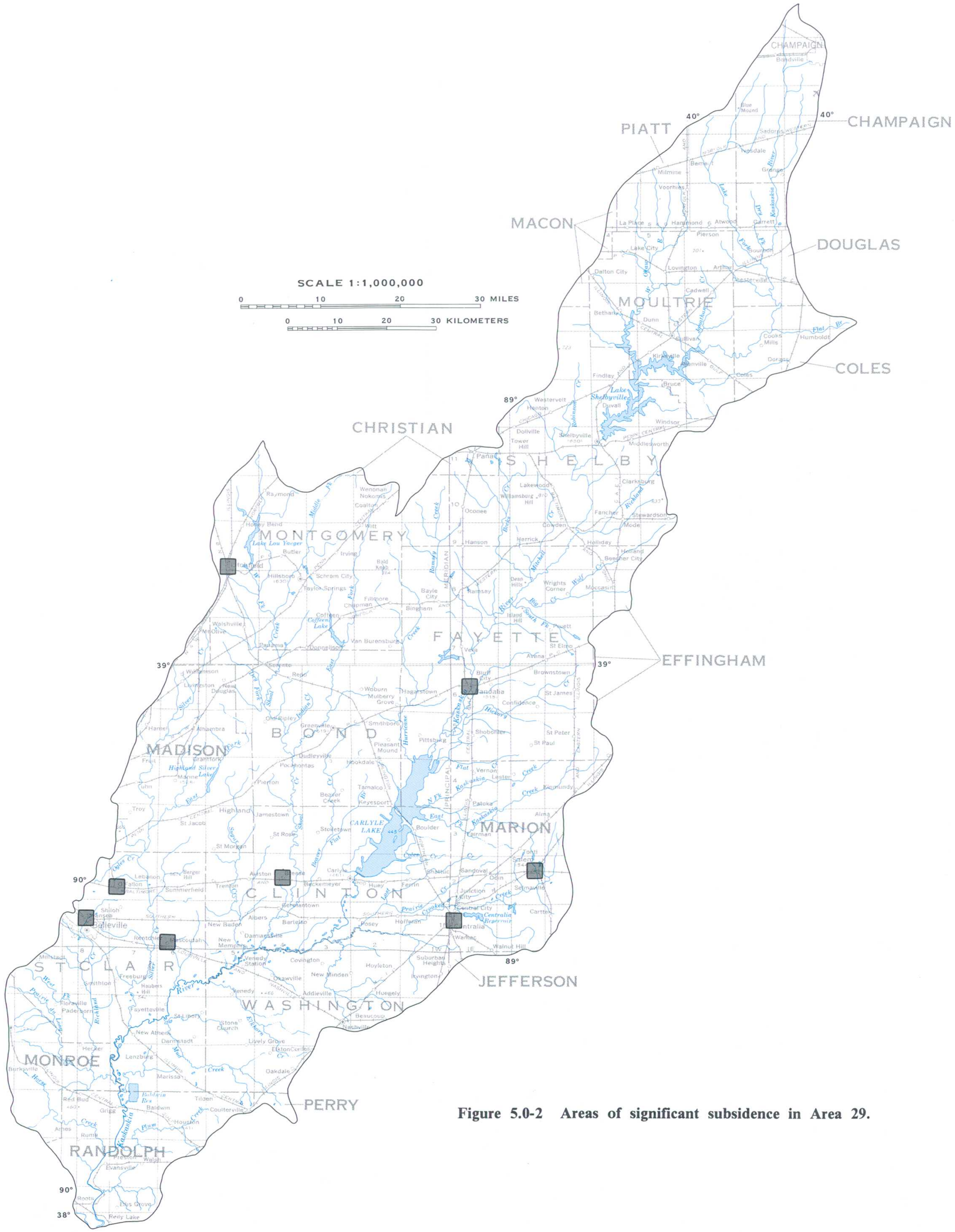
Seventy-six percent of Area 29 is used for agriculture and only 0.5 percent of the total land area has been affected by coal mining.

Area 29 covers 5,801 square miles in central Illinois. Agriculture is the dominant land use with 66.0 percent cropland and 9.8 percent pasture. The main crops are corn and soybeans. Beef cattle and hogs are also raised. The remainder of the land uses and their percentages are shown in figure 5.0-1.

The mined land includes all land that has been affected by mining, both past and present. This is mainly land that has been surface mined. About 0.02 percent of the total surface area has been affected by underground mining with approximately 4 percent of Area 29 having been undermined.

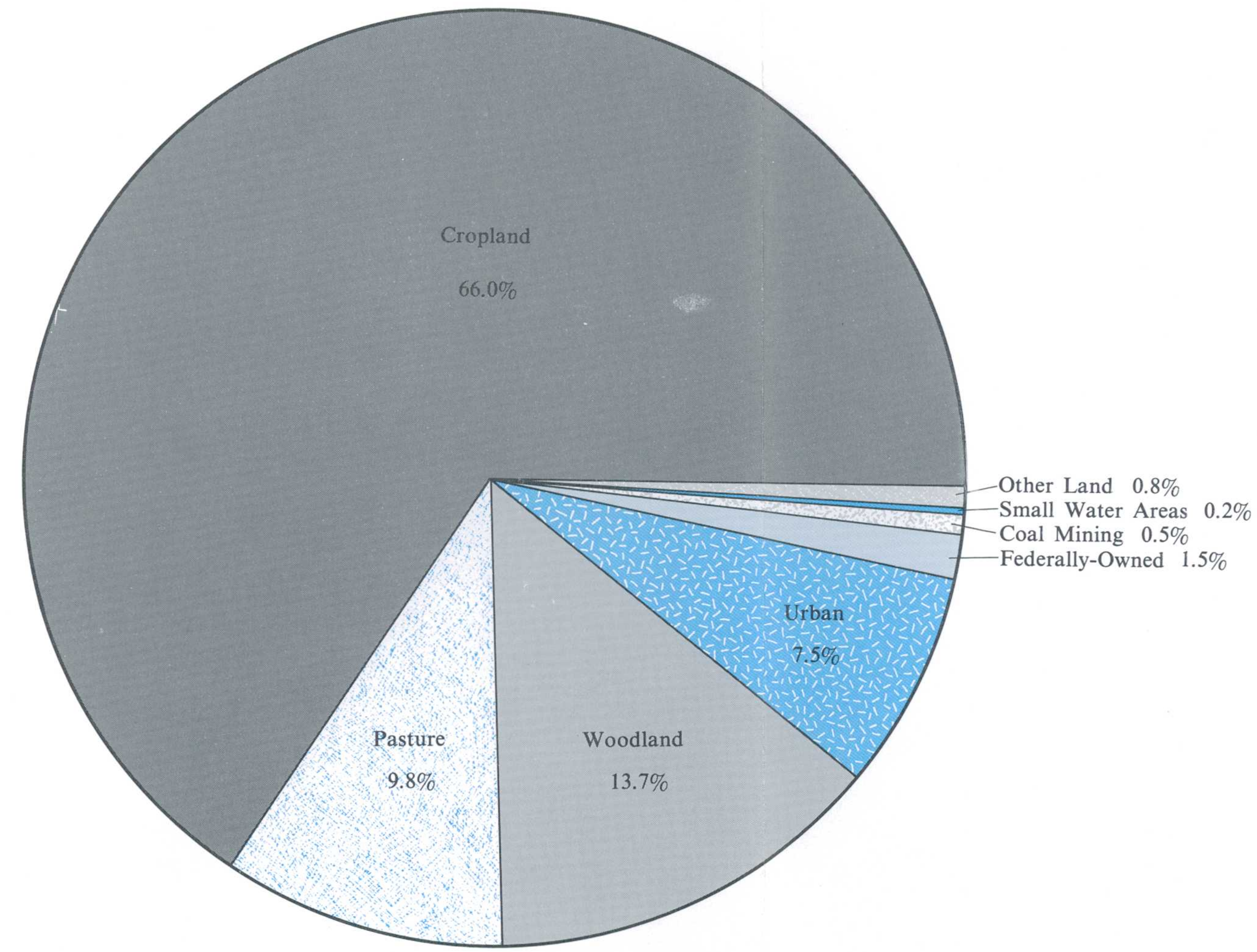
Subsidence is a problem in undermined areas. Damage caused by subsidence has occurred in Breese in Clinton County, Vandalia in Fayette County, Centralia and Salem in Marion County, Litchfield in Montgomery County, and Muscoutah, O'Fallon, and Swansea in St. Clair County (fig. 5.0-2) (Nawrot and others, 1980).

At present, there are five active underground mines, one each in Clinton, Montgomery, and St. Clair Counties and two in Randolph County. There is a sixth underground mine under construction in St. Clair County. There are two active surface mines, one in Randolph County and one in St. Clair County (Hopkins, 1975, updated in 1980). Sand, gravel, and stone are also mined in the area (Samson, 1981).



BASE FROM U.S. GEOLOGICAL SURVEY
STATE BASE MAP, 1:500,000, 1972

Figure 5.0-2 Areas of significant subsidence in Area 29.



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

Figure 5.0-1 Land use, 1967.

6.0 WATER USE

Surface Water is Dominant Source

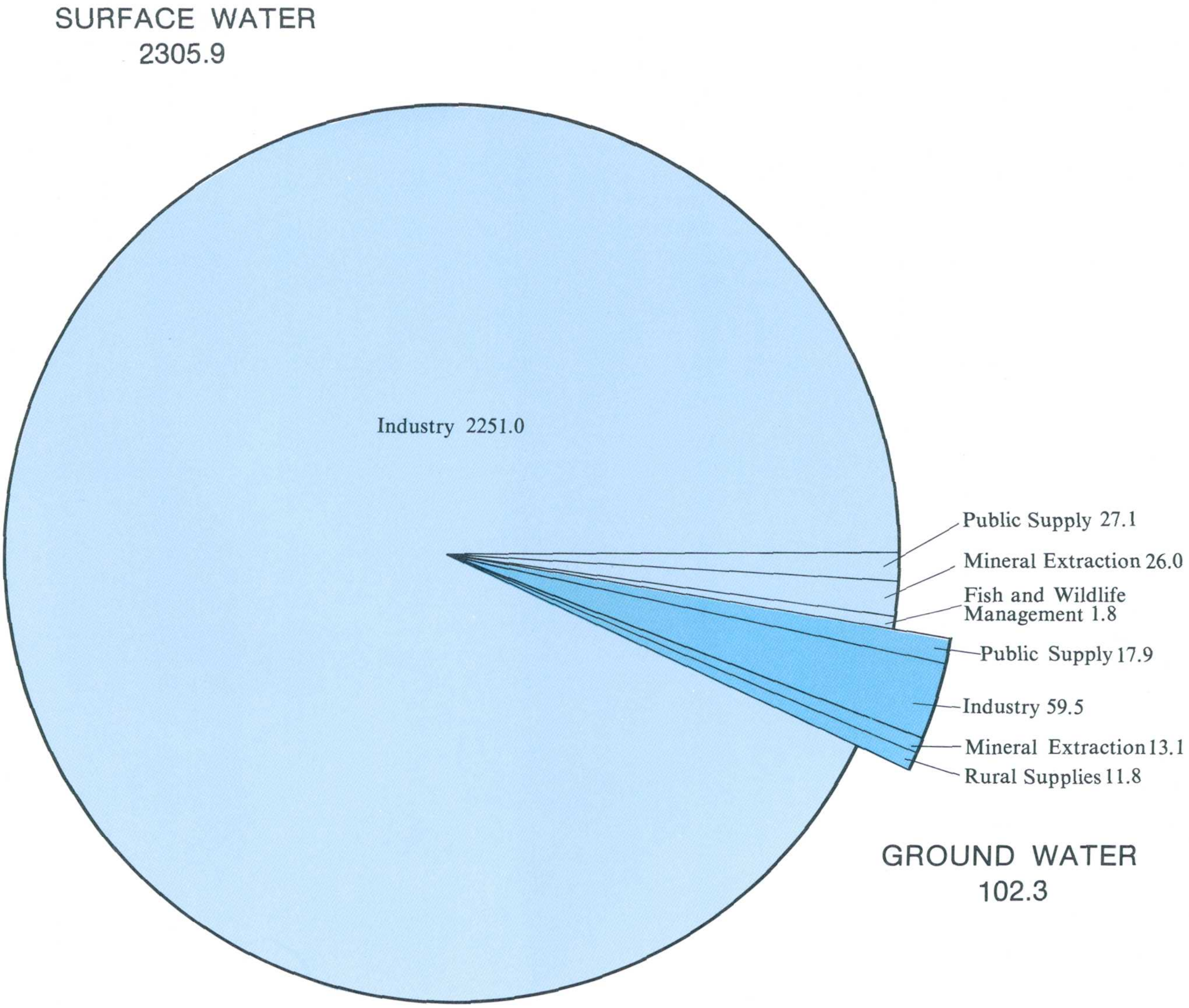
Ninety-six percent of the water used is obtained from surface-water sources.

Total water withdrawal in Area 29 was 2,408 million gallons per day (mgal/d) in 1978 (Kirk and others, 1979). About 102.3 mgal/d (4 percent) was from ground water (fig. 6.0-1).

Ninety-six percent (2,311 mgal/d) of the total amount of water withdrawn was used for industry, 1.8 percent (45.0 mgal/d) was used for public supply, 1.6 percent (39.1 mgal/d) was used for mineral extraction, 0.5 percent (11.8 mgal/d) was used for rural supplies (domestic, livestock, and irrigation), and 0.1 percent (1.8 mgal/d) was used for fish and wildlife management.

There are 12 reservoirs in Area 29 that are used for water supply and 2 that are used for powerplant cooling. The largest reservoirs in the area are Carlyle Lake (26,000 acres) and Lake Shelbyville (11,100 acres). These lakes are used for water supply, flood control, and recreation (Illinois Environmental Protection Agency, 1978a). There are 22 potential reservoir sites in the area (Dawes and Terstriep, 1966a, 1966b).

In 1970, 57 towns in the area were using ground water for their municipal supply, 48 towns were using surface water and outside sources, and 6 towns did not have municipal water supplies. The towns of Belleville, O'Fallon, Shiloh, Swansea, and Humboldt obtain their water from outside the Kaskaskia River basin. A study to develop plans for meeting future water requirements in the basin (Singh and others, 1972) found that 48 towns do not have adequate ground-water supplies to meet present requirements, 13 towns will have inadequate ground-water supplies by 2010, and 50 towns have adequate ground-water potential to meet water requirements in 2020.



Data from Kirk and others, 1979.

Figure 6.0-1 1978 water use, in million gallons per day.

7.0 PRECIPITATION

Area has a High Frequency of Severe Weather

Mean annual precipitation in Area 29 ranges from 37 to 40 inches and 50 percent of the precipitation is produced by thunderstorms.

The mean annual precipitation in Area 29 ranges from 37 to 40 inches (fig. 7.0-1). The mean annual snowfall ranges from 15 inches along the southeastern edge of the area to 21 inches in the northernmost part of the area (fig. 7.0-2). More than 60 percent of the annual precipitation occurs between April and September. The driest months are February and December. The wettest months are usually May and June.

Area 29 is located in the part of Illinois that experiences many forms of severe weather including drought, thunderstorms, tornadoes, hail, ice storms, and snowstorms. The western half of the area has experienced the greatest precipitation deficiencies ever measured in Illinois. Drought conditions occur more frequently in this area than in any other part of the State. In the period between April and September (the warmer half-year), less than 13 inches of rainfall may occur on the average of once every 5 years. There is also a high frequency of intense short-duration warm season rainstorms. About 50 percent of the annual precipitation is produced by thunderstorms. The area has freezing rain and sleet on an average of 9 to 10 days per year (Dawes and Terstriep, 1966a, 1966b).

The 24-hour rainfall amount that can be expected to be equaled or exceeded on the average of once in 2 years ranges from 3.0 inches in the northern part of the area to 3.6 inches in the southern part of the area (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.

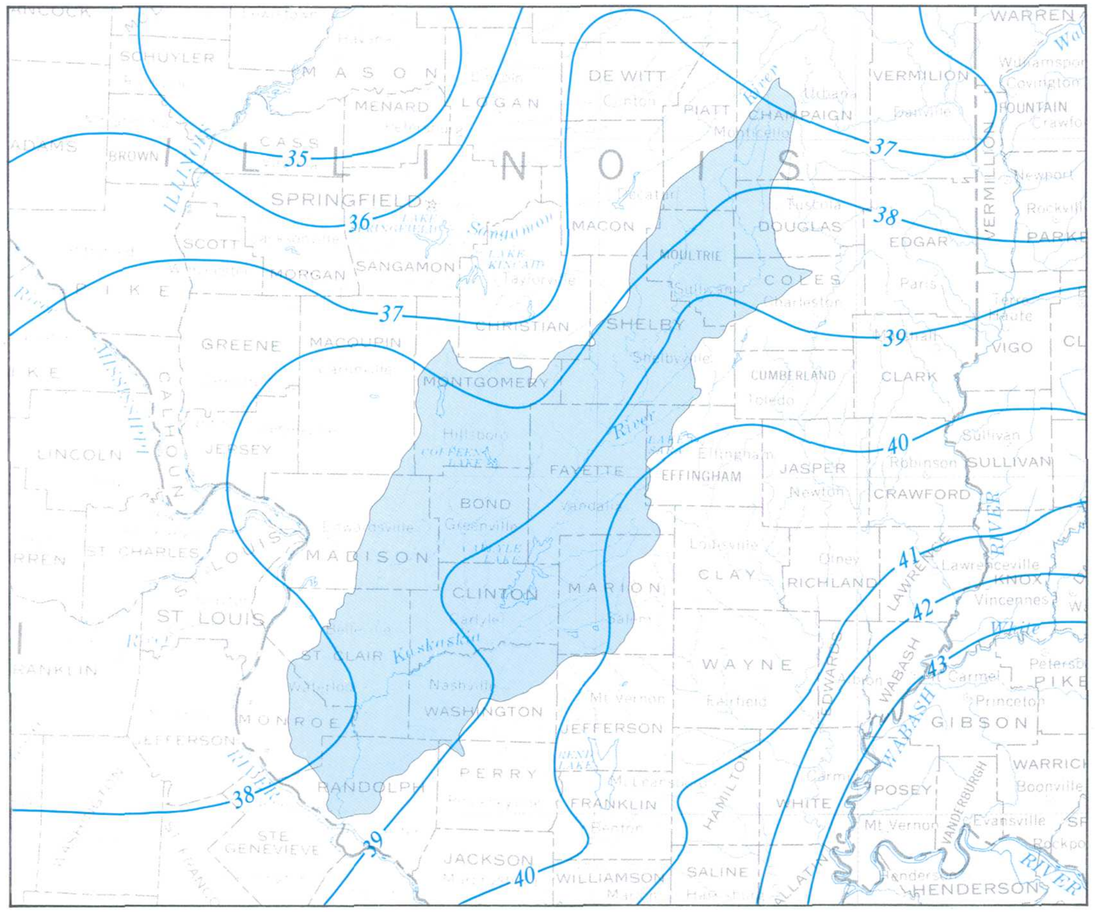


Figure 7.0-1 Mean annual precipitation, in inches. *Precipitation isolines from Dawes and Terstriep, 1966a, 1966b.*

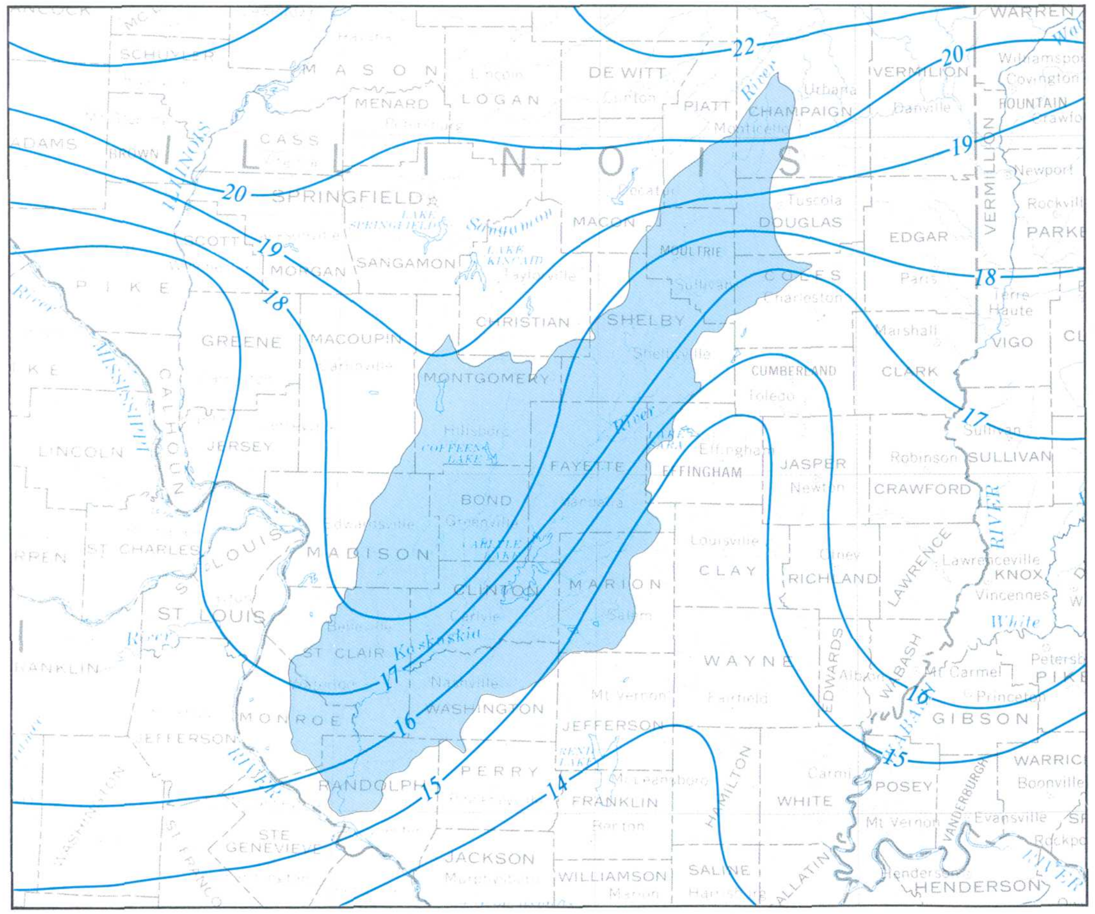


Figure 7.0-2 Mean annual snowfall, in inches. *Snowfall isolines from Dawes and Terstriep, 1966a, 1966b.*

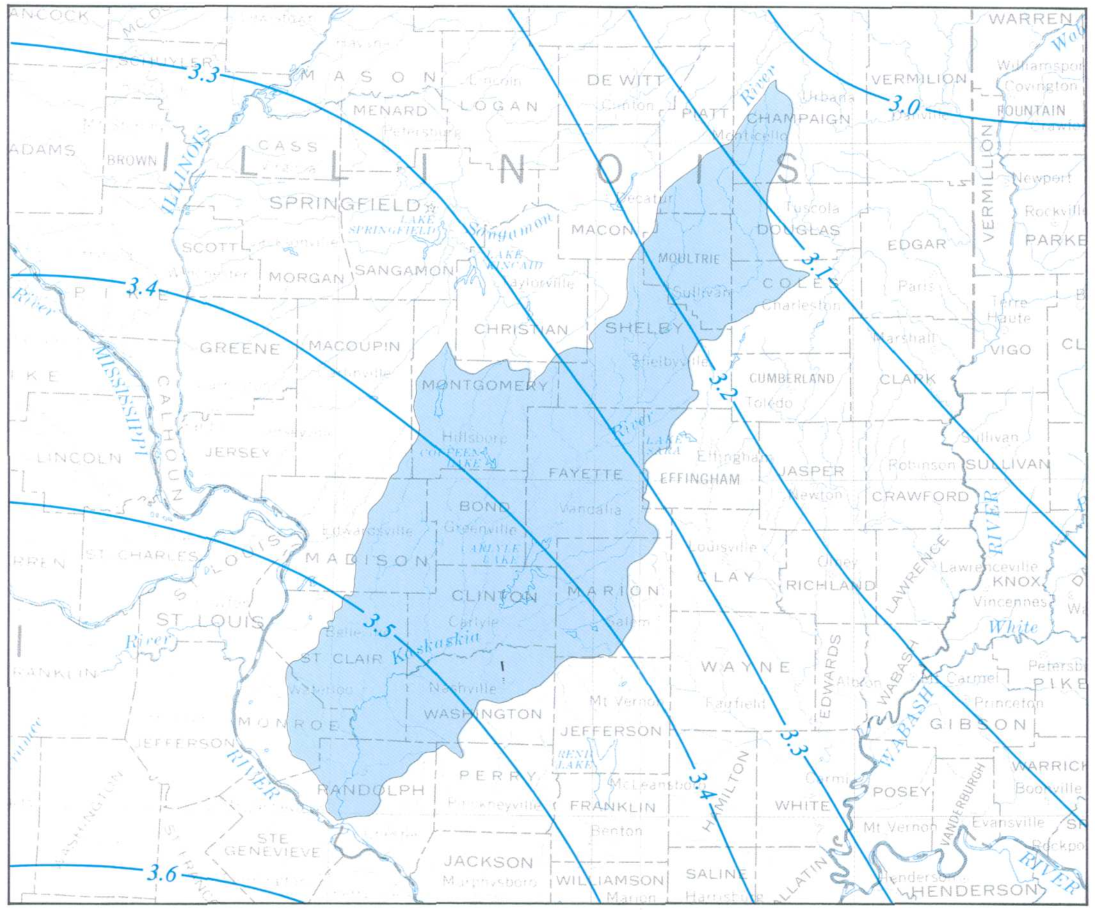


Figure 7.0-3 Two-year, 24-hour rainfall, in inches. *Rainfall isolines from Herschfield, 1961.*

—*3.1*— Lines of equal precipitation in inches

Table 7.0-1 Precipitation frequency values, in inches.

Precipitation frequency values 10, 30, 60 minutes from Frederick and others, 1977.
Precipitation frequency values 12 and 24 hour from Herschfield, 1961.

FREQUENCY	10 minute	30 minute	60 minute	12 hour	24 hour
2 year	0.72	1.22	1.55	3.0	3.4
5 year	0.85	1.53	2.00	3.7	4.2
10 year	0.95	1.72	2.25	4.2	4.8
25 year	1.11	2.02	2.66	4.7	5.5
50 year	1.23	2.26	2.98	5.3	6.1
100 year	1.35	2.49	3.30	5.8	6.7

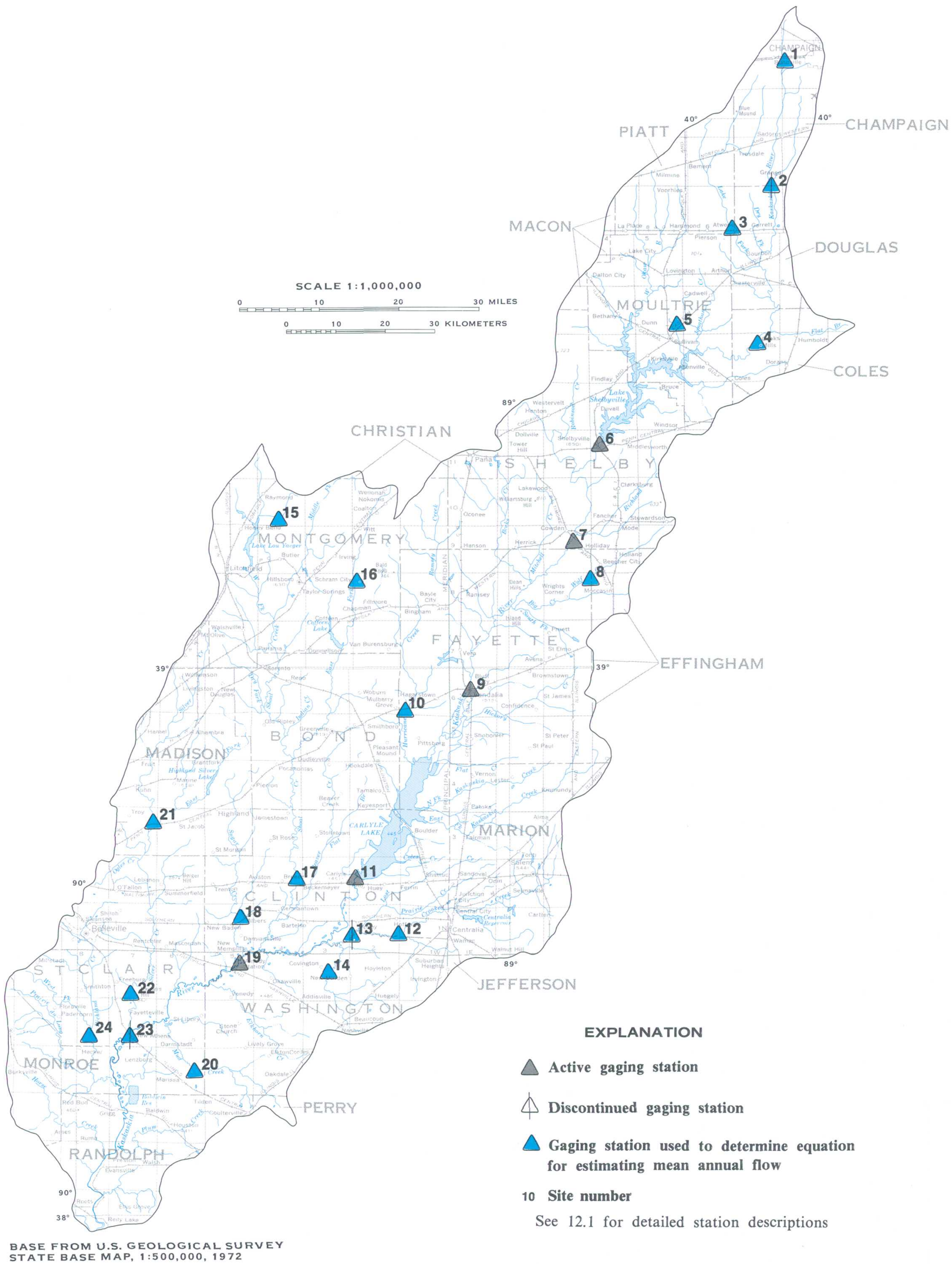
Streamflow Information Available at 24 Sites

Mean annual streamflow can be estimated from drainage area.

