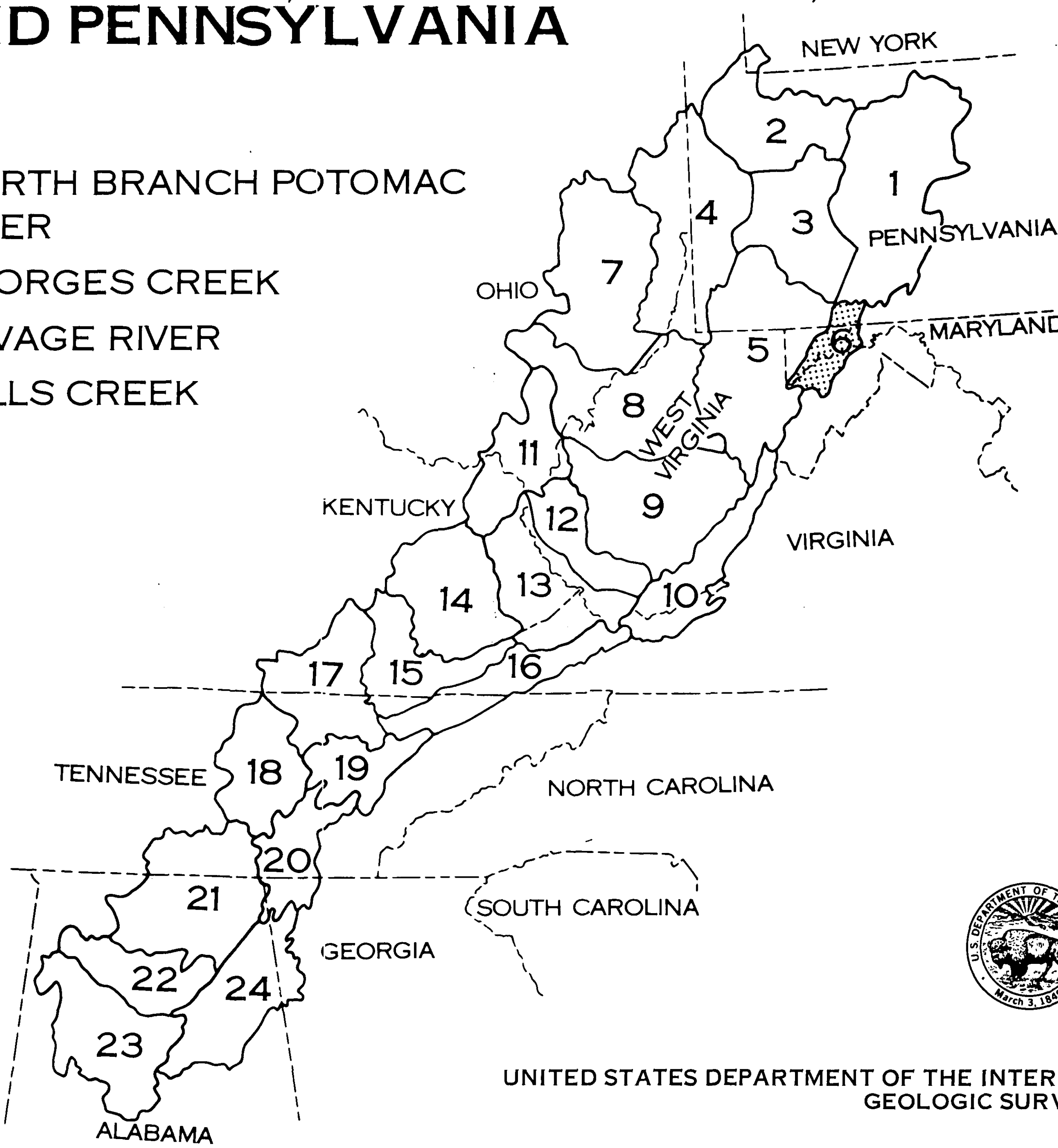
HYDROLOGY OF AREA 6, EASTERN COAL PROVINCE, MARYLAND, WEST VIRGINIA, AND PENNSYLVANIA

- NORTH BRANCH POTOMAC RIVER
- GEORGES CREEK
- SAVAGE RIVER
- WILLS CREEK



UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGIC SURVEY

WATER-RESOURCES INVESTIGATIONS
OPEN-FILE REPORT 83-33

HYDROLOGY OF AREA 6, EASTERN COAL PROVINCE, MARYLAND, WEST VIRGINIA, AND PENNSYLVANIA

BY
WARD W. STAUBITZ AND JOHN R. SOBASHINSKI

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TOWSON, MARYLAND
SEPTEMBER 1983

UNITED STATES DEPARTMENT OF THE INTERIOR

JAMES G. WATT, *SECRETARY*

GEOLOGICAL SURVEY

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Towson, Maryland 21204

CONTENTS

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

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

Multiply	By	To obtain
inches (in)	25.40	millimeters (mm)
inches per hour (in/h)	25.4	millimeters per hour (mm/h)
	2.54	centimeters per hour (cm/h)
feet (ft)	0.3048	meters (m)
feet per mile (ft/mi)	0.1894	meters per kilometer (m/km)
miles (mi)	1.609	kilometers (km)
square miles (mi^2)	2.590	square kilometers (km^2)
gallons per minute (gal/min)	0.06309	liters per second (L/s)
million gallons per day (mgal/d)	0.04381	cubic meters per second (m^3/s)
	3785.	cubic meters per day (m^3/d)
cubic feet per second (ft^3/s)	0.02832	cubic meters per second $(m^3/s)/km^2$
cubic feet per second per square mile $[(ft^3/s)/mi^2]$	0.01093	cubic meters per second per square kilometer $[(m^3/s)km^2]$
tons per square mile per year $[(ton/mi^2)/yr]$	0.3503	metric tons per square kilometer per year $[(t/km^2)/a]$
micromhos per centimeter at 25° Celsius (μmhos/cm)	100	microsiemens per meter at 25° Celsius (μS/m)

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

HYDROLOGY OF AREA 6, EASTERN COAL PROVINCE, MARYLAND, WEST VIRGINIA, AND PENNSYLVANIA

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Abstract

This report broadly characterizes the hydrology of Area 6, the 1,329 square-mile North Branch Potomac River basin. Area 6 is one of 24 study areas located within the Eastern Coal Province for which hydrologic reports are being prepared.

Area 6 comprises parts of Maryland, Pennsylvania, and West Virginia and is almost evenly divided between two physiographic provinces. The Allegheny Mountain section of the Appalachian Plateaus physiographic province encompasses the western half of the area and contains coal-bearing rocks of Pennsylvanian age. The area contains two coal-producing regions, the Georges Creek Coal Field and the Upper Potomac Coal Field, which have 1.6 billion tons of mineable coal reserves available from 16 major coal seams. Coal production from the area amounted to 3.8 million tons in 1978 and has been steadily increasing in the last several years. The eastern half of the area lies within the Middle section of the Valley and Ridge physiographic province and contains non-coal-bearing rocks of pre-Pennsylvanian age.

Area 6 has a continental, temperate climate and receives between 36 and 45 inches of precipitation depending on elevation. The soils of the area were formed from noncarbonate, sedimentary rocks and are generally of high acidity and low fertility. Forest land occupies over 80 percent of the land surface, whereas surface mining occupies only about 1.5 percent of the land surface.

The area is drained entirely by the North Branch Potomac River. Major tributaries that drain coal mining areas are Stony River, Abram Creek, Savage River, Georges Creek, and Wills Creek. New Creek, Evitts Creek, and Patterson Creek drain unmined areas.

Water used in the area is mostly from surface-water resources. Ground-water accounts for only 0.5 percent of total water withdrawals. Seventy-two percent of ground-water withdrawals are used by the coal-mining industry.

More than 140 miles of streams in Area 6 are affected by mine drainage. These streams are devoid of fish life and otherwise have severely reduced biological communities.

The mean dissolved-solids concentrations and specific conductances were more than three times greater for streams draining coal mining areas than for streams draining unmined areas. Mean sulfate concentration was 10 times greater for streams draining coal mining areas; iron and manganese were five to 50 times greater in mined areas. The mean pH and net alkalinity of streams draining unmined areas were higher than those of streams draining mined areas, 1.7 pH units and 32.5 mg/L as $CaCO_3$ higher, respectively. Although concentrations of trace metals in water and bottom sediments were generally low for streams draining both mined and unmined areas, those from unmined areas were noticeably higher. Stream suspended-sediment loads increased dramatically in the vicinity of active mining; however, sedimentation was much less pronounced further downstream.

The U.S. Geological Survey has recently collected hydrologic data from 56 sites in Area 6. These data are available from computer storage through the National Water Data Exchange (NAWDEX).

1.0 INTRODUCTION

1.1 Objective

Area 6 Report Submitted in Response to Public Law 95-87

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

This report provides hydrologic information, using a brief text with an accompanying map, chart, graph, or other illustration for each of a series of water-resources related topics. The summation of the topical discussions provides a description of the hydrology of the area. The information contained herein should be useful to surface-mine owners, operators, and consulting engineers in 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. The Act established a new Federal agency, Office of Surface Mining Reclamation and Enforcement (OSM), within the U.S. Department of the Interior, whose function is to set guidelines for controlling the adverse effects of coal mining on the environment. The act provided for establishment of State-level regulatory authorities to administer and enforce State laws meeting the Federal guidelines. Further provided in the Act is the backup provision that, if no satisfactory State program is developed, the Federal regulations will be enforced by OSM.

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" of the land.

This report broadly characterizes the hydrology of Area 6 in Maryland, Pennsylvania, and West Virginia, as delineated in figure 1.1-1. The hydrologic information presented or available through sources identified in this report may be used in describing the hydrology of the "general area" of any proposed mine. Furthermore, it is expected that this hydrologic information will be supplemented by the lease applicant's specific site data, as well as data from other sources, to provide a more detailed picture of the hydrology in the vicinity of the mine and the anticipated hydrologic consequences of the mining operation.

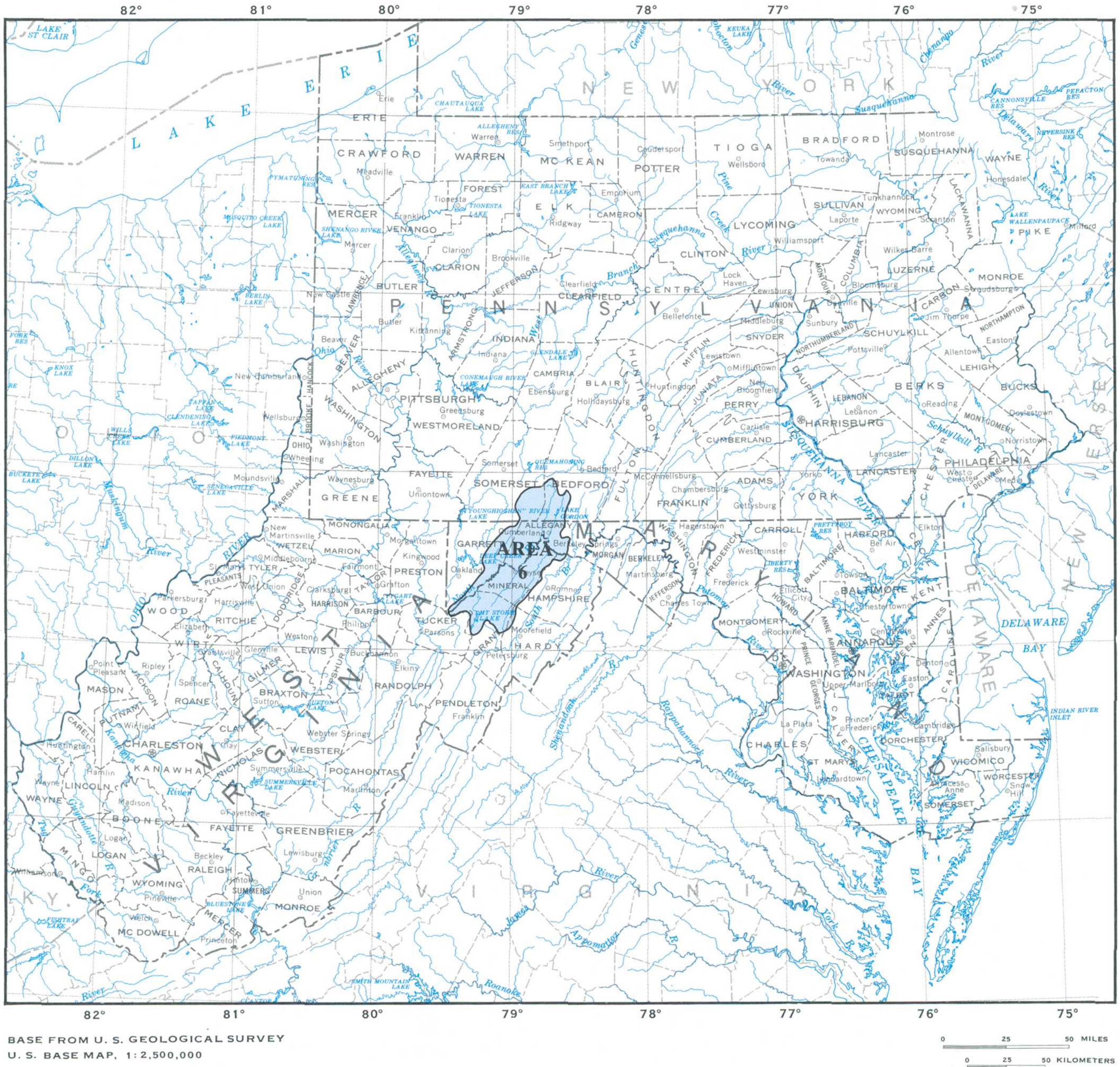


Figure 1.1-1 Location of Area 6.

Area 6 Encompasses North Branch Potomac River Basin

The area is located in the northern part of the Eastern Coal Province in adjoining parts of Maryland, Pennsylvania, and West Virginia.

The Eastern Coal Province is divided into 24 study areas. The division is based on hydrologic factors, location, size, and mining activity. Hydrologic units (drainage basins) or parts of units are combined to form each area (see front cover for areas in the Eastern Coal Province).

Area 6 contains 1,329 square miles and is drained entirely by the North Branch Potomac River. The major tributaries to the North Branch Potomac River are Stony River, Abram Creek, Savage River, and Georges Creek, which drain coal mining areas, and New, Evitts, and Patterson Creeks, which drain areas having no coal mining (fig. 1.2-1).

The area is situated in adjoining parts of three states. It contains parts of Allegany and Garrett Counties in Maryland; Bedford and Somerset Counties in Pennsylvania; and Grant, Hampshire, Mineral, Preston, and Tucker Counties in West Virginia. The largest concentrations of population are Cumberland, Md., Frostburg, Md., and Keyser, W. Va. (fig. 1.2-1).

Area 6 lies within the Appalachian Plateaus and the Valley and Ridge physiographic provinces (fig. 1.2-2). The Appalachian Plateau, which constitutes approximately the western half of the area, contains two coal-producing regions, the Georges Creek Coal Field and the Upper Potomac Coal Field (fig. 1.2-3). In 1978 over 3.8 million tons of coal were produced from these two coal fields. Coal production in the area increased steadily from 1970 to 1980 and is expected to continue to increase for the next few years.

The coals of greatest economic value in the area are found in the Monongahela, Conemaugh, and Allegheny Formations of the Pennsylvanian System. Coals of lesser importance are also found in the Pottsville Formation of the Pennsylvanian System and the Dunkard Group of the Permian System.

BASE FROM U.S. GEOLOGICAL SURVEY
1966, 1974, 1975; 1:500,000

Figure 1.2-1 Drainage basins.

SCALE 1:750,000

0 10 20 30 MILES

0 10 20 30 KILOMETERS

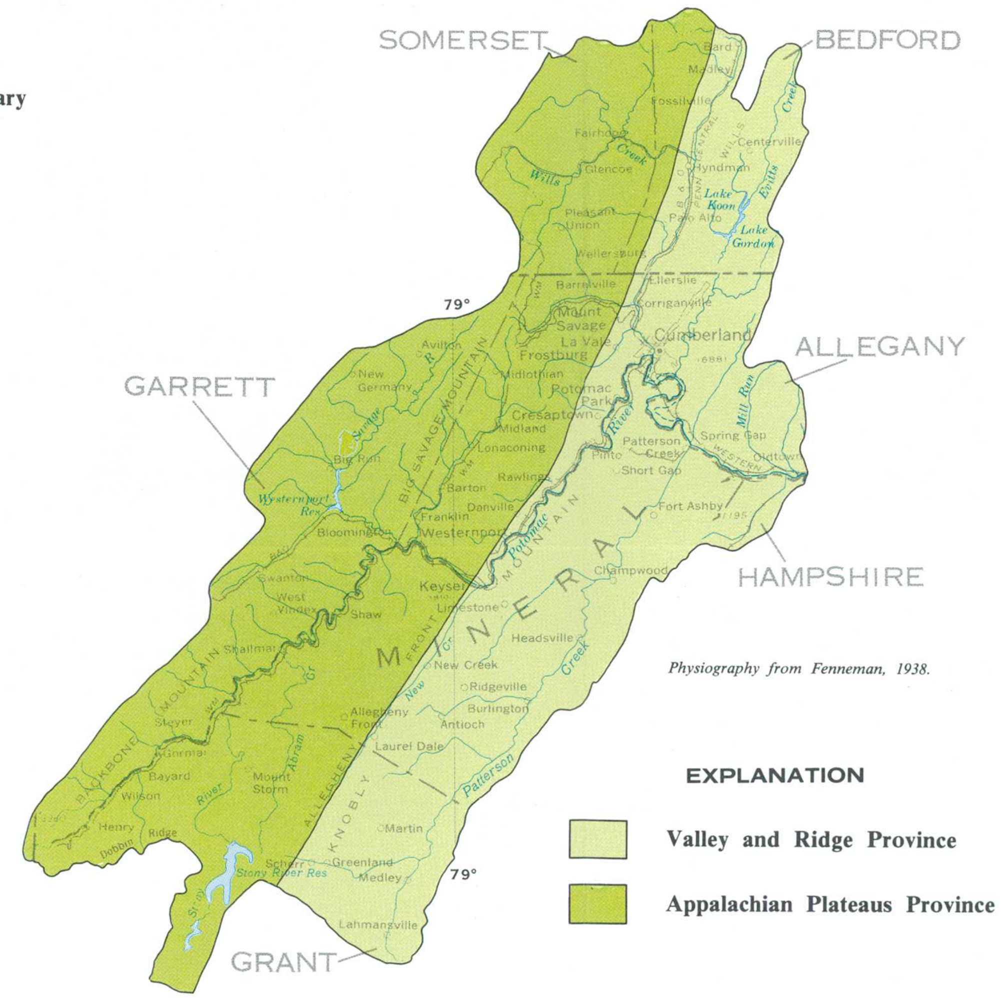


Figure 1.2-2 Physiographic divisions.

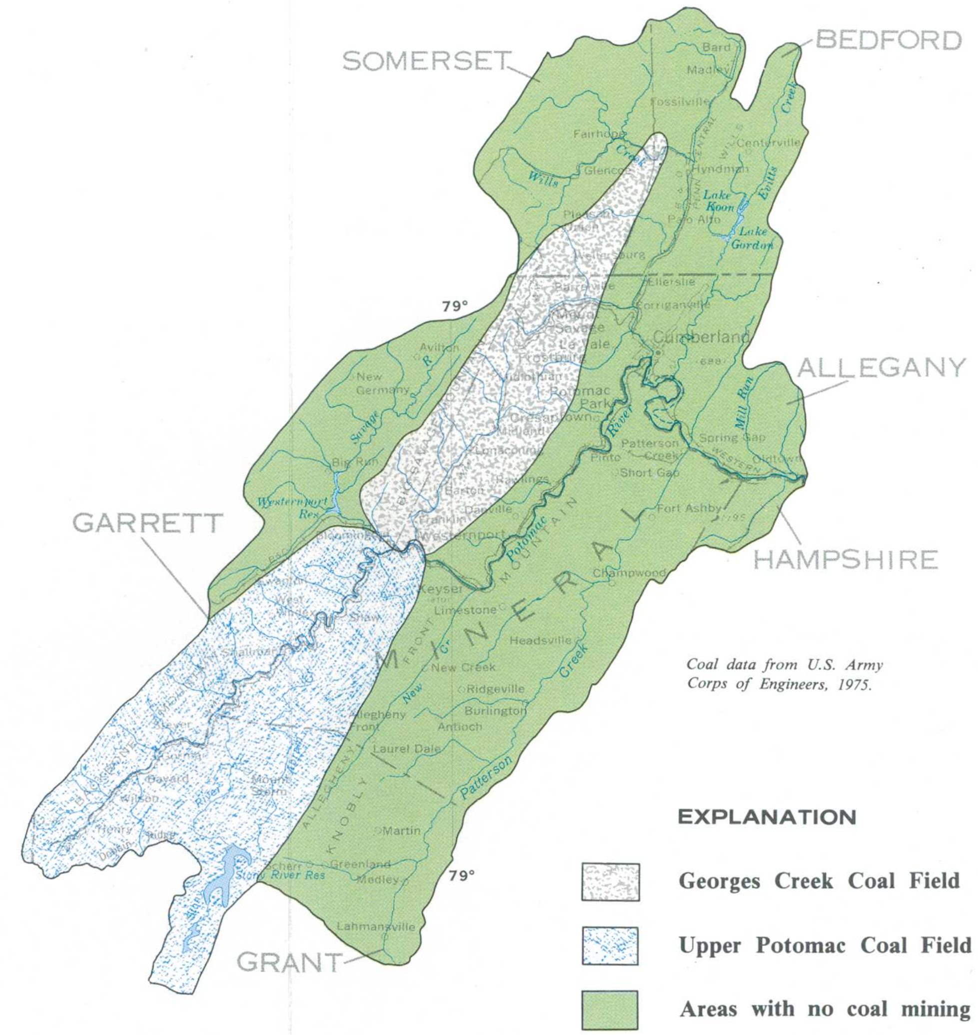


Figure 1.2-3 Coal-mining areas.

Area 6 Lies within Two Physiographic Provinces

The area is nearly evenly divided between the Appalachian Plateaus and Valley and Ridge physiographic provinces.

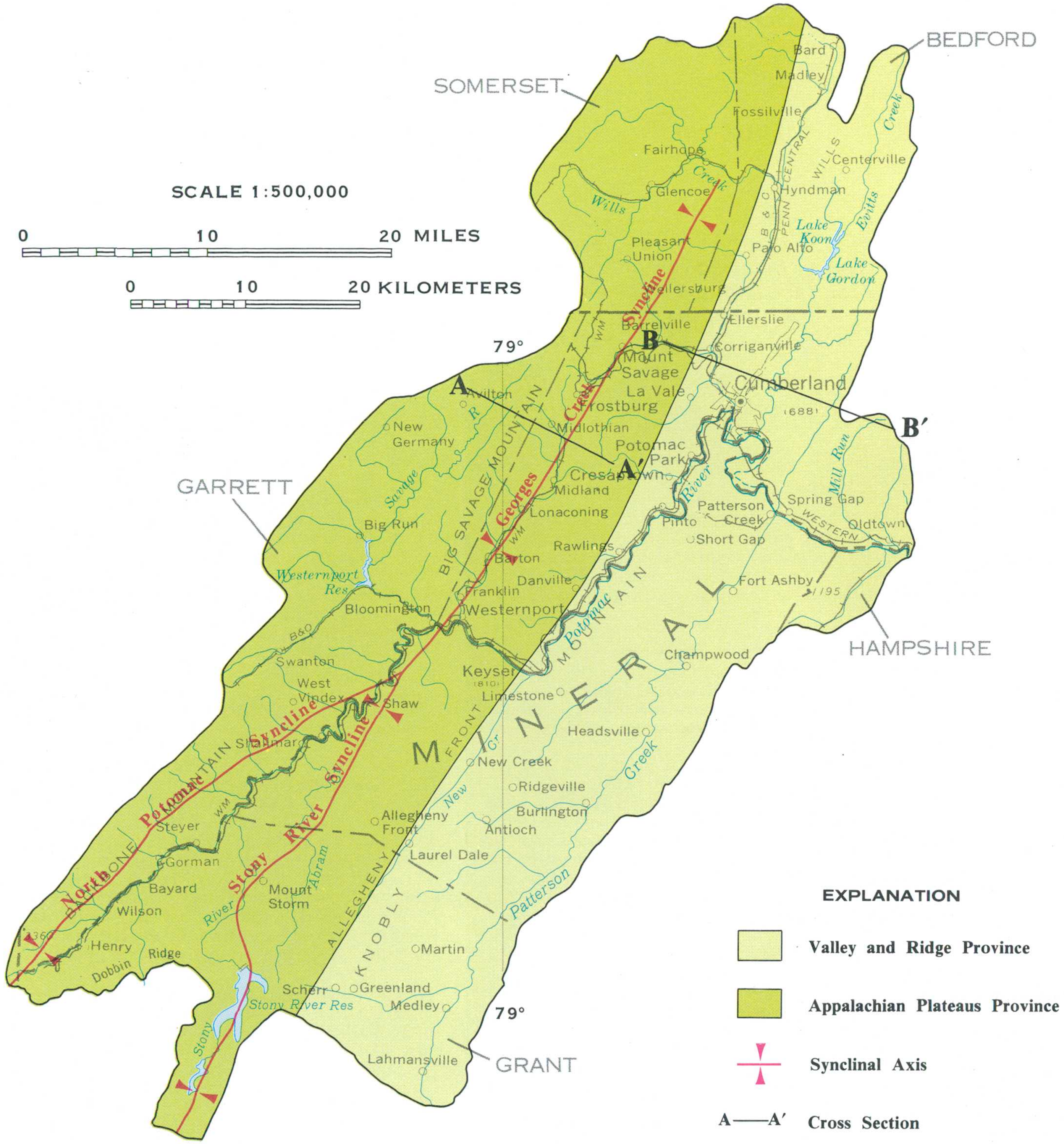
The western half of Area 6 lies within the Allegheny Mountain section of the Appalachian Plateaus physiographic province (fig. 2.1.1-1). The most important structural feature in the western half of the area is a gently sloping synclinal basin that contains coal-bearing rocks of the Pennsylvanian System (fig. 2.1.1-2). The northern part of the basin follows the Georges Creek Syncline from near Wellersburg, Pa., south to Shaw, W. Va., where the syncline splits. At the split the North Potomac Syncline forms the primary synclinal axis, extends west from Shaw and passes through Kempton, Md. The Stony River Syncline forms the secondary synclinal axis and extends southwest to the Stony River Reservoir (U.S. Army Corps of Engineers, 1976a).

