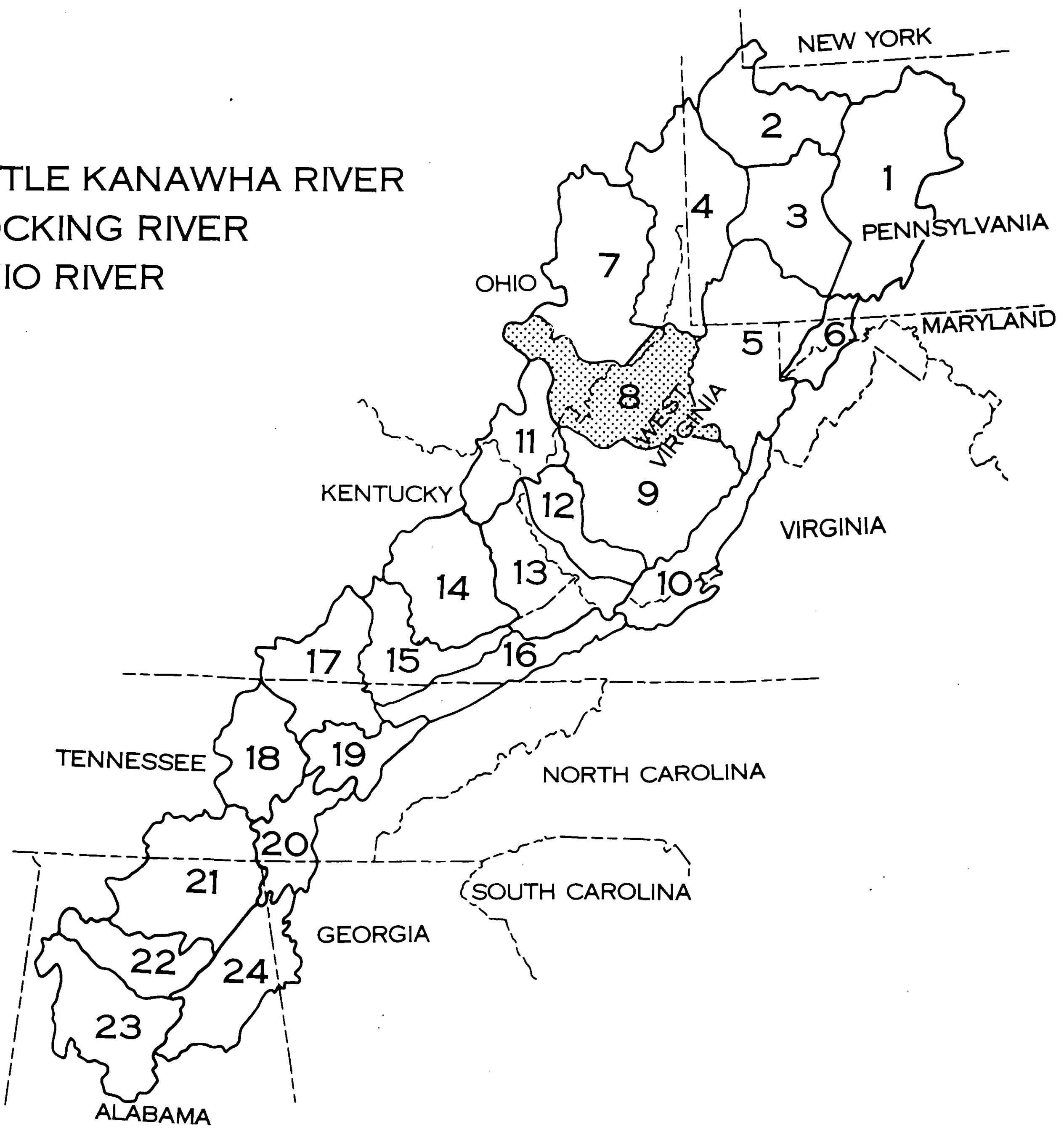
HYDROLOGY OF AREA 8, EASTERN COAL PROVINCE, WEST VIRGINIA AND OHIO

- LITTLE KANAWHA RIVER
- HOCKING RIVER
- OHIO RIVER



UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

WATER-RESOURCES INVESTIGATIONS
OPEN-FILE REPORT 84-463

HYDROLOGY OF AREA 8, EASTERN COAL PROVINCE, WEST VIRGINIA AND OHIO

BY
E. A. FRIEL, T. A. EHLKE, W. A. HOBBA, JR., S. M. WARD, AND R. A. SHULTZ

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LAKEWOOD, COLORADO
JANUARY 1987

DEPARTMENT OF THE INTERIOR

DONALD PAUL HODEL, *SECRETARY*

UNITED STATES GEOLOGICAL SURVEY

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Charleston, West Virginia 25301

CONTENTS

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

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

Multiply	By	To obtain
inch (in.)	25.4	millimeter (mm)
inch per hour (in/h)	25.4	millimeter per hour (mm/h)
	2.54	centimeter per hour (cm/h)
foot (ft)	0.3048	meter (m)
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
mile (mi)	1.609	kilometer (km)
acre	4,047	square meter (m^2)
square mile (mi^2)	2.590	square kilometer (km^2)
gallon per minute (gal/min)	0.00378	cubic meter per minute (m^3/min)
million gallon per minute (Mgal/d)	0.04381	cubic meter per second (m^3/sec)
	3,785	cubic meter per day (m^3/d)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
cubic foot per second per square mile [(ft^3/s)/mi^2]	0.01093	cubic meter per second per square kilometer [(m^3/s)/km^2]
ton, short	0.9072	megagram (Mg)
ton per square mile per year [(ton/mi^2)/yr]	0.3503	megagram per square kilometer per year [(Mg/km^2)/a]
degree Fahrenheit (°F)	°C=5/9 (°F−32)	degree Celsius (°C)
micromho per centimeter at 25° Celsius (μmho/cm)	1.000	microsiemens per centimeter at 25° Celsius (μS/m)

Sea level: In this report ''sea level'' referes to the 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 of 1929.''

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ABSTRACT

This report presents general hydrologic information about Area 8, in the Eastern Coal Province, for use by hydrologists, consulting engineers, mine operators, and regulatory personnel. The report format consists of brief texts and supporting illustrations and tables on a series of hydrologic topics which together describe the hydrology of the area.

Area 8 is located in the Upper Ohio River main-stem drainage and is one of the 24 hydrologic areas in the Eastern Coal province of the United States. It lies within the Appalachian Plateaus (Kanawha section) and Central Lowlands (Till Plains section) physiographic provinces and includes about 5,960 square miles in southeastern Ohio and northwestern West Virginia. The study area includes the Hocking River, Little Kanawha River, Shade River, Middle Island Creek, Fishing Creek, and other Ohio River tributaries. Sedimentary rocks of Mississippian, Pennsylvanian, and Permian age crop out in the area. The major rock units from oldest to youngest are the Mississippian, undivided rocks (including the Maxville Limestone), the Allegheny Formation and Pottsville Group, the Conemaugh Group, the Monongahela Group, and the Dunkard Group. Coal is present in the Pennsylvanian and Permian Systems.

About 61 percent of the land is covered by forest, and most of the remaining land is pasture and cropland. Only about 2 percent of the land has been affected by mining. Land slope ranges from relatively level floodplains to steep hillsides (4,200 feet per mile). Stream-channel slopes range from about 1 foot per mile to greater than 40 feet per mile. There is a wide range of soil types (29 soil associations) that are grouped in five land-resource areas.

Annual precipitation averages about 41 inches and ranges from about 37 inches along the western edge of the area to about 60 inches along the eastern edge of the area. Average air temperatures range from about 35°F in winter to about 72°F in summer. Estimated water use in the area during 1980 was 1,170 million gallons per day of which 90 percent was for power generation. Coal production during 1980 was about 1 million tons from 26 surface mines and about 6.7 million tons from 6 underground mines.

Surface-water data are available for 158 locations in the area. Streamflow and water quality are influenced by geology, climate, size of drainage area, regulation, land use, and water use. The mean-annual runoff ranges from about 13 inches in the Hocking River basin to about 29 inches in the headwaters of the Little Kanawha River basin. The Ohio, Little Kanawha, and Hocking Rivers are partly controlled by dams to lessen flooding.

The median specific conductance of surface water in the area was 260 micromhos per centimeter and ranged from 41 to 4,035 micromhos per centimeter. The median pH was 7.3 and ranged from 2.9 to 8.1. The median alkalinity was 42 milligrams per liter and ranged from 0 to 290 milligrams per liter. Sulfate concentration ranged from 4.8 to 2,845 milligrams per liter, had a median value of 35.5 milligrams per liter, and was highest in mined areas. Total iron concentration ranged from 100 to 565,000 micrograms per liter, and had a median value of 630 micrograms per liter. The median concentration of dissolved manganese was 64 micrograms per liter and ranged from 10 to 5,100 micrograms per liter. Both concentrations of iron and manganese were found to be highest in mined areas. Estimated annual suspended-sediment yield ranged from 133 to 544 tons per square mile.

Well yields range from less than 1 to 350 gallons per minute. The most productive aquifers are the Allegheny Formation and Pottsville Group, Mississippian rocks, and unconsolidated alluvium. The most dominant types of ground water are bicarbonate and chloride. The pH ranges from 5.8 to 9.0. Ground water from the Mississippian rocks contains lesser amounts of dissolved solids than water from the Lower Pennsylvanian rocks. Water with high chloride content is present in some valley areas.

Hydrologic data are stored in central computer files and may be obtained from the National Water Data Storage and Retrieval System.

Area 8 Report Submitted in Support of Public Law 95-87

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

This report broadly characterizes the hydrology of Area 8 in southeastern Ohio and northwestern West Virginia. The hydrologic information available through identified sources, may be used in describing the hydrology of the "general area" of any proposed mine. Furthermore, it is expected that this hydrologic information will be supplemented by the lease applicant's specific site data as well as data from other sources to provide a more detailed picture of the hydrology of the area in the vicinity of the mine and the anticipated hydrologic consequences of the mining operation.

This report provides broad hydrologic information, by means of a brief text with an accompanying map, chart, graph, or other illustrations, for each of a series of water-resources-related topics. The summation of these discussions provides a description of the hydrology of the Coal Area 8. This information should be useful to surface-mine owners and operators and to consulting engineers for the preparation of permits, and to regulatory authorities in appraising the adequacy of permit applications.

A need for hydrologic information and analysis on a scale never before required nationally was initiated when the "Surface Mining Control and Reclamation Act of 1977" was signed into law as Public Law 95-87, August 3, 1977.

In recognizing the potentially adverse impact that coal mining may have on water resources, Public Law 95-87 requires (1) that each mining-permit applicant make an analysis of the potential effects of the proposed mine on the hydrology of the mine site and adjacent area, (2) that "an appropriate Federal or State agency" provide to each mining-permit applicant "hydrologic information on the general area prior to mining," and (3) that measures be taken by mining permittees to control adverse effects of mining on the "hydrologic balance" and reclamation of the land. Some typical aspects of surface mining such as (A) active surface mining, (B) reclaimed surface-mined area, (C) drainage from abandoned surface-mined area, and (D) drainage from an active surface-mine area are shown in figure 1.1-1.

View looking south.

View looking west.

View looking east.

A. Active surface mining.

View looking west.

View looking east.

View looking north.

B. Reclaimed surface-mined area.

View looking north.

C. Drainage from abandoned mines.

View looking north.

D. Drainage from an active mine.

Figure 1.1-1 Typical aspects of surface mining.

Area 8 is Located in Central Part of Eastern Coal Province

Area 8 is located in southeastern Ohio and northwestern West Virginia in 2 physiographic provinces and includes all or parts of 27 counties.

The Eastern Coal Province is divided into 24 hydrologic reporting areas. The divisions are based on hydrologic factors, location, size, and mining activity. Hydrologic units (drainage basins) or parts of units are combined to form each area (fig. 1.2-1).

Area 8 is in the central part of the Eastern Coal Province in southeastern Ohio and northwestern West Virginia. The western tip of the area is in the Central Lowlands (Till Plains section) physiographic province which is characterized by young till plains where morainic topography is rare. The remainder of the area is in the Appalachian Plateaus (Kanawha section) province (fig. 1.2-2) which is characterized by mature plateau with moderate to strong relief (Fenneman, 1964). The area includes parts of Monroe, Washington, Fairfield, Hocking, Perry, Morgan, Athens, Meigs, and Galia Counties in Ohio and parts or all of Marshall, Wetzel, Tyler, Doddridge, Pleasants, Ritchie, Lewis, Upshur, Webster, Braxton, Gilmer, Clay, Calhoun, Roane, Wirt, Wood, Jackson, and Mason Counties in West Virginia. The area lies within the Ohio River basin and covers approximately 2,020 mi^2 in Ohio and approximately 3,940 mi^2 in West Virginia. The Ohio River is the boundary between Ohio and West Virginia. The 1980 population of about 395,000 is concentrated in cities along the major streams. The major cities are Athens, Lancaster, and Logan, Ohio; Parkersburg, Vienna, and New Martinsville, W. Va.

The major natural resources of the area include petroleum, natural gas, coal, timber, and brine. Coal mining in the area includes both surface and underground mining and is confined primarily to Hocking, Meigs, Monroe, and Perry Counties in Ohio and Braxton, Gilmer, Lewis, and Mason Counties in West Virginia.

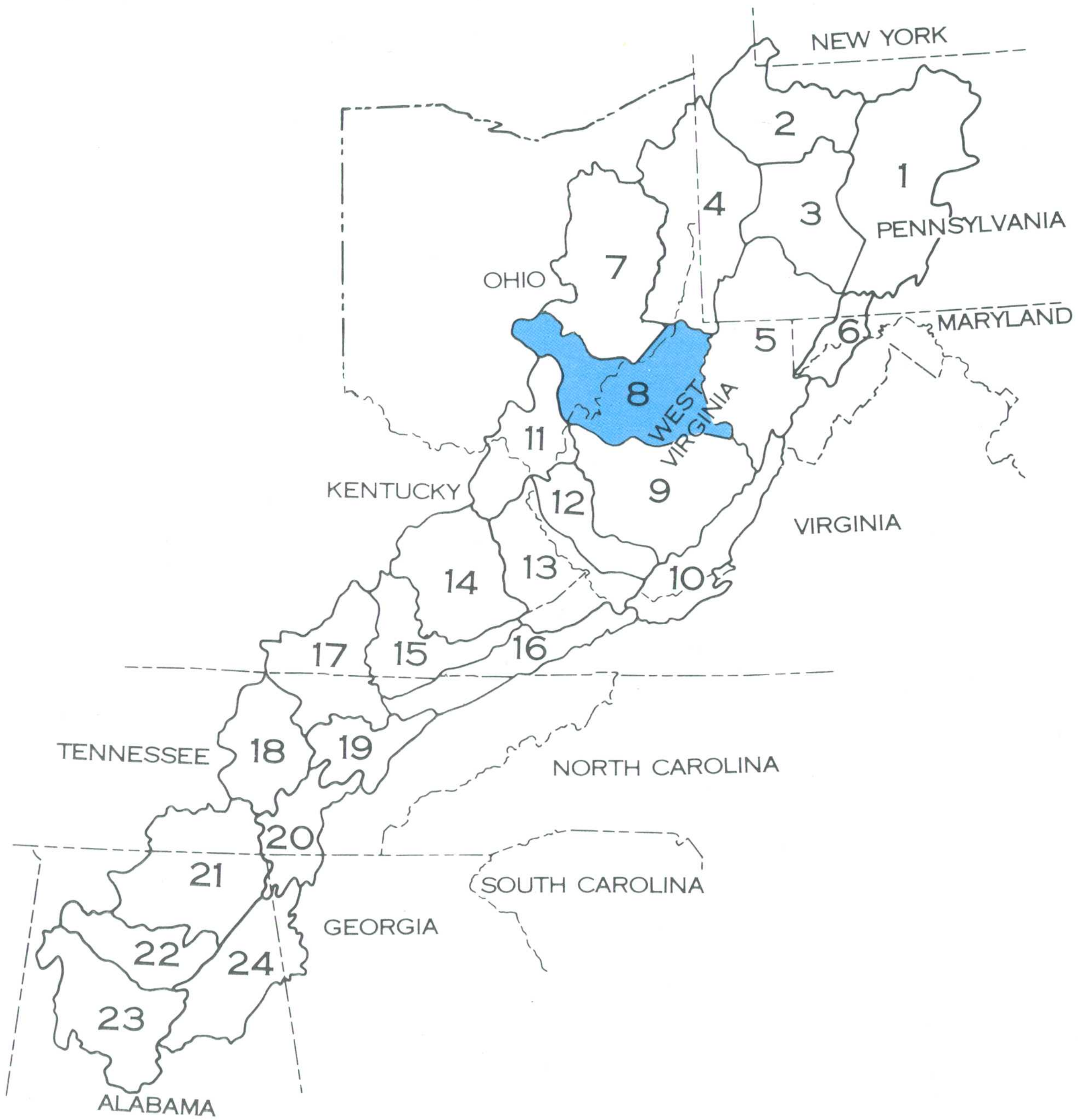
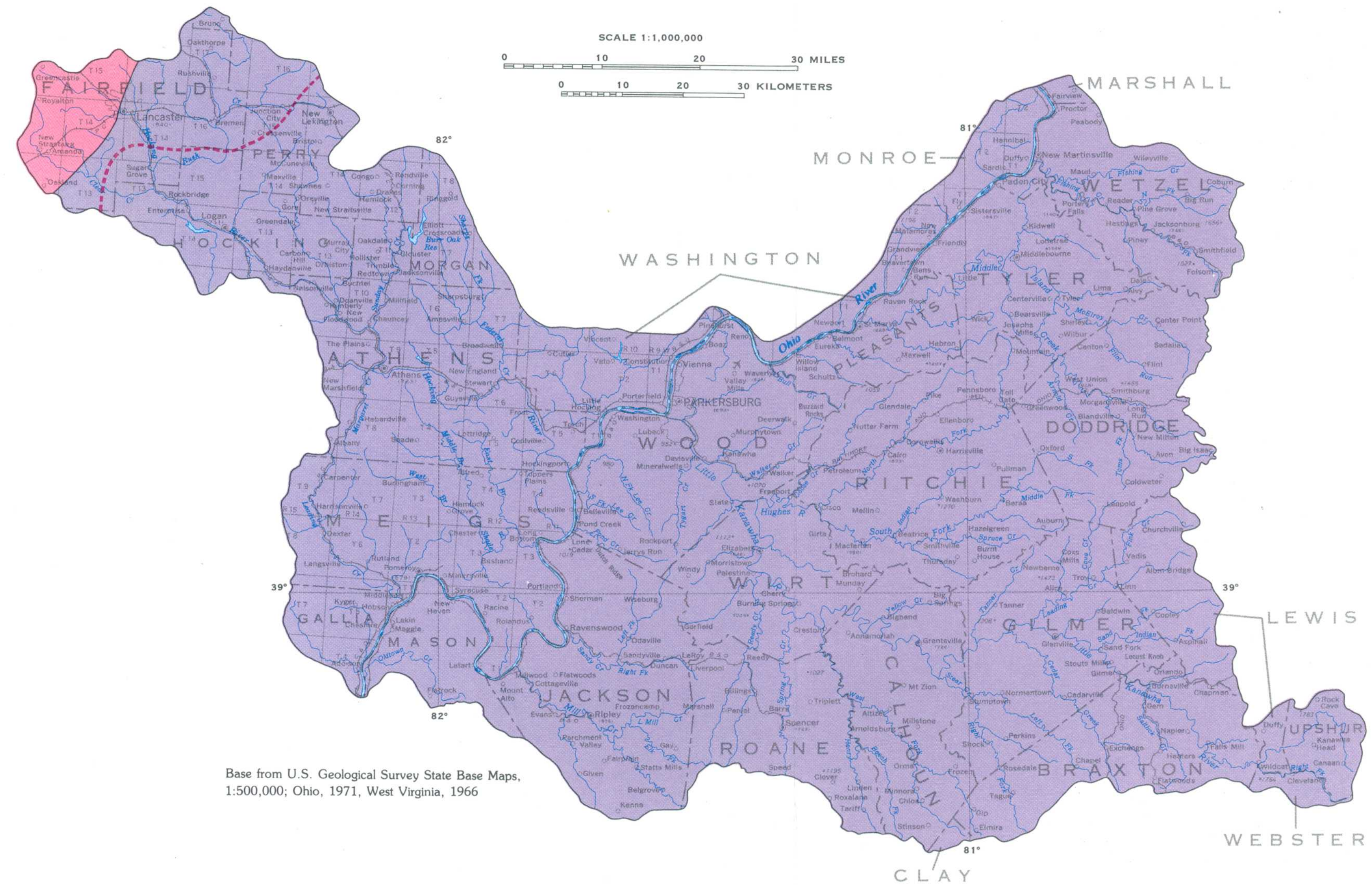


Figure 1.2-1 Location of Area 8 in Ohio and West Virginia in the Eastern Coal Province.



EXPLANATION

PHYSIOGRAPHIC PROVINCE

- Central Lowlands (Till Plains section)
- Appalachian Plateaus (Kanawha section)
- Southern limit of continental glaciation

Figure 1.2-2 Physiographic provinces in Area 8.

2.0 GENERAL FEATURES
2.1 Surface Drainage

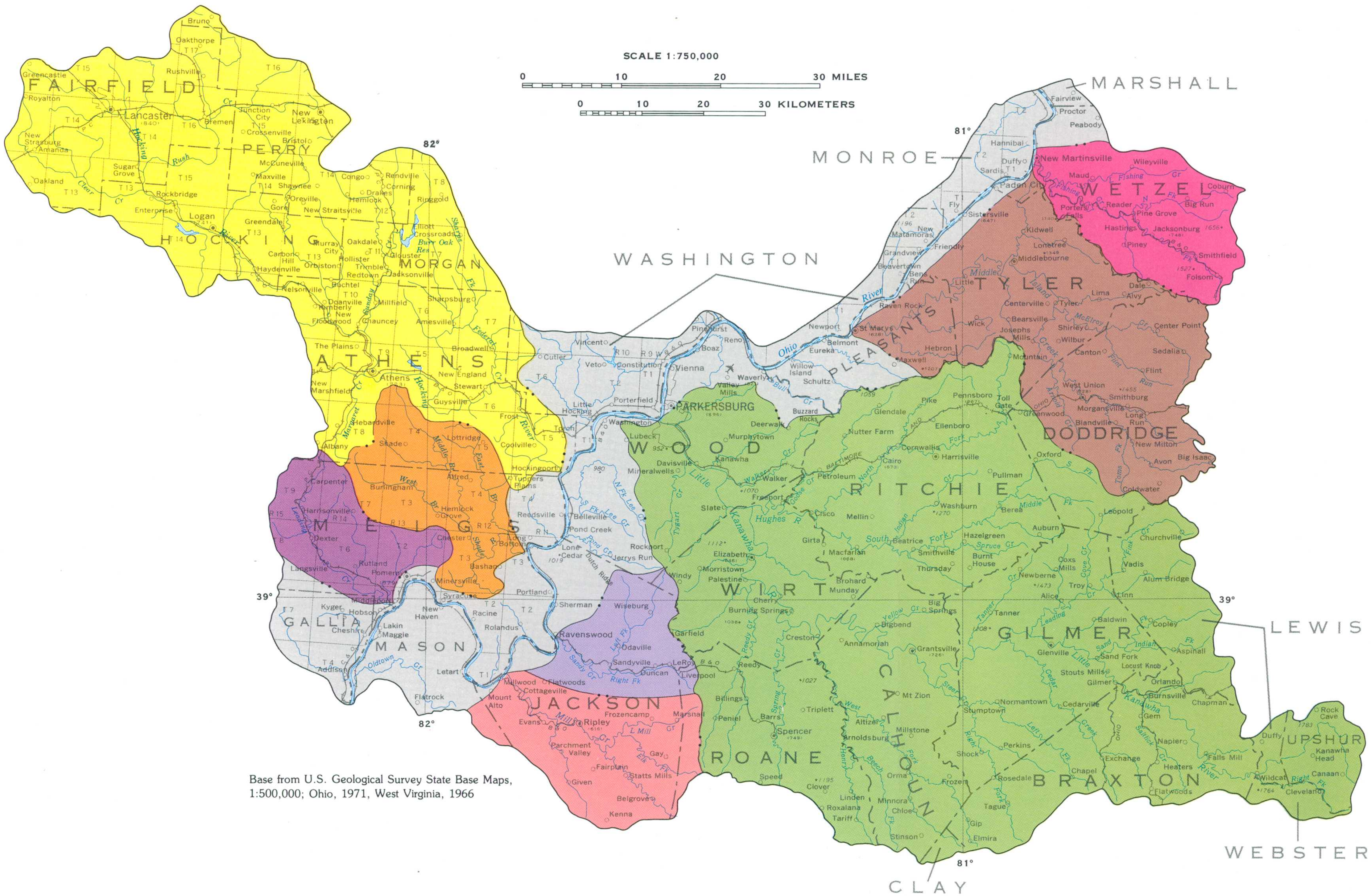
Upper Ohio River Main Stem Drains Area

Area 8 is drained by tributaries of the Ohio River in West Virginia and Ohio. Two major tributaries of the Ohio River—the Little Kanawha River in West Virginia (2,309 square miles), and the Hocking River in Ohio (1,197 square miles)—drain 59 percent of Area 8.

Area 8 has a surface area of about 5,960 mi^2 (square miles). Approximately 3,940 mi^2, two-thirds of the area, are in West Virginia and approximately 2,020 mi^2 are in Ohio. About 146 miles of the upper Ohio River main stem bisects the area and is the state boundary between Ohio and West Virginia. The northern boundary of Area 8 intersects the Ohio River main stem 3.5 miles upstream from Proctor, W. Va. The southern boundary intersects the Ohio River main stem 3.0 miles downstream from Addison, W. Va.

The major tributaries within the area are the Little Kanawha River, which drains 2,309 mi^2 of West Virginia, and the Hocking River, which drains 1,197 mi^2 of Ohio. Both of these rivers drain about 59 percent of each State within Area 8 and are the longest rivers in the area. The Little Kanawha River is 160 miles long, flows to the northwest, and enters the Ohio River at Parkersburg, W. Va. The Hocking River is 100 miles long, flows to the southeast, and enters the Ohio River at Hockingport, Ohio, 14.7 miles downstream from Parkersburg, W. Va. Stream density (miles of stream per square mile) for the Little Kanawha River at Grantsville, W. Va. (drainage area 913 mi^2) is 2.40, and the stream density for the Hocking River at Athens, Ohio (drainage area 944 mi^2) is 2.29 (Langbein and others, 1947).

Some of the larger West Virginia tributaries of the Ohio River are Fishing Creek, Middle Island Creek, Sandy Creek, and Mill Creek. Some of the larger tributaries in Ohio are the Shade River and Leading Creek. The surface drainage network is shown in figure 2.1-1. Drainage areas for specific sites are given in section 9.1.



EXPLANATION

MAJOR TRIBUTARY		BASIN DRAINAGE AREA, IN SQUARE MILES
1	Fishing Creek	220
2	Middle Island Creek	563
3	Little Kanawha River	2309
4	Hocking River	1197
5	Shade River	221
6	Sandy Creek	115
7	Mill Creek	230
8	Leading Creek	150
9	Minor Ohio River tributaries	955

—·· — Drainage boundary

Figure 2.1-1 Major tributaries in Area 8.

Five Major Rock Units are Exposed in Area

The strata exposed in Area 8 represent five rock units within the Mississippian, Pennsylvanian, and Permian Systems. No coal is found in the Mississippian rocks

The rock strata are generally downwarped near the center of the area and upward near the eastern and western boundaries of the area. Numerous gentle folds trending to the northeast are superimposed on this "synical" structure. Thus, even though the Ohio River flows through the lowest part of the area, its channel lies in the youngest rock in the area.

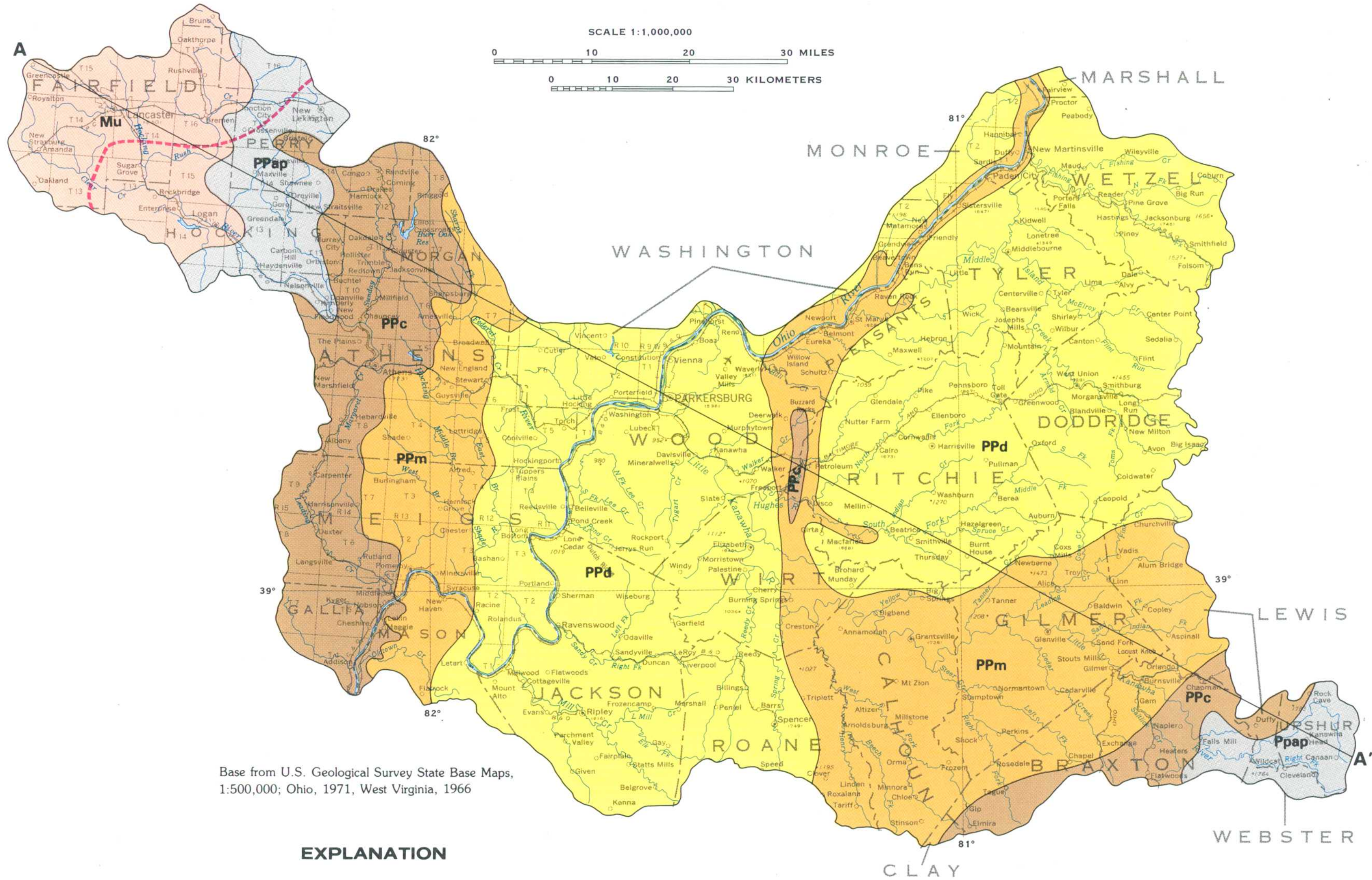
The coal resources of Area 8 are found in the Pennsylvanian and Permian Systems[1] (fig. 2.2-1). Thus, coal underlies all of Area 8 except the extreme western part that is underlain by rocks of Mississippian age.

The undifferentiated rocks of the Mississippian System are primarily massive sandstone, siltstone, shale, and the Maxville Limestone (in Ohio). This part of the study area has been subjected to glaciation; therefore, parts of the area are underlain, by as much as 180 feet of sand, gravel, clay, or till deposits of the Pleistocene and Holocene Epochs. Because the Mississippian System does not contain coal beds, it is not shown in the stratigraphic column in figure 2.2-2.

The Pennsylvanian System, in order of increasing age, is composed of the lower part of the Dunkard Group, the Monongahela Group, the Conemaugh Group, and the Allegheny Formation and Pottsville Group in West Virginia. The Monongahela, Conemaugh, and Pottsville are formation rank in Ohio. These rocks contain the bulk of the coal beds in Area 8 (fig. 2.2-2). In addition to coal these formations contain beds of sandstone, shale, limestone, and clay. West of the Ohio River, the beds generally dip to the southeast at about 30 feet per mile. East of the River, the rocks undulate, but the general dip is to the northwest.

More detailed geologic maps are available for Ohio (Brownocker, 1981) and West Virginia (Cardwell, 1968).

[1] Geologic names are those used by the West Virginia Geological and Economic Survey, and do not necessarily conform to those used by the U.S. Geological Survey.



Base from U.S. Geological Survey State Base Maps, 1:500,000; Ohio, 1971, West Virginia, 1966

Generalized geology modified from Ohio River Basin Commission, 1978, Map 503-17.

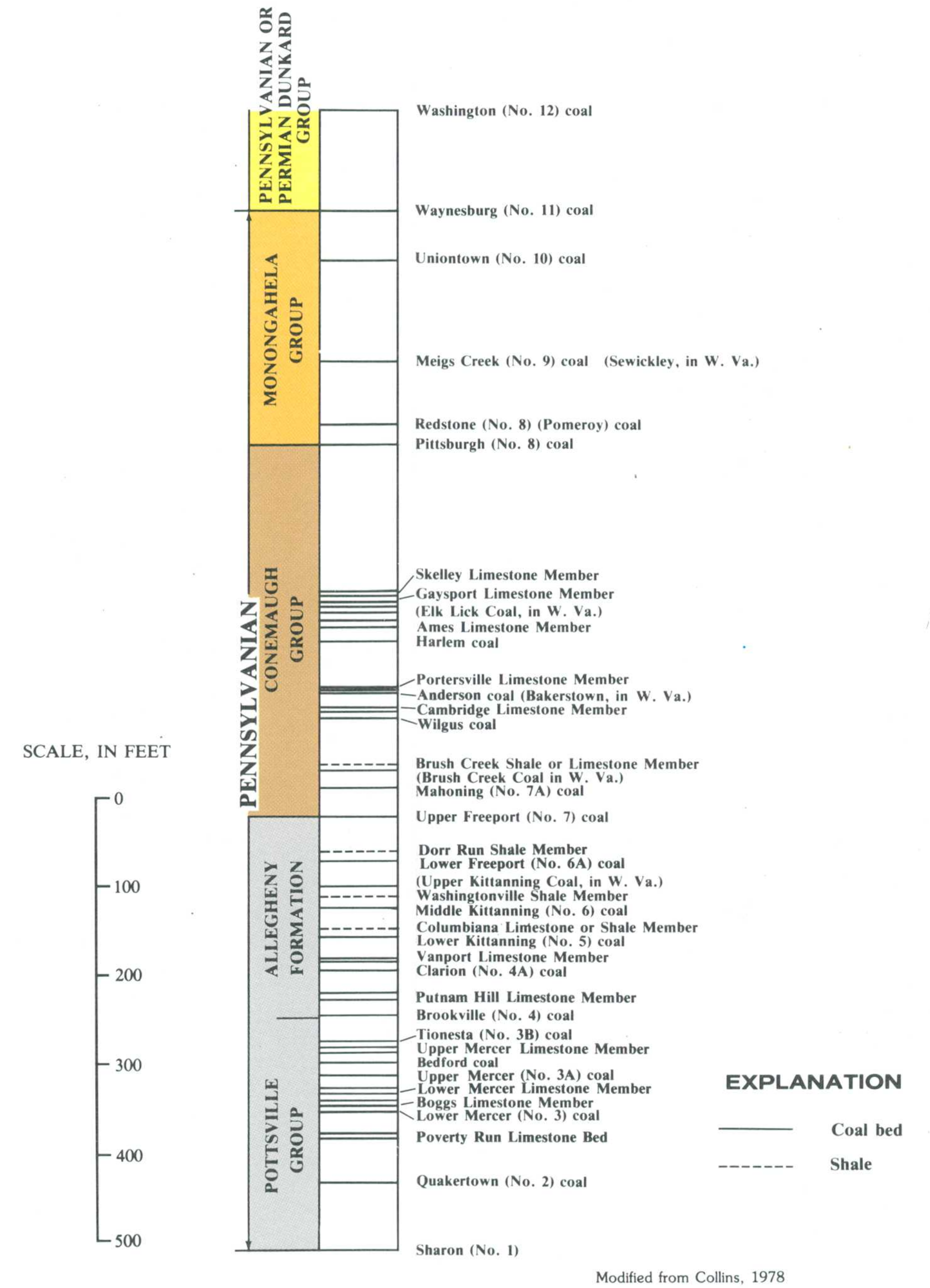
EXPLANATION

AGE		GENERALIZED GEOLOGY	THICKNESS, IN FEET
PERMIAN OR PENNSYLVANIAN	PPd	Dunkard Group: Shale, sandstone, limestone, and coal	0-1150
PENNSYLVANIAN	PPm	Monongahela Group: Shale, sandstone, limestone, and coal	0-450
	PPc	Conemaugh Group: Sandstone, shale, limestone, and coal.	0-550
	PPap	Allegheny Formation and Pottsville Group: Sandstone conglomerate, shale, and coal.	0-550
MISSISSIPPIAN	Mu	Sedimentary rocks, undivided: Siltstone, shale, sandstone, glacial deposits (Pleistocene age), and Maxville Limestone	0-700

Note: Geologic names are those used by the West Virginia Geological and Economic Survey, and do not necessarily conform to those used by the U.S. Geological Survey. The Monongahela, Conemaugh, and Pottsville are formation rank in Ohio.

Geologic contact

Glacial boundary



Modified from Collins, 1978

Figure 2.2-2 Stratigraphic positions of coal beds in Area 8.

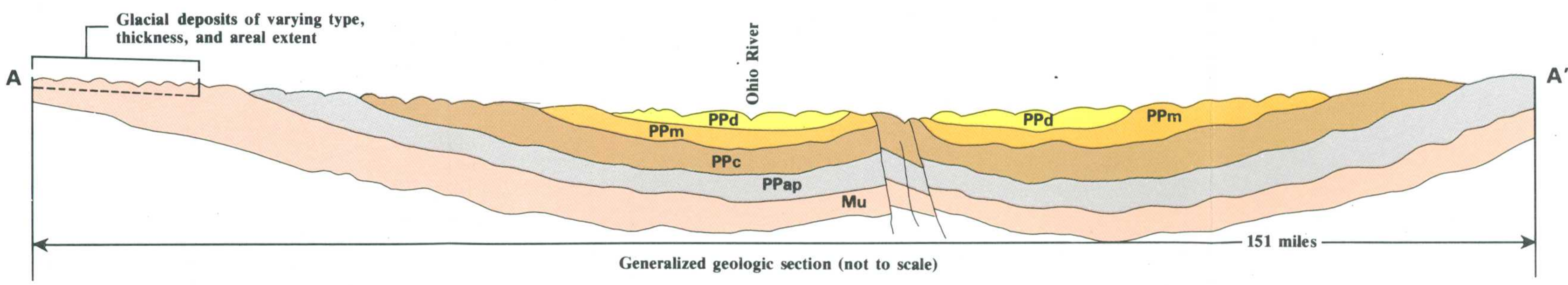


Figure 2.2-1 Generalized geology.

Slope Ranges from Steep Hillsides Along Narrow Ravines and Ridges to Gentle Rolling Hills

Most of Area 8 has average land slopes in excess of 1,000 feet per mile. Land slopes are greatest in Wetzel, Calhoun, Gilmer, and Clay Counties. Gentle slopes are found in alluvial terraces and where the land was once glaciated.

The topography in Area 8 is characterized by steep hillslopes along narrow ravines and ridges to gentle rolling hills. Most of Area 8 has average slopes in excess of 1,000 ft/mi (feet per mile). Land slope is greatest in Wetzel, Calhoun, Gilmer, and Clay Counties in West Virginia, as shown in figure 2.3-1. The maximum land slopes are about 4,200 ft/mi, and level land is found on floodplains along narrow streams. Areas with an average slope in excess of about 1,300 ft/mi are unsuitable for farming or construction. In these areas, forest land is the major land use.

The gentlest land slopes are found in parts of Fairfield, Morgan, and Perry Counties in Ohio. Relatively flat alluvial terraces lie along the Ohio River and the lower reaches of its major tributaries. Agriculture is the main land use in these areas. Perry and Morgan Counties are the only counties with more agricultural land than forest.

Average land slopes are steeper in West Virginia than in Ohio. The average land slope in the Little Kanawha basin above Grantsville, W. Va., is about 1,670 ft/mi. The average land slope in the Hocking River basin above Athens, Ohio, is about 740 ft/mi (Langbein and others, 1947).

Stream-channel slope [1] was obtained by measuring the distance on topographic maps between altitude contours at the points where they intersected the streams. The channel slope was then divided into five categories (figure 2.3-2). It is generally greatest in the areas of greatest relief. The steepest channel slopes are found on the Ohio River tributaries in Washington and Monroe Counties and in the headwaters of the Little Kanawha River basin.