There are 21 active gaging stations in Area 29. Data from three additional inactive stations are also available. All of these stations are listed in section 13.1 and are shown on figure 8.1.1-1.

Mean annual flow (Q_a), in cubic feet per second (ft^3/s), of ungaged streams can be estimated from the drainage area-streamflow relation of gaged streams (fig. 8.1.1-2). The drainage area-streamflow relation in Area 29 is expressed by the equation $Q_a = 0.81\ A$ where A is the drainage area, in square miles. The drainage area is plotted against the mean annual discharge for each gaging station. The points on the graph are labeled with the map number of the gaging stations used to develop this relation (section 13.1). This relation is based on streamflow records from 19 gaging stations with an average of 16 years of record and with drainage areas ranging from 8.05 to 5,181 square miles. The Kaskaskia River at New Athens (Map Number 23) is now regulated by Carlyle Reservoir. The mean annual discharge from the time prior to regulation was used in developing the relation. The Kaskaskia River is also regulated by Lake Shelbyville (fig. 8.1.1-1).

The mean annual streamflow in an area is dependent upon the following drainage basin characteristics (in order of importance): the drainage area, the soil index which is a factor indicating the rainfall-runoff relation of a soil, the mean annual precipitation, the percentage of the area covered by forest, the percentage of the area that is lakes and ponds, the mean elevation of the drainage basin, the main-channel slope determined from elevations at points 10 and 85 percent of the distance from the point in question to the basin divide, and the length of the channel from the point in question to the basin divide (Sieber, 1970). In Area 29, the drainage area is the most significant basin characteristic and can be used to estimate the mean annual streamflow in ungaged areas.



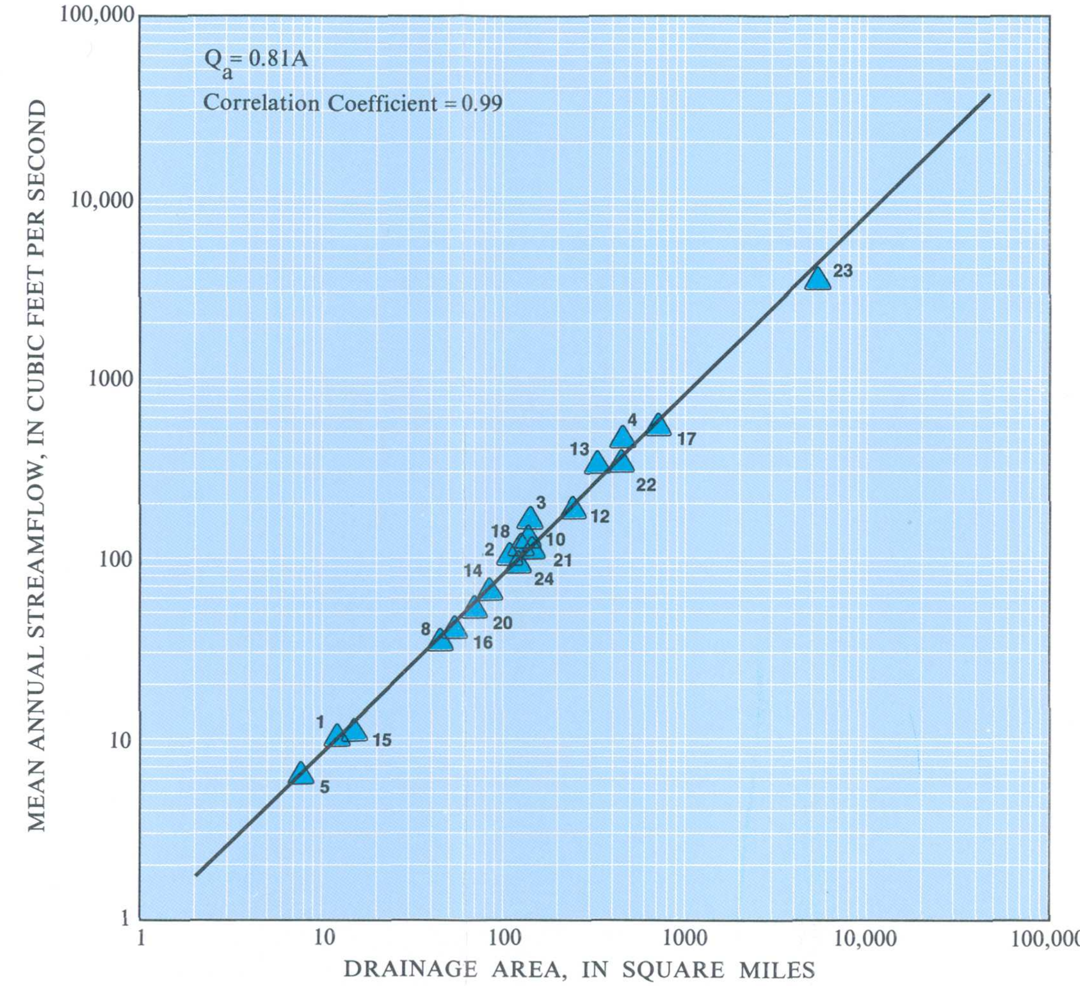


Figure 8.1.1-2 Relation between drainage area and mean annual streamflow in Area 29.

The 7-Day, 10-Year Low Flow can be Estimated from Drainage Area

The 7-day, 10-year low flow for most streams, except the Kaskaskia River and its major tributaries, is zero.

The 7-day, 10-year low flow (Q_L) is the annual minimum 7-day mean flow having a 10-year recurrence interval. This is the flow condition on which most water-quality standards are based. In Area 29, Q_L, in cubic feet per second, can be estimated using the equation $Q_L = 0.0006\ A^{1.27}$, where A is the drainage area, in square miles. This relation was developed by plotting drainage area versus the 7-day, 10-year low flow at 16 gaging stations in the area (fig. 8.1.2-1). The locations of these stations are shown in figure 8.1.2-2.

During times of low flow, most of the streamflow is derived from ground water. This is called baseflow. Additional flow may come from wastewater plant outfalls. In the area, all streams except the Kaskaskia River, Richland Creek, Silver Creek, and Shoal Creek and streams receiving wastewater plant discharges have zero 7-day, 10-year low flows (Singh and Stall, 1973).

Low flows for durations other than 7 days and for recurrence intervals other than 10 years can be computed from streamflow records. Lara (1970) presents this information for seven gaging stations in the area.

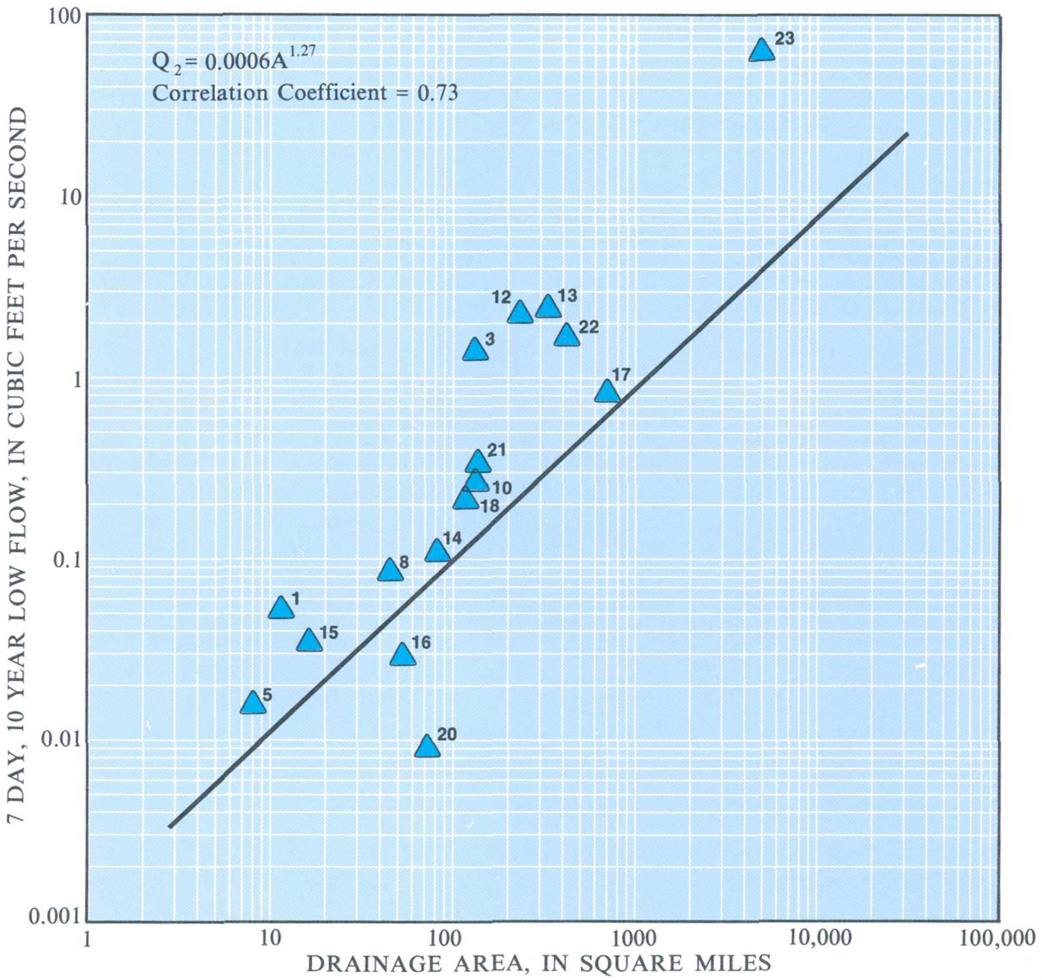


Figure 8.1.2-1 Relation between drainage area and 7-day, 10-year low flow in Area 29.

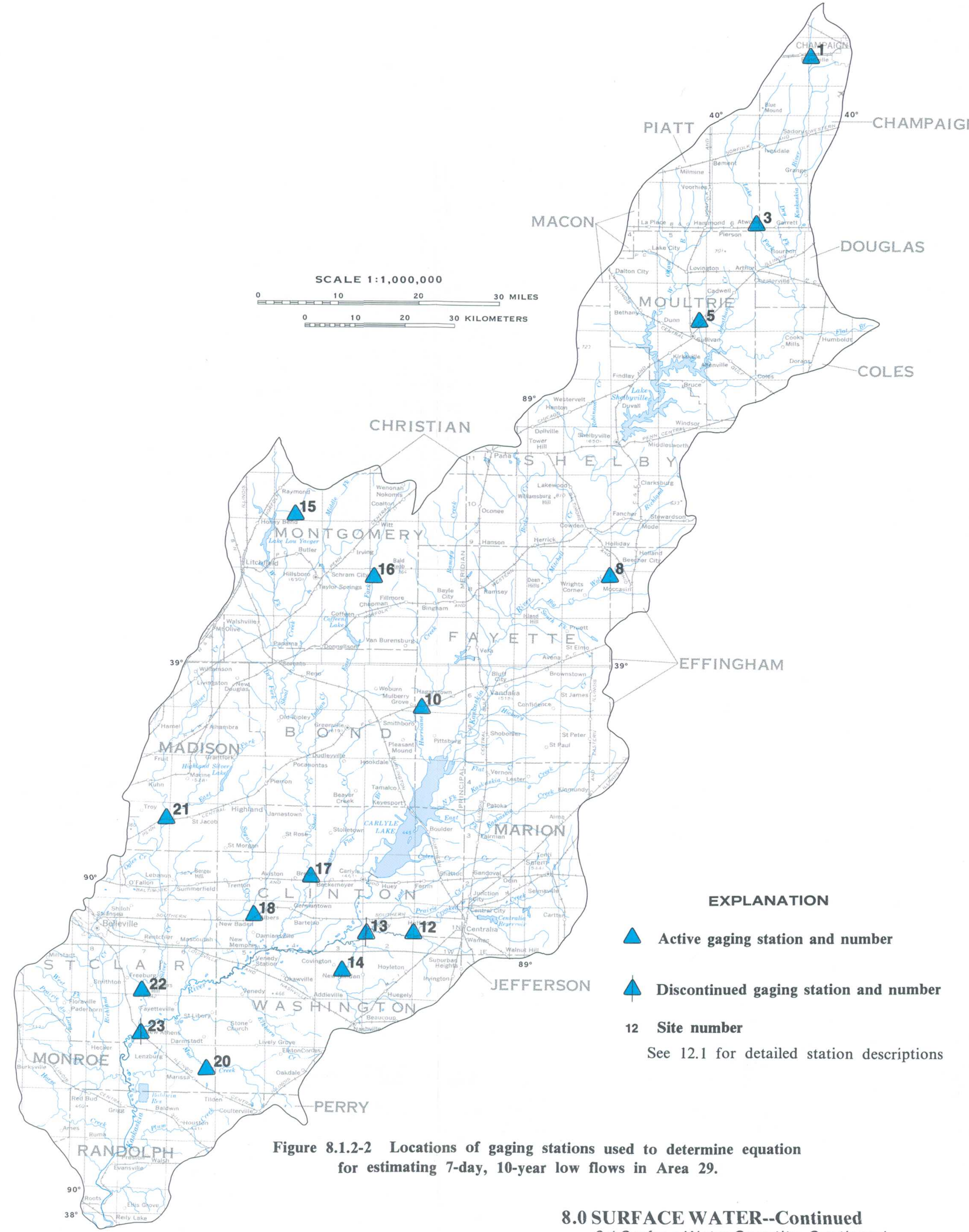


Figure 8.1.2-2 Locations of gaging stations used to determine equation for estimating 7-day, 10-year low flows in Area 29.

8.0 SURFACE WATER--Continued

8.1 Surface-Water Quantity--Continued

8.1.2 Low Flow

Floodflows can be Estimated

Much of the area along the Kaskaskia River and its major tributaries is subject to flooding. Lakes have been built to provide flood control.

The annual peak discharge that will be exceeded on the average of once in 10 years ($Q_{P,10}$), in cubic feet per second, can be estimated using the equation $Q_{P,10} = 101\ A^{0.767}\ S^{0.494}\ (I-2.5)^{0.833}$. A is the drainage area, in square miles, and S is the slope of the channel, in feet per mile, determined by the difference between elevations at points 10 and 85 percent of the distance along the main channel from the point in question to the basin divide divided by the distance between those two points. I is the 2-year, 24-hour rainfall intensity, in inches, and ranges from 3.0 inches at the northern end to 3.6 inches at the southern end of the area (Curtis, 1977).

Equations for determining peak discharges that will be exceeded on the average of once in 2 years ($Q_{P,2}$), 10 years ($Q_{P,10}$), 25 years ($Q_{P,25}$), 50 years ($Q_{P,50}$), and 100 years ($Q_{P,100}$) are given in table 8.1.3-1. The method for estimating floodflows is described in "Technique for Estimating Magnitude and Frequency of Floods in Illinois" (Curtis, 1977).

The 7-day, 10-year high flow (Q_H) is the annual maximum 7-day mean flow having a 10-year recurrence interval. In Area 29, Q_H, in cubic feet per second, can be estimated using the equation $Q_H = 18.9\ A^{0.97}$, where A is the drainage area, in square miles. This relation was developed by plotting drainage area versus the 7-day, 10-year high flow at 18 gaging stations in the area (fig. 8.1.3-1). These stations are listed in section 13.1.

Much of the area along the Kaskaskia River and its major tributaries is subject to flooding. Carlyle Lake and Lake Shelbyville were built, in part, to provide flood control in the basin. Flood-prone area maps have been compiled for several areas in Area 29 (fig. 8.1.3-2). These maps can be obtained from the U.S. Geological Survey, Champaign County Bank Plaza, 4th Floor, 102 East Main Street, Urbana, Illinois 61801.

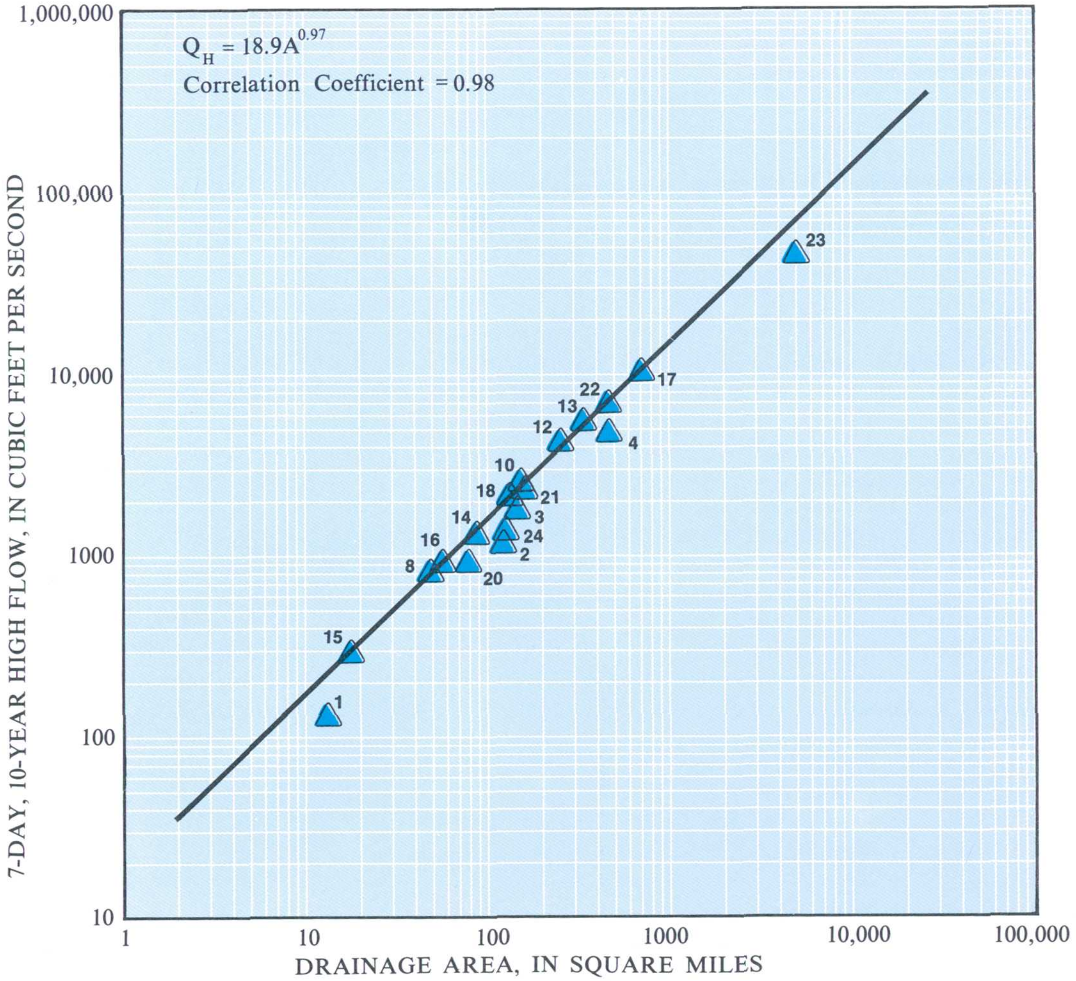


Figure 8.1.3-1 Relation between drainage area and 7-day, 10-year high flow in Area 29.

EXPLANATION

Hydrologic Investigations Atlas available

Flood-prone area map available from Illinois District

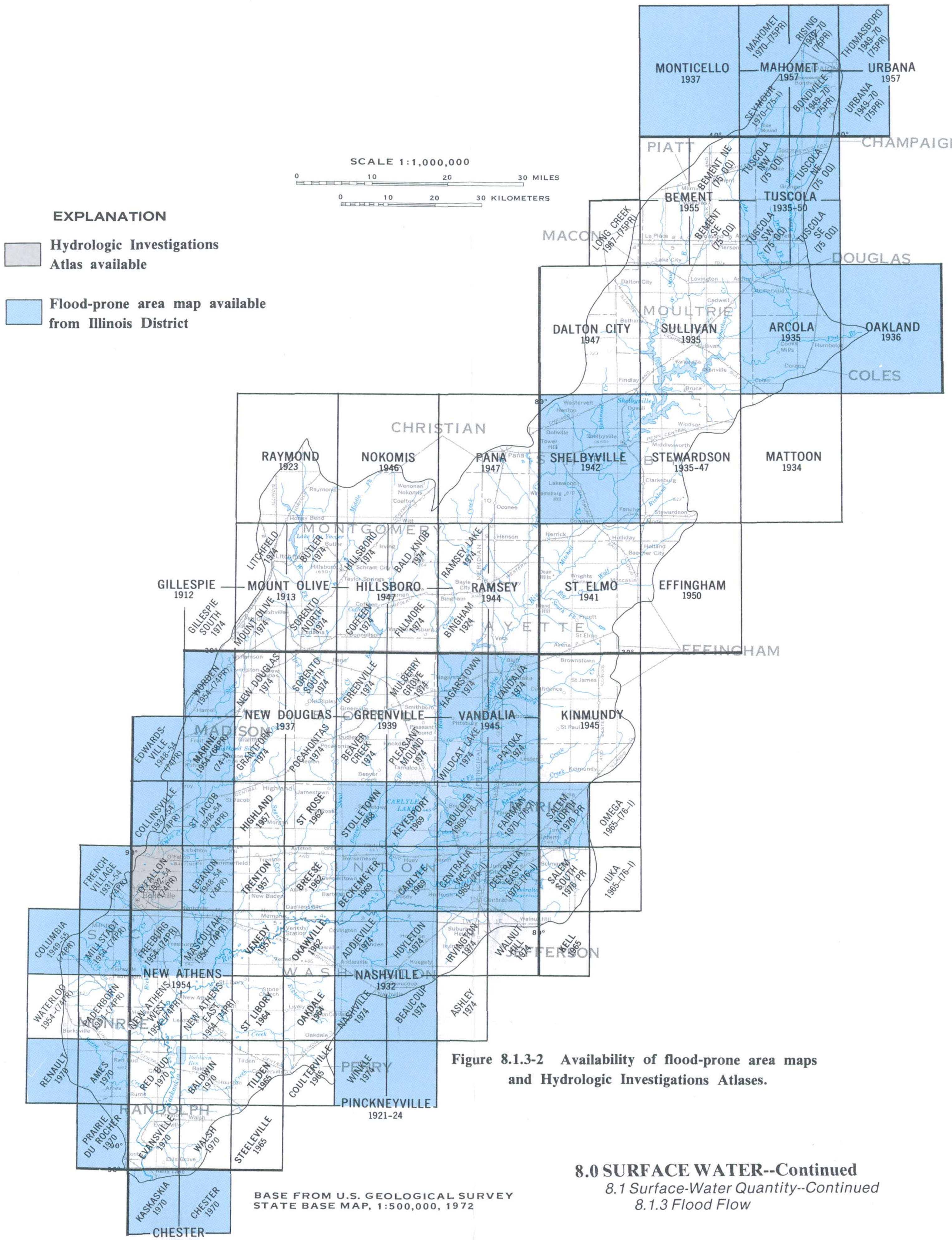


Figure 8.1.3-2 Availability of flood-prone area maps and Hydrologic Investigations Atlases.

Water-Quality Data are Available for Sites Upstream and Downstream of Surface Mining in Area 29

Measurements of specific conductance, pH, alkalinity, iron, manganese, sulfate, and other constituents are available at 39 sites in Area 29.

Specific conductance, pH, alkalinity, sulfate, dissolved and total-recoverable iron, and dissolved and total-recoverable manganese are important when assessing water quality of areas influenced by surface mining. Water-quality data of this nature are available at 39 sites in the Kaskaskia River basin (fig. 8.2.1-1). Eleven of these sites are downstream from past or present surface-mining activities. Ten sites are downstream from past or present oil and gas production or underground-mining activities. Nine sites are on the main stem of the Kaskaskia River and nine sites are upstream of, and hence unaffected by, mining activities (table 8.2.1-1). These data, included in sections 8.2.1 through 8.2.11 of this report, were collected by the U.S. Geological Survey and the Illinois Environmental Protection Agency. The type and frequency of data collected vary at each site and between sites. In addition, reconnaissance data were collected at 93 sites throughout the watershed (section 11.2). These data, which include specific conductance, pH, dissolved oxygen, and water temperature were collected during a 3-day sampling period in November 1980 (section 11.3).

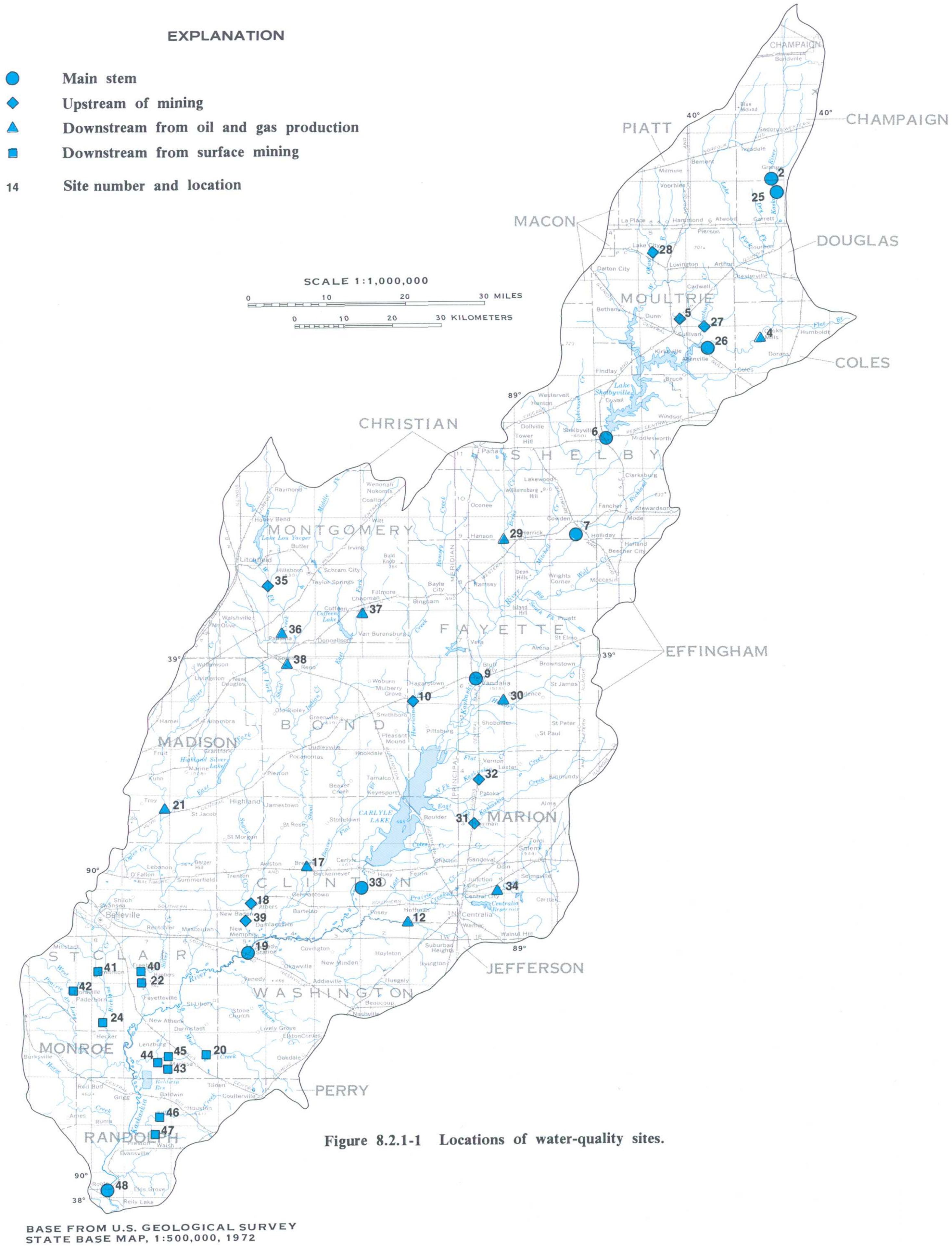


Figure 8.2.1-1 Locations of water-quality sites.