The basin formed by the syncline is a single structural unit, which is divided by the Savage River into the Georges Creek basin in the north and the Upper Potomac basin in the south (Amsden and others, 1954). The upturned edges of the synclinal basin form two long parallel mountain crests, with the Allegheny Front to the east and Backbone and Big Savage mountains to the west. It is along the flanks of these two mountain crests that surface mining occurs.

Georges Creek in the north and the North Branch Potomac River in the south similarly follow the synclinal axis and drain the intervening valley. The upper reaches of these two streams and their tributaries drain shallow stream valleys with relatively gentle topographic forms. Further downstream, these streams have cut deep channels exposing coal-bearing rocks and leaving narrow valleys with steep, sloped walls. It is along these coal outcorps that early surface mining most frequently occurred.

The eastern half of Area 6 lies within the Middle section of the Valley and Ridge physiographic province (fig. 2.1.1-1). This area is characterized by numerous asymetrical synclines and anticlines which form sets of long, sharp-crested mountain ridges and relatively flat intervening valleys which cross the area from northeast to southwest. The principal mountains are composed of hard rocks, whereas the intervening valleys and low hills are composed of softer rocks which erode more readily. The major streams in the area follow these valleys and drain directly into the North Branch Potomac River. The surface rocks of the Valley and Ridge province are older than those found in the Appalachian Plateaus and contain no mineable coal seams. The rocks of the Valley and Ridge province also have tighter folds than those found in the Appalachian Plateaus and have flank dips which are usually greater than 30 degrees (Reger and Tucker, 1924).

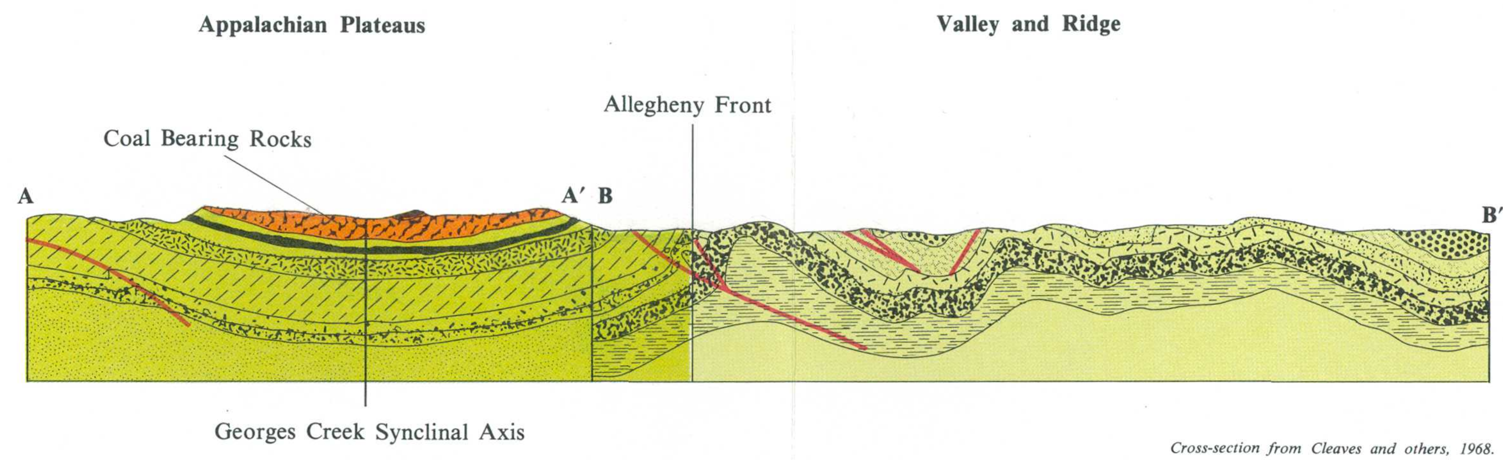
Elevations within Area 6 range from 4140 feet above sea level at the headwaters of Stony River on the Allegheny Front to 540 feet above sea level where the north and south branches of the Potomac River meet. Total relief of the area is 3600 feet; elevations generally decline from the southwest toward the northeast.



BASE FROM U.S. GEOLOGICAL SURVEY
1966, 1974, 1975; 1:500,000

Physiography from Fenneman, 1938. Synclinal axes from U.S. Army Corps of Engineers, 1975.

Figure 2.1.1-1 Physiographic divisions and synclinal axes.



Cross-section from Cleaves and others, 1968.

Figure 2.1.1-2 Composite cross-section showing structure of Area 6.

The Coal-Bearing Pennsylvanian System is Present in Area 6

The surface bedrock of Area 6 is composed entirely of sedimentary rock. The surface bedrock in the eastern half of the area is Ordovician, Silurian, and Devonian, and that in the western half is Devonian, Mississippian, Pennsylvanian, and Permian.

The strata exposed at the surface in Area 6 are sedimentary rocks, which range in age from Late Ordovician to Permian. The surface rocks are older in the eastern part of the area, and successively younger rocks crop out to the west (fig. 2.1.2-1).

In the Valley and Ridge province, the eroded edges of the folded strata crop out in thin linear parallel belts that range in age from Upper Ordovician to Devonian. These rocks consist of limestones, sandstones, and shales, but contain no mineable coal deposits (Reger and Tucker, 1924).

The strata exposed in the Appalachian Plateaus province range in age from late Devonian through Mississippian and Pennsylvanian and include a veneer of Permian. The important coal beds in the area are found within the Pennsylvanian System (Amsden and others, 1954).

The Pennsylvanian System is subdivided into the Pottsville, Allegheny, Conemaugh, and Monongahela Formations (fig. 2.1.2-2). These rocks crop out to the west of the Allegheny Front in the Georges Creek and the Upper Potomac synclinal basins. The most complete section of the Pennsylvanian System in the area is found in the Georges Creek basin. Here the Pennsylvanian beds are 1600 to 1800 feet thick and in places are overlain by 350 feet or more of Permian beds (Amsden and others, 1954).

The Pottsville Formation is the lowest part of the Pennsylvanian System. It extends from the top of the Mississippian, Mauch Chunk Formation to the bottom of the Brookville Coal of the Alleghany Formation, and ranges in thickness from 60 feet in the upper Georges Creek basin to 450 feet in the Upper Potomac basin. The Pottsville Formation has an areal distribution similar to that of the Allegheny Formation, and in Maryland it has been mapped with the Allegheny Formation as a single stratigraphic unit. In Maryland the Pottsville Formation is composed of approximately 75 percent sandstone, 22 percent shale and fire clay, and 3 percent coal. The Pottsville Formation includes as many as six coal seams, all of which appear to be thin, impure, irregular, and of little economic importance in the area (Reger and Tucker, 1924; Clark, 1905; and Amsden and others, 1954).

The Allegheny Formation overlies the Pottsville Formation. It extends from the bottom of the Brookville Coal to the top of the Upper Freeport Coal and ranges in thickness from 150 feet to over 280 feet within the area. The Allegheny Formation appears at the surface along the eastern and western rim of the Georges Creek and Upper Potomac basins, and along the most deeply incised portions of the North Branch Potomac River and some of its tributaries. In Maryland the Allegheny Formation is composed of approximately 60 percent sandstone, 21 percent sandy shale and fire clay, 10 percent coal, and 9 percent limestone. The dominant beds are massive, fine to medium grained, quartzose sandstones. The coal seams of economic importance in the area in the Allegheny Formation are the Upper Freeport, Upper Kittanning, Middle Kittanning, Lower Kittanning, and Brookville Coals (Reger and Tucker, 1924; Clark, 1905; and Amsden and others, 1954).

The Conemaugh Formation overlies the Allegheny Formation. It extends from the top of the Upper Freeport Coal to the base of the Pittsburgh Coal and ranges in thickness from 770 feet to 900 feet. The Conemaugh Formation crops out extensively throughout the Upper Potomac and Georges Creek basins, and in Maryland is composed of approximately 55 percent shale, 36 percent sandstone, 7 percent coal, and 2 percent limestone. Individual beds are relatively thin, ranging from a few inches to less than 20 feet in thickness. The coal seams of economic importance in the Conemaugh Formation are the Little Pittsburgh, Franklin, Barton, Harlem, Brush Creek, and Upper and Lower Bakerstown Coals (Reger and Tucker, 1924; Clark, 1905; and Amsden and others, 1954).

The Monongahela Formation is the uppermost formation in the Pennsylvanian System. It extends from the base of the Waynesburg Coal and ranges in thickness from less than 175 feet to greater than 270 feet. The Monongahela Formation crops out most extensively in the middle of the Georges Creek basin. In the upper and lower Georges Creek basin and in the Upper Potomac basin, the Monongahela Formation has been largely eroded, and it appears only on isolated ridgetops. In Maryland the Monongahela Formation consists of approximately 42 percent sandstone, 42 percent sandy shale, 16 percent coal, and less than 1 percent limestone. The coal seams of economic importance in the Monongahela Formation are the Waynesburg, Redstone, Lower Sewickley, and Pittsburgh Coals (Reger and Tucker, 1924; Clark, 1905; and Amsden and others, 1954).

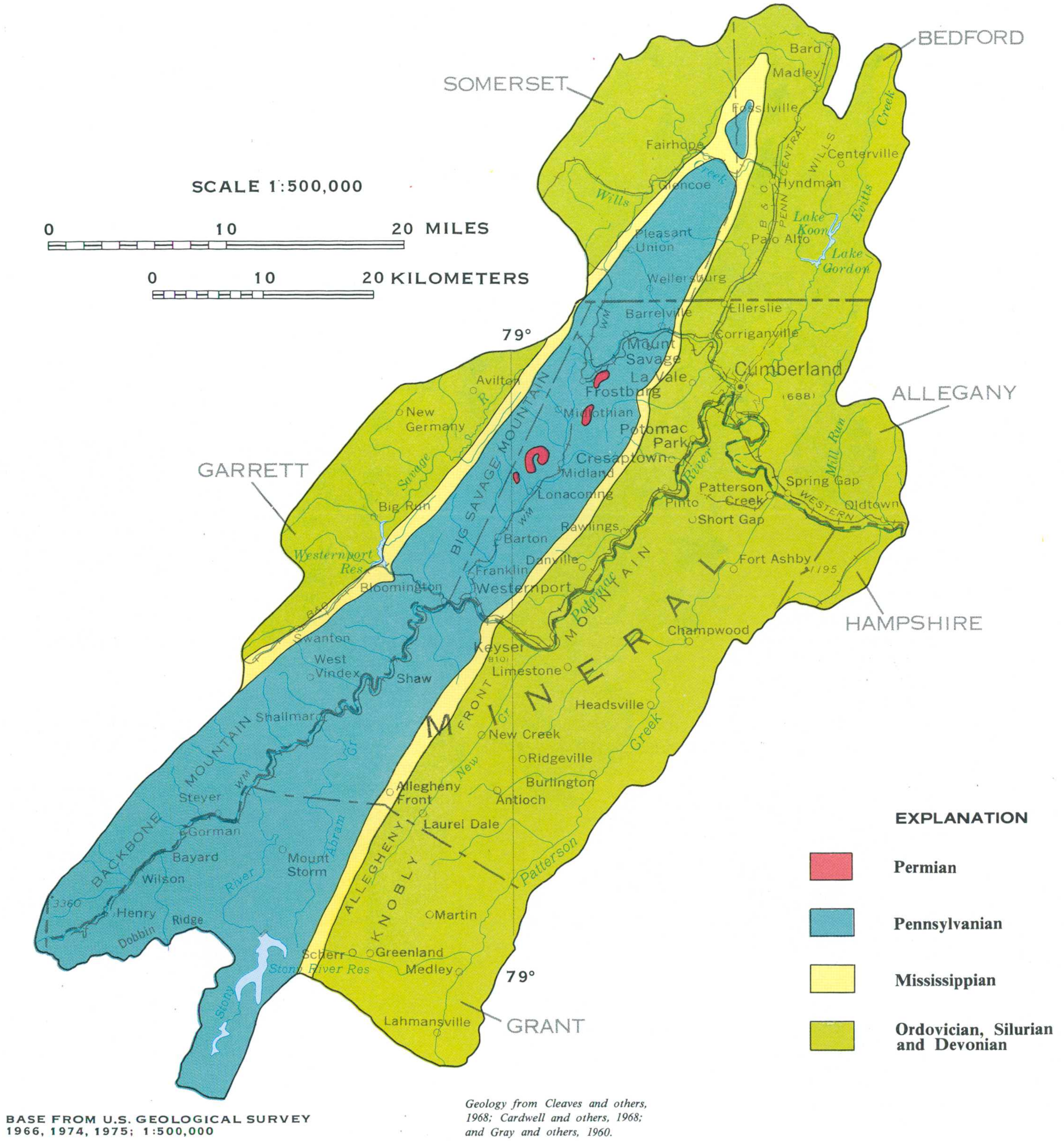


Figure 2.1.2-1 Surface geology.

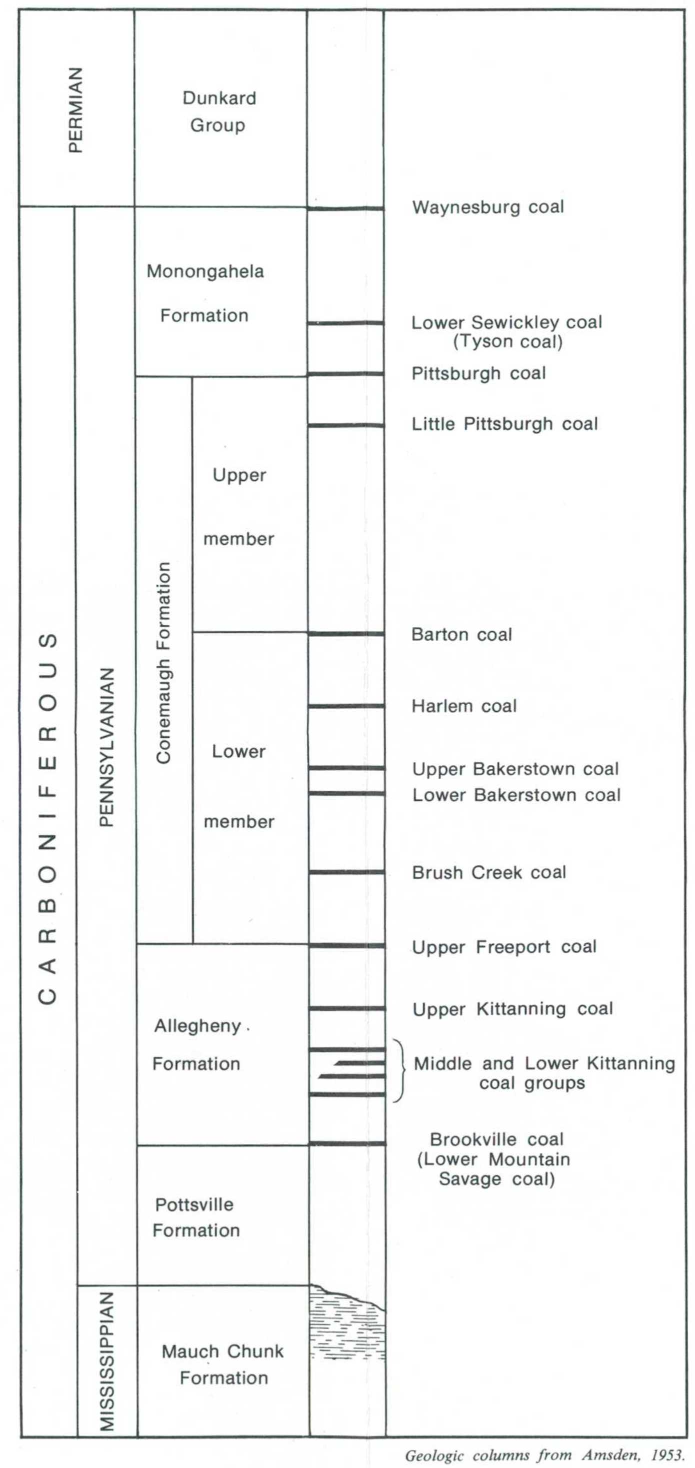


Figure 2.1.2-2 Columnar section showing coal seams and subdivisions of Pennsylvanian strata in Garrett County, Maryland.

Soils in Area 6 Generally have High Acidity and Low Fertility

The soils of the area were formed from noncarbonate sedimentary rocks.

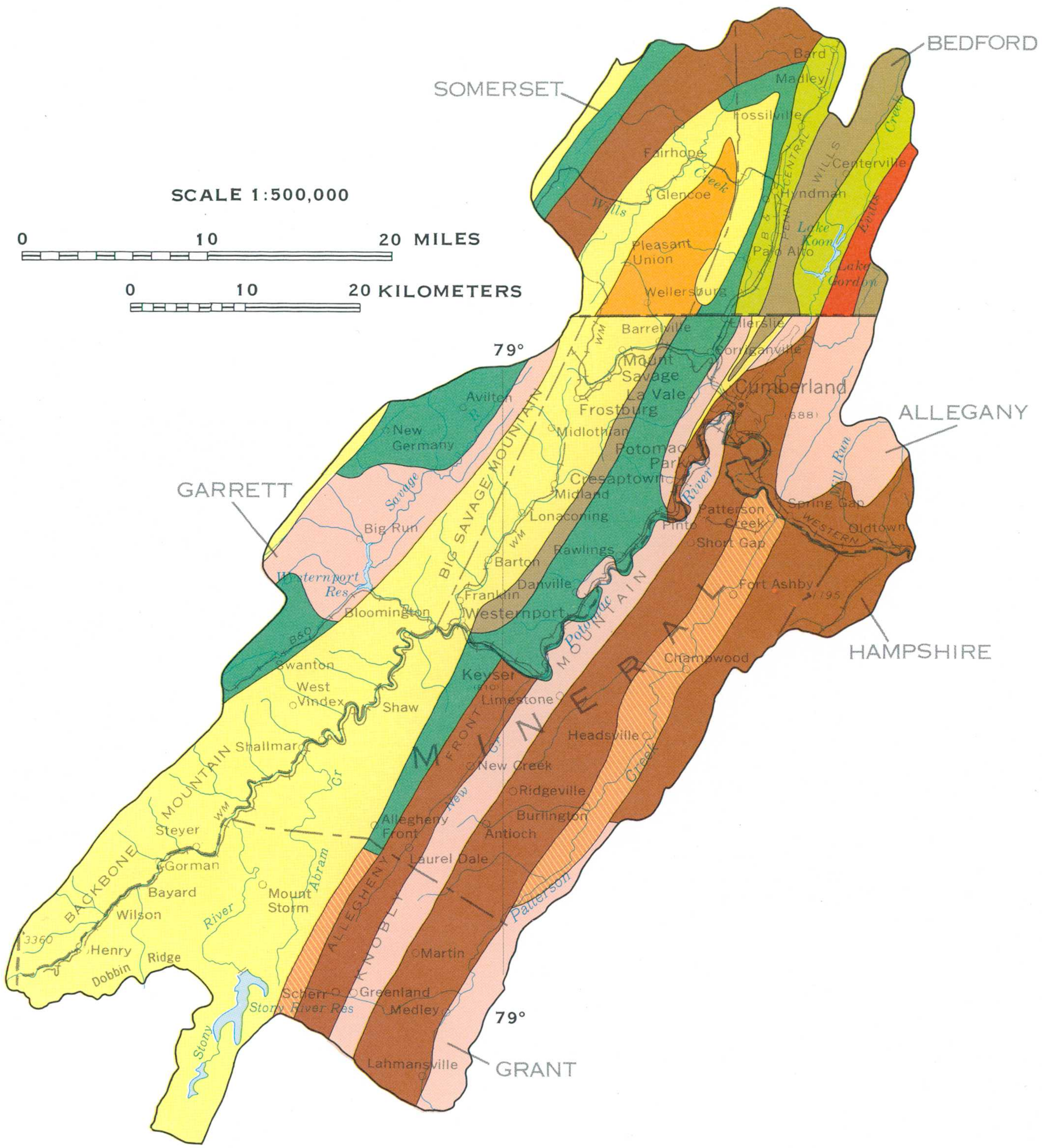
Soils develop on the land surface as a result of interactions of climate, vegetation, bedrock type, and slope. The soils of the Appalachian Plateaus section of the area were formed from materials weathered from noncarbonate sedimentary rock, sandstones, siltstones, shales, and coal. The slopes in this region range from very steep along the stream valleys to gentle along the ridge tops and flood plains. The soils formed in the Appalachian Plateaus section of Area 6 are generally of high acidity and low fertility and range in depth from 10 to 72 inches (table 2.2-1). These soils have the characteristics of hydrologic groups B and C (table 2.2-2) and include small areas of rough, stony land and bare rock along hills and steep slopes (U.S. Environmental Protection Agency, 1980; Pennsylvania Office of Resources Management, 1979).

Where the topography is similar, the soils of the Valley and Ridge province are similar to those found in the Appalachian Plateaus province. These soils were formed predominantly of materials weathered from noncarbonate sedimentary rocks, range in depth from 15 to 17 inches, and have the hydrologic characteristics of groups C or C-D. There are, however, a few soils in the Valley and Ridge province formed of materials weathered from limestone. These soils have depths of greater than 70 inches and have the hydrologic characteristics of group B.

Figure 2.2-1 is a general soils map showing the 20 soil associations in the area that have a distinctive pattern of soils, relief, and drainage. Typically, a soil association consists of more than one major soil and some minor soils. The association is named for the major soils.

Figure 2.2-1 is a composite of the general soil maps of Allegany and Garrett Counties in Maryland (U.S. Department of Agriculture, 1974 and 1977); the General Soil Map of West Virginia (U.S. Department of Agriculture, 1979); and the General Soil Map of Pennsylvania (U.S. Department of Agriculture, 1973). These individual soil maps used different series concepts and do not agree in soil association names and boundary placements at the county and state borders.

Figure 2.2-1 and table 2.2-1 are useful only for general planning. More detailed information can be found in the county soil surveys available from the U.S. Department of Agriculture, Soil Conservation Service. Soil surveys are presently available for Allegany and Garrett Counties in Maryland, and Mineral County in West Virginia. Soil surveys of Grant County in West Virginia and Bedford and Somerset Counties in Pennsylvania have been started.



BASE FROM U.S. GEOLOGICAL SURVEY
1966, 1974, 1975; 1:500,000

Figure 2.2-1 Soil associations.

Table 2.2-1 Soils of Maryland, West Virginia, and Pennsylvania.