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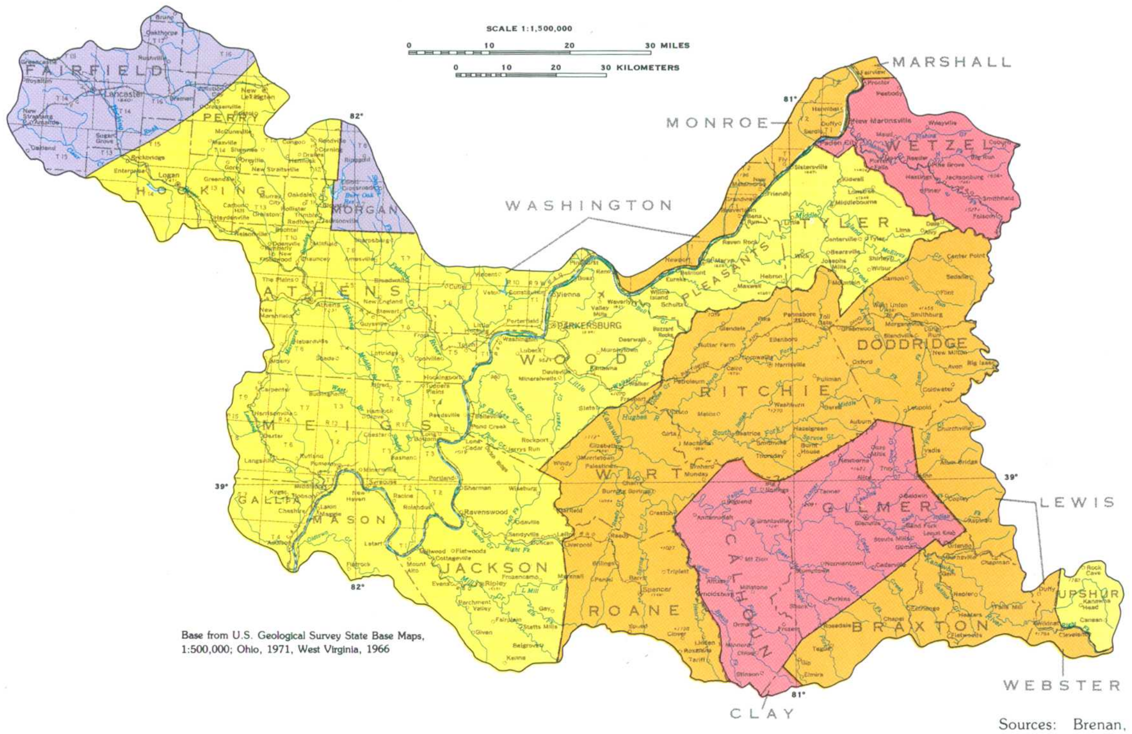
[1] The drop of the channel, in feet, relative to distance along the channel.



Base from U.S. Geological Survey State Base Maps, 1:500,000; Ohio, 1971, West Virginia, 1966

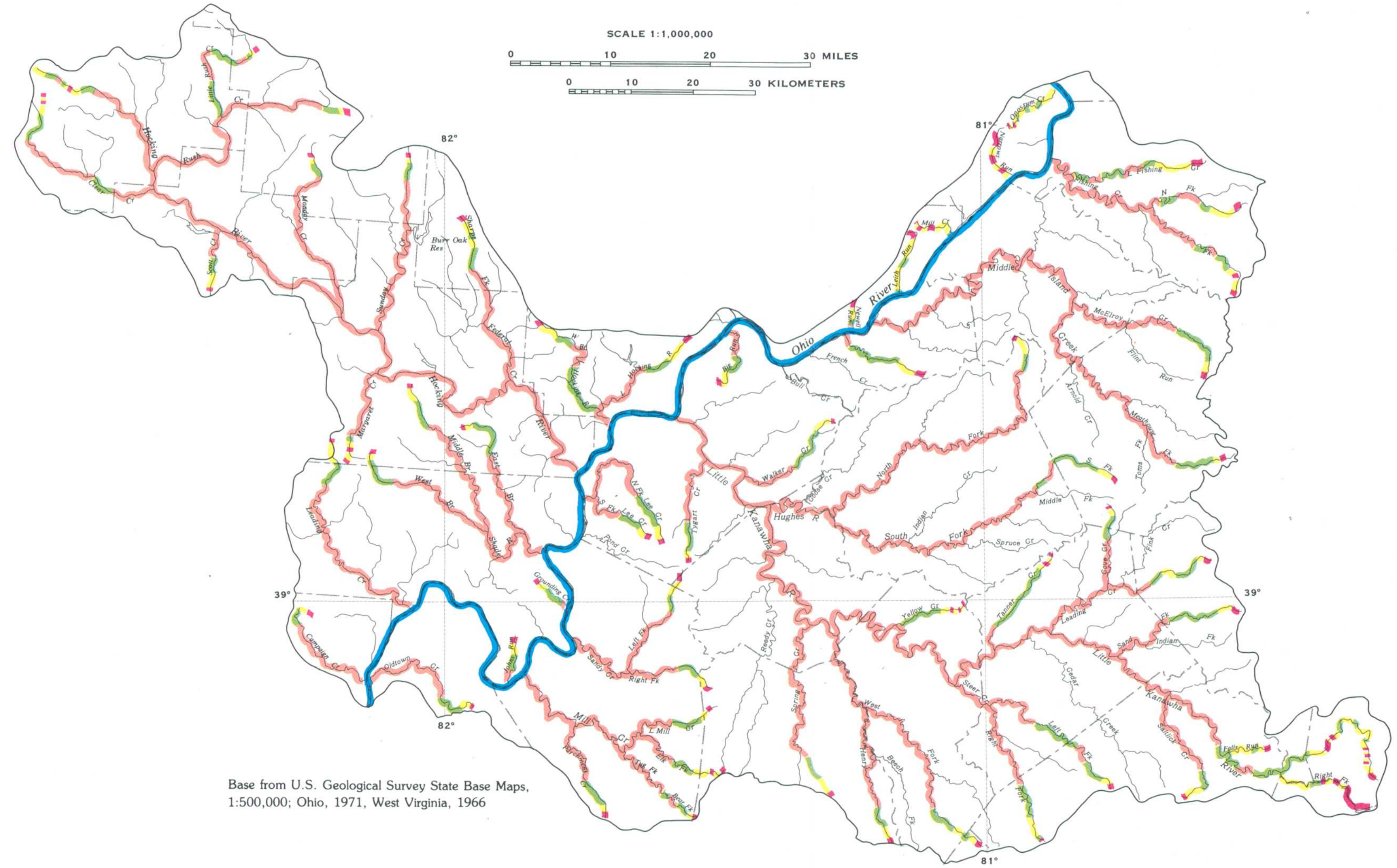
Sources: Brenan, 1981; Langbein and others, 1947.
Land slopes for West Virginia are county-wide averages.

EXPLANATION

LAND SLOPE, IN FEET PER MILE

- Less than 1000
- 1000-1449
- 1450-1800
- Greater than 1800

Figure 2.3-1 Average land slope.



Base from U.S. Geological Survey State Base Maps, 1:500,000; Ohio, 1971, West Virginia, 1966

EXPLANATION

CHANNEL SLOPE, IN FEET PER MILE

- Less than 1
- 1-10
- 10-30
- 30-100
- Greater than 100

Figure 2.3-2 Channel slope.

Soils in Five Land-Resource Areas in Area 8 are Formed Over Shale, Sandstone, Siltstone, Limestone, and Coal

Soils in Area 8 are derived from five rock types. Numerous soil types comprise 29 soil associations and are grouped in five land-resource areas.

There are numerous soil types comprising 29 soil associations within Area 8. The nomenclature for these soil associations varies by state, although they can be grouped into five land-resource areas (LRA) (U.S. Department of Agriculture, 1981). A land-resource area is a geographic area characterized by a unique combination of soils, slope, erosion characteristics, climate, vegetation, water resources, and land use.

The distribution of the 29 soil associations and five land-resource areas is shown in figure 2.4-1. The individual soils maps of each state use different series concepts, and association names do not agree. Therefore, it may be difficult to compare soils within a land-resource area involving more than one state. More detailed data on soils can be obtained from soil surveys of the individual counties of Ohio and West Virginia prepared by the Soil Conservation Service.

The five land-resource areas are: Indiana and Ohio Till Plain Association (LRA 111), Western Allegheny Plateau Association (LRA 124), Central Allegheny Plateau Association (LRA 126), Eastern Allegheny Plateau and Mountains Association (LRA 127), and Eastern Ohio Till Plain Association (LRA 139).

Soils of the Central Allegheny Plateau Land-Resource Area (LRA 126) cover about 85 percent of Area 8. These soils are formed over rocks of the Dunkard Group and Monongahela Group (fig. 2.2-1), which are composed of shale, sandstone, limestone, and coal. This land-resource area covers nearly all of the West Virginia part of Area 8 with the exception of the extreme southeastern part, which is covered by soils of the Eastern Allegheny Plateau and Mountains Association (LRA 127). These soils are formed over rocks of the Allegheny Formation and Pottsville Group, which are comprised of sandstone, conglomerate, shale, and coal. The Central Allegheny Plateau Land-Resource Area (LRA 126) extends into Ohio, and covers nearly all of the drainage to the east of Sandy Creek and Margaret Creek near Athens, Ohio.

Soils of the Western Allegheny Plateau Association (LRA 124) are in the northwest section of Area 8 in the upper Hocking River drainage, northwest of Athens, Ohio. These soils are formed over rocks of the Conemaugh Group, the Allegheny Formation and Pottsville Group, and undivided Mississippian rocks consisting of siltstone, shale, sandstone, Maxville Limestone, and glacial deposits. Soils of the Indiana and Ohio Till Plain Association (LRA 111) and Eastern Till Plain Association (LRA 139) are in the extreme northwestern section near Lancaster, Ohio. These soils are formed over undivided Mississippian rocks including the Maxville Limestone. The southern boundary of the Eastern Till Plain Association (LRA 139) coincides closely with the southern limit of continental glaciation.

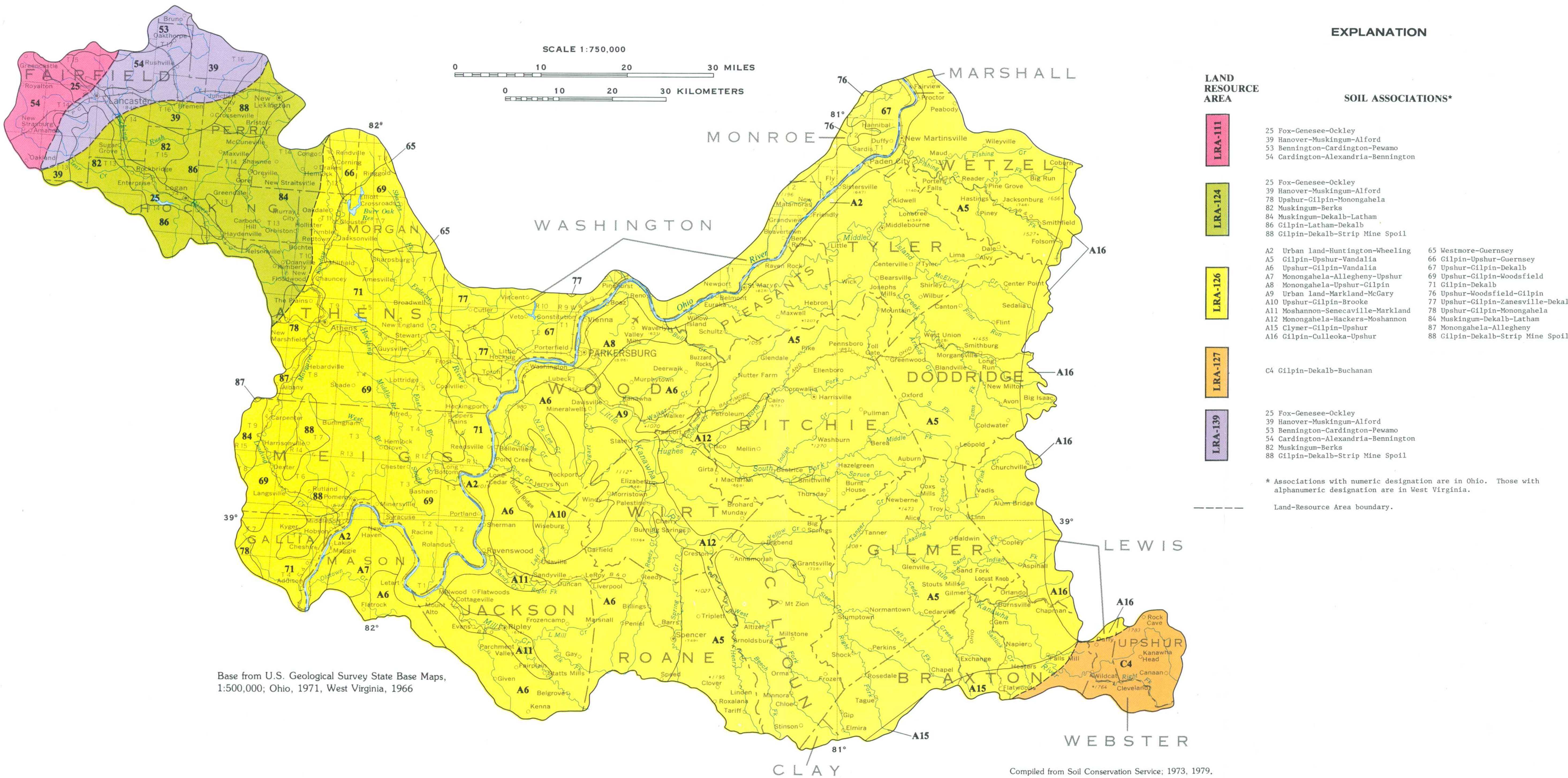


Figure 2.4-1 Soil associations and land-resource areas.

Area has a Continental Climate

Geography and topography cause Area 8 to have a continental climate; average temperatures range from the mid-30's in winter to the low 70's in summer. Average annual precipitation is about 41 inches.

The two most important influences on the climate in Area 8 are geography and topography. The area lies too far inland to be influenced significantly by the Atlantic Ocean, and, therefore, has a continental climate. There are four distinct seasons, with a moderately severe winter climate and warm, showery weather in the summer. Variations of these general climatic features are influenced by the rugged topography.

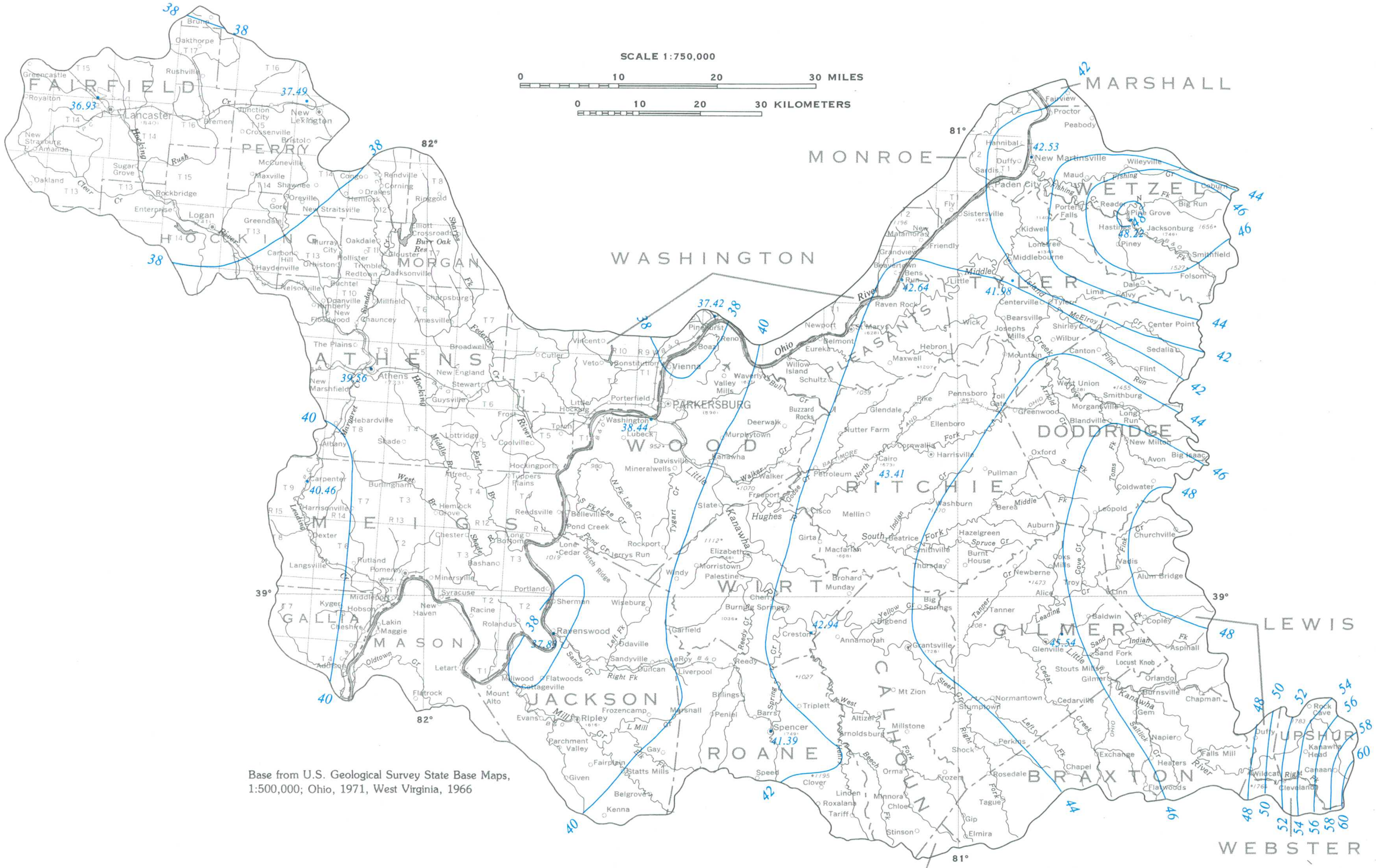
Average monthly temperatures range from the mid-30's in winter to the low 70's in summer. Differences in average temperature within the area are the result of topography; the higher elevations, such as the extreme eastern part of the area, average a few degrees cooler than the lower elevations. Figure 2.5-1 shows the average monthly temperatures for the area during the period 1941-70. Cold waves with near or subzero temperatures occur on an average of three times each winter, but as a rule do not last more than 2 or 3 days. Parkersburg, W. Va., recorded a low of −27°F in February 1899. Hot and humid weather, sometimes lasting two weeks, occurs infrequently when warm, humid air flows northward from the Gulf of Mexico. Temperatures near or over 100°F have been recorded at all observation stations in the area. Parkersburg reached a high of 106°F in August 1918.

Annual precipitation during the period 1941-70 averaged about 41 inches, whereas amounts at recording stations ranged from 36.93 inches near Lancaster, Ohio, to 48.22 inches at Hastings, W. Va. Figure 2.5-2 shows that precipitation increased eastward across Area 8 from about 37 inches to about 60 inches. As the rain and snow-producing atmospheric currents move eastward into the higher elevations, they are subjected to orographic lifting, are cooled, and cannot hold as much moisture. The effect is to intensify precipitation. July ranks as the wettest month and October the driest, as shown by figure 2.5-3.

The amount of snowfall varies with elevation. The heaviest snowfalls occur in the extreme eastern part of the area, where annual amounts exceeding 65 inches are not uncommon. Snowfall in the rest of the area ranges from about 20 inches in the southern part to about 25 to 30 inches in the northern and western parts.

During the 17-month period of April 1979 to August 1980, five recording stations with long-term records received an average of 75 inches of precipitation—approximately 13 inches above normal. The highest amount of precipitation occurred during July 1980, whereas the least amount occurred during February 1980.

These data were taken from publications of the National Oceanic and Atmospheric Administration (1973a, 1973b, 1977, and 1978).



Base from U.S. Geological Survey State Base Maps, 1:500,000; Ohio, 1971, West Virginia, 1966

Data compiled from National Oceanic and Atmospheric Administration 1973a, 1973b, 1977, and 1978. Interpretation of data by U.S. Geological Survey.

EXPLANATION

40 —— 40 Line of equal precipitation, in inches

Figure 2.5-2 Average annual precipitation, 1941-70.

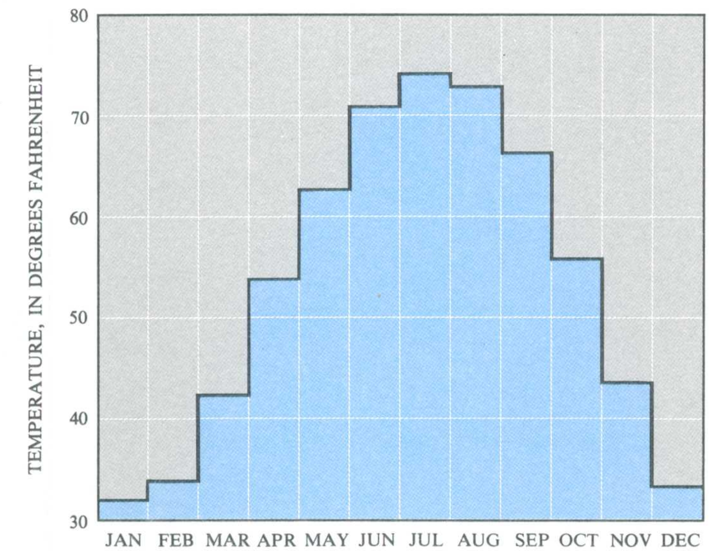


Figure 2.5-1 Average monthly temperature, 1941-70.

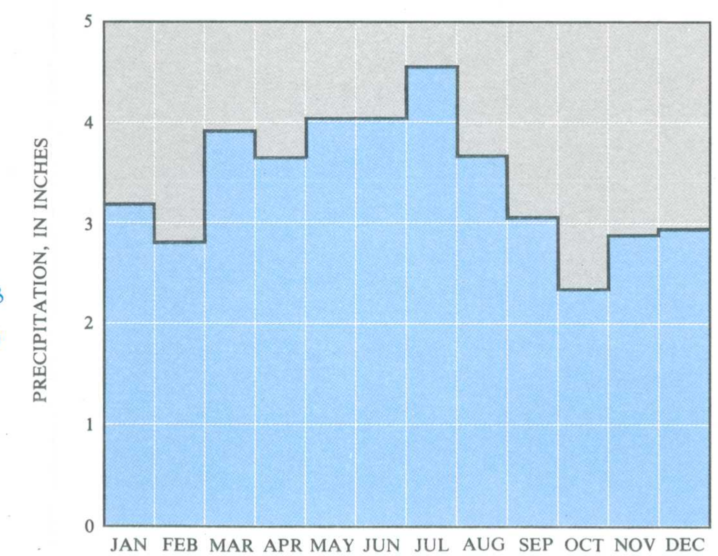


Figure 2.5-3 Average monthly precipitation, 1941-70.

Land in Area is Largely Forested

About 61 percent of the land in Area 8 is forested. Agricultural land, including cropland and pasture, composes most of the remaining area. About 2 percent of the land has been affected by mining.

In 1967 the U.S. Soil Conservation Service made an inventory of land use; the land was categorized into cropland, pasture, forest, other rural land, Federal non-cropland[1], urban and built-up, and small water bodies[2]. Table 2.6-1 shows the amount of each category by county. Because the land-use figures are for whole counties, and many of the counties do not lie entirely within Area 8, a column showing the percentage of each county within Area 8 is included.

Land use is strongly influenced by the topography and availability of mineral resources. Land with an average slope in excess of 1,300 ft/mi (feet per mile) is difficult to farm or build on. All counties within Area 8 in West Virginia except Wood, Jackson, Mason, and Upshur have average land slopes in excess of 1,300 ft/mi. Average land slope in Ohio is generally less than 1,300 ft/mi, which may explain why counties in Ohio average higher percent urban and built-up land (4.8 percent) than those in West Virginia (2.3 percent).

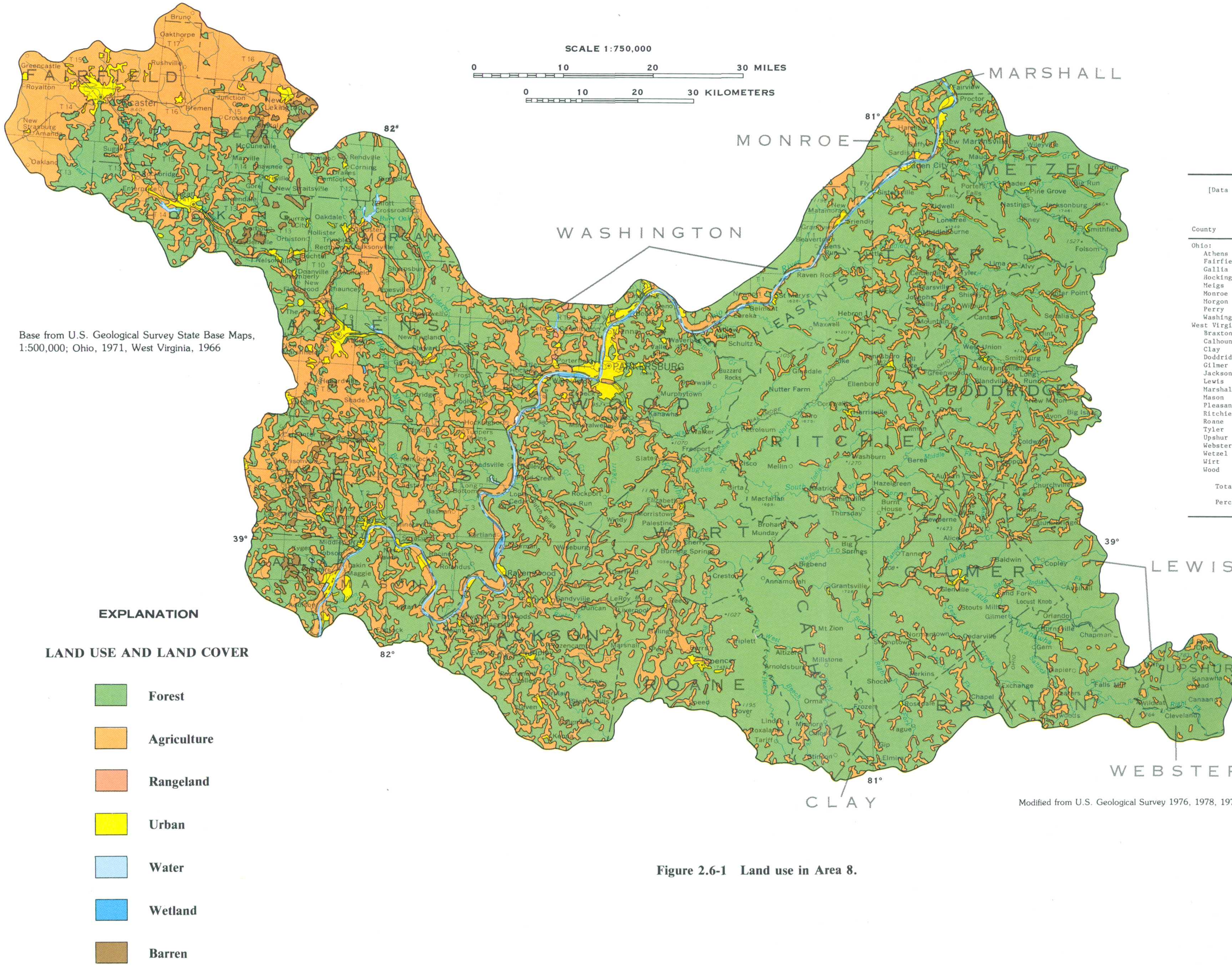
The majority of the land in the area, about 61 percent, is forested. Pleasants, Wetzel, Calhoun, Gilmer, Clay, and Webster Counties are over 75 percent forested. Agriculture, including cropland and pasture, covers most of the remaining area, about 27 percent. It is estimated that only about 2 percent of the land in Area 8 has been affected by mining—about 0.1 percent in West Virginia and about 4 percent in Ohio. Fairfield and Morgan Counties in Ohio are the only counties with higher percentages of agriculture than forest. Cropland covers about 64 percent of Fairfield County. Cropland and pasture combined make up about 48 percent of Morgan County. Urban and built-up, federal non-cropland, other rural, and small water bodies (less than 40 acres) make up the remaining 9 percent of land use.

The extent of oil and gas activities in the area is not well known. Although some records have been kept by the West Virginia Geological and Economic Survey since the turn of the century, well permits and records have been required by law only since 1929. The West Virginia Geological and Economic Survey has a data base on wells in West Virginia, and it was estimated in 1972 that the locations of about half the wells drilled since 1860 were known. Bain and Friel (1972, p. 113) show an oil and gas well density map for the Little Kanawha River basin from about 1900 to 1968. Data from Patchen (1982), shows an average of 349 oil and gas well completions per year for Area 8 in West Virginia during the 1970's. Countywide figures were used without regard to the amount of each county within Area 8. Drilling information in Ohio was unavailable.

Land use in Area 8 has been mapped by the U.S. Geological Survey from color infrared photography taken from 1972 to 1978 (U.S. Geological Survey, 1976, 1978, 1979a, 1980b). The maps are at a scale of 1:250,000 and delineate land use and cover into nine major categories, which are further subdivided into 37 minor categories. Figure 2.6-1 shows the extent of the major categories found in Area 8. Areal units smaller than 10 acres are not included. The West Virginia Geological and Economic Survey has summarized the U.S. Geological Survey maps for West Virginia (West Virginia Geological and Economic Survey, 1979 and 1980) showing acreage and percentage of land use by county.

Rangeland, wetland, and barren land are categories shown in figure 2.6-1, but are not included in table 2.6-1. Rangeland and wetland comprise less than 1 percent of the total area. Barren land consists mostly of surface mines, but also includes gravel pits, quarries and transitional areas. Land-use statistics from the West Virginia Geological and Economic Survey (1979 and 1980) show there are less than 1,000 acres of barren land in Area 8 in West Virginia. Data on the area of barren land in Ohio were unavailable.

[1] Land not used for crops.
[2] Less than 40 acres



Base from U.S. Geological Survey State Base Maps, 1:500,000; Ohio, 1971, West Virginia, 1966

Modified from U.S. Geological Survey 1976, 1978, 1979a, 1980b.

Figure 2.6-1 Land use in Area 8.

Table 2.6-1 Land use, by county

[Data from U.S. Soil Conservation Service, 1970a and 1970b. Values under land-use categories are in acres]

County	Percentage of county within Area 8	Cropland	Pasture	Forest	Other rural	Federal non-cropland	Urban built up	Small water bodies	Total land area
Ohio:									
Athens	89	38,326	70,518	180,043	5,719	7,535	18,949	1,200	322,290
Fairfield	55	207,918	28,323	52,138	13,730	0	19,963	1,128	323,200
Gallia	16	49,227	71,386	154,600	7,074	6,007	11,647	1,050	300,991
Hocking	49	41,045	18,636	173,084	3,354	21,393	10,118	1,020	268,650
Meigs	93	48,263	41,251	168,100	6,938	100	11,945	1,013	277,610
Monroe	16	44,852	71,815	147,607	9,009	4,420	13,386	112	291,200
Morgon	20	41,823	86,721	115,000	10,808	2,439	9,482	607	266,880
Perry	51	72,883	34,581	116,500	6,053	16,253	14,340	1,150	261,760
Washington	33	56,279	67,892	239,500	10,708	12,000	21,161	140	407,680
West Virginia:									
Braxton	53	31,981	55,874	213,633	11,912	10,500	6,100	900	330,900
Calhoun	99	12,607	20,528	138,600	4,263	0	2,802	1,000	179,800
Clay	2	8,139	13,923	189,350	2,788	0	3,200	1,500	218,900
Doddridge	100	16,149	24,438	149,625	10,488	0	3,200	300	204,200
Gilmer	100	16,026	26,344	167,468	2,863	0	3,999	300	217,000
Jackson	86	30,148	42,530	206,174	7,846	0	9,000	617	296,315
Lewis	39	18,100	71,591	134,300	21,400	0	5,187	322	250,900
Marshall	3	26,135	45,507	110,920	5,242	0	7,496	500	195,800
Mason	28	42,520	56,358	162,304	7,207	0	7,511	500	276,400
Pleasants	100	4,668	5,000	68,910	2,213	0	2,009	400	83,200
Ritchie	100	25,971	57,240	197,200	1,477	0	6,510	882	289,280
Roane	48	25,500	69,700	197,800	11,400	0	6,000	600	311,000
Tyler	100	19,298	32,242	105,716	3,038	0	3,206	300	163,800
Upshur	18	23,814	52,996	131,400	11,590	0	5,000	500	225,300
Webster	4	7,232	6,238	266,049	4,520	64,700	3,311	500	352,600
Wetzel	71	8,292	15,204	196,067	6,121	0	5,616	400	231,700
Wirt	100	11,556	22,108	109,932	3,304	0	2,500	400	149,800
Wood	100	19,579	43,573	145,900	10,950	0	15,098	400	235,500
Total Area		948,331	1,152,517	4,237,969	202,015	145,347	228,736	17,741	6,932,656
Percentage of total area		13.7	16.6	61.1	2.91	2.10	3.30	0.26	---

3.0 WATER USE

Principal Water Uses are for Power Generation and for Public and Rural Supply

Estimated total water use in Area 8 for 1980 was 1,170 million gallons per day. About 90 percent of the water was used for power generation; much of the water was returned to the streams.

During 1980, an estimated 1,170 Mgal/d (million gallons per day) of water was used in the area. Of this amount, about 1,050 Mgal/d (90 percent) was used for cooling purposes in fossil-fuel power-generation plants located along the Ohio River. The power plants consumed[1] about 36 Mgal/d and the rest was returned to the river. The remaining 117 Mgal/d (10 percent) of water used in Area 8 (table 3.0-1) was for public supply (2.3 percent), rural domestic and livestock supply (0.7 percent), irrigation (0.1 percent), and for industry and mine pumpage (7.0 percent). About 11 Mgal/d (4 percent) of this water was consumed. Instream uses such as recreation and navigation were not considered in this report.

The greatest use of water in Area 8 is along the Ohio River where power-generation plants and the large industrial users are located. Most of this water is pumped from the river or from wells in the alluvium and a part is returned to the river after use.

Water-use data in the area, by county, are given in figure 3.0-1. Insufficient detailed information was available to determine what percentage of water was being used in parts of several Ohio counties. Therefore, the water-use figures are given for counties only if more than half the county lies within Area 8.

Figure 3.0-1 shows that Athens, Fairfield, and Wood Counties are the largest users of ground water. This water is used primarily for public supply and industry, but in Athens County some is used for power generation. Mason and Pleasants Counties are the largest users of surface water. This water is used primarily for power generation.

The data in this report are from Hathaway and Eberle (1981), and Stevens and Lessing (1982). Additional information may be obtained from the West Virginia Geological and Economic Survey.

Water-use data for 1980 are being collected and compiled by State agencies. These data are indexed by the National Water Data Exchange (NAWDEX). For details about NAWDEX, see section 7.2 of this report.

[1] Water not available for immediate re-use.

Table 3.0-1 Water use, in million gallons per day

[The values shown include an additional 64.5 Mgal/d surface water and 2.80 Mgal/d ground water estimated for self-supplied industrial use.]

Water source	Public supply	Agriculture and rural domestic	Irrigation	Mining and industrial	Power	Total
Ground water	22.5	5.6	(1)	14.7	3.5	46.4
Surface water	5.1	2.2	0.8	67.5	1047.8	1123.4
Total	27.6	7.8	0.8	82.2	1051.3	1169.8
Total percent	2.3	.7	.1	7.0	89.9	100.0

(1) All irrigation water assumed to be derived from surface-water source.

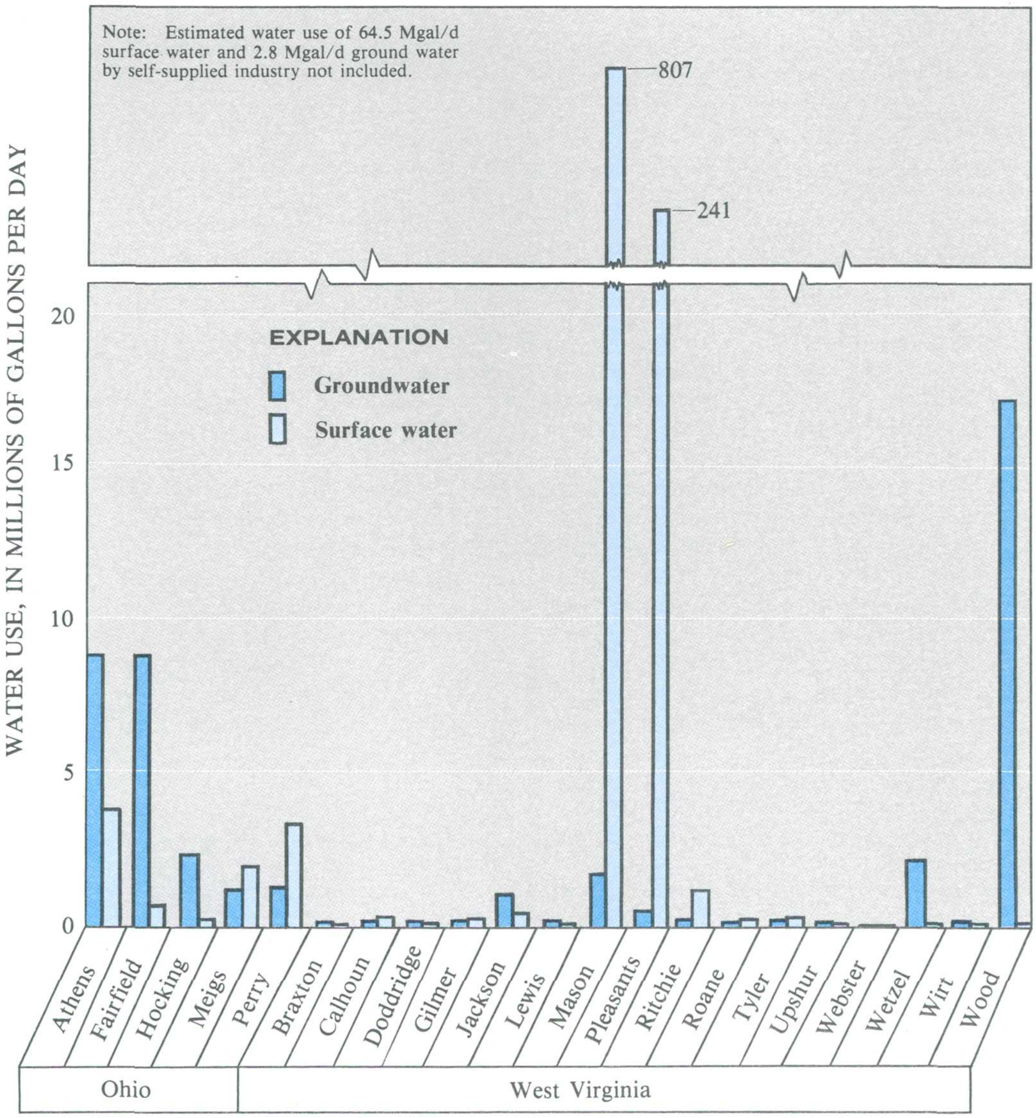


Figure 3.0-1 Water use, by county.

Coal of Varying Pollution Potential Underlies Most of Area 8

The rocks of Mississippian age are the only ones that do not contain coal. The Middle Kittanning (No. 6), Lower Kittanning (No. 5), and Clarion (No. 4a) seams rank high in pollution potential.

Coal is beneath all of Area 8 except the extreme western part underlain by Mississippian rocks. However, some of the coal is either inaccessible or not minable under current economic and technologic conditions. Estimated coal resources[1] for Ohio and estimated recoverable reserves[2] for West Virginia are shown in tables 4.1-1 and 4.1-2 by county. A map prepared by the West Virginia Geological and Economic Survey in 1981 shows the original bituminous coal reserves in West Virginia. The western two-thirds of the Little Kanawha River basin plus Pleasants and Jackson Counties are barren of minable coal. In Ohio, Mississippian rocks crop out in the western part of the area, and no coal is found in the Hocking River basin west of Logan in Hocking County.

Factors important in understanding the impact coal mining may have on a particular drainage basin include (1) the geography of the basin, (2) the pollution potential of its coal beds, (3) the present conditions of its abandoned mines, (4) the extent of the mining, (5) the mining technique to be used, and (6) the present water quality (Ohio Environmental Protection Agency, 1979, p. IV-64). Spoil areas may also cause pollution problems. Krothe and others (1980) showed that drainage from spoil areas generally contains high concentrations of iron, manganese, aluminum, sulfate, magnesium, and calcium and may degrade the water quality of receiving streams. The Ohio Environmental Protection Agency published a report in 1979 ranking Ohio's coal beds pollution potential as high, moderate, or low based on the sulfur content and the nature of the pyrite (iron sulfide) found in the coal seam and overburden. For surface mines, the success of natural or man-induced revegetation and the surface-water quality of the mining sites was also considered. For underground mines, the quality of the water draining from the mines was added to the factors.