Table 8.2.1-1 Water-quality sites in Area 29.

Site Number	Station Number	Station Name	Latitude ° ' "	Longitude ° ' "	Drainage Area	Number of Observations	Period of Record	Land Use
2	05590400	Kaskaskia River nr Pesotum	39 52 44	88 22 35	109	19	77-80	MS
4	05591200	Kaskaskia River at Cooks Mills	39 34 59	88 54 50	473	108	70-80	OG
5	05591500	A Creek at Sullivan	39 37 11	88 36 17	8.05	37	78-80	US
6	05592000	Kaskaskia River at Shelbyville	39 24 25	88 46 50	1,054	98	71-80	MS
7	05592100	Kaskaskia River at Cowden	39 13 50	88 50 33	1,330	40	77-80	MS
9	05592500	Kaskaskia River at Vandalia	38 57 35	89 05 20	1,940	140	50-56, 66-71, 78-80	MS
10	05592800	Hurricane Creek nr Mulberry Grove	38 55 21	89 14 14	152	30	78-80	US
12	05593520	Crooked Creek nr Hoffman	38 30 25	89 16 24	254	22	79-80	OG
17	05594000	Shoal Creek nr Breese	38 36 35	89 29 40	735	86	71-76, 78-80	OG
18	25594090	Sugar Creek at Albers	38 32 29	89 37 36	124	38	77-80	US
19	05594100	Kaskaskia River nr Venedy Station	38 27 02	89 37 39	4,393	134	71-80	MS
20	05594330	Mud Creek nr Marissa	38 15 46	89 43 56	72.4	6	79-80	SM
21	05594450	Silver Creek nr Troy	38 43 00	89 49 45	154	40	77-80	OG
22	05594800	Silver Creek nr Freeburg	38 24 22	89 52 26	464	35	78-80	SM
24	05595200	Richland Creek nr Hecker	38 19 26	89 58 15	129	36	78-80	SM
25	05590420	Kaskaskia River nr Tuscola	39 51 53	88 21 52	113	16	79-80	MS
26	05591300	Kaskaskia River nr Allenville	39 34 22	88 31 56	506	11	1980	MS
27	05591400	Jonathan Creek nr Sullivan	39 36 04	88 32 46	54.7	11	1980	US
28	05591700	West Okaw River nr Lovington	39 43 52	88 39 43	111	11	1980	US
29	05592195	Bear Creek at Herrick	39 12 59	89 01 14	97	22	79-80	OG
30	05593600	Hickory Creek nr Bluff City	38 55 30	89 02 20	77.6	29	77-80	OG
31	05592900	E Fk Kaskaskia River nr Sandoval	38 41 20	89 05 55	113	29	77-80	US
32	05592930	N Fk Kaskaskia River nr Patoka	38 46 25	89 05 10	39.1	26	77-80	US
33	05593010	Kaskaskia River below Caryle	38 34 28	89 22 09	2,734	39	77-80	MS
34	05593505	Crooked Creek nr Odin	38 33 50	89 03 01	89.2	33	78-80	OG
35	05593750	W Fk Shoal Creek nr Litchfield	39 08 17	89 34 39	138	6	79-80	US
36	05593800	Shoal Creek nr Panama	39 02 25	89 33 03	286	41	77-80	OG
37	05593910	E Fk Shoal Creek at Shilo Church nr Coffeen	39 04 26	89 21 36	76	5	79-80	OG
38	05593930	E Fk Shoal Cr nr Paisley Corners	38 57 57	89 24 42	113	6	79-80	OG
39	05594095	Sugar Creek nr Damiansville	39 30 49	89 38 09	163	5	79-80	US
40	05594795	Heberers Branch nr Freeburg	38 26 20	89 50 29	2.55	5	75,79,80	SM
41	05595185	Douglas Creek nr Smithton	38 25 28	89 59 14	16.9	7	75,77,80	SM
42	05595190	W Fk Richland Creek at Floraville	38 22 54	90 02 43	15.5	6	75,79,80	SM
43	05595226	Doza Creek nr Lenzburg	38 15 39	89 49 12	17.6	18	78-80	SM
44	05595228	S Br Doza Creek nr Lenzburg	38 14 56	89 50 10	8.0	17	78-80	SM
45	05595230	Doza Creek nr New Athens	38 15 17	89 51 41	37.6	5	75,79,80	SM
46	05595280	Plum Creek nr Baldwin	38 08 48	89 50 35	60.9	21	79-80	SM
47	05595295	Little Plum Creek nr Walsh	38 07 13	89 50 50	17	8	75,79,80	SM
48	05595400	Kaskaskia River at Roots	38 00 58	89 57 14	5,790	38	78-80	MS

MS - Main Stem Kaskaskia River
OG - Downstream of oil and gas production
US - Upstream (unaffected by) mining
SM - Downstream of surface mining

Water-Quality Data Variability can be Attributed to Several Factors

Land use, physiographic region, and climate are among the major factors affecting water quality.

Surface and underground coal mining, oil and gas production, and urban and agricultural activities are the primary land uses affecting water quality in the Kaskaskia River basin.

Surface mining can change water quality, primarily by causing lower pH values and higher specific conductance values, and by raising levels of iron, manganese, and sulfate. The type and extent of change is dependent on mining and reclamation practices, the type of overburden, and other land uses in the coal-mining region.

The production of oil and gas can affect water quality. The Salem Consolidated oil field, the third most productive in Illinois, is located in the lower Kaskaskia River basin (Samson, 1981). During the production of oil, large volumes of ground-water brines may be brought to the surface (Illinois Environmental Protection Agency, 1978b, 1979) thereby increasing chloride, specific conductance, and total dissolved solids values of natural waters. Physiography exerts a strong influence on the chemical characteristics of streams in two ways. First, it controls the amount of time water is in contact with soil and rock, thereby controlling the amount of minerals extracted from the soil and rock material; and second, it indirectly determines the type of land use that is dominant, which influences point and non-point source pollution (Wallace, 1980, p. 20).

Climate tends to affect concentrations of most constituents, primarily due to variations in streamflow. Some constituents exhibit a direct, and some an inverse, concentration to flow relation. Changes in runoff characteristics may also accompany seasonal changes in vegetation.

In this report, the data from the water-quality sites were divided into four sets (fig. 8.2.2-1): Downstream from surface mining, downstream from oil and gas production, upstream from mining activities, and Kaskaskia River main stem.

The first three sets are based on land use. The sites were classified using topographic maps, soil survey aerial photos, land use maps, and field reconnaissance of the area. Main Stem sites are all sites located on the main stem of the Kaskaskia River. Upstream from mining sites consist of those sites which have no surface mining or oil and gas production in their watersheds, and, if underground mining is present, it is so far upstream that it is presumed to have no affect. Downstream from surface mining sites are sites which have either past or present surface-mining operations within their watershed. Downstream from oil and gas production sites have wells located within their watershed. In some instances both oil and gas production and surface mining were found in the same watershed. In these cases a judgment was made according to size of mine or oil field, proximity to stream, and other physical factors, as to which land use contributed most to water quality.

Some of the effects of land use and physiography on water type are demonstrated by the Stiff patterns (Stiff, 1951) shown in figure 8.2.2-2. Concentrations are given in milliequivalents per liter (meq) which means that the concentrations of all ions are chemically equivalent. Sites downstream from surface mining are shown to have a sodium sulfate water type, whereas the other water-quality sites have a calcium bicarbonate water type. These Stiff patterns represent the average constituent concentrations at all sites for which sufficient data were available.

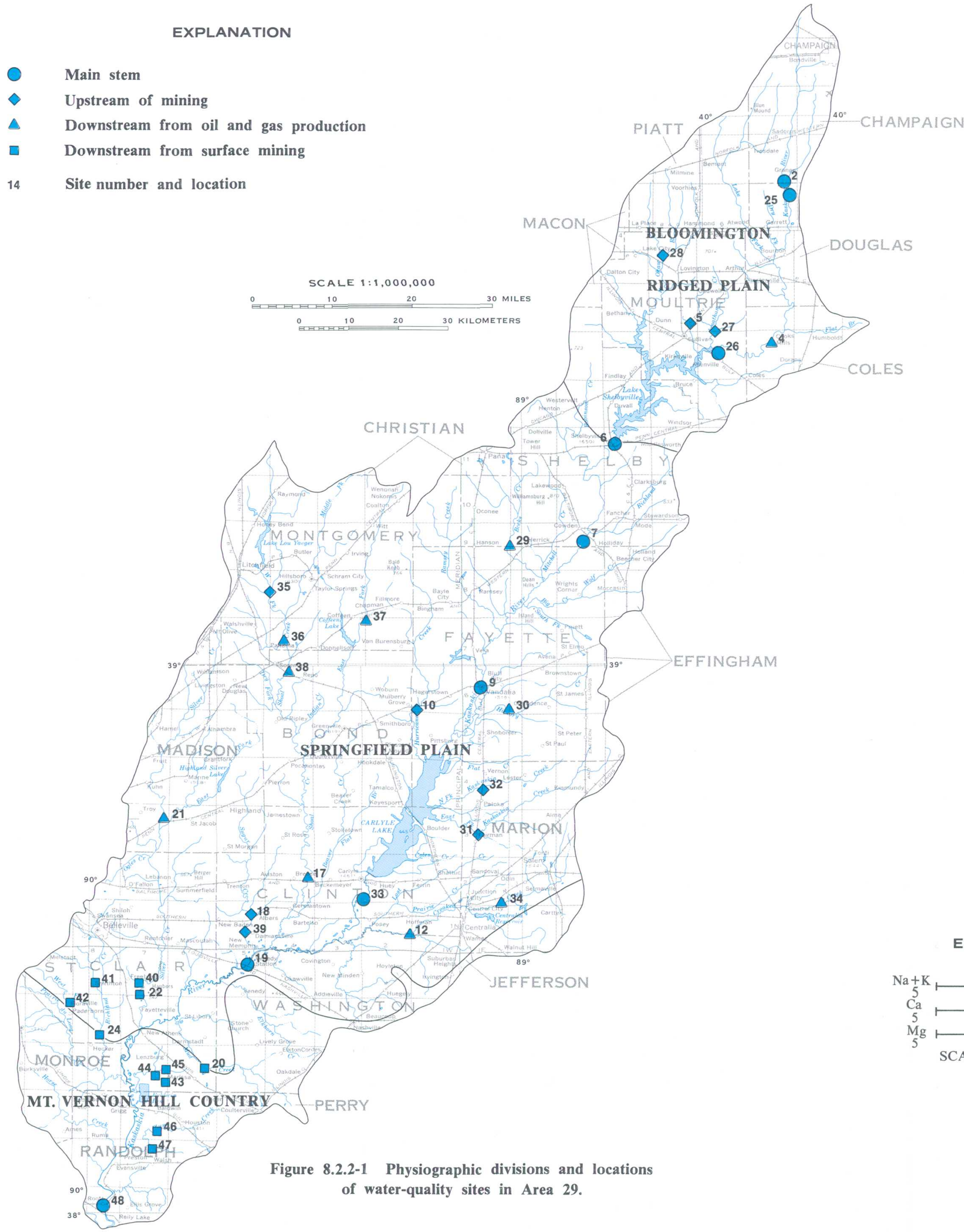


Figure 8.2.2-1 Physiographic divisions and locations of water-quality sites in Area 29.

BASE FROM U.S. GEOLOGICAL SURVEY
STATE BASE MAP, 1:500,000, 1972

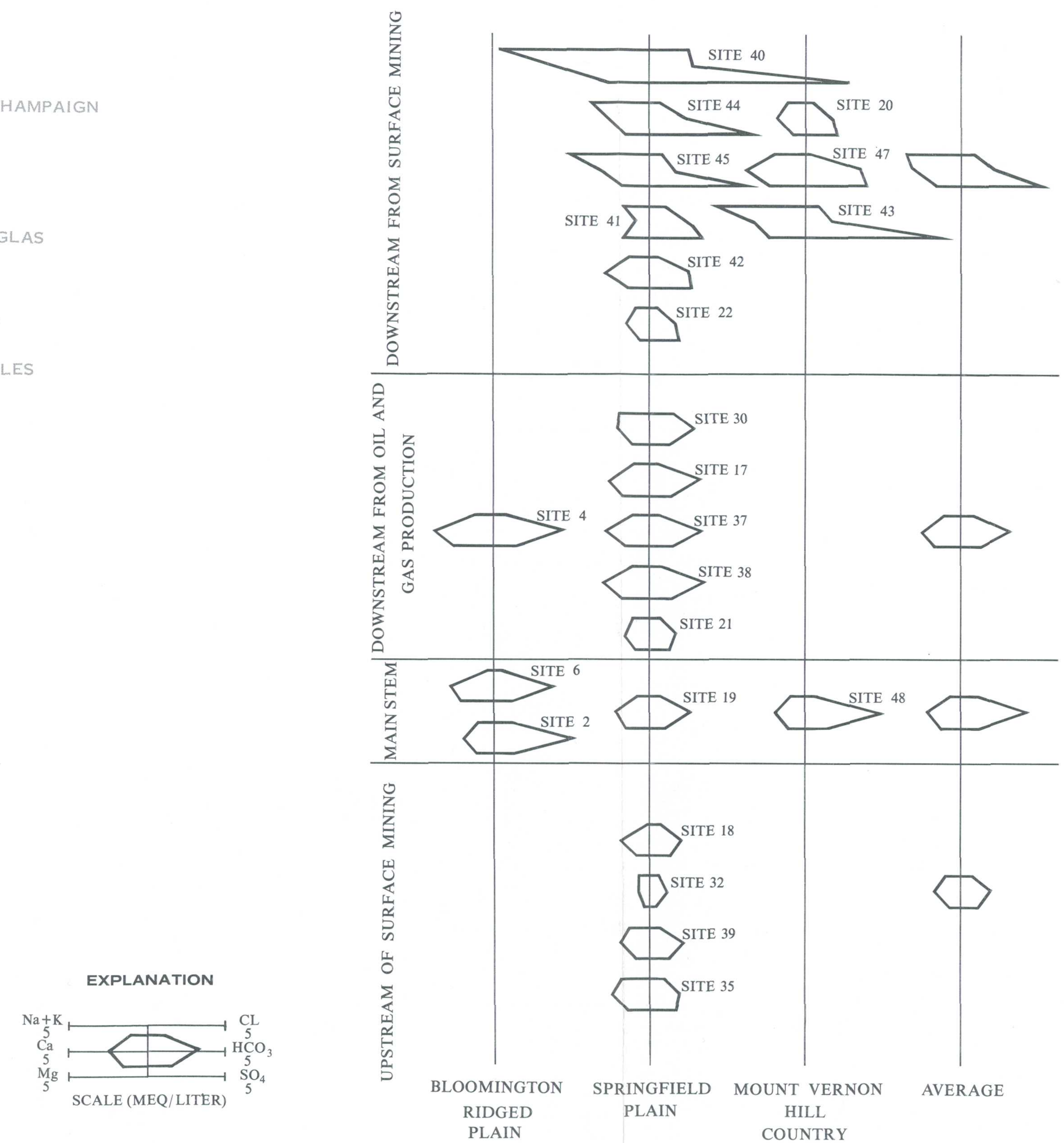


Figure 8.2.2-2 Stiff patterns for sites with sufficient data.

Specific Conductance and Dissolved Solids are High in Streams Draining Surface Coal-Mining Areas

Regression coefficients for dissolved solids versus specific conductance indicate a difference in the chemical character of the water at sites downstream from surface mining compared to other sites in the area.

Specific conductance is defined as "the reciprocal of the resistance, in ohms, measured between opposite faces of a centimeter cube of an aqueous solution at a specific temperature" (Hem, 1970). In this report, specific conductance is reported as micromhos per centimeter at 25°C (μmhos/cm at 25°C).

Specific conductance can be a useful tool for estimating dissolved solids concentrations. In Illinois streams and rivers, the relation between specific conductance and dissolved solids is nearly linear. Equations relating specific conductance and dissolved solids are commonly of the form $KA=S$ (Hem, 1970), where K is conductance in μmhos/cm at 25°C, S is dissolved solids in milligrams per liter (mg/L), and A is a regression coefficient (slope). Hem (1970) states that A is usually between 0.55 and 0.75. The higher values in this range are associated with waters with high sulfate concentrations.

The relation between specific conductance and dissolved solids was computed for all sites in Area 29. The regression coefficient varied considerably according to land use (fig. 8.2.3-1). Surface-mining affected sites had an equation with a coefficient (A) of 0.70 and a standard error of 102 mg/L for 48 observations. The sites affected by oil and gas production had a coefficient (A) of 0.59 and a standard error of 53 mg/L for 49 observations. The upstream and main stem sites had coefficients (A) of 0.58 and 0.60, and standard errors of 40 and 19 mg/L for 6 and 75 observations, respectively. The high value of A for surface-mined-area sites reflects high sulfate concentrations. High values downstream from mining are due to accelerated weathering of exposed pyritic material in coal spoil banks, which results in production of sulfuric acid and soluble mineral salts. The acidic water reacts with other minerals and produces water with a high dissolved solids concentration. This highly mineralized water near mined areas becomes diluted as it moves downstream.

Specific conductance of water draining oil- and gas-drilled areas may be high due to release of brines during the drilling practice and discharge from aquifers associated with this oil-bearing region.

Measured values of specific conductance ranged from 50 to 9,600 μmhos/cm at 25°C, with a mean value of 625 μmhos/cm at 25°C (fig. 8.2.3-2, 8.2.3-3, and table 8.2.3-1).

Specific conductance values of streams in the area vary seasonally (fig. 8.2.3-4). The peak in spring for sites downstream from surface mines indicates flushing of mined-area spoils and scour of bottom materials releasing high mineral-content water. The peak in August for sites below the oil and gas wells indicates that ground-water brines may be contributing a large portion of total flow at this time, either from the drilling process or by direct seepage from ground-water aquifers to the surface water. The generally steady specific conductance values at sites on the main stem indicate the effects of dilution.

Reconnaissance specific-conductance data from the entire area ranged from 203 to 4,630 μmhos/cm at 25°C with a mean of 725 μmhos/cm at 25°C (fig. 8.2.3-2). All specific-conductance values over 1,200 μmhos/cm at 25°C were in close proximity to oil wells, hence, ground-water brines.

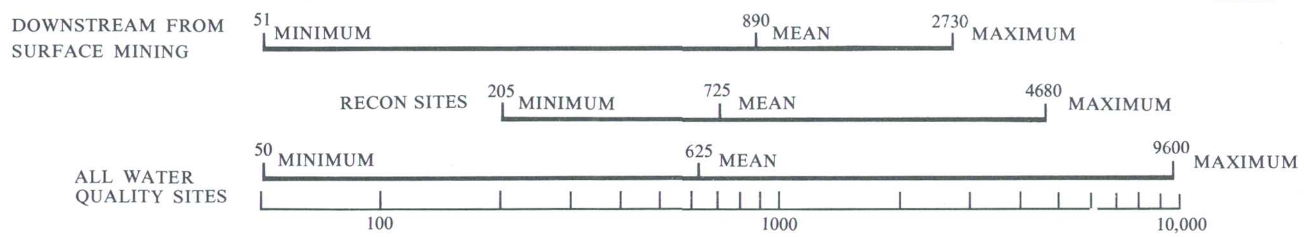


Figure 8.2.3-2 Range and mean values of specific conductance, in micromhos per centimeter at 25°C.

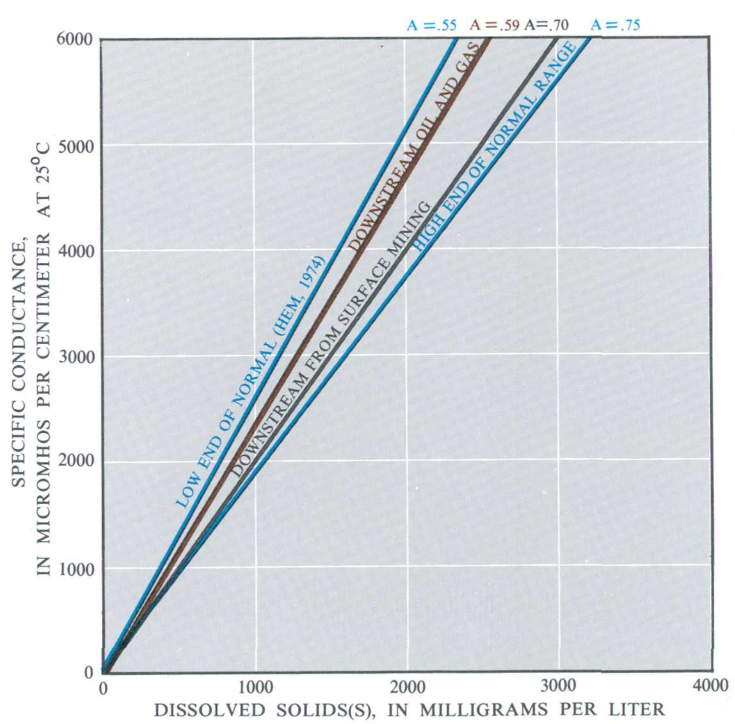


Figure 8.2.3-1 Relation between specific conductance and dissolved solids in Area 29.

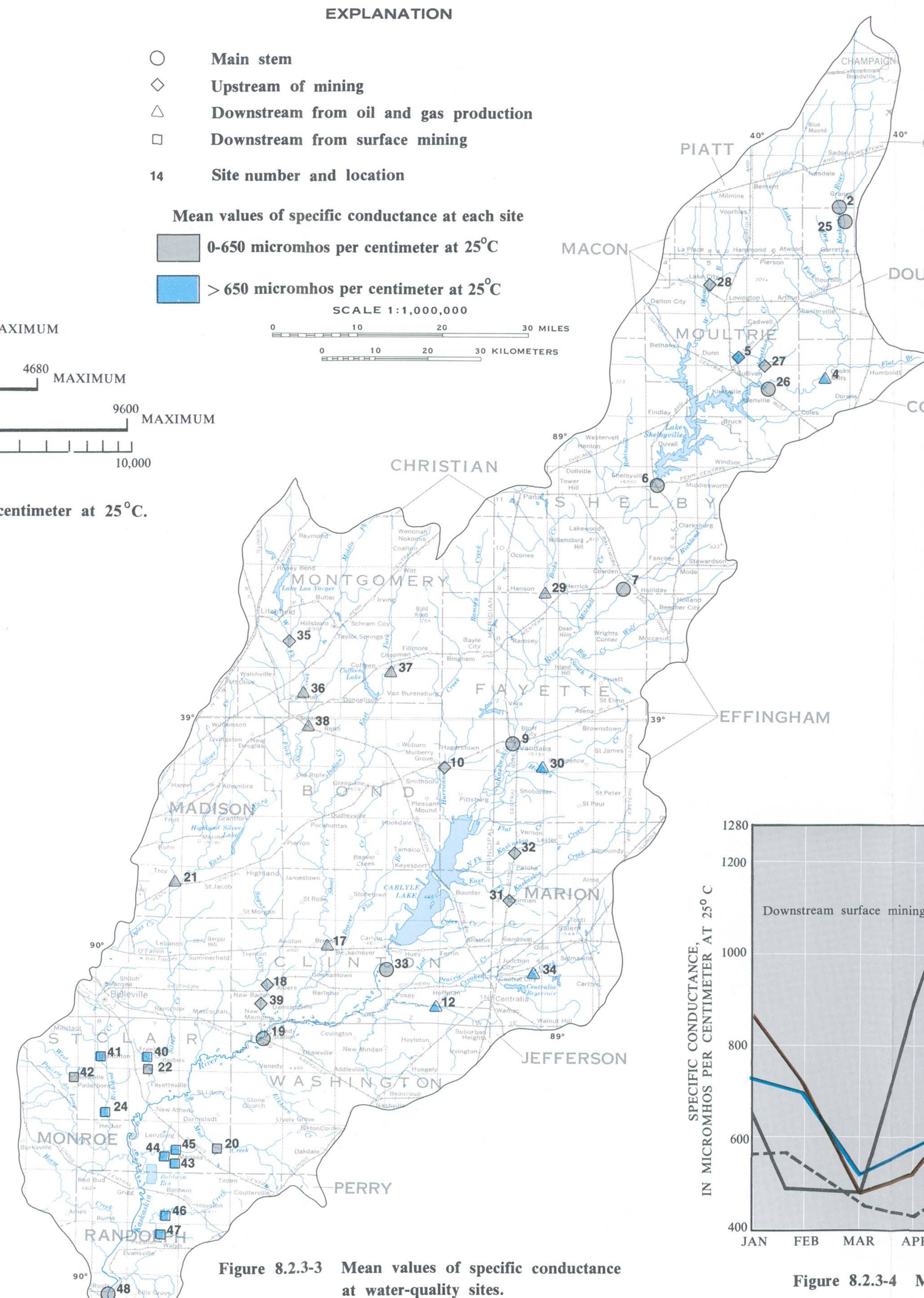


Figure 8.2.3-3 Mean values of specific conductance at water-quality sites.

BASE FROM U.S. GEOLOGICAL SURVEY STATE BASE MAP, 1:500,000, 1972

Table 8.2.3-1 Specific conductance values, in micromhos per centimeter at 25°C., measured at water-quality sites.

Site Number	Number of Observations	Minimum	Mean	Maximum
Downstream from surface mining				
20	5	270	430	530
22	21	63	517	930
24	21	51	676	1,330
40	5	720	1,864	2,730
41	7	575	905	1,160
42	6	342	630	800
43	18	415	1,066	2,130
44	17	195	889	2,440
45	5	395	1,085	1,550
46	21	418	1,211	2,580
47	7	515	919	1,360
Downstream from oil and gas production				
4	44	400	732	1,240
12	22	223	1,129	9,600
17	5	453	526	585
21	12	71	513	740
29	24	160	639	1,490
30	21	550	684	1,173
34	28	219	716	1,391
36	7	440	564	650
37	39	250	560	930
38	4	365	478	560
Main Stem				
2	18	480	634	745
6	37	295	461	710
7	38	315	480	700
9	29	134	546	821
19	76	139	449	750
25	18	570	648	730
26	11	290	633	930
33	34	50	425	640
48	438	188	424	879
Upstream of mining				
5	36	260	674	890
10	28	126	606	940
18	20	65	548	960
27	11	470	597	750
28	11	445	641	940
31	27	159	465	1,020
32	25	136	543	3,173
35	5	245	587	820
39	5	250	515	990

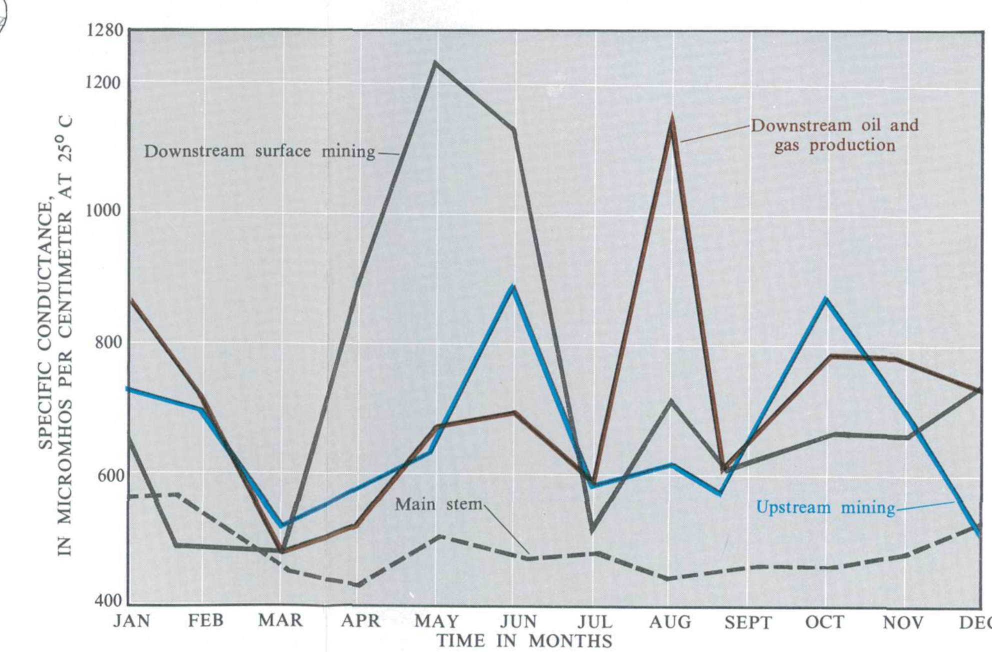


Figure 8.2.3-4 Monthly variations of specific conductance values.