Maryland Soil Associations

Allegany County

- Gilpin-Dekalb-Cookport: Gently sloping to very steep, well-drained, and moderately well-drained, dominantly very stony soils that are moderately deep over sandstone and shale.
- Stony land-Dekalb: Stony land and sloping to very steep, well-drained, very stony soils that are moderately deep over sandstone.
- Weikert-Calvin-Lehew: Gently sloping to very steep, somewhat excessively drained and well-drained, shaly to very stony soils that limestone or moderately deep over shale and sandstone.
- Elliber-Dekalb-Opequon: Gently sloping to very steep, well-drained, cherty or channery to very stony soils that are shallow or deep over are shallow to moderately deep over sandstone.
- Weikert-Gilpin: Gently sloping to very steep, somewhat excessively drained and well-drained, shaly to very stony soils that are dominantly shallow over shale.

Garrett County

- Calvin-Gilpin: Gently sloping to steep, moderately deep, well-drained soils; formed over acid, red to gray shale and sandstone.
- Dekalb-Calvin-Gilpin: Gently sloping to steep, moderately deep, well-drained, very stony soils; formed over acid, red to gray sandstone and shale.
- Dekalb-Gilpin-Cookport: Gently sloping to steep, moderately deep, well-drained and moderately well-drained, very stony soils; formed over acid, gray to yellowish sandstone and shale.

Pennsylvania Soil Associations

Soil Association Name	Percent of Each Soil in Assn.[a]	Dominant Slope (Percent)	Drainage Class[b]	Depth of Soil (Inches)	Hydrologic Group
Calvin	25	3-20	W	30	C
Leck Kill	25	3-25	W	50	B
Meckesville	10	3-15	W	70	C
Berks	50	8-30	W	30	C
Weikert	15	3-40	W	15	C/D
Bedington	5	3-15	W	60	B
DeKalb	40	3-35	W	30	C
Laidig	20	3-20	W	70	C
Buchanan	5	3-25	MW	70	C
Hazleton	40	3-20	W	60	B
Cookport	20	0-12	MW	60	C
Rayne	35	3-15	W	60	B
Wharton	10	3-20	MW	60	C
Ernest	10	0-15	MW	72	C
Edom	40	3-20	W	50	C
Weikert	20	3-40	W	15	C/D
Klinesville	5	3-35	W	15	C/D
Morrison	70	3-20	W	60	B
Vanderlip	10	3-20	W	60	A

[a] Percentages do not total 100 because of minor soils in each association.
[b] W-Well drained; MW-Moderately well drained.

Source: *U.S. Department of Agriculture, 1973, 1974, 1977, and 1979 Pennsylvania Office of Resources Management, 1979.*

West Virginia Soil Associations

- Wharton-Gilpin-Clymer
- Dekalb-Lehew-Teas
- Pope-Monongahela
- DeKalb-Elliber-Murril
- Berks-Weikert

Table 2.2-2 Hydrologic characteristics of Pennsylvania soils.

Hydrologic Group	
A	(Low runoff potential.) Soils having high infiltration rates even when thoroughly wetted. These consist chiefly of deep, well to excessively drained sands or gravels. These soils have a high rate of water transmission in that water readily passes through them.
A/B	Combined properties of soil groups A and B.
B	Soils having moderate infiltration rates when thoroughly wetted. These consist chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.
B/C	Combined properties of soil groups B and C.
C	Soils having slow infiltration rates when thoroughly wetted. These consist chiefly of soils with a layer that impedes downward movement of water or soils with moderately fine to fine texture. These soils have a slow rate of water transmission.
C/D	Combined properties of soil groups C and D.
D	(High runoff potential.) Soils having very slow infiltration rates when thoroughly wetted. These consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very slow rate of water transmission.

Source: *Pennsylvania Office of Resource Management, 1979*

Area is Largely Forested

Forest land occupies over 80 percent of the land surface in Area 6.

Land use affects the hydrology of a watershed by determining the ground-cover characteristics of the watershed. Ground cover influences the infiltration and runoff rates of precipitation and the susceptibility of soils to erosion. These are principal factors affecting the frequency and magnitude of flood flows, the quantity of ground-water recharge, and the sediment yield from watersheds. Land use also affects the water quality of streams by determining the nature and quantity of materials available for solution and transport by ground water and surface water. Six land-use categories and the percentage of area occupied by each are shown in figure 2.3-1.

Land use within Area 6 is largely influenced by the physiography and topography of the area. The steep slopes and sharp ridges of the Valley and Ridge province limit urban, industrial, and agricultural development to the flat, relatively broad stream valleys. The steep slopes of deeply incised stream valleys in the Appalachian Plateaus province also limit development to narrow stream valleys and broad, relatively flat upland areas. The remaining areas are almost entirely forested. The areal distribution of land use is shown in figure 2.3-2.

Surface mining and deep mining for coal are widespread throughout the Appalachian Plateaus section of the area. Figure 2.3-3 shows the percent area of selected watersheds which have been disturbed by surface mining prior to 1981. This information was compiled from the U.S. Army Corps of Engineers (1976b), the Annual Reports of the Maryland Bureau of Mines (1976-1980), quarterly reports released by the West Virginia Geological and Economic Survey (1976-1981), and from inspection of surface mine permits at the Pennsylvania Bureau of Mining and Reclamation in Ebensburg, Pa. Figure 2.3-3 also lists the number of deep mine entrances within selected watersheds, as tallied by the U.S. Army Corps of Engineers (1976b).

BASE FROM U.S. GEOLOGICAL SURVEY
1966, 1974, 1975; 1:500,000

EXPLANATION

LAND USE

Urban	Forest	Wetlands
Agricultural	Water	Barren land, including strip mines

Figure 2.3-2 Areal distribution of land use.

SCALE 1:500,000

0 10 20 MILES

0 10 20 KILOMETERS

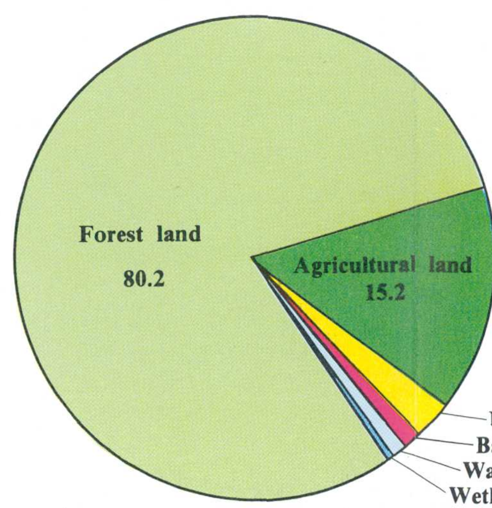


Figure 2.3-1 Land use as percentage of total area.

EXPLANATION

8.6 Area disturbed by surface mines in percent

11 Number of deep-mine entrances

Watershed boundary

Figure 2.3-3 Number of deep-mine entrances and percent area disturbed by surface mines in Area 6 watersheds prior to 1981.

North Branch Potomac River Drains Entire Area

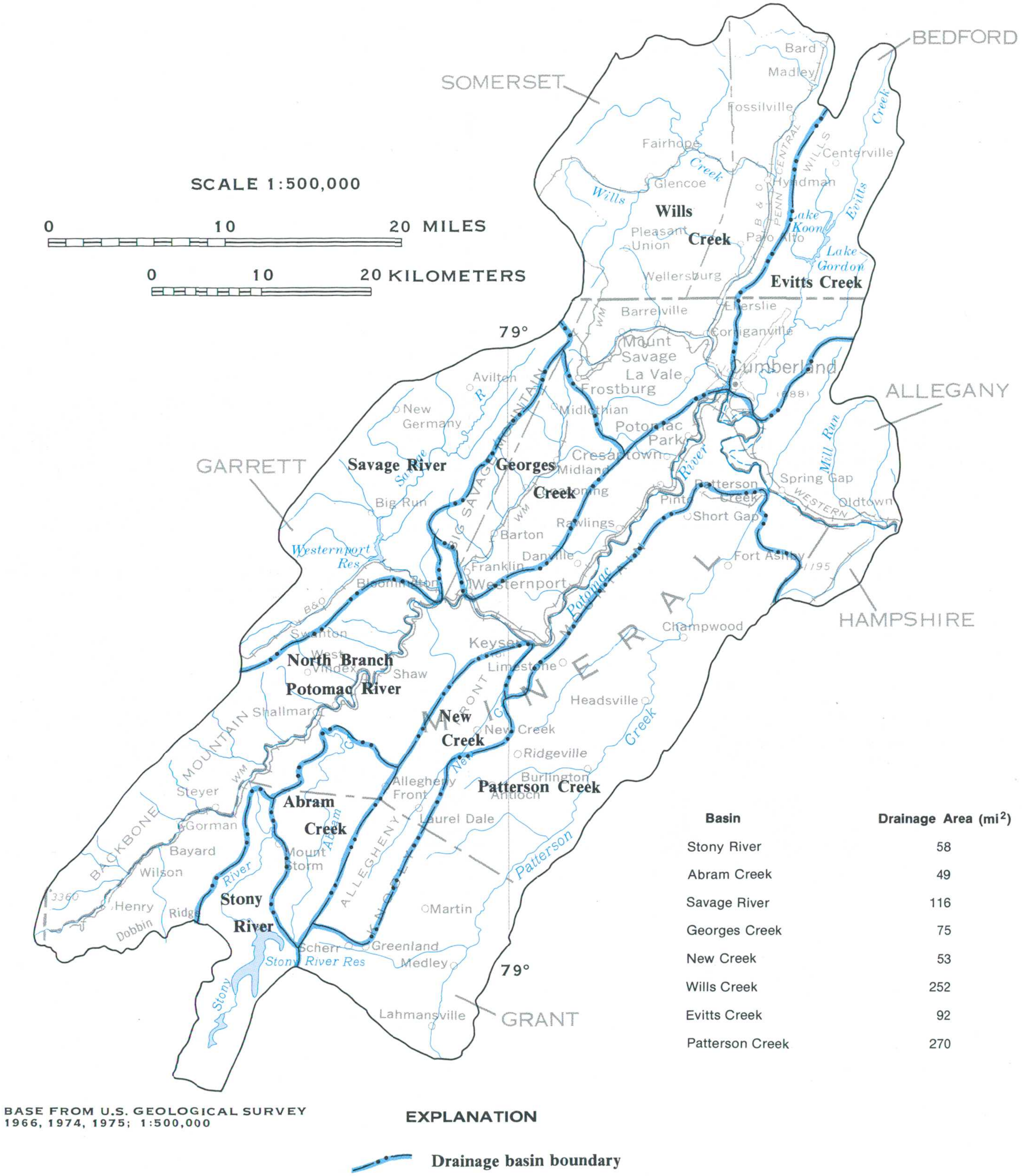
Eight major tributaries to the North Branch Potomac River drain 72 percent of the area's 1,329 square miles.

Area 6 is drained entirely by the North Branch Potomac River and encompasses 1,329 square miles of three states--Maryland, West Virginia, and Pennsylvania. The North Branch Potomac River has eight major tributaries which drain 72 percent of the area (fig. 2.4-1). These tributaries are Stony River, Abram Creek, Savage River, Georges Creek, New Creek, Wills Creek, Evitts Creek, and Patterson Creek. A substantial number of small streams also drain directly into the North Branch Potomac River and are not designated as major drainage basin divisions in figure 2.4-1. The river-mile location of tributaries to the North Branch Potomac River and U.S. Geological Survey gaging stations on the North Branch are shown in figure 2.4-2.

For most of its length the North Branch Potomac River generally follows a northeasterly path, forming the boundary between Maryland and West Virginia. The confluence with the South Branch Potomac River constitutes the downstream boundary of the North Branch Potomac River basin. At the confluence, the North and South Branches form the Potomac River which drains into the Chesapeake Bay, some 264 miles downstream.

The upper portion of the North Branch Potomac River basin and the watersheds of Stony River, Abram Creek, Georges Creek, and Wills Creek are underlain by coal measures of the Upper Potomac and Georges Creek Coal Fields. Most of the Savage River and all of the New, Evitts, and Patterson Creek watersheds are not underlain by coal bearing rocks.

Because the topography and underlying formations of the Savage River, New Creek, and Patterson Creek basins provide good opportunities for impoundment and regulation of their surface-water resources, numerous reservoirs and small check dams have been built in these watersheds. The Bloomington Dam (river mile 62), recently built on the North Branch Potomac River, provides the largest reservoir in the area and will be used to control flood flow, augument low-flow water supply, and improve the downstream water quality by selective dilution of acid inflow to the reservoir.



Basin	Drainage Area (mi^2)
Stony River	58
Abram Creek	49
Savage River	116
Georges Creek	75
New Creek	53
Wills Creek	252
Evitts Creek	92
Patterson Creek	270

Figure 2.4-1 Major drainage basins.

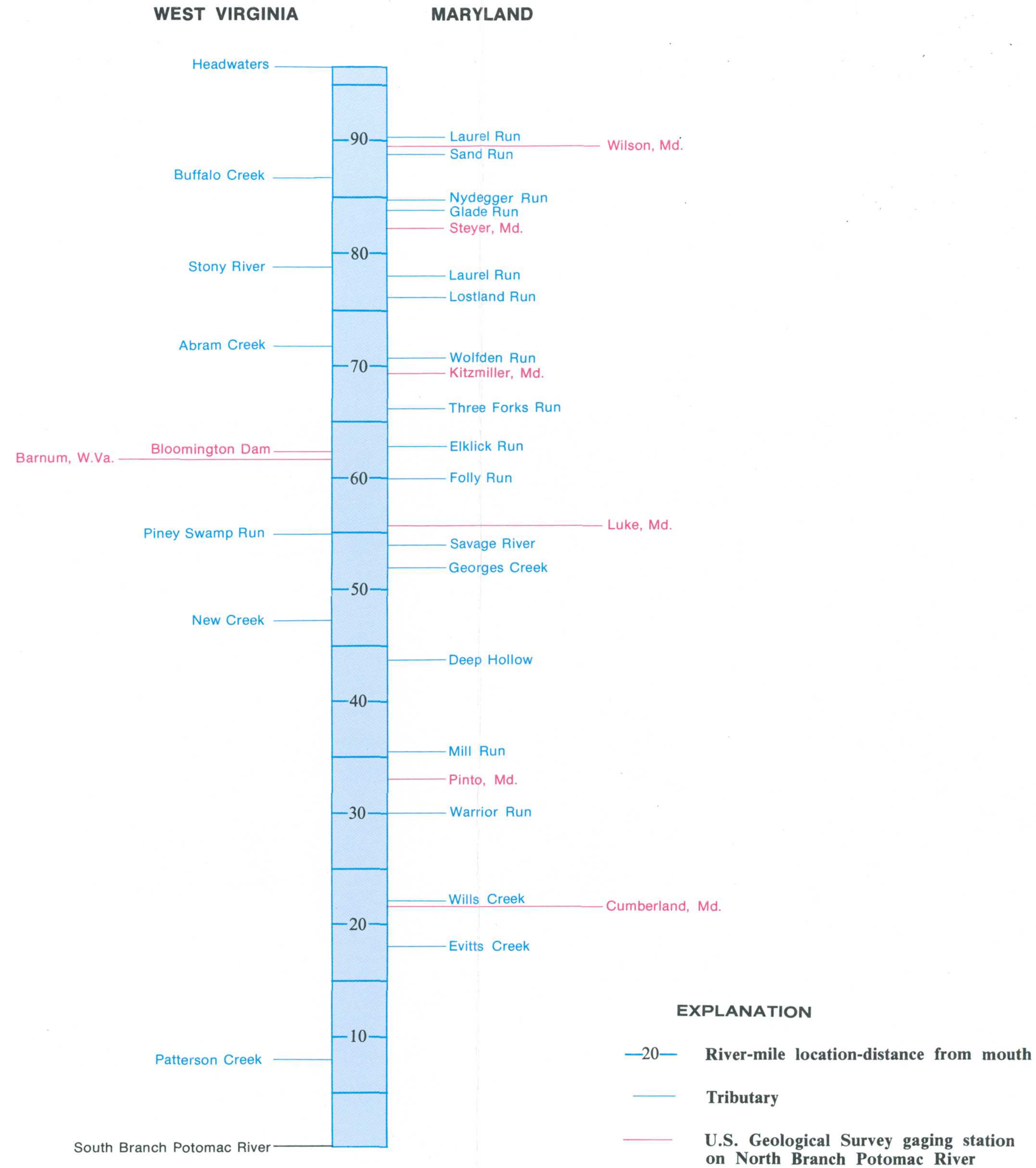


Figure 2.4-2 Location of tributaries to the North Branch Potomac River and main-stem U.S. Geological Survey gages, in river miles from the mouth.

Water Use is 1.2 Billion Gallons Per Day

Approximately 99.5 percent of water withdrawals are from surface-water supplies. Over 98 percent of water withdrawals are for nonconsumptive uses.

The quantity of water withdrawn for various uses in Area 6 is shown in figure 2.5-1. Approximately 99.5 percent of the total water use in the area is withdrawn from surface-water supplies. The Virginia Electric Power Company (VEPCO) coal-fired power plant in Mineral County, W. Va., withdraws the single greatest amount of water in the area. This water is used for cooling purposes and amounts to over 94 percent of total water use in the area. This water is withdrawn from the Stony River Reservoir, and except for small consumptive losses, the majority is returned to Stony River after use. Over 98 percent of water withdrawals in the area are for non-consumptive uses.

Withdrawals for public water supply in Area 6 are generally from surface-water sources and account for slightly more than 1 percent of total water use. The majority of this water (9.8 mgd) is withdrawn by the city of Cumberland, Md. from Evitts Creek. Westernport, Md., and Piedmont, W. Va., withdraw water from Savage River; Keyser, W. Va., withdraws water from New Creek. Many smaller communities also withdraw water from small reservoirs in the headwaters of high quality streams.

Ground-water withdrawals amount to slightly over 0.5 percent of the total. The mining industry uses 72 percent of total ground-water withdrawals for processing coal and for draining surface and deep mines. Rural domestic water use accounts for 15 percent of ground-water withdrawal, and the remaining 13 percent is used for public water supply and for commercial and industrial purposes.

Water-use data were collected through personal communications with the Maryland Department of Natural Resources and the Pennsylvania Department of Natural Resources, and from the publication "Water Use in West Virginia" (Lessing and others, 1981).

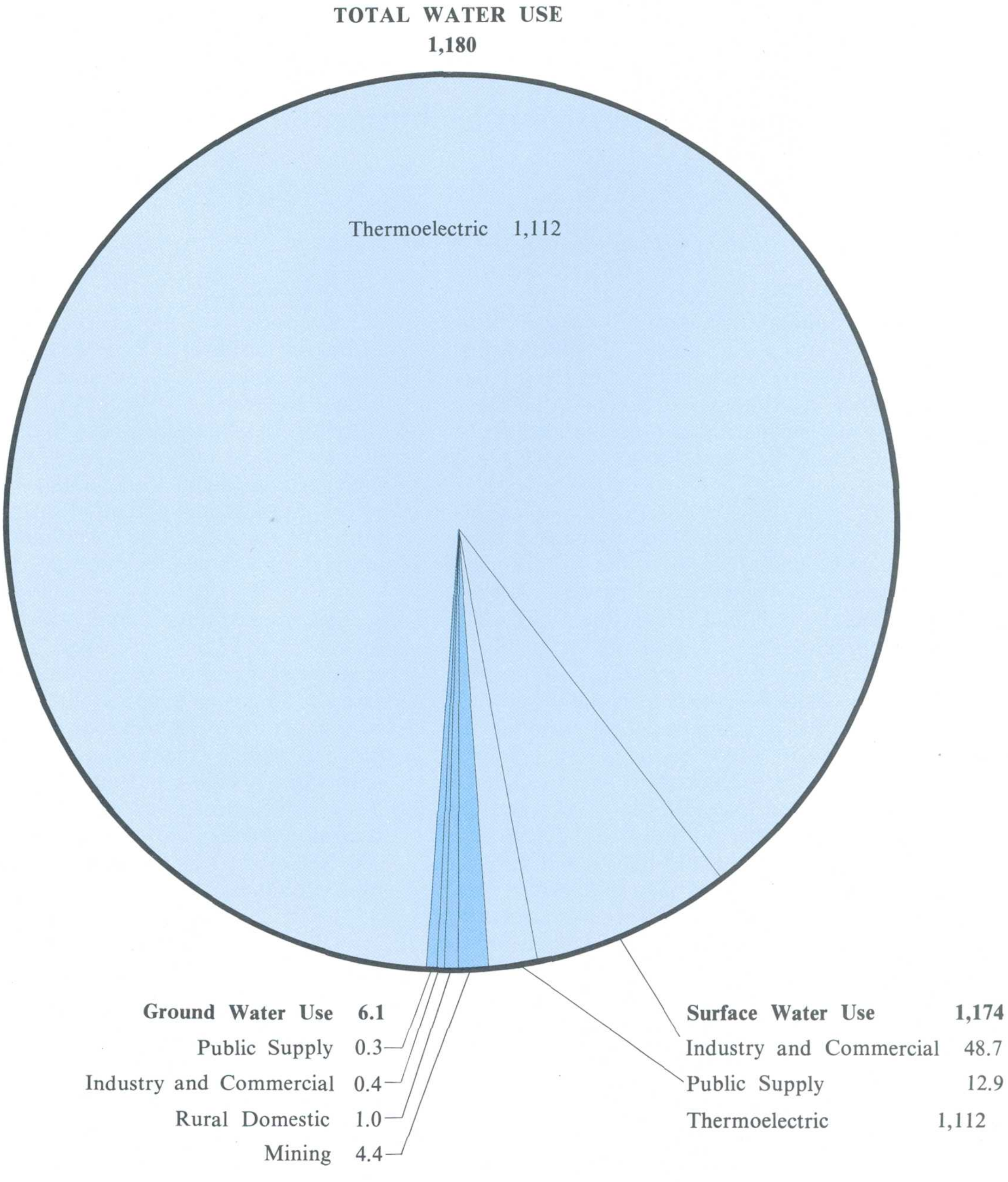


Figure 2.5-1 Water use, in million gallons per day.

Area 6 Characterized by a Continental Temperate Climate

Area climate is influenced by local variations in elevation and topography.

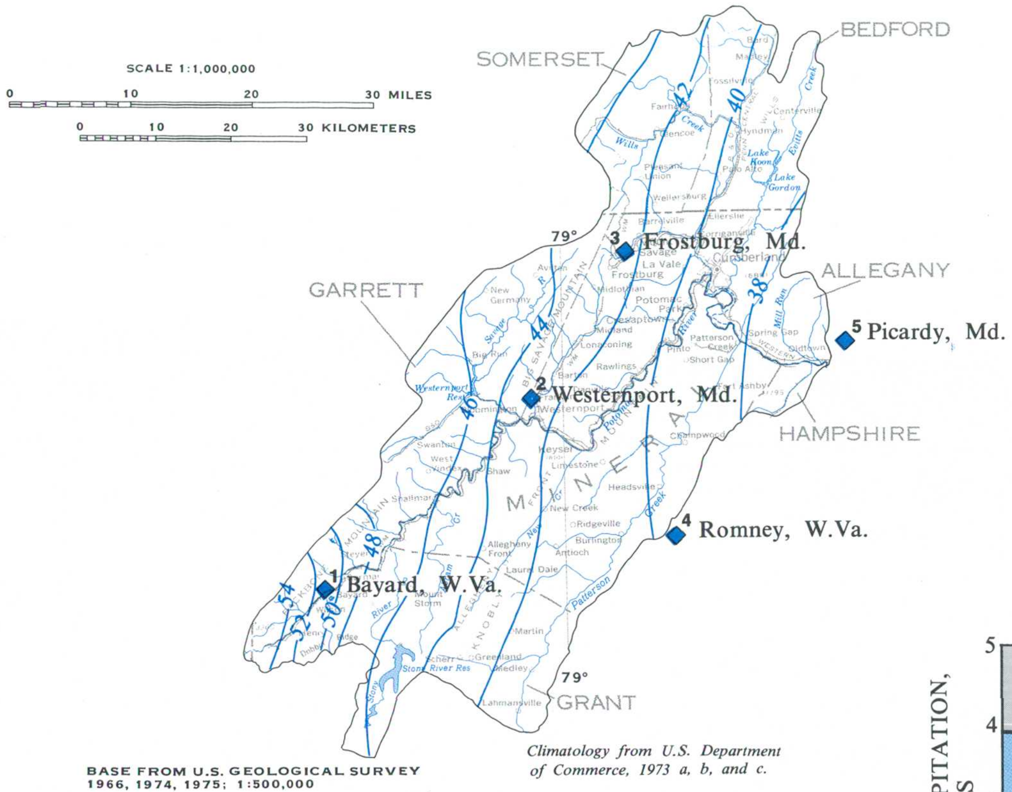
The mean annual precipitation is greatest in the western half of Area 6 (fig. 2.6-1). The Appalachian Plateaus province in the western part of the area has a mean annual precipitation of over 45 inches, as compared to the mean annual precipitation of only 36 inches in the Valley and Ridge province to the east.