Seams that were mined in Ohio during 1980 include the Clarion (No. 4a), Pittsburgh (No. 8), Middle Kittanning (No. 6), Upper Freeport (No. 7), Lower Freeport (No. 6a), Brookville (No. 4), and Lower Kittanning (No. 5). For seams that were surface mined, the Middle Kittanning (No. 6) and Lower Kittanning (No. 5) rank high in pollution potential while the Upper Freeport (No. 7), Lower Freeport (No. 6a), and Brookville (No. 4) rank moderate in pollution potential. For underground mined seams, the Clarion (No. 4a) ranks high in pollution potential, whereas the Pittsburgh (No. 8) ranks low.

Information found in Babu and others (1973), Collins (1978), and Botoman and Stith (1978) shows that coal in Area 8 is high volatile bituminous with less than 65 percent fixed carbon (dry ash-free). Total sulfur content averages slightly over 3 percent, with a range of from 0.5 percent in a small area on the Ritchie-Gilmer County line in West Virginia to 4.11 percent in the Clarion (No. 4a) seam in Ohio. Average calorific values range from 11,771 BTU/lb to about 13,500 BTU/lb.

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[1] Resources are all deposits, including those not minable under current technology. They are often estimated from the known geology of a region.
[2] Reserves are known deposits minable by present technology.

Table 4.1-1 Original minable and estimated recoverable coal reserves for West Virginia, 1980.

[Source: West Virginia Department of Mines, 1980. Counties that are not listed contain no minable reserves]

County	Percent of county within Area 8	Original minable reserves (short tons)	Estimated recoverable reserves (short tons)
Braxton	53	2,323,332,633	1,151,298,977
Calhoun	99	251,017,114	125,508,557
Clay	2	3,237,869,854	1,899,031,018
Doddridge	100	1,119,317,757	671,587,864
Gilmer	100	1,019,245,455	496,246,429
Lewis	39	2,776,037,160	1,369,775,928
Marshall	3	4,448,857,374	2,079,958,321
Mason	28	339,976,480	152,372,265
Roane	48	674,768,793	404,861,276
Tyler	100	948,133,232	474,066,616
Upshur	18	3,554,551,754	1,725,911,241
Webster	4	6,305,536,510	3,739,650,133
Wetzel	71	3,321,923,236	1,660,868,193
Wirt	100	22,302,720	11,151,360

Table 4.1-2 Estimated coal reserves for Ohio, 1977.

[Source: Estimated original resources and cumulative production from Collins, 1978. Counties not listed contain no resources]

County	Percent of county within Area 8	Estimated original resources (short tons)	Cumulative production 1800-1977 (short tons)	Estimated resources as of 1977 (short tons)
Athens	89	2,225,354,000	199,705,000	2,025,649,000
Gallia	16	1,642,616,000	16,800,000	1,625,816,000
Hocking	49	347,699,000	78,963,000	268,736,000
Meigs	93	942,190,000	54,806,000	887,384,000
Monroe	16	2,985,416,000	12,217,000	2,973,199,000
Morgan	20	1,419,433,000	42,665,000	1,376,768,000
Perry	51	1,148,247,000	188,808,000	959,439,000
Washington	33	1,262,721,000	3,929,000	1,258,792,000

About 7.7 Million Tons of Coal was Produced from 32 Mines During 1980

During 1980, Area 8 mines produced an estimated 7.7 million tons of coal, 6.7 million tons from 6 underground mines and 1 million tons from 26 surface mines.

Information in annual reports of the Ohio Division of Mines (1980) and the West Virginia Department of Mines (1980) shows about 7.7 million tons of coal were produced during 1980 in Area 8. About 6.7 million tons were produced from underground mines and 1 million tons from surface mines. Past coal production for West Virginia from 1975 to 1980 in the area is shown in figure 4.2-1. Data for Ohio was unavailable. During this period, surface mines were worked in Lewis, Braxton, Gilmer, and Mason Counties; and underground mines were worked in Braxton, Gilmer, Mason, and Webster Counties.

During 1980, there were 32 mines operated—26 surface and 6 underground—with the majority of surface mines in Hocking, Perry and Braxton Counties. The locations of the mines are shown in figure 4.2-2. Mines in Ohio were located only by their townships. Where Area 8 boundaries divided a township, topographic maps were used to determine if the mines were in or out of the study area. Mines that could not be located were included in the 1980 total production. Therefore, the production estimate and number of mines may be high. All figures are based on these estimates. It should also be noted that underground mines with their portals outside of the study area may have been mined in the study area, but would not be included.

Table 4.2-1 shows the number and type of mines, and the production by county during 1980. The underground mines, two in Meigs County, Ohio and one in Monroe County, Ohio, accounted for 77 percent of the total coal production. These mines worked the Clarion (No. 4a) and Pittsburgh (No. 8) seams. Seams that were mined, in order from highest to lowest yield, include the Clarion (No. 4a), Pittsburgh (No. 8), Middle Kittanning (No. 6), Upper Freeport (No. 7), Lower Freeport (No. 6a), Bakerstown, Brookville (No. 4), and the Lower Kittanning (No. 5).

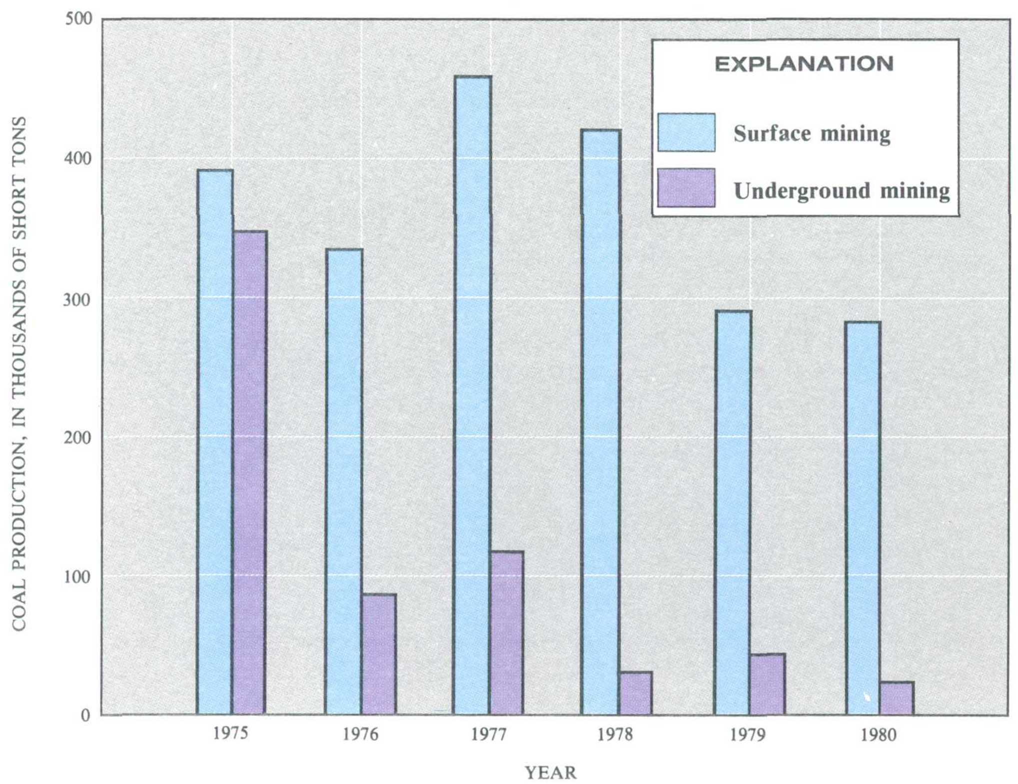
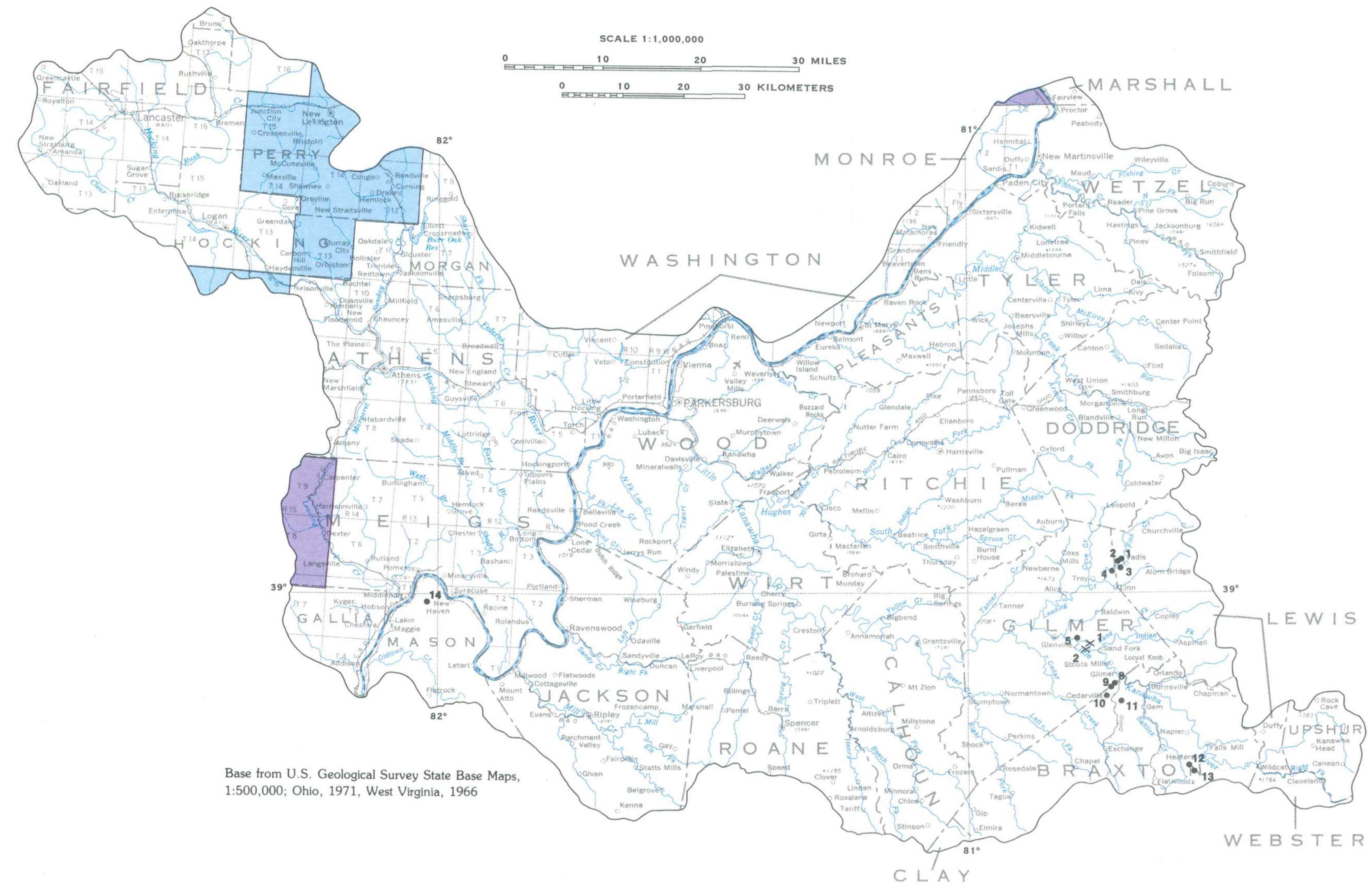


Figure 4.2-1 Coal production in Area 8 in West Virginia, 1975-80.

Table 4.2-1 Coal production in Area 8 during 1980, by county

County	Number of surface mines	Surface mine production (short tons)	Number of underground mines	Underground mine production (short tons)
Ohio:				
Hocking	7	299,521	0	0
Meigs	0	0	2	4,209,578
Monroe	0	0	2	2,421,916
Perry	7	481,811	0	0
West Virginia:				
Braxton	6	92,593	0	0
Gilmer	2	45,516	2	25,307
Lewis	3	145,464	0	0
Mason	1	644	0	0



EXPLANATION

×[1] Locations of underground mines

•[12] Locations of surface mines

Townships where there are mines (specific locations of mines not available)

Surface

Underground

Figure 4.2-2 Locations of active surface and underground mines during 1980.

INFORMATION OF SURFACE WATER AVAILABLE FOR 158 LOCATIONS

Streamflow data for some sites in Area 8 have been collected for more than 50 years with most of the water-quality and suspended-sediment data collected within the past 20 years. Data collection was intensified during 1979 in response to the Surface Mining Control and Reclamation Act.

Streamflow, water-quality, or suspended-sediment data are available for 158 sites in West Virginia and Ohio in Area 8 (fig. 5.1-1). Some streamflow stations have been operated for more than 50 years. However, most water-quality and suspended-sediment information has been collected in the past 20 years. The data network was expanded by 90 partial-record synoptic sites[1] in 1979 in response to the Surface Mining Control and Reclamation Act. The location of each data collection site, period of operation, type of record, and other pertininent information are included in Section 9.1.

Various types of discharge information are available depending on the purpose for which the streamflow station was established and operated. Major types include (1) continuous records of water levels and discharge, (2) records of flood stages and flood discharges, and (3) instantaneous measurements of various streamflow rates.

Water-quality information includes field and laboratory analyses. Some of the more prevalent chemical characteristics include water temperature, specific conductance, pH, dissolved and total minerals content, and dissolved and total metals content. Suspended-sediment data are available for four daily sites active in 1981 and for seven events sites[2] active in 1980 (see section 5.3.8).

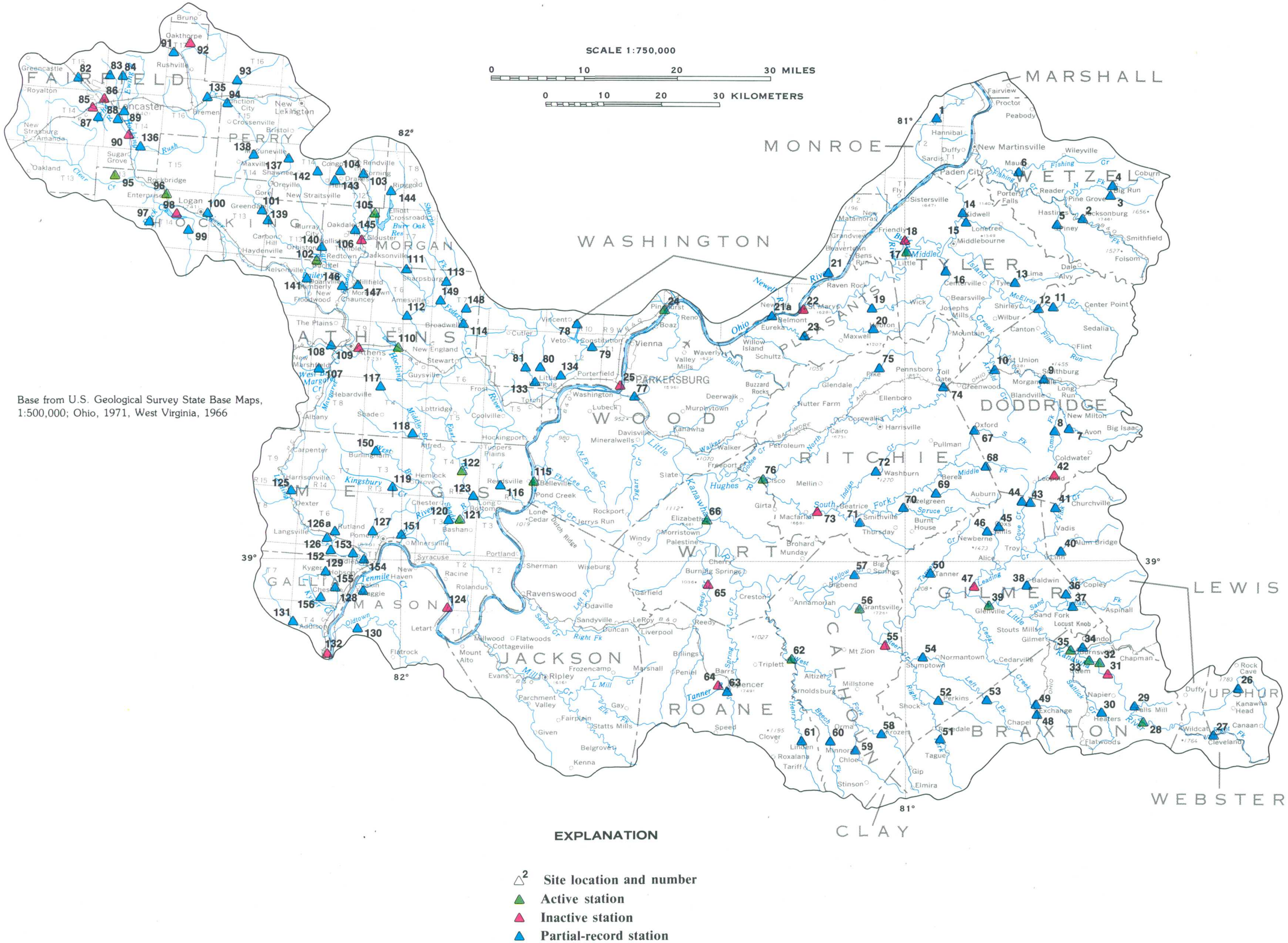
Information in addition to that given in sections 9.1 and 9.2 can be obtained from U.S. Geological Survey computer files through the National Data Exchange (NAWDEX, see section 7.2) or from the annual data publications "Water Resources Data for West Virginia" or "Water Resources Data for Ohio" available from:

U.S. Geological Survey
603 Morris Street
Charleston, West Virginia 25301

or

U.S. Geological Survey
975 West Third Street
Columbus, Ohio 43212

[1] A partial-record site where limited streamflow, chemical, suspended-sediment, and/or biological data including benthic-invertebrate data are collected intermittently and at selected times.
[2] A site where data are collected during storms.



Base from U.S. Geological Survey State Base Maps, 1:500,000; Ohio, 1971, West Virginia, 1966

Figure 5.1-1 Surface-water data network.

Basin and Climate Characteristics Affect Low Flow of Streams in Area

Low flows of streams are highest in areas underlain by the Mississippian undivided rocks and lowest in areas underlain by the Upper Pennsylvanian rocks.

Low-flow statistics for streams are commonly used to plan water-supply facilities in order to assure an uninterrupted supply during dry periods. Low-flow data are also used in the design of waste-treatment facilities to ensure adequate dilution of wastewater discharged to streams during low-flow periods. Low flow at any specific location depends primarily on precipitation over the basin and the soil, and geologic characteristics which control the recharge and discharge rates in the basin, among other factors. A characteristic that is commonly used to define streamflow is the 7-day, 10-year low flow[1]. The 7-day, 10 year ($M_{7,10}$) and 7-day, 2-year ($M_{7,2}$) low flows for several sites in Area 8 (fig. 5.2.1-1) are shown in table 5.2.1-1. Some of the data presented in table 5.2.1-1 represent streamflow from non-concurrent time periods; therefore, caution should be used when comparing stations. The $M_{7,10}$ low flows in Area 8, which are not influenced by regulation, vary from 0.0005 $(ft^3/s)/mi^2$ (cubic feet per second per square mile) to 0.10 $(ft^3/s)/mi^2$. The lowest $M_{7,10}$ values are found in the east-central part of the area underlain by the Dunkard and Monongahela Groups of the Upper Pennsylvanian rocks. The highest $M_{7,10}$ values are found in the western part of the area that is underlain by Mississippian undivided rocks and glacial deposits. There is no flow in many streams during very dry periods. Most of the coal mining activities in Area 8 are in the Pennsylvanian rocks.

Streamflow regulation by dams influence streamflow in the Little Kanawha, Hocking, and Ohio Rivers. Release of water from storage behind the dams generally augments low flows during dry periods. The basin climate and size of drainage area also affect low flow. The smaller the drainage area, the greater the chance that a stream may go dry during periods of drought. Wastewater discharges also increase streamflow and may change water quality. It has been estimated that water use is approximately 50 to 80 gal/d (gallons per day) per person, and most of the water is returned to streams as wastewater.

Mine drainage and mine pumpage also can influence streamflow. In a study of underground mining and mine collapse in northern West Virginia, Hobba (1981) reported that there was an increase in the low flow of streams in mined-out areas and in areas downstream from active mining. There was a decrease in the low flow of streams in areas in the vicinity of active mining. In a study of coal mines as sources of water for public supply in northern Upshur County, W. Va., just outside the eastern boundary of Area 8, Hobba (1984b) reported the approximate rate of drainage from a mine was slightly more than 1 (gal/min)/acre (gallon per minute per acre). This is in general agreement with Carpenter and Herndon (1933) who report that mines in the Pittsburgh Coal normally discharge 0.7 (gal/min)/acre and about half that amount during a drought.

Additional low-flow information are contained in reports by Bain and Friel, 1972, and by Johnson and Metzker, 1981.

[1] The lowest 7-consecutive day average flow has a 10-year recurrence interval.

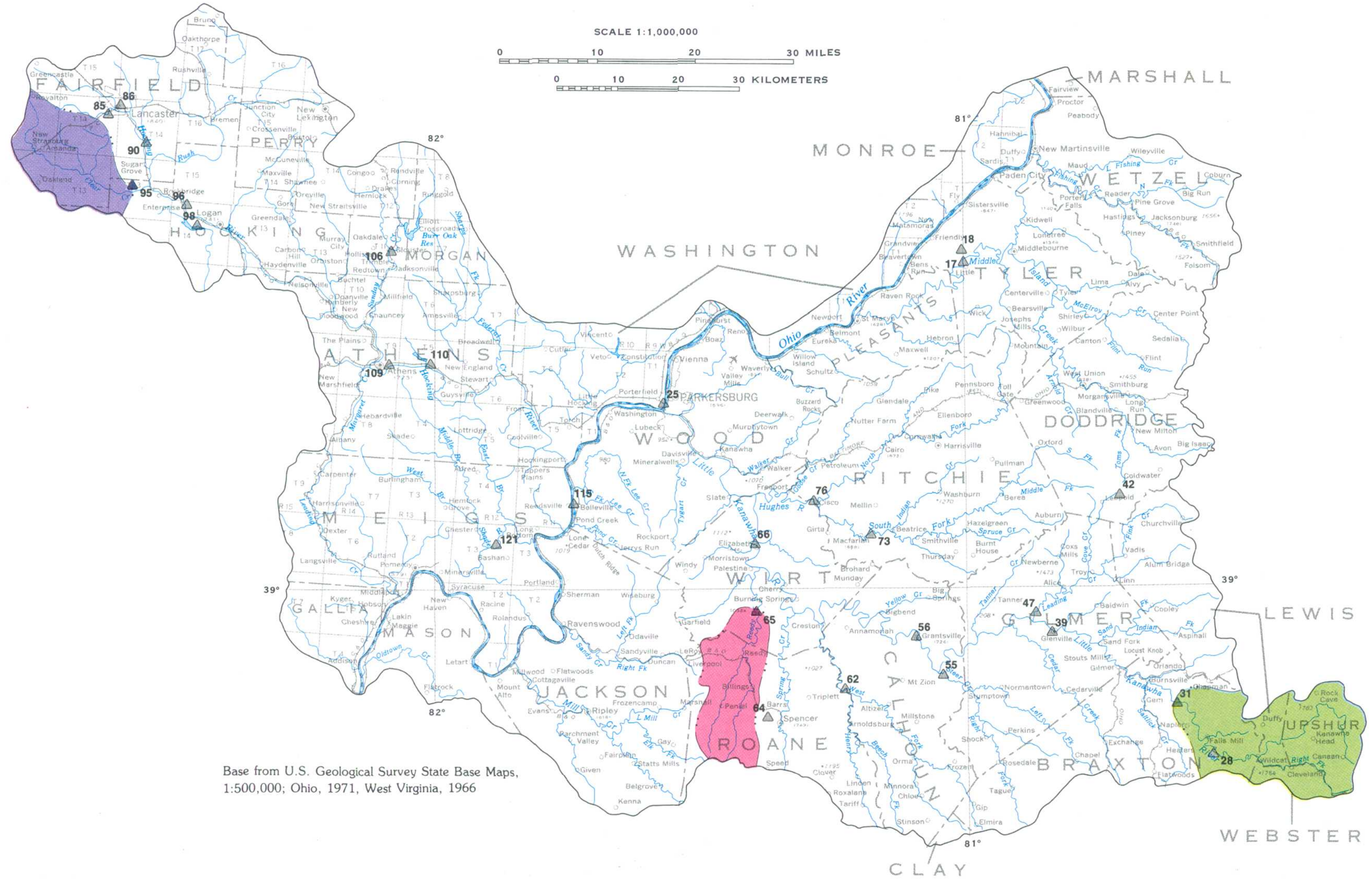


Figure 5.2.2-1 Location of flow-duration sites.

EXPLANATION

—·· — Basin boundary

△95 Site location and number

Table 5.2.2-1 Flow duration of selected streams

Site No.	Station name	Period of record	Drainage area (mi²)	Discharge, in cubic feet per second, that was equaled or exceeded for indicated percent of time: 10	25	50	70	75	90	95
17	Middle Island Creek at Little, W. Va.	1916-80	458	1,600	640	210	71	50	12	4.5
18	Buffalo Run near Little, W. Va.	1970-77	4.21	13	4.6	1.4	0.5	0.4	0.2	0.1
25	Ohio River at Parkersburg, W. Va.	1941-68	35,600	120,000	70,000	28,000	16,000	13,000	7,600	6,200
28	Little Kanawha River near Wildcat, W. Va.	1975-80	112	580	280	110	53	39	14	8.7
31	Little Kanawha River near Burnsville, W. Va.	1938-73	155	700	340	130	47	34	8.1	3.5
39	Little Kanawha River at Glenville, W. Va.1/	1929-78	386	1,500	650	230	84	61	18	7.7
42	Buck Run near Leopole, W. Va.	1970-77	2.91	11	4.2	1.5	.5	.4	.1	0
47	Leading Creek near Glenville, W. Va.	1938-51	144	490	210	71	27	20	5.2	1.9
55	Steer Creek near Grantsville, W. Va.1/	1938-75	166	530	210	65	21	14	2.8	.8
56	Little Kanawha River at Grantsville, W. Va.1/	1929-78	913	3,300	1,400	470	170	120	36	14
62	West Fork Little Kanawha River at Rocksdale, W. Va.	1929-75	205	630	250	71	22	16	3.1	1.1
64	Tanner Run at Spencer, W. Va.	1970-77	2.82	9.0	3.6	1.2	.4	.2	.1	.0
65	Reedy Creek near Reedy, W. Va.	1952-78	79.4	220	78	20	5.3	3.7	.8	.4
66	Little Kanawha River at Palestine, W. Va.1/	1940-78	1,515	5,600	2,200	770	310	230	80	31
73	South Fork Hughes River at Macfarlan, W. Va.	1916,1938-51	210	750	280	93	33	23	6.4	3.0
76	Hughes River at Cisco, W. Va.	1929-80	452	1,500	550	170	54	38	12	4.1
85	Hunters Run at Lancaster, Ohio	1957-79	10.0	21	11	5.1	2.7	2.3	1.3	1.0
86	Hocking River at Lancaster, Ohio	1957-74	48.2	83	42	21	13	11	6.3	4.8
90	Hocking River near Lancaster, Ohio	1924-32	90.3	200	92	42	25	23	17	13
95	Clear Creek near Rockbridge, Ohio	1940-80	89.0	180	91	44	25	22	16	13
96	Hocking River at Enterprise, Ohio	1932-55	459	1,000	460	180	89	76	51	42
		*1961-80	---	1,100	540	240	130	110	67	53
		1931-78	---	1,000	480	190	100	86	54	44
98	Clear Fork near Logan, Ohio	1943-47	14.8	38	17	5.8	2.0	1.7	1.1	.8
106	Sunday Creek at Glouster, Ohio	*1952-78	104	290	110	31	13	10	5.1	3.7
109	Hocking River at Athens, Ohio	1916-52	943	2,500	1,000	410	180	150	86	70
		*1961-76	---	2,500	1,100	430	210	180	95	73
		1915-76	---	2,400	1,050	400	180	140	83	66
110	Hocking River below Athens, Ohio	1977-80	957	3,100	1,500	710	380	310	190	150
115	Ohio River at Bellville Dam, W. Va.	1975-80	39,300	130,000	88,000	48,000	28,000	25,000	15,000	12,000
121	Shade River near Chester, Ohio	1966-80	156	410	170	63	25	20	7.8	5.0

* Regulated
1/ Regulated since 1978 by Burnsville Dam. Minimum release is 20 ft³/s.

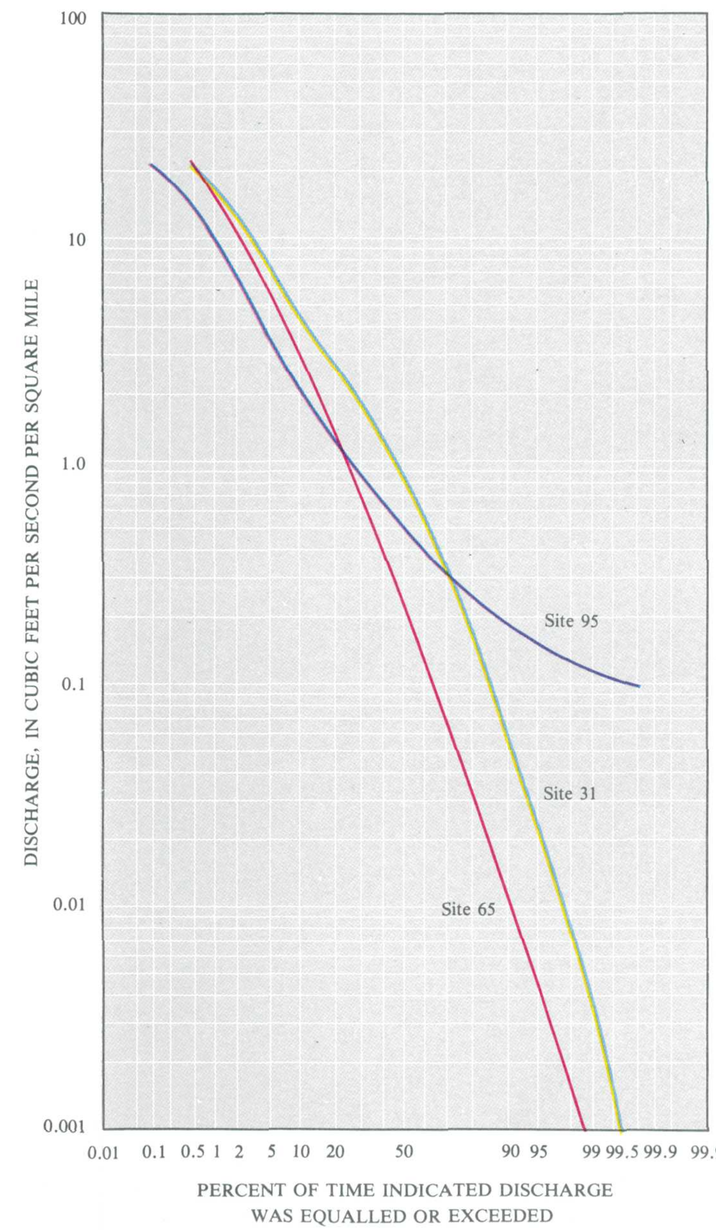


Figure 5.2.2-2 Streamflow duration curves for selected sites.

Flow of Streams Draining the Mississippian Rocks is Well Sustained

Flow-duration curves indicate that discharges of streams draining the Mississippian rocks are less variable than discharges of streams located elsewhere in Area 8.

The flow of a stream at a given point, such as at a gaging station, is the surface and subsurface runoff from the drainage basin. The streamflow record is an integration of the effects of climate, topography, and geology, and gives the distribution of runoff both in time and in magnitude. The flows can be arranged according to frequency of occurrence and plotted as a flow-duration curve[1]. The resulting curve represents the flow characteristics of the stream throughout the range of discharge without regard to the sequence of occurrence and shows the integrated effect of the various factors that influence runoff in that basin. Thus, flow-duration curves provide a convenient means of comparing the flow characteristics of one stream, or basin, with another.

The slope of the flow-duration curve for a stream is a measure of that stream's variability of flow. A steep slope indicates highly variable flow, whereas a flat slope indicates a more uniform flow which tends to be equalized by release of surface- or ground-water storage.

Streamflow data for selected sites (fig. 5.2.2-1) are summarized in flow-duration table 5.2.2-1 for unregulated and regulated periods of time. Some of these data represent streamflow from different periods of time; therefore, caution should be used when comparing streams.

The flow-duration curves for three unregulated streams in Area 8 (fig. 5.2.2-2) show the differences in flow variability. These curves are for streamflow stations having 20 or more years of record and are plotted in unit discharge (cubic feet per second per square mile) so that more direct comparison may be made. The curve for Clear Creek near Rockbridge, Ohio (site 95) has a flat slope, which indicates that streamflow during dry periods is well sustained. The Clear Creek basin is underlain by Mississippian rocks and glacial deposits where the ground-water storage capacity is greater than that for the other two basins.

The flow of Reedy Creek near Reedy, W. Va. (site 65) is more variable than the flow of the Little Kanawha River near Burnsville, W.Va. (site 31). The Reedy Creek basin is underlain by rocks of the Dunkard Group where the ground-water yield to streams is low and water runs off rapidly during periods of high flow. The flow-duration curves for sites 31 and 65 show the streamflow variability to be similar for the two sites. The curve for site 31 occupies the higher position because the drainage basin receives about 12 inches more annual precipitation than the drainage basin for site 65.

There are seasonal variations in flow duration in Area 8 due to seasonal distribution of precipitation, evapotranspiration, and ground-water levels. For example, during the spring season (March through May) the discharge at site 95 corresponding to the 50 percent duration point was 86 ft^3/s, whereas discharge at the same duration point for the fall season (September through November) was 21 ft^3/s (Johnson and Metzker, 1981).

Surface and underground mines can affect streamflow duration when streamflow is augmented by mine drainage or discharge of pumped mine water. The effect on the low-flow portion of the curve is similar to streamflow sustained by ground-water discharge during dry periods. However, the opposite effect can occur in areas where there is interbasin transfer of water. Although there are no streamflow records in Area 8 which show the influence of coal mining on flow duration, Hobba (1981) found in adjacent basins that after the deep mining of coal was completed, the streamflow was less variable due to various factors which are explained in his report.

Regulation by man-made reservoirs affects streamflow variability and the shape of flow-duration curves by reducing flood peaks and increasing low flows. The flows of the Hocking, Little Kanawha, and Ohio Rivers are affected by regulation.

[1] A cumulative-frequency curve showing the percentage of time that a specific daily discharge was equaled or exceeded during a given period of time.

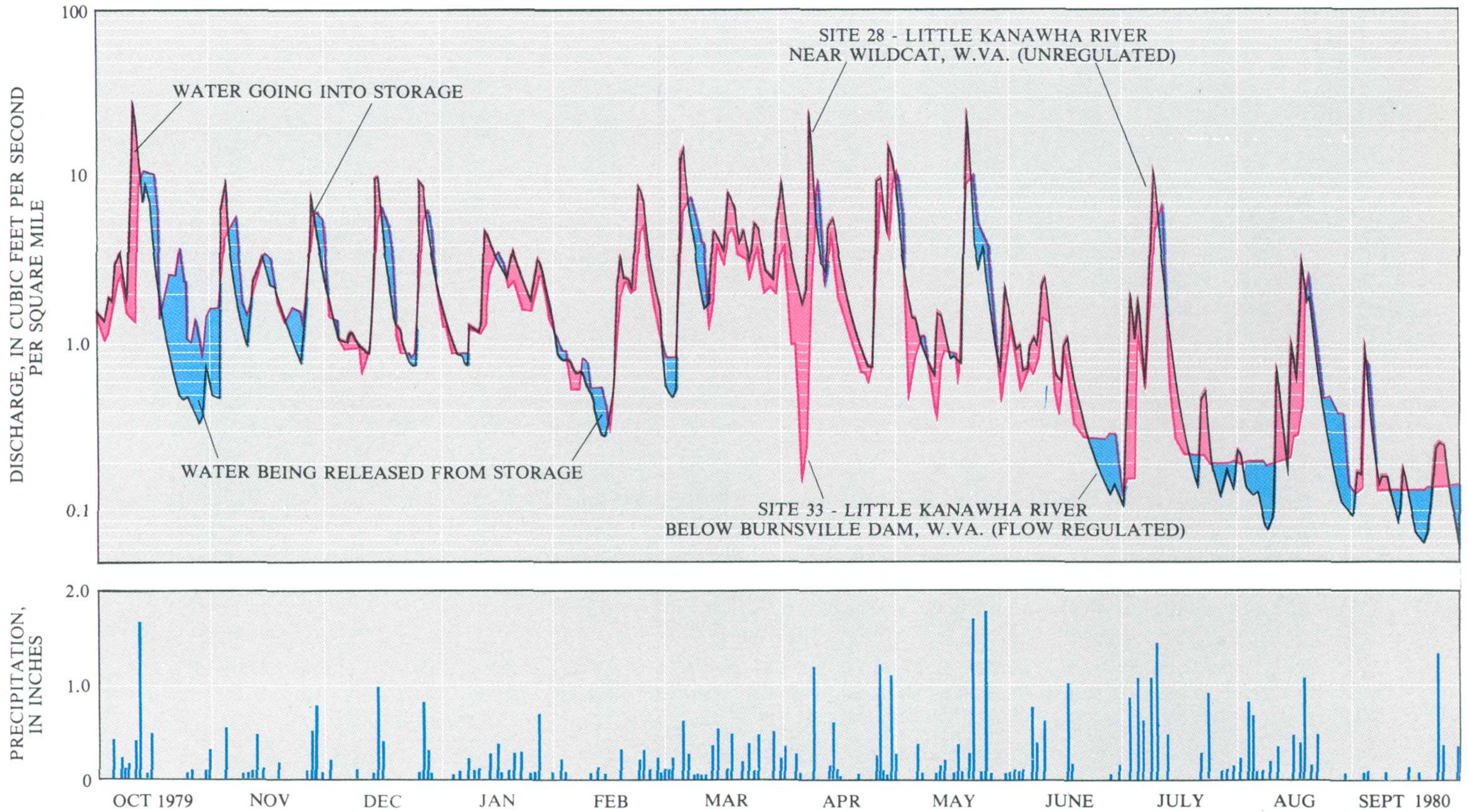


Figure 5.2.3-1 Daily discharge for Little Kanawha River near Wildcat and below Burnsville Dam, West Virginia, and precipitation at Burnsville, West Virginia (water year 1980).

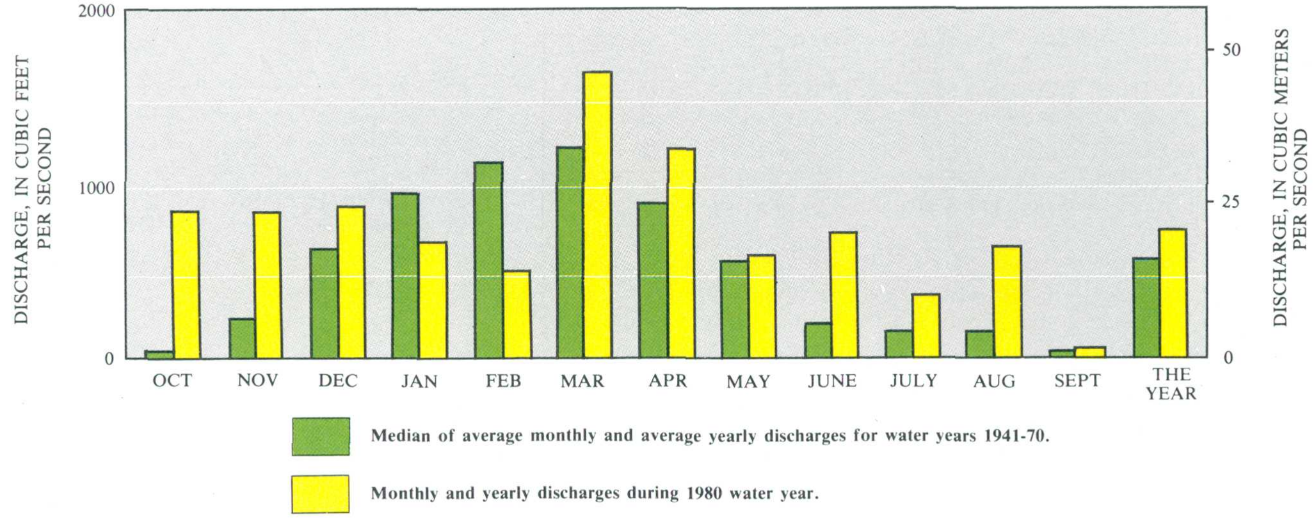


Figure 5.2.3-2 Seasonal pattern of streamflow at site 76, Hughes River at Cisco, West Virginia.