Values for pH are Usually in Near-Neutral Range

The pH of stream water in Area 29 was found to fluctuate in the near-neutral range and generally was not significantly lowered by coal-mining operations.

"pH" is defined as the negative base-10 logarithm of the hydrogen-ion activity in moles per liter. A pH value of 7.0 represents neutral water. Values less than 7.0 denote acidic waters, and values greater than 7.0 denote alkaline water. Figure 8.2.4-1 shows maximum and minimum values of pH measured at water-quality sites in Area 29.

As a result of the mining process, weathering of the iron sulfides, pyrite and marcasite, is accelerated and subsequent reactions create acidic solutions with low pH values. The overall equations for pyrite oxidation are:

$$FeS_2\,(S) + 7/2\,O_2 + H_2O = Fe^{+2} + 2SO_4^{-2} + 2H^+$$

$$Fe^{+2} + \tfrac{1}{4}O_2 + H^+ = Fe^{+3} + \tfrac{1}{2}H_2O$$

$$Fe^{+3} + 3H_2O = Fe(OH)_3\,(S) + 3H^+$$

$$FeS_2\,(S) + 14\,Fe^{+3} + 8H_2O = 15Fe^{+2} + 2SO_4^{-2} + 16H^+$$

This chemical breakdown of pyrite usually increases concentrations of iron, sulfate, and hydrogen ions in water (Biesecker and George, 1966, p. 3). Reactions of this acidic mine drainage with carbonate minerals reduces the acidity, increases dissolved solids, and adds calcium and magnesium ions to the water. The influence of carbonate-bearing rocks is demonstrated by the neutral pH's of most sites in the area.

The pH's measured at water-quality sites in the area ranged from 6.2 to 9.1 (fig. 8.2.4-2). This range is somewhat larger than that of pH 6.5 to 8.5 given by Hem (1970) for "river water in areas not influenced by pollution," however, the large majority of values do fall in this range (table 8.2.4-1).

The reconnaisance data pH values ranged from 6.5 to 8.5, with most of the highest values found in the Kaskaskia River main stem or just downstream from ponds or lakes. pH values between 6.5 and 9.0 are considered adequate for freshwater aquatic life (U.S. Environmental Protection Agency, 1976).

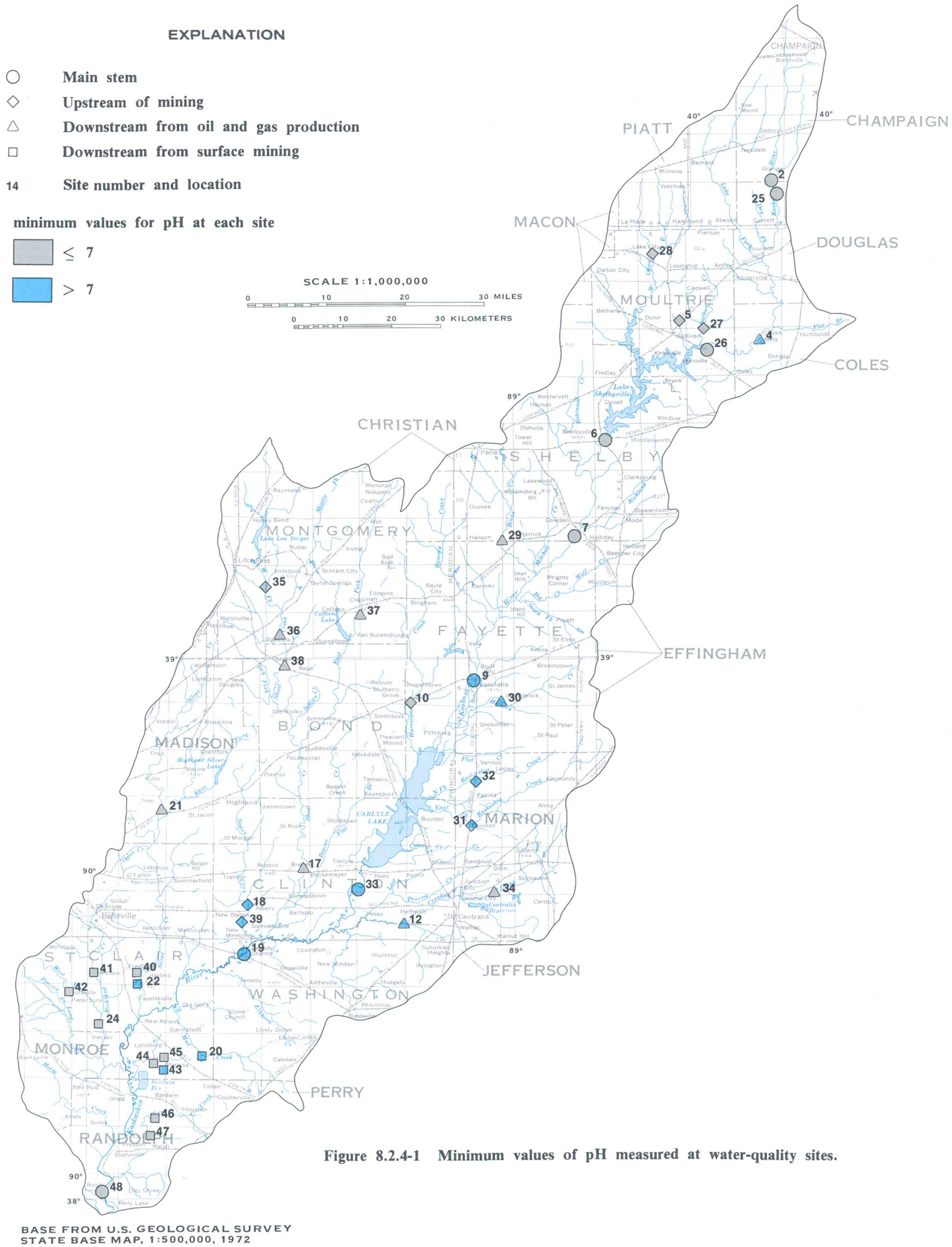


Figure 8.2.4-1 Minimum values of pH measured at water-quality sites.

Table 8.2.4-1 pH values measured at water-quality sites.

Site Number	Number of Observations	Minimum	Mean	Maximum
	Downstream from surface mining			
20	5	6.6	7.26	7.9
22	34	6.7	7.36	8.3
24	35	7.0	7.42	8.6
40	5	7.2	7.70	8.1
41	7	7.4	7.80	8.4
42	6	7.6	7.95	8.6
43	18	6.9	7.97	9.1
44	17	7.0	7.71	8.6
45	5	7.6	7.98	9.0
47	7	7.3	7.84	8.3
	Downstream from oil and gas production			
4	43	6.5	7.63	8.5
12	21	6.7	7.13	7.3
17	26	7.0	7.21	7.6
21	36	7.0	7.39	8.6
29	22	7.5	7.86	8.2
30	28	6.5	7.29	7.9
34	32	7.1	7.47	8.9
36	40	7.4	7.96	8.7
37	4	7.3	7.48	7.8
38	5	7.5	7.56	7.7
	Main Stem			
2	18	7.7	8.14	8.5
6	39	7.6	8.19	8.9
7	38	7.5	8.12	8.7
9	29	6.9	7.75	8.3
19	76	6.2	7.60	8.3
25	14	7.4	8.15	8.8
26	10	7.3	8.02	8.4
33	38	6.7	7.62	8.6
48	37	7.0	7.78	8.3
	Upstream of mining			
5	36	7.4	8.01	8.5
10	28	7.1	7.58	8.2
18	33	6.6	7.06	8.0
27	10	7.6	7.96	8.4
28	10	7.5	8.09	8.3
31	28	6.3	7.16	7.9
32	24	6.2	7.07	7.7
35	5	7.3	7.70	7.9
39	5	6.5	7.14	7.5
46	21	7.0	7.81	8.1

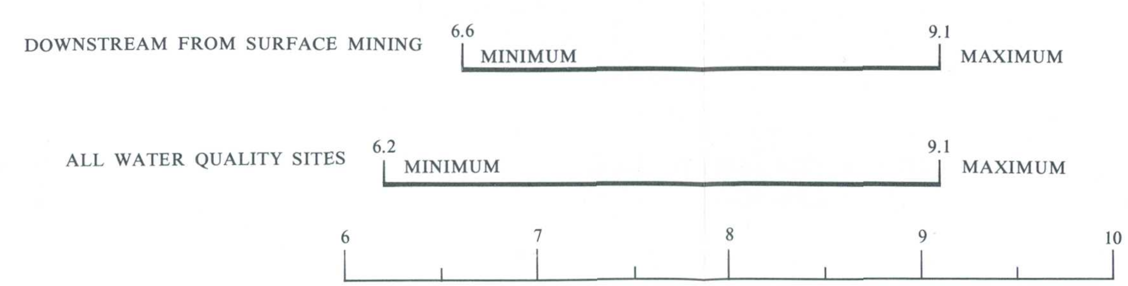


Figure 8.2.4-2 Range of values of pH.

Concentrations of Iron Vary Widely

High concentrations of total and dissolved iron are found downstream from surface mining.

Iron is an important constituent of the surface and ground water in this area because of its abundance in the sedimentary rocks of the Pennsylvanian system. Iron is generally present as ferrous iron (Fe^{+2}) in the dissolved phase and as ferric iron (Fe^{+3}) in the suspended phase. In the presence of dissolved oxygen, dissolved iron is precipitated as a yellow or red hydroxide or oxide (U.S. Environmental Protection Agency, 1976, p. 153). Surface-mining processes increase the amount of iron available by exposing more surface area of iron-bearing minerals (pyrite and marcasite) to weathering conditions.

During storm events, especially during summer when flow is low, the streams can be subjected to large amounts of iron in runoff from previously exposed pyritic materials. Concentrations of total-recoverable (dissolved plus suspended) iron can also be increased during storms when iron-hydroxide precipitates sorbed to bottom sediments are scoured by runoff water and put back into suspension (Geidel, 1979). The processes of scouring and flushing are demonstrated in figure 8.2.5-1. Seasonal peaks are in spring, when mined-area runoff adds iron and high flows cause bottom scour, and in late summer during perennial low flows when runoff events can add significant amounts of iron. The total-recoverable iron concentrations at sites downstream from surface mining are higher than those in the main stem of the Kaskaskia River, though both exhibit similar seasonal fluctuations.

The measured range of concentrations for dissolved iron was from 0 to 2,300 micrograms per liter ($\mu g/L$) (table 8.2.5-1) with a mean concentration of 137 $\mu g/L$. Mean dissolved iron concentrations, at each site, are displayed in figure 8.2.5-2.

Total-recoverable iron concentrations ranged from 0 to 54,000 $\mu g/L$ with a mean concentration of 2,500 $\mu g/L$. Mean total-recoverable iron concentrations, at each site, are shown in figure 8.2.5-3.

Iron is an essential trace element required by plants and animals. It is a vital oxygen transport mechanism in the blood of all vertebrate animals, and its absence in plants can be a limiting growth factor. Dissolved iron concentrations exceeding 300 $\mu g/L$ impart an objectionable taste to water, cause staining, and generally limit the waters use for many domestic and industrial purposes.

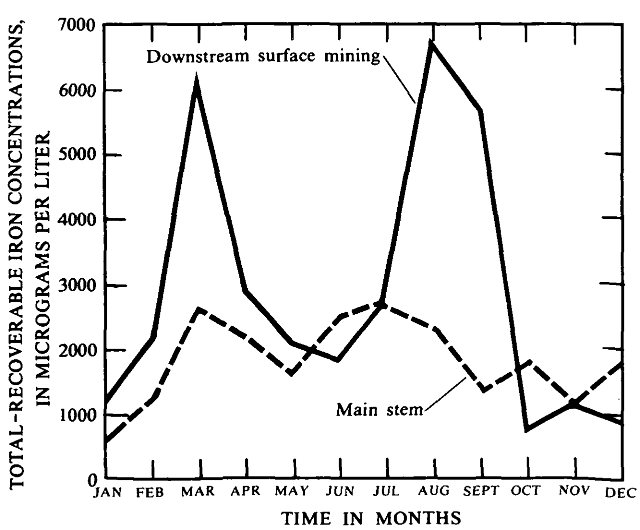


Figure 8.2.5-1 Monthly variations in total-recoverable iron concentrations.

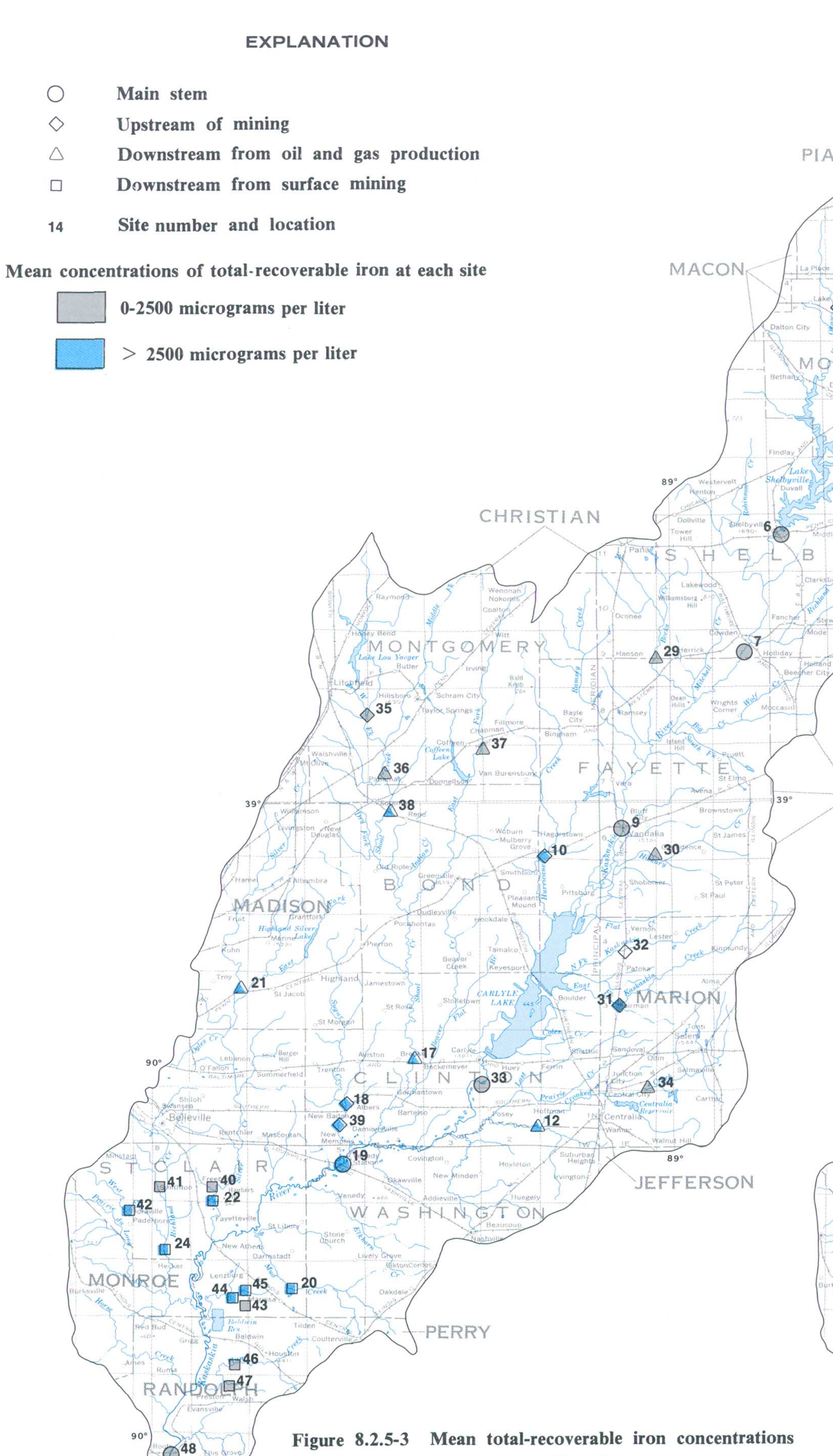


Figure 8.2.5-3 Mean total-recoverable iron concentrations at water-quality sites.

BASE FROM U.S. GEOLOGICAL SURVEY STATE BASE MAP, 1:500,000, 1972

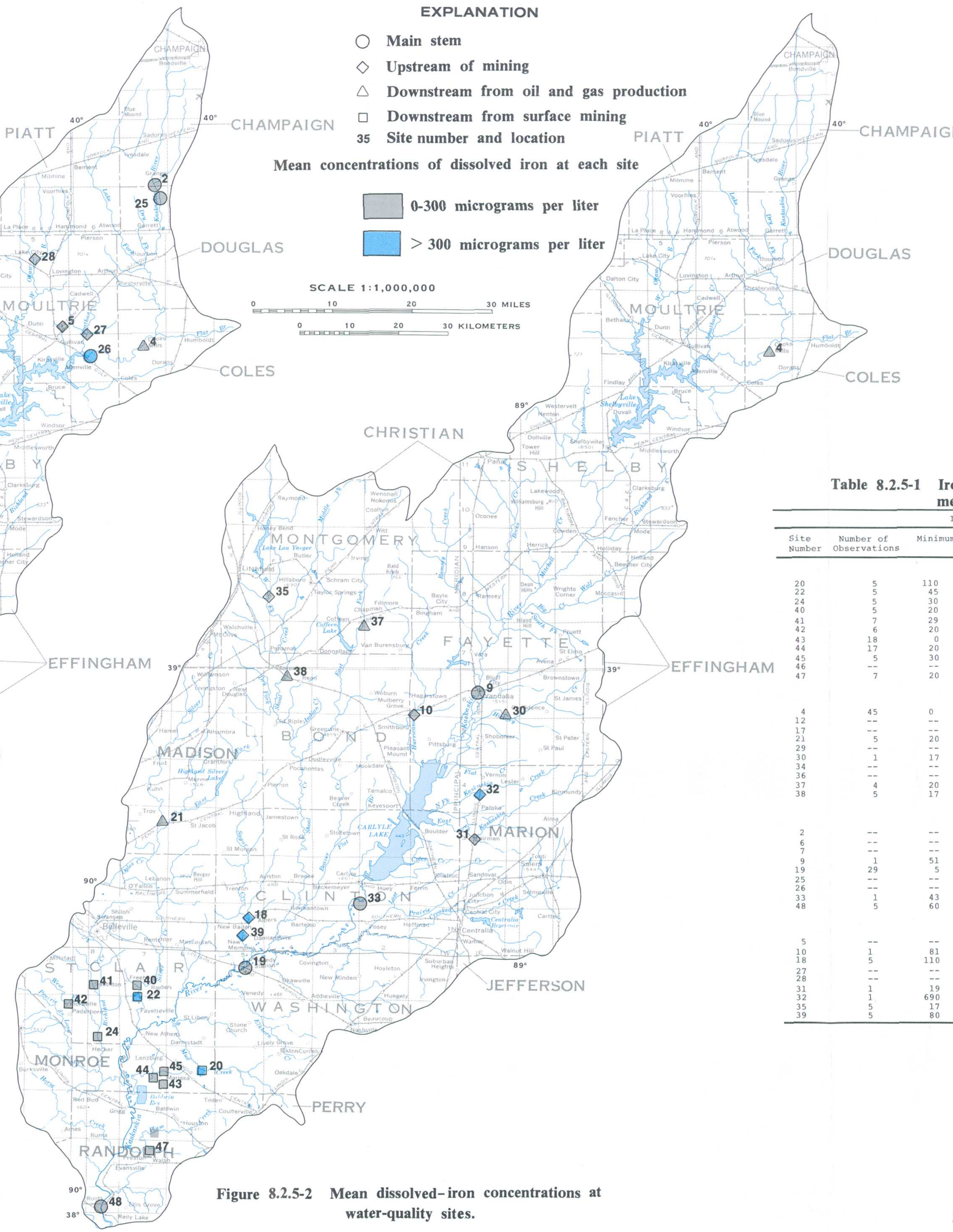


Figure 8.2.5-2 Mean dissolved-iron concentrations at water-quality sites.

Table 8.2.5-1 Iron concentrations, in micrograms per liter, measured at water-quality sites.

	Iron Dissolved				Iron Total			
Site Number	Number of Observations	Minimum	Mean	Maximum	Number of Observations	Minimum	Mean	Maximum
				Downstream from surface mining				
20	5	110	308	1,000	5	490	7,518	28,000
22	5	45	439	1,000	34	680	2,709	7,200
24	5	30	190	730	35	300	3,749	52,000
40	5	20	39	70	3	200	803	1,900
41	7	29	41	80	5	240	896	1,400
42	6	20	56	101	4	330	565	780
43	18	0	35	180	18	200	2,611	11,000
44	17	20	103	270	17	230	4,596	18,000
45	5	30	79	200	3	920	3,907	8,700
46	--	--	--	--	20	240	2,421	10,000
47	7	20	65	140	5	220	1,364	4,400
				Downstream from oil and gas production				
4	45	0	135	501	46	50	1,235	3,400
12	--	--	--	--	21	470	2,942	15,000
17	--	--	--	--	25	500	3,253	17,000
21	5	20	136	340	37	270	3,292	19,000
29	--	--	--	--	15	690	1,073	2,400
30	1	17	17	17	17	760	2,252	13,800
34	--	--	--	--	21	480	1,292	4,200
36	--	--	--	--	37	340	2,468	37,000
37	4	20	141	440	4	450	1,413	2,500
38	5	17	50	80	5	710	6.138	25,000
				Main Stem				
2	--	--	--	--	2	500	1,067	1,500
6	--	--	--	--	15	0	236	500
7	--	--	--	--	15	300	1,261	4,100
9	1	51	51	51	15	540	2,285	11,600
19	29	5	153	2,300	49	510	3,328	15,000
25	--	--	--	--	7	110	706	1,800
26	--	--	--	--	5	480	3,056	11,300
33	1	43	43	43	11	430	982	1,900
48	5	60	132	220	38	100	1,636	8,900
				Upstream of mining				
5	--	--	--	--	12	200	961	1,600
10	1	81	81	81	15	610	3,013	16,400
18	5	110	468	1,300	34	620	3,857	54,000
27	--	--	--	--	5	540	1,228	2,300
28	--	--	--	--	6	360	2,320	7,800
31	1	19	19	19	17	360	2,940	21,200
32	1	690	690	690	16	370	1,979	9,700
35	5	17	67	140	5	680	1,222	2,500
39	5	80	332	700	5	1,700	3,720	7,000

Concentrations of Manganese Vary Widely

Highest mean concentrations of dissolved and total manganese are found downstream from surface mining.

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

Manganese normally occurs in small quantities in water, and generally is derived from soils rich in organic material and from geologic strata underlying the basins. Accelerated weathering of manganese minerals present in coal-mine spoils produces large quantities of soluble manganese salts that are contributed to streamflow draining mined areas.

Aeration and dilution by alkaline streams (pH 8.0) rapidly decreases the high concentrations. Dissolved manganese concentrations in acidic or near-neutral streams draining mined areas generally remain higher than those in streams draining unmined areas.

Aeration of alkaline mine drainage usually causes the precipitation of insoluble hydrous manganese oxides. Sorption of these precipitates on stream sediments results in high total-recoverable manganese (dissolved plus suspended). Hydrous manganese oxides adsorb cations so that high concentrations of manganese may reduce concentrations of boron, cadmium, copper, nickel, and zinc.

Dissolved manganese concentrations in Area 29 ranged from 0 to 3,400 μg/L with a mean concentration of 265 μg/L (table 8.2.6-1). Mean concentrations of dissolved manganese at sites in Area 29 for which data are available are portrayed in figure 8.2.6-1.

Total-recoverable manganese concentrations in Area 29 ranged from 10 to 6,400 μg/L with a mean concentration of 493 μg/L (table 8.2.6-1). Mean concentrations of total-recoverable manganese at sites in Area 29 are shown in figure 8.2.6-2.

Dissolved manganese concentrations were higher than total-recoverable manganese concentrations at some sites, due to sampling for the two constituents at different times. Average monthly concentrations of total-recoverable manganese for downstream of surface mining and main stem Kaskaskia River sites are shown in figure 8.2.6-3.

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

EXPLANATION

○ Main stem
◇ Upstream of mining
△ Downstream from oil and gas production
□ Downstream from surface mining
14 Site number and location

Mean concentration of dissolved manganese at each site

0-400 micrograms per liter

> 400 micrograms per liter

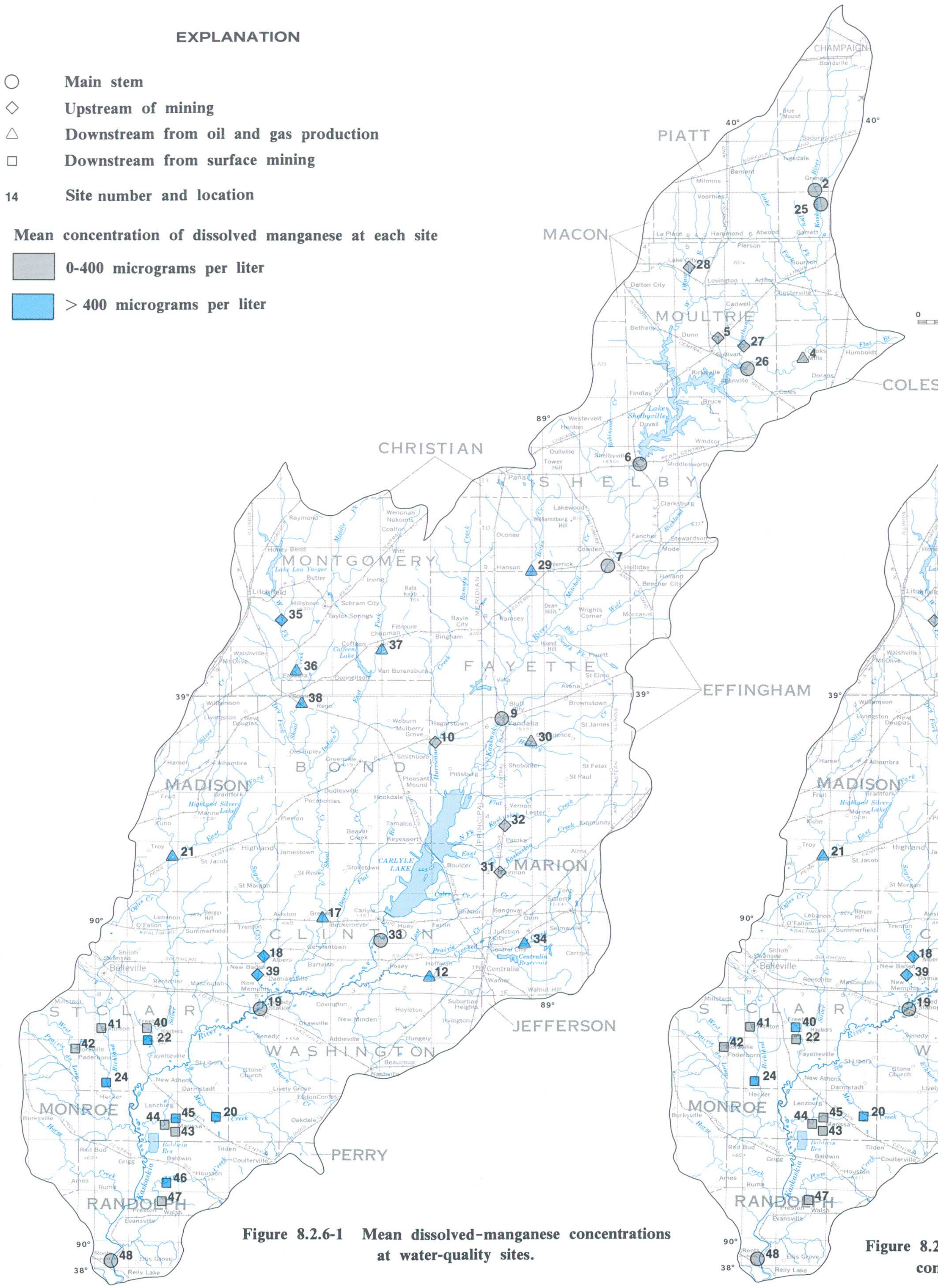


Figure 8.2.6-1 Mean dissolved-manganese concentrations at water-quality sites.