The Allegheny Mountains have the highest elevation in the area and are responsible for increased precipitation on the Appalachian Plateaus. Westerly storms ascend the mountains from the Ohio Valley causing temperatures to drop in the air mass and precipitation to increase. As storms descend the leeward slopes of the Allegheny Mountains and enter the Valley and Ridge province, the descending air masses are warmed, clouds dissipate and precipitation decreases (U.S. Department of Commerce, 1959). Like elevation, precipitation in the area decreases steadily from the southwest to the northeast. Precipitation varies throughout the year in both the Appalachian Plateaus and Valley and Ridge provinces. Precipitation tends to be greater in the spring and summer, and less in the fall and winter. March is the month with the greatest amount of precipitation. Figure 2.6-2 shows the mean monthly precipitation at three weather stations located in the Appalachian Plateaus (Bayard, W. Va., and Frostburg and Westernport, Md.) and two weather stations located in the Valley and Ridge (Picardy, Md., and Romney, W. Va.). Although the Romney and Picardy stations are not located within Area 6, they are near the area (fig. 2.6-1) and are representative of regional precipitation conditions.

Thunderstorms develop during 40 days in an average year, with the peak of the thunderstorm season occurring in July. The 10-year, 24-hour rainfall intensities are shown in figure 2.6-3. Snowfall within the basin varies considerable. Average annual snowfall ranges from 30 inches in the Valley and Ridge to over 100 inches in the Appalachian Plateaus. Assuming a water equivalent of one inch of rain per 10 inches of snowfall, snowfall in the Appalachian Plateaus accounts for up to 20 percent of the mean annual precipitation, whereas, snowfall in the Valley and Ridge contributes about 8 percent of the mean annual precipitation.

The mean annual temperatures in the area vary from 47°F to 53°F. The coldest part of the area is the southwest, where the mean minimum daily temperature in January is less than 20°F. Frost penetration here to depths of 18 inches or more is common. The range of monthly mean temperatures at four stations in the area is shown in figure 2.6-4. Lower monthly mean temperatures of the Appalachian Plateaus stations are due mainly to higher elevations; for every 300 feet of increase in elevation, temperatures drop by approximately 1°F.

Climatic data for Area 6 are published monthly in the Maryland, Pennsylvania and West Virginia volumes of "Climatological Data," available from the National Oceanic and Atmospheric Administration (NOAA), Asheville, N.C. (U.S. Department of Commerce, 1979-1981a, b, and c). Long-term rainfall and temperature data are also available by state in a publication entitled "Monthly Normals of Temperature, Precipitation, and Heating and Cooling Degrees Days 1941-1970". (U.S. Department of Commerce, 1973a, b, and c). Utilization of climatic data for a specific location should take local variations of elevation and topography into account.

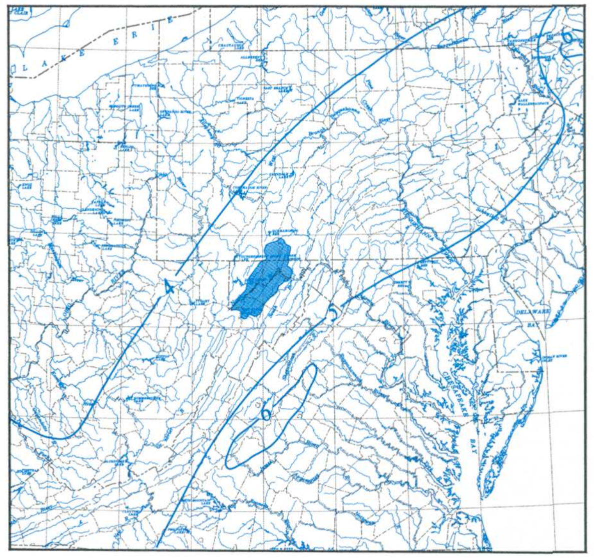


EXPLANATION

◆3 Weather station and number

—40— Line of equal annual precipitation, in inches

Figure 2.6-1 Mean annual precipitation.

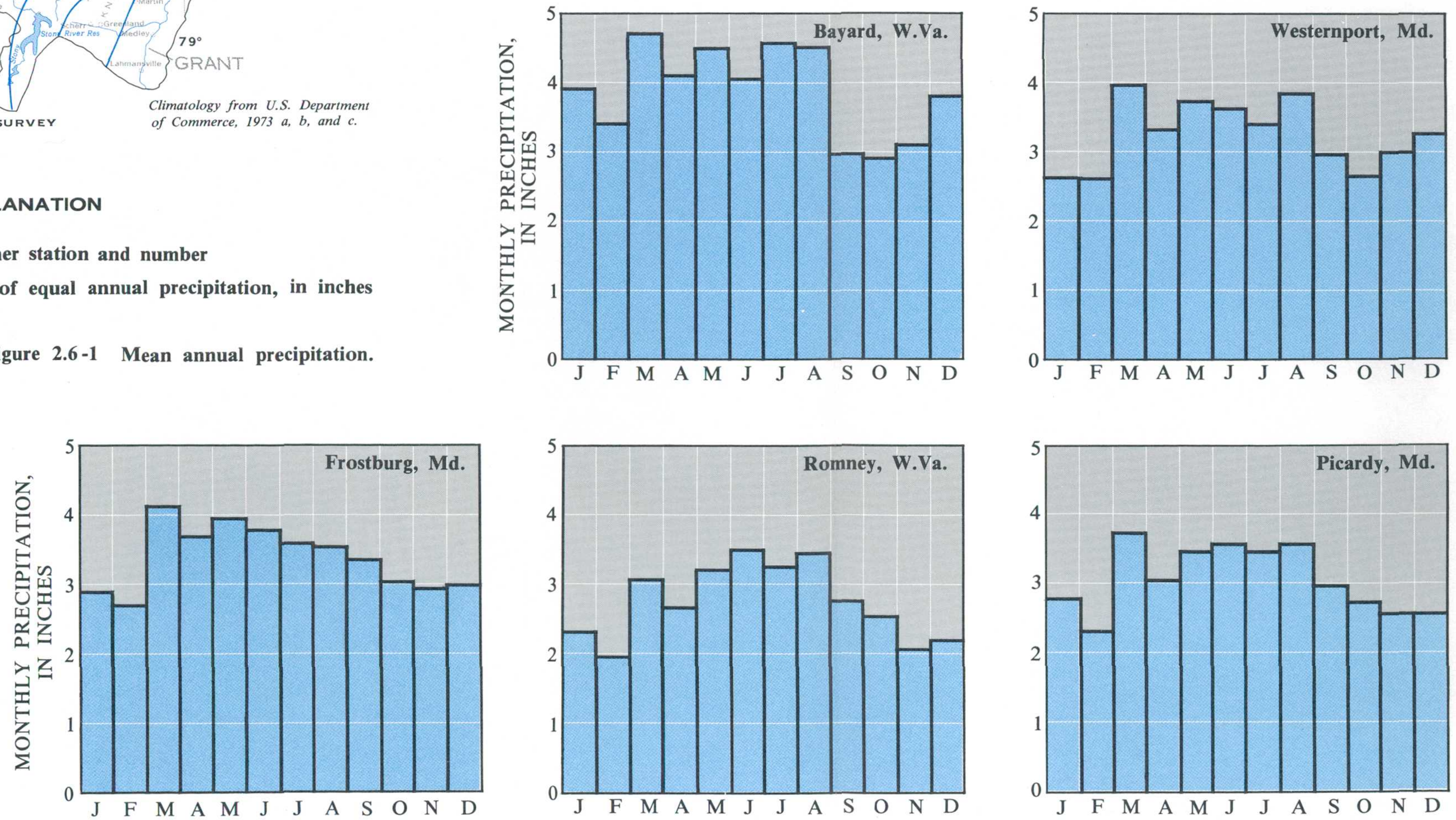


Climatology from U.S. Department of Commerce, 1961.

EXPLANATION

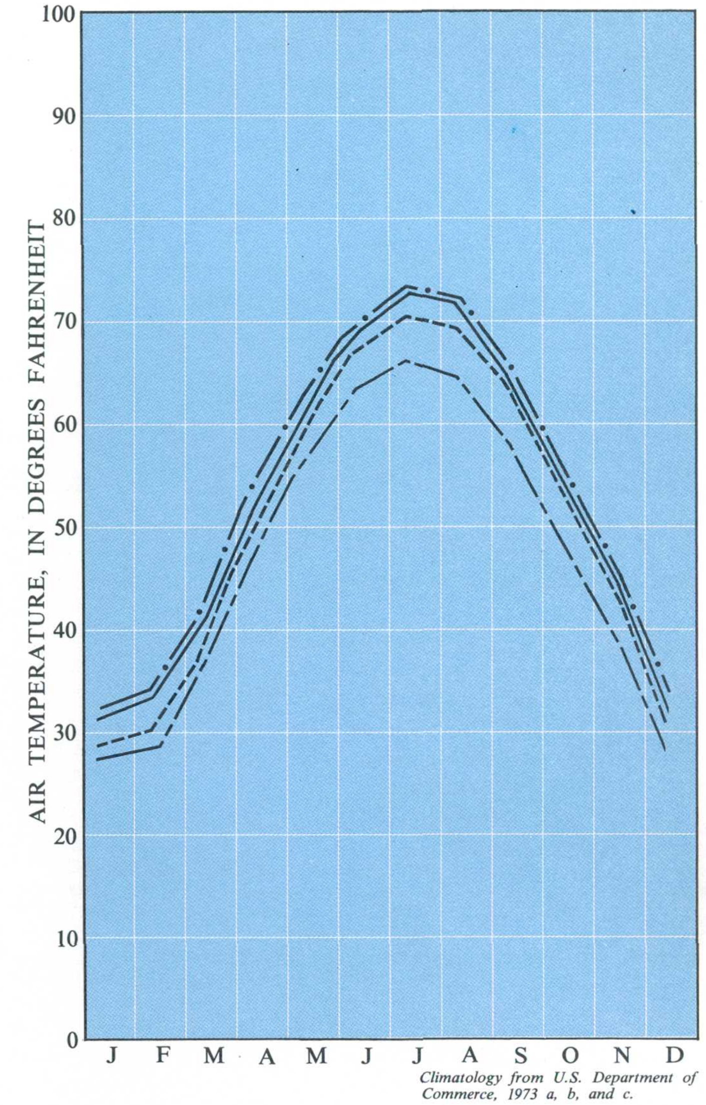
—5— Line of equal 10-year, 24-hour rainfall intensities, in inches

Figure 2.6-3 10-year, 24-hour rainfall intensities.



Climatology from U.S. Department of Commerce, 1973 a, b, and c.

Figure 2.6-2 Mean monthly precipitation at weather stations in and near Area 6 (1941-1970).



EXPLANATION

—·— Westernport, Md. (Elev. 950 ft.)

—— Picardy, Md. (Elev. 1030 ft.)

------ Frostburg, Md. (Elev. 2140 ft.)

— — Bayard, W.Va. (Elev. 2375 ft.)

Figure 2.6-4 Mean monthly temperature variation at weather stations in and near Area 6.

3.0 COAL RESERVES AND PRODUCTION

Area 6 Contains 1.6 Billion Tons of Mineable-Coal Reserves

The reserves are found in two coal fields and tend to be high BTU, low sulfur coal, of which about 11 percent is strippable.

Area 6 contains 1.6 billion tons of mineable-coal reserves in 16 major coal seams. The reserves in the area amount to 0.37 percent of the demonstrated coal reserve base of the United States (U.S. Bureau of Mines, 1975). Approximately 11 percent (176 million tons) of the reserve in the area is strippable (coal seems greater than 18 inches thick and less than 150 feet deep) and 89 percent (1,433 million tons) is deep-mineable (coal seams greater than 24 inches thick). The Upper Freeport and Lower Bakerstown seams found extensively in the Upper Potomac Coal Field together contain about 70 percent of the mineable reserves in Area 6. Table 3.0-1 lists the major coal seams in the area, the total reserves in each seam, and the reserves which are strippable and deep-mineable.

The coal reserves of the area tend to have a high heating capacity (BTU rating) and low sulfur content. These coals are in high demand in the steam and metallurgical coal markets, because they produce large amounts of energy per unit weight and their low sulfur content means they can be burned without expensive pollution control measures. Only the Redstone seam has a BTU rating less than 12,500. Nearly one third of the total coal reserves in the area, 534 million tons, are low sulfur (less than 1.5 percent sulfur content). Of these low-sulfur reserves over 43 million tons are strippable coal found in the Barton, Upper Freeport, and Lower Bakerstown seams. The availability of these high BTU and low-sulfur coals should lead to further continued mining within the area (U.S. Army Corps of Engineers, 1976a).

Coal was mined and used locally in Area 6 prior to 1782. Coal shipments out of the area began in 1820 and increased greatly with the opening of the Baltimore and Ohio Railroad in 1842 and the Chesapeake and Ohio Canal in 1850. Coal production in the area steadily increased throughout the latter half of the 19th century, making Area 6 one of the most important coal-producing regions in the United States at that time (Clark, 1905). Coal production peaked in Maryland in 1907, when 5.5 million tons were mined, and then decreased steadily until 1954, when 440,000 tons were mined. Coal production has been increasing since 1954.

Coal is currently mined from nearly every major seam in the area. During 1978 coal was mined from 14 seams and production totaled 3,833,278 tons. No single seam produced more than 16 percent of the total figure; however, 64 percent of total production came from four seams: The Upper Bakerstown, Upper Kittanning, Lower Bakerstown, and Pittsburgh. Table 3.0-1 lists the production from each seam for 1978.

The coal-mining region of Area 6 has traditionally been subdivided into two separate coal fields, the Georges Creek and the Upper Potomac Coal Fields (fig. 3.0-1). Although there is no structural reason for this subdivision, the coal fields are geographically separate and have followed separate patterns of development. Around the turn of the century, deep mining in the Pittsburgh and Sewickley coal seams in the Georges Creek Coal Field accounted for most of the coal production in Area 6. By 1920 these two seams were largely mined out, and production shifted south to the Upper Potomac Coal Field and the abundant Lower Bakerstown and Upper Freeport seams. For many years, coal production was nearly equal from the two coal fields; however, in recent years, the Upper Potomac Coal Field has out-produced the Georges Creek Coal Field. In future years this trend is likely to continue (U.S. Army Corps of Engineers, 1976a).

Table 3.0-1 Reserves, 1978 production figures, and heating capacity of mineable coals in Area 6.

Coal seam	Reserves, in million tons: Total	Strippable	Deep mineable	Production in Area 6 1978 - tons	Average BTU (dry)
Waynesburg	4.83	2.49	2.34	203,609	13,720
Sewickley	9.92	5.16	4.76	254,100	12,810
Redstone	1.59	1.32	.27	70,100	11,890
Pittsburgh	18.92	3.82	15.10	564,117	13,920
Little Pittsburgh	.10	0	.10	0	13,380
Franklin	15.50	8.67	6.83	172,163	12,730
Barton	68.31	15.26	53.05	283,095	13,070
Harlem	4.70	0	4.70	75,131	13,485
Upper Bakerstown	174.64	7.85	166.79	76,867	13,410
Lower Bakerstown	356.88	34.04	322.84	630,656	13,710
Mahoning	52.84	4.13	48.71	15,321	13,760
Upper Freeport	755.70	46.85	708.85	616,313	13,690
Upper Kittanning	95.18	8.19	86.99	557,470	13,660
Middle Kittanning	20.70	20.70	0	244,058	——
Lower Kittanning	16.56	5.2	11.36	70,278	13,540
Clarion (Brookville)	12.36	12.36	0	0	13,620
Total	1609	176	1433	3,833,278	——

Reserve figures from: U.S. Army Corps of Engineers, 1976a.

Production figures from: Maryland Bureau of Mines, 1978; Pennsylvania Department of Environmental Resources, 1978; and West Virginia Department of Mines, 1978.

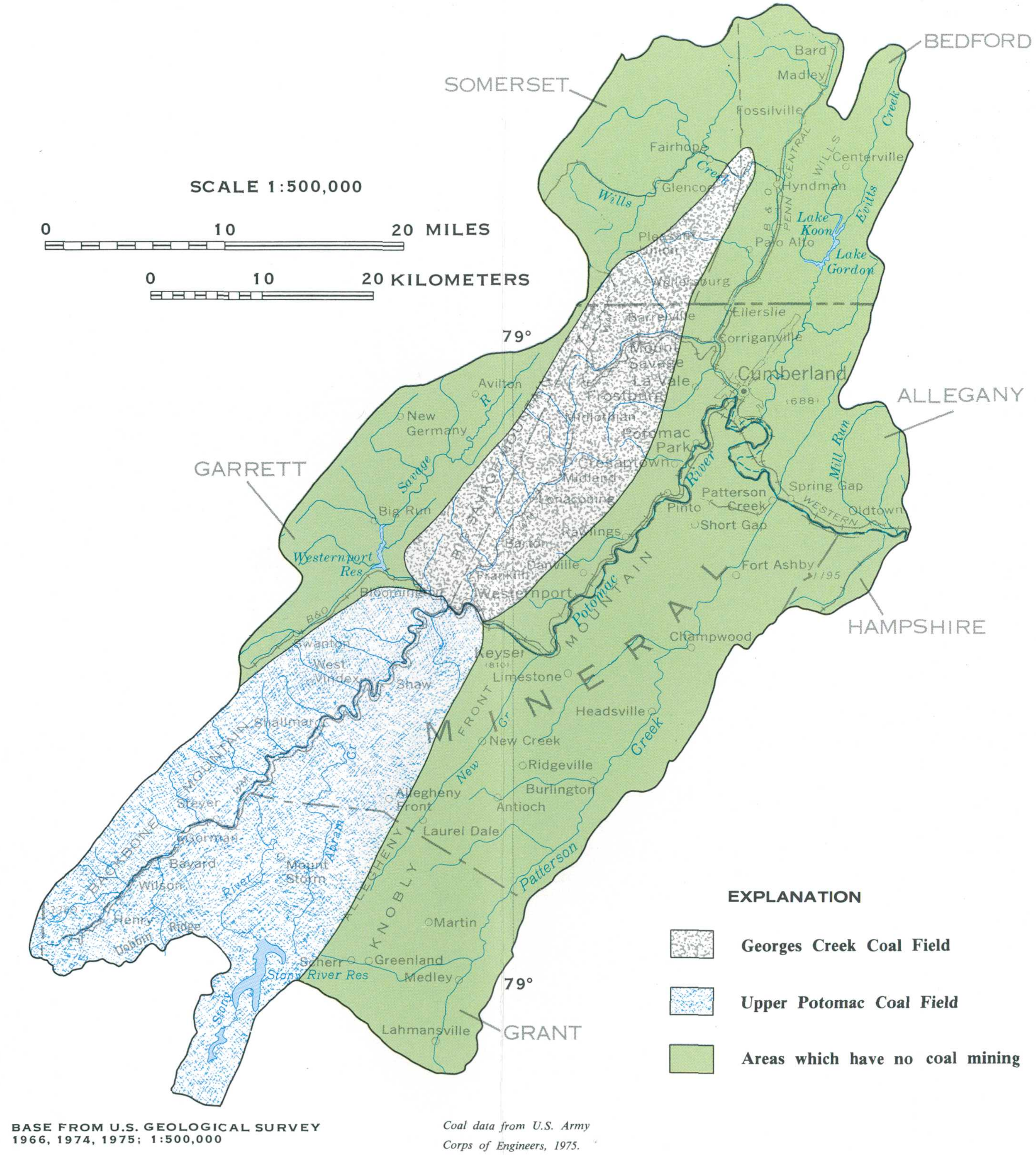


Figure 3.0-1 Coal-mining areas.

Streamflow Information from 56 Sites

Streamflow information is available from 18 continuous-record stations, 10 low-flow partial-record stations, 3 crest-stage partial-record stations, and 25 miscellaneous-discharge-measurement sites.

Streamflow information is available from 56 surface-water data-collection sites in Area 6. These sites form a systematic, hydrologic data-collection network which has operated with a varing number of stations since 1899. During 1981 the network consisted of 18 continuous-record stations, 10 low-flow partial-record stations, 3 crest-stage partial-record stations, and 25 miscellaneous-discharge-measurement sites. The locations of these sites are shown in figure 4.1-1, and brief station descriptions, including drainage areas and periods of record, are presented in section 10.1.

Continuous-record stations are locations where a continuous record of stream stage (height of the water above an arbitrary datum) is obtained by instruments that measure and automatically record the water-surface elevation of a stream. The continuous record of stream stage is converted to a continuous record of stream discharge by a stage-discharge relationship. The results are generally reported as daily mean discharge values and the extremes for the period of record. Continuous-record stations provide the most detailed streamflow data. This information is used to determine flood-frequency, extreme flows of record, flood-volume frequency, flow duration, low-flow frequency, and other hydrologic characteristics of a stream.

Low-flow partial-record stations have no recording devices. Discharge measurements are made several times per year during periods of low flow, and the results are reported as instantaneous discharge in cubic feet per second. Concurrent data from continuous record stations are incorporated with data from low-flow partial-record stations to develop regionalized low-flow relationships.

Crest-stage partial-record stations are equipped with simple recording devices that measure peak stream stage during a given period. A stage-discharge relation, developed through a series of direct and indirect discharge measurements, is then used to compute the peak flow during the intervening time period between inspections. The annual maximum discharge is generally reported from crest-stage partial-record stations, and these data can be analyzed to determine the flood-frequency characteristics of a stream.

Miscellaneous-discharge-measurement sites are sites where discharge measurements are not made on a long-term, systematic basis. These are sites where one or several discharge measurements are made for particular reasons. Measurements are generally made at these sites during periods of drought or flood to give better areal coverage to those events. They may also be made when water-quality samples are collected, to facilitate computing loads of dissolved and suspended constituents. Data from miscellaneous-discharge-measurements sites are generally reported as instantaneous discharges in cubic feet per second.

Streamflow data collected from these surface-water, data-collection sites are reported on an annual basis in the U.S. Geological Survey publications "Water Resources Data for Maryland and Delaware," (U.S. Geological Survey, 1979a, 1980a, and 1981a) and "Water Resources Data for Pennsylvania, Volume 2, Susquehanna and Potomac River Basins," (U.S. Geological Survey, 1980c and 1981c) which are available, respectively, from:

U.S. Geological Survey
Water Resources Division
208 Carroll Building
8600 La Salle Road
Towson, Maryland 21204

U.S. Geological Survey
Water Resources Division
P.O. Box 1107
228 Walnut Street
Harrisburg, Pennsylvania 17108

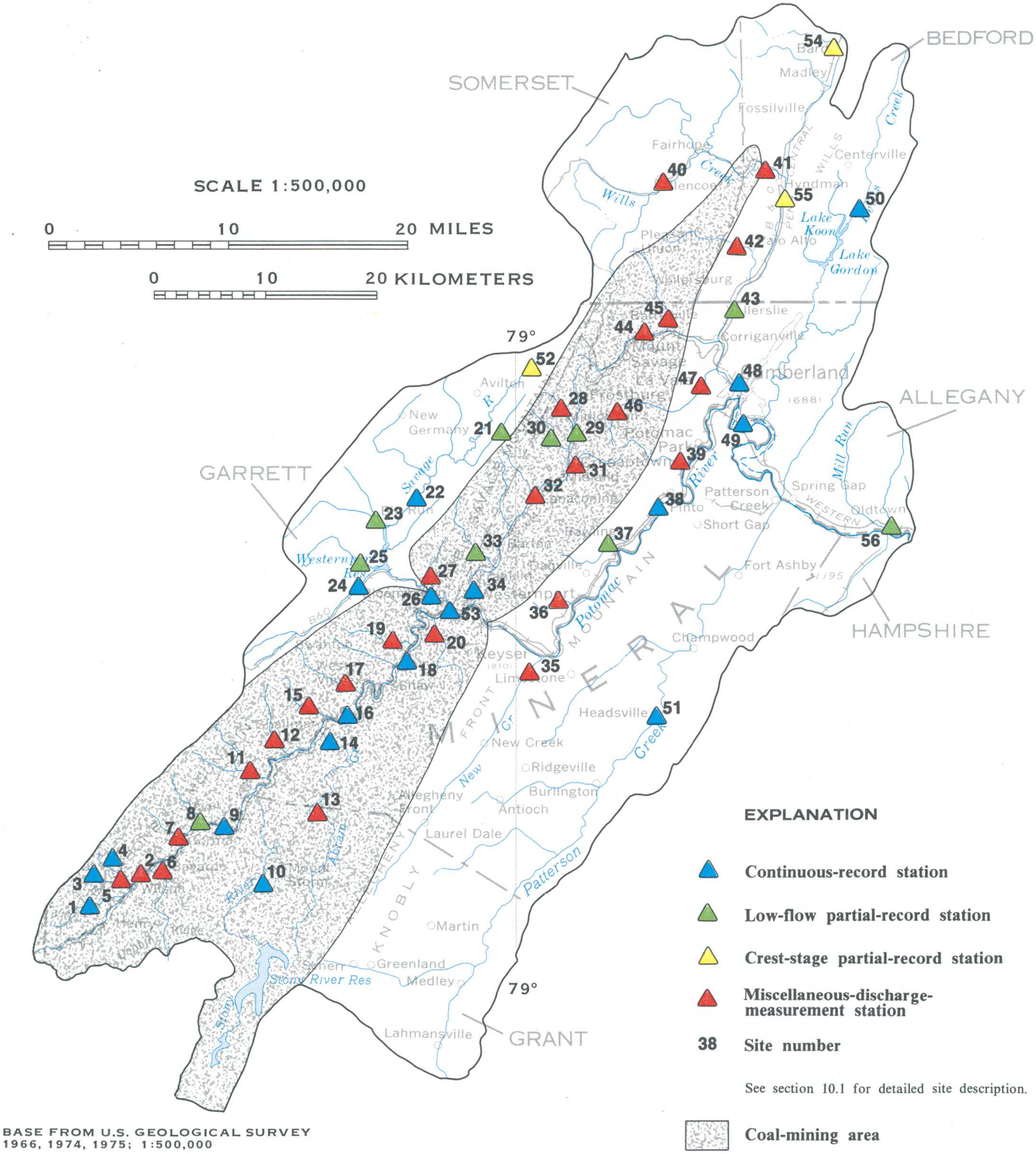


Figure 4.1-1 Locations of streamflow-measurement stations.