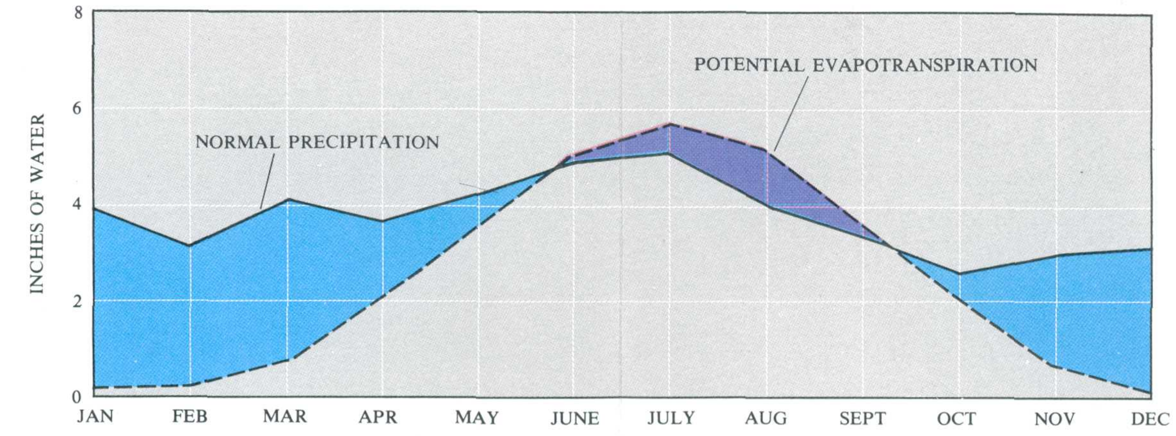


Figure 5.2.3-3 Normal monthly precipitation and potential evapotranspiration, 1931-60, at Cairo, West Virginia.

From Bain, 1972

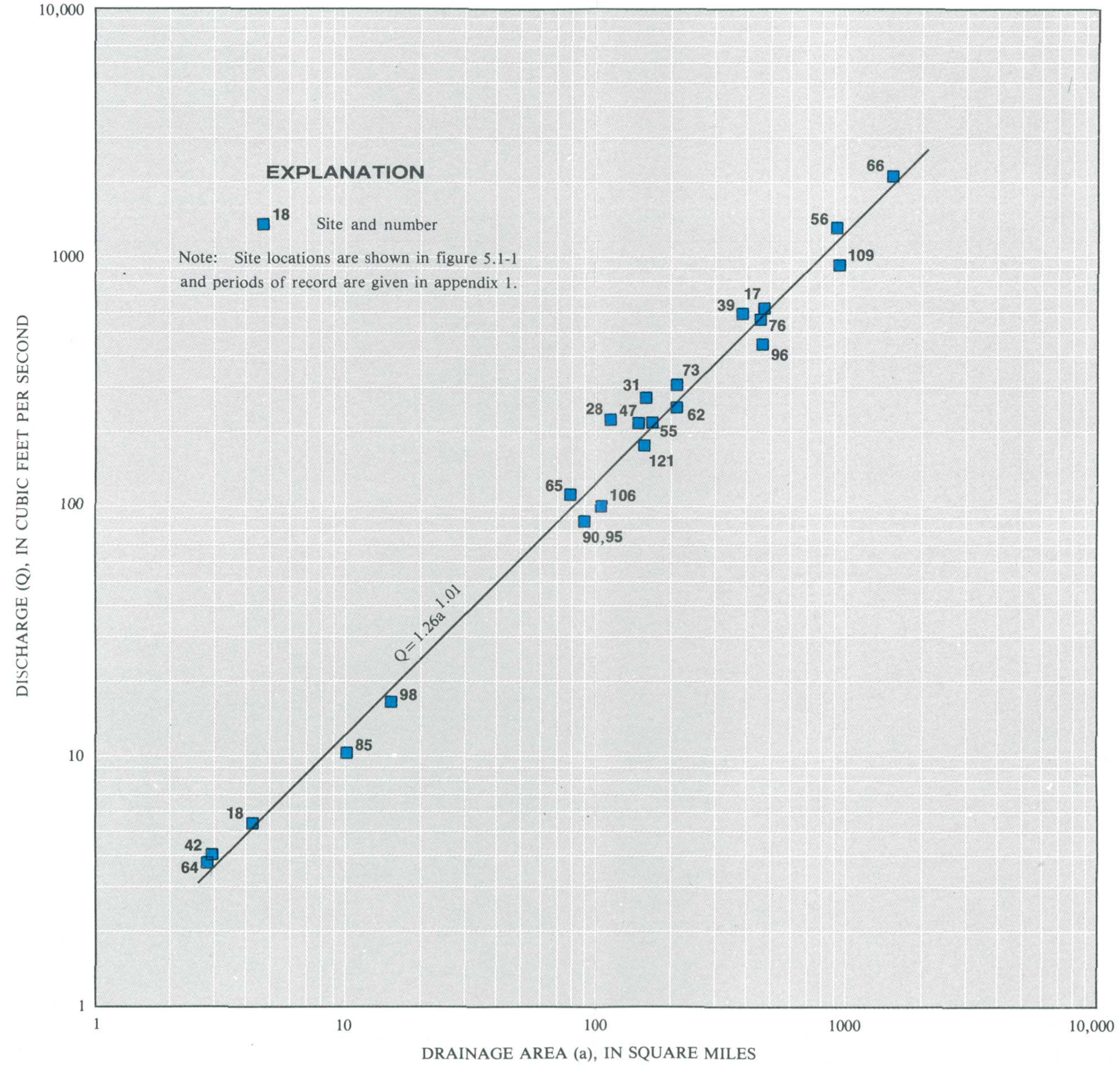


Figure 5.2.3-4 Relation of average-annual runoff to drainage area.

Annual Runoff in Area Ranges from 13 to 29 Inches Per Year

The lowest annual runoff (13.3 inches per year) occurs in the Hocking River basin and the highest annual runoff (28.6 inches per year) occurs in the Little Kanawha River basin.

Streamflow in unregulated streams in Area 8 varies during any given year with changes in precipitation and evapotranspiration. One of the hydrographs shown in figure 5.2.3-1, Little Kanawha River near Wildcat, W. Va. (site 28), shows the variation of average-daily streamflow with precipitation for the period October 1, 1979 to September 30, 1980. The flow variation at site 28 is typical of unregulated streams in the area.

Monthly and seasonal variations in streamflow for Hughes River at Cisco, W. Va. (site 76) are shown in figure 5.2.3-2. Monthly variations in precipitation and potential evapotranspiration for Cairo, W. Va., located in the central part of the area, are illustrated in figure 5.2.3-3. These variations are typical for the area. Average annual evapotranspiration losses in the area are about 28 in/yr (Berry, 1945).

Average annual runoff in Area 8 varies with drainage-area size as well as precipitation. The lowest runoff (13.3 in/yr) occurs in the Hocking River basin in the western part of the area, where annual precipitation is about 37 in (inches). The highest runoff (28.6 in/yr) occurs in the higher elevations in the headwaters of the Little Kanawha River basin in the eastern part of the area, where the annual precipitation is 50 to 60 in. The average annual flow of the Ohio River at Parkersburg, W. Va. (site 25) is 48,200 ft^3/s (18.3 in/yr). The variation in average annual runoff in the area with drainage-area size is shown in figure 5.2.3-4.

Mining activity can affect average annual runoff when streamflow is augmented by mine drainage or pumpage. Although there are no streamflow records in Area 8 that show the influence of mining on annual runoff, Hobba (1981) found, in an adjacent basin, that the annual runoff was greater after deep mining of coal was completed. When surface runoff is the water is rerouted through the mine. Mining activities can cause changes in interbasin transfer of water, which can result in an increase or decrease of annual runoff in a specific basin.

Flow in the Hocking, Little Kanawha, and Ohio Rivers is affected by streamflow regulation. Regulation caused by change of water stored in reservoirs usually increases flow during dry periods and reduces peak flows during periods of high storm runoff, but does not cause a significant change in the average annual flow. The hydrograph (fig. 5.2.3-1) for Little Kanawha River below Burnsville Dam (site 33) shows the influence of the operation of the dam on the average daily flow. There are 34 reservoirs in the entire Ohio River basin upstream from Belleville, W. Va., that are being operated for flood control and other important purposes (U.S. Army Corps of Engineers, 1975).

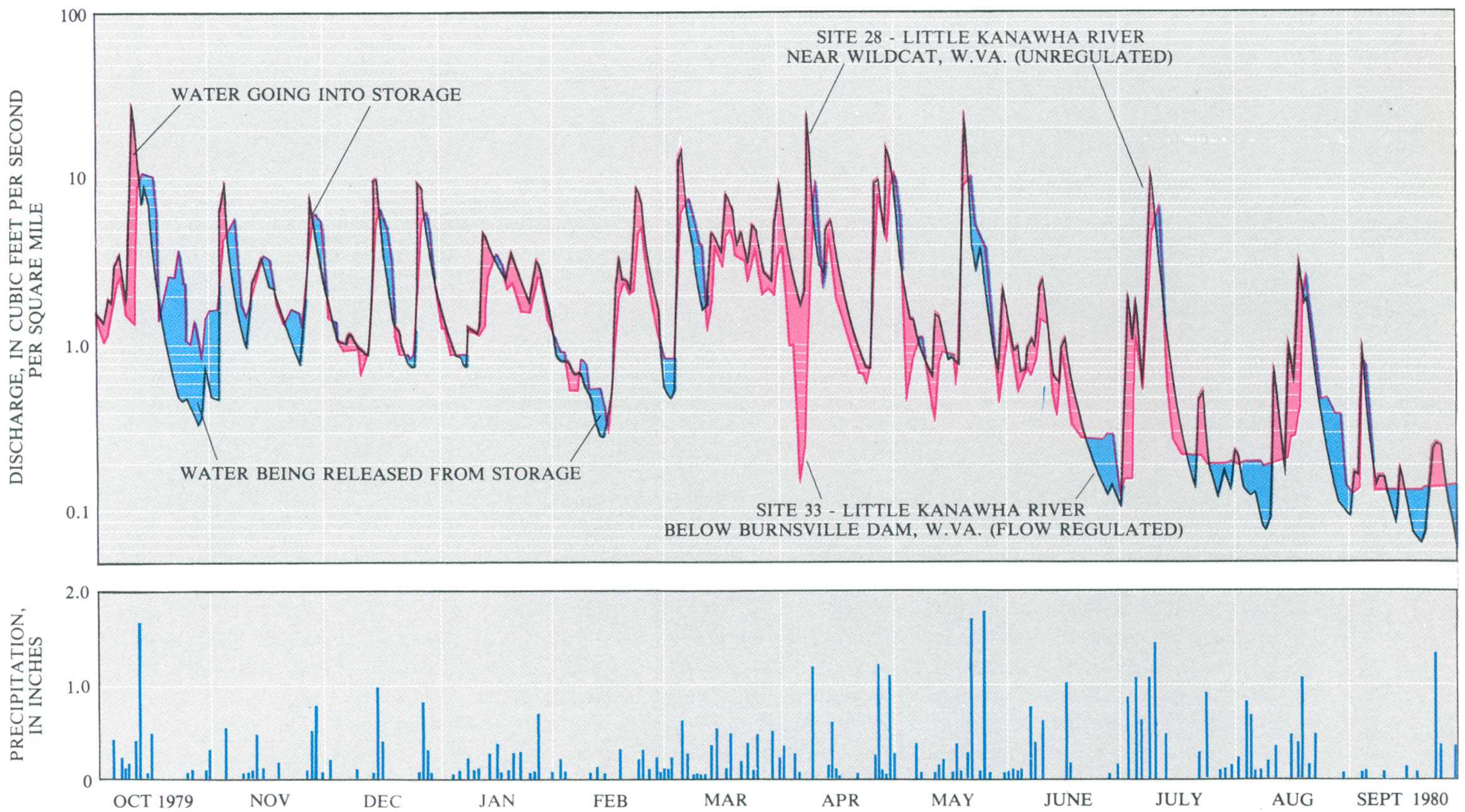


Figure 5.2.3-1 Daily discharge for Little Kanawha River near Wildcat and below Burnsville Dam, West Virginia, and precipitation at Burnsville, West Virginia (water year 1980).

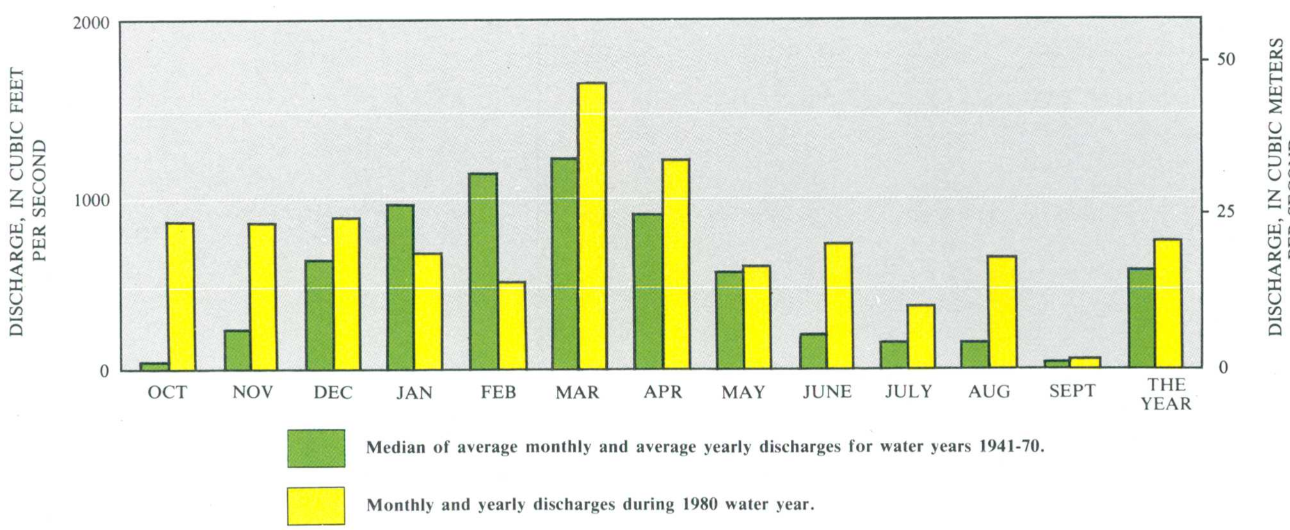


Figure 5.2.3-2 Seasonal pattern of streamflow at site 76, Hughes River at Cisco, West Virginia.

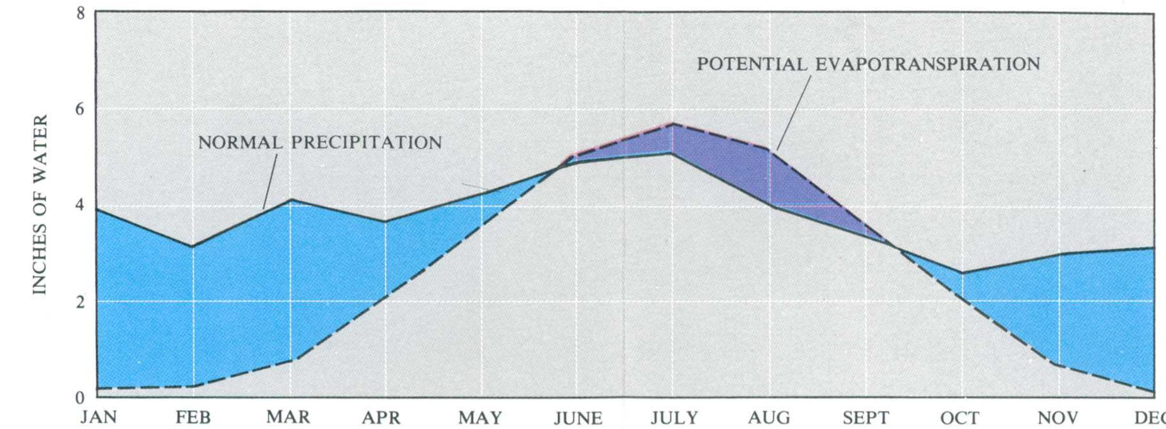


Figure 5.2.3-3 Normal monthly precipitation and potential evapotranspiration, 1931-60, at Cairo, West Virginia.

From Bain, 1972

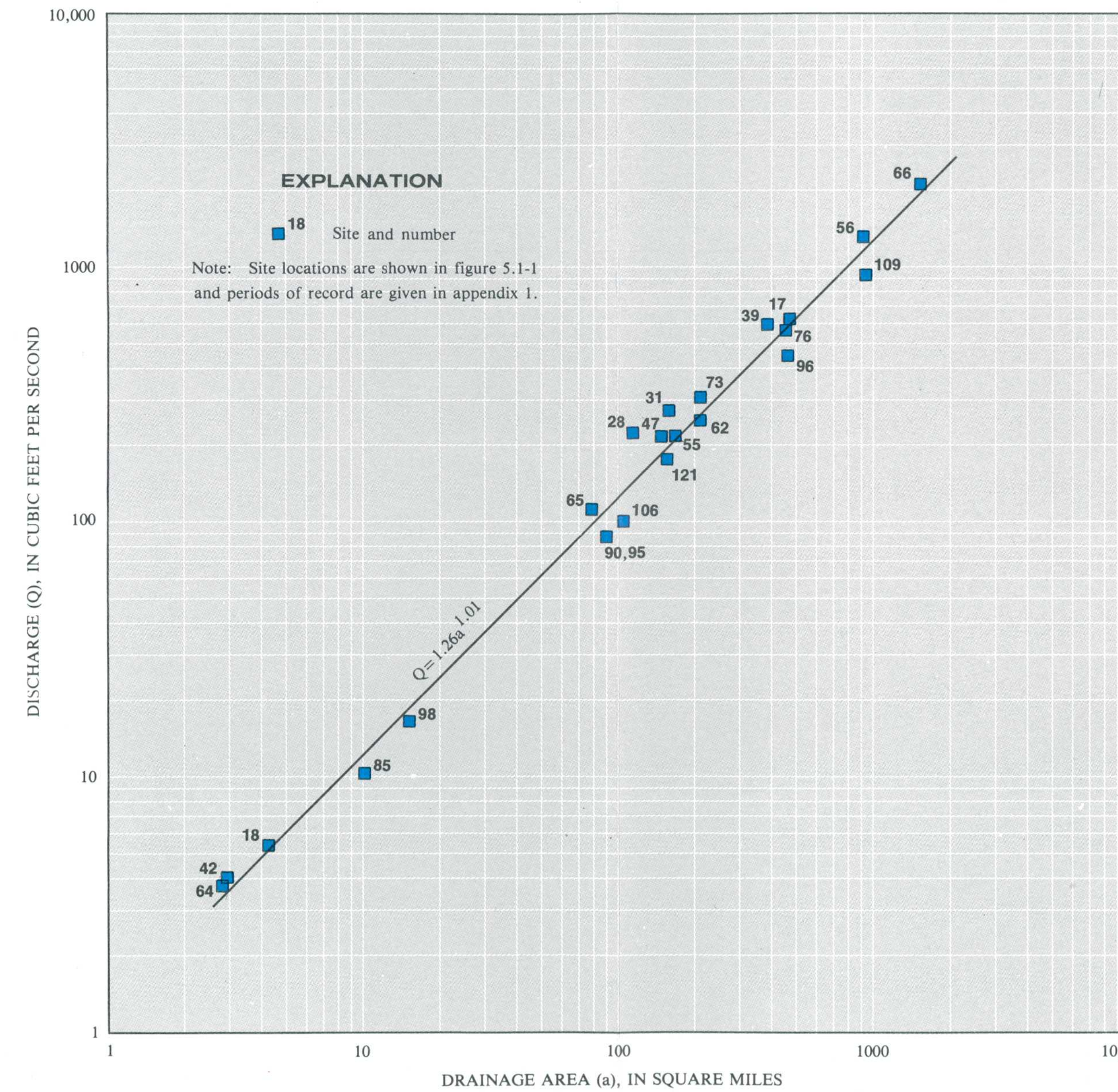


Figure 5.2.3-4 Relation of average-annual runoff to drainage area.

Flood Magnitude and Frequency Vary with Rainfall and Drainage Area

Drainage area and amount and frequency of precipitation are the primary basin characteristics that determine the magnitude and frequency of floods in Area 8.

Estimates of the magnitude and frequency of floods are needed for safe and economical design of hydraulic structures and flood-plain management. Flood frequencies are generally expressed in terms of probability of occurrence. For example, a flood discharge (Q_T) having a 2 percent chance of being exceeded in any one year also is described as a 50 (inverse of 0.02) year recurrence-interval flood. Techniques are presented to provide methods for estimating the magnitude of peak discharges of T-year frequencies for unregulated streams in Area 8. Regression analyses were used to develop equations that relate river-basin characteristics to peak discharges at streamflow stations. Equation 1 for the Ohio part of Area 8 is $Q_T = aA^xS^y$, and equation 2 for the West Virginia part is $Q_T = aA^x$, where:

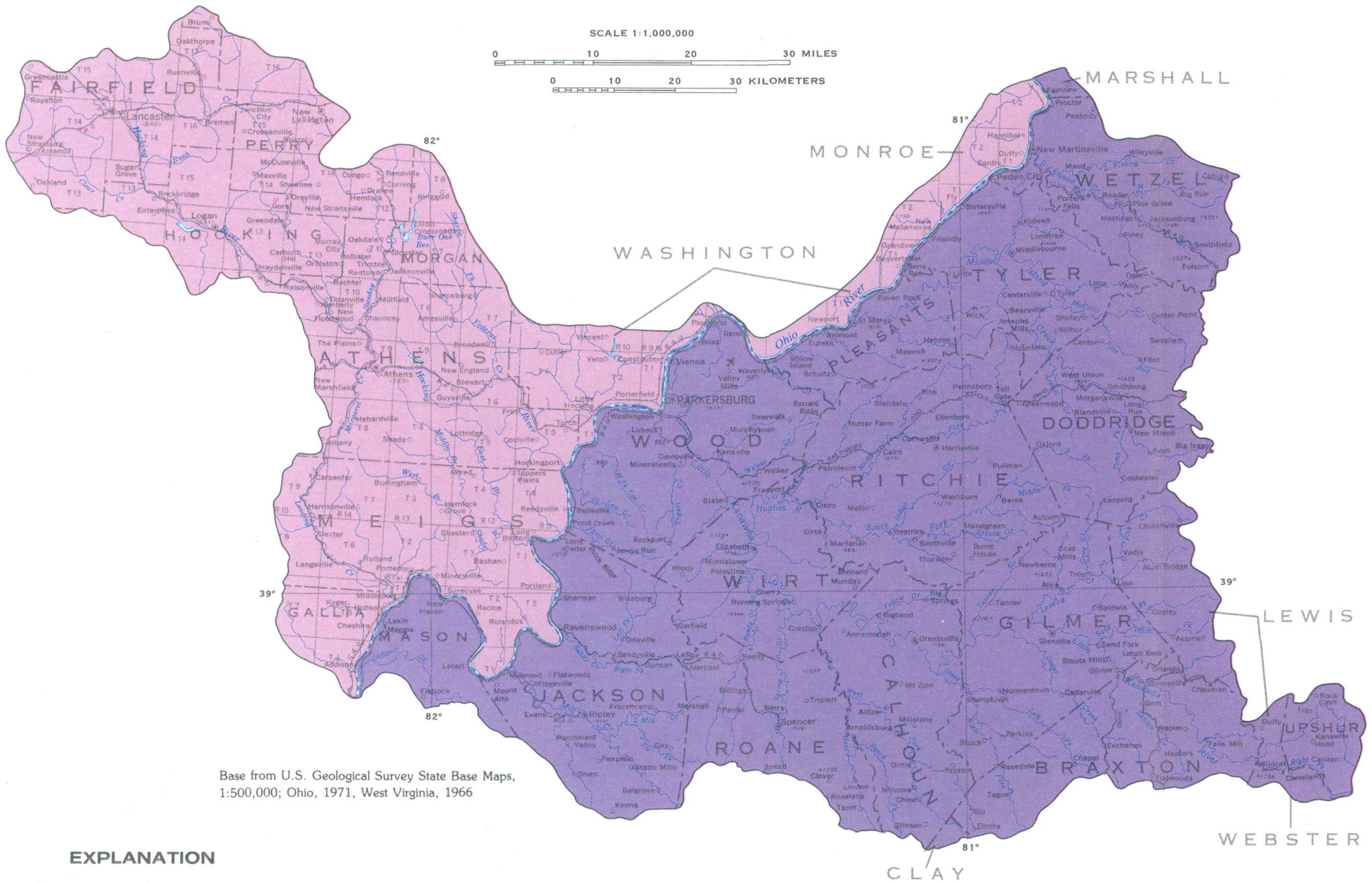
Q_T = annual peak discharge, in cubic feet per second,
T = recurrence interval, in years,
A = drainage area, in square miles,
S = main-channel slope, in feet per mile, computed as the difference between elevations at 10 and 85 percent of the channel distance from the streamflow station to the basin divide, divided by the channel distance between the two points,

a = regression constant, and
x,y = exponents.

Regression equations and graphs applicable to the West Virginia part of Area 8 (fig. 5.2.4-1) are presented in figure 5.2.4-2. Those equations applicable to the Ohio part of the area (fig. 5.2.4-1) are presented in table 5.2.4-1. The methods presented here for computing flood-peak discharges should only be used for streams with drainage areas between 0.3 and 2,000 mi² in West Virginia, and with drainage areas greater than 0.1 mi² in Area 8 in Ohio. They should not be used to estimate peak flows of streams draining urban areas or for streams having significant regulation. When comparing the two methods for small drainage areas, equation 1 ($Q_T = aA^xS^y$) gives a smaller standard error of estimate (4 percent at Q_2 and 8 percent at Q_{100}) than does equation 2 ($Q^T = aA^x$) since equation 1 uses one additional variable. For streams smaller than about 25 mi² in the immediate vicinity and on both sides of the Ohio River, equation 1 would give results with a slightly better standard error of estimate.

Flood peaks are modified along the Little Kanawha and Hocking Rivers by the Burnsville and Burr Oak Reservoirs, respectively, and by several smaller flood-water detention reservoirs. Flood heights along the Ohio River are reduced by the operation of 34 flood-control reservoirs and numerous other flood-water detention reservoirs upstream from Belleville, W. Va. Detailed flood-plain studies and other flood-plain information for the area are available from the U.S. Army Corps of Engineers, Huntington District, Huntington, W. Va.

Whetzel and Bettandorff (1984) present techniques for estimating various streamflow characteristics, such as, peak flows, mean monthly and annual flows, flow durations, flow volumes, and low flows at ungaged sites on unregulated streams in the Eastern Coal region. This report supersedes all previously published reports when estimating flood peaks and avoids differences across area boundaries.



EXPLANATION

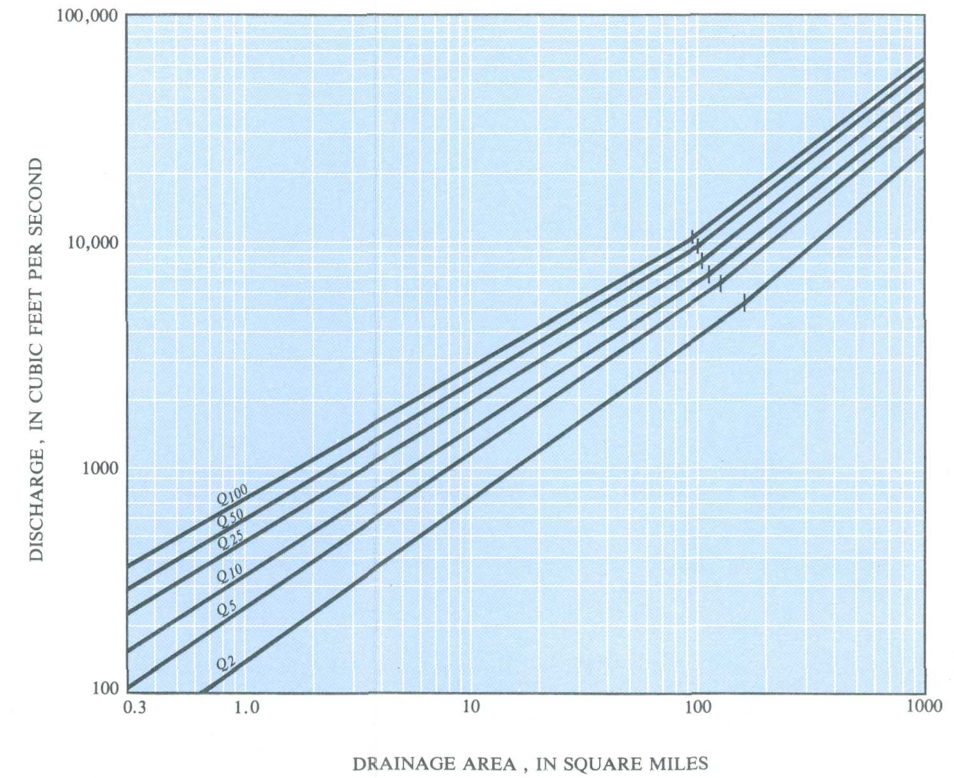
West Virginia Flood Region 1
From Runner, 1980

Ohio Flood Area 2
From Webber and Bartlett, 1976

Figure 5.2.4-1 Location of West Virginia Flood Region 1 and Ohio Flood Area 2.

Table 5.2.4-1 Regression equations for estimating peak discharges in the Ohio part of Area 8. (from Webber and Bartlett, 1976)

Peak flow characteristic Q_T	Estimating equation	Standard error of estimate (percent)
Q_2	$42.6\ \underline{A}^{0.802}\ \underline{S}^{0.225}$	33
Q_5	$45.4\ \underline{A}^{0.820}\ \underline{S}^{0.373}$	28
Q_{10}	$47.4\ \underline{A}^{0.830}\ \underline{S}^{0.447}$	27
Q_{25}	$49.5\ \underline{A}^{0.842}\ \underline{S}^{0.525}$	27
Q_{50}	$50.9\ \underline{A}^{0.850}\ \underline{S}^{0.575}$	29
Q_{100}	$52.6\ \underline{A}^{0.857}\ \underline{S}^{0.619}$	32



EXPLANATION

Regression equations for estimating peak discharges in the West Virginia part of Area 8. (from Runner, 1980).

Peak flow characteristics Q_T	Estimating equation[1]	Standard error of estimate (percent)	Drainage area break point (square miles)	Estimating equation[2]	Standard error of estimate (percent)
(1)	(2)	(3)	(4)	(5)	(6)
Q_2	$131\ A^{0.734}$	37	160	$74\ A^{0.847}$	25
Q_5	$235\ A^{0.683}$	37	125	$115\ A^{0.831}$	25
Q_{10}	$324\ A^{0.655}$	37	116	$149\ A^{0.818}$	27
Q_{25}	$461\ A^{0.625}$	39	106	$203\ A^{0.801}$	29
Q_{50}	$583\ A^{0.604}$	40	99	$249\ A^{0.789}$	32
Q_{100}	$724\ A^{0.586}$	42	95	$303\ A^{0.777}$	35

1/ Use for drainage areas from 0.3 mi^2 to size shown in column 4 (Drainage area break point).

2/ Use for drainage areas larger than size shown in column 4.

Figure 5.2.4-2 Relation of peak discharges to drainage areas in Area 8 in West Virginia.

Flood-Prone Area Maps Available for Area

The limits of the 100-year flood in Area 8 are delineated on 62 7½-minute quadrangle maps.

The National Flood Insurance Act of 1968 and the Flood Disaster Protection Act of 1973 established programs for investigating the extent of flooding in urban areas and rural communities. Flood-prone area maps prior to 1969 were for "approximate areas occasionally flooded." In 1969, the project was changed to delineate the approximate boundaries of the 100-year flood. In 1969, the U.S. Geological Survey began a mapping program to delineate flood-prone areas for all affected communities, recreational areas, and areas with the potential for development. Maps were produced using stage-frequency relations at gaging stations, profiles of high-water marks, and regional flood-frequency curves. In general, the delineated areas are for natural stream conditions and give the user a quick way of identifying areas of potential flood hazards.

Most flood damage is due to encroachment on the flood plains by industrial, commercial, and residential developments. Areas where flooding may produce significant damage are referred to as "flood-prone areas." Many flood-prone areas along the Ohio River and its tributaries are occupied by man and his buildings and property. The locations of 62 flood-prone area maps in Area 8 are shown on figure 5.2.5-1. Completed flood-prone area maps are shown with the quadrangle name for each available 7½-minute map. An example of a flood-prone area map is shown in figure 5.2.5-2. Prints of the maps are available upon request from:

U.S. Geological Survey
603 Morris Street
Charleston, West Virginia 25301

or

U.S. Geological Survey
975 West Third Avenue
Columbus, Ohio 43212

More detailed flood-plain studies and flood-plain information reports are available from U.S. Army Corps of Engineers, Huntington District, Huntington, West Virginia.

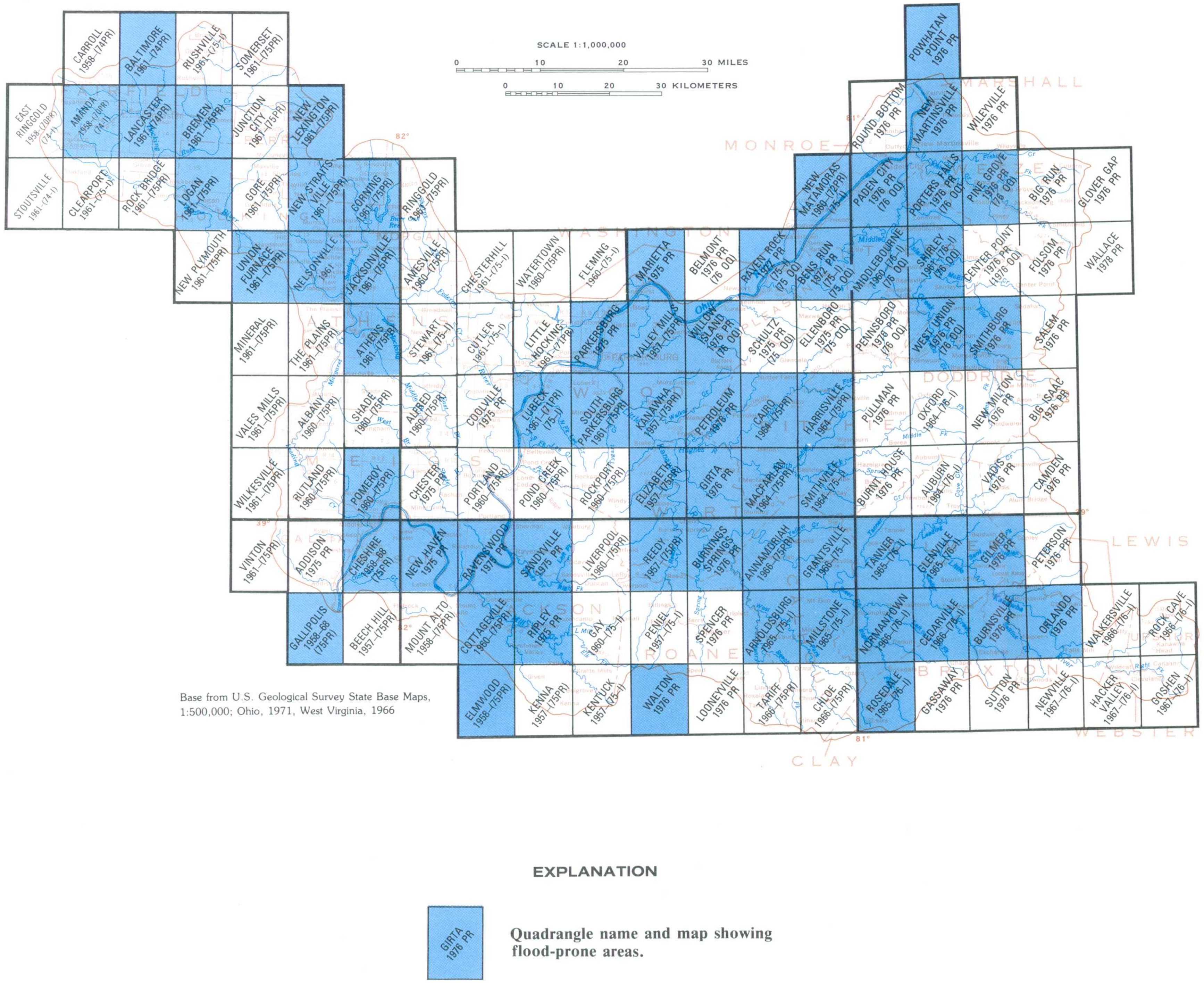


Figure 5.2.5-1 Availability of flood-prone area maps.

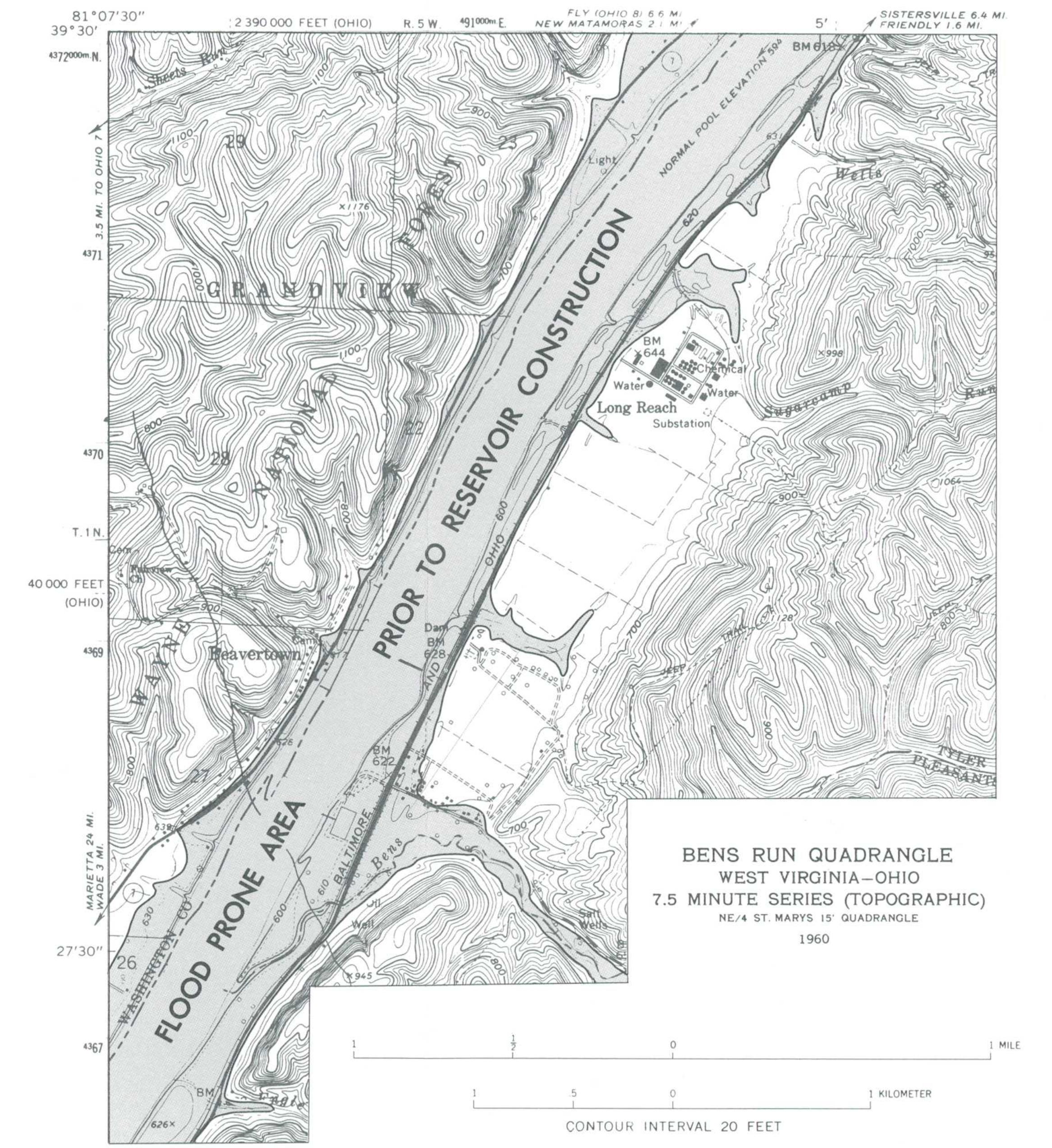


Figure 5.2.5-2 Example flood-prone area map.

Water-Quality Investigations are Supported by Laboratory Analytical Services and a Quality-Assurance Program

The U.S. Geological Survey uses field and laboratory analyses to describe water quality. Quality assurance is maintained by following established standards and techniques. Data are stored in computer files and retrieved through WATSTORE and STORET.

Water quality is described by the U.S. Geological Survey using a variety of instruments and techniques. Chemical characteristics subject to rapid change after collection are measured on site by electrometric or physical methods as shown in table 5.3.1-1. Characteristics measured on site include pH, specific conductance, water temperature, dissolved-oxygen concentration, alkalinity, acidity, and microbiological analyses such as fecal coliform and fecal streptococci density. Methods for measurement of chemical characteristics are described in Skougstad and others (1979), Garbarino and Taylor (1979), and Fredericks (1968). Methods for the measurement of suspended sediment are described by Guy (1969). Biological and microbiological methods are described by Greeson and others (1977), and Greeson (1979). Table 5.3.1-1 is a listing of water-quality characteristics that may be available at sites listed in section 9.1 and shown in figure 5.1-1. Not all water-quality characteristics were measured at all stations.

Chemical concentrations were determined for dissolved, suspended, and total-recoverable constituents in water, as well as total-recoverable constituents in bottom material. Concentrations of major constituents (calcium, magnesium, sodium, potassium, chloride, sulfate, fluoride, and bicarbonate) and most trace elements were determined for the dissolved phase. Dissolved and total recoverable concentrations of iron, manganese, and other selected constituents also are available.

Water-quality data from laboratory and field analyses are stored in WATSTORE and STORET computer files, and can be retrieved through terminals having access to these files (see sections 7.1 and 7.3 for information about WATSTORE).