BASE FROM U.S. GEOLOGICAL SURVEY STATE BASE MAP, 1:500,000, 1972

EXPLANATION

○ Main stem
◇ Upstream of mining
△ Downstream from oil and gas production
□ Downstream from surface mining
35 Site number and location

Mean concentration of total-recoverable manganese at each site

0-400 micrograms per liter

> 400 micrograms per liter

SCALE 1:1,000,000

0 10 20 30 MILES

0 10 20 30 KILOMETERS

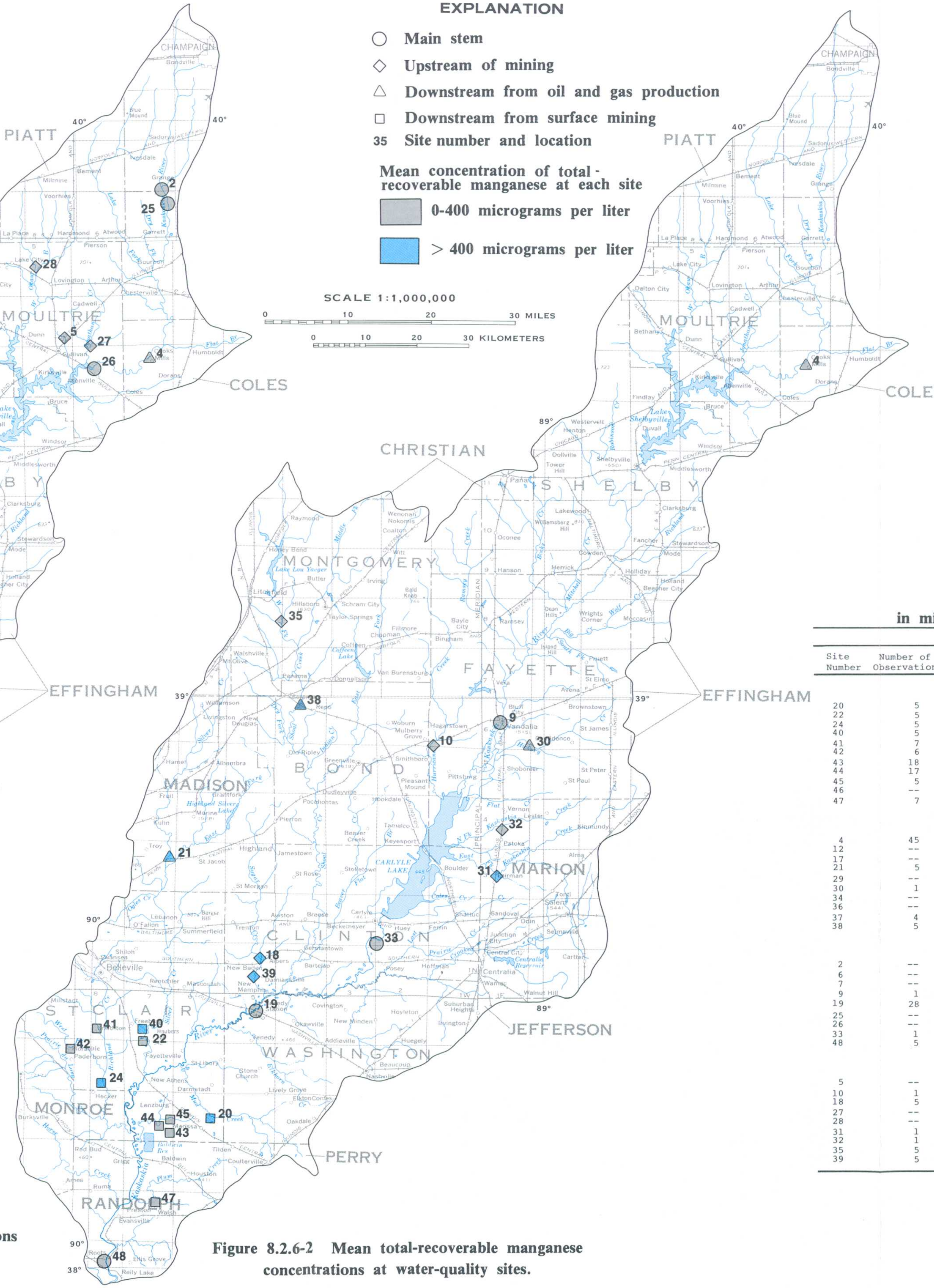


Figure 8.2.6-2 Mean total-recoverable manganese concentrations at water-quality sites.

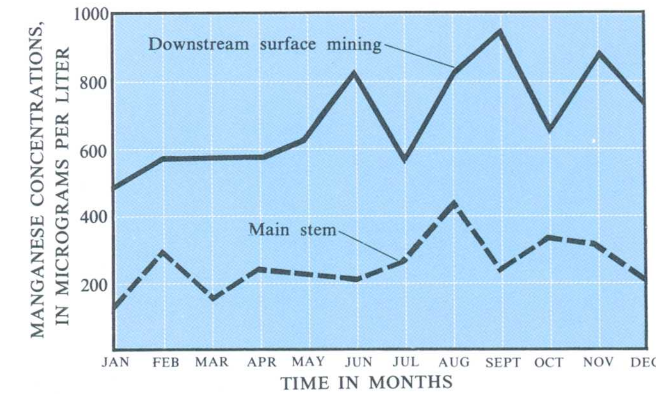


Figure 8.2.6-3 Monthly variations in total-recoverable manganese concentrations.

Table 8.2.6-1 Manganese concentrations, in micrograms per liter, measured at water-quality sites.

	Mn Dissolved				Mn Total			
Site Number	Number of Observations	Minimum	Mean	Maximum	Number of Observations	Minimum	Mean	Maximum
Downstream from surface mining								
20	5	70	1,158	3,400	5	280	1,732	3,800
22	5	90	356	840	34	200	636	1,400
24	5	180	468	700	35	370	1,023	2,700
40	5	60	862	2,800	3	60	237	460
41	7	80	261	420	5	180	346	470
42	6	30	170	570	4	90	243	650
43	18	10	207	510	10	200	325	550
44	17	10	55	400	7	30	103	400
45	5	40	288	790	3	330	530	790
46	--	--	--	--	20	210	1,048	6,400
47	7	70	181	290	5	150	320	570
Downstream from oil and gas production								
4	45	0	58	1,130	45	20	100	1,110
12	--	--	--	--	21	100	900	2,100
17	--	--	--	--	25	130	514	1,100
21	5	100	786	1,700	37	130	850	5.600
29	--	--	--	--	11	290	410	600
30	1	340	340	340	17	90	396	640
34	--	--	--	--	21	160	783	2,100
36	--	--	--	--	37	140	536	3,500
37	4	240	488	1,110	4	360	548	1,000
38	5	20	352	820	5	330	710	1.300
Main Stem								
2	--	--	--	--	3	50	93	160
6	--	--	--	--	12	10	253	1,160
7	--	--	--	--	12	60	149	270
9	1	10	10	10	15	170	295	570
19	28	6	240	1,100	50	10	320	960
25	--	--	--	--	7	20	70	230
26	--	--	--	--	5	50	134	350
33	1	19	19	19	11	100	155	200
48	5	30	117	280	38	70	275	790
Upstream of mining								
5	--	--	--	--	9	10	138	330
10	1	383	383	383	15	200	371	910
18	5	220	490	1,100	34	160	635	2,200
27	--	--	--	--	5	50	198	360
28	--	--	--	--	6	30	130	340
31	1	430	430	430	17	190	368	820
32	1	356	356	356	16	100	377	1,600
35	5	100	380	900	5	310	514	980
39	5	40	472	1,200	5	120	574	1,100

Sulfate Concentrations are Higher Downstream than Upstream of Mining

Sulfate concentrations ranged from 12 to 260 milligrams per liter upstream of surface mining, and from 19 to 3,500 milligrams per liter downstream from surface mining.

Sulfur occurs in coal and associated strata as metallic sulfides, mainly in the form of pyrite (FeS_2). When oxidized, the sulfides yield the sulfate ion and ferric oxide. Accelerated weathering of coal-mine spoils produces large quantities of soluble mineral salts to contribute to streamflow.

Concentration of sulfate (SO_4) depends on the amount available at some source and the subsequent dilution in streams. Dilution depends on the discharge of the stream. Sulfate concentration has a direct relationship to flow, with highest values occurring in the spring (fig. 8.2.7-1). This is due to the effects of flushout. There is also another sulfate peak in late autumn during low flow reflecting longer residence time of waters in spoil areas and the lack of dilution by rainfall.

Sulfate concentrations upstream from surface mining in Area 29 ranged from 12 to 260 mg/L with a mean of 80 mg/L. Sulfate concentrations downstream from surface mining ranged from 19 to 3,500 mg/L with a mean of 301 mg/L (fig. 8.2.7-2, fig. 8.2.7-3, and table 8.2.7-1).

Toler (1980) related annual sulfate loads to the area of surface mines as a percentage of total drainage area and showed that, in southern Illinois, sulfate can be used as an indicator of mine drainage (fig. 8.2.7-4).

Sulfur is a necessary element for the sustenance of all living things. However, amounts in excess of 250 mg/L can cause physiological effects, undesirable tastes, and can raise costs for water treatment (U.S. Environmental Protection Agency, 1976).

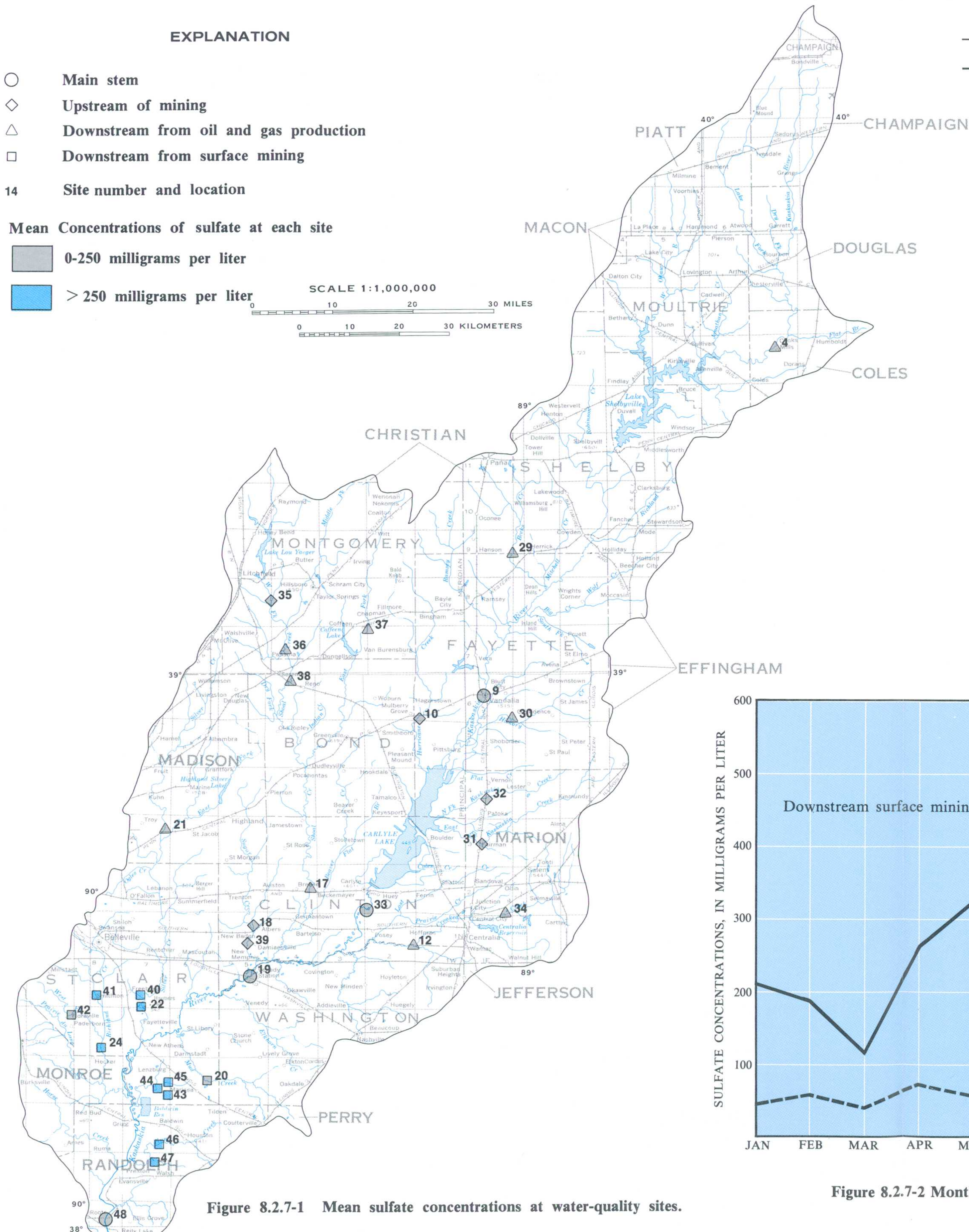


Figure 8.2.7-1 Mean sulfate concentrations at water-quality sites.

BASE FROM U.S. GEOLOGICAL SURVEY STATE BASE MAP, 1:500,000, 1972

Table 8.2.7-1 Sulfate concentrations, in milligrams per liter, measured at water-quality sites.

Site Number	Number of Observations	Minimum	Mean	Maximum
	Downstream from surface mining			
20	5	55	88	120
40	5	270	798	1,300
22	34	19	113	300
41	7	120	298	500
42	6	67	154	220
24	35	37	336	3,500
43	18	140	400	820
44	17	39	292	1,100
45	5	110	404	710
46	21	89	419	1,200
47	7	130	299	570
	Downstream from oil and gas production			
4	45	32	98	600
29	22	34	96	435
30	28	27	97	207
34	21	31	107	230
12	20	33	116	210
36	32	36	72	150
37	4	40	58	86
38	5	50	81	120
17	26	32	84	144
21	39	12	116	335

Site Number	Number of Observations	Minimum	Mean	Maximum
	Main Stem			
9	23	13	39	60
33	9	26	34	38
19	75	16	47	100
48	38	28	69	675
	Upstream of mining			
10	9	43	74	114
31	28	15	94	260
32	25	12	52	139
35	5	36	81	120
18	37	27	92	215
39	5	13	58	120

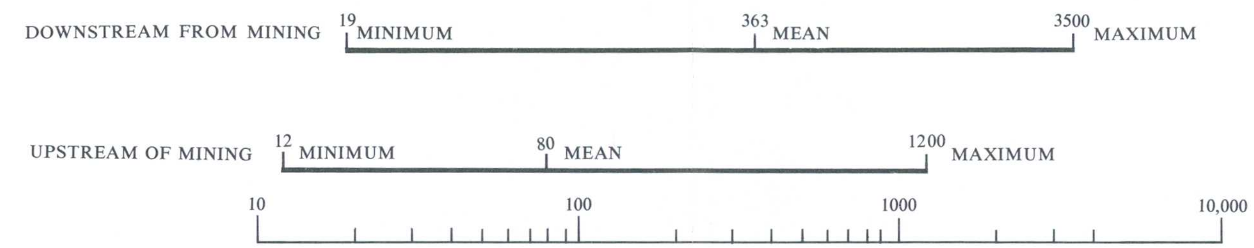


Figure 8.2.7-3 Range and mean values of sulfate, in milligrams per liter.

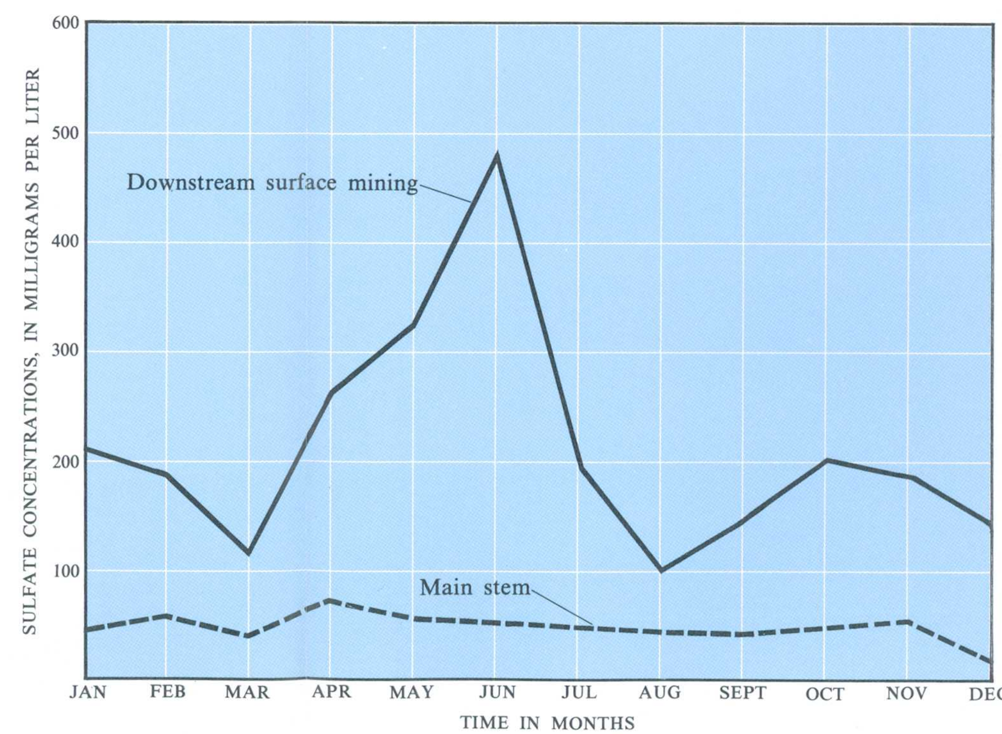


Figure 8.2.7-2 Monthly variations in sulfate concentrations.

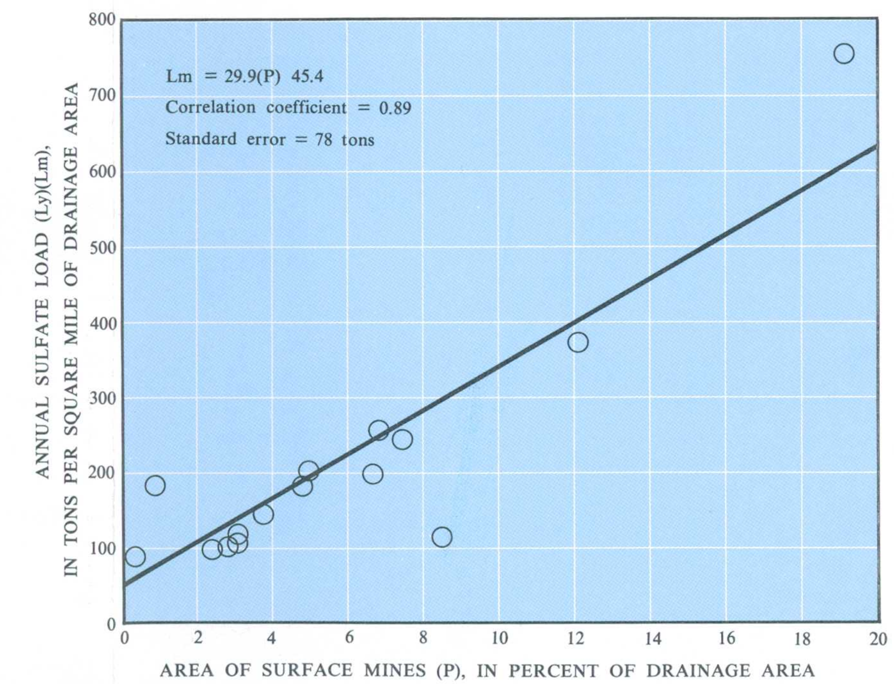


Figure 8.2.7-4 Relationship between annual sulfate load and percent of strip-mined land in southern Illinois (Toler, 1980).

Alkalinity Values are Lower Downstream from Mining

Alkalinity values averaged 125 milligrams per liter as calcium carbonate at sites downstream from mining and 146 milligrams per liter at all other sites.

Alkalinity is defined as the capacity of a solution to react with hydrogen ions and is commonly reported in milligrams per liter as calcium carbonate (mg/L as $CaCO_3$) even though $CaCO_3$ may not be the source of, or be responsible for, all the buffering capacity.

Surface waters derive their capability to react with hydrogen ions from the material with which they come in contact. Calcareous materials contribute to alkalinity through the following reaction:

$$CaCO_3 + H^+ = Ca^{++} + HCO_3^-$$

This reaction is limited by the solubility of $CaCO_3$ in water (Garrels and Christ, 1965). Water in contact with $CaCO_3$ is quickly saturated with respect to carbonate-bicarbonate equilibrium, and the amount of alkalinity available for neutralization becomes fixed early on.

The variability of alkalinity values at sites depends on land use upstream of the site. Alkalinity values downstream from surface mining were found to have a mean of 125 mg/L whereas, sites downstream from agriculture and forest land average 160 mg/L (table 8.2.8-1). Alkalinity values downstream from mining can vary considerably depending on the length of time that acidic materials weather before contact with water or the length of time alkaline materials and water are in contact. To protect the neutralizing capabilities of calcareous minerals, the alkaline-producing strata must be placed hydrologically antecedent to acid-producing material (Geidel, 1979).

Physiographic region affects alkalinity values in Area 29. In the Bloomington Ridged Plain, which has surficial deposits of Wisconsinan age, surface waters have a mean alkalinity value of 227 mg/L as $CaCO_3$. The sites in the Springfield Plain and the Mount Vernon Hill Country, which have surficial deposits of Illinoian age, have a mean alkalinity value of 133 mg/L as $CaCO_3$ The high alkalinity values in the Bloomington Ridged Plain area reflect the amount of contact time water has with the outwash terraces of calcareous sand and gravel typical of this region.

Alkalinity values are at their minimum in the spring months and reach their maximum during late fall (fig. 8.2.8-1). The frequency and duration of flushing events in the spring and fall are important to the amount of alkalinity produced. There appears to be a long term increase of alkalinity values in Area 29 (Crown and Flemal, 1978), probably due to human influences. Alkalinity values over the entire area ranged from 0 to 410 mg/L as $CaCO_3$ with a mean of 141 mg/L as $CaCO_3$ (fig 8.2.8-2). Ranges of mean alkalinity values at sampling sites are displayed in figure 8.2.8-3.

Acidity was only detectable at a few sites, due to the neutralizing capabilities of soils and rocks present in the area.

Alkalinity values of 20 mg/L or more are generally recommended for freshwater aquatic life (U.S. Environmental Protection Agency, 1976). Values less than this (poorly buffered) leave the water susceptible to rapid changes in pH. Alkalinity values greater than 50 mg/L as $CaCO_3$ can be excessively corrosive to pumping equipment.

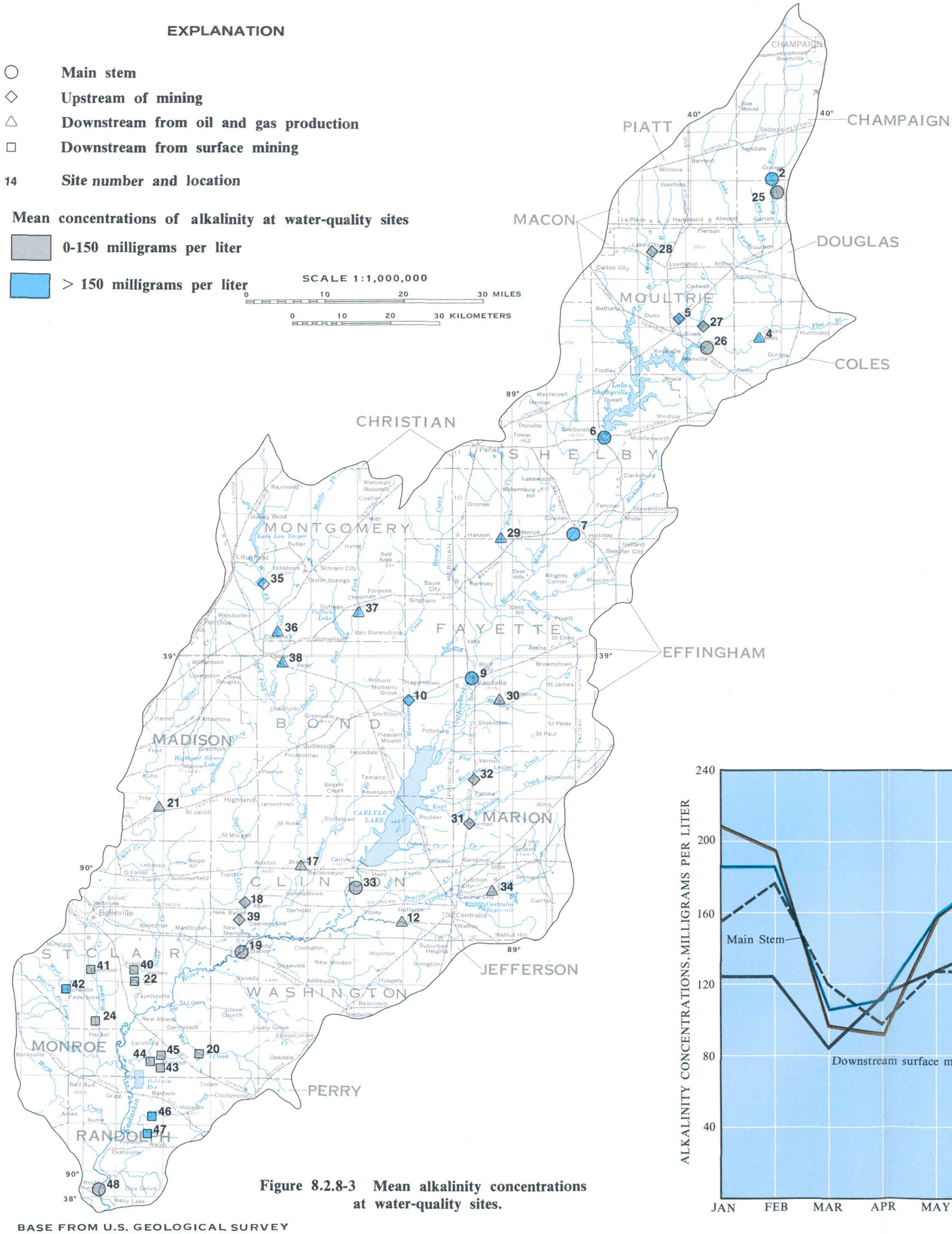


Figure 8.2.8-3 Mean alkalinity concentrations at water-quality sites.

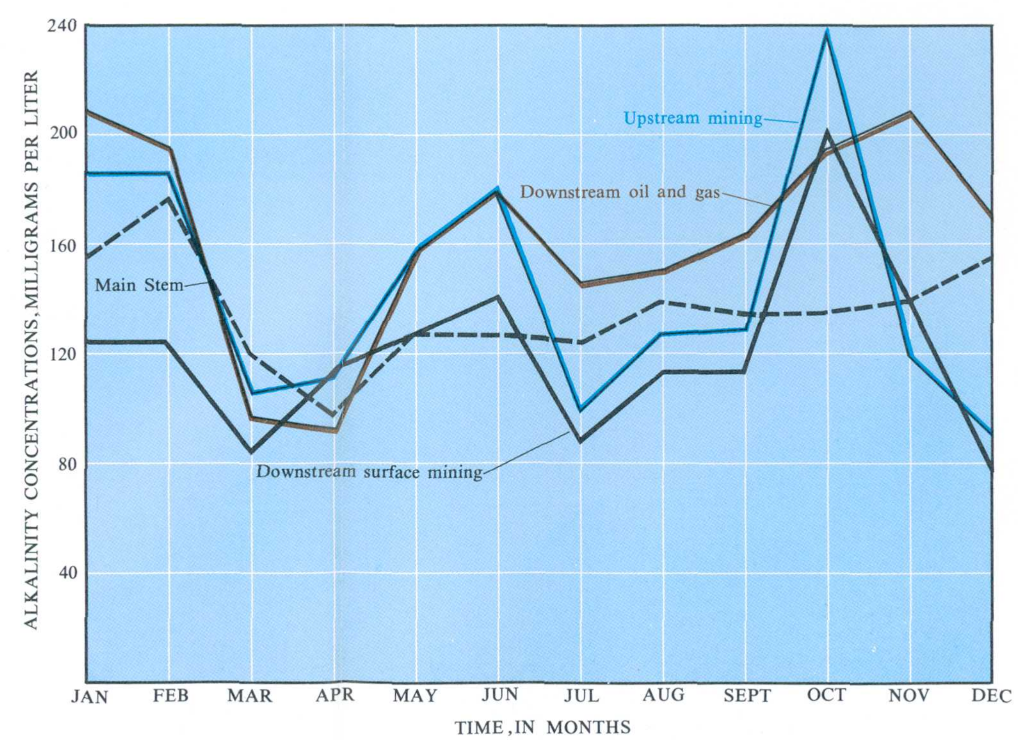


Figure 8.2.8-1 Monthly variations in alkalinity concentrations.