Water-Quality Information Available from 48 Sites

The hydrologic network was designed to yield water-quality information for a large number of streams and to observe the seasonal variations of each stream.

Water-quality data were collected at 51 sites in the area from April 1979 through September 1981. The data-collection network was composed of three types of stations: trend, regular, and synoptic. There were 1 trend, 7 regular, and 43 synoptic stations in the network. The major differences between these stations were in the sampling frequency and the water-quality parameters chosen for sampling. Figure 4.2-1 shows the location of the data-collection sites, and section 10.1 gives a brief station description and lists the period of record at each site.

The one trend station in the network was located at the U.S. Geological Survey gaging station at the North Branch Potomac River near Cumberland, Md., site 49 (fig. 4.2-1). The purpose of this station was to monitor the streamflow and water-quality of the North Branch Potomac River, which drains the entire area. Streamflow, specific conductance, and water temperature were recorded continuously; suspended-sediment data were collected daily; and water-quality samples were collected monthly at this site.

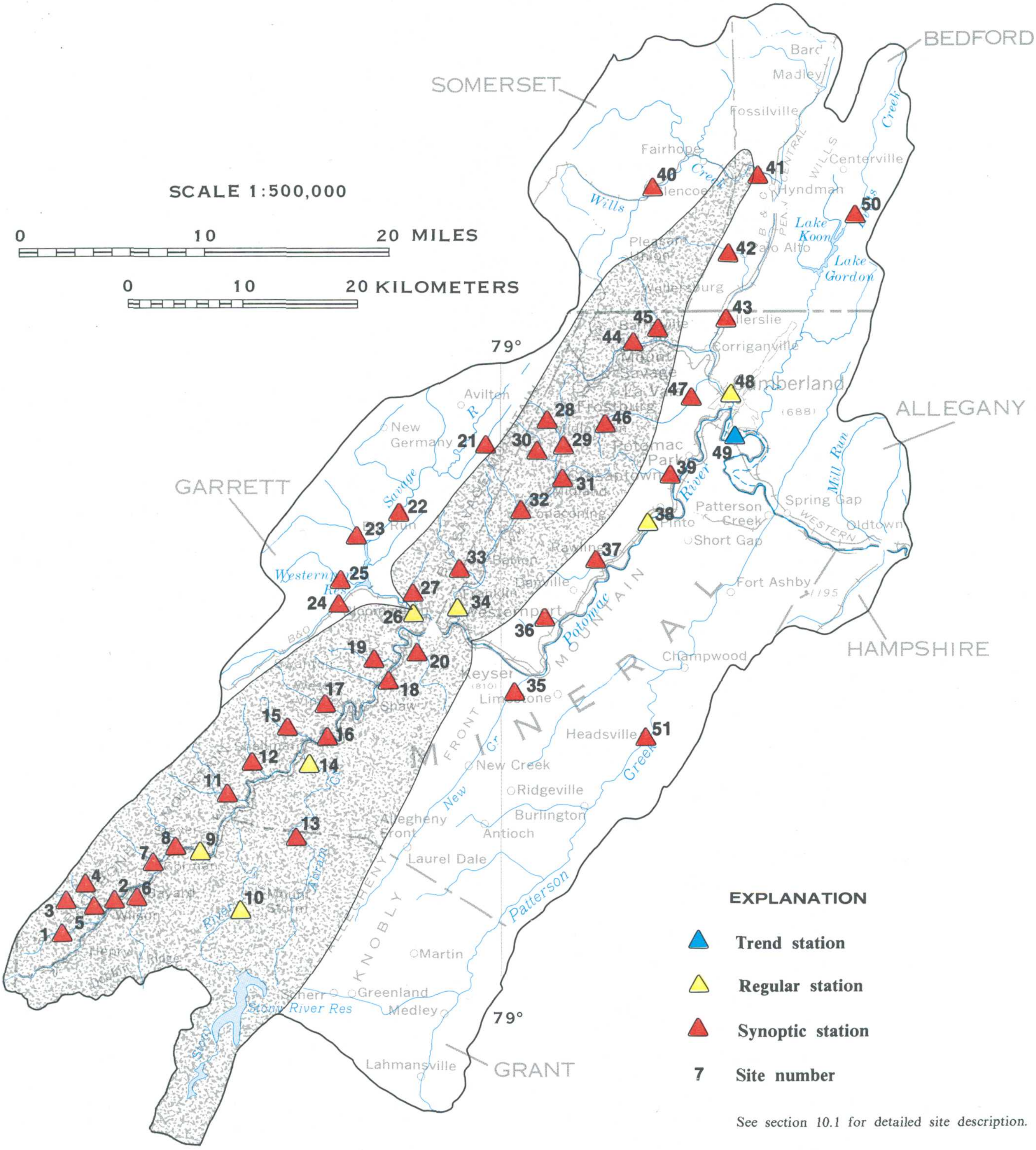
The seven regular stations in the network were located at USGS gages along the North Branch Potomac River and at downstream locations on its major tributaries. The purpose of these stations was to delineate the variations in streamflow and water-quality of the major streams within the area. Streamflow was recorded continuously, and water-quality samples were collected approximately monthly.

The purpose of the 43 synoptic stations was to obtain water-quality data from relatively small streams over a large area during different hydrologic conditions. Water-quality samples were collected, and concurrent discharge measurements were made, each year during periods of high, medium, and low base flow. Daily and event suspended-sediment data and continuous record of streamflow were also obtained at two of the synoptic sites.

Once per year at all sites, trace metal samples were collected in the water column and from the bottom material, and the presence or absence of several orders and phyla of benthic invertebrates was noted.

From April to November 1979, data were collected at 26 synoptic stations. On April 1980 the network was redesigned. At that time 11 synoptic stations were discontinued and 18 new sites were added, to increase the areal coverage of the study and to allow for more intensified study of active and projected surface-mining areas. In April 1981 the network was once again redesigned, and 18 synoptic stations were discontinued. The one trend and seven regular stations were operated continuously from April 1979 through September 1981.

Further information about the period of record, water-quality constituents sampled for, and actual data is available through the computerized National Water Data Exchange (NAWDEX--see section 8.2). Data are also published in U.S. Geological Survey reports "Water Resources Data for Maryland and Delaware" (U.S. Geological Survey 1979a, 1980a, and 1981a), "Water Resources Data for Pennsylvania, Volume 2, Susquehanna and Potomac River Basins" (U.S. Geological Survey 1980c and 1981c), and in U.S. Geological Survey Open-File Report 81-812, "Quality of Surface Water in the Coal-Mining Areas of Western Maryland and Adjacent Areas of Pennsylvania and West Virginia from April 1979 to June 1980" (Staubitz, 1981).



BASE FROM U.S. GEOLOGICAL SURVEY
1966, 1974, 1975; 1:500,000

Figure 4.2-1 Locations of water-quality stations.

Ground-Water Information Available for 24 Locations

The majority of observation wells tap the Conemaugh and Allegheny Formations.

Ground-water-level data are available from 24 observation wells in Area 6. Fourteen of these wells have continuous records, and 10 have periodic measurements. The well locations and site numbers are shown in figure 4.3-1. Information for each station, including site number, local identification number, latitude, longitude, water-bearing unit, period of record, frequency of measurement, and depth of well, are listed in section 10.2.

The majority of observation wells in the area (site numbers 1-19) tap the Conemaugh and Allegheny Formations and are monitored as a part of a cooperative study between the Maryland Geological Survey and the U.S. Geological Survey. The purpose of this study is to investigate the impact of deep mining for coal on the local hydrologic system.

As a part of this study, 13 wells were drilled during 1979 and 1980 to various depths in three clusters, and continuous water-level recorders were installed on each of the wells. At each of the clusters, individuals wells are open to different water-bearing zones. The three clusters consist of sites 6-9, 11-14, and 15-19 (fig. 4.3-1). Since 1978, six other wells in the area have been monitored on a periodic basis as part of the study. The five remaining observation wells in Area 6 generally have long-term records and have been used to monitor regional water-level fluctuations.

Additional information about ground-water data is available from (1) the National Water Data Exchange (NAWDEX-see section 8.2), (2) the National Water Data Storage and Retrieval System (WATSTORE-see section 8.3), and published annual U.S. Geological Survey reports, "Water Resources Data for Maryland and Delaware" (U.S. Geological Survey, 1979a, 1980a, and 1981a) and "Water Resources Data for West Virginia" (U.S. Geological Survey, 1979b, 1980b, and 1981b). In addition, records from 1,100 water wells and 120 springs (including 56 chemical analyses) in Garrett County, Md., are listed in Maryland Geological Survey Basic Data Report No. 11 (Nutter and others, 1980). Ground-water-quality information for 43 wells in Allegheny County, Md., and four wells in Garrett County, Md., is also listed in Maryland Geological Survey Basic-Data Report No. 10 (Woll, 1978).

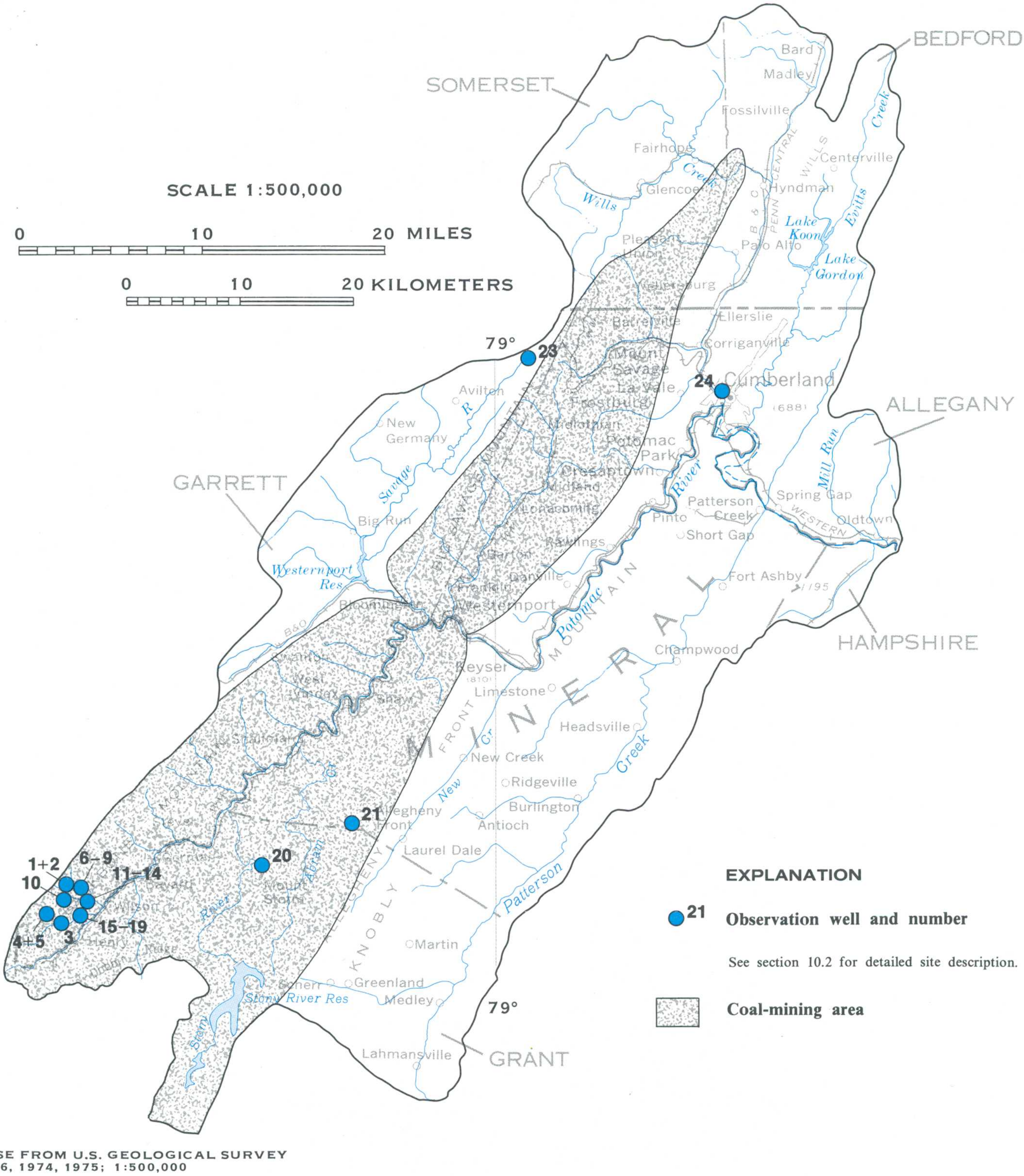


Figure 4.3-1 Locations of observation wells.

Flood Flow Determined by Climatic and Drainage-Basin Characteristics

Peak-discharge and flood-volume data are available for 12 U.S. Geological Survey gaging stations in the area.

Flood flows are determined by a combination of climatic and drainage-basin characteristics. Climatic factors dictate the quantity and rate of water available to the hydrologic system, while drainage-basin characteristics determine the storage and routing of water within the system. Climatic factors of greatest importance are the intensity, duration, and seasonal distribution of precipitation. Drainage-basin characteristics of greatest importance are drainage area, basin slope and shape, soil composition, land use, and ground cover.

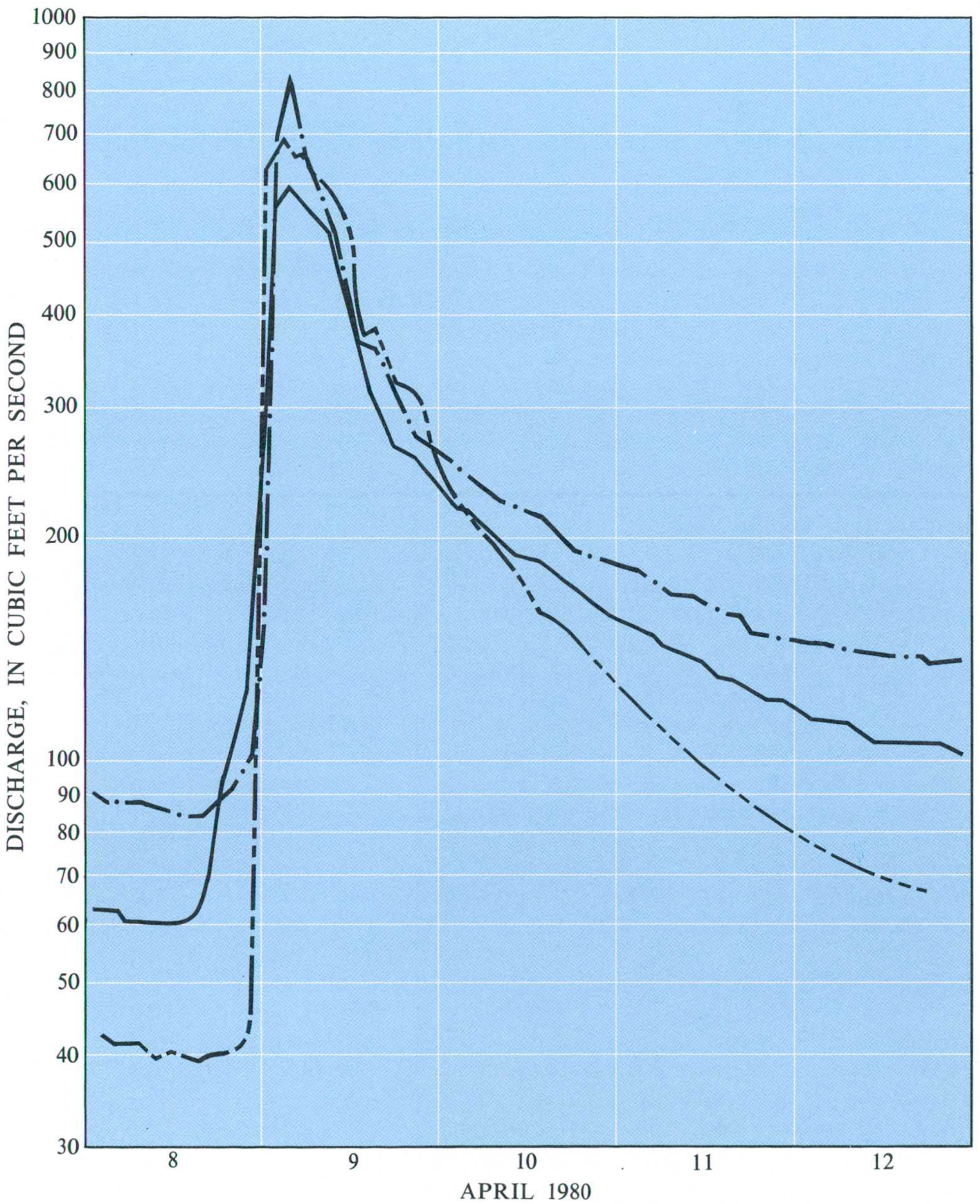
The largest flood peaks of record in Area 6 have been caused by weakened hurricanes, traveling northeastward along the east side of the Allegheny Front during late summer and early fall. However, these storms occur infrequently in the area. The flood peak of the year for larger streams generally results from large-dimension, frontal storms occurring in the late winter and early spring. These storms can cause particularly large floods when snow pack covers the ground. Small watersheds (drainage basins less than 50 square miles) are more sensitive to high-intensity short-duration thunderstorms, which often cause localized flash flooding during the late spring and summer.

Typical hydrographs from three U.S. Geological Survey gaging stations are shown in figure 5.1.1-1, and the locations of the gages and their drainage basins are shown in figure 5.1.1-2. The rise in stage at these three gaging stations resulted from a high-intensity thunderstorm on April 9, 1980, in which 1.77 inches of rain was measured at the Savage River Dam. The steep slopes and high peaks of the hydrographs are indicative of rapidly accumulating runoff, which is caused by the high intensity of rainfall and by the steep slopes and narrow flood plains characteristic of the smaller drainage basins in the area.

The peak discharge is an important characteristic of flood flows. The magnitude and recurrence frequency of peak discharges are useful in determining the proper design of structures built along or across a stream. Section 10.3 lists the magnitude of the observed peak flows of record for U.S. Geological Survey gaging stations within the area that have long-term, surface-water records. It also lists peak discharges and flood volumes for various recurrence intervals.

Peak discharges are estimated statistically by fitting a log-Pearson Type III distribution to the record of annual peaks for long-term gaging stations. A recurrence interval, or return period, is defined as the average interval of time within which an event of a given magnitude will be exceeded only once. Thus, a flood with a recurrence interval of 25 years (Q25) would be exceeded, on the average, once in 25 years. The same flood, therefore, has a 4 percent probability of being exceeded in any given year. The log-Pearson Type III distribution and its application for estimating flood-flow frequencies is described in U.S. Water Resources Council Bulletin No. 17B (U.S. Water Resources Council, 1981).

Estimates of flood-volume for one-day periods with 2-, 10-, and 25-year recurrence intervals are also included in section 10.3. These flood values are the maximum volumes of flow expected for a given time period and recurrence interval. This information is useful in determining reservoir storage capacity. This flood volume is determined by using long-term values of highest mean discharge for various consecutive-day periods. The actual volume of flow is determined by multiplying the given discharge in cubic feet per second by the number of seconds in the time period. This analysis is made using calendar days (in section 10.3, the period is one calendar day). The maximum-average discharge computed for one calendar day is usually lower than a maximum-average discharge computed for the highest 24-hour period. The percentage difference in discharge between maximum daily values and maximum 24-hour values would be greater for small streams than for larger ones (Hobba and others, 1972).



EXPLANATION

—·—·— Abram Creek near Oakmont, W.Va.

——— Evitts Creek near Centerville, Pa.

—-—-— Crabtree Creek near Swanton, Md.

Figure 5.1.1-1 Storm hydrographs for three U.S. Geological Survey gaging stations, April 8-12, 1980.

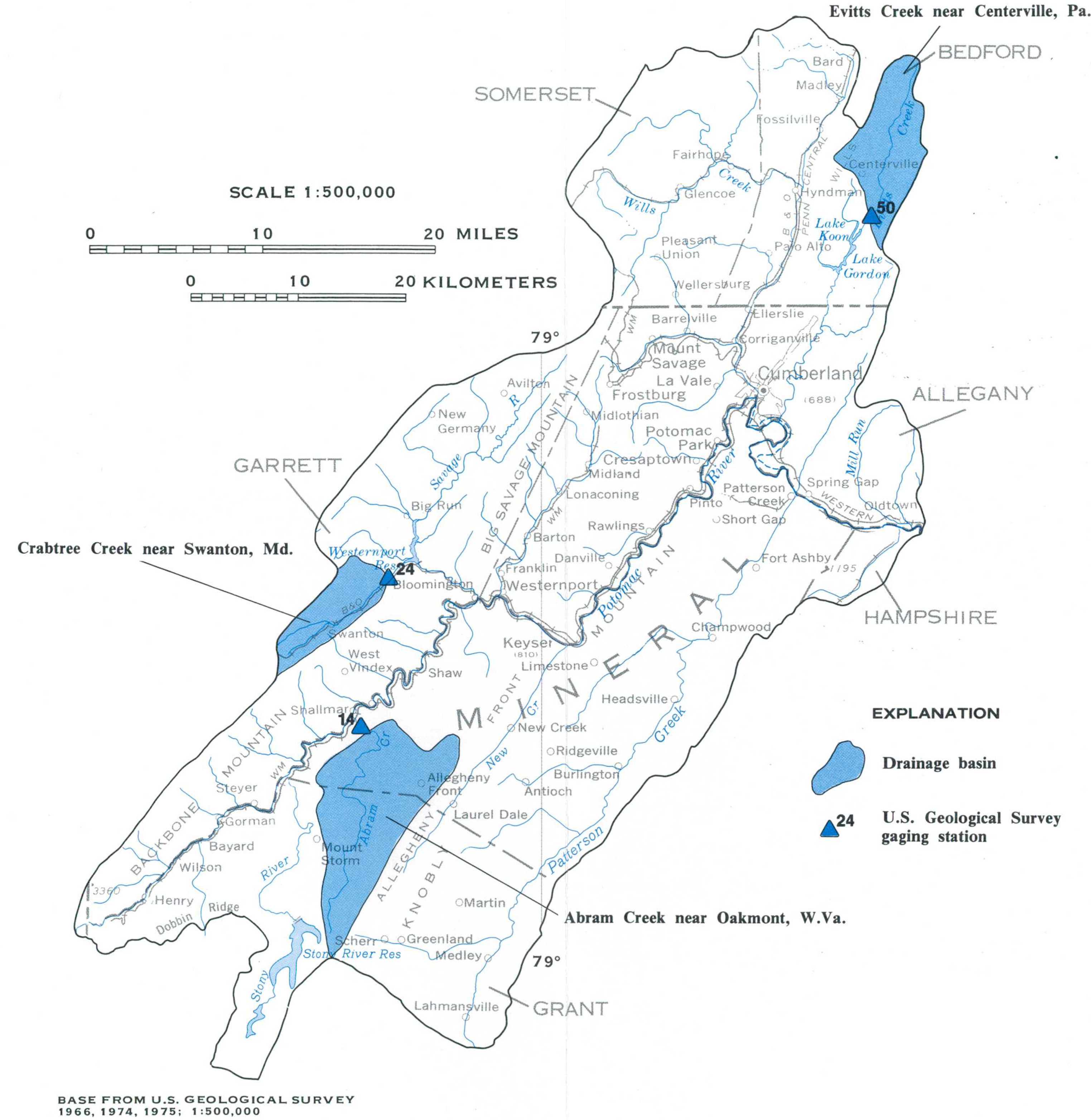


Figure 5.1.1-2 Drainage basins of sites 14, 24, and 50.