Quality of field and laboratory analytical results is assured by use of reference samples, analysis of replicate samples, and review of analytical results. The quality-assurance program is maintained by the U.S. Geological Survey water-quality laboratory in Denver and by District offices responsible for sample collection and field determinations of selected water-quality characteristics.

Table 5.3.1-1 Field measurements and laboratory analyses used to describe water-quality conditions

Field measurements	Method	Reference	WATSTORE code
Specific conductance	Electrometric	Skougstad and others, 1979	00095
pH	do	do	00400
Water temperature	Thermometric or electrometric	do	00010
Dissolved oxygen	Electrometric, polarographic probe	do	00300
Alkalinity	Electrometric titration	do	00410
Acidity	do	do	71825
Total coliform	Membrane filter	Greeson and others, 1977	31501
Tecal coliform	do	Greeson, 1979	31625
Fecal streptococci	do	do	31673
Laboratory analyses			
Major ions (dissolved)			
Calcium	Atomic absorption spectrometric	Skougstad and others, 1979	00915
Magnesium	do	do	00925
Sodium	do	do	00930
Potassium	do	do	00935
Bicarbonate	Normally calculated from field alkalinity	do	00440
Carbonate	do		00445
Sulfate	Automated colorimetric	do	00945
Chloride	do	do	00940
Silica	ICAP (inductively coupled argon plasma)	Garbarino and Taylor, 1979	00955
Minor ions (dissolved)			
Barium	ICAP	Garbarino and Taylor, 1979	01005
Beryllium	do	do	01010
Cadmium	do	do	01025
Cobalt	do	do	01035
Copper	do	do	01040
Iron	Atomic absorption spectrometric	Skougstad and others, 1979	01046
Lead	ICAP	Garbarino and Taylor, 1979	01049
Lithium	do	do	01130
Manganese	Atomic absorption spectrometric	Skougstad and others. 1979	01056
Molybdenum	ICAP	Garbarino and Taylor, 1979	01060
Strontium	do	do	01080
Vanadium	do	do	01085
Zinc	do	do	01090
Minor elements in water (total recoverable)			
Iron	Atomic absorption spectrometric	Skougstad and others, 1979	01045
Manganese	do	do	01055
Minor elements in bottom material (total recoverable)			
Arsenic	Atomic absorption spectrometric	Skougstad and others, 1979	01003
Cadmium	do	do	01028
Chromium	do	do	01029
Cobalt	do	do	01038
Copper	do	do	01043
Iron	do	do	01170
Lead	do	do	01052
Manganese	do	do	01053
Mercury	do	do	71921
Selenium	do	do	01148
Zinc	do	do	01093
Organic constituents			
Total organic carbon	Carbon organic wet oxidation	Fredericks, 1968	00680
Coal in bottom material	Gravimetric	Skougstad and others, 1979	82031
Physical properties of water			
Dissolved residue on evaporation at 180°C	Gravimetric	Skougstad and others, 1979	70300
Suspended sediment	do	Guy, 1969	80154
Turbidity	Nephelometric	Skougstad and others, 1979	00076

Lithology and Land Use are Major Variables Affecting Specific Conductance of Surface Water in Area 8

Streams draining the Allegheny Formation and Pottsville Group have the greatest median specific conductances; these rock units are mined extensively in Ohio.

The lithology of shallow rocks in the area is one of the most important factors affecting specific conductance. Water draining from rock outcrops that contain relatively soluble minerals such as calcite ($CaCO_3$) tends to have higher specific conductance than water draining from areas having relatively insoluble minerals such as quartz-cemented sandstone. Salt deposits such as halite (NaCl) are highly soluble in water, and tend to impart a high specific conductance to water where they are present. Accidental release of brines and pit waste from oil and gas exploration are another source of high specific conductance water.

In Area 8, rock outcrops underlying the area were divided into five major geologic units. The median specific conductance of water from streams draining the Dunkard and Monongahela Groups was lowest—165 and 171 μmho/cm (micromhos per centimeter at 25°C)—whereas water from streams draining the Allegheny Formation and Pottsville Group in Ohio had the greatest median specific conductance, 1,030 μmho/cm. The Allegheny Formation and Pottsville Group both contain coal and are mined extensively in Ohio. Results of the Duncan's multiple-range test (table 5.3.2-1) indicate that water from the Allegheny Formation and Pottsville Group had a significantly greater specific conductance (at the 0.05 significance level) than water from the other geologic units.

The generalized surficial geology of the area and the median specific conductance at surface-water sites are shown in figure 5.3.2-1. The median specific conductance 1 at 148 sites was 260 μmho/cm and ranged from 41 to 4,040 μmho/cm. The median specific conductance at 50 percent of the sites ranged from 140 to 545 μmho/cm. The specific-conductance values in figure 5.3.2-1 represent an unequal number of observations per site and are for the period 1974-1982.

Land use is another important variable affecting the specific conductance of water. For example, when surficial material is disturbed by surface mining, consolidated rocks overlying the coal are broken up into smaller fragments. The increase in surface area plus exposure to weathering results in increased mineralization of surface water draining from the mined areas. Once surface mining has occurred, the effect on specific conductance is likely to last a long time. Pfaff and others (1981) reported that water from mined areas in Ohio had significantly higher specific conductance than water from unmined areas.

Reclamation of the mined areas did not decrease the specific conductance of the water in comparison with water from abandoned mining sites. This is probably a major reason why the median specific conductance of water at sites underlain by the Monongahela Group in Ohio was 472 μmho/cm, compared to 128 μmho/cm for water at West Virginia sites draining this same geologic unit.

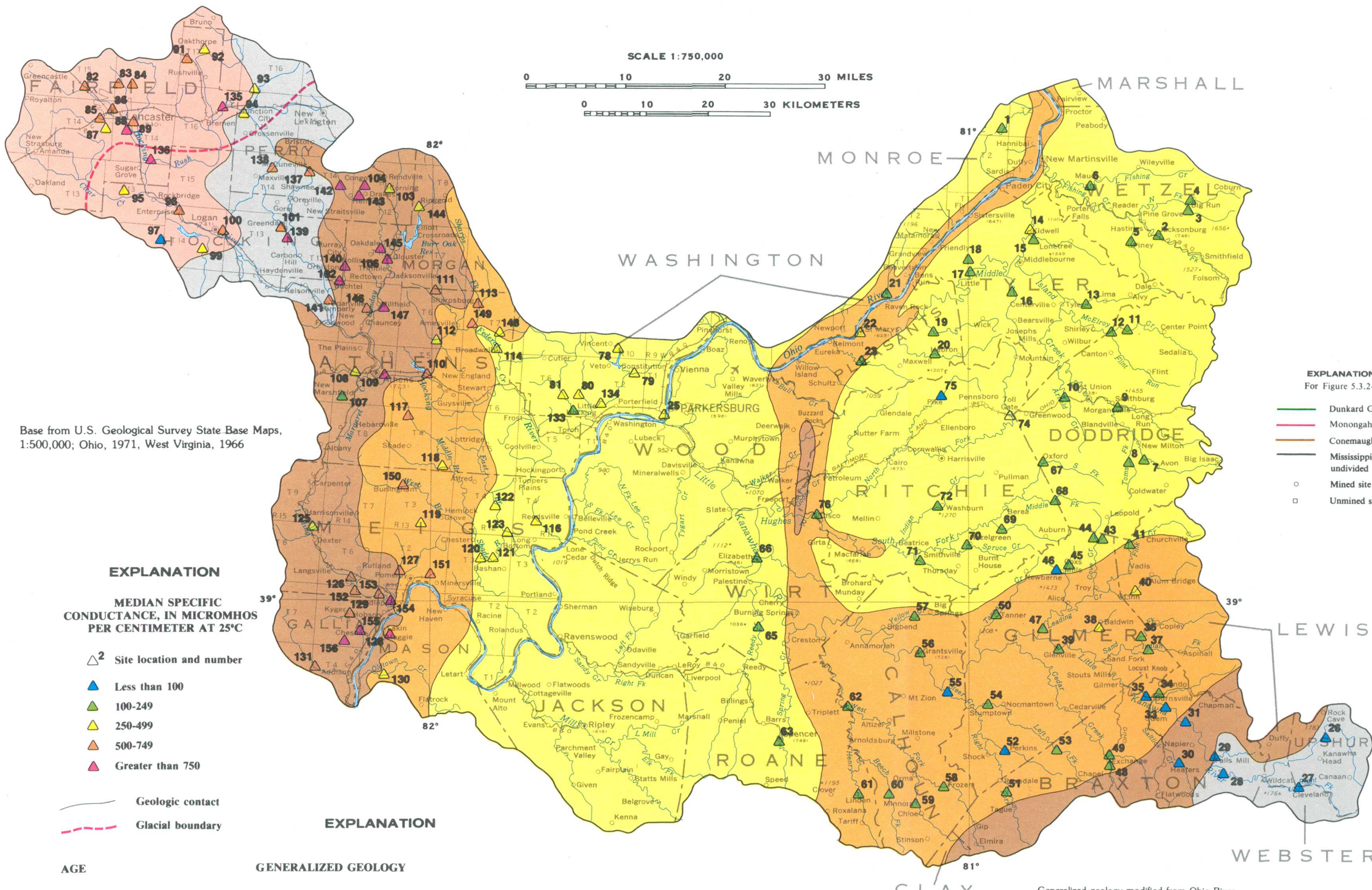
A major difference in land use between areas underlain by the Monongahela Group in Ohio and those in West Virginia is the degree of mining. A small amount of mining in rocks of the Monongahela Group occurs near sites 38 and 40 in West Virginia, but the extent of mining in the same geologic unit in Ohio is much greater. (See Pfaff and others, 1981 for detailed information regarding coal mining in Ohio). Abandoned oil and gas wells and the effects of drilling also can affect the specific conductance of surface water. Upward movement of brine from deep aquifers either during drilling or leakage from corroded and abandoned wells can easily contaminate shallow aquifers and surface waters (Bain, 1970; and Bain and Friel, 1972).

Precipitation and evapotranspiration affect specific conductance. In general, high specific conductance tends to be associated with low flow during prolonged periods of little or no rainfall, when streamflow is derived primarily from ground water. At higher stream discharges, when most streamflow is derived from overland flow, the specific conductance is lower. The relationship shown in figure 5.3.2-2 for the Little Kanawha River at Palestine, W. Va. (site 66) is typical of many streams in the area.

Specific conductance is closely related to the dissolved-solids content of water, a criterion in the EPA's secondary drinking water regulations (U.S. Environmental Protection Agency, 1979). The relationship between specific conductance and dissolved solids is slightly different for water from each geologic unit (figure 5.3.2-3). For example, at a specific conductance of 600 μmho/cm, surface water from the Mississippian rocks has a dissolved solids concentration of about 380 mg/L; from the Monongahela Group, about 408 mg/L; and from the Conemaugh Group, about 390 mg/L.

The summation of the major anions and cations (Ca, Mg, Na, K, HCO_3, SO_4, and Cl) is known as the total ion concentration. The total ion concentration is commonly expressed in milliequivalents per liter and is useful to describe the chemical balance of water. The relationship between specific conductance and total ion concentration, which was developed by regression analysis (fig. 5.3.2-4) indicates, for example, that a typical stream in Area 8 that has a specific conductance of 400 μmho/cm has a total ion concentration of about 7.8 milliequivalents per liter.

[1] All water-quality statistics referred to in this report are based on reducing the data at each site to one value, the mathematical median.



EXPLANATION

AGE	GENERALIZED GEOLOGY
PERMIAN OR PENNSYLVANIAN	Dunkard Group: Shale, sandstone, limestone, and coal
PENNSYLVANIAN	Monongahela Group: Shale, sandstone, limestone, and coal
	Conemaugh Group: Sandstone, shale, limestone, and coal.
	Allegheny Formation and Pottsville Group: Sandstone conglomerate, shale, and coal.
MISSISSIPPIAN	Sedimentary rocks, undivided: Siltstone, shale, sandstone, glacial deposits, and Maxville Limestone

Note: Geologic names are those used by the West Virginia Geological and Economic Survey, and do not necessarily conform to those used by the U.S. Geological Survey. The Monongahela, Conemaugh, and Pottsville are formation rank in Ohio.

Figure 5.3.2-1 Median specific conductance at surface-water sites and generalized surficial geology.

Table 5.3.2-1 Relationship between specific conductance of surface water and geologic unit

Geologic unit	Median specific conductance (µmho/cm)	Mean specific conductance (µmho/cm)	Duncans multiple range teat grouping*
Dunkard Group	165	211	B
Monongahela Group	171	369	B
Conemaugh Group	291	430	B
Pottsville Group and Allegheny Formation	1,030	1,180	A
Maxville Limestone	528	572	B

* The letters A and B represent Duncans multiple test grouping. Mean values having the same letter (A or B) are not significantly different at the 0.05 confidence level.

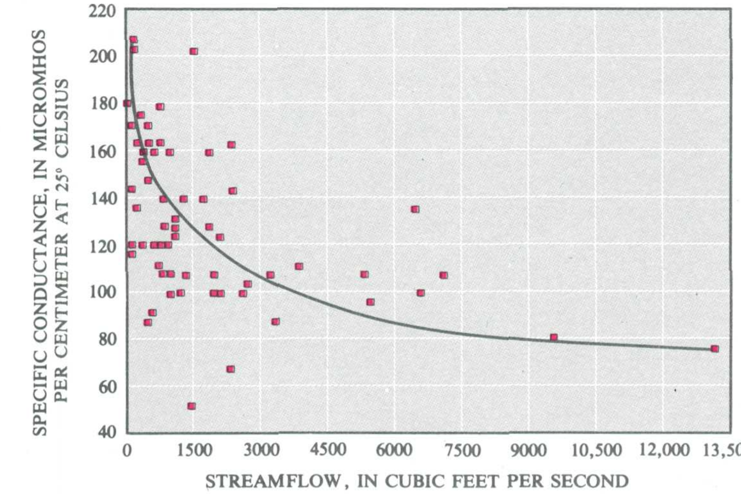


Figure 5.3.2-2 Relationship between specific conductance and streamflow for the Little Kanawha River at Palestine, West Virginia (site 66).

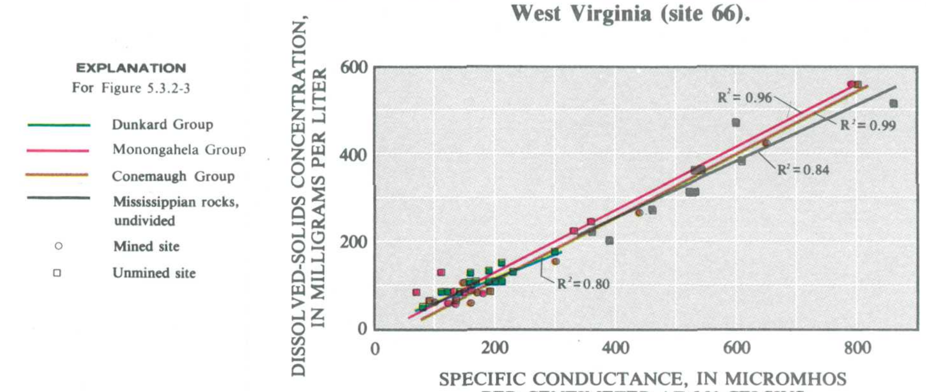


Figure 5.3.2-3 Relationship between dissolved solids and specific conductance for major geologic units.

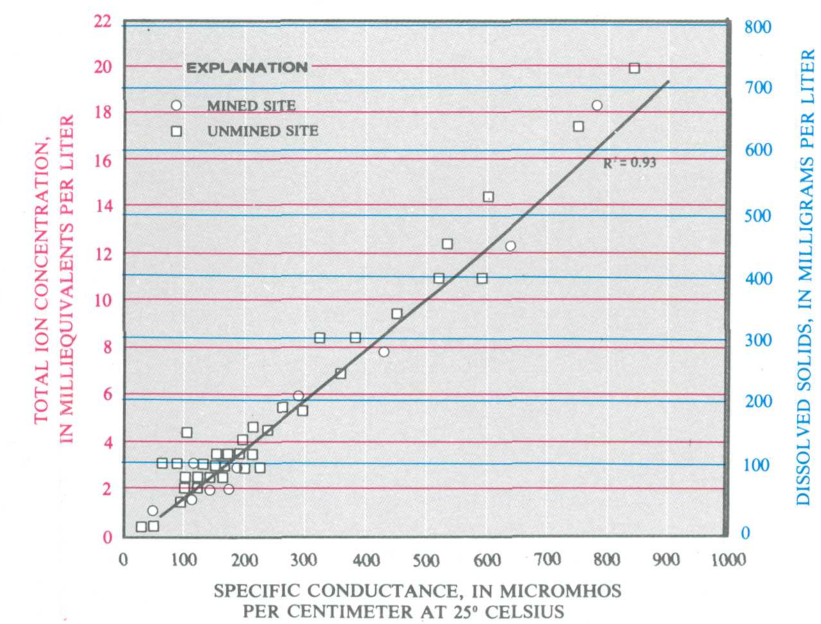


Figure 5.3.2-4 Relationship between specific conductance, dissolved solids, and total ion concentration.

Lowest Surface-Water pH Values are Associated with Extensively Mined Areas in Ohio

Lithology and land use are the major factors affecting the pH of surface water. Alkaline water is predominant in areas underlain by glacial deposits and the Mississippian rocks. The Allegheny Formation and Pottsville Group are extensively mined in Ohio and have the lowest stream pH.

The lithology of the shallow rocks in the area is one of the most important variables affecting the pH. In Area 8, for the purpose of this discussion, the rock outcrops are divided into five major geologic units, as shown in figure 5.3.3-1.

Water having the highest median pH (7.7) is present in streams draining the glacial deposits and Mississippian rocks in Ohio (table 5.3.3-1). The Mississippian rocks (shown in figure 5.3.3-1 as undivided sedimentary rocks of Mississippian age) crop out in the extreme western portion of the study area and underlie the headwaters of the Hocking River. This geologic unit contains no coal. The land uses in this area are principally forest, pasture, and cropland. The soils overlying the Mississippian rocks developed primarily over glacial drift of Wisconsin and Illinoian Age and generally are alkaline and well drained. Because of the pH, drainage characteristics, and degree of development, these soils make prime farmland. The median pH at 148 surface-water sites was 7.3 and ranged from pH 2.9 to 8.1. The median pH at 50 percent of the sites ranged from 6.9 to 7.5. The median pH for all sites is shown in figure 5.3.3-1.

The median pH from streams draining the Dunkard, Monongahela, and Conemaugh Groups was 7.4, 7.2, and 7.2, respectively. These pH values were not significantly different at the 0.05 significance level. However, the median pH of streams draining the Allegheny Formation and Pottsville Group was 5.0, which was significantly lower than the pH of water from the other rock units. The Allegheny Formation and Pottsville Group contain coal and are extensively surface mined in Ohio. Mining in these rock units is less in the West Virginia portion of Area 8.

Land use is probably the second most important factor affecting the pH of surface water. Disturbance of rocks and soils during mining tends to increase the minerals in solution and can drastically affect the pH of water draining from these areas. Weathering of minerals overlying extensive limestone areas, such as the Maxville Limestone, forms alkaline solutions because of the hydrolysis of calcium carbonate, as follows:

$$CaCO_3 + H_2O \rightleftharpoons HCO^-{}_3 - OH^-$$

and

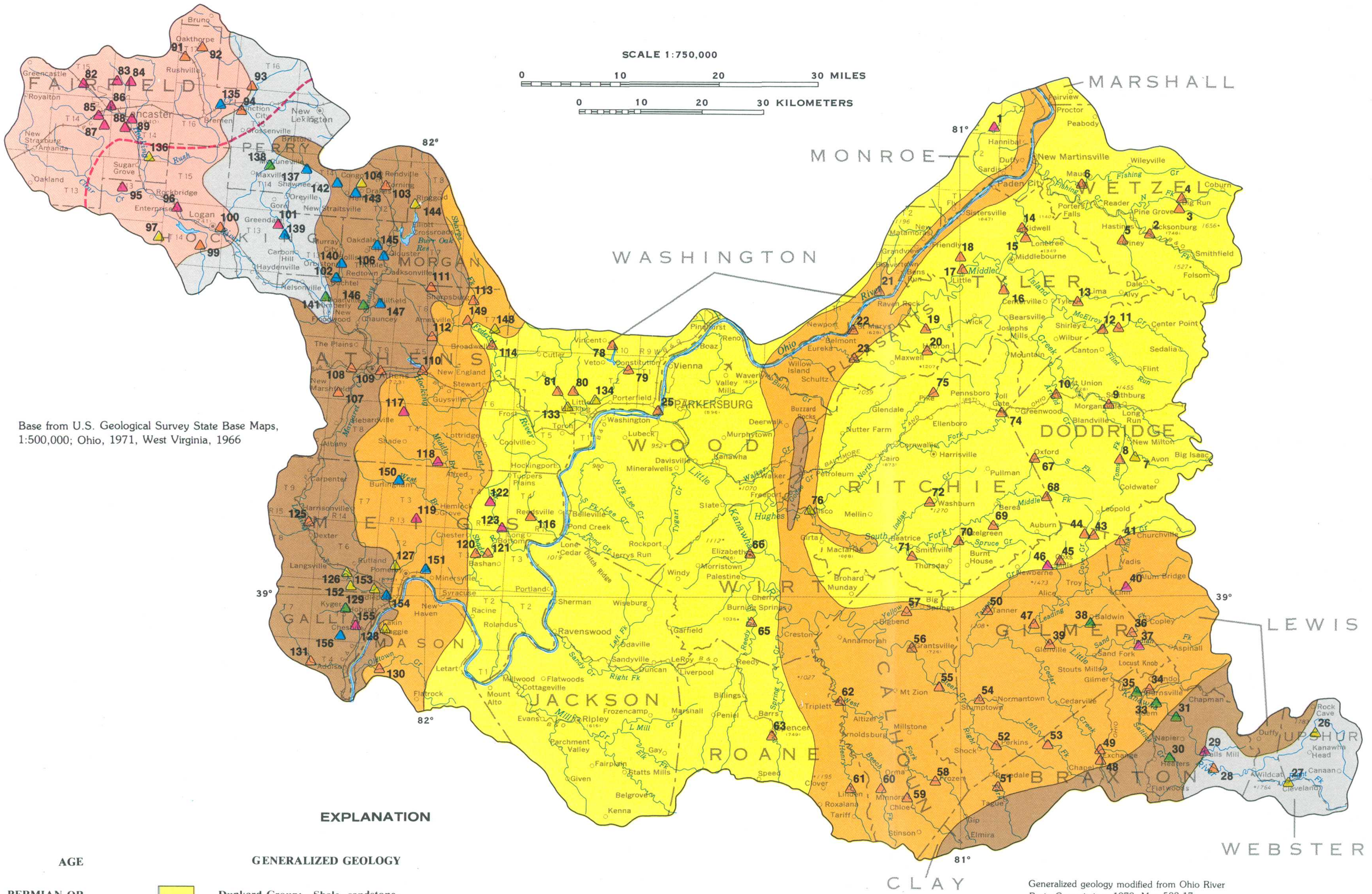
$$HCO^-{}_3 + H^+ \rightleftharpoons H_2CO_3$$

The net effect of these chemical reactions is reflected in the distribution of pH values shown in figure 5.3.3-1. High stream pH values generally are present in the headwaters of the Hocking River where the Mississippian rocks crop out.

Surface mining disturbs the land surface and exposes rocks associated with coal resources to weathering. The rock units in Area 8 contain significant concentrations of oxidizable sulfides (principally pyrite, FeS_2), which can be rapidly oxidized to sulfate, hydrogen ion, and ferrous iron, as follows:

$$FeS_2 + H_2O + 7/2O_2 \xrightarrow{\text{bacteria}} Fe^{+2} + 2H^+ SO_4{}^{-2}$$

The pH of water draining from surface mined areas in Ohio commonly ranges from 2.0 to 4.0 as a result (Pfaff and others, 1981). Portions of the area that are extensively surface mined tend to have lower surface water pH values than unmined areas. This is shown by the presence of relatively acidic water in areas in Ohio underlain principally by the Monongahela Group, Conemaugh Group, and the Allegheny Formation and Pottsville Group, all of which contain coal resources (fig. 5.3.3-1). Far less mining of coal resources of the Monongahela Group has occurred in West Virginia than in Ohio. This is reflected in the lower median pH (6.9) of water at sites overlying the Monongahela group in Ohio compared with water at sites overlying the same group in West Virginia (pH 7.2).



Base from U.S. Geological Survey State Base Maps, 1:500,000; Ohio, 1971, West Virginia, 1966

Generalized geology modified from Ohio River Basin Commission, 1978, Map 503-17.

EXPLANATION

AGE		GENERALIZED GEOLOGY
PERMIAN OR PENNSYLVANIAN		Dunkard Group: Shale, sandstone, limestone, and coal
PENNSYLVANIAN		Monongahela Group: Shale, sandstone, limestone, and coal
		Conemaugh Group: Sandstone, shale, limestone, and coal.
		Allegheny Formation and Pottsville Group: Sandstone conglomerate, shale, and coal.
MISSISSIPPIAN		Sedimentary rocks, undivided: Siltstone, shale, sandstone, glacial deposits, and Maxville Limestone

Note: Geologic names are those used by the West Virginia Geological and Economic Survey, and do not necessarily conform to those used by the U.S. Geological Survey. The Monongahela, Conemaugh, and Pottsville are formation rank in Ohio.

MEDIAN pH

△2 Site location and number

- Less than 5.6
- 5.6-6.2
- 6.3-6.9
- 7.0-7.6
- Greater than 7.6

Geologic contact

Glacial boundary

Figure 5.3.3-1 Median pH at surface-water sites and generalized surficial geology.

Table 5.3.3-1 Median pH of surface water by geologic unit

Geologic unit	Median pH
Dunkard Group	7.4
Monongahela Group	7.2
Conemaugh Group	7.2
Allegheny Formation and Pottsville Group.	5.0
Mississippian rocks, undivided and glacial area.	7.7

Water From Sites Overlying the Mississippian Rocks in Ohio had the Highest Alkalinity

Lithology is the primary factor affecting the alkalinity of surface water. Streams overlying the Mississippian rocks had the highest alkalinity concentration while streams overlying the Allegheny Formation and Pottsville Group had the lowest.

Surface water in Area 8 varies widely in alkalinity content. Rainfall typically contains very low alkalinity, whereas ground water generally has higher alkalinity, principally because of the greater bicarbonate concentration. The lithology of an area is the primary factor affecting the alkalinity of surface and ground water. Bicarbonate, carbonate, and hydroxyl ions result from the solution of limestone as follows:

$$CaCO_3 \text{ (limestone)} + H_2O \rightleftharpoons Ca^{+2} + HCO^-_3 + OH^-$$

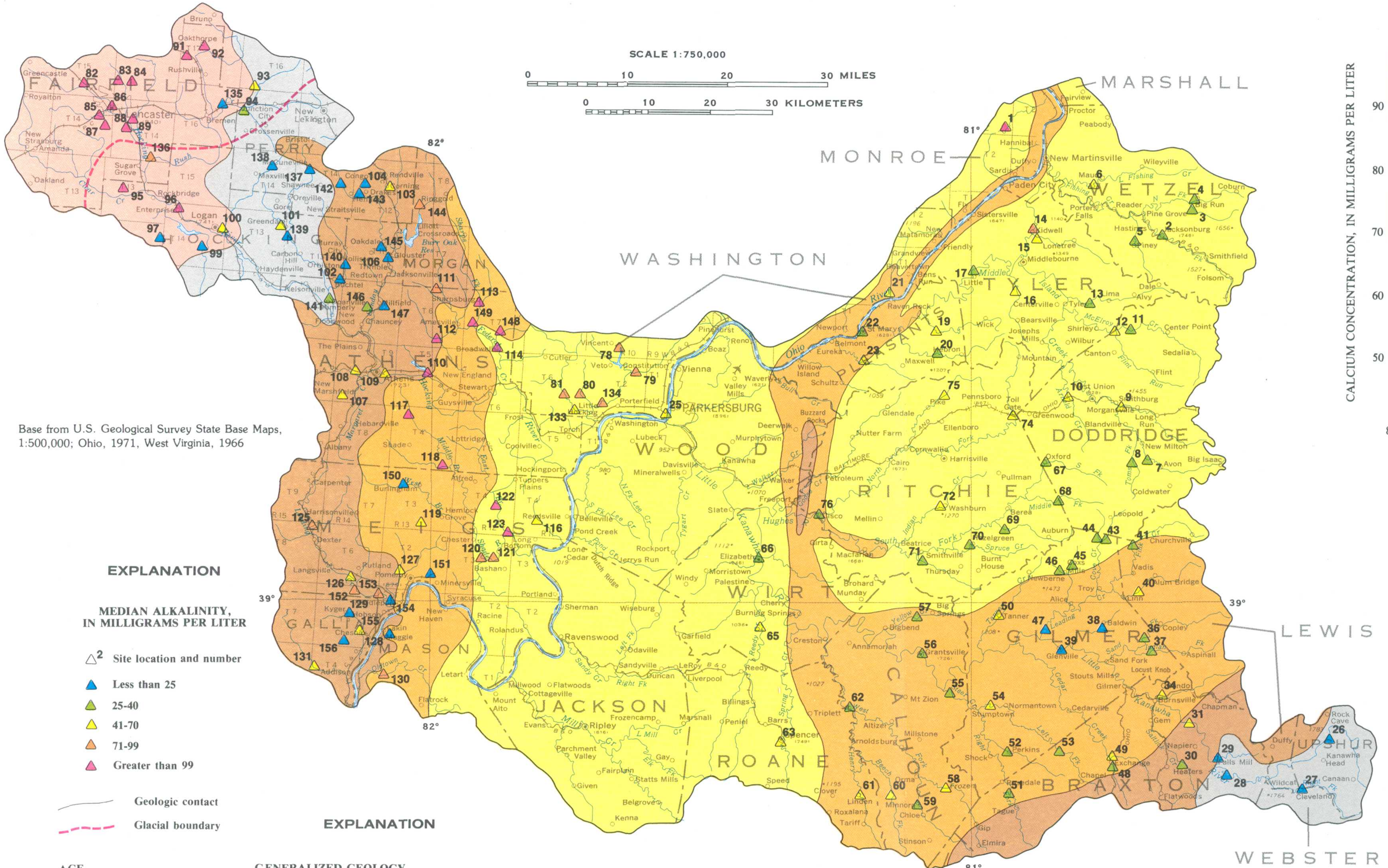
$$HCO^-_3 + H^+ \rightleftharpoons H_2CO_3$$

Land use is another important factor affecting the alkalinity concentration of water. Disturbance of rocks and soils during surface mining tends to increase the minerals in solution. Rocks in Area 8 contain measurable quantities of oxidizable sulfides that can be rapidly oxidized to sulfuric acid. Drainage from this source is characterized by a low pH and little or no alkalinity. Sites at which 50 percent or more of the upstream drainage area was disturbed by mining were considered to be affected. Pfaff and others (1981) reported that sites in Ohio that received drainage from abandoned coal mines had significantly lower alkalinity than sites draining unmined areas. Results from this study support that conclusion. Water from streams categorized as being affected by coal mining had significantly lower mean alkalinity (37.5 mg/L) than did water at sites unaffected by mining (70 mg/L) at the 0.05 level of significance.

The median alkalinity at 144 surface-water sites was 42 mg/L and ranged from 0 to 290 mg/L. The median alkalinity at 50 percent of the sites ranged from 27 to 74 mg/L. The median alkalinity and surficial geology for all sites are shown in figure 5.3.4-1.

The rocks underlying the area are divided into five major geologic units, as shown in figure 5.3.4-1. Water from streams draining the Mississippian rocks in Ohio had the highest median alkalinity concentration (176 mg/L). Median alkalinity concentrations in water draining the Dunkard, Conemaugh, and Monongahela Groups in Ohio and West Virginia are shown in table 5.3.4-1. The median alkalinity in water from the Dunkard, Monongahela, and Conemaugh Groups was 47, 40, and 42 mg/L, respectively. The median alkalinity in water from the Allegheny Formation and Pottsville Group was significantly lower than water from the other rock units, 5 mg/L. The Mississippian rocks contain the Maxville Limestone, which is of marine origin and is of variable thickness (generally less than 200 feet). The other major rock units in Area 8 contain lesser thicknesses of limestone. When hydrolysis of limestone occurs, equivalent quantities of bicarbonate and calcium are produced. This results in the relationship between the calcium and alkalinity concentrations shown in figure 5.3.4-2.

Acidity is an important chemical characteristic to measure in areas affected by coal mining. When present in significant quantities, it indicates the presence of oxidizable sulfur compounds that can adversely affect the quality of water, if suitable reclamation is not followed. Water at most sites in Area 8 had no measurable acidity (less than 1 mg/L as H^-); however, water at 10 sites (table 5.3.4-2) did have median acidity concentrations exceeding 1 mg/L as H^-. Water at nearly all of these sites was from the Allegheny Formation or Pottsville Group, both of which contain coal resources and are extensively surface mined in Ohio. Water from several streams draining the Conemaugh and Monongahela Groups also had measurable acidity concentrations.



Base from U.S. Geological Survey State Base Maps, 1:500,000; Ohio, 1971, West Virginia, 1966

EXPLANATION

MEDIAN ALKALINITY, IN MILLIGRAMS PER LITER

△2 Site location and number
Less than 25
25-40
41-70
71-99
Greater than 99

Geologic contact
Glacial boundary

EXPLANATION

AGE	GENERALIZED GEOLOGY
PERMIAN OR PENNSYLVANIAN	Dunkard Group: Shale, sandstone, limestone, and coal
PENNSYLVANIAN	Monongahela Group: Shale, sandstone, limestone, and coal
	Conemaugh Group: Sandstone, shale, limestone, and coal.
	Allegheny Formation and Pottsville Group: Sandstone conglomerate, shale, and coal.
MISSISSIPPIAN	Sedimentary rocks, undivided: Siltstone, shale, sandstone, glacial deposits, and Maxville Limestone

Note: Geologic names are those used by the West Virginia Geological and Economic Survey, and do not necessarily conform to those used by the U.S. Geological Survey. The Monongahela, Conemaugh, and Pottsville are formation rank in Ohio.

Generalized geology modified from Ohio River Basin Commission, 1978, Map 503-17.

Figure 5.3.4-1 Median alkalinity at surface-water sites and generalized surficial geology.

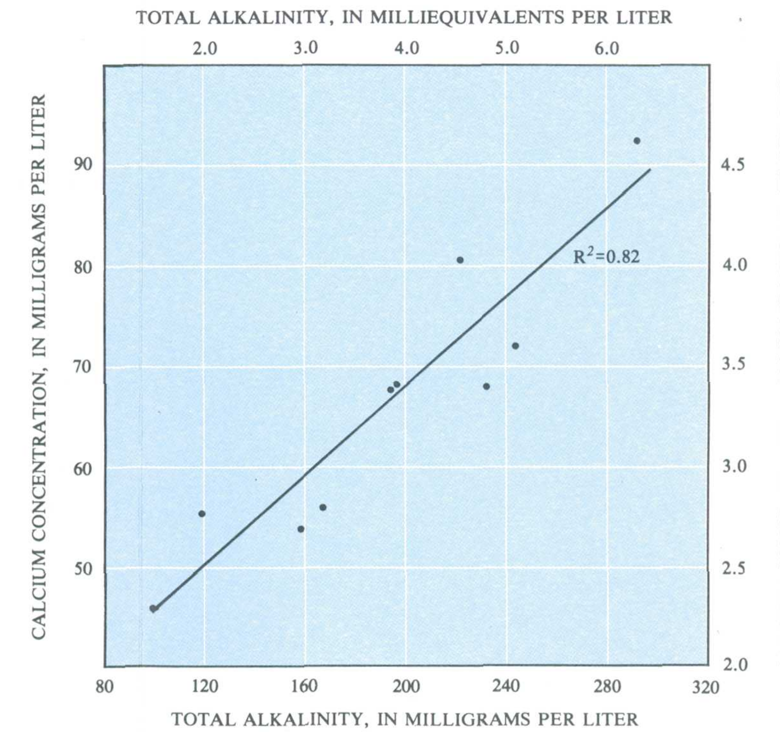


Figure 5.3.4-2 Relationship between total alkalinity and calcium concentration at surface-water sites overlying the Mississippian rocks.

Table 5.3.4-1 Median alkalinity at surface-water sites overlying the Dunkard, Conemaugh, and Monongahela Groups in Ohio and West Virginia

Geologic unit	Median alkalinity, in milligrams per liter: West Virginia	Ohio
Dunkard Group	38.5	98
Conemaugh Group	38	55
Monongahela Group	33	94

Table 5.3.4-2 Relationship between acidity concentration and geologic unit

Geologic unit	Number of sites having a median acidity concentration exceeding 1 mg/L as H^+	Total number of sites	Median concentration, in mg/L
Dunkard Group	0	31	0.1
Monongahela Group	1	17	.1
Conemaugh Group	2	19	.1
Pottsville Group and Allegheny Formation.	7	8	2.2

Sulfate Concentrations were Highest in Streams Draining Mined Areas

The highest sulfate concentrations were found in streams overlying the Pottsville Group and Allegheny Formation, which are extensively mined in Ohio.

The lithology of the shallow rocks in Area 8 is the primary factor affecting the sulfate concentration of water. Sulfur is present in rocks largely as sulfide such as pyrite (FeS_2) and marcasite. Weathering of pyrite produces sulfate (SO_4^{-2}), hydrogen ion (H^+), and iron (Fe^{+2}) by action of autotrophic bacteria such as *Thiobacillus* as follows:

$$FeS_2 + H_2O + 7/2O_2 \xrightarrow{\text{bacteria}} Fe^{+2} + 2H^+ 2SO^{-2}$$

The solution of gypsum ($CaSO_4$) probably is a lesser source of sulfate in Area 8 than is the oxidation of pyrite. Precipitation is another minor source of sulfate. Winter precipitation in most of West Virginia and in eastern Ohio averaged about 2 to 4 mg/L sulfate during 1980-81 (Peters and Bonelli, 1982).

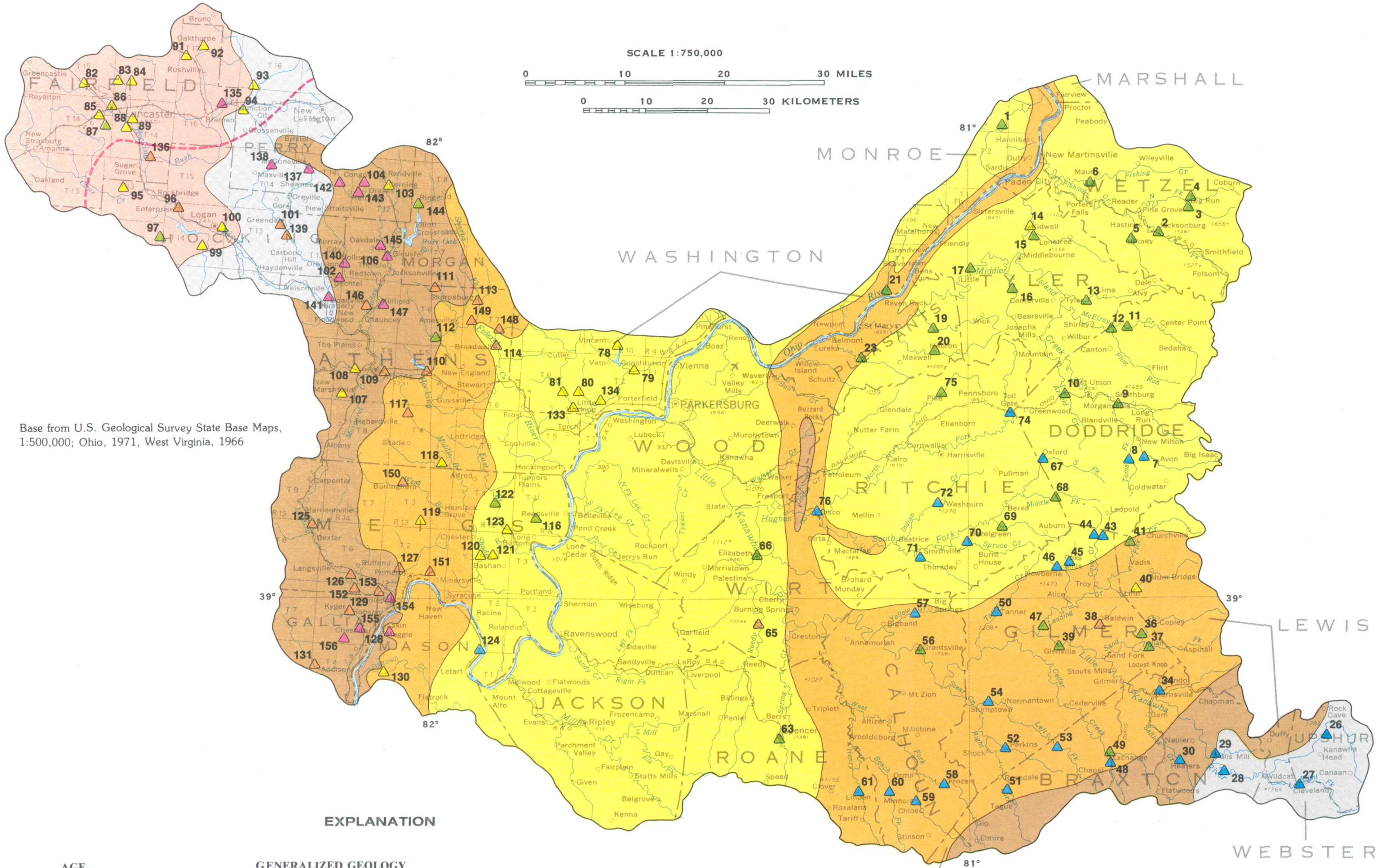
The median sulfate concentration at 139 surface-water sites was 35.5 mg/L and ranged from 4.8 to 2,845 mg/L. The sulfate concentrations described here represent an unequal number of observations per site and are for the period 1974-82. The median sulfate concentration at 50 percent of the sites ranged from 16 to 104 mg/L. The median sulfate concentration for all sites, and the generalized surfical geology of the area, are shown in figure 5.3.5-1.