Table 8.2.8-1 Acidity and alkalinity concentrations, in milligrams per liter as $CaCO_3$, measured at water-quality sites.

Site Number	Number of Observations	Mean Alkalinity Value	Number of Observations	Mean Acidity Value
		Downstream from surface mining		
20	5	85	4	.5
22	34	124	17	.7
24	35	45	19	0
40	5	105	4	0
41	7	148	4	0
42	6	156	4	0
43	18	90	6	0
44	17	103	3	0
45	5	103	4	0
46	19	178	13	0
47	7	174	4	0
		Downstream from oil and gas production		
4	45	229	0	0
12	18	97	8	6
17	26	140	13	0
21	38	141	21	4
29	1	165	1	0
30	28	135	1	0
34	22	118	11	0
36	37	172	24	0
37	4	162	2	0
38	5	174	2	0
		Main Stem		
2	4	229	1	0
6	5	198	0	0
7	5	187	0	0
9	24	160	2	0
19	75	132	27	2
25	0	0	0	0
26	0	0	0	0
33	9	123	0	0
48	38	114	28	0
		Upstream of mining		
27	0	0	0	0
5	4	236	0	0
28	0	---	0	0
10	9	222	0	0
31	27	106	1	0
32	25	89	1	0
35	5	156	2	0
18	37	147	20	0
39	5	118	3	2

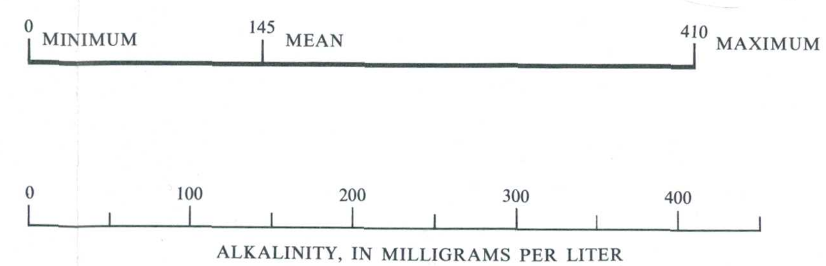


Figure 8.2.8-2 Range and mean alkalinity values.

Calcium and Magnesium Values are Higher Downstream than Upstream of Surface Mining

Hardness values averaged 280 milligrams per liter as calcium carbonate downstream from mining and 185 milligrams per liter as calcium carbonate upstream of mining activities.

Hardness is defined as a characteristic of water that represents the total concentration of just the calcium and magnesium ions expressed as $CaCO_3$. Hardness is computed by multiplying the sum of the milliequivalents per liter of calcium and magnesium by 50, and is generally entitled "hardness as $CaCO_3$."

Calcium and magnesium are separated from rock strata when acidic water contacts pyritic materials. Therefore, they can be good indicators of mine drainage. They can also be leached from gypsum and other evaporative minerals such as $CaSO_4$ and $MgSO_4$. Calcium precipitates from solution more readily than magnesium in the aqueous system.

Calcium concentrations in Area 29 range from <0.5 to 140 mg/L with a mean of 56 mg/L. Magnesium concentrations range from <0.5 to 66 mg/L with a mean of 23 mg/L (figs. 8.2.9-1 and 8.2.9-2 and table 8.2.9-1). This gives a mean hardness, as $CaCO_3$, concentration of 235 mg/L, which is described as hard by the U.S. Environmental Protection Agency (1976, p. 75).

Calcium has a maximum seasonal concentration in winter, possibly caused by runoff of road salts. Magnesium has a minimum in summer and a maximum in late fall. Hardness as $CaCO_3$ shows a long-term increase similar to alkalinity, calcium, and magnesium (Crown and Flemal, 1978).

Land use plays an important part in affecting hardness values. Downstream from oil and gas production, excess calcium is present due to the groundwater brines. Downstream from surface coal mining, calcium and magnesium values are higher, probably due to leaching of calcium and magnesium salts from exposed pyritic materials.

The standards by which hard water is judged have become more rigorous over the years. Many public water supplies are now softened to less than 100 mg/L of hardness. According to the American Water Works Association (Bean, 1962), "ideal" quality water should not contain more than 80 mg/L of hardness. Hardness causes scale in boilers and hot water heaters, and in recent years some authors (Muss, 1962) have reported apparent correlations between hardness and cardiovascular disease.

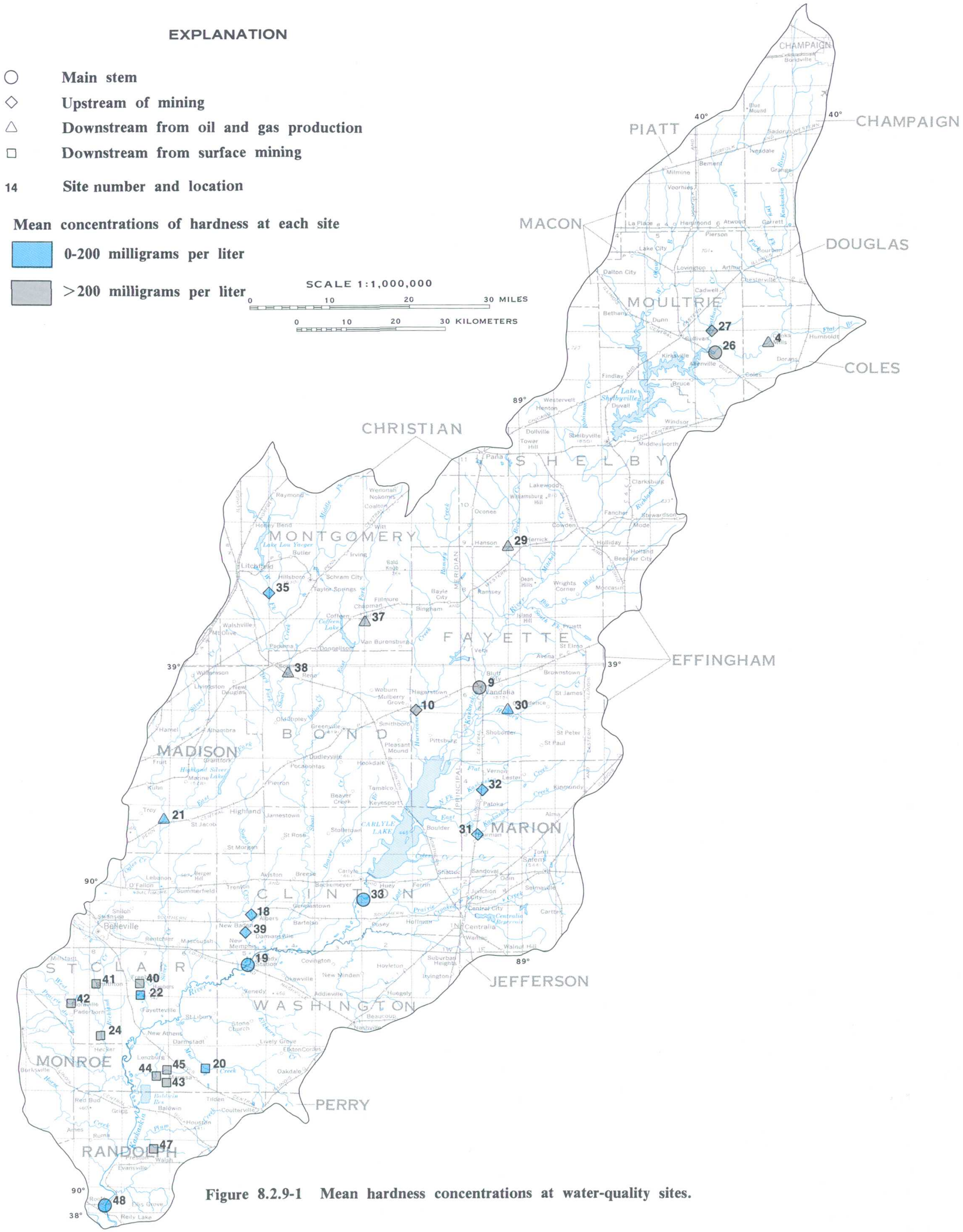


Figure 8.2.9-1 Mean hardness concentrations at water-quality sites.

BASE FROM U.S. GEOLOGICAL SURVEY
STATE BASE MAP, 1:500,000, 1972

Table 8.2.9-1 Calcium and magnesium concentrations, in milligrams per liter, measured at water-quality sites.

Site Number	Number of Observations	Mean Value of Dissolved Calcium	Number of Observations	Mean Value of Dissolved Magnesium
Downstream from surface mining				
20	2	35	2	12
22	2	31	2	9
24	2	92	2	30
40	1	120	1	37
41	2	80	2	21
42	2	64	2	19
43	17	69	17	27
44	17	61	17	24
45	1	68	1	24
47	2	79	2	28
Downstream from oil and gas production				
4	45	74	45	32
21	2	32	2	11
29	1	71	1	25
30	1	41	1	15
37	2	55	2	19
38	2	57	2	21
Main Stem				
9	1	49	1	21
19	73	42	73	19
26	1	84	1	40
33	1	42	1	18
48	2	39	2	14
Upstream of mining				
10	1	56	1	22
18	2	38	2	12
27	1	75	1	39
31	1	17	1	5
32	1	14	1	5
35	2	50	2	16
39	2	37	2	11

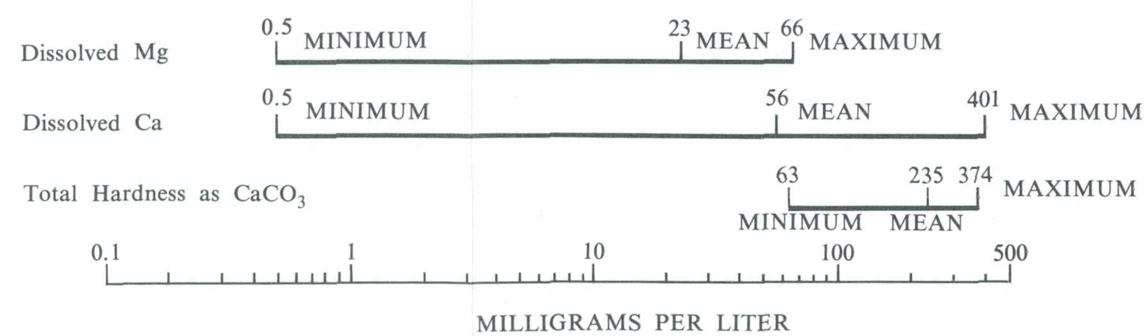


Figure 8.2.9-2 Range and mean values of hardness, in milligrams per liter.

Concentrations of Sodium, Potassium, and Minor Elements are Higher Downstream than Upstream of Mining

Except for total copper and total cadmium, additional element concentrations are higher downstream than upstream of surface mining.

Minor elements normally occur in small quantities in most streams. In low concentrations, minor elements are essential to life. In higher concentrations, some can be toxic to plants and animals. In coal-mine areas, accelerated weathering of pyritic materials can increase concentrations of sodium, potassium, and minor elements in streams. Concentrations of many additional elements differed between sites upstream and downstream from surface mining (fig. 8.2.10-1).

The ranges of concentrations of these constituents are relatively narrow because pH values are near the neutral range in all samples. At lower pH's many of these elements are more susceptible to dissolution.

Recommended limits for selected constituents in domestic water are: Boron - 1,000 $\mu g/L$, cadmium - 10 $\mu g/L$, chromium - 50 $\mu g/L$, copper - 1,000 $\mu g/L$, nickel - 130 $\mu g/L$, and zinc - 5,000 $\mu g/L$ (U.S. Environmental Protection Agency, 1976). Elements that may exceed these limits in and near surface mining usually decrease rapidly in nearby stream reaches due to precipitation and chemical reactions.

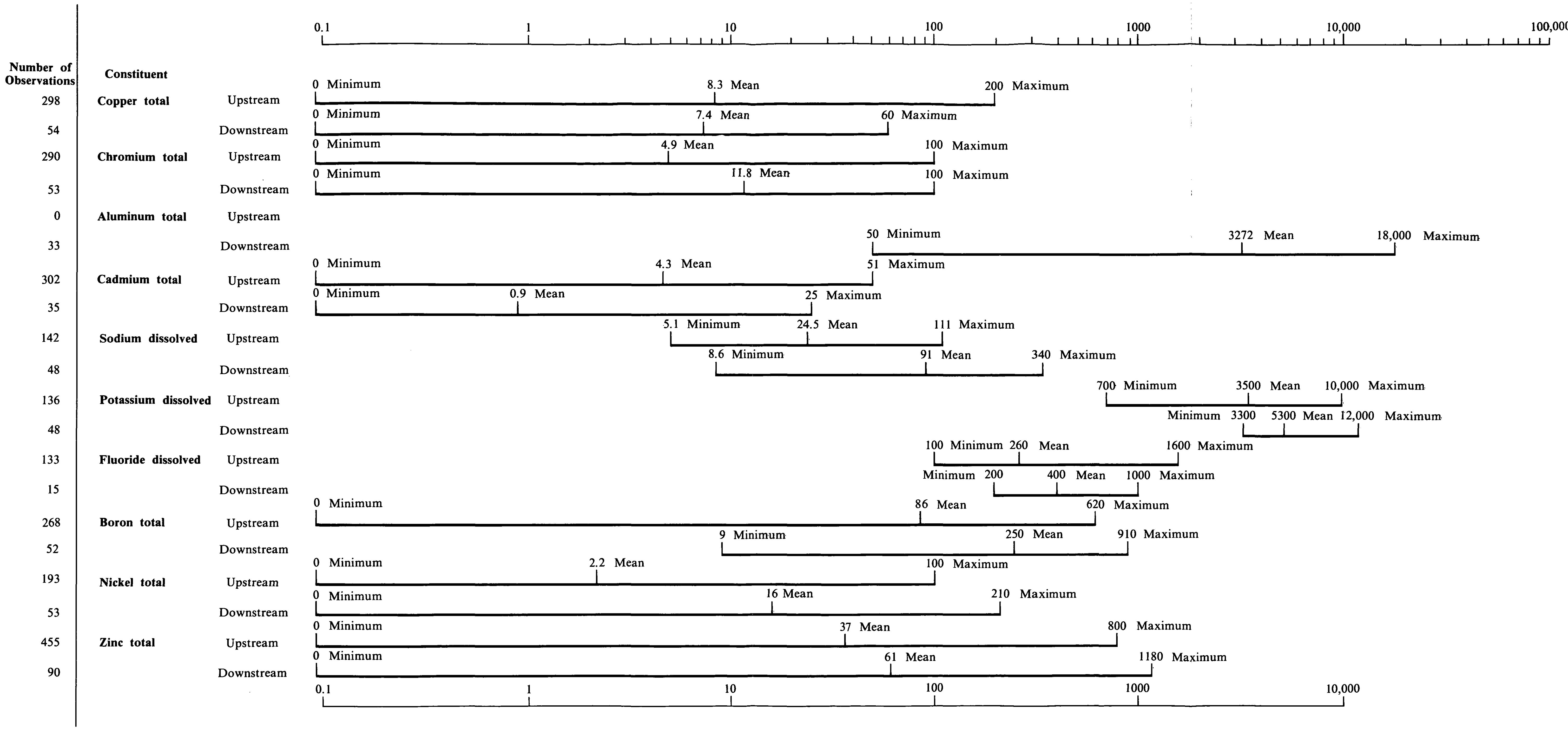


Figure 8.2.10-1 Range and mean values of additional elements, in micrograms per liter.

Average Suspended Sediment Yield was 221 Tons Per Square Mile

Variations in suspended sediment concentrations are probably caused by land use, geology, physiography, and streamflow.

Fluvial sedimentation includes the processes of erosion, transport, and deposition of soil or rock fragments (Guy, 1970). Suspended sediment is that portion carried in suspension by the turbulent components of streamflow. Suspended sediment is affected by numerous factors including physiography, soils, land use, and climate.

Four water-quality sites had sufficient suspended-sediment data to accurately compute sediment yields. Loads were computed using either daily or monthly sediment data and extrapolating out to a year, or by using the transport-duration technique of suspended-sediment load computation. Yields were computed by dividing annual load by the drainage area at the site.

Kaskaskia River at Cooks Mills, Illinois, drains 473 mi^2 of primarily agricultural land of medium-textured loess soils in the Bloomington Ridged Plain physiographic region, and had an annual suspended-sediment yield of 219 $tons/mi^2$ (table 8.2.11-1). Kaskaskia River near Venedy Station, Illinois, located in the Springfield Plain physiographic region, drains 4,393 mi^2 (76 percent of Area 29) of which less than 5 percent has been mined. This site had the lowest annual suspended-sediment yield, 89 $tons/mi^2$. This is probably due to its proximity downstream of Carlyle Lake, which could act as a trap for suspended sediment. Doza Creek near Lenzburg, Illinois, drains 18 mi^2 of 50 percent surface-mined land in the Mount Vernon Hill Country physiographic region. The annual suspended-sediment yield at this site was 151 $tons/mi^2$ (T. P. Brabets, written commun., 1980). South Branch Doza Creek near Lenzburg, Illinois, drains 8 mi^2 of approximately 10 percent surface-mined land and 90 percent loess-capped agricultural land. This site had the highest annual suspended-sediment yield, 425 $tons/mi^2$, probably due to the small size of the basin and agricultural methods practiced. Particle-size analyses for all of these sites showed that over 90 percent of annual suspended-sediment load was less than 0.0625 millimeters in size, which is silt- and clay-size range.

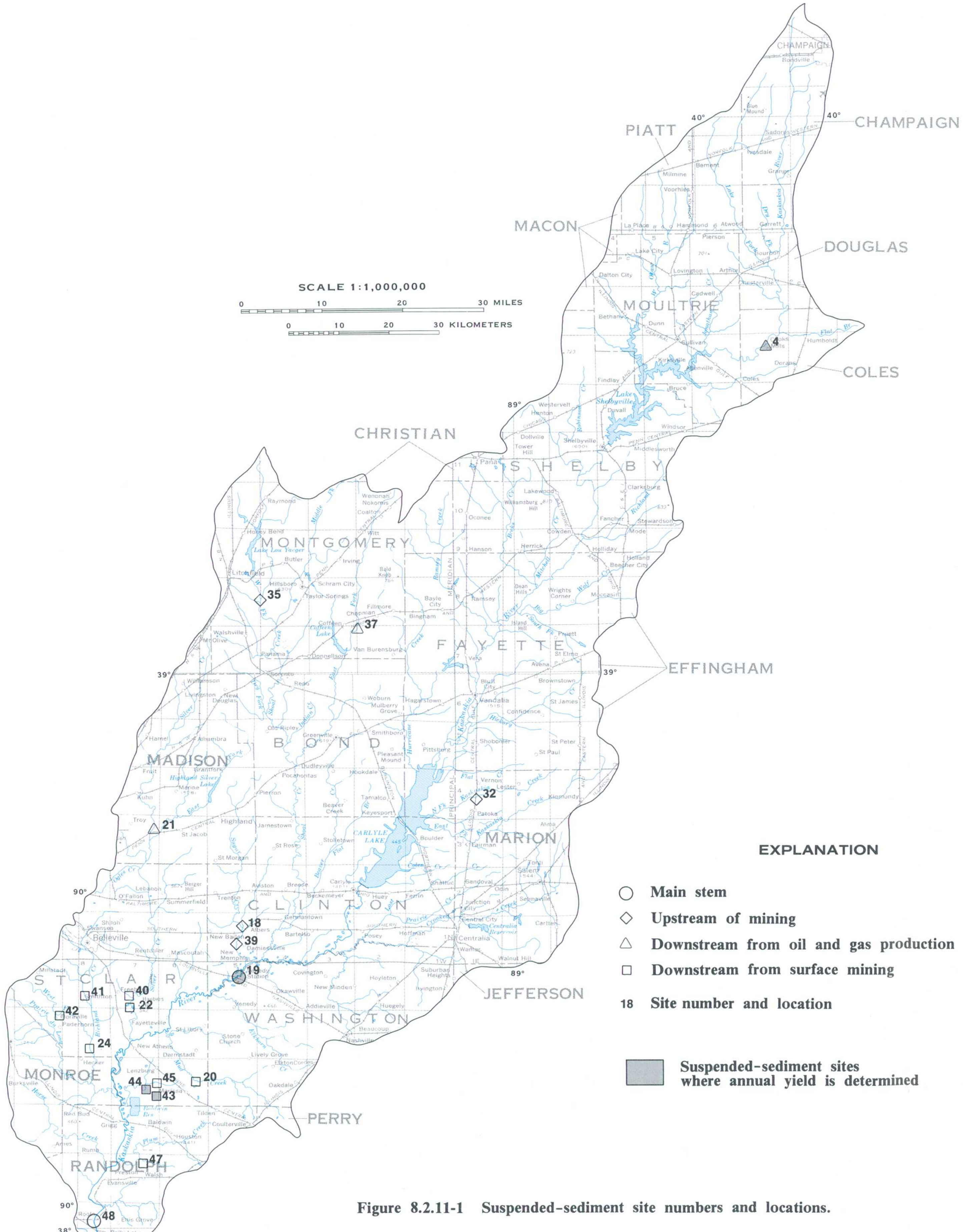
Twenty-six suspended-sediment samples were collected at seven synoptic sites upstream from surface mining. The concentrations ranged from 9 to 1,490 mg/L. From 29 miscellaneous samples at eight synoptic sites downstream from surface-mining operations (past or present), the suspended-sediment concentrations ranged from 7 to 1,400 mg/L (fig. 8.2.11-1). Samples were collected at streamflows ranging from low to high.

Storm runoff appears to be one of the major factors affecting suspended-sediment concentration. During low flow, concentrations of suspended sediment are low. At high flow, resulting from storm events, suspended-sediment concentrations are high. Peak suspended-sediment concentrations usually occur just prior to peak discharge (fig. 8.2.11-2) during storm events. Particle size analysis of suspended sediment showed that, except for 5 samples (taken at very low flows), 95-100 percent of all suspended sediment was composed of material finer than sand particles (less than 0.0625 mm). The few times that silt- and clay-size concentrations were below the 95 to 100 percent range were either during low flow when a few sand particles can drastically affect the percentage, or during high flow when stream energy is sufficient to transport larger particles.

Bedload, the sediment transported along and immediately adjacent to the streambed, is unmeasured and not included in reported sediment yields.

Suspended sediment is a principal transport mechanism for heavy metals. In nearly neutral systems, most of the metals present are sorbed onto sediment (Parker and Carey, 1980). Clay- and silt-sized particles have high cation-anion exchange capacities due to their large surface areas, and, hence, act as excellent transporters of heavy metals in the suspended phase.

High suspended-sediment concentrations can be deleterious in several ways. Suspended sediment affects the light penetration in water and thus reduces the growth of microscopic organisms on which insects and fish feed (Gottschalk, 1965). Sediment can also reduce habitat for macroinvertebrates through deposition (Flemal, 1981) and can prematurely age reservoirs by limiting the storage capacity due to deposition (Porterfield and Dunnam, 1964, p. 9).



BASE FROM U.S. GEOLOGICAL SURVEY STATE BASE MAP, 1:500,000, 1972

Figure 8.2.11-1 Suspended-sediment site numbers and locations.

Table 8.2.11-1 Suspended-sediment yields in Area 29.

SITE	SITE NUMBER	PERIOD OF RECORD	DRAINAGE AREA mi^2	PERCENT MINED	ANNUAL SEDIMENT YIELD tons/mi^2
Doza Creek near Lenzburg	43	1978-80	18	50	151
South Branch Doza Creek near Lenzburg	44	1978-80	8	≤10	425
Kaskaskia River near Venedy Station	19	1975-78	4,393	<5	89
Kaskaskia River at Cooks Mills	4	1979-81	473	0	219

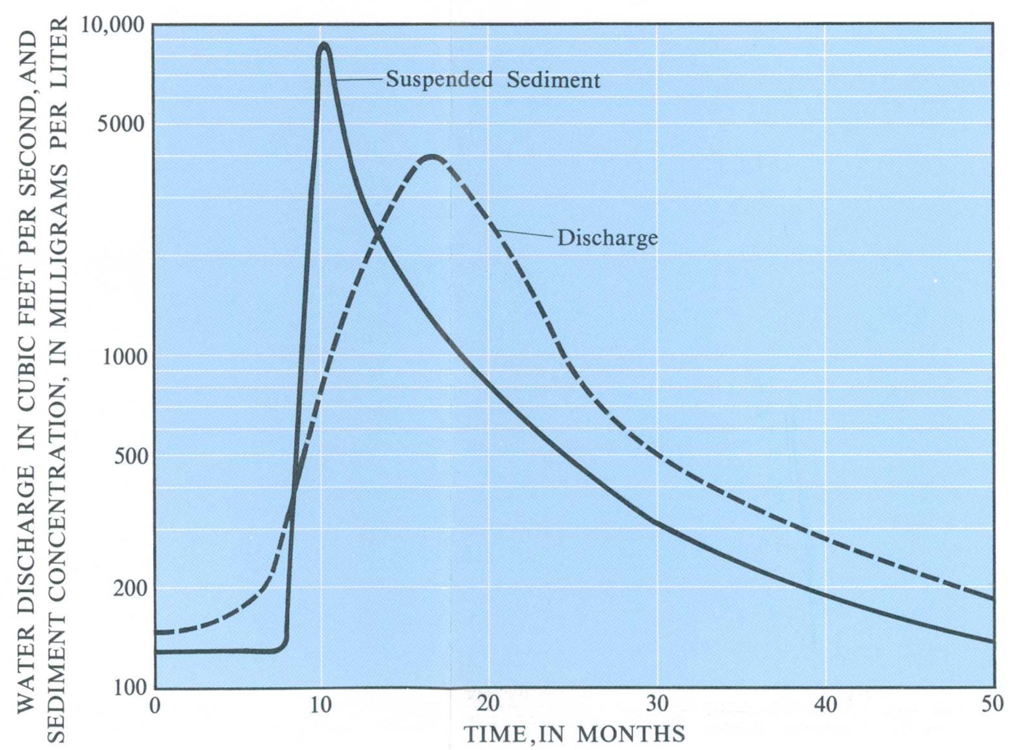


Figure 8.2.11-2 Typical sediment concentration graph as related to temporal distribution of water discharge hydrograph.

Aquifer Yields Vary Throughout the Area

Yields of 20 gallons per minute or more can be obtained from the sand-and-gravel aquifer throughout most of the area while chances of obtaining such yields in bedrock wells are poor.

The major aquifers in Area 29 are unconsolidated glacial deposits and bedrock of Pennsylvanian and Mississippian age. The unconsolidated deposits are found in preglacial bedrock valleys and in the bottomlands along the Kaskaskia River and its tributaries. Unconsolidated deposits are thin or absent on the uplands. In these areas, shallow sandstones and limestones of Pennsylvanian and Mississippian age are used for small water supplies (Selkregg and others, 1957).

Yields of 500 gal/min or more can be obtained from sand-and-gravel wells in the extreme northern part of Area 29. Yields along the Kaskaskia River valley can be 100 gal/min or more. Throughout most of the rest of the area, yields from sand and gravel wells are 20 gal/min or more (fig. 9.1-1). The chances of yields of 20 gal/min or more in bedrock wells are poor throughout the area (fig. 9.1-2) (Smith and Stall, 1975). Because of the low yields of most wells in Area 29, large water supplies are obtained from surface water.

Recharge is primarily from precipitation and takes place at bedrock outcrops throughout the area and by percolation into and through overlying unconsolidated materials (Selkregg and others, 1957). Figure 9.1-3 is a hypothetical geologic cross section that shows the relative positions of water-bearing materials in the area.

To date, ground water has not been a problem in most of the underground coal mines in Illinois. Eleven of the 15 underground mines operating in 1975 reported pumping from 0 to 3,530 cubic feet of water per day. The other four mines pumped from 10,590 to 176,000 cubic feet per day. Due to the low hydraulic conductivity of the rocks around the mines, many of the mines remain dry for many years after mining ceases (Cartwright and Hunt, 1978).

Pumping water out of surface mines causes the local water table to change so that the water flows toward the mine. The lowering of the water table in the vicinity of the mine could cause nearby wells to go dry. When the mine is abandoned, it will fill with water and the water table will be re-established. Reclamation of surface mines by filling with mine spoils can also cause changes in the local water table. Mine spoils generally have a much higher hydraulic conductivity than the original undisturbed material. Because of this, more precipitation can infiltrate and the new water table will be higher than the original one (Cartwright and Hunt, 1981).