Methods Available for Estimating Peak Flows at Ungaged Sites

Equations have been developed to estimate peak flows with recurrence intervals from 2 to 100 years at sites on ungaged streams.

Peak flows at various recurrence intervals may be estimated for sites on ungaged streams. Carpenter (1980) describes a method to estimate peak flows with recurrence intervals from 2 to 100 years for natural drainage basins without urban development or regulated flow, and with drainage areas greater than two square miles. Carpenter's method employs multiple-regression techniques to develop regionalized equations relating basin and climatic characteristics to peak flows observed at gaged sites. These equations can be applied to estimate peak flows at ungaged sites on streams within the same regions.

Data used to develop Carpenter's equations were taken from sites that had over 10 years of annual-peak discharge data and that were not significantly affected by regulations of urbanization. Many of these sites are located within or close to Area 6. Carpenter's equations are thus applicable to sites on ungaged streams within Area 6.

The equations developed by Carpenter are listed in table 5.1.2-1. Drainage areas (A) are determined by planimetering the basins on the best available topographic maps. Forest cover (F), shaded green on U.S. Geological Survey topographic maps, can be measured by the grid method (a minimum of 100 grid intersections is recommended) and expressed as a percentage of the total drainage area. The 2-year, 24-hour precipitation (I) can be determined from U.S. Weather Service Technical Paper 29 (U.S. Department of Commerce, 1958).

Table 5.1.2-1 also lists the standard error of estimate computed by Carpenter for each peak-flow-estimating equation. The standard error of estimate is a measure of how well the peaks computed by an estimating equation agree with the observed peaks used to derive the equation. The standard error of estimate is, therefore, an indication of the accuracy of results that may be expected when using these equations.

Carpenter (1980) also describes methods for estimating peak discharges at gaged sites, at ungaged sites on gaged streams, and at ungaged sites between gaged sites on the same stream. For further information on the methods described above, refer to U.S. Geological Survey Water Resource Investigations Open-File Report 80-1016, "Technique for Estimating Magnitude and Frequency of Floods in Maryland" (Carpenter, 1980).

Table 5.1.2-1 Equations for estimating peak discharges for small watersheds in Area 6 and related standard errors of estimate.

Peak-discharge-estimating equations	Standard error of estimate (percent)
$Q_2 = 142A^{0.745}(F+10)^{-0.273}I^{0.669}$	40
$Q_5 = 120A^{0.731}(F+10)^{-0.275}I^{1.358}$	38
$Q_{10} = 106A^{0.724}(F+10)^{-0.286}I^{1.810}$	39
$Q_{25} = 90.1A^{0.717}(F+10)^{-0.307}I^{2.376}$	42
$Q_{50} = 78.5A^{0.712}(F+10)^{-0.323}I^{2.793}$	45
$Q_{100} = 66.6A^{0.708}(F+10)^{-0.336}I^{3.212}$	49

Where:

Q_2, Q_5, Q_{10}, ..., Q_{100}, –peak discharge for floods with recurrence intervals of 2 years, 5 years, 10 years,..., 100 years, in cubic feet per second.

A drainage area, in square miles;

F forest cover, in percent of total drainage area; and

I 2-year, 24 hour precipitation, in inches.

Most Flood Damage Occurs in Developed Areas on Flood Plains

Maps delineating flood-prone areas are available from the U.S. Geological Survey.

Most flood damage results from developing residential, industrial, and commercial areas on flood plains. Due to the rugged topography of Area 6, flat land for development is commonly available only along the flood plains of major streams. In addition the railroads and major highways follow the stream valleys. The combination of these factors has led to considerable development in the flood plains, which results in the exposure of these areas to potential flood damage.

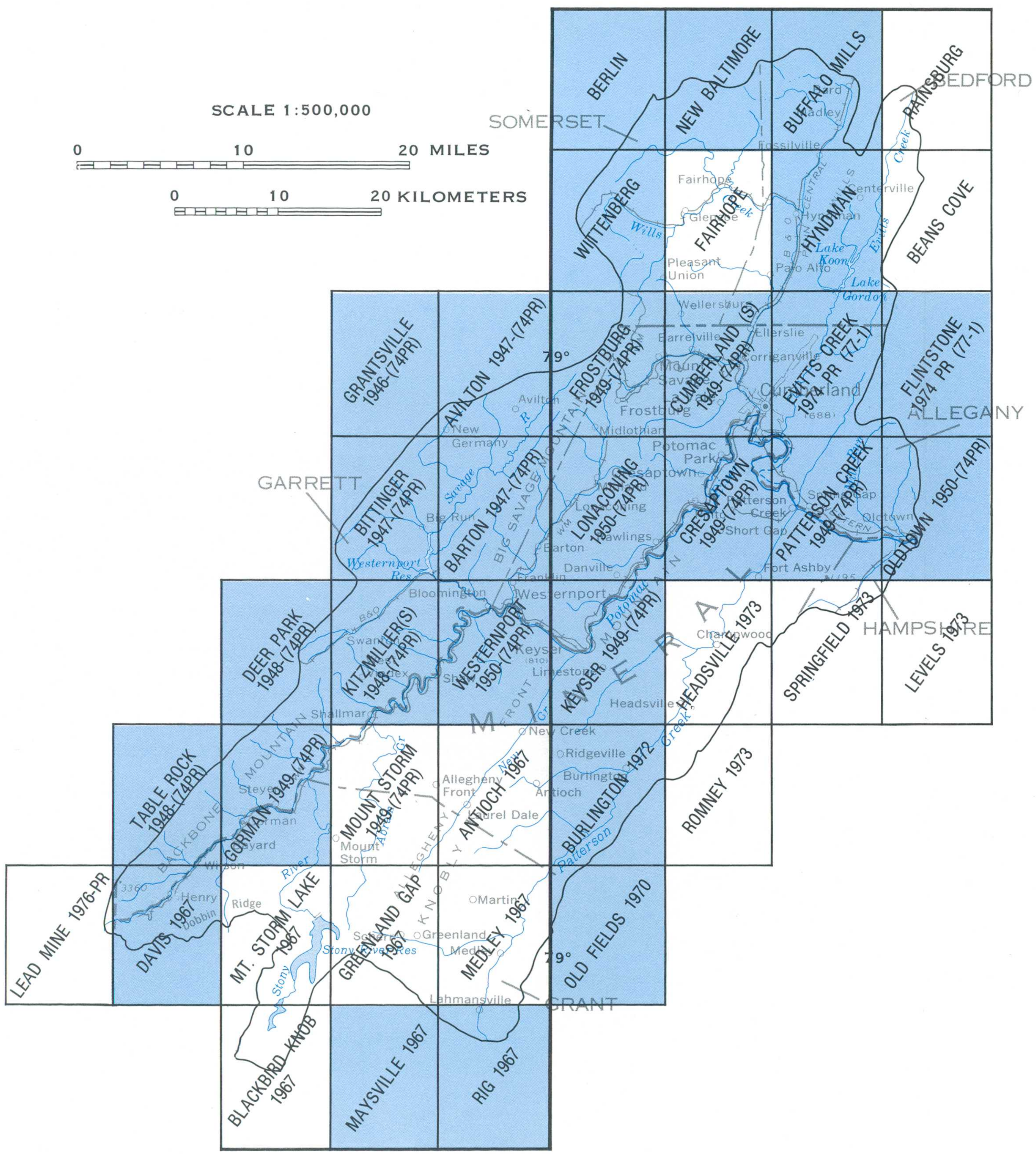
In the past flood damage has been concentrated in the Luke-Piedmont-Westernport area of Maryland and West Virginia and near Cumberland, Md. (U.S. Army Corps of Engineers, 1970). Significant damage in these areas resulted from flood in 1924, 1936, 1954, 1955, and 1972. With the completion of the Bloomington Dam, the flood peaks below Bloomington, Md., should be reduced, and the areas along the North Branch Potomac River from Luke to Cumberland should be less susceptible to flooding. Areas where significant flood damage may occur are referred to as "flood-prone areas". The U.S. Geological Survey has defined as "flood-prone" those areas which would be inundated in a 100-year flood. There is, on the average, about one chance in 100 that the designated areas will be inundated in any given year (G. W. Edelen and E. D. Cobb, Hydrologists, U.S. Geological Survey, written communic., 1969).

Flood-prone areas have been delineated on maps which correspond to U.S. Geological Survey 7½-minute topographic quadrangles. As shown in figure 5.1.3-1, flood-prone area maps are available for many of the respective states from the following U.S. Geological Survey offices:

U.S. Geological Survey
Water Resources Division
208 Carroll Building
8600 La Salle Road
Towson, Maryland 21204

U.S. Geological Survey
Water Resources Division
Room 3017 Federal Building and Courthouse
500 Quarrier Street, East
Charleston, West Virginia 25301

U.S. Geological Survey
Water Resources Division
228 Walnut Street
P.O. Box 1107
Harrisburg, Pennsylvania 17108



BASE FROM U.S. GEOLOGICAL SURVEY
1966, 1974, 1975; 1:500,000

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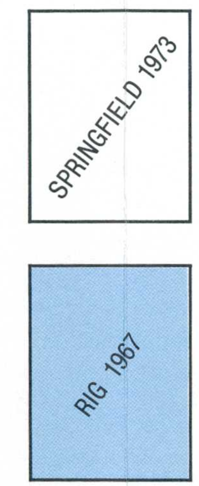


7½-minute topographic map

Flood-prone area map

Figure 5.1.3-1 Flood-prone areas.

Mean-Annual and Mean-Monthly Streamflows are Influenced by Several Basin and Climatic Characteristics

Drainage area, precipitation, and evapotranspiration are major factors influencing mean flows.

Mean-annual and mean-monthly flows are related to several basin and climatic characteristics. Analysis of streamflow data from Maryland, Pennsylvania, and West Virginia streams in and adjacent to Area 6 has shown that precipitation, evapotranspiration (evaporation plus transpiration), drainage area, and sometimes mean basin elevation are major factors influencing mean flows in this region (William J. Herb, Hydrologist, U.S. Geological Survey, Harrisburg, Pa., written communic., 1981).

Figure 5.2-1 shows the mean-monthly discharges for 52 years of record and the observed monthly discharges for the 1979-81 water years for the North Branch Potomac near Cumberland, site 49. Long-term, mean-monthly precipitation and observed monthly precipitation are shown in figure 5.2-2. Air temperature is the main climatic variable affecting water loss due to evaporation and transpiration, and its average and long-term seasonal patterns are as shown in figure 5.2-3.

The hydrograph of mean-monthly discharges (figure 5.2-1) illustrates a typical annual streamflow cycle: streamflow is lowest during July, August, and September, because evapotranspiration is greatest during these summer months; streamflow increases from October through February, because evapotranspiration decreases greatly, while precipitation decreases only slightly; streamflow peaks in March due to low evapotranspiration and increased precipitation, combined with runoff from snowmelt as air temperatures rise; and streamflow diminishes during April, May, and June due to decreasing precipitation and increasing evapotranspiration.

Departures of the observed monthly-mean flows from the long-term monthly averages commonly occur due to the variability of seasonal precipitation and evapotranspiration. The effect of fluctuating precipitation and evapotranspiration patterns on streamflow are clearly illustrated by comparing figure 5.2-1 with figures 5.2-2 and 5.2-3 during several periods of the 1979, 1980, and 1981 water years. The periods of greatest precipitation are invariably the periods of greatest discharge.

Precipitation and temperature data are from publications of "Climatological Data for Maryland and Delaware," published monthly by the National Oceanic and Atmospheric Administration, National Climate Center, Asheville, North Carolina.

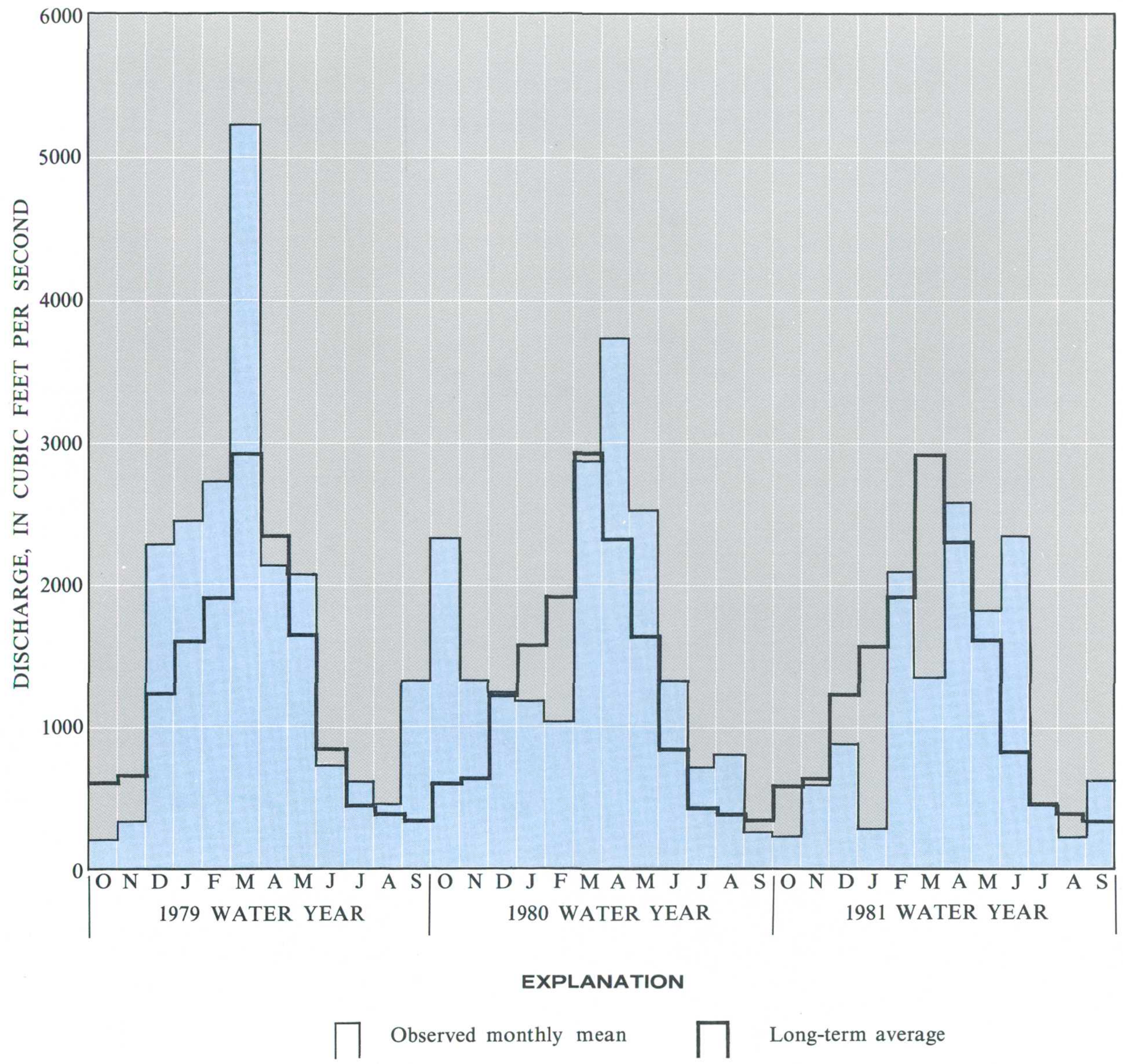


Figure 5.2-1 Monthly discharge for the North Branch Potomac River at Cumberland, Md.

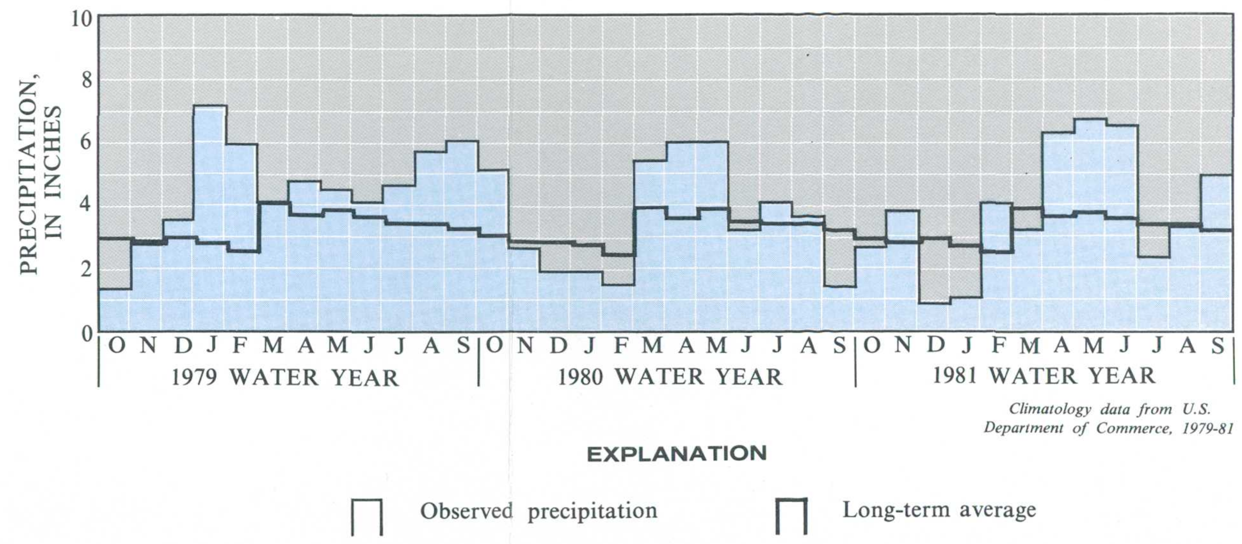


Figure 5.2-2 Monthly precipitation at Frostburg, Md.

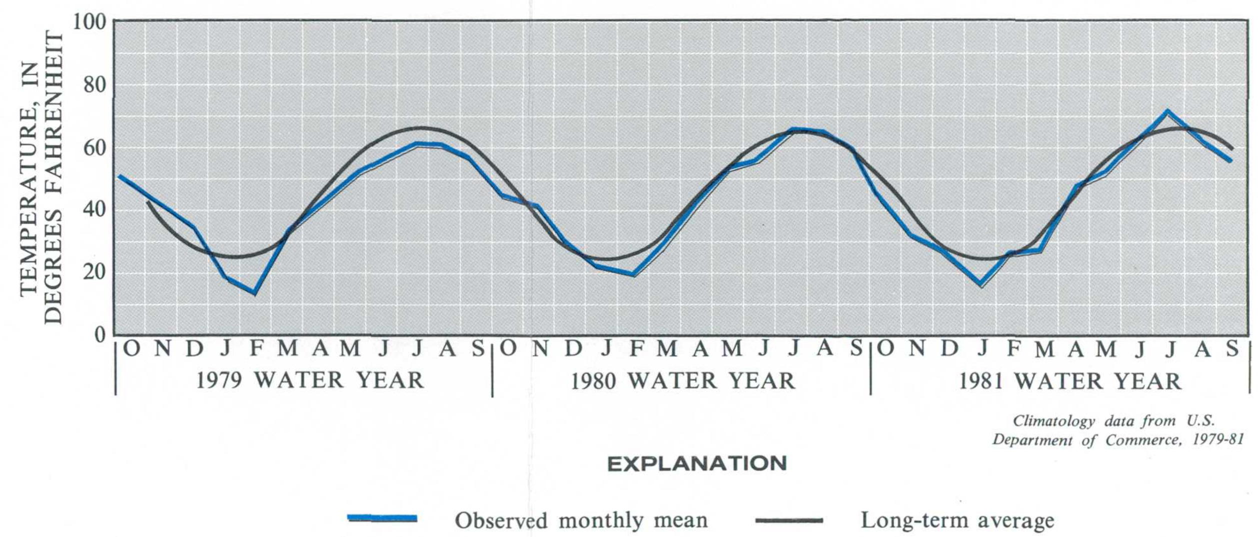


Figure 5.2-3 Monthly air temperature at Frostburg, Md.

Low-Flow Characteristics of Streams in Area 6 Vary Due To Differences in Underlying Geology

Aquifers in the area vary widely in their ability to store water and, consequently, in their ability to sustain streamflow during periods of no rainfall.

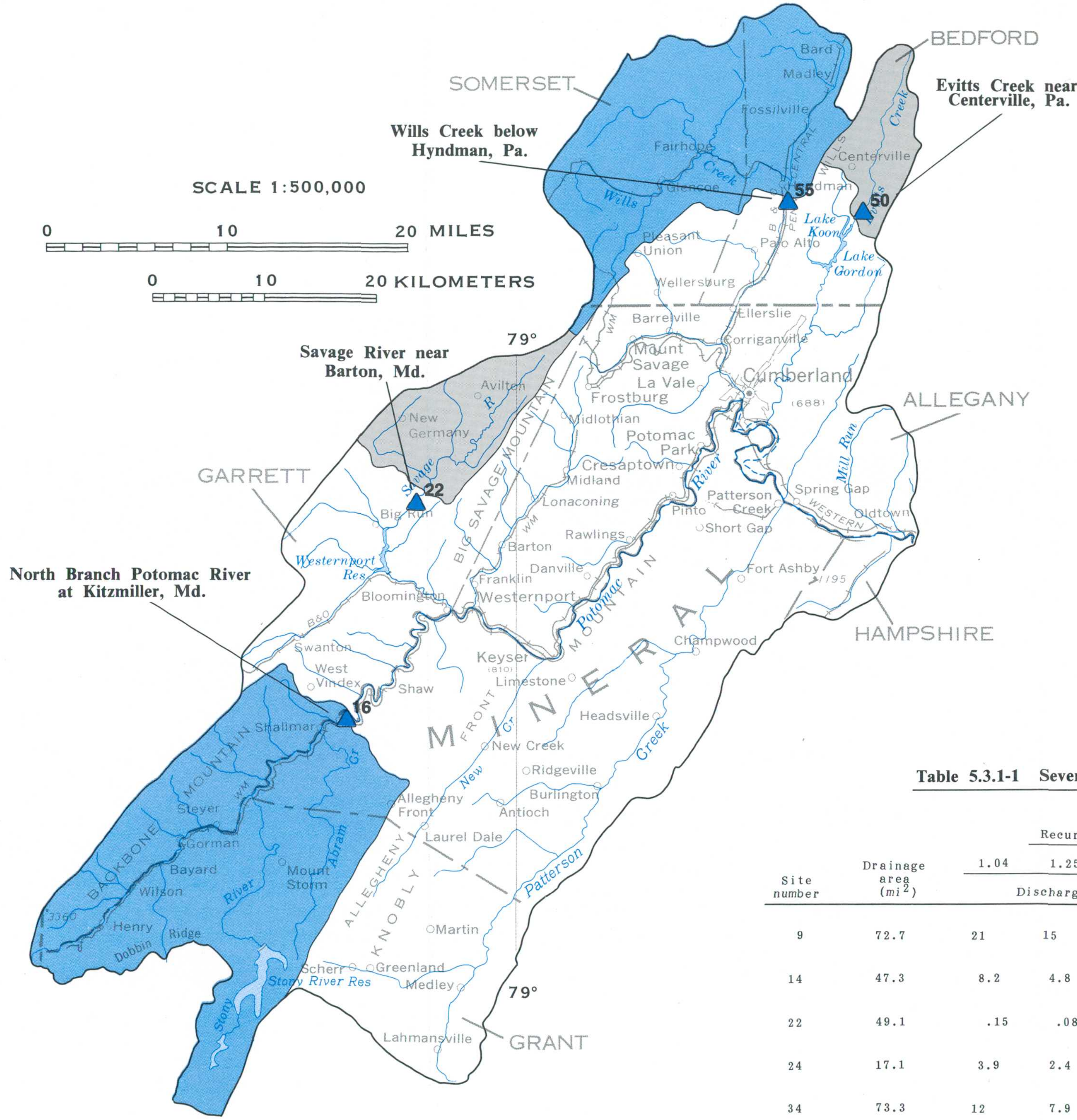
A stream is considered to be at base flow during periods of no rainfall, when streamflow is supplied by ground-water discharge. Low-base flows (low flows) are largely determined by the local ground-water environment of the watershed. Factors which influence ground-water discharges include the amount of water in storage, the permeability of the aquifer material, and the slope of the existing water table.