The chemical composition of the shallow rocks is an important factor affecting the sulfate concentration in surface water throughout Area 8. Water from streams draining the Dunkard Group had the lowest median sulfate concentration, 21 mg/L. The median sulfate concentration in water from the Monongahela Group, Conemaugh Group, and Mississippian rocks were 30, 63, and 52 mg/L, respectively. The median sulfate concentration in water from the Allegheny Formation and Pottsville Group (340 mg/L), was significantly higher (at the 0.05 level) than water from the other rock units. The Allegheny Formation and Pottsville Group both contain coal resources that are extensively mined in Ohio.

Land use is another important factor that can affect the sulfate concentration of surface water. Any land disturbance, such as surface mining, which results in the exposure of sulfur containing rocks to weathering, will tend to result in increased levels of sulfate in drainage from mined areas. All surface-water sites were categorized with regard to coal mining. Sites having 50 percent or more of the upstream drainage area disturbed by mining were categorized as "mined". Sites categorized as "mined" had a significantly greater median sulfate concentration (135 mg/L) than did "unmined" sites (28 mg/L). Other investigators have shown similar results. Pfaff and others (1981) reported that drainage from abandoned mining and reclaimed areas had a significantly greater sulfate concentration (about 8 times higher) than did unmined areas. They also reported that site reclamation did not significantly decrease the sulfate concentration in water draining from these areas.

Agriculture is a significant land use category in Area 8, particularly in Fairfield County, Ohio. The sulfate concentration of surface water in this portion of Area 8 generally was less than 50 mg/L. Other portions of Area 8 in Ohio with lesser proportions of agricultural area had as high or higher median sulfate concentrations in surface water. For this reason, agriculture probably does not have a significant effect on the sulfate concentration of surface water in Area 8.

Sulfate is a major component of the solute load in streams throughout Area 8. Many water-quality characteristics such as specific conductance and concentrations of hardness, calcium, magnesium, iron, manganese, aluminum, dissolved solids, and total acidity, often correlate highly with sulfate concentration. This permits the quantitative prediction of sulfate concentration by regression analysis where one or more of the other chemical characteristics are known. The relationships of sulfate concentrations to specific conductance and to hardness concentrations are shown respectively in figures 5.3.5-2 and 5.3.5-3 for most geologic units.



EXPLANATION

AGE	GENERALIZED GEOLOGY
PERMIAN OR PENNSYLVANIAN	Dunkard Group: Shale, sandstone, limestone, and coal
PENNSYLVANIAN	Monongahela Group: Shale, sandstone, limestone, and coal
	Conemaugh Group: Sandstone, shale, limestone, and coal.
	Allegheny Formation and Pottsville Group: Sandstone conglomerate, shale, and coal.
MISSISSIPPIAN	Sedimentary rocks, undivided: Siltstone, shale, sandstone, glacial deposits, and Maxville Limestone

Note: Geologic names are those used by the West Virginia Geological and Economic Survey, and do not necessarily conform to those used by the U.S. Geological Survey. The Monongahela, Conemaugh, and Pottsville are formation rank in Ohio.

MEDIAN SULFATE CONCENTRATION, IN MILLIGRAMS PER LITER

- △2 Site location and number
- Less than 16
- 16-34
- 35-89
- 90-250
- Greater than 250

- Geologic contact
- Glacial boundary

Figure 5.3.5-1 Median sulfate concentration at surface-water sites and generalized surficial geology.

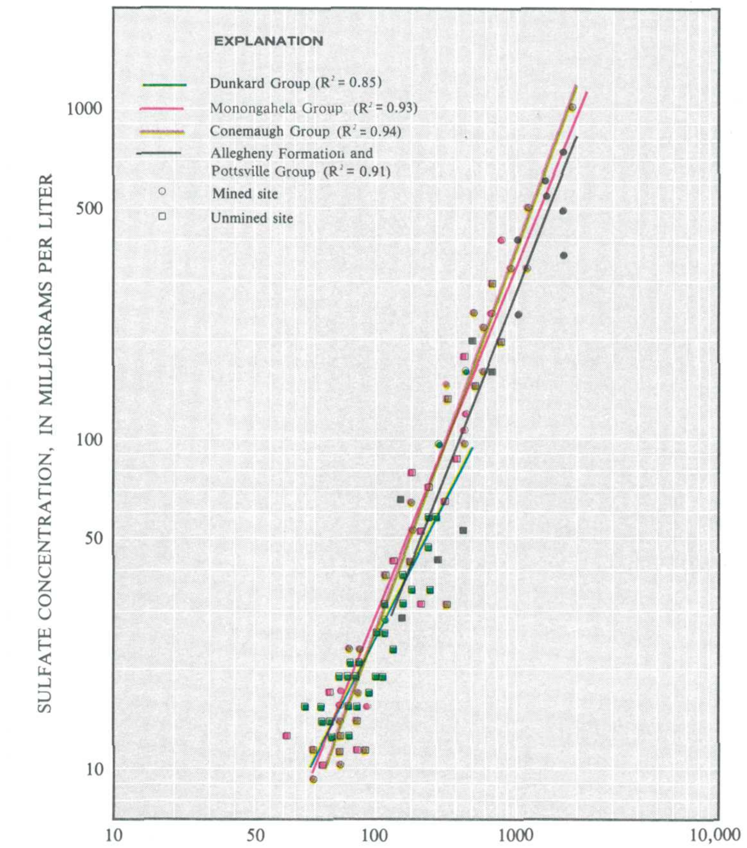


Figure 5.3.5-2 Relationship between sulfate concentration and specific conductance at surface-water sites overlying selected geologic units.

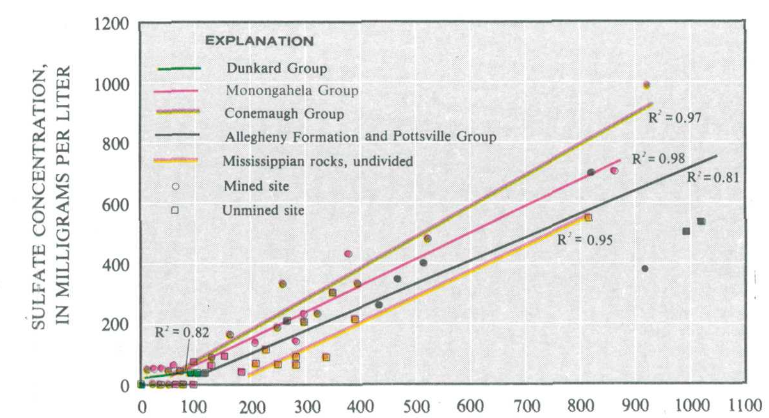


Figure 5.3.5-3 Relationship between total hardness and sulfate concentration for major geologic units.

Dissolved-Iron Concentrations were Greatest in Streams Draining Mined Areas

Streams draining mined areas had more than 16 times greater dissolved-iron concentrations than streams draining unmined areas.

Iron is present in rocks primarily as the sulfide (FeS_2, iron pyrite) and carbonate ($FeCO_3$, siderite). Natural weathering of rock outcrops containing these minerals probably accounts for much of the iron in surface water through the following reaction:

$$FeS_2 + H_2O + 7/2O_2 \xrightarrow{\text{bacteria}} Fe^{+2} + 2H^+ + 2SO_4^{-2}$$

Surface mining accelerates the solution of these minerals by breaking the consolidated rocks overlying the coal into smaller fragments which have a much greater surface area. Drainage from spoil areas, coal piles and mined areas tends to be associated with increased concentrations of iron as a result. For example, Pfaff and others (1981) reported that streams affected by abandoned coal mine drainage averaged greater than 5,000 μg/L dissolved iron. Iron concentrations in streams draining unmined basins generally do not exceed 1,000 μg/L.

The median concentration of dissolved iron at 108 surface-water sites was 66 μg/L and ranged from 14 to 17,000 μg/L. The iron concentrations described here represent an unequal number of observations per site and are for the period 1974-1982. The median dissolved-iron concentration at 50 percent of the sites ranged from 50 to 90 μg/L. Total iron concentrations (dissolved plus suspended) were typically much higher than dissolved-iron concentrations (median 630 μg/L, range 100 to 565,000 μg/L, range of half the sites 410 to 1,038 μg/L). The median dissolved and total iron concentrations at all sites and the generalized surficial geology of Area 8 are respectively shown in figures 5.3.6-1 and 5.3.6-2.

Land use is an important factor that influences the iron concentration in surface water throughout Area 8. Any land disturbance that exposes rocks containing sulfide to weathering will increase the concentration of dissolved iron in water draining from the disturbed areas. Surface-water sites were categorized as either "mined" or "unmined" based on the extent of coal mining within the drainage basin. Sites having 50 percent or more of the upstream drainage area disturbed by mining were considered to be affected by mining. Water from the mined areas had a significantly greater (16 times increase) median dissolved-iron concentration at the 0.05 confidence level (1,153 μg/L versus 69 μg/L) than water from the unmined areas. Total iron concentration was not significantly different between mined and unmined sites at the same confidence level.

The lithology of the rocks in the area is another variable that affects the concentration of iron in surface water. Water from streams draining the Dunkard Group and Mississippian rocks had the lowest median dissolved iron concentration, 60 μg/L. Median dissolved-iron concentrations in water from the Conemaugh and Monongahela Groups were slightly greater (69 and 70 μg/L, respectively). Water from streams draining the Allegheny Formation and Pottsville Group had the greatest median dissolved iron concentration, 110 μg/L. There was no significant statistical difference in these concentrations at the 0.05 confidence level. The relationship between total iron concentration and geologic unit was much the same. Median total iron concentration was lowest in water from the Dunkard Group (520 μg/L) and greatest in water from the Allegheny Formation and Pottsville Group (1,950 μg/L). However, there was no significant statistical difference in total iron concentration between geologic units at the 0.05 confidence level. It is likely that the high iron concentrations observed in water from the Allegheny Formation and Pottsville Group reflect the low median pH of water from those units (median pH = 5.0).

EXPLANATION

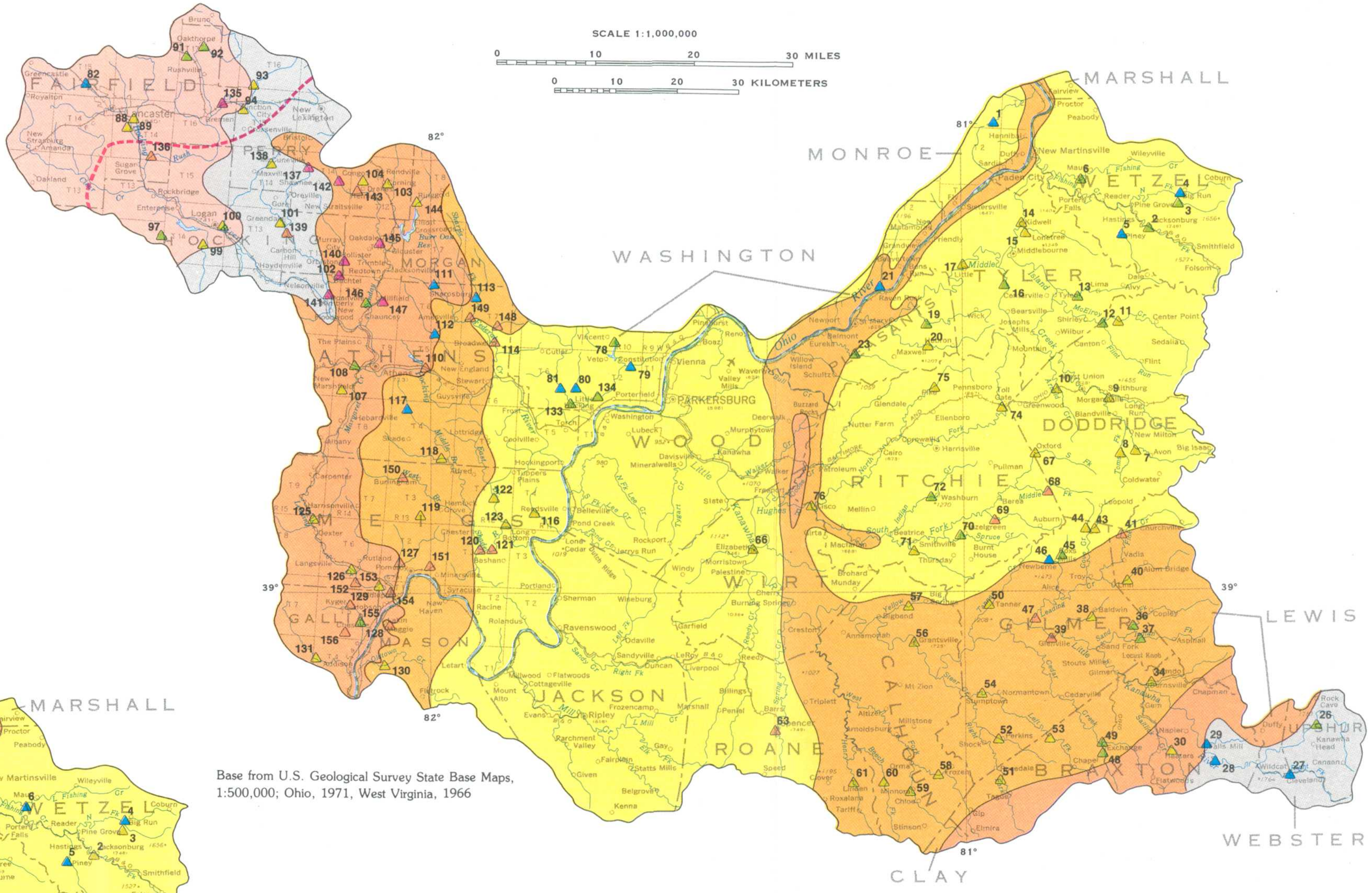
AGE	GENERALIZED GEOLOGY
PERMIAN OR PENNSYLVANIAN	Dunkard Group: Shale, sandstone, limestone, and coal
	Monongahela Group: Shale, sandstone, limestone, and coal
PENNSYLVANIAN	Conemaugh Group: Sandstone, shale, limestone, and coal
	Allegheny Formation and Pottsville Group: Sandstone conglomerate, shale, and coal
MISSISSIPPIAN	Sedimentary rocks, undivided: Siltstone, shale, sandstone, glacial deposits, and Maxville Limestone

MEDIAN DISSOLVED IRON CONCENTRATION, IN MICROGRAMS PER LITER

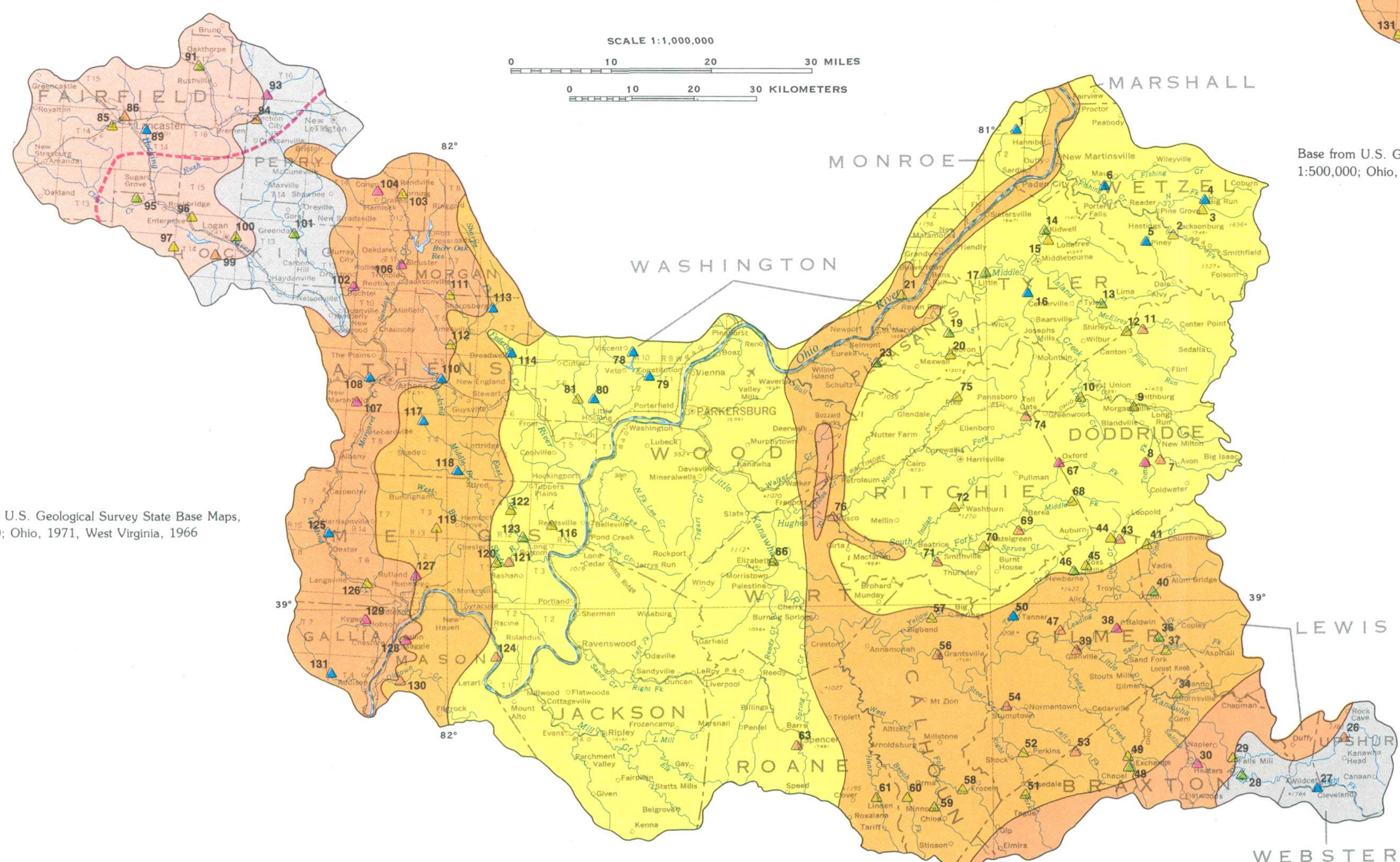
- △2 Site location and number
- ▲ 0-30
- ▲ 31-50
- ▲ 51-80
- ▲ 81-120
- ▲ Greater than 120
- Geologic contact
- Glacial boundary

Note: Geologic names are those used by the West Virginia Geological and Economic Survey, and do not necessarily conform to those used by the U.S. Geological Survey. The Monongahela, Conemaugh, and Pottsville are formation rank in Ohio.

Generalized geology modified from Ohio River Basin Commission, 1978, Map 503-17.



Base from U.S. Geological Survey State Base Maps, 1:500,000; Ohio, 1971, West Virginia, 1966



Base from U.S. Geological Survey State Base Maps, 1:500,000; Ohio, 1971, West Virginia, 1966

Figure 5.3.6-1 Median dissolved-iron concentration at surface-water sites and generalized surficial geology.

EXPLANATION

AGE	GENERALIZED GEOLOGY
PERMIAN OR PENNSYLVANIAN	Dunkard Group: Shale, sandstone, limestone, and coal
	Monongahela Group: Shale, sandstone, limestone, and coal
PENNSYLVANIAN	Conemaugh Group: Sandstone, shale, limestone, and coal
	Allegheny Formation and Pottsville Group: Sandstone conglomerate, shale, and coal
MISSISSIPPIAN	Sedimentary rocks, undivided: Siltstone, shale, sandstone, glacial deposits, and Maxville Limestone

MEDIAN TOTAL IRON CONCENTRATION, IN MICROGRAMS PER LITER

- △2 Site location and number
- ▲ 0-300
- ▲ 301-500
- ▲ 501-1000
- ▲ 1001-5000
- ▲ Greater than 5000
- Geologic contact
- Glacial boundary

Note: Geologic names are those used by the West Virginia Geological and Economic Survey, and do not necessarily conform to those used by the U.S. Geological Survey. The Monongahela, Conemaugh, and Pottsville are formation rank in Ohio.

Generalized geology modified from Ohio River Basin Commission, 1978, Map 503-17.

Figure 5.3.6-2 Median total iron concentration at surface-water sites and generalized surficial geology.

Mining Causes Increased Manganese Concentration

The concentration of dissolved manganese in surface water was significantly greater at sites overlying the Allegheny Formation and Pottsville Group than at sites overlying other geologic units.

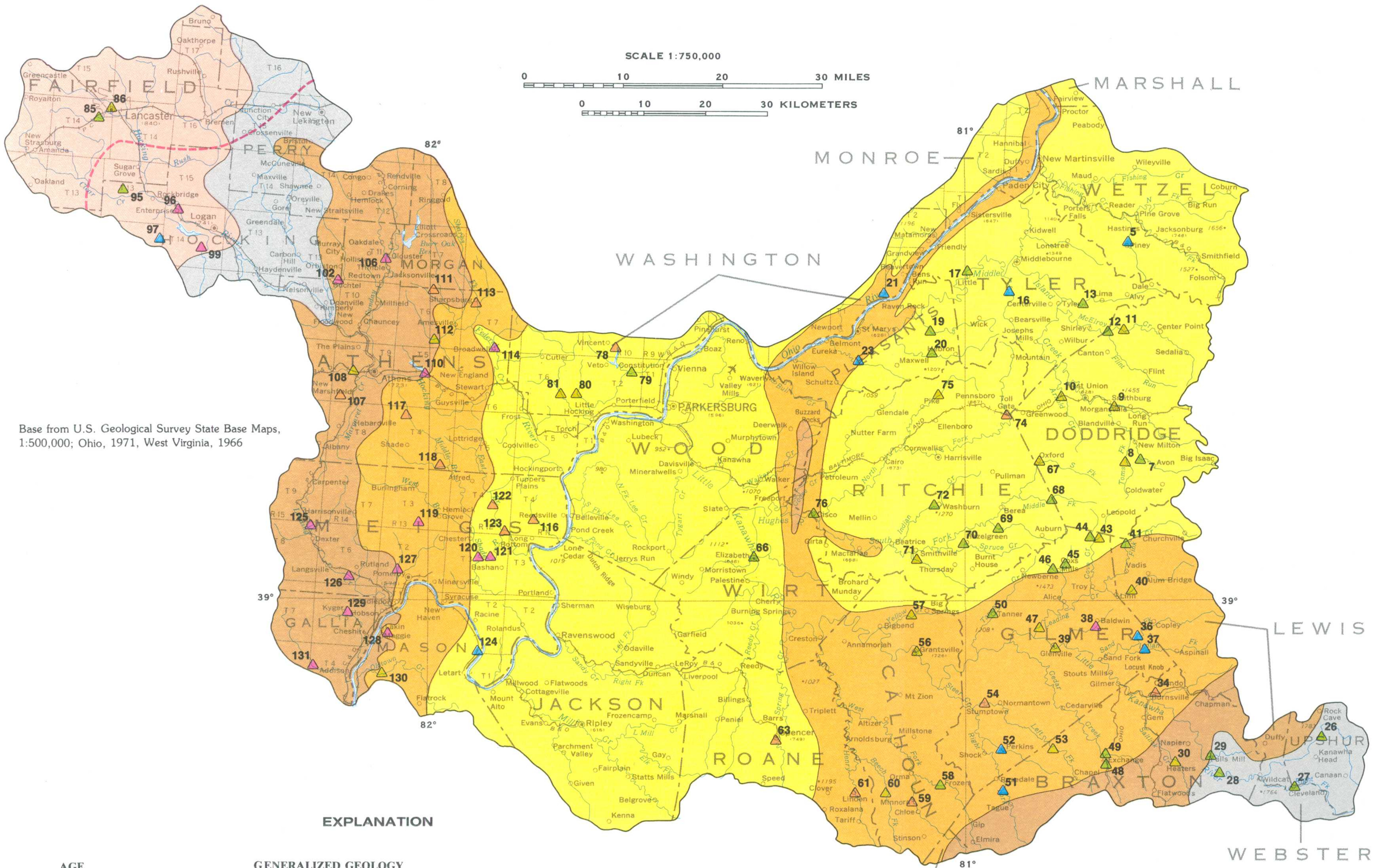
The concentration of manganese in surface water throughout Area 8 was highly variable and generally exceeded quality criteria at most sites. Manganese concentrations exceeding 50 μg/L (micrograms per liter) may give drinking water a bad taste. For this reason, a maximum recommended concentration of 50 μg/L is specified in the National Secondary Drinking Water Regulations (U.S. Environmental Protection Agency, 1979). West Virginia water-quality standards for allstream categories permit a maximum manganese concentration of 1,000 μg/L. Ohio standards for surface waters designated as public supply are permitted a maximum of 50 μg/L (Ohio Environmental Protection Agency, 1978).

Manganese is present in most metamorphic and sedimentary rocks as manganese oxide or hydroxide and may also be present as the oxidate associated with iron minerals. Clay minerals may contain manganese oxide or hydroxide (Hem, 1970). Manganese is common in sedimentary rocks associated with coal resources and enters surface water when these rocks and mining wastes are exposed to prolonged weathering. For example, Pfaff and others (1981) reported total manganese concentrations ranging from 430 to 8,300 μg/L at several sites in the Snow Fork basin, Ohio (near site 102). The Snow Fork basin contains extensive abandoned surface mined areas and about 60 percent of the basin is underlain by abandoned drift mines (Pfaff and others, 1981, p. 30).

The median concentration of dissolved manganese at 108 surface-water sites in Area 8 was 64 μg/L and ranged from 10 to 5,100 μg/L. The manganese concentrations described here represent an unequal number of observations per site and are for the period 1974-1982. The median dissolved-manganese concentration at 50 percent of the sites ranged from 40 to 178 μg/L. Manganese adsorbs to suspended sediment; thus, total manganese concentrations (median 130 μg/L) were much greater than the dissolved concentrations. The median dissolved-manganese concentration at surface-water sites and the generalized surfical geology of the area are shown in figure 5.3.7-1.

Lithology is one of the most important factors affecting the concentration of manganese in surface water. Water from streams draining the Dunkard Group had the lowest median manganese concentration, 50 μg/L. Median manganese concentrations in water from streams draining the Monongahela and Conemaugh Groups, and the Mississippian rocks were slightly greater (75, 102, and 60 μg/L) but these differences were not significant at the 0.05 confidence level. Total manganese generally exceeded the dissolved manganese concentration by a factor of 1.4 to 4.6 as shown in table 5.3.7-1. The greater manganese concentrations observed at sites overlying the Allegheny Formation and Pottsville Group (650 μg/L dissolved, 3,000 μg/L total) probably reflect the generally lower pH found in streams in those areas.

Land use has an important influence on the manganese concentration in surface water. Because manganese containing minerals may be associated with coal resources, any land disturbance that exposes rocks containing manganese to weathering will result in increased concentrations of dissolved and total manganese in streams draining the disturbed areas. Surface-water sites were categorized as being either "mined" or "unmined" based on the extent of coal mining within the drainage basin. Sites having 50 percent or more of the upstream drainage area disturbed by mining were categorized as "mined". Water from the mined areas had a significantly greater mean dissolved-manganese concentration (699 μg/L) than did water from unmined areas (202 μg/L) at the 0.05 confidence level. Similarly, the median concentrations of dissolved and total manganese in surface water were compared for sites in Ohio to West Virginia overlying the Dunkard and Conemaugh Groups. The land-use classifications for the West Virginia portion of the Dunkard and Conemaugh Groups differ from that of Ohio mainly due to the lesser degree of coal mining (see section 2.6, Land Use). The values shown in table 5.3.7-2 indicate that dissolved and total manganese concentrations were much higher in Ohio than in West Virginia for the same geologic unit. Slight differences in mineralogy probably also are present from east to west in the study area.



Base from U.S. Geological Survey State Base Maps, 1:500,000; Ohio, 1971, West Virginia, 1966

Generalized geology modified from Ohio River Basin Commission, 1978, Map 503-17.

EXPLANATION

AGE		GENERALIZED GEOLOGY
PERMIAN OR PENNSYLVANIAN		Dunkard Group: Shale, sandstone, limestone, and coal
PENNSYLVANIAN		Monongahela Group: Shale, sandstone, limestone, and coal
		Conemaugh Group: Sandstone, shale, limestone, and coal.
		Allegheny Formation and Pottsville Group: Sandstone conglomerate, shale, and coal.
MISSISSIPPIAN		Sedimentary rocks, undivided: Siltstone, shale, sandstone, glacial deposits, and Maxville Limestone

Note: Geologic names are those used by the West Virginia Geological and Economic Survey, and do not necessarily conform to those used by the U.S. Geological Survey. The Monongahela, Conemaugh, and Pottsville are formation rank in Ohio.

MEDIAN DISSOLVED MANGANESE CONCENTRATION, IN MICROGRAMS PER LITER

△2 Site location and number

- Less than 25
- 26-50
- 51-100
- 101-250
- Greater than 250

Geologic contact

Glacial boundary

Figure 5.3.7-1 Median dissolved-manganese concentration at surface-water sites and generalized surficial geology.

Table 5.3.7-1 Median dissolved and total manganese concentration in surface water at sites overlying the Dunkard, Monongahela, and Conemaugh Groups, Allegheny Formation and Pottsville Group, and the Mississippian rocks

Geologic Unit	Dissolved manganese concentration, in micrograms per liter	Total manganese concentration, in micrograms per liter
Dunkard Group	50	72
Monongahela Group	75	132
Conemaugh Group	102	258
Allegheny Formation and Pottsville Group	650	3,000
Mississippian rocks	60	100

Table 5.3.7-2 Median dissolved and total manganese concentration at sites overlying the Dunkard and Conemaugh Groups in West Virginia and Ohio

Geologic unit	Manganese concentration, in micrograms per liter: Ohio Dissolved	Ohio Total	West Virginia Dissolved	West Virginia Total
Dunkard	115	170	40	70
Conemaugh	430	935	88	130

Annual Suspended-Sediment Yields Range from 133 to 336 Tons per Square Mile

Annual suspended-sediment yields are relatively low and range from 133 to 336 tons per square mile, in Water Year 1981. Land-use practices and other factors such as slope, topography, precipitation duration, and precipitation intensity affect suspended-sediment yields.

Daily suspended-sediment and streamflow records at four sites in Area 8 (fig. 5.3.8-1) indicate relatively low annual suspended-sediment yields ranging from 133 to 336 tons/mi^2 (tons per square mile) during the 1981 Water Year. Bedload, which is the sediment transported along the streambed, was not measured. The sediment data reported represent only the suspended-sediment portion of the total sediment discharged.

Average daily water discharge, maximum daily sediment concentration, maximum daily sediment load, and annual sediment yield for the sites are given in table 5.3.8-1. The relationship between streamflow and suspended-sediment yields for three of the sites are shown in figure 5.3.8-2. The sediment-yield curves shown in figure 5.3.8-2 indicate that sediment-production rates differ substantially among the sites. The difference among the curves reflect, in part, differences in land use among the basins.

East Branch Shade River near Tuppers Plain, Ohio (site 122, drainage area 37.5 mi^2) drains a relatively undisturbed basin, whereas the Little Kanawha River near Wildcat, W. Va. (site 28, drainage area 112 mi^2) drains a basin with less than 5 percent of its drainage area surface mined. Nearly half of the drainage upstream from Hocking River below Athens, Ohio (site 110, drainage area 957 mi^2) is classified as agricultural land, and about 10 percent of the drainage is classified as mined area. These two land-use activities probably contribute to the higher suspended-sediment yield at site 110 as compared to yields at sites 122 and 28 (fig. 5.3.8-2). Land-use activities such as urbanization, agriculture, logging, and other soil-disturbing activities in the larger Hocking River basin mask the contribution of sediment from mining activities. Sediment contributions from individual land-use activities are difficult to differentiate from the total load unless they are measured separately.

In addition to land-use practices, other factors such as slope, topography, precipitation duration, and precipitation intensity affect suspended-sediment yields. For example, daily-sediment data collected from April to September 1981 at Snow Fork Monday Creek at Buchtel, Ohio (site 102, drainage area 24.4 mi^2), which drains a small forested basin with considerable surface-mined area, indicates that most of the suspended-sediment load is transported during high-flow periods. Suspended-sediment load transported during three storms during the 6-month period at site 102 produced nearly 65 percent of the total sediment load. Appropriate land-use practices and reclamation can greatly reduce soil erosion from disturbed areas and lessen suspended-sediment yields.

Sites with sediment data (fig. 5.3.8-1) are listed in section 9.1. The suspended-sediment data are published in Water Resources Data reports for Ohio and West Virginia (U.S. Geological Survey, 1979b-e, 1980 c-f, 1981 a-c).

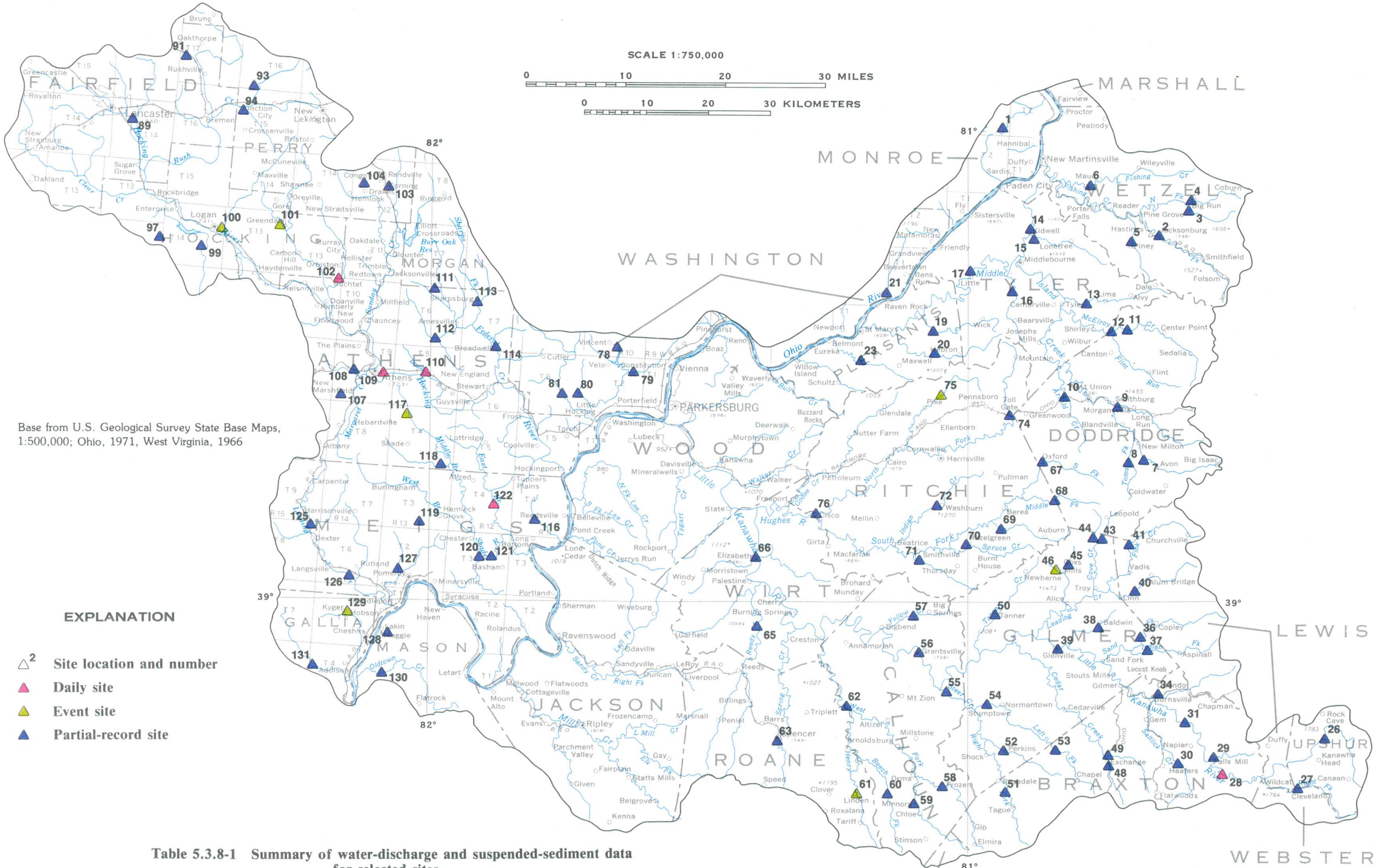


Figure 5.3.8-1 Suspended-sediment sites.

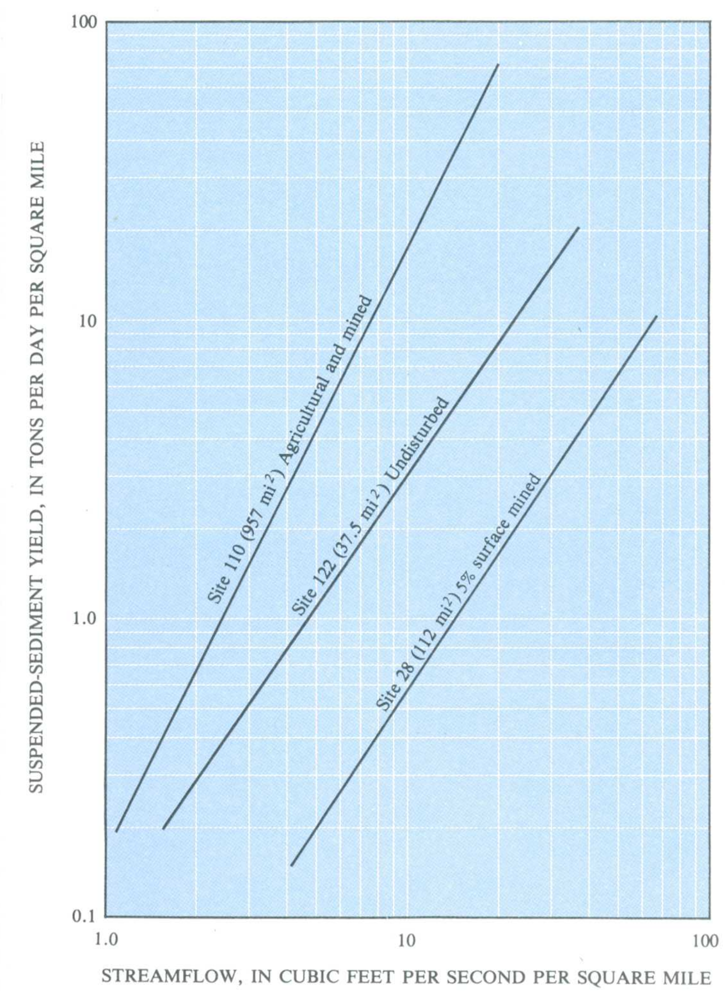


Figure 5.3.8-2 Relationship between streamflow and suspended-sediment yields at selected daily suspended-sediment sites, April 1980 to September 1981.

Table 5.3.8-1 Summary of water-discharge and suspended-sediment data for selected sites

Site No.	Period of record	Average daily water discharge (ft^3/s)	Maximum daily sediment concentration (mg/L)	Maximum daily sediment load (tons)	Annual sediment yield ($tons/mi^2$)
28	June 21 to September 30, 1979	148	479	2,260	*54.6
	October 1979 to September 1980	281	1,180	14,900	352
	October 1980 to September 1981	242	355	3,260	133
110	October 1978 to September 1979	1,800	2,290	52,200	544
	October 1979 to September 1980	1,575	1,200	14,300	411
	October 1980 to September 1981	1,243	1,580	19,900	327
122	April to September 1980	42.0	872	1,230	*162
	October 1980 to September 1981	33.7	822	1,250	189
102	April to September 1981	41.2	1,260	2,140	*336

* Yield shown is for part of the year.

The Rocks of Area 8 may be Grouped into Three Major Aquifers

Three major aquifers in Area 8 are recharged by precipitation and, in some places, by leakage from streams or adjacent basins.

Ground water occurrence in Area 8 is similar to that described by A. K. Sparkes (in Harkins and others, 1981, p. 50) for the same rock units in Alabama.

Ground water in Area 8 is derived from precipitation. Part of the precipitation returns to the atmosphere through evaporation and transpiration, part flows into streams and lakes as runoff, and part seeps downward through the soil and rocks to the zone of saturation.

Direct infiltration of precipitation into the aquifers is the major means of recharge, although some aquifers receive recharge indirectly by leakage from adjacent aquifers or basins. Recharge also may result from streams flowing over the outcrops of aquifers. Where the water level in an aquifer is below that of the stream, water may percolate through the stream channel and into the aquifer.