EXPLANATION

[dashed pattern] Areas where municipal and industrial water supplies are usually developed from other sources

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

- [white] 20 gallons per minute or more
- [light blue] 100 gallons per minute or more
- [blue, stippled] 500 gallons per minute or more

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

- [light purple] 20 gallons per minute or more
- [purple] 100 gallons per minute or more

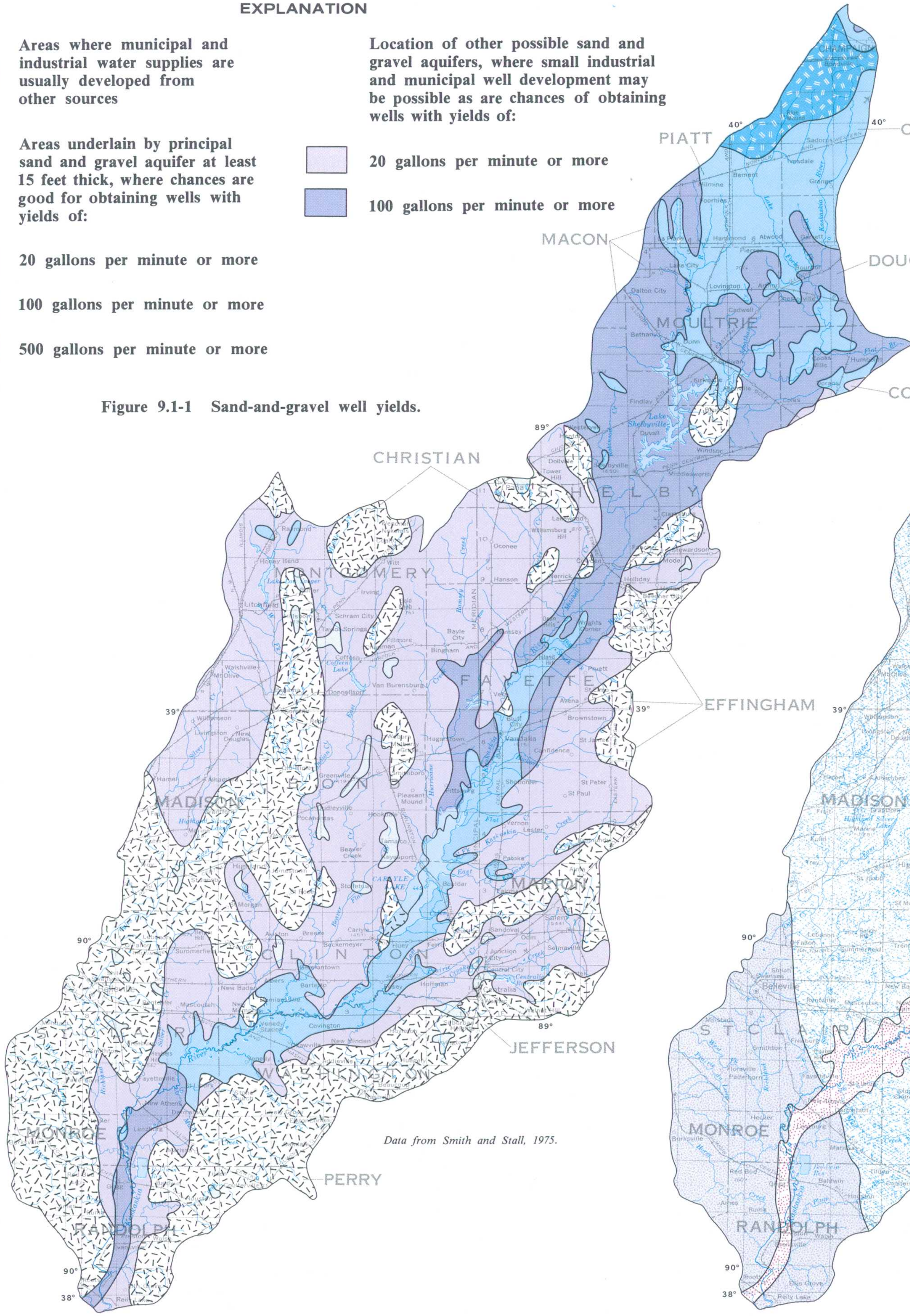
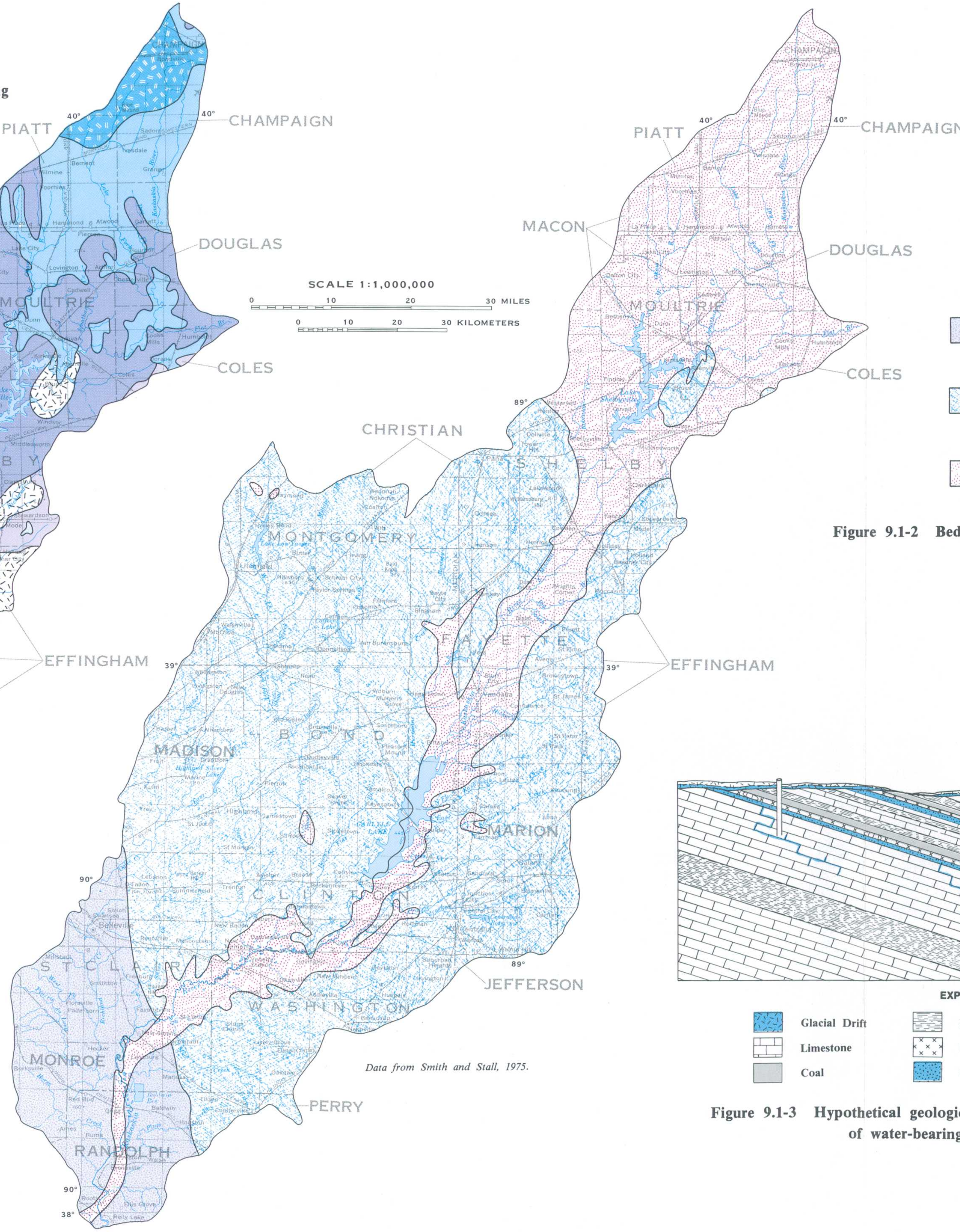


Figure 9.1-1 Sand-and-gravel well yields.

SCALE 1:1,000,000

0 10 20 30 MILES

0 10 20 30 KILOMETERS

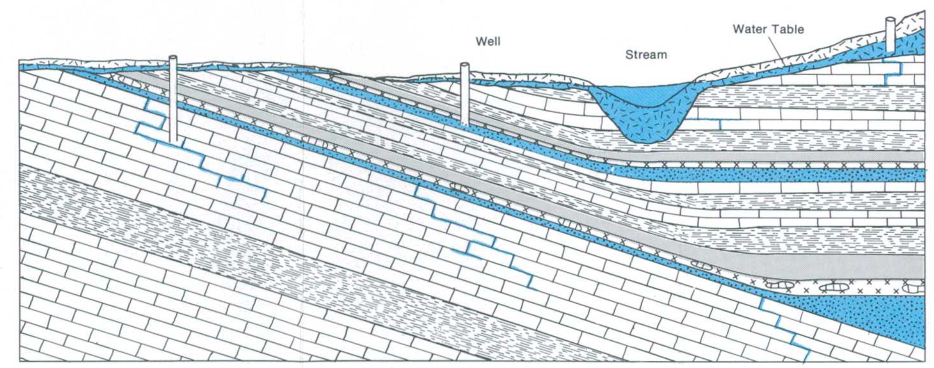


EXPLANATION

Chances of obtaining a well with a yield of:

- [light purple] 20 gallons per minute or more from Mississippian limestones and sandstones are poor
- [light blue] 10 gallons per minute or more from Pennsylvanian limestones and sandstones are poor
- [pink, stippled] Geologic conditions generally favor development of unconsolidated deposits

Figure 9.1-2 Bedrock well yields.



EXPLANATION

Glacial Drift	Shale	Limestone (nodular)
Limestone	Underclay	
Coal	Sandstone	

Figure 9.1-3 Hypothetical geologic cross-section showing relative positions of water-bearing materials (blue areas).

BASE FROM U.S. GEOLOGICAL SURVEY STATE BASE MAP, 1:500,000, 1972

Dissolved Solids Concentrations Increase with Depth

In general, water in the area ranges from hard to very hard. Iron concentrations that exceed the 0.3 mg/L criterion for domestic water supplies are common in the area.

The concentration of dissolved solids in ground water in Area 29 tends to increase as depth increases. Dissolved-solids concentrations in water from unconsolidated deposits (drift) range from 211 to 901 mg/L with a mean concentration of 498 mg/L. Dissolved-solids concentrations in water from bedrock range from 343 to 640 mg/L with a mean concentration of 534 mg/L (Larson, 1963). Analyses of oil-field brines in the area showed that total dissolved-solids concentrations were over 22,000 mg/L at a depth of about 500 feet (Meents and others, 1952). Fresh water is generally found at depths of 300 feet or less in the Illinois Basin (Cartwright and Hunt, 1978). The U.S. Environmental Protection Agency (1977) recommends a limit of 500 mg/L total dissolved solids in drinking water. Higher levels can be consumed with no harmful effects, but water containing more than 4,000 mg/L total dissolved solids is generally considered unfit for human consumption (McKee and Wolf, 1963). In general, water in the area ranges from hard (150 to 300 mg/L as calcium carbonate) to very hard (greater than 300 mg/L as calcium carbonate).

Iron concentrations that exceed the 0.3 mg/L criterion for domestic water supplies (U.S. Environmental Protection Agency, 1976) are common in the area. Seventy-two percent of the municipal wells listed in table 9.2-1 had iron concentrations that exceeded that criterion. Water from many of the wells in the area is treated for softening and/or iron removal. Concentrations of other constituents and corresponding U.S. Environmental Protection Agency (1976) water-quality criteria are given in table 9.2-1.

Figure 9.2-1 (Walker, 1969) shows that much of Area 29 has a moderate to high potential for chemical, thermal, or bacterial contamination of ground water. These are areas where 1) permeability of material above the water table is high; 2) bedrock is at or near the surface; or 3) the water table is near the land surface.

Cartwright and others (1981, fig. 1, p. 14) have mapped geologic conditions relating to the feasibility of sanitary landfill sites in Illinois. They show the general area mapped by Walker (fig. 9.0-1) as having a moderate contamination potential to have generally favorable geologic conditions relating to the feasibility of sanitary landfill sites.

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

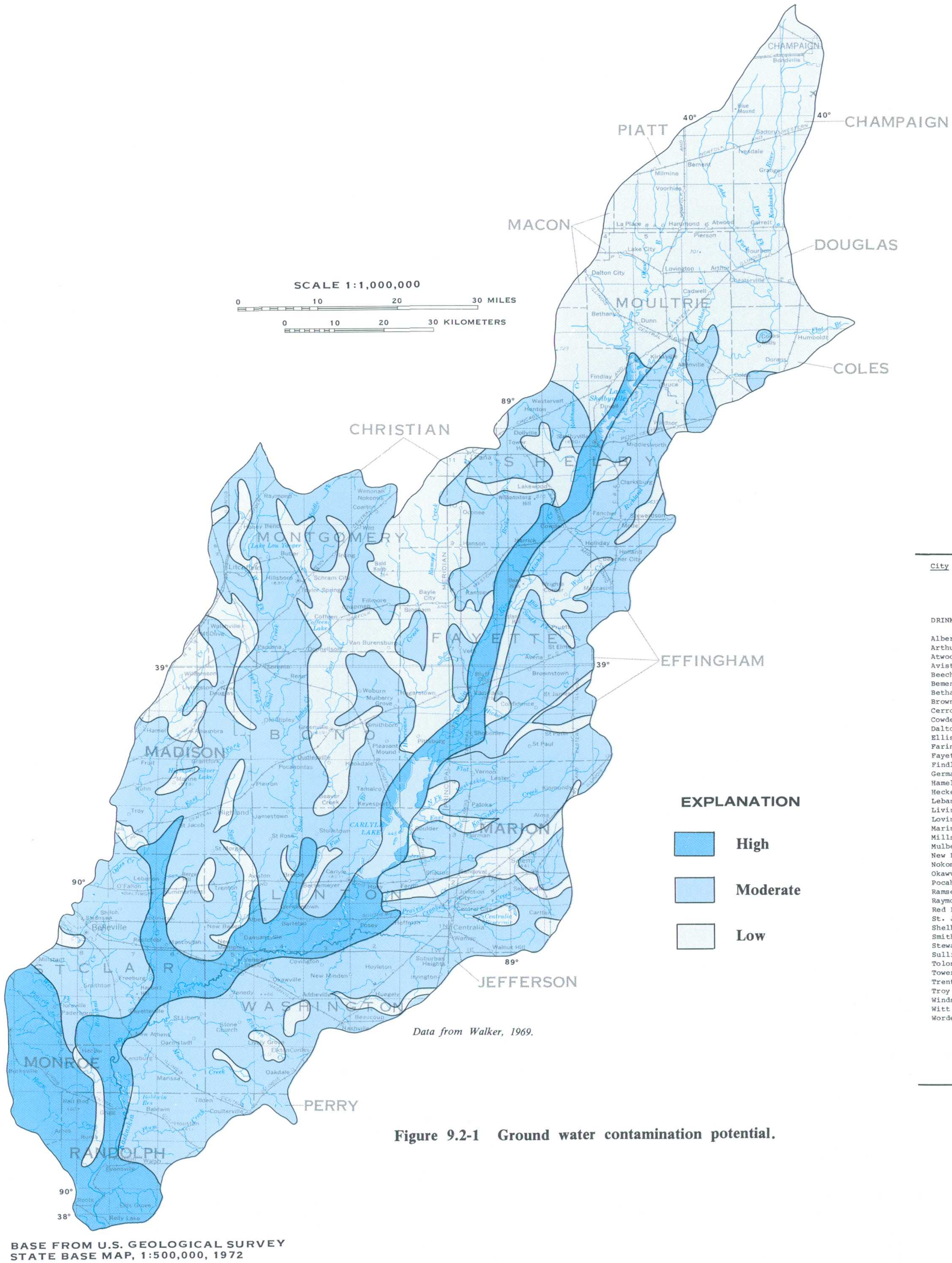


Figure 9.2-1 Ground water contamination potential.

Table 9.2-1 Concentrations, in milligrams per liter, of various water-quality constituents for cities in Area 29 (from Larson, 1963) and corresponding U.S. Environmental Protection Agency drinking water criteria.

City	Source	Iron Fe	Manganese Mn	Ammonium NH_4	Sodium Na	Calcium Ca	Magnesium Mg	Silica SiO_2	Boron B	Fluoride F	Nitrate NO_3	Chloride Cl	Sulfate SO_4	Alkalinity (as $CaCO_3$)	Total Hardness	Total Dissolved Solids	pH	Temperature °F
DRINKING WATER CRITERIA		0.3	0.05						0.75	2.0	10.0	250	250		500			
Albers	D	3.6	0.0	1.8	41	79.0	24.7	19	0.2	0.2	0.7	5	1	380	299	394		59.5
Arthur	D	1.2	0.0	1.1	101	59.5	28.6	24		0.3	1.0	4	1	552	421	557	7.4	55.7
Atwood	D	1.6	0.0	2.2	22	111.8	34.4	30		0.4	0.5	2	3	468	379	470	7.3	56.0
Aviston	D	2.8	0.1	1.3	68	76.5	26.2	18	Tr	0.1	0.8	39	2	392	299	481		57.5
Beecher City	D	3.7	0.2	Tr	18	75.1	23.1	19		0.3	10.6	6	50	252	283	338		55.2
Bement	D	0.4	0.1	2.3	49	69.4	35.9	23		0.3	0.1	22	2	400	321	444		55.2
Bethany	D	1.7	0.2	Tr	42	77.0	33.2	26		0.3	10.1	9	1	400	329	432	7.2	55.5
Brownstown	D	Tr	Tr	0.2	114	85.7	33.0	23		0.1	0.3	45	178	348	350	678		58.0
Cerro Gordo	D	0.8	Tr	Tr	16	85.5	35.7	14		0.3	1.0	21	108	244	320	382	7.1	55.0
Cowden	D	0.1	Tr	Tr	3	87.3	34.5	20		0.1	9.5	7	62	284	361	420	7.0	
Dalton City	D	6.0								0.3	0.5	25		604	412	661		56.0
Ellis Grove	D	5.4								0.1	0.2	8		324	332	365		
Farina	D	0.2	0.1	Tr	61	72.8	28.9	25	0.0	0.3	2.4	26	6	390	301	458		58.5
Fayetteville	D	5.3	0.2							0.1	0.2	4		396	355	392		58.5
Findlay	D	4.8	0.0	11.3	148	58.9	27.9	23		0.3	0.4	82	1	500	263	642		57.8
Germantown	D	Tr	0.0	0.0	42	75.3	28.7	16	0.1	0.4	15.4	17	103	254	307	465		58.0
Hamel	D	2.8	0.0	5.9	138	55.0	26.9	14	0.4	0.9	1.1	60	1	476	248	594		56.0
Hecker	S	0.2	Tr	0.1	247	5.5	9.0	10	2.7	4.8	2.7	20	42	480	18	640		59.0
Lebanon	D	5.6	1.0	0.4	29	114.9	33.1	20		0.4	0.4	36	127	304	424	553		55.0
Livingston	D	15.8										26		168	596	740		55.0
Lovington	D	1.3	0.0	8.7	59	101.3	46.1	24	0.4	0.0	0.8	28	1	556	443	590		55.0
Marine	D	3.9	Tr	4.8	71	65.0	29.5	17	0.4	0.5	4.7	46	1	500	284	571		56.0
Millstadt	S	0.4	0.1	2.0	20	72.0	25.6	14		0.4	0.3	4	5	324	285	343		58.5
Mulberry Grove	D	29.0	1.5	1.4	27	88.0	29.7	22	0.0	0.1	0.8	14	186	192	342	501		57.5
New Baden	D	6.9	0.5	Tr	16	37.5	14.8	16	0.0	0.1	1.6	10	33	140	155	219		57.0
Nokomis	D	5.8	0.2	0.5	55	110.6	27.4	29		0.4	0.0	47	225	208	389	632		54.5
Okawville	D	4.8	0.4	0.3	32	140.4	34.2	26		0.1	0.2	19	206	320	492	674	7.1	56.2
Pocahontas	D	18.0	0.6	Tr	14	37.5	13.3	24	Tr	0.2	2.8	12	20	140	149	211		
Ramsey	D	1.6	0.2	Tr	15	181.1	65.4	20		0.1	1.4	17	412	300	722	901	7.7	55.7
Raymond	D	Tr	0.0	Tr	28	76.1	23.5	25		0.1	0.4	11	35	296	287	374	7.1	54.0
Red Bud	D	2.0	0.0	0.3	20	68.2	22.2	8	0.1	0.1	0.2	10	12	280	262	304		59.0
St. Jacob	S	0.1	0.0	3.4	107	57.0	30.6	22	Tr	0.5	1.1	28	1	468	269	538		62.5
Shelbyville	D	0.1	0.4	0.5	1	117.6	43.7	17	0.0	0.1	2.2	24	87	348	474	508		55.0
Smithton	S	Tr	0.0	Tr	126	29.0	11.5	12	0.1	1.6	8.6	37	26	308	120	431		57.0
Stewardson	D	0.0	Tr	Tr	36	65.5	23.6	18	0.0	0.1	1.2	3	32	300	261	376		56.5
Sullivan	D	3.2	Tr	0.4	10	78.4	33.7	20		0.1	3.4	5	4	344	335	349	7.3	55.5
Tolono	D	4.1		4.0	115	93.4	32.8	27	0.4	0.3	1.1	6	1	620	369	640		
Tower Hill	S	2.9	0.1	0.6	44	62.5	16.4	24	0.0	0.3	0.0	24	2	284	224	376		
Trenton	S	Tr	0.0	0.6	386	4.5	3.1	8	0.5	1.0	1.1	215	1	562	24	950		58.5
Troy	D	0.1	0.1	Tr	9	102.5	44.4	25	0.3	0.1	1.3	7	149	292	438	517		56.5
Windsor	D	6.0	0.0	8.2	35	72.5	39.5	18	0.5	0.7	5.5	5	1	432	344	446		56.0
Witt	D	5.3	0.2	0.1	44	69.3	20.0	26		0.2	Tr	15	61	268	256	388	7.1	55.0
Worden	D	0.9	Tr	2.4	207	36.4	17.0	8	0.1	0.5	0.1	90	71	416	161	715		58.0

Symbols:
Source
D - unconsolidated materials above the bedrock
S - sandstone deposits
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 10.2, 10.3, 10.4, and 10.5.

NAWDEX Simplifies Access to Water Data

The National Water-Data Exchange (NAWDEX) is a nationwide program managed by the U.S. Geological Survey to assist users of water data or water-related data 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. 10.2-1). 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. 10.2-2), which identifies sites for which water data are available, the type of data available for each site, and the organization retaining the data. NAWDEX also maintains a Water-Data Sources Directory (fig. 10.2-3) 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

or

NAWDEX ASSISTANCE CENTER
Illinois
U.S. Geological Survey
Water Resources Division
Champaign County Bank Plaza
4th floor
102 East Main Street
Urbana, IL 61801

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

Hours: 8:00 - 4:30 central time

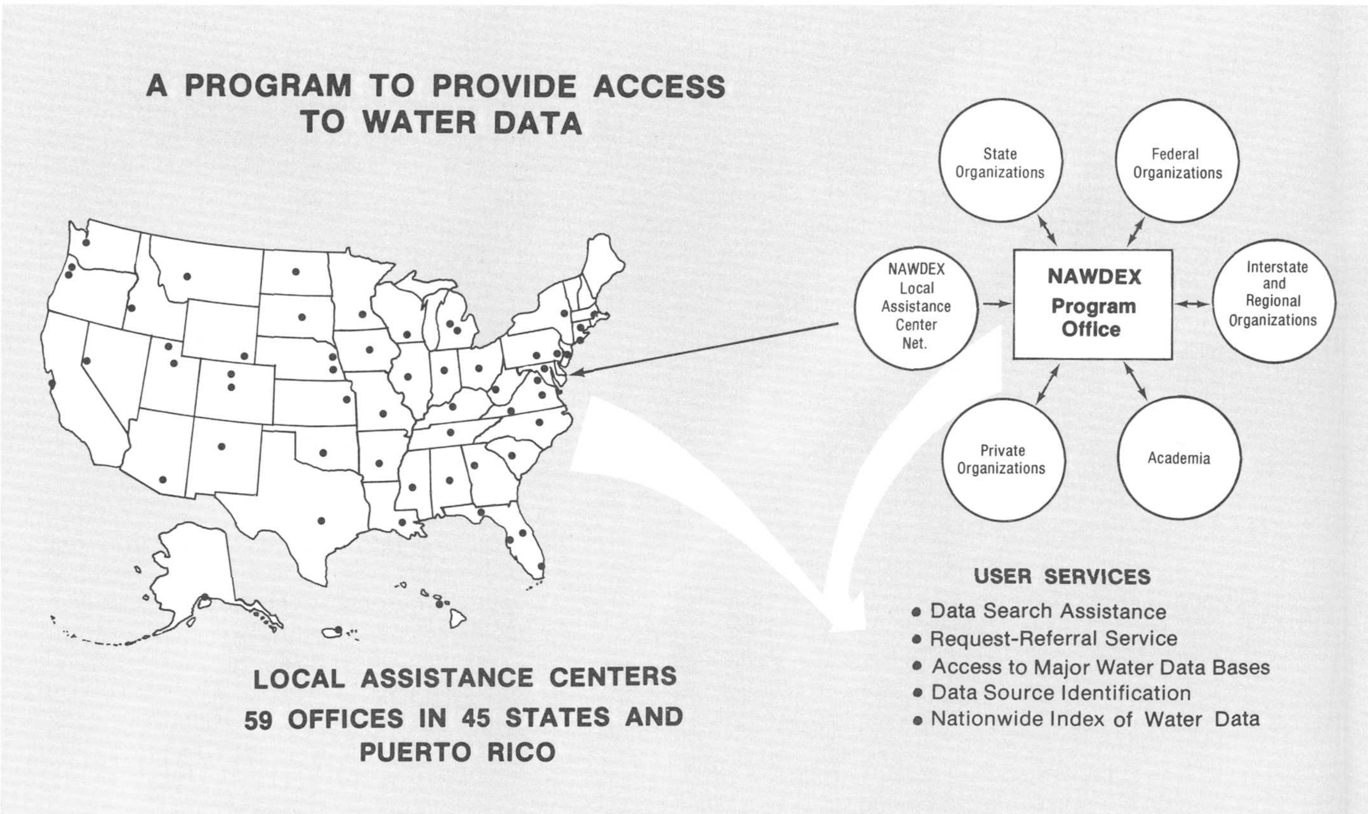


Figure 10.2-1 Access to water data.

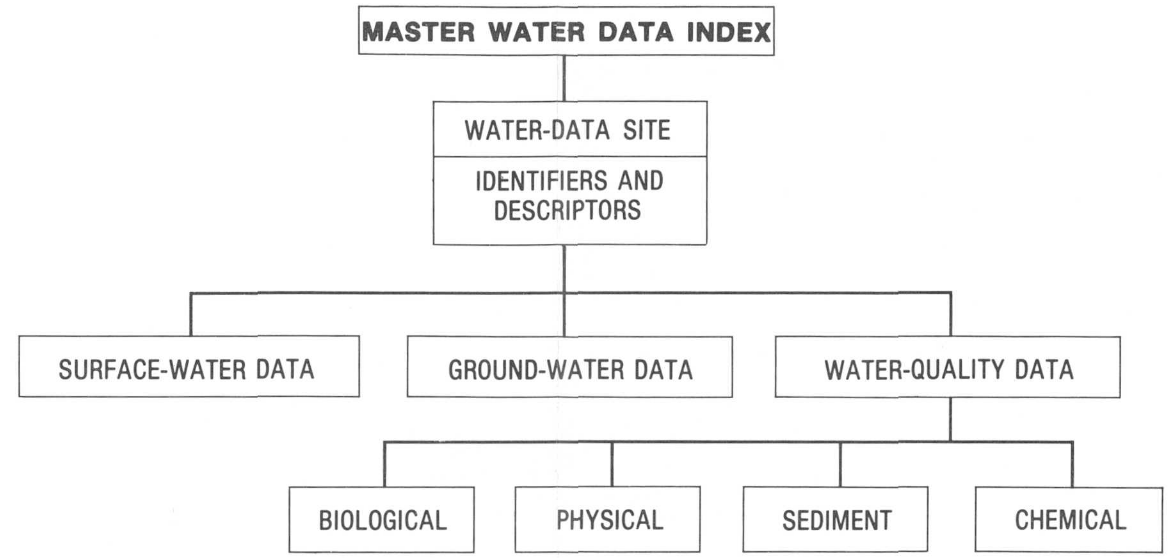


Figure 10.2-2 Master water-data index.