Low-flow characteristics for gaged sites that are not subject to significant regulation or diversion are shown for Area 6 in table 5.3.1-1. Table 5.3.1-1 lists the calculated 7-day, low-flow discharges for recurrence intervals of 1.04, 1.25, 2, 5, 10, and 20 years, based on station data through 1979. The 7-day low flow with a 2-year recurrence interval (7Q2) is a commonly used index for low-flow determinations. This 7Q2 is the lowest average flow that occurs during any seven consecutive days in an average 2-year interval. There is a 50 percent chance in any given year that the low 7-day discharge will be less than the tabulated 7Q2 value.

Low-flow discharge values can be compared on an equal-area basis. Adjusting low flow by drainage area allows direct comparison of ground-water yields or unit flows from watersheds having different drainage areas. The location of four representative watersheds and their 7-day, low-flow curves, adjusted for drainage area, are shown in figures 5.3.1-1 and figure 5.3.1-2, respectively.

The Wills Creek watershed is underlain by shales, sandy siltstones, and thin-bedded sandstones of Pennsylvanian age, which have a low capacity for ground-water storage; therefore they produce low unit-flow values. Base flow of Evitts Creek is well sustained by productive aquifers of the Oriskany Sandstone, Helderberg Limestone, and Tonoloway Limestone, which produce high unit-flow values. Aquifers of intermediate productivity, chiefly sandstone, shales, and sandy shales of the Jennings and Hampshire Formations, sustain the base flow of the Savage River. The watershed of the North Branch Potomac River above Kitzmiller is underlain mainly by Pennsylvanian sandstones and shales, which likewise produce an high unit-flow values (U.S. Army Corps of Engineers, 1977).

The similar shapes of low-flow curves for the North Branch Potomac River at Kitzmiller and the Savage River near Barton are indicative of similar ground-water environments. The greater discharge of the North Branch Potomac River at Kitzmiller is due mainly to greater precipitation in this watershed. Greater precipitation in a watershed generally increases ground-water storage and sustains streamflow at a greater rate during low-flow periods.



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1966, 1974, 1975; 1:500,000

EXPLANATION

▲16 Gaging station and number

See section 10.1 for detailed site description.

Figure 5.3.1-1 Drainage basins of sites 16, 22, 50, and 55.

Table 5.3.1-1 Seven-day low flows.

Site number	Drainage area (mi²)	Recurrence interval in years: 1.04	1.25	2	5	10	20
		Discharge in cubic feet per second					
9	72.7	21	15	11	5.9	4.2	3.2
14	47.3	8.2	4.8	2.4	.84	.35	.20
22	49.1	.15	.08	.04	.02	.02	.01
24	17.1	3.9	2.4	1.6	1.2	1.0	.94
34	73.3	12	7.9	5.4	3.6	2.9	2.4
38	596	170	140	100	75	60	50
48	247	46	32	22	16	13	11
50	30.3	5.9	4.2	3.0	2.2	1.8	1.6
51	219	24	12	6.7	3.8	2.9	2.3
53	45.7	5.2	3.4	2.2	1.3	1.0	.79
55	146	19	5.5	2.4	1.2	.87	.69

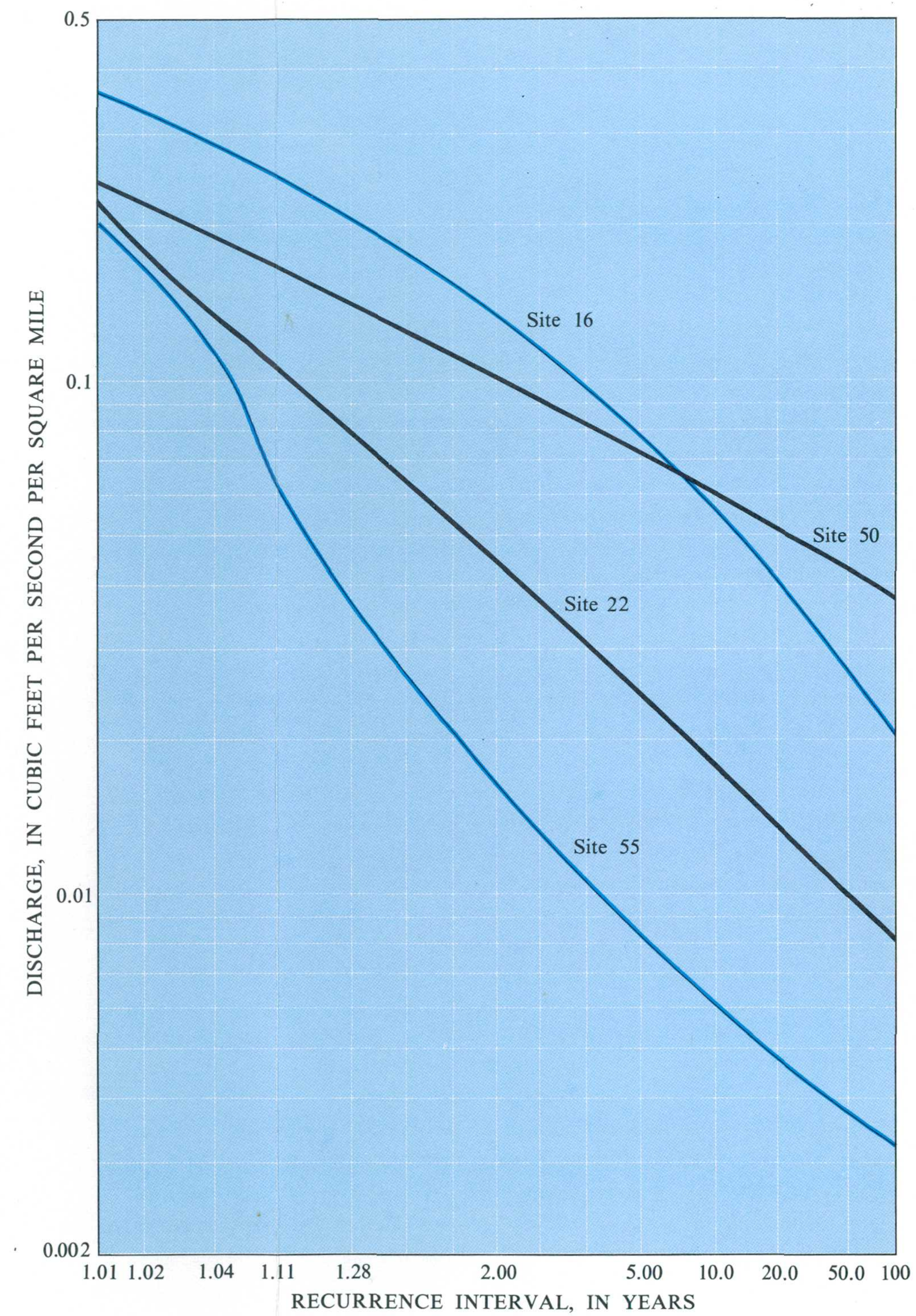


Figure 5.3.1-2 Seven-day low flow.

Methods Available for Estimating Low Flows at Ungaged Sites

Equations have been developed to estimate low flows with recurrence intervals from 5 to 100 years at sites on ungaged streams in Area 6.

Flippo (1981) describes a method that uses multiple-regression equations with independent variables of drainage area, a geologic index, and an annual precipitation index, to estimate average-minimum discharges for 3-, 7-, 30-, and 120-consecutive-day periods at recurrence intervals of 5, 10, 20, 50, and 100 years. Flippo also presents equations for estimating monthly low flows for the months of May through October.

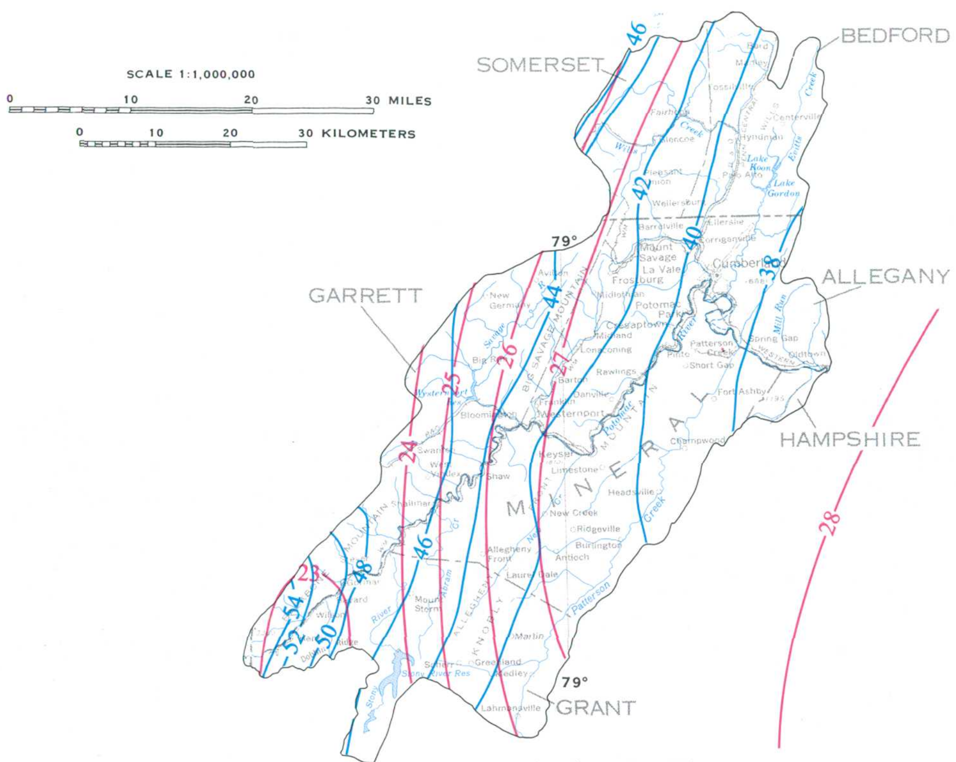
Flippo divided Pennsylvania and portions of Maryland and West Virginia into a number of low-flow regions and developed equations using data from gaged streams in each region. The Maryland and Pennsylvania parts of Area 6 are located in Flippo's low-flow region 8. Although the West Virginia portion of Area 6 is not included in this region, the equations developed for region 8 may give reasonable low-flow estimates for watersheds in this portion of the area also. Table 5.3.2-1 shows the annual low-flow equations developed for region 8 and includes the coefficient of determination, the standard error of the estimate, and a description of the variables used in the equation.

In Area 6 the geologic index (G) ranges from 0.3 to 6.0, and the annual precipitation index (PI) ranges from about 9 to 31 inches. Table 5.3.2-2 and figure 5.3.2-1 show, respectively, the geologic and precipitation indices to be used in the low-flow equations.

These equations are applicable to unregulated streams with drainage areas greater than seven square miles. Because of streamflow regulation, the equations should not be used for any North Branch Potomac River main stream station downstream from Steyer, Maryland. Also, these equations do not apply to streams in the Wills Creek watershed downstream from the confluence with Little Wills Creek, because of significantly different streamflow characteristics in this region. Prior to using this method, refer to the report of Flippo (1982) for a detailed discussion of the application, accuracy, and limitations of the method.

Another method for estimating low-flow characteristics of ungaged streams in Area 6 is being developed by D. H. Carpenter (personal communic., 1982). Carpenter is developing multiple-regression equations for three low-flow regions in Maryland to estimate annual low flows for 7-, 14-, and 30-consecutive-day periods at recurrence intervals of 2, 10, and 20 years. Regression equations developed for the low-flow region that includes Area 6 use drainage area as a single independent variable. A published report presenting Carpenter's method is anticipated in the near future and will be available from:

U.S. Geological Survey
Water Resources Division
208 Carroll Building
8600 La Salle Road
Towson, Maryland 21204



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1966, 1974, 1975; 1:500,000

Climatological data from U.S. Department of Commerce, 1973 a, b, and c; and Thornwaite, 1948.

EXPLANATION

—40— Line of equal annual precipitation, in inches

—27— Line of equal annual potential evapotranspiration, in inches

PI = Annual precipitation - annual potential evapotranspiration

Figure 5.3.2-1 Data necessary to calculate precipitation indices (PI).

Table 5.3.2-1 Regression equations for annual low flows of unregulated streams.

Equation form: LOG Y = LOG C + B1LOG A + B2G + B3LOG PI
Where:
Y = Annual low-flow characteristic (A3,5 = Annual low flow for 3 consecutive days with a 5-year recurrence interval, in cubic feet per second),
A = Drainage area, in square miles,
G = Geologic index,
PI = Annual precipitation index in inches.

Flow character-istic (Y)	Regression constant (LOG C)	Regression coefficients (B1)	(B2)	(B3)	Standard error of estimate (percent)	Coefficient of deter-mination (percent)
A3,5	-4.063	0.931	0.418	2.063	34	96.6
A3,10	-4.463	.936	.449	2.253	37	96.4
A3,20	-4.858	.951	.475	2.446	41	95.8
A3,50	-5.286	.956	.506	2.663	48	94.6
A3,100	-5.573	.966	.526	2.800	54	93.8
A7,5	-3.982	.926	.410	2.042	33	96.8
A7,10	-4.345	.929	.441	2.208	33	96.8
A7,20	-4.667	.936	.463	2.356	36	96.5
A7,50	-5.098	.949	.495	2.563	42	95.7
A7,100	-5.364	.956	.516	2.687	46	95.1
A30,5	-3.698	.938	.361	1.952	31	97.0
A30,10	-4.089	.939	.389	2.148	30	97.2
A30,20	-4.413	.948	.408	2.303	33	96.9
A30,50	-4.855	.954	.441	2.529	37	96.3
A30,100	-5.138	.960	.460	2.669	39	95.9
A120,5	-3.022	.959	.256	1.697	29	97.0
A120,10	-3.280	.955	.272	1.818	29	96.9
A120,20	-3.512	.949	.290	1.926	30	96.9
A120,50	-3.797	.945	.310	2.059	34	96.2
A120,100	-3.851	.938	.317	2.049	34	96.2

Table 5.3.2-2 Geologic indices (G) for rock-stratigraphic units.

Geologic age	Geologic unit	Geologic index (G)
Permian	*Washington Formation*	0.3
	Greene Formation	.5
Permian and Pennsylvanian	Waynesburg Formation	.5
Pennsylvanian	Monongahela through Pottsville Formations	.7
	Llewellyn Formation	3.0
	All other Pennsylvanian units	.5
Mississippian	Mauch Chunk Formation	.4
	Burgoon Sandstone through Cuyahoga Group, undifferentiated	.7
	All other Mississippian units	.5
Mississippian and Devonian	Pocono and Rockwell Formations, undivided; Spechty Kopf Formation	1.0
	Berea Sandstone through Venango Formations, undivided	1.5
	All other Mississippian and Devonian units	.5
Upper Devonian	Lock Haven and Trimmers Rock Formation	.4
	Foreknobs Formation, Brallier and Harrell Formations, undivided	.5
	Catskill Formation, undivided	.9
	Members: Irish Valley	.3
	Poplar Gap and Packerton	1.2
	Sherman Creek, Long Run and Beaverdam Run	.8
	All other members of the Catskill Formation	1.0
	All other Upper Devonian units	.3
Middle and Lower Devonian	Hamilton Group, undivided	.9
	Mahantango and Marcellus of Hamilton group and Onondaga Formation	1.0
	Old Port Formation	3.0
	All other Middle and Lower Devonian units	2.0
Devonian and Silurian	Onondaga Formation through Poxono Island equivalent, undivided	1.0
	Keyser and Tonoloway Formations, undivided	3.0
	All other Devonion and Silurian units	2.0
Silurian	Wills Creek Formation and Clinton Formation	.8
	Wills Tuscarora Formation	1.0
	All other Silurian units	3.0
Ordovician	Juniata Formation and Reedsville Shale	.3
	Hamburg sequence (except limestone)	.4
	Bald Eagle and Martingsburg Formations; metadiabase	.5
	Limestone of Hamburg sequence, Jacksonburg Limestone, and Cocalico Shale	1.0
	Hershey, Myerstown and Annville Limestones	2.0
	Coburn Formation through Nealmont Formation, undivided; Rockdale Run Formation	4.0
	Benner Formation through Loysburg Formation; Axemann Limestone, Stonehenge Limestone/Larke Dolomite, and Conestoga Limestone	5.0
	All other Ordovician units	6.0

Source: Flippo, 1982.

Flow-Duration Presented for 11 Sites

Area streams are well sustained, especially during low flows.

A flow-duration curve is a cumulative-frequency curve that shows the percentage of time that a specific daily discharge can be exceeded. Flow-duration curves are used to show discharge characteristics of streams over the range of flow conditions experienced throughout a given period of record, irrespective of the chronological sequence of the daily flows. A flow-duration curve developed from a particular period of record may or may not be representative of long-term conditions.

Table 5.4-1 shows flow-duration, discharge data for 11 gaged sites on eight unregulated streams in the area. These data were developed using daily-discharge values from gaged streams having drainage areas ranging from 17.1 to 247 square miles.

Flow-duration curves can also be presented in units of discharge adjusted by drainage areas. Figure 5.4-1 shows the unit flow-duration curves from 11 gaged sites representing eight streams in Area 6. The shaded segments of these graphs encompass the range of all 11 individual curves.

Hydrologic and geologic characteristics of drainage basins influence the shape of flow-duration curves. Curves with steep slopes depict highly variable streamflow, derived mainly from direct-surface runoff. Flow-duration curves with more gentle slopes indicate that a significant part of the flow originates as delayed surface runoff or from groundwater storage. A flat slope at the lower end of the curve like that of Evitts Creek, Site 50, reflects low-base flows that are well sustained, whereas a steep slope at the lower end, like that of Wills Creek, Site 55, reflects low-base flows that are not well sustained (Searcy, 1959). In general the flow duration curves show that streams in Area 6 are, for the most part, well sustained, especially during low flows.

Table 5.4-1 Flow-duration discharge data.

Site number	Drainage area $(mi)^2$	Percent of time specified discharge exceeded / Discharge in cubic feet per second						
		95	90	75	70	50	25	10
9	72.7	11	17	37	45	95	210	410
14	47.3	2.1	4.0	12	15	36	85	170
16	225	31	42	88	110	250	560	110
22	49.1	2.5	3.8	9.3	12	31	86	190
24	17.1	1.7	2.1	4.1	5.2	13	35	72
34	73.3	5.1	6.5	12	15	35	96	200
35	51.2	2.1	2.7	5.2	6.3	16	50	110
48	247	22	28	52	6.9	140	380	790
50	30.3	2.7	3.4	5.8	64	15	37	74
51	219	7.0	9.8	20	25	58	170	420
55	146	3.4	5.5	15	19	61	200	480

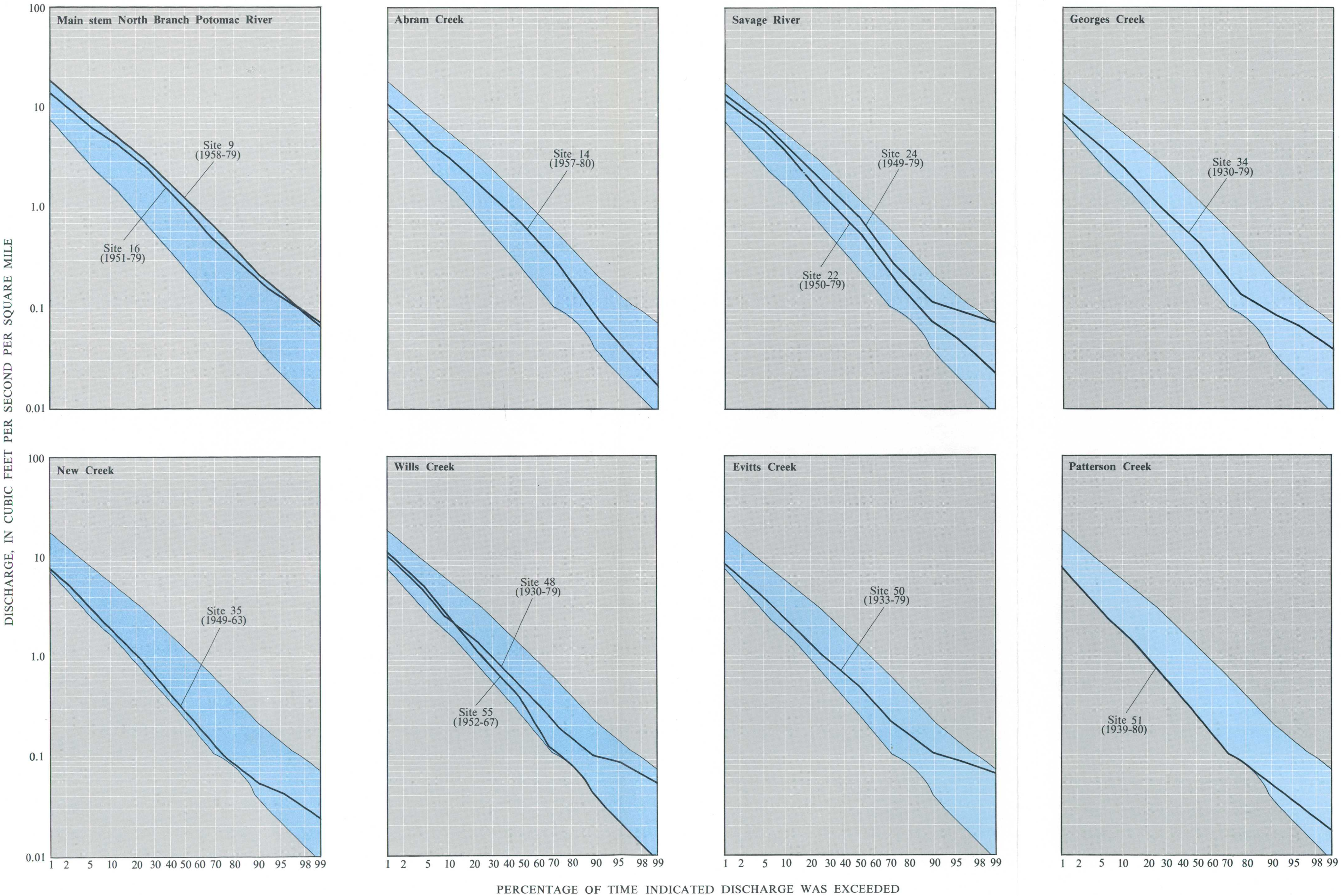


Figure 5.4-1 Flow-duration discharge data.

Mine Drainage Affects Streams in Area

Over 140 miles of streams in Area 6 are devoid of fish due to the effects of acid mine drainage.

Due to the effects of acid mine drainage, 40 miles of the North Branch Potomac River upstream from Luke, Md., and over 100 miles of its tributary streams are devoid of fish life and otherwise have severely reduced biological communities. In addition many more miles of streams in the area are affected by acid mine drainage either periodically or to a lesser extent (Palmer, 1975).

In the past the North Branch Potomac River from Luke, Md., to its confluence with the South Branch Potomac River at Old Town, Md., has been periodically subject to heavy doses of acid during low-flow periods. In the upper, acidic reaches of the North Branch during intense rainfall, the runoff produces a surge of water that pushed the acidic water in the channel ahead of it. The acidic water is then quickly carried many miles below the point where neutralization would occur under normal flow conditions. These acidic curves suddenly reduce the pH of the usually near-neutral river water below Luke and severely shock the river ecosystem. In the past fish kills due to acidic curves have been reported as far downstream as Old Town. In the future these acid slugs should be eliminated by impoundment and controlled release of acidic river water at the newly constructed Bloomington Dam (Juhle, 1978).

Mine drainage consists of ground or surface water emitted from a mine or mine site. Mine drainage commonly has low pH and large concentrations of iron, sulfate, manganese, acidity, hardness, dissolved solids, and trace metals. The solution of these constituents in ground and surface waters normally proceeds at a very slow rate as a part of the natural weathering process. However, mining activity greatly increases the surface area of rocks exposed to water and air and thereby accelerates the natural weathering process to such an extent that unusually large concentrations of these constituents result (Appalachian Regional Commission, 1969).