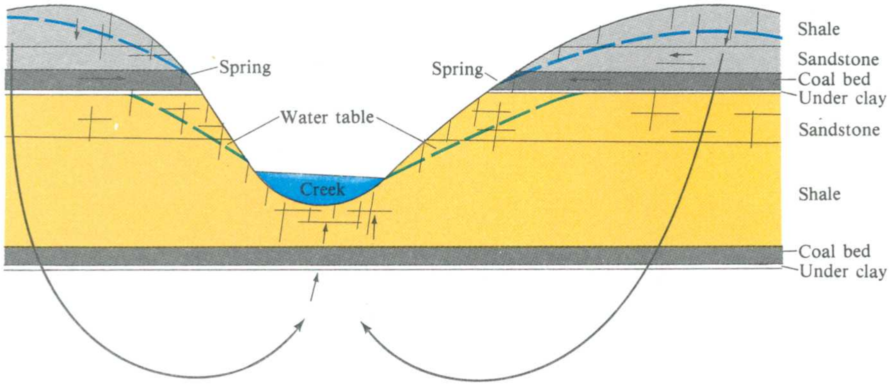
Ground-water movement in Area 8 generally is toward points of discharge such as streams, wells, or coal mines. The path which water must take as it flows varies with the three different rock units in Area 8 (fig. 6.1-1).

Water flows slowly through the rocks of the Dunkard and Monongahela Groups. These rocks largely consist of shale beds that have poorly developed joints and fractures except in some valley areas. The most permeable parts of these units in the Little Kanawha River basin (Bain and Friel, 1972, p. 61) are the coal and sandstone beds near the base of the Dunkard Group and near the top of the Monongahela Group. Direction of water movement in these rock units is controlled primarily by orientation of fractures and hydraulic gradient. Water tends to be perched on clay layers that underlie coal beds.

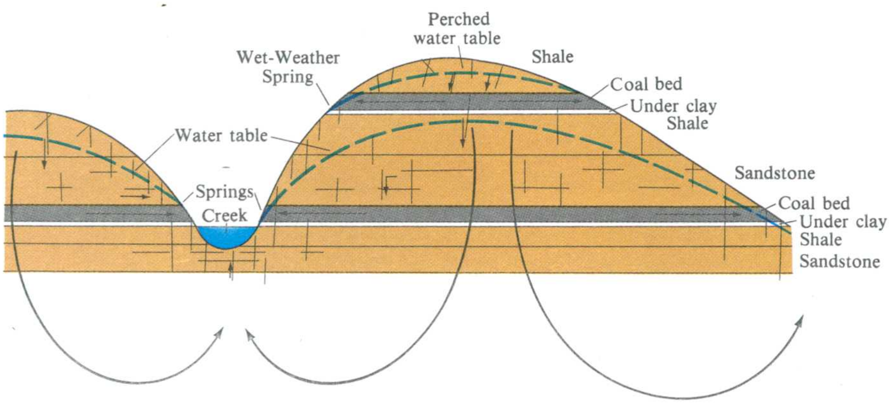
The Conemaugh Group generally contains more fractured and jointed sandstone beds than the Dunkard or Monongahela Groups. This generally makes the Conemaugh Group a better water-bearing unit than the Dunkard or the Monongahela Group. However, Bain and Friel (1972, p. 58) report slightly better yields from wells in the Monongahela Group than in the Conemaugh Group. In the Ohio part of Area 8, Deutsch and others (1967, p. 4-10) report higher average yields from wells in the Conemaugh Group.

The Allegheny Formation and Pottsville Group, and the Upper Mississippian rocks largely consist of beds of fractured and jointed sandstone and coal beds (no coal beds in Mississippian rocks) which permit the movement and storage of relatively large quantities of water. Direction of water movement in these formations is controlled locally by orientation of fractures and the hydraulic gradient. The Mississippian rocks contain a limestone formation, but it is not known as a major source of water (Deutsch and others, 1967, p. 49).

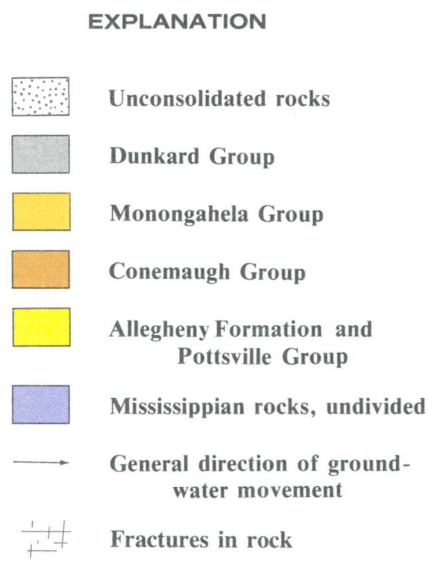
Bain and Friel (1972, p. 170) report that "aside from the obvious surface effects of coal production, collapse of shallow underground coal mines causes fracturing of the overburden from mine to ground surface in a narrow arc directly above the mine. The consequence to stored ground water is twofold. In the first place, precipitation and stored ground water are channeled through the fractures into the mine, to be discharged at some lower mine outlet. The mine workings, in effect, shortcircuit the natural ground-water-flow paths, causing a general lowering of ground-water levels. In the second place, the fracturing exposes a vastly greater rock area to air and water, causing increased generation of acid water from pyrite-bearing rocks. Water users in areas thus affected often resort to cisterns or to private and public water supplies as sources of potable water."

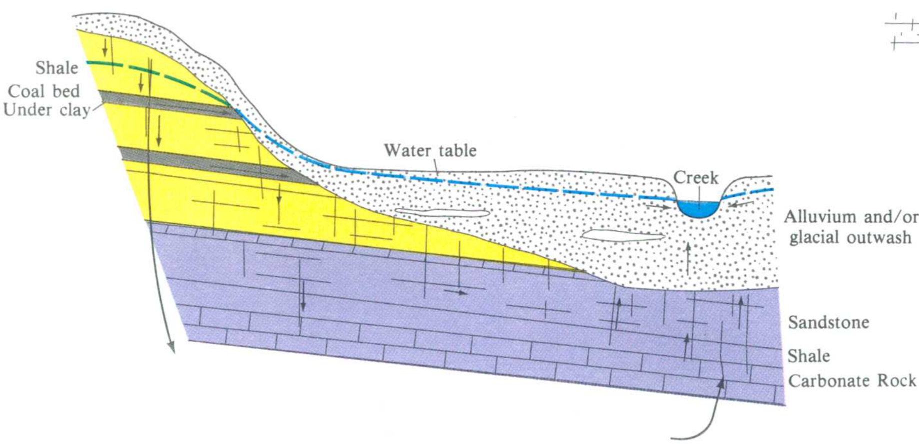


Lithology and occurrence and movement of ground water in the Dunkard and Monongahela Groups (generally the poorest aquifers in the area).



Lithology and occurrence and movement of ground water in the Conemaugh Group.





Lithology and occurrence and movement of ground water in the Mississippian rocks and unconsolidated deposits (generally the best aquifers in the area).

Figure 6.1-1 General features of ground-water occurrence and movement in the coal and rocks of Area 8.

Well Yields in Coal Mining Areas are Highest from Allegheny Formation and Pottsville Group

Well yields in the consolidated rock units in Area 8 range from less than 1 to 350 gallons per minute. Coal mining may lower water levels and well yields.

The principal sources of ground water in most of the area are the Dunkard and the Monongahela Groups (fig. 6.2-1). Although these rocks generally yield less water than the other geologic units, they are areally extensive and, therefore, supply water to many domestic wells. Most well yields are adequate for most domestic and farm needs. Yields generally range from less than 1 to 45 gal/min (gallons per minute), but the average may be 5 gal/min or less (Deutsch and others, 1967, p. 4-10). In valleys underlain by fractured rock in the Little Kanawha basin (Bain and Friel 1972, p. 64), yields of more than 100 gal/min occur.

The best consolidated rock aquifers in the area are the Allegheny Formation and Pottsville Group, and Mississippian rocks. The amount of water available to wells depends on the topography, lithology, degree of joints or fractures, degree and depth of weathering, and the presence of saturated solution cavities in soluble rocks.

The high yielding area at the eastern tip of Area 8 is underlain by the Allegheny Formation and Pottsville Group. Both units are predominantly sandstones and wells tapping them are generally more than adequate for domestic supplies. Yields of wells in this part of Area 8 range from 3 to more than 20 gal/min; the median yield is more than 10 gal/min (Bain and Friel, 1972, p. 64). Yields exceeding 100 gal/min may be available in valleys underlain by thick fractured sandstone. Few water wells tap the Mississippian rocks in this area.

The high yielding area at the western tip of Area 8 is underlain by the Allegheny Formation and Pottsville Group, and rocks of Mississippian age. The Mississippian rocks also are predominantly massive sandstone, siltstone, shale and limestone, but contain no coal beds. Yields of wells tapping the rocks in this part of Area 8 may be 600 gal/min or more (Deutsch and others, 1967, p. 4-6).

The alluvium along the Ohio and Hocking Rivers is the best unconsolidated rock aquifer in Area 8. The alluvium may be as much as 120 feet thick and yields of drilled wells range from 5 to 500 gal/min (Carlston and Graeff, 1955, p. 93). Sand and gravel outwash deposits near Lancaster are nearly 200 ft. thick, but become thinner to the south (Deutsch and others, 1967, p. 4-7). A Rainey collector well (large diameter collector well having horizontal drainage lateral lines to carry water to it) yields as much as 2,000 gal/min.

Wells in the Conemaugh Group yield less than 50 gal/min of water to wells. This group consists of cyclical sequences of sandstone, siltstone, shale, limestone, coal, and underclay. The highest yields are generally obtained from wells in valleys underlain by the massive sandstone at the base of the group.

Studies in other drainage basins near Area 8 by Friel and others (1967) and Hobba (1981) indicate that underground coal mining generally has a detrimental effect on wells and the availability of ground water, but there are also some beneficial effects. Some of the detrimental effects of underground mining are that it:

1. Often lowers ground-water levels and water level, may fluctuate as much as 100 feet annually;
2. may dry up wells or springs; and
3. may lower well yield.

Some of the beneficial effects of underground mining are that it:

1. May cause increased infiltration, if subsidence occurs, and concurrently reduces evapotranspiration; and
2. may cause large volumes of water to be stored in abandoned flooded mines. This water may be suitable for some uses, and it also increases the low flow of streams.

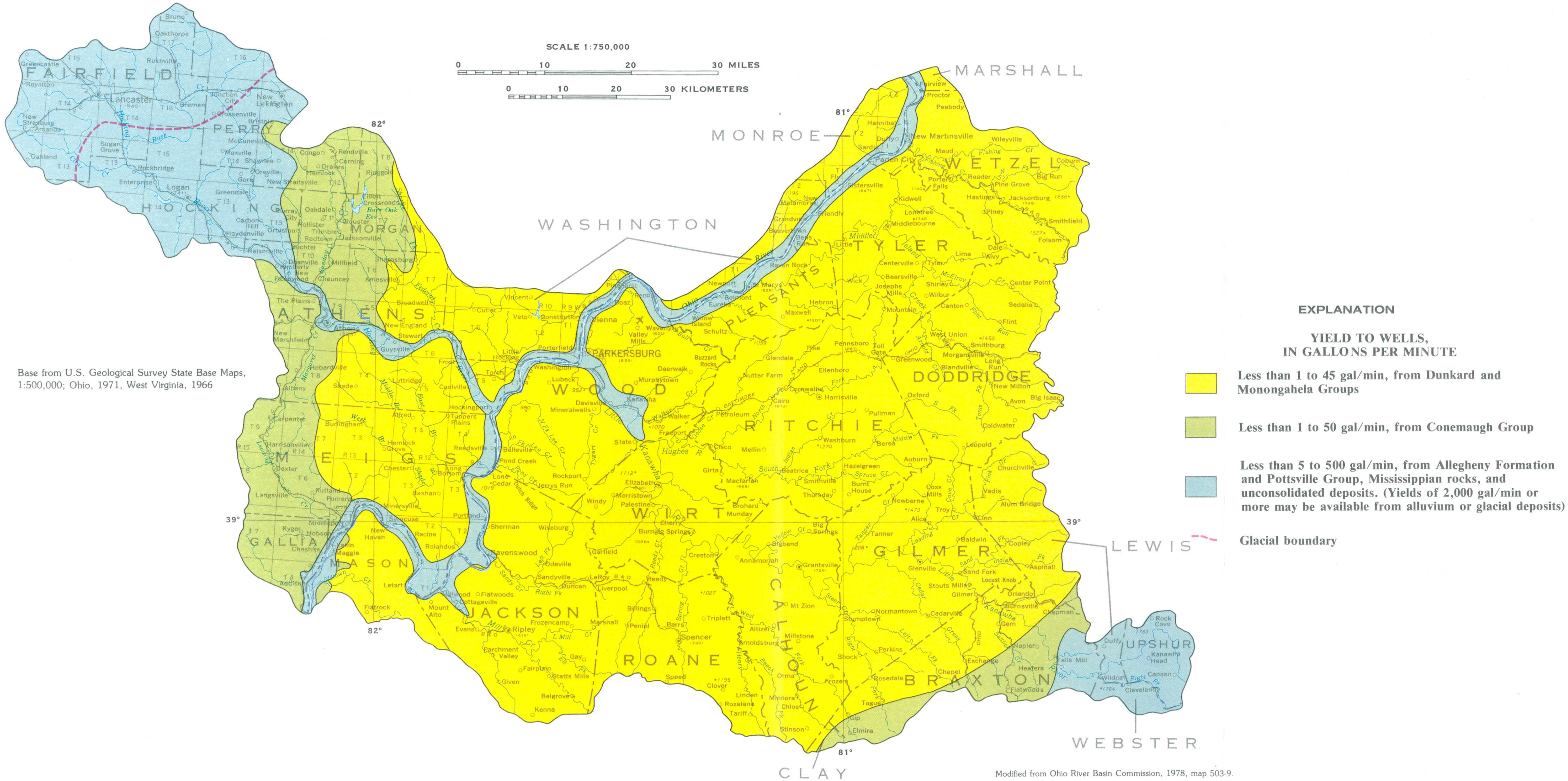


Figure 6.2-1 Availability of ground water.

Average Specific Conductance of Water is Lowest from Coal-Bearing Rocks of the Allegheny Formation and Pottsville Group

Water from the Allegheny Formation and Pottsville Group generally has the lowest specific conductance, but has the highest iron and manganese content in areas undisturbed by mining.

Ground-water quality within Area 8 is highly variable as shown in table 6.3-1. Water from the Mississippian rocks is almost entirely of the calcium magnesium bicarbonate type (Sedam, 1970). Water from the Pennsylvanian rocks also is predominately of the calcium magnesium bicarbonate type, but there are places where salty water is leaking upward from depth and mixing with the calcium magnesium bicarbonate water. In these places, sodium and chloride are the dominant ions. The bar graphs in figure 6.3-1 depict the total concentration of dissolved constituents in the water. The pie diagrams depict the percentage of each constituent to the total concentration. Two of the diagrams show that the water from well 32-4-38 is salty, but that water from well 32-4-8 is not, even though both wells tap the Monongahela Group. The pie diagrams are especially useful for showing water type and dominant ion composition of ground water. A scan of the diagrams shows the dominance of bicarbonate and chloride types of water in the area.

Water high in chloride content is often found in valley areas due to the rise of deep circulating water along fractures and through oil and gas wells having deteriorated casings or no casings at all. These wells and perhaps some poorly constructed water wells permit deep salty water to move upward into freshwater zones.

Other studies in West Virginia (Bader, 1984; and Hobba, 1984a) show that water from the Permian and Upper Pennsylvanian rocks (Dunkard, Monongahela, and Conemaugh Groups) consistently contain greater concentrations of dissolved minerals, hardness, and chloride (table 6.3-1) than water from the middle and lower Pennsylvanian rocks (Allegheny Formation and Pottsville Group). Surface-water quality indicates that the average specific conductance of water from the Allegheny Formation and Pottsville Group is higher than for the other coal-bearing rocks. This may be due to the weathering of pyrite material within these rocks after mining has occurred. In a recent study of small basins in West Virginia adjacent to the Ohio River, R. A. Shultz (U.S. Geological Survey, written commun., 1984) concludes, in regard to the coal-bearing formations, that within the Permian and Upper Pennsylvanian rocks "there is little difference in water quality from one geologic unit to another." His conclusion is based on 70 complete water analyses of which 53 samples were from the Dunkard Group, 11 from the Monongahela Group, and 6 from the Conemaugh Group. Water from the Mississippian rocks, which contain no coal resources, has about the same range of dissolved solids as water from the Lower Pennsylvanian rocks.

Table 6.3-1 shows the range and average specific conductance of water from the various geologic units. Because specific conductance is directly proportional to dissolved solids content, these values indicate the relative amounts of dissolved solids in water from the various geologic units. Figure 6.3-2 shows the relation between specific conductance and total dissolved solids in 130 water samples from all of the rock units in the area. This graph shows essentially the same relationship as that shown for specific conductance and dissolved solids in surface water (see section 5.3.2) draining all geologic units.

The pH of ground water in the area ranges from 5.8 to 9.0, but most of the water has a pH from 6.0 to 8.0. Ground water having the lowest pH is generally found in the unconsolidated alluvium along the Ohio River or in the Allegheny Formation and Pottsville Group in the extreme eastern part of the area.

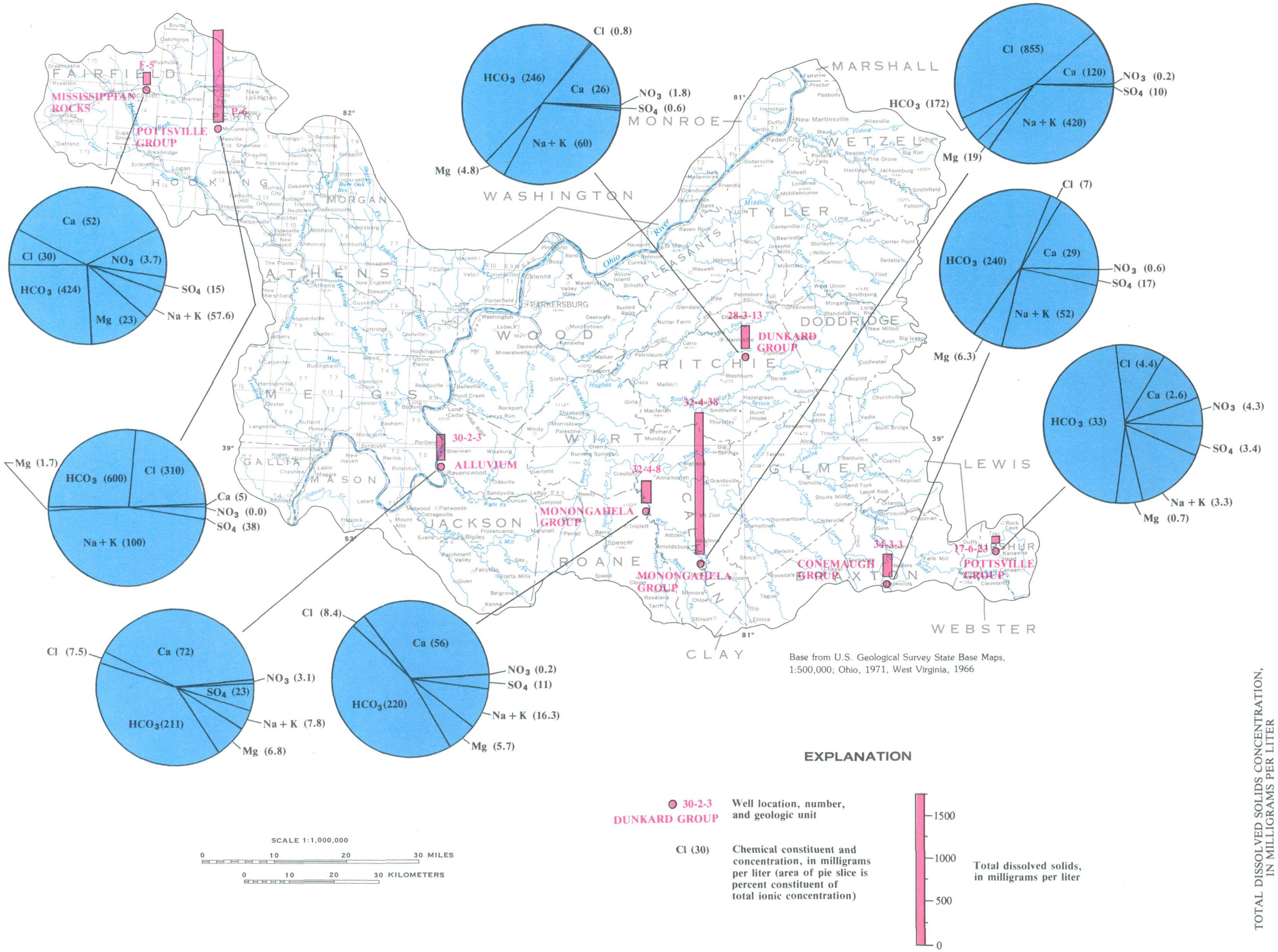


Figure 6.3-1 Chemical composition of water from various geologic units.

Table 6.3-1 Summary of chemical analyses of ground water

Geologic unit		Specific conductance (µmho/cm at 25°C)	pH (units)	Hardness (mg/L as $CaCO_3$)	Chloride (mg/L)	Iron (µg/L)
Alluvium or Glacial Deposit 1/	Range	170-2,700	5.8-8.6	13-530	5-740	3-21,000
	Average	735	---	230	68	1,350
	Number of wells	70	70	48	50	50
Dunkard Group 2/	Range	290-4,380	6.4-8.9	2-510	1-1,440	3-8,000
	Average	840	---	128	76	550
	Number of wells	307	307	306	307	306
Monongahela Group 2/	Range	265-8,400	6.8-9.0	5-420	2-2,500	0-5,000
	Average	1,770	---	97	79	485
	Number of wells	246	246	244	244	244
Conemaugh Group 2/	Range	344-3,670	7.0-9.0	17-476	8-3,500	0-5,000
	Average	1,133	---	94	58	900
	Number of wells	302	302	302	302	302
Allegheny Formation and Pottsville Group 2/	Range	52-1,900	6.1-9.1	5-200	5-330	3-6,000
	Average	335	---	74	37	1,980
	Number of wells	58	58	55	58	58
Mississippian Rocks 3/	Range	155-1,650	6.1-8.0	65-300	1.0-74	40-1,100
	Average	---	---	---	---	---
	Number of wells	3	3	3	3	3

1/ Chemical analyses are for water from five wells in Ohio and the remainder of wells are in West Virginia.

2/ Chemical analyses are for water from wells in West Virginia as reported by Friel and Bain (1971) and by R. A. Shultz (written commun, 1984).

3/ Chemical analyses are for water from wells in Ohio.

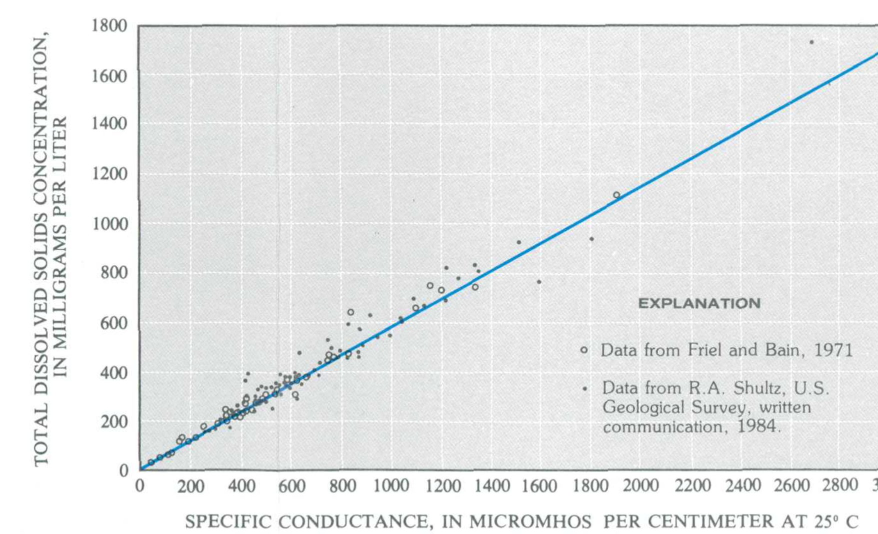


Figure 6.3-2 Relationship between dissolved solids and specific conductance of ground water in Area 8.

NAWDEX, WATSTORE, OWDC have Water-Data Information

Water data are collected in coal areas by large numbers 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 for 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 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." Special indexes to the Catalog are being made available to the public to assist in identifying available water-data activities in coal provinces of the United States.

A more detailed explanation of these three activities is given in sections 7.2, 7.3, and 7.4.

NAWDEX Matches User Needs to Available Data

NAWDEX (National Water Data Exchange) is a national confederation of water-oriented organizations working together to improve access to water data. Objectives of NAWDEX are to assist users of water data in the identification, location, and acquisition of needed data. The U.S. Geological Survey manages NAWDEX through Survey headquarters in Reston, Virginia, and local assistance centers in major cities.

The function of NAWDEX is to index the data held by NAWDEX members and participants so as to provide a central source of water-data information available from a number of organizations (fig. 7.2-1). A central Program Office located at U.S. Geological Survey national headquarters in Reston, Virginia, provides data-exchange policy and guidelines for participants. The major functions of the Program Office are to (1) maintain a computerized Master Water-Data Index (fig. 7.2-2) that identifies sites for which data are available and the organization responsible for the data; (2) provide access to water-data bases held by participants; and (3) maintain a Water-Data Sources Directory (fig. 7.2-3) that identifies participating organizations and locations from which data may be obtained.

Services are available through a Program Office at the U.S. Geological Survey National Center in Reston, Virginia, and through a nationwide network of assistance centers located in 45 states and Puerto Rico. A directory is available from the Program Office upon request which lists organizations, personal contacts, addresses, telephone numbers and office hours for each NAWDEX assistance center (U.S. Geological Survey, 1980a).

Charges for NAWDEX services may be assessed at the option of the organization providing the requested data or data service. Charges will be assessed for computer and extensive personnel time, duplicating services, or other costs encountered by NAWDEX in the course of providing services. In any case, charges will not exceed the actual direct costs involved. Estimates of cost will be provided by all NAWDEX assistance centers upon request, and in all cases when costs are expected 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, Virginia 22092
Telephone: (703) 860-6031
FTS 928-6031
Hours: 7:45 - 4:15

NAWDEX ASSISTANCE CENTER
West Virginia
U.S. Geological Survey
Water Resources Division
603 Morris Street
Charleston, West Virginia 25301
Telephone (304) 347-5130
FTS 930-5130
Hours: 7:45 - 4:30

NAWDEX ASSISTANCE CENTER
Ohio
U.S. Geological Survey
Water Resources Division
975 West Third Avenue
Columbus, Ohio 43212
Telephone: (614) 469-5553
FTS 943-5553
Hours 7:45-4:30 Eastern Time

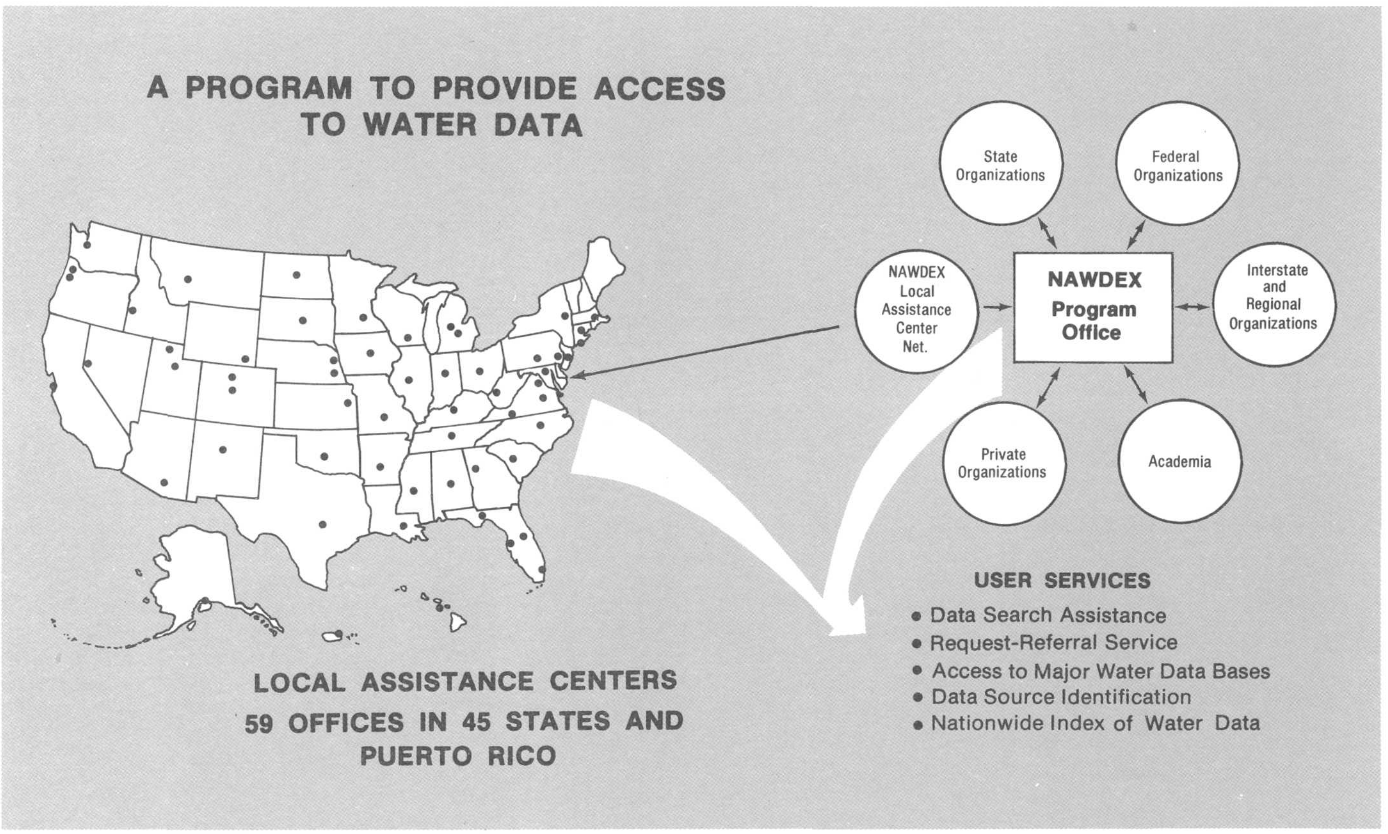


Figure 7.2-1 Access to water data.

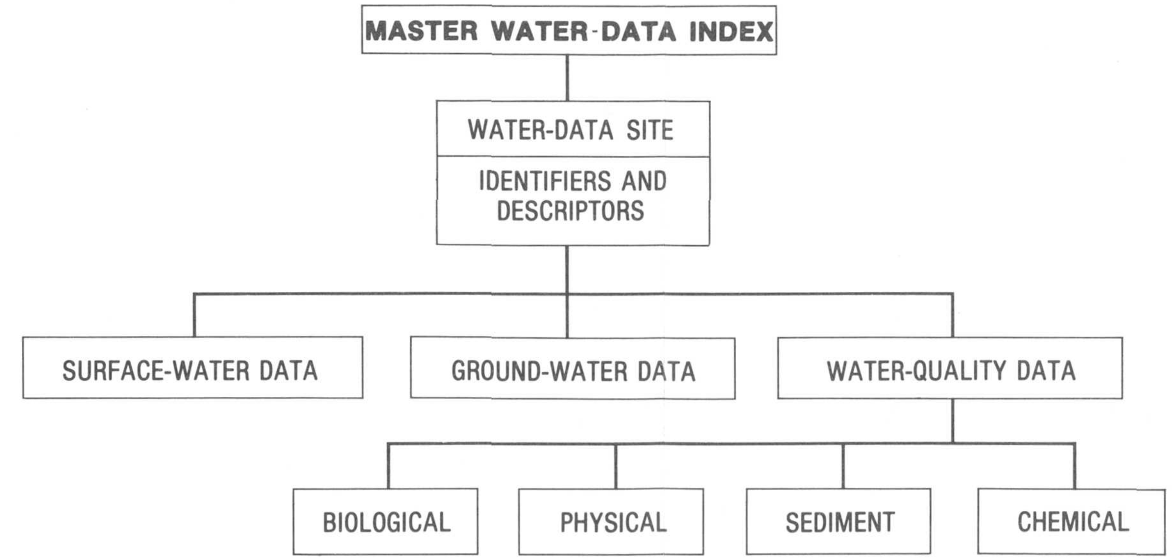


Figure 7.2-2 Master water-data index.

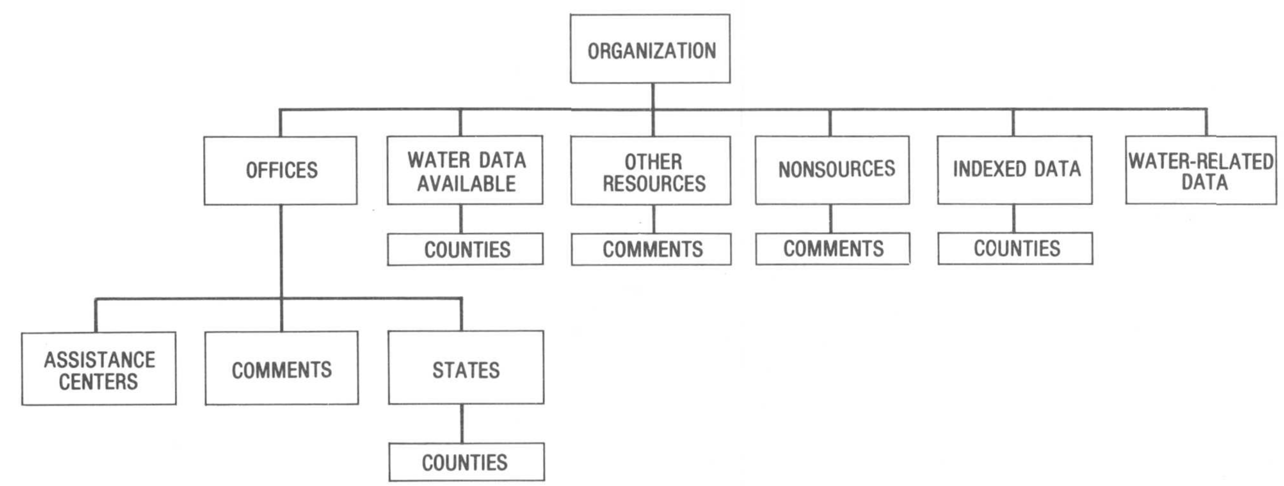


Figure 7.2-3 Water-data sources directory.

WATSTORE Automated Data System

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

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

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

U.S. Geological Survey
Water Resources Division
603 Morris Street
Charleston, West Virginia 25301

U.S. Geological Survey
Water Resources Division
975 West Third Avenue
Columbus, Ohio 43212

The Geological Survey collected data across the Nation during 1982 at approximately 16,000 stream-gaging stations, 1,000 lakes and reservoirs, 5,200 surface-water quality stations, 1,020 sediment stations, 30,000 water-level observation wells, and 12,500 ground-water quality wells. Each year, many water-data collection sites are added and others are discontinued; thus, large amounts of diversified data, both current and historical, are amassed by the Survey's data-collection activities.

The WATSTORE system consists of several files in which data are grouped and stored by common characteristics and data-collection frequencies. The system also is designed to allow for the inclusion of additional data files as needed. Currently, files are maintained for the storage of (1) surface-water, quality-of-water, and ground-water data measured on a daily or continuous basis; (2) annual peak values for streamflow stations; (3) chemical analyses for surface- and ground-water sites; (4) water parameters measured more frequently than daily; and (5) geologic and inventory data for ground-water sites. In addition, an index file of sites for which data are stored in the system is also maintained (fig. 7.3-1). 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. This file currently contains over 200 million daily values including data on streamflow, river stages, reservoir contents, water temperatures, specific conductance, sediment concentrations, sediment discharges, and ground-water levels.

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

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

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

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

All data files of the WATSTORE system are maintained and managed on the central computer facilities of the Geological Survey at its National Center. However, data may be entered into or retrieved from

WATSTORE at a number of locations that are part of a nationwide telecommunication network.

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

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

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

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

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

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

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

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

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

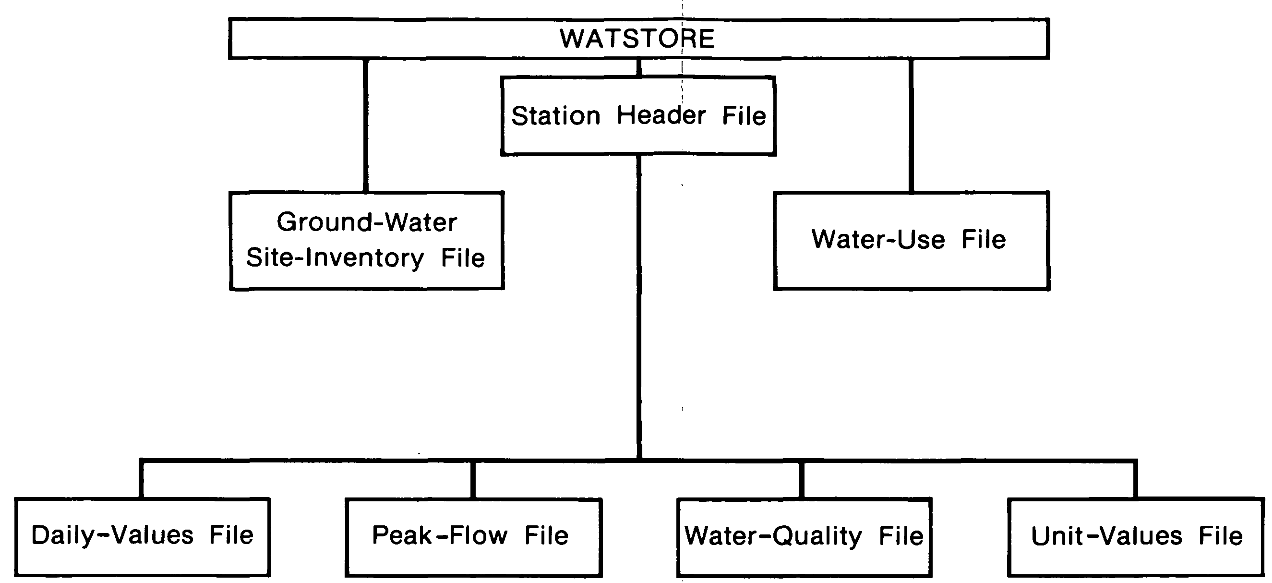


Figure 7.3-1 Index-file stored data.

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 U.S. Geological Survey's Office of Water Data Coordination (OWDC).

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

This special index consists of five volumes (fig. 7.4.1): Volume I, Eastern Coal Province; Volume II, Interior Coal Province; Volume III, Northern Great Plains and Rocky Mountain Coal Provinces; Volume IV, Gulf Coast Coal Province; and Volume V, Pacific Coast and Alaska Coal Provinces. The information presented will aid the user in obtaining data for evaluating the effects of coal mining on water resources and in developing plans for meeting additional water-data needs. The report does not contain the actual data; rather, it provides information that will enable the user to determine if needed data are available.

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

Those who need additional information from the Catalog file or who need assistance in obtaining water data should contact the National Water Data Exchange (NAWDEX) (see section 7.2).

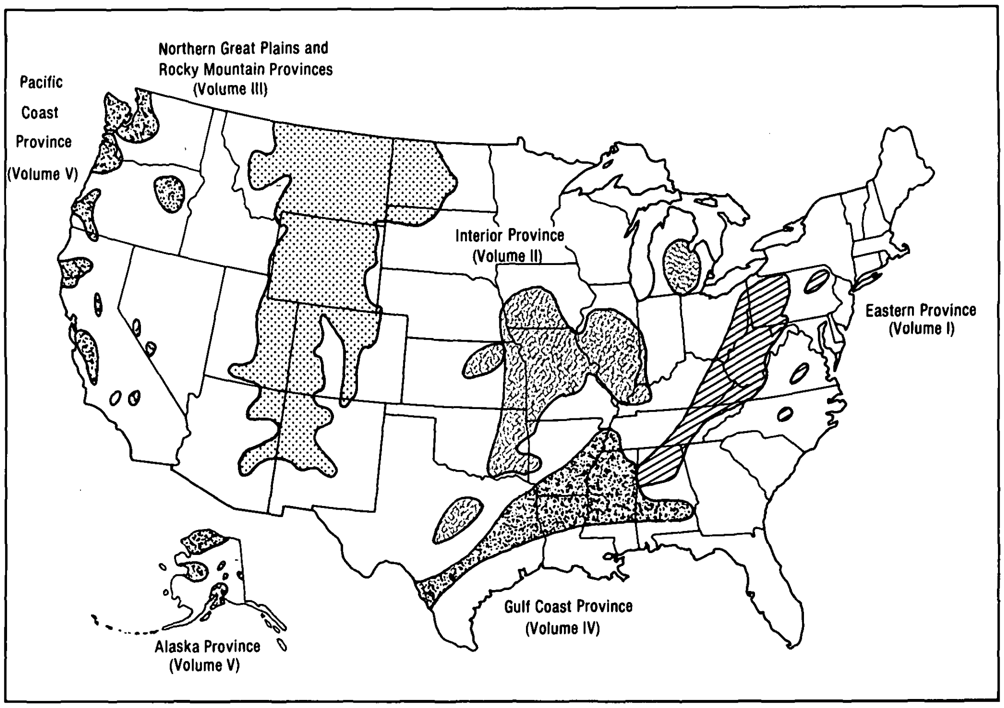


Figure 7.4-1 Volumes of "Index to Water-Data Activities in Coal Provinces of the United States" (Catalog of Information on Water Data)

8.0 GLOSSARY

Glossary of Terms Used in Hydrologic Reports Defined

Technical terms that are used in this hydrologic report are defined.