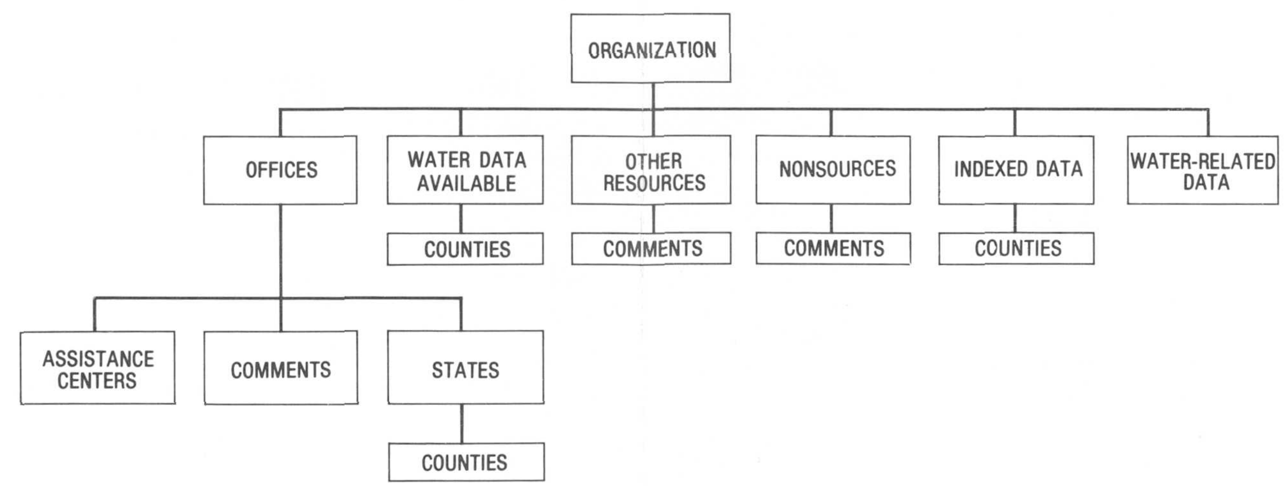


Figure 10.2-3 Water-data sources directory.

WATSTORE Automated Data System

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

The National Water-Data Storage and Retrieval System (WATSTORE) was established in November 1971 to computerize the water-data system of the Geological Survey 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 Geological Survey at its National Center in Reston, Va. Data may be obtained from WATSTORE through the 46 district offices of the Water Resources Division. 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 (1981) collects data at approximately 16,000 stream-gaging stations, 1,000 lakes and reservoirs, 5,200 surface-water quality stations, 1,000 sediment stations, 30,000 observation wells, and 12,500 ground-water quality wells. Each year many water-data collection sites are added, and others are discontinued. Thus, large amounts of diversified data, both current and historical, are amassed by the data-collection activities of the Survey.

The WATSTORE system consists of several files in which data are grouped and are stored by common characteristics and data-collection frequencies. The system is designed to allow for the addition of data files as needed. Files are maintained for the storage of (1) surface-water, quality-of-water, and ground-water data measured on a daily or continuous basis; (2) annual peak values for streamflow stations; (3) chemical analyses for surface- and ground-water sites; (4) water parameters measured more frequently than daily; and (5) geologic and inventory data for ground-water sites. In addition, an index file of sites for which data are stored in the system is also maintained (fig. 10.3-1). A brief description of each file follows:

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

Daily-Values File: All water-data parameters measured or observed, either on a daily or on a continuous basis, and numerically reduced to daily values are stored in this file. Instantaneous measurements at fixed-time intervals, daily mean values, and statistics such as daily maximum and minimum values also may be stored. The file currently contains over 200 million daily measurements, including data on streamflow, river stage, reservoir content, water temperature, specific conductance, sediment concentration, sediment discharge, and ground-water level.

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

Water-Quality File: More than 1.4 million analyses of water samples in this file describe the chemical, physical, biological, and radiochemical characteristics of both surface water and ground water. These analyses include data for 185 constituents and properties.

Unit-Values File: Water parameters measured more frequently than daily are stored in this file.

Rainfall, stream-discharge, and water temperature data are examples of the types of data stored in the Unit-Values File.

Ground-Water Site-Inventory File: This file is maintained with WATSTORE independent of the preceding files, but it is cross referenced to the Water Quality and the Daily-Values Files. The file contains inventory data on wells, and springs. Examples of data are site location, site identification, geohydrologic characteristics, well-construction history, and field measurements of water temperature. The file is designed to accomodate 270 data elements and currently contains data for nearly 780,000 sites.

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

Remote Job-Entry Sites: Almost all district offices of the Water Resources Division are equipped with high-speed computer terminals for remote access to the WATSTORE system. These terminals allow each site to put data into or retrieve data from the system within times ranging from several minutes to overnight, depending on the priority of 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 stage, specific conductance, water temperature, turbidity, wind direction, and chloride concentration. Data are recorded on 16-channel paper tape and are transmitted over telephone lines to the receiver at Reston, Va. The data are recorded on magnetic tape for use on the central computer. Extensive testing of satellite data-collection platforms indicates their feasibility for collecting realtime hydrologic data on a national scale. Battery-operated radios are used as the communication link to the satellite. About 200 data-relay stations are being operated currently (1981).

Central-Laboratory System: The two water-quality laboratories of the Water Resources Division, in Denver, Colo., and Doraville, Ga., analyze more than 150,000 water samples per year. These laboratories are equipped to determine concentrations of dissolved constituents ranging from chloride to complex organic compounds, such as pesticides, and to measure various properties of water. After verification by laboratory personnel, results of each analysis are transmitted by a computer terminal to the central computer facilities for storage in the Water-Quality File of WATSTORE.

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

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

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

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

Digital Plotting: WATSTORE also makes use of software systems that prepare data for digital plotting on peripheral off-line plotters available at the central computer site. Hydrographs, frequency-distribution curves, X-Y point plots, contours, and three-dimensional illustrations can be plotted.

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

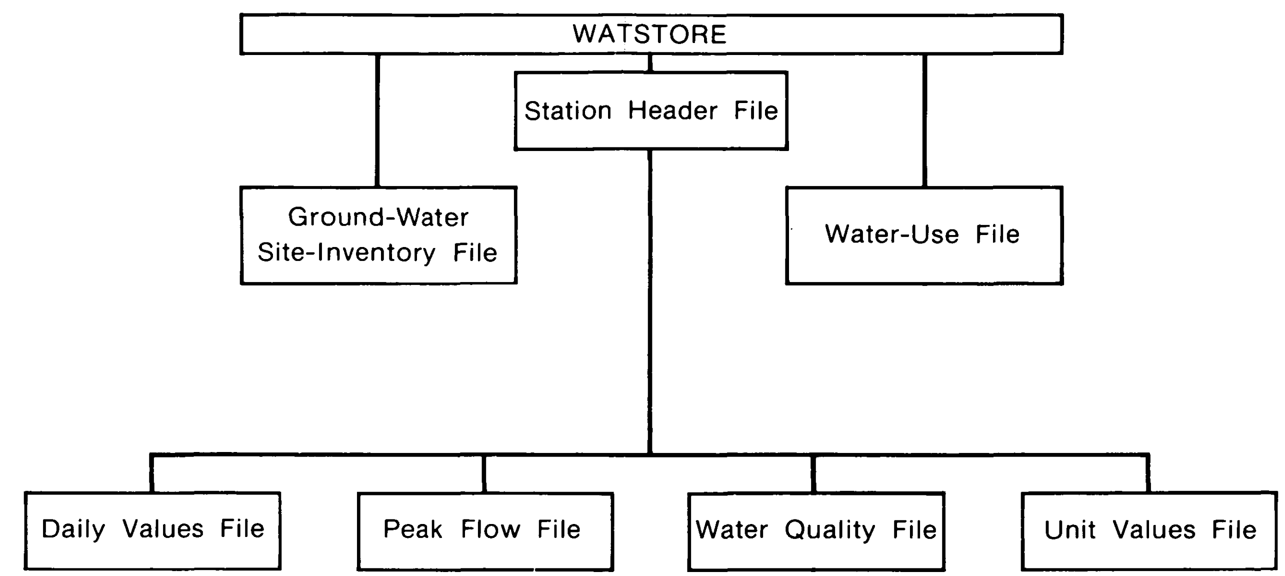


Figure 10.3-1 Index file stored data.

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. 10.4-1): volume I, Eastern Coal province; volume II, Interior Coal province; volume III, Northern Great Plains and Rocky Mountain Coal provinces; volume IV, Gulf Coast Coal province; and volume V, Pacific Coast and Alaska Coal provinces. The 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 10.2).

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

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

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

or

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

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

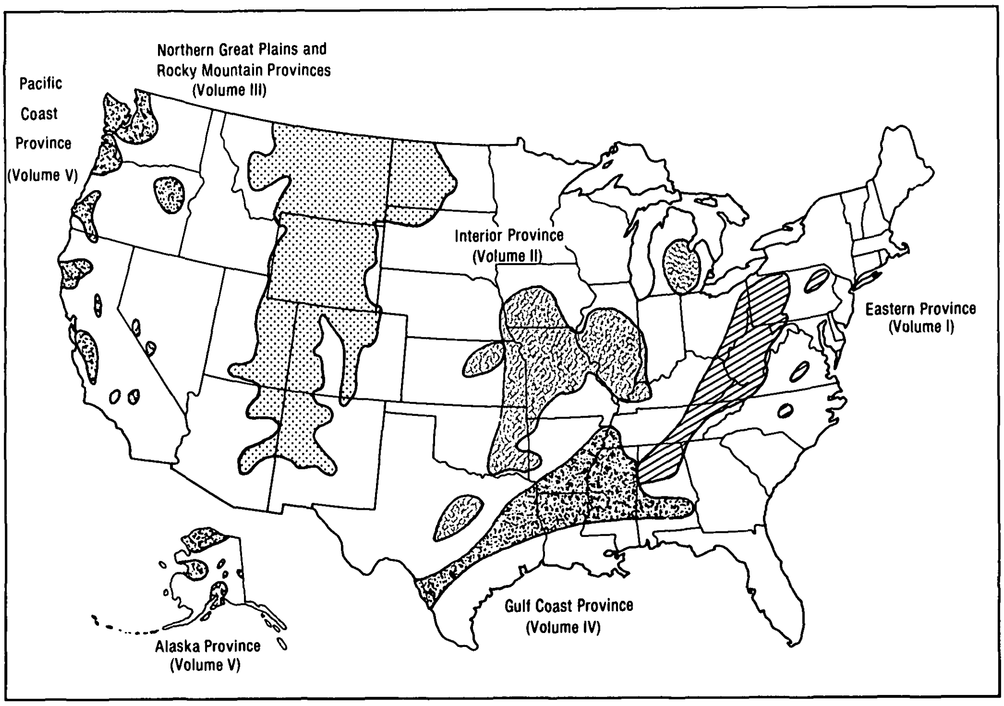


Figure 10.4-1 Index volumes and related provinces.

STORET is U.S. Environmental Protection Agency Computerized Data Base System

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

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

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

There are 1,800 water-quality parameters defined within STORET's WQF. In 1976 there were data from over 200,000 unique collection points in the system. Figure 10.5-1 illustrates how data are retrieved from 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

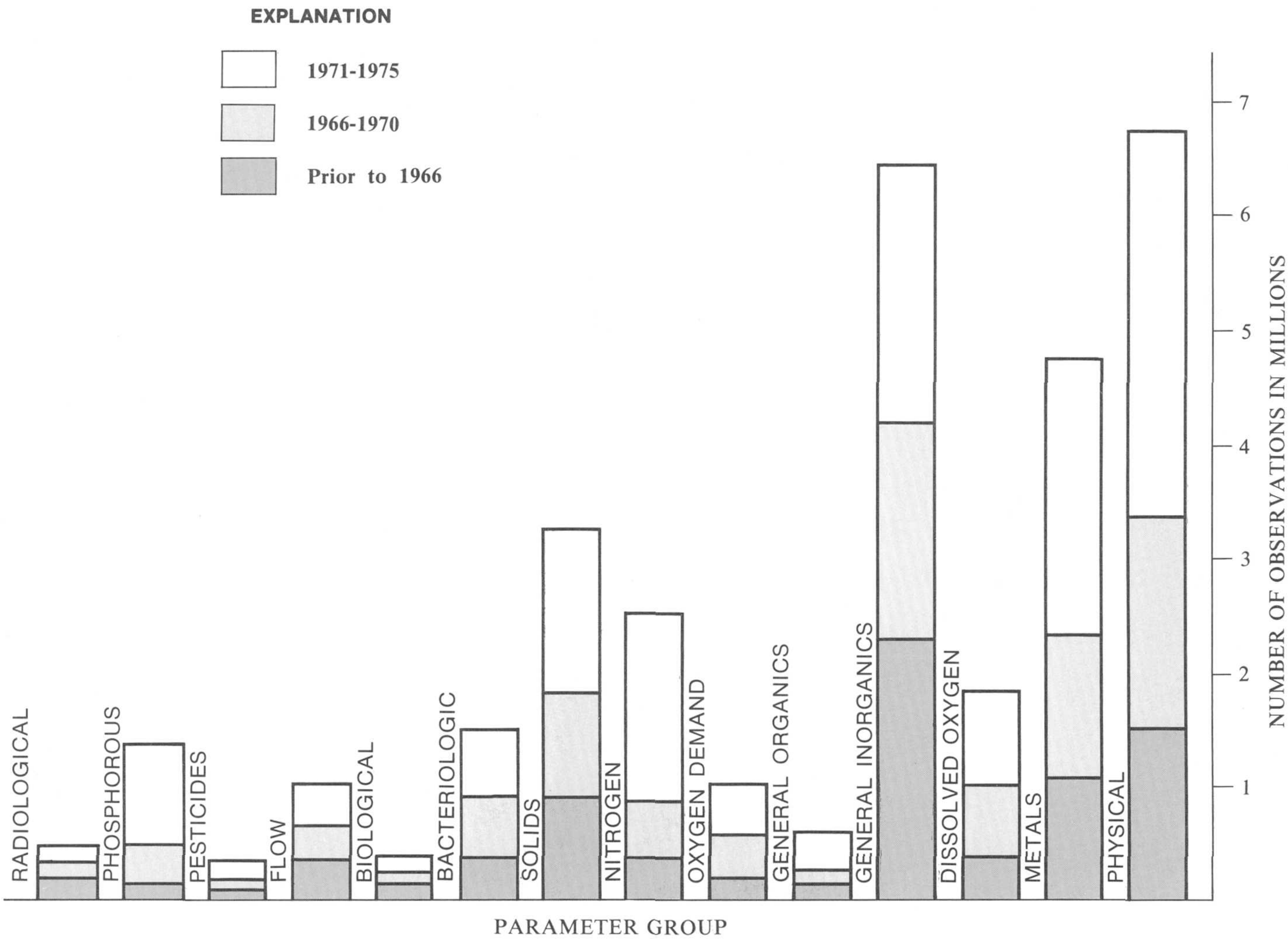


Fig. 10.5-1 Parameter groups and number of observations in the Water Quality File (from STORET User Handbook).

11.0 SUPPLEMENTAL INFORMATION FOR AREA 29

11.1 Gaging Stations

Active gaging stations and gaging stations used in development of mean annual stream flow equation (indicated by an asterisk (*)).

Map number	Station number	Station name	Drainage area (mi^2)	Average flow (ft^3/s)	Period of record (month/year)
1	*05590000	Kaskaskia Ditch at Bondville Lat 40°06'47", long 88°20'55", NW¼NW¼ sec.18, T.19 N., R.8 E., Champaign County	12.4	10.1	12/48-
2	*05590400	Kaskaskia River near Pesotum Lat 39°52'44", long 88°22'35", on north boundary of sec.2, T.16 N., R.7 E., Douglas County	109	104	10/64-9/79
3	*05590800	Lake Fork at Atwood Lat 39°48'30", long 88°28'34", NE¼NW¼ sec.36, T.16 N., R.6 E., Piatt County	149	173	10/72-
4	*05591200	Kaskaskia River at Cooks Mills Lat 39°34'59", long 88°24'50", NW¼SW¼ sec.10, T.13 N., R.7 E., Coles County	473	484	10/70-
5	*05591500	Asa Creek at Sullivan Lt 39°37'11", long 88°36'17", NE¼NE¼ sec.35, T.14 N., R.5 E., Moultrie County	8.05	6.05	07/50-
6	05592000	Kaskaskia River at Shelbyville Lat 39°24'25", long 88°46'50", SE¼SW¼ sec.8, T.11 N., R.4 E., Shelby County	1,054	[1]1,012	[1]06/69-
7	05592100	Kaskaskia River near Cowden Lat 39°13'50", long 88°50'33" NW corner sec.14, T.9 N., R.3 E., Shelby County	1,330	1,286	07/70-
8	*05592300	Wolf Creek near Beecher City Lat 39°09'30", long 88°48'20", NE¼NE¼ sec.12, T.8 N., R.3 E., Fayette County	47.9	36.8	12/58-

Active gaging stations and gaging stations used in development of mean annual stream flow equation (indicated by an asterisk (*)). Continued

Map number	Station number	Station name	Drainage area (mi^2)	Average flow (ft^3/s)	Period of record (month/year)
9	05592500	Kaskaskia River at Vandalia Lat 38°57'35", long 89°05'20", SE¼, sec.16, T.6 N., R.1 E., Fayette County	1,940	[1]1,840	[1]06/69-
10	*05592800	Hurricane Creek near Mulberry Grove Lat 38°55'21", long 89°14'14", NW¼SE¼sec.31, T.6 N., R.1 W., Fayette County	152	139	10/70-
11	05593000	Kaskaskia River at Carlyle Lat 38°36'42", long 89°21'22", SE¼ sec.18, T.2 N., R.2 W., Clinton County	2,719	[2]2,418	[2]04/67-
12	*05593520	Crooked Creek near Hoffman Lat 38°30'25", long 89°16'24", NE¼ sec.26, T.1 N., R.2 W., Washington County	254	194	10/68-
13	*05593525	Crooked Creek near Posey Lat 38°31'08", long 89°21'08", NE¼NE¼ sec.19, T.1 N., R.2 W., Clinton County	344	343	10/67-09/74
14	*05593575	Little Crooked Creek near New Minden Lat 38°26'30", long 89°25'00", Center of sec.15, T.1 S., R.3 W., Montgomery County	84.3	65.5	10/67-
15	*05593600	Blue Grass Creek near Raymond Lat 39°16'07", long 89°32'02", NE¼SE¼ sec.33, T.10 N., R.4 W., Montgomery County	17.3	12.0	05/60-
16	*05593900	East Fork Shoal Creek near Coffeen Lat 39°08'56", long 89°21'08" NW¼SE¼ sec.7, T,8 N., R.2 W., Montgomery County	55.5	40.8	10/63-

Active gaging stations and gaging stations used in development of mean annual stream flow equation (indicated by an asterisk (*)). Continued

Map number	Station number	Station name	Drainage area (mi^2)	Average flow (ft^3/s)	Period of record (month/year)
17	*05594000	Shoal Creek near Breese Lat 38°36'35", long 89°29'40", SW1/4SW1/4 sec.13, T.2 N., R.4 W., Clinton County	735	515	11/09-12/12 10/45-
18	*05594090	Sugar Creek at Albers Lat 38°32'29", long 89°37'36", SW1/4SW1/4 sec.11, T.1 N., R.5 W., Clinton County	124	116	10/72-
19	05594100	Kaskaskia River near Venedy Station Lat 38°27'02", long 89°37'39", NW1/4 sec.14, T.1 S., R.5 W., Washington County	4,393	3,689	10/69-
20	*05594330	Mud Creek near Marissa Lat 38°15'46", long 89°43'56", NE1/4NW1/4 sec.23, T.3 S., R.6 W., St. Clair County	72.4	52.9	10/70-
21	*05594450	Silver Creek near Troy Lat 38°43'00", long 89°49'45", SE1/4SW1/4 sec.12, T.3 N., R.7 W., Madison County	154	116	10/66-
22	*05594800	Silver Creek near Freeburg Lat 38°24'22", long 89°52'26", NE1/4NE1/4 sec.33, T.1 S., R.7 W., St. Clair County	464	341	10/70-
23	*05595000	Kaskaskia River at New Athens Lat 38°19'45", long 89°52'45", NE1/4 sec.28, T.2 S., R.7 W., St. Clair County	5,181	[3]3,622	[3]10/09-12/12 06/14-09/21 10/34-09/71
24	*05595200	Richland Creek near Hecker Lat 38°19'26", long 89°58'15", SW1/4SE1/4 sec.27 projected, T.2 S., R.8 W., St. Clair County	129	94.0	10/69-

[1]Since construction of the Lake Shelbyville
[2]Since construction of Carlyle Lake
[3]Prior to construction of Carlyle Lake

BASE FROM U.S. GEOLOGICAL SURVEY
STATE BASE MAP, 1:500,000, 1972

11.0 SUPPLEMENTAL INFORMATION FOR AREA 29 --Continued

11.2 Reconnaissance Sites and Site Numbers

Site Number	Station Name	Drainage Area mi^2	Temper-ature °C	pH	Specific Conduct-ance μmhos	Dissolved O_2 mg/L	Land Use*
1	Two Mile Slough	35.3	10.1	7.6	640	12.0	A
2	Kaskaskia River nr Pesotum	109	10.2	8.1	642	15.5	A
3	Kaskaskia River at Sadorous	59.9	9.6	7.3	751	5.6	A
5	Asa Creek at Sullivan	8.05	14.0	7.9	729	12.8	A
6	Kaskaskia River below Lake Shelbyville dam	1,054	12.5	7.7	427	11.5	W
8	West Fork Kaskaskia River	19.1	13.3	6.5	1,151	6.1	A
9	Kaskaskia River at Vandalia	1,940	12.3	7.9	453	10.3	---
10	Hurricane Creek nr Mulberry Grove	152	9.6	7.5	691	8.1	W
11	Kaskaskia River at Cooks Mill	473	8.3	7.5	779	9.0	P,A,W
12	Crooked Creek nr Hoffman	254	11.2	6.9	749	3.2	W
13	Jonathan Creek	54.7	9.5	7.5	663	8.3	P,A
14	Dry Fork	24.7	12.3	7.8	711	13.5	A,P
15	Whitley Creek at mouth	53.1	10.4	7.8	522	12.8	W
16	West Okaw River	171	10.4	7.8	826	10.9	W
17	Shoal Creek nr Breese	735	9.8	7.3	555	6.2	W
18	Sugar Creek at Albers	124	7.3	7.2	456	----	A
19	Kaskaskia River nr Venedy Station	4,393	9.7	8.0	377	----	---
20	Mud Creek nr Marrisa	72.4	10.4	7.0	250	----	A,W
21	Silver Creek nr Troy	154	8.4	6.8	807	----	A
22	Silver Creek nr Freeburg	464	9.7	6.9	456	----	A,W
23	Big Creek above S.Fork	100	11.1	7.1	2,530	6.8	W
24	Richland Creek nr Hecker	129	11.7	7.2	983	----	A
26	Kaskaskia River at Allenville	506	7.9	7.6	763	10.3	W
29	Bear Creek	---	11.4	8.0	554	10.2	A
30	Hickory Creek nr Bluff City	77.6	12.0	6.9	465	3.7	A
31	E. Fork Kaskaskia River	113	6.7	7.1	456	3.7	A
32	N. Fork Kaskaskia River	39.1	8.9	6.9	203	4.8	P
33	Kaskaskia River at Carlyle	27.9	11.0	8.1	423	12.1	Pk/Lk
34	Crooked Creek nr Odin	89.2	9.6	7.0	846	4.6	W
35	W.Fk Shoal Creek at Lake Lou Yager	108	9.9	7.6	508	12.4	Lk
36	Shoal Creek above Lake Fork	286	4.6	7.9	608	10.9	W
37	E. Fk. Shoal Creek nr Coffeen	<80	7.7	7.3	697	5.4	A,W
38	E. Fk. Shoal Creek nr Woburn	--	8.4	7.2	619	3.0	W
40	Heberers Branch nr Freeburg	2.55	---- -	NO	FLOW--	------	------
47	Little Plum Creek at mouth	17.8	9.4	7.4	560	---	A,W,M
48	Kaskaskia River at Roots	5,790	13.5	7.8	536	---	---
49	Plum Creek	---	10.2	7.8	382	3.6	W
50	Kaskaskia River at Chesterville	360	8.9	7.7	838	7.6	A,W
51	Middle Fork at Shoal Creek	---	7.9	7.7	579	2.4	W
52	Vandalia Drainage	*50	11.8	7.4	740	5.2	A
53	Lake Fork	45.6	9.4	NO	FLOW--	------	-------
54	Dry Fork	47.5	12.3	NO	FLOW--	------	-------
55	Shoal Creek	445	7.3	7.4	558	7.7	W
56	Sandy Run Ditch	---	12.8	7.6	604	9.7	A
57	Louse Creek	---	---- -	NO	FLOW--	------	-------
58	Lake Fork at Atwood	149	10.0	7.8	692	10.7	A

Site Number	Station Name	Drainage Area mi^2	Temperature °C	pH	Specific Conductance μ mhos	Dissolved O_2 mg/L	Land Use*
59	Beaver Creek	----	---	NO	FLOW	-----	
60	Flat Branch	<24.9	7.6	7.4	417	6.2	W
61	Beaver Creek nr Beckmeyer	131	---	7.0	655	3.1	W
62	Shoal Creek at Hwy 161	889	10.2	7.4	715	8.3	W
63	Sugar Creek nr St. Morgan	59.7	10.3	7.1	1,077	---	A,W
64	Lake Branch	22.3	7.1	7.0	496	---	A,W
65	Kaskaskia River nr Cowden	1,330	12.0	7.8	429	10.9	W
66	Kaskaskia River above Big Creek	1,574	12.0	7.7	443	10.8	W
67	Williams Creek	16.2	--NO	FLOW	--	----	-----
68	Elkhorn Creek nr Lively Grove	27.7	--NO	FLOW	---	----	-----
69	Elkhorn Ckeek	88.7	7.3	7.0	233	----	A,W
70	Rayhill Slough	----	10.0	7.3	490	----	A,W
71	Rheinhart Slough	----	11.8	7.3	505	----	A,W
72	Mud Creek nr Elkton	34.0	--NO	FLOW	---	----	-----
73	Wolf Creek nr Beecher	47.9	9.9	7.2	695	6.5	W
74	Mud Creek nr Darmstadt	94.7	10.2	6.8	328	----	A,W
75	Little Muddy Creek	----	9.4	7.0	460	----	A,W
76	Silver Creek nr Fruit	----	8.5	6.6	552	----	A
77	Mocassin Creek	33.1	10.0	6.8	1,380	1.4	A,O
78	Sugar Fork at Mouth	30.7	9.2	6.7	337	----	A,W
79	E.Fk. Silver Creek	57.1	10.6	6.6	273	----	A,W
80	E.Fk. Silver Creek at Mouth	98.1	8.4	6.5	344	----	A
81	Silver Creek nr Lebanon	324	9.2	6.7	704	----	A,W
82	Little Silver Creek	50.8	8.8	6.6	574	----	A,W
83	Silver Creek at Mascoutah	451	9.4	6.8	511	----	A,W
84	Loop Creek	18.0	10.4	6.8	809	----	A
85	South Fork at mouth	38.1	9.9	7.0	4,630	8.2	A,O
86	Big Ck at Wrights Corner	87.3	11.7	6.8	4,360	5.5	Fe Precip Oil Slick
87	Prairie Du Long	79.7	10.1	7.0	410	----	A,W
88	Crooked Creek nr Posey	344	9.6	7.0	781	5.5	W
89	Horse Creek	94	9.6	7.1	415	----	A,W
90	Camp Creek	12.3	--NO	FLOW	---	----	---
91	Nine Mile Creek	43.9	10.0	6.8	310	----	A,W
92	Beaver Pond Creek	----	12.2	7.0	755	3.4	W
94	Copper Slough	15.9	12.7	7.1	677	4.9	A
95	Lake Fork	----	9.4	7.6	756	7.8	W
96	Flat Creek at mouth	39.6	8.3	7.5	649	8.8	A
97	Bolt Creek	9.68	10.9	8.4	526	15.5	W
98	Ash Creek	19.9	11.5	7.5	546	9.3	A,W
99	Ramsey Creek nr Ramsey	97.3	9.3	7.9	742	10.4	W
100	Hoffman Creek	11.6	9.6	7.7	663	9.2	A
101	Flat Creek	721.5	--NO	FLOW	---	---	Lumbering
102	Turkey Creek	----	--NO	FLOW	---	---	---
103	Prairie Creek	----	9.9	7.3	855	8.9	A
104	Prairie Creek	----	--NO	FLOW	---	---	---
105	Lost Creek	<38.3	8.7	7.2	693	6.5	A
106	Lost Creek at mouth	78.5	11.0	7.0	714	4.5	W

O - Oil and gas production
M - Mining
Lk - Lake
A - Agriculture
W - Woods
P - Pasture
Pk - Park

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