Acidity is the quantitative capacity of an aqueous medium to react with hydroxyl ions, and is expressed in milligrams per liter (mg/L) as hydrogen ion (H^+) for this report. Acidity may also be expressed in milligrams per liter as calcium carbonate by multiplying the results of mg/L as H^+ by 50.05 (American Society for Testing and Materials, 1979).

Alkalinity is a measure of the ability of water to resist pH change caused by addition of a strong acid and is a measure of the buffering capacity of water. The alkalinity of a solution is due to the presence of hydroxyl, carbonate, and bicarbonate ions and for this report is expressed in milligrams per liter as calcium carbonate.

Anion is a negatively charged ion.

Anticline is a fold, generally convex upward, whose core contains the stratigraphically older rocks.

Aquifer is a geologic formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs.

Alluvial aquifer is an aquifer located in unconsolidated stream deposits of comparatively recent time.

Base flow (or base runoff) is sustained or fair-weather runoff composed largely of ground-water discharge.

Benthic invertebrate, for this study, is an animal without a backbone, living within or near the bottom of an aquatic environment, which is retained on a 210-micrometer mesh sieve.

Bituminous coal is a coal which ranks below anthracite, containing about 80 percent carbon and 10 percent oxygen.

Cation is a positively charged ion.

Channel slope is the quotient of the total fall, in feet, of a segment of stream channel divided by the corresponding total length, in miles, of that segment; it is expressed in feet per mile.

Coefficient of determination (r^2), in linear regression, is the square of the correlation coefficient. The coefficient of determination × 100 provides a measure of the percentage of the variation of the dependent variable explained by variation of the independent variable.

Cubic foot per second (cfs, ft^3/s) is the rate of discharge representing a volume of 1 cubic foot passing a given point during 1 second and is equivalent to approximately 7.48 gallons per second, or 448.8 gallons per minute, or 0.02832 cubic meters per second.

Dewatering, in this report, refers to the artificial discharge of water from an aquifer because the aquifer is exposed in a mine pit. Removal of such water from the mine pit also may be termed dewatering.

Discharge is the volume of water (or more correctly, volume of water plus suspended sediment) that passes a given point within a given period of time.

Instantaneous discharge is the discharge at a particular instant in time.

Mean discharge is the arithmetic mean of individual discharges during a specific period of time.

Dissolved refers to that material in a representative water sample that passes through a 0.45-micrometer membrane filter. This may include some very small (colloidal) suspended particles as well as the amount of substance present in true chemical solution. Determinations of "dissolved" constituents are made on subsamples of the filtrate.

Dissolved solids is the weight of residue resulting from the evaporation of a sample aliquot at 180° Celsius, and is expressed as milligrams per liter. It is also referred to as residue on evaporation at 180° Celsius or total dissolved solids. The dissolved solids concentration may affect the specific conductance and other chemical characteristics of a water sample.

Diversity index is a dimensionless value relating the numbers of individuals of all species present to the number of species present at a site.

Drainage area of a stream at a specific location is that area, measured in a horizontal plane, enclosed by a topographic divide from which direct surface runoff from precipitation normally drains by gravity into the stream above the specified point. Figures of drainage area given herein include all closed basins, or noncontributing areas, within the area, unless otherwise noted.

Drainage basin is a part of the surface of the Earth that is occupied by a drainage system, which consists of a surface stream or a body of impounded surface water together with all tributary surface streams and bodies of impounded surface water.

Duncan's Multiple Range Test is a statistical procedure that compares the means of different groups to determine if they are significantly different at the 0.05 significance level. This test was performed by the Statistical Analysis System (SAS) procedure (Helvig and Council, 1979).

Ephemeral stream is one which flows only in direct response to precipitation and whose channel is above the water table.

Evapotranspiration is the water withdrawn from a land area by evaporation from water surfaces and moist soil and by plant transpiration; also, the loss of water from leaf and stem tissues of growing vegetation.

Gaging station is a particular site on a stream, canal, lake, or reservoir where systematic observations of hydrologic data are obtained. When used in connection with a discharge record, the term is applied only to those gaging stations where a continuous record of discharge is computed.

Ground-water underflow is subsurface ground-water flow or recharge; the flow of water through the soil or a subsurface stratum, or under a structure.

Hogback is a long sharp ridge carved by differential erosion from a steeply dipping resistant layer or series of layers of sedimentary or igneous rock.

Hydrograph is a graph showing discharge, water level, or other property of water with respect to time.

Hydrologic unit is a geographic area representing part or all of a surface-drainage basin or distinct hydrologic feature as delineated by the Office of Water Data Coordination on the State Hydrologic Unit Maps; each hydrologic unit is identified by an eight-digit number.

Igneous rock is one that is formed by solidification from molten or partially molten materials.

Ion is an atom, group of atoms, or molecule that has acquired a net electrical charge.

Lithology is the physical character of a rock, generally determined by observation with the unaided eye or with the aid of a low-power magnifier.

Load is the amount of material, whether dissolved, suspended, or on the bed, which is moved and transported by a flowing stream past a point in a given period of time such as a day, month, or year.

Median of a set of measurements X1, X2. . .Xn is the value X such that it falls in the middle of the set of X values when they have been ordered from the least numerical value to the greatest value.

Metamorphic rock is a rock which has been altered in composition, texture, or internal structure in response to pronounced changes of temperature, pressure, and chemical environment.

Micrograms per liter (μg/L) is a unit expressing the concentration of chemical constituents in solution as mass (micrograms) of solute per unit volume (liter) of solution. One thousand micrograms per liter is equivalent to one milligram per liter.

Micromho (μmho) is one-millionth of a mho, which is the unit of specific conductance that is equal to the reciprocal of the ohm (the unit of electrical resistance).

Milliequivalents per liter is the concept of chemical equivalence obtained by multiplying the concentration of substance, in milligrams per liter, by the reciprocal of the combining weight of the appropriate ions. If the formula weight of the ion is divided by the charge, the result is termed the "combining weight" (Hem, 1970).

Milligrams per liter (mg/L) is a unit for expressing the concentration of chemical constituents in solution. Milligrams per liter represent the mass of solute per unit volume (liter) of solution. Concentration of suspended sediment also is expressed in mg/L, and is based on the mass of sediment per liter of water-sediment mixture.

Orogeny is the process of mountain formation.

Oxidation is the removal of one or more electrons from an element or ion, which increases its positive charge or decreases its negative charge.

Partial-record station is a particular site where limited streamflow water-quality data are collected systematically over a period of years.

Perennial stream is one that flows continuously.

Permeability is the property or state of allowing passage of gases or fluids.

pH is a measure of the hydrogen ion (H^+) activity in water and is expressed as the negative base 10 logarithm of the hydrogen ion activity in moles per liter (mol/L). The pH can have any value from 0 to 14. Values less than 7 are acidic and values greater than 7 are alkaline. A solution with a pH of 7 is considered neutral.

Recharge is the process by which water is added to the zone of saturation, either directly into a formation or indirectly by way of another formation. Recharge is also the quantity of water that is added to the zone of saturation.

Recurrence interval is (1) the average time interval between actual occurrences of a hydrologic event of a given or greater magnitude; (2) the average interval in which a flood of a given size recurs as an annual maximum; or (3) the average interval between floods of a given size, regardless of their relationship to the year or any other part of time.

Reduction is the addition of one or more electrons to an element or ion, thus reducing its positive charge or increasing its negative charge.

Regression analysis is a mathematical technique used to estimate the value of one quantitative variable by considering its relationship with one or more other quantitative variables.

Runoff is that part of the precipitation that appears in surface streams.

Sediment is solid material that originates mostly from disintegrated rocks and is transported by, suspended in, or deposited from water; it includes chemical and biochemical precipitates and decomposed organic material, such as humus. The quantity, characteristics, occurrence, and origin of sediment in streams are influenced by environmental factors. Some major factors are degree of slope, length of slope, soil characteristics, land use, and quantity and intensity of precipitation.

Sediment yield is the amount of sediment discharged from the drainage basin.

Suspended sediment is the sediment that, at any given time, is suspended by the upward components of turbulent currents, or that is in suspension as a colloid.

Suspended-sediment concentration is the velocity-weighted concentration of suspended sediment in the sampled zone (from the water surface to a point approximately 0.3 foot above the bed) expressed as milligrams of dry sediment per liter of water-sediment mixture (mg/L).

Sedimentary rock is a rock formed by the accumulation of sediment in water or from the air. The sediment may consist of rock fragments of various sizes, of the remains or products of animals and plants, of the product or chemical action or evaporation, or a mixture of these materials.

Solute is any substance derived from the atmosphere, vegetation, soil, or rocks and dissolved in water.

Specific conductance is a measure of the ability of a water to conduct an electrical current. It is expressed in micromhos per centimeter at 25 ° Celsius. Specific conductance is related to the number and specific chemical types of ions in solution and can be used for approximating the dissolved-solids content in the water.

Standard error of estimate, in linear regression, is the standard deviation of the residuals. A residual is the difference between the actual value and the value predicted from the regression equation. Standard error of estimate has the same units as the dependent variable and indicates how reliably it may be estimated from a given value of the independent variable. It may also be expressed as a percentage of the mean expression of the dependent variable.

Streamflow is the discharge that occurs in a natural channel. Although the term "discharge" can be applied to the flow of a canal, the word "streamflow" uniquely describes the discharge in a surface stream course. The term "streamflow" is more general than "runoff", as streamflow may be applied to discharge whether or not it is affected by diversion or regulation.

Syncline is a fold (of which the core contains the stratigraphically) younger rocks; it is generally convex downward.

Water year is a continuous 12-month period arbitrarily selected to present data relative to hydrologic or meteorologic phenomena during which a complete annual hydrologic cycle occurs. The water year selected by the U.S. Geological Survey is the period October 1 through September 30.

Water yield is the runoff from the drainage basin, including ground-water outflow that appears in the stream plus ground-water outflow that bypasses the gaging station and leaves the basin underground. Water yield is the precipitation minus the evapotranspiration.

Appendix 1 List of surface-water network stations in Area 8

* A partial-record synoptic site where chemical quality, discharge, and (or) biological data were collected intermittently during 1979-81.

Site	Station number or latitude/ longitude	Station name	County	Drainage area, in square miles	Type of record and period collected: Discharge	Stage only	Chemical quality	Suspended sediment
1*	394101080555800	Opossum Cr nr Hannibal, Ohio	Monroe	7.38	---	---	---	---
2*	393156080383339	K01.0 S Fk Fishing Cr at Hwy 82 Br at Jacksonburg, W. Va.	Wetzel	62.8	---	---	---	---
3*	393405080345839	K02.0 N Fk Fishing Cr at Hwy 15/2 Br at Kingston, W. Va.	Wetzel	10.1	---	---	---	---
4*	393445080353139	K03.0 Wiley Fk at Hwy 15 Br at Kingston, W. Va.	Wetzel	15.5	---	---	---	---
5*	393057080414039	K04.0 Piney Fk at Hwy 56/1 Br at Piney, W. Va.	Wetzel	10.3	---	---	---	---
6*	393618080461939	K05.0 Little Fishing Cr at Hwy 38 Br at Childs, W. Va.	Wetzel	34.7	---	---	---	---
7*	391231080403039	K06.0 Meathouse Fk at Hwy 56 Br nr Avon, W. Va.	Doddridge	29.8	---	---	---	---
8*	391220080421239	K07.0 Toms Fk at Br at Market, W. Va.	Doddridge	12.8	---	---	---	---
9*	391705080432439	K08.0 Buckeye Cr at Hwy 50/30 at Smithburg, W. Va.	Doddridge	38.7	---	---	---	---
10*	391745080491839	K09.0 Arnold Cr at Hwy 11 Br at Central Station, W. Va.	Doddridge	20.6	---	---	---	---
11*	392338080422139	K10.0 McElroy Cr at Hwy 12 Br nr Ashley, W. Va.	Doddridge	57.2	---	---	---	---
12*	392312080435739	K11.0 Flint Rn at Hwy 3 Br nr Canton, W. Va.	Doddridge	19.5	---	---	---	---
13*	392556080470739	K12.0 Indian Cr at Hwy 55/2 Br at Big Moses, W. Va.	Tyler	24.0	---	---	---	---
14*	393225080531939	K13.0 Point Pleasant Cr at Hwy 11/6 at Kidwell, W. Va.	Tyler	22.5	---	---	---	---
15*	393210080530639	K14.0 Elk Fk at Hwy 11 Br at Kidwell, W. Va.	Tyler	21.1	---	---	---	---
16*	392634080544739	K15.0 Sancho Cr at Hwy 7 Br nr Sancho, W. Va.	Tyler	13.1	---	---	---	---
17*	392830080595039	K16.0 Middle Island Cr at Little, W. Va.	Tyler	458	1928-81	1915-22	1960-61, 1965 1968-74, 1976-81	1968-74
18	03114650	Buffalo Rn nr Little, W. Va.	Tyler	4.21	1969-77	---	1976, 1977	---
19*	392339081033739	K17.0 Sugar Cr at Hwy 3/8 Br at Shawnee, W. Va.	Pleasants	17.8	---	---	---	---
20*	392145081032839	K18.0 McKim Cr at Hwy 30 Br nr Pine Grove Church, W. Va.	Pleasants	16.4	---	---	---	---
21*	392713081085800	Leith Rn nr Newport, Ohio	Washington	9.50	---	---	---	---
21a*	392345081163001	Newell Rn nr Newport, Ohio	Washington	---	---	---	---	---
22	03115000	Ohio R at St. Marys, W. Va.	Pleasants	26,850	1938-72	---	---	---
23*	392053081111839	K19.0 Left Fk French Cr at Hwy 22 Br at Calcutta, W. Va.	Pleasants	8.96	---	---	---	---
24	03150800	Ohio R nr Marietta, Ohio	Washington	35,600	---	1968-81	---	---
25	03151000	Ohio R at Parkersburg, W. Va.	Wood	35,600	1940-68	---	---	---
26*	384759080203839	M01.0 Little Kanawha R at Hwy 20 Br at Arlington, W. Va.	Upshur	31.7	---	---	---	---
27*	384348080231739	M02.0 Right Fk Little Kanawha R at Hwy 20 Br at Cleveland, W. Va.	Upshur	21.8	---	---	---	---
28*	384400080312339	M03.0 Little Kanawha R nr Wildcat, W. Va.	Braxton	112	1973-81	---	1969, 1976-81	1979-81
29*	384628080325739	M04.0 Falls Rn at Hwy 24/1 Br at Falls Mills, W. Va.	Braxton	10.3	---	---	---	---
30*	384607080365939	M05.0 Saltlick Cr at US 19 Br at Saltlick Bridge, W. Va.	Braxton	22.3	---	---	---	---
31	03151500	Little Kanawha R nr Burnsville, W. Va.	Braxton	155	1937-73	---	1960-61, 1965-67, 1970-74	1967
32	03151518	Burnsville Lake nr Burnsville, W. Va.	Braxton	163	---	1976-81	---	---
33	03151520	Little Kanawha R Bl Burnsville Dam, W. Va.	Braxton	163	1976-81	---	---	---
34*	385149080385539	M06.0 Oil Cr at Private Br at Burnsville, W. Va.	Braxton	29.3	---	---	---	---
35	03151600	Little Kanawha R at Burnsville, W. Va.	Braxton	248	1974-78	1978-81	---	---
36*	385641080411239	M07.0 Sand Fk at Hwy 11 Br nr Donlan, W. Va.	Gilmer	40.6	---	---	---	---
37*	385530080403639	M08.0 Indian Fk at Hwy 36 Br at Blackburn, W. Va.	Gilmer	14.5	---	---	---	---
38*	385737080455539	M09.0 Stewart Cr at Hwy 119 Br at Baldwin, W. Va.	Gilmer	3.33	---	---	---	---
39	03152000	Little Kanawha R at Glenville, W. Va.	Gilmer	386	1928-81	1915-22	1968, 1950-58, 1960-61, 1963, 1965-67, 1970, 1974, 1976-81	1967
40*	390105080414139	M10.0 Leading Cr at Hwy 119/3 Br at Pickle St, W. Va.	Lewis	22.1	---	---	---	---
41*	390506080421939	M11.0 Fink Cr at Hwy 11 Br at Hurst, W. Va.	Lewis	26.0	---	---	---	---

9.0 SUPPLEMENTARY INFORMATION FOR AREA 8--Continued

9.1 Surface-Water Network Stations

Site	Station number or latitude/ longitude	Station name	County	Drainage area, in square miles	Type of record and period collected			
					Discharge	Stage only	Chemical quality	Suspended sediment
42	03152200	Buck Rn nr Leopold, W. Va.	Doddridge	2.91	1969-77	---	1976-77	---
43*	395220080455039	M12.0 Cove Cr at Private Br at Conings, W. Va.	Gilmer	9.36	---	---	---	
44*	390522080465539	M13.0 Bear Fk at Hwy 8 Br nr Conings, W. Va.	Gilmer	4.88	---	---	---	---
45*	390234080492839	M14.0 Horn Cr at Hwy 47 Br at Coxs Mills, W. Va.	Gilmer	5.26	---	---	---	---
46*	390247080492239	M15.0 Coxcamp Fk at Hwy 47 Br at Coxs Mills, W. Va.	Gilmer	2.83	---	---	---	1980
47	03152500	Leading Cr nr Glenville, W. Va.	Gilmer	144	1938-51	---	1965-67	---
48*	384608080443339	M16.0 Perkins Fk at Hwy 19/26 Br at Exchange, W. Va.	Braxton	12.4	---	---	---	---
49*	384627080444739	M17.0 Cedar Cr at RR Br at Exchange, W. Va.	Braxton	10.1	---	---	---	---
50*	385852080565839	M18.0 Tanner Cr at Hwy 20 Br at Tanner, W. Va.	Gilmer	12.4	---	---	---	---
51*	384322080555839	M19.0 Right Fk Steer Cr at Hwy 9 Br nr Rosedale, W. Va.	Braxton	30.7	---	---	---	---
52*	384657080554639	M20.0 Crooked Fk at Hwy 52/4 Br at Perkins, W. Va.	Gilmer	11.5	---	---	---	---
53*	384722080504939	M21.0 Left Fk Steer Cr at Hwy 7/1 Br nr Chapel, W. Va.	Braxton	15.3	---	---	---	---
54*	385102080574839	M22.0 Left Fk Steer Cr at Hwy 119/21 Br at Lockney, W. Va.	Gilmer	42.6	---	---	---	---
55	03153000	Steer Cr nr Grantsville, W. Va.	Calhoun	166	1937-55	---	1960-61, 1965-67	1967-68
56	03153500	Little Kanawha R at Grantsville, W. Va.	Calhoun	913	1928-78	1978-81	1960-61, 1965-67, 1969-74, 1976-78, 1980-81	1967-74
57*	384852081055939	M23.0 Yellow Cr at Hwy 4/8 Br at Ayers, W. Va.	Calhoun	7.87	---	---	---	---
58*	384359081024039	M24.0 Left Fork at Hwy 11/3 Br at Euclid, W. Va.	Calhoun	20.1	---	---	---	---
59*	384234081055839	M25.0 West Fk Little Kanawha R at Hwy 16 Br at Minnora, W. Va.	Calhoun	30.6	---	---	---	---
60*	384328081085839	M26.0 Beech Fk at Hwy 13 Br at Milo, W. Va.	Calhoun	14.6	---	---	---	---
61*	384310081124039	M27.0 Henry Fk at Hwy 25 Br at Linden, W. Va.	Roane	23.5	---	---	---	1980
62	03154000	West Fk Little Kanawha R at Rocksdale, W. Va.	Calhoun	205	1928-31, 1937-75	1975-81	1960-61, 1965-67, 1970-74	1967
63*	384803081205839	M28.0 Spring Cr at Hwy 33 Br at Spencer, W. Va.	Roane	29.4	---	---	---	---
64	03154250	Tanner Rn at Spencer, W. Va.	Roane	2.82	1969-77	---	1976-77	---
65	03154500	Reedy Cr nr Reedy, W. Va.	Roane	79.4	1951-78	---	1960-61, 1965-67	1967
66*	390335081233539	M29.0 Little Kanawha R at Palestine, W. Va.	Wirt	1515	1939-81	1915-22	1960-61, 1965-67 1976-81	1967-68, 1978-80
67*	391215080515339	M30.0 South Fk Hughes R at Hwy 52 Br at Oxford, W. Va.	Doddridge	13.7	---	---	---	---
68*	390855080502739	M31.0 Middle Fk at Hwy 22/3 Br nr Holbrook, W. Va.	Ritchie	12.8	---	---	---	---
69*	390638080565439	M32.0 Bone Cr at Hwy 7/14 Br nr Berea, W. Va.	Ritchie	17.8	---	---	---	---
70*	390436081004439	M33.0 Spruce Cr at Hwy 19/4 Br nr Hazelgreen, W. Va.	Ritchie	20.1	---	---	---	---
71*	390333081053539	M34.0 Leatherbark Cr at Hwy 16 Br at Smithville, W. Va.	Ritchie	17.8	---	---	---	---
72*	390821081031739	M35.0 Indian Cr at Hwy 16 Br at Washburn, W. Va.	Ritchie	15.0				
73	03155200	South Fk Hughes R at Macfarlan, W. Va.	Ritchie	210	1915-16, 1937-51	---	1965-66, 1967, 1969	---
74*	391629080555339	M36.0 North Fk Hughes R at Hwy 50/40 Br at Toll Gate, W. Va.	Ritchie	23.0	---	---	---	---
75*	391808081030339	M37.0 Bonds Cr at Hwy 1 Br at Highland, W. Va.	Ritchie	11.5	---	---	---	1980
76*	390710081164039	M38.0 Hughes R at Cisco, W. Va.	Ritchie	452	1928-31, 1938-81	1915-	1960-61, 1965-67, 1976-81	1967-68
77	03155600	Little Kanawha R at Parkersburg, W. Va.	Wood	2297	---	---	1965-67	
78*	392224081391400	Tupper Cr at Vincent, Ohio	Washington	5.24	---	---	---	---
79*	392010081371600	East Br Little Hocking R nr Belpre, Ohio	Washington	12.0	---	---	---	---
80*	391805081434200	Little W Br L Hocking R nr Little Hocking, Ohio	Washington	4.59	---	---	---	---
81*	391810081453000	West Br L Hocking R nr Cutler, Ohio	Washington	30.4	---	---	---	---
82	394439082392800	Hocking R ab Lancaster, Ohio	Fairfield	12.0	---	---	---	---
83	394515082351900	Fetters Rn nr Lancaster, Ohio	Fairfield	6.55	---	---	---	---

Site	Station number or latitude/ longitude	Station name	County	Drainage area, in square miles	Type of record and period collected: Discharge	Stage only	Chemical quality	Suspended sediment
84	394512082334800	Ewing Rn nr Lancaster, Ohio	Fairfield	2.1	---	---	---	---
85	03156000	Hunters Rn at Lancaster, Ohio	Fairfield	10.0	1956-79	---	1965-77, 1980	---
86	03156400	Hocking R at Lancaster, Ohio	Fairfield	48.2	1956-74	---	1966-67, 1969-74	---
87	394111082364100	Tarhe Rn nr Lancaster, Ohio	Fairfield	1.5	---	---	---	---
88	394110082342400	Hocking R bl Lancaster, Ohio	Fairfield	66.6	---	---	---	---
89*	394129082334300	Pleasant Rn nr Lancaster, Ohio	Fairfield	14.8	---	---	---	---
90	03156500	Hocking R nr Lancaster, Ohio	Fairfield	90.3	1923-32	---	---	---
91*	394716082273400	Unnamed Tr L Rush Cr nr Rushville, Ohio	Fairfield	13.4	---	---	---	---
92	03156600	Little Rush Cr nr Rushville, Ohio	Fairfield	30.0	1979-80	---	1979-80	---
93*	394456082195600	Center Br nr Somerset, Ohio	Perry	18.6	---	---	---	---
94*	394238082205900	No Name Cr nr Breman, Ohio	Perry	6.14	---	---	---	---
95	03157000	Clear Cr nr Rockbridge, Ohio	Hocking	89.0	1939-81	---	1965-77	---
96	03157500	Hocking R at Enterprise, Ohio	Hocking	459	1930-81	---	1965-77	---
97*	393112082300800	Duck Cr nr Rockbridge, Ohio	Hocking	2.32	---	---	---	---
98	03158000	Clear Fk nr Logan, Ohio	Hocking	14.8	1941-47	---	---	---
99*	393052082252700	Scott Cr nr Carbon Hill, Ohio	Hocking	13.3	---	---	---	---
100*	393211082232900	Oldtown Cr at Logan, Ohio	Hocking	21.9	---	---	---	---
101*	393226082163400	Little Monday Cr nr Carbon Hill, Ohio	Hocking	25.1	---	---	---	---
102*	392750082101500	Snow Fk Monday Cr at Buchtel, Ohio	Athens	24.2	1981	---	1981	1981
103*	393554082041500	Dotson Cr nr Corning, Ohio	Perry	5.99	---	---	---	---
104*	393534082071500	No Name Tr W Br Sunday Cr nr Corning, Ohio	Perry	7.78	---	---	---	---
105	03158500	Burr Oak Reservoir at Burr Oak, Ohio	Athens	33.1	---	1952-81	---	---
106	03159000	Sunday Cr at Glouster, Ohio	Athens	104	1951-78	---	1964-77	---
107*	391743082100100	West Br Margaret Cr nr New Marshfield, Ohio	Athens	9.40	---	---	---	---
108*	391951082082400	Factory Cr nr The Plains, Ohio	Athens	8.89	---	---	---	---
109	03159500	Hocking R at Athens, Ohio	Athens	943	1907, 1915-76	---	1966-74	1956-65
110	03159510	Hocking R bl Athens, Ohio	Athens	957	1976-81	---	1966-80	1978-81
111*	392710081592600	Miners Fk nr Amesville, Ohio	Athens	9.88	---	---	---	---
112*	392250081592900	Mush Rn nr Amesville, Ohio	Athens	13.1	---	---	---	---
113*	392611081544600	Opossum Rn nr Amesville, Ohio	Athens	8.97	---	---	---	---
114*	392205081524800	Marietta Rn nr Stewart, Ohio	Athens	10.1	---	---	---	---
115	03159530	Ohio R at Bellville Dam, W. Va.	Wood	39,300	1974-81	---	---	---
116*	390711081482400	Forked Rn nr Long Bottom, Ohio	Meigs	3.98	---	---	---	---
117*	391604082022300	Long Rn nr Athens, Ohio	Athens	4.96	---	---	---	1980
118*	391148081583000	Pratt Fk M Br Shade R nr Shade, Ohio	Athens	10.7	---	---	---	---
119*	390648082005600	Kingsbury Cr nr Pomeroy, Ohio	Meigs	13.5	---	---	---	---
120*	390346081540100	Horse Cave Cr nr Chester, Ohio	Meigs	18.3	---	---	---	---
121	03159540	Shade R nr Chester, Ohio	Meigs	156	1965-81	---	1965-77, 1979-81	1970-74
122	03159555	East Br Shade R nr Tuppers Plains, Ohio	Meigs	37.5	1980-81	---	1980-81	1980-81
123*	390611081514400	East Br Shade R nr Long Bottom, Ohio	Meigs	39.3	---	---	---	---
124	03159870	Ohio R at Racine Dam, W. Va.	Mason	40,100	1979-80	---	---	---
125*	390622082131000	Mud Fk Leading Cr nr Dexter, Ohio	Meigs	12.2	---	---	---	1979-80
126*	390150082081800	Little Leading Cr nr Rutland, Ohio	Meigs	24.2	---	---	---	---
126a*	390240082075001	Little Leading Cr at Rutland, Ohio	Meigs	21.6	---	---	---	---
127*	390239082030800	East Br Thomas Fk nr Pomeroy, Ohio	Meigs	10.8	---	---	---	---

Site	Station number or latitude/ longitude	Station name	County	Drainage area, in square miles	Type of record and period collected			
					Discharge	Stage only	Chemical quality	Suspended sediment
128*	385728082042439	L02.0 Tenmile Cr at Hwy 8 Br at Lakin, W. Va.	Mason	9.19	---	---	---	---
129*	385916082090200	Jessie Cr nr Rutland, Ohio	Gallia	2.69	---	---	---	---
130*	385347082044039	L01.0 Oldtown Cr at Hwy 13 Br at McClintic WLS, W. Va.	Mason	35.2	---	---	---	---
131*	385418082131000	Champaign Cr nr Addison, Ohio	Gallia	32.2	---	---	---	---
132	03160000	Ohio R at Pomeroy, Ohio	Meigs	40,500	1936-37, 1940-68	---	---	---
133	391649081442200	West Br L Hocking R nr Little Hocking, Ohio	Washington	---	---	---	---	---
134	391739081411600	East Br L Hocking R nr Porterfield, Ohio	Washington	---	---	---	1975	---
135	394306082240700	Rush Cr nr Bremen, Ohio	Fairfield	---	---	1975	---	---
136	393818082304200	Rush Cr nr Sugar Grove, Ohio	Fairfield	229	---	---	1975	---
137	393743082135800	Monday Cr at McCuneville, Ohio	Perry	3.50	---	---	1975	---
138	393745082183300	L Monday Cr nr Maxville, Ohio	Perry	4.80	---	---	1975	---
139	393109082162900	Monday Cr nr Greendale, Ohio	Hocking	---	---	---	1975	---
140	392917082095700	Snow Fk nr Murray City, Ohio	Hocking	---	---	---	1975	---
141	392607082113000	Monday Cr at Doanville, Ohio	Athens	114	---	---	1975	---
142	393621082102300	Pine Fk nr Hemlock, Ohio	Perry	---	---	---	1975	---
143	393529082071500	West Br Sunday Cr at Drakes, Ohio	Perry	---	---	---	1975	---
144	393412082015700	East Br Sunday Cr ab Burr Oak Lake, Ohio	Morgan	---	---	---	1975	---
145	393006082052700	Mud Fk at Glouster, Ohio	Athens	7.30	---	---	1975	---
146	392548082071000	Carr Bailey Rn nr Morristown, Ohio	Athens	---	---	---	1975	---
147	392555082053200	Sunday Cr at Millfield, Ohio	Athens	---	---	---	1975	---
148	392359081522800	Federal Cr at Amesville, Ohio	Athens	---	---	---	1975	---
149	392409081554800	Sharps Fk nr Amesville, Ohio	Athens	35.7	---	---	1975	---
150	391016082025100	West Br Shade R nr Burlingham, Ohio	Meigs	---	---	---	1975	---
151	390222081594900	Kerr Rn at Pomeroy, Ohio	Meigs	---	---	---	1975	---
152	390046082081800	Leading Cr nr Rutland, Ohio	Meigs	89.3	---	---	1975	---
153	390031082050700	Leading Cr nr Middleport, Ohio	Meigs	117	---	---	1975	---
154	390017082042700	Thomas Fk nr Middleport, Ohio	Meigs	---	---	---	1975	---
155	385708082073300	Kyger Cr nr Cheshire, Ohio	Gallia	---	---	---	1975	---
156	385548082092100	L Kyger Cr nr Cheshire, Ohio	Gallia	---	---	---	1975	---

Appendix 2 Water-quality data collected at sites in Area 8 in Ohio
Water year October 1980 to September 1981

Site No.	Cadmium, dissolved (µg/L as Cd)	Cobalt, dissolved (µg/L as Co)	Copper, dissolved (µg/L as Cu)	Iron, total recoverable (µg/L as Fe)	Iron, suspended recoverable (µg/L as Fe)	Iron, dissolved (µg/L as Fe)	Lead, dissolved (µg/L as Pb)	Lithium, dissolved (µg/L as Li)	Manganese, total recoverable (µg/L as Mn)	Manganese, suspended recoverable (µg/L as Mn)	Manganese, dissolved (µg/L as Mn)	Molybdenum, dissolved (µg/L as Mo)	Strontium, dissolved (µg/L as Sr)	Vanadium, dissolved (µg/L as V)	Zinc, dissolved (µg/L as Zn)
21	6	3	10	180	170	6	10	4	10	0	13	10	240	6.0	87
21a	2	3	10	180	180	3	10	4	10	4	6	10	260	6.0	36
81	1	3	10	450	430	21	12	4	210	0	--	10	210	6.0	8
89	<1	<3	<10	240	200	41	13	7	20	0	20	<10	640	<6.0	27
91	2	3	<10	530	450	79	21	<4	100	0	100	<10	320	<6.0	5
94	3	5	<10	800	640	160	<10	6	1400	0	1400	<10	430	<6.0	13
99	1	4	<10	1000	860	140	<10	<4	510	0	530	<10	180	<6.0	6
100	1	<3	<10	360	320	40	<10	11	110	80	32	<10	500	<6.0	36
102	<1	290	21	19000	1000	18000	<10	180	6000	0	6300	<10	670	<6.0	500
	--	--	--	41000	23000	18000	--	--	7000	0	7000	--	--	--	--
111	2	<3	<10	370	350	21	<10	5	640	30	610	<10	340	<6.0	7
114	2	4	10	630	590	43	16	11	1200	0	1300	10	540	6.0	51
117	1	3	10	400	390	15	10	6	130	10	120	10	450	6.0	4
119	<1	<3	<10	2100	2100	22	<10	5	2200	100	2100	<10	260	<6.0	13
121	--	--	--	1800	1800	30	--	--	910	40	870	--	--	--	--
	3	<3	<10	870	860	8	<10	<4	890	40	850	<10	260	<6.0	25
122	<1	<3	<10	670	660	7	11	<4	580	110	470	<10	300	<6.0	7
	--	--	--	1500	1400	70	--	--	800	220	580	--	--	--	--
126a	3	3	10	380	360	21	10	9	1300	0	1400	10	530	6.0	24
131	<1	<3	<10	420	390	35	<10	5	290	50	240	<10	200	<6.0	14

Water year October 1980 to September 1981

Site No.	Carbonate, field (mg/L as CO_3)	Alkalinity, field (mg/L as $CaCO_3$)	Carbon dioxide, dissolved (mg/L as CO_2)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Silica, dissolved (mg/L as SiO_2)	Solids, sum of constituents, dissolved (mg/L)	Solids, dissolved (ton/ac-ft)	Solids, dissolved (ton/d)	Aluminum, total recoverable (µg/L as Al)	Aluminum, suspended recoverable (µgL as Al)	Aluminum, dissolved (µg/L as Al)	Barium, dissolved (µg/L as Ba)	Beryllium, dissolved (µg/L as BE)
21	0	119	1.9	30	27	3.7	189	0.26	0.09	150	130	20	70	1
21a	0	134	2.1	52	9.6	5.6	210	.29	.09	90	60	30	60	1
81	0	108	3.4	39	10	2.3	166	.23	.16	230	220	10	90	1
89	254	254	8.3	65	33	5.7	494	.67	2.2	70	60	10	90	<1
91	173	173	22	31	13	2.9	297	.40	.34	190	160	30	70	<1
94	108	108	22	67	86	2.0	372	.51	.00	180	170	10	60	<1
99	97	97	32	78	22	4.8	278	.38	.08	110	100	10	70	<1
100	218	218	2.8	57	170	4.9	674	.92	.60	130	60	70	240	<1
102	0 0	0 0	.0 .0	930 730	16 --	46 --	1270 --	1.7 1.9	13.5 14.7	31000 --	1000 --	30000 --	30 --	9 --
111	148	148	15	120	19	5.5	398	.54	.00	140	130	10	90	<1
114	105	105	22	390	17	8.0	716	.97	.13	160	130	30	120	1
117	0	115	4.6	260	8.7	5.8	482	.66	.17	130	120	10	60	1
119	0	80	5.1	110	10	6.9	245	.33	.09	700	670	30	70	<1
121	0 0	70 106	6.8 8.5	100 74	-- 17	-- 4.0	-- 227	.36 .31	11.3 1.8	-- 330	-- 320	-- 10	-- 80	-- <1
122	0 0	165 164	5.3 10	21 21	37 --	3.8 --	230 --	.31 .30	.19 2.5	280 --	270 --	10 --	160 --	<1 --
126a	0	83	5.3	120	190	6.6	537	.73	.12	130	120	10	30	1
131	0	102	4.1	110	12	3.4	260	.35	.04	130	120	10	40	<1

Water year October 1980 to September 1981

Site No.	Date	Time	Stream-flow, instan-taneous (ft^3/s)	Spe-cific con-duct-ance (µmho)	pH	Temper-ature (°C)	Hard-ness (mg/L as $CaCO_3$)	Hard-ness, noncar-bonate (mg/L as $CaCO_3$)	Acidity (mg/L as H)	Acidity (mg/L as $CaCO_3$)	Calcium, dis-solved (mg/L as Ca)	Magne-sium, dis-solved (mg/L as Mg)	Sodium, dis-solved (mg/L as Na)	Sodium ad-sorp-tion ratio	Bicar-bonate, field (mg/L as HCO_3)
21	8-24	1315	0.17	400	8.0	23.0	160	40	0.0	0.0	48	9.4	12	0.4	119
21a	8-24	1415	.14	425	8.0	22.0	190	54	.0	.0	57	11.0	8.0	.3	134
81	8-26	0930	.35	350	7.7	17.0	140	28	--	--	39	9.3	12	.5	108
89	8-25	0930	1.6	680	8.0	18.0	310	59	.0	.0	79	28	28	.7	0
91	8-25	1030	.42	450	7.4	19.0	200	27	.0	.0	52	17	7.0	.2	0
94	8-25	1130	.00	660	7.2	19.0	220	110	.0	.0	52	21	34	1.1	0
99	8-25	1600	.10	460	7.0	22.0	180	86	.0	.0	42	19	14	.5	0
100	8-25	1500	.33	1000	8.4	27.0	160	0	.0	.0	39	14	170	6.4	0
102	8-25	1400	3.9	1800	3.0	20.0	550	550	5.9	297	110	66	36	.7	0
	9-17	1320	3.9	1830	2.8	15.0	--	--	6.5	323	--	--	--	--	0
111	8-26	0830	.00	580	7.5	16.0	240	91	.0	.0	69	16	19	.6	0
114	8-26	1100	.06	950	7.2	18.0	470	370	.0	.0	143	28	23	.5	0
117	8-25	1015	.13	800	7.6	16.5	380	260	--	--	109	26	15	.4	115
119	8-25	1420	.13	450	7.4	24.0	180	100	--	--	56	10	10	.3	80
121	8-11	0915	16	414	7.3	22.0	--	--	--	--	--	--	--	--	85
	8-26	1435	3.0	450	7.3	20.5	180	72	--	--	53	11	15	.5	106
122	8-26	1235	.30	500	7.7	23.5	190	23	--	--	57	11	18	.6	165
	9-15	1045	4.2	376	7.5	21.0	--	--	--	--	--	--	--	--	200
126a	8-26	1700	.08	1000	7.4	24.0	270	190	.0	.0	83	16	78	2.2	83
131	8-26	1615	.06	500	7.6	23.0	190	92	--	--	56	13	15	.5	102

Appendix 3 Inactive Surface-water stations in Area 8

Site	Station number	Station name	Drainage area (mi^2	Type and period of		
				Discharge	QW	Sediment
18	03114650	Buffalo Rn nr Little, WV	4.21	1969-77	1976-77	---
22	03115000	Ohio R at St. Marys, WV	26,850	1938-72		
25	03151000	Ohio R at Parkersburg, WV	35,600	1940-68		
31	03151500	Little Kanawha R nr Burnsville, WV	155	1937-73	1960-61,1965-67,1970-74	1967
42	03152200	Buck Rn nr Leopold, WV	2.91	1969-77	1976-77	---
47	03152500	Leading Cr nr Glenville, WV	144	1938-51	1965-67	---
55	03153000	Steer Cr nr Grantsville, WV	166	1937-75	1960-61,1965-67	1967-68
64	03154250	Tanner Rn at Spencer, WV	2.82	1969-77	1976-77	---
65	03154500	Reedy Cr nr Reedy, WV	79.4	1951-78	1960-61,1965-67	1967
73	03155200	South Fk Hughes R at Macfarlan, WV	210	1915-16,1937-51	1965-66,1967,1969	---
85	03156000	Hunters Rn at Lancaster, OH	10.0	1956-79	1965-77,1980	---
86	03156400	Hocking R at Lancaster, OH	48.2	1956-74	1966-67,1969-74	
90	03156500	Hocking R nr Lancaster, OH	90.3	1923-32	---	
92	03156600	Little Rush Cr nr Rushville, OH	30.0	1979-80	1979-80	---
98	03158000	Clear Fk nr Logan, OH	14.8	1941-47	---	
106	03159000	Sunday Cr at Glouster, OH	104	1951-78	1966-67,1969-77	
109	03159500	Hocking R at Athens, OH	943	1907,1915-76	1966-74	1956-65
124	03159870	Ohio R at Racine Dam, WV	40,100	1979-80	---	---
132	03160000	Ohio R at Pomeroy, OH	40,500	1936-37,1940-68		

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