The initial reaction in the formation of acid mine drainage is the oxidation of the iron-sulfide minerals, pyrite and marcasite. Depending on the physical and chemical conditions present, the reaction proceeds to form sulfuric acid and either ferric hydroxide, basic ferric sulfide, or ferrous iron. But regardless of the reaction mechanism, the oxidation of one molecule of pyrite ultimately leads to the release of four hydrogens ions. This is the cause of the acidity in acid mine drainage (U.S. Army Corp of Engineers, 1969).

Other constituents, such as dissolved manganese and trace metals, found in mine drainage are produced by secondary reactions of sulfuric acid with minerals in the rocks found in the mine and along the stream valleys. These mine-drainage constituents, along with iron and sulfate, are indicators of mine-drainage pollution that may persist long after the acid in the mine drainage has been neutralized.

The quality and quantity of mine drainage varies from one site to another. Mine drainage is a function of the volume of water entering the mine, contact time, and availability of reactive materials; it is, therefore, greatly affected by the hydrologic, geologic, and topographic features of the mine site, the type of mining method employed, the operating status of the mine, and the reclamation procedures followed after mining is completed (U.S. Army Corps of Engineers, 1969). In 1972 a study of mine drainage in the Georges Creek Coal Field identified 360 mine drainage discharge points (Abar, 1978). These discharge points had flows ranging from 0.0016 to 24.76 ft^3/s, pH values from 2.0 to 7.7, iron concentrations from 0.1 to 727 mg/L, and acidities ranging from 3 to 2,480 mg/L as $CaCO_3$. Of these 360 discharge points 210 had waters that were strongly acidic, with large concentrations of iron and sulfate. Thus, the water quality of over one-half of the mine drainage discharges in the Georges Creek Coal Field was significantly degraded.

Discharge of acid mine drainage to surface water changes the water quality by lowering the pH, reducing the natural alkalinity, increasing the total hardness, and adding undesirable and potentially toxic amounts of sulfate, iron, manganese, aluminum, and other trace metals. Acid mine drainage can be lethal to fish and can render a natural stream unfit for aquatic habitation. This reduces the aesthetic and recreational value of the stream and may reduce the property value of adjoining lands. Acid mine drainage may also increase the cost of municipal and industrial water treatment and can cause damage to in-stream structures and equipment such as bridges, culverts, and pumps. The visual effects of acid mine drainage on three streams in Area 6 are shown in figures 6.1-1, -2, and -3.

Figure 6.1-1 Aaron Run flowing alongside a spoil pipe at Bloomington, Md.

Figure 6.1-2 Mill Run at Morrison, Md.

Figure 6.1-3 Three Forks Run at Vindex, Md.

Large Specific-Conductances Measured in Streams Draining Mined Areas

Specific conductance, which can be used to estimate dissolved-solids concentrations, was three times greater for streams draining mined areas than for streams draining unmined areas.

Specific conductances and dissolved-solids concentrations tend to be greater in streams draining coal mining areas than in streams draining unmined areas. As seen in figure 6.2-1 the mean specific conductances and dissolved-solids concentrations of streams draining coal mining areas are three times greater than those for streams draining unmined areas. The minimum, maximum, and mean specific-conductance values and dissolved-solids concentrations for individual sites in Area 6 are listed in section 10.4, and figures 6.2-2 and 6.2-3, respectively, show ranges of mean specific conductances and dissolved-solids concentrations measured at individual stations.

Specific conductance, reported as micromhos per centimeter (μmhos/cm) at 25°C, is a measure of the ability of water to conduct electricity and serves as a good estimate of dissolved-solids concentration. Dissolved-solids concentration, reported as milligrams per liter (mg/L), is a measure of the total concentration of dissolved material in a water sample. Most dissolved solids are in solution as ionic species, which give the solution the capacity to conduct electricity. As ion concentrations increase, conductance of the solution increases in an approximately linear manner (Hem, 1970). Specific conductance can, therefore, be used to estimate dissolved-solids concentrations once the relationship is known.

The relationship between specific conductance and dissolved solids is affected by the type of ions in solution, their relative concentrations, and the ionic strength of the water. Therefore, the relationship must be determined separately for waters that are significantly different in ionic characteristics. The relation between specific conductance and dissolved solids for streams draining mined areas in Area 6 is shown in figure 6.2-4.

Specific conductances are generally inversely proportional to water discharge at individual stream sites. At low flow streamflow is largely composed of ground-water discharges that have had prolonged contact with soluble minerals. These waters have relatively large concentrations of dissolved minerals and, therefore, have relatively large specific conductances. At high flow streamflow is largely composed of waters that have had much shorter contact time with soluble minerals. These waters are, therefore, not greatly mineralized and have relatively small specific conductances. The relationship between discharge and specific conductance observed at Abram Creek at Oakmont, W. Va., site 14, is shown in figure 6.2-5.

The relationship between specific conductance and discharge also appears on a seasonal basis. In general the highest specific-conductances are found during the summer and fall low-flow periods, and the lowest during the late-winter and spring high-flow periods. Figure 6.2-6 shows the variation in monthly values of specific conductance and discharge, measured at site 14.

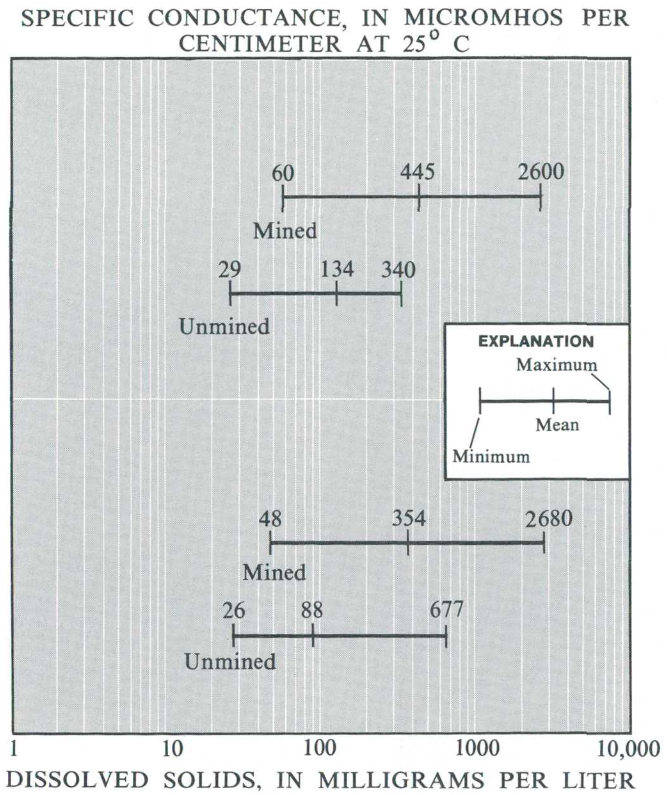


Figure 6.2-1 Range of specific conductances and dissolved-solids concentrations draining mined and unmined regions.

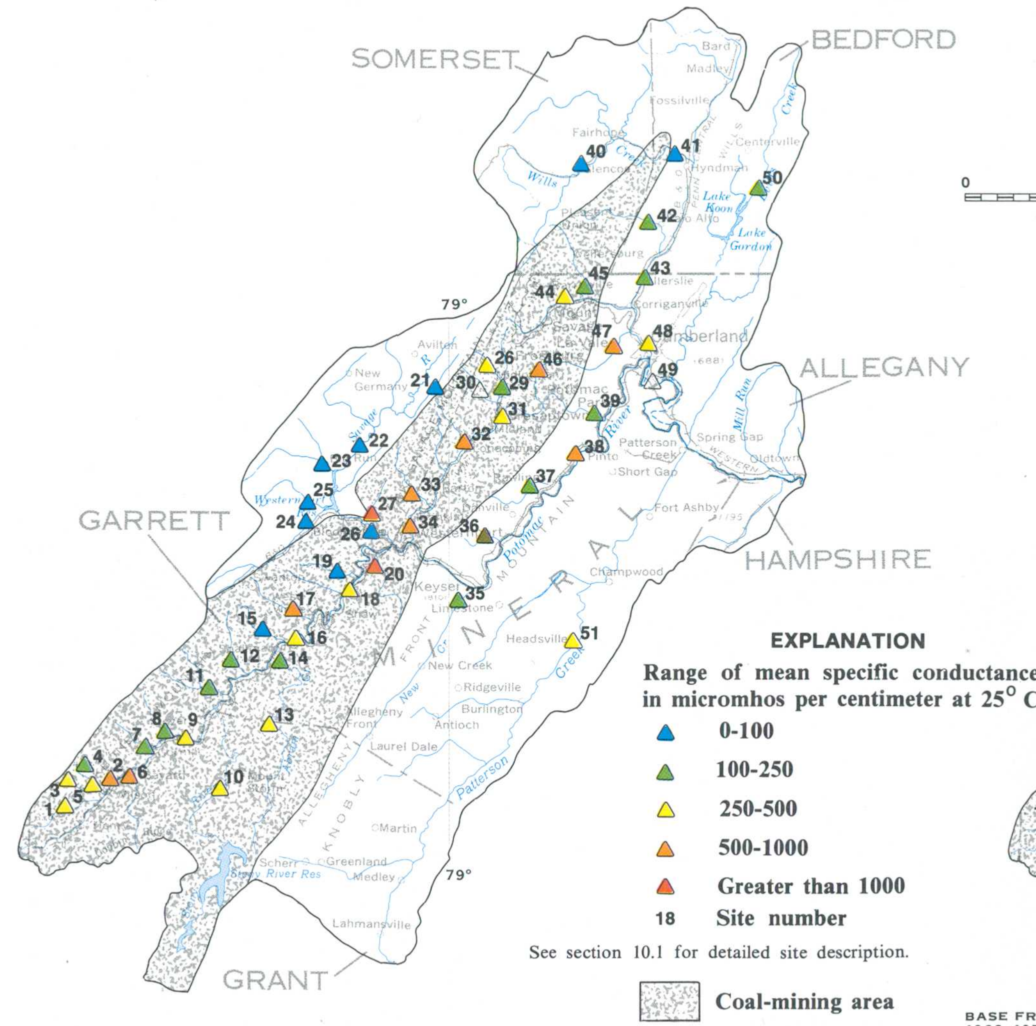


Figure 6.2-2 Mean specific conductances measured at selected sites.

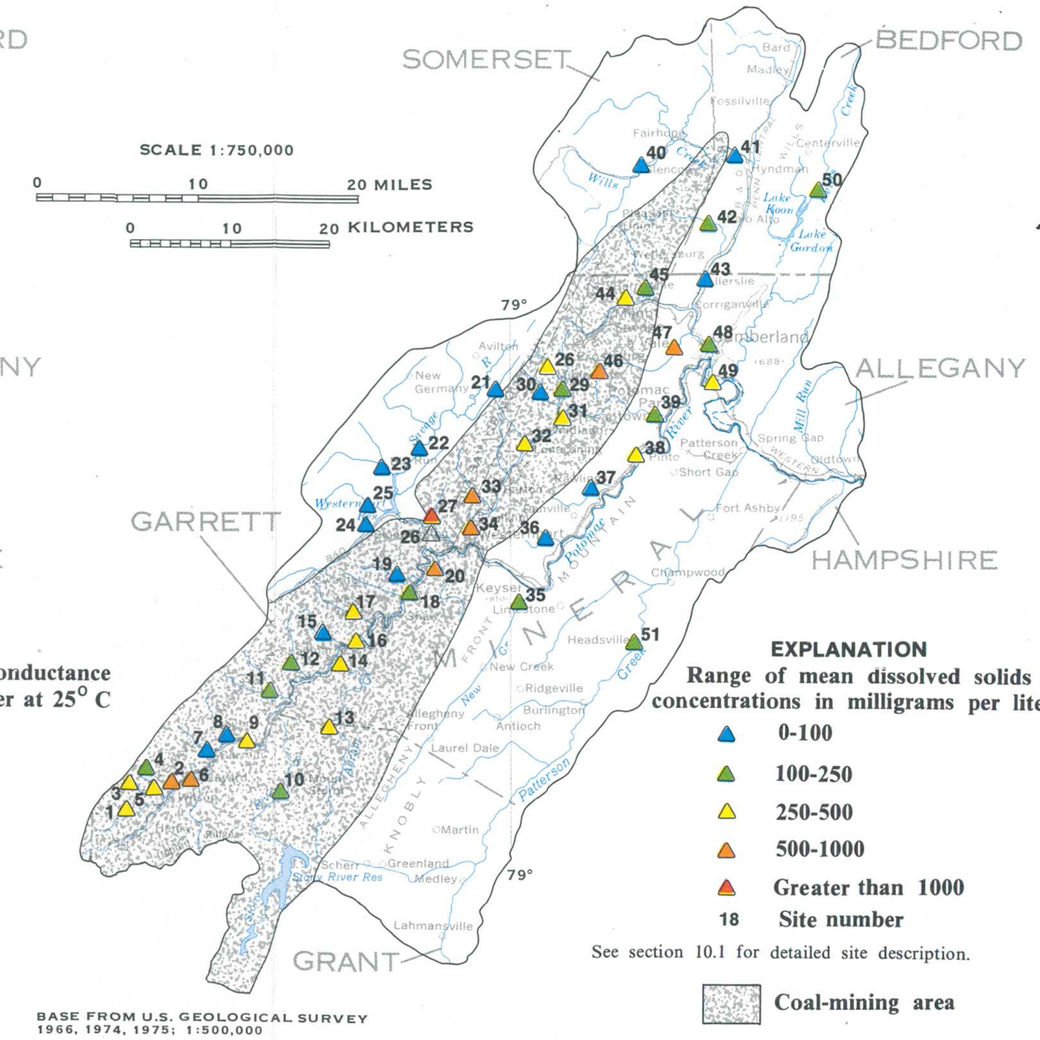


Figure 6.2-3 Mean dissolved-solids concentrations measured at selected sites.

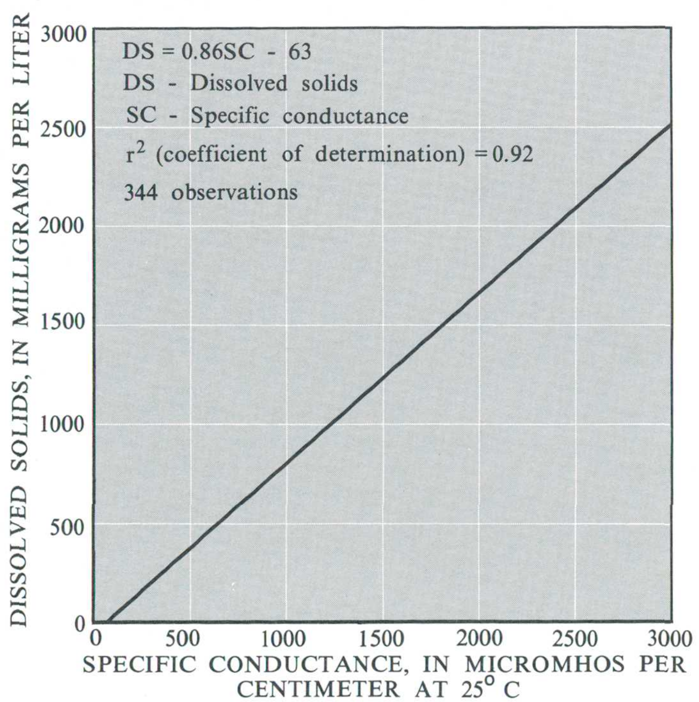


Figure 6.2-4 Relation between specific conductance and dissolved solids for mined areas.

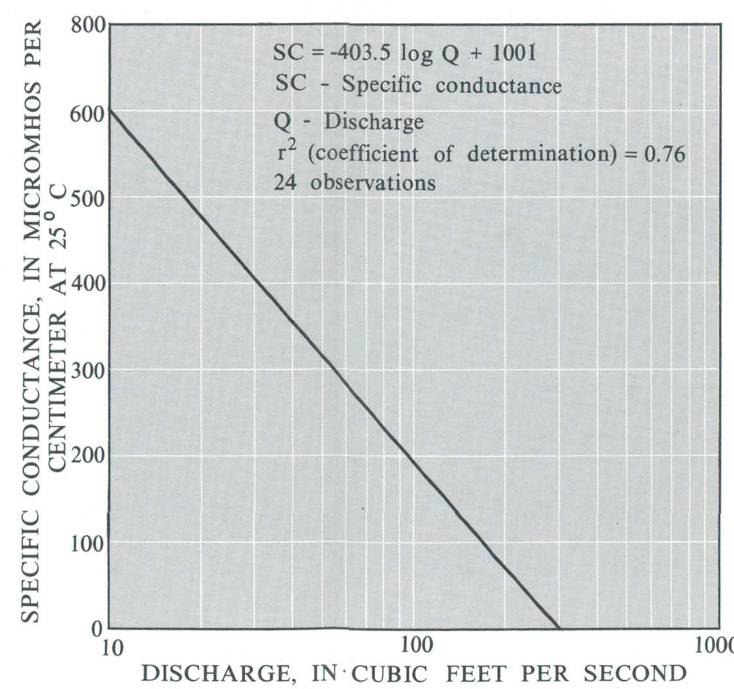


Figure 6.2-5 Relation between discharge and specific conductance at Site 14, Abram Creek at Oakmont, W.Va.

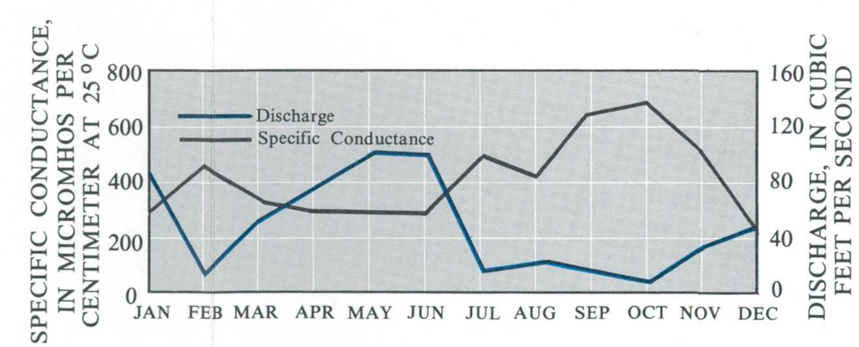


Figure 6.2-6 Discharge and specific conductances measured monthly during 1980 at site 14, Abram Creek at Oakmont, W.Va.

pH of Streams Generally Lower in Coal Mining Areas

The mean pH of streams draining coal mining areas was 1.7 pH units less than that of streams draining unmined areas.

pH is the negative base 10 log of the hydrogen-ion activity in moles per liter. A low pH represents a greater hydrogen-ion concentration than a high pH. Because the pH scale is logarithmic, relatively small changes in pH represent large changes in hydrogen-ion activity. A decrease of 1.0 pH unit represents a 10-fold increase in hydrogen-ion activity, and a 2.0 pH-unit decrease represents a 100-fold increase.

The pH of natural waters is generally controlled by a single dominant chemical reaction or set of interrelated reactions. The controlling reactant species are generally those present in the water or available to it in the greatest quantities (Hem, 1970). The pH of Area 6 streams that are unaffected by pollution is generally controlled by the carbonate system, composed of carbon dioxide (CO_2), carbonic acid (H_2CO_3), bicarbonate ion (HCO_3^-), and carbonate ions (CO_3^{-2}) (Hollyday and McKenzie, 1973). Carbon dioxide is available to water through contact with the atmosphere and from decay of organic material in the soil. Solution of carbon dioxide in water follows a series of reactions,

$$CO_2 + H_2O \rightleftharpoons H_2CO_3$$
$$H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$$
$$HCO_3^- \rightleftharpoons H^+ + CO_3^{-2}$$

which release free hydrogen ions into solution and lower the pH of pure water. The pH of pure water in contact with atmospheric carbon dioxide is 5.65. Carbonate ions are also available through contact with carbonate minerals such as calcite ($CaCO_3$). Free hydrogen ions in the water react with the calcite,

$$CaCO_3 + H^+ \rightleftharpoons Ca^{+2} + HCO_3^-$$

which reduces the free hydrogen-ion concentration in the water and raises the pH. The pH of pure water at equilibrium with calcite in the presence of atmospheric carbon dioxide is 8.4. Although other reactants are available to the system in lesser quantities, the carbonate system is dominant and tends to regulate the pH to between 5.65 and 8.3 for these streams unaffected by pollution or mining. Figure 6.3-1 shows the areal distribution of mean pH values in Area 6, and figure 6.3-2 shows that the pH of streams unaffected by mining ranged from 5.6 to 9.1.

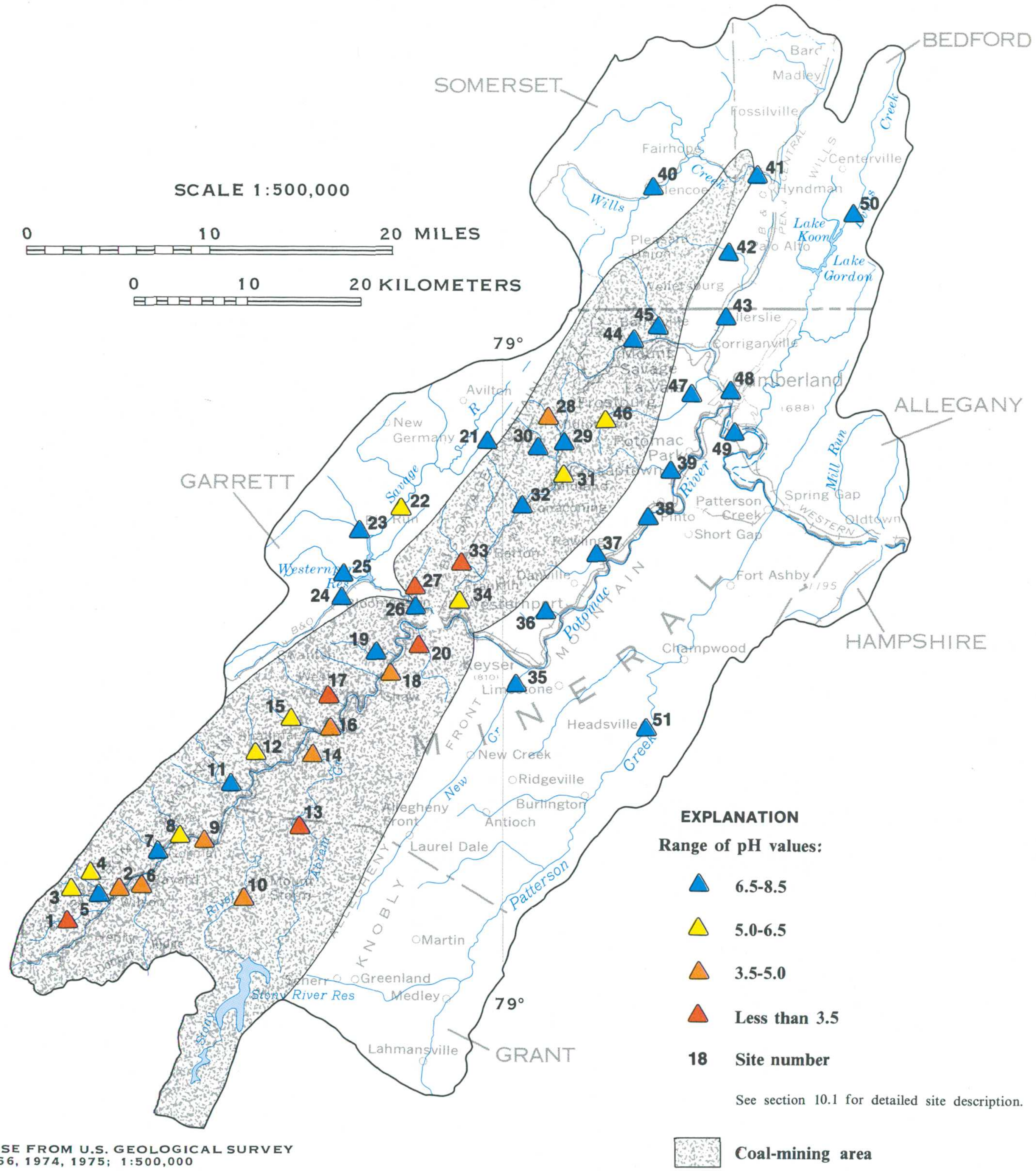
In coal mining areas the pH of streams may be lowered when the oxidation of pyrite becomes the dominant reaction. Pyrite (FeS_2), when exposed to oxygen and water, undergoes the general reaction:

$$FeS_2 + 7/2\,O_2 + H_2O \rightleftharpoons Fe^{+2} + 2SO_4^{-2} + 2H^+$$
$$Fe^{+2} + 1/4\,O_2 + 5/2\,H_2O \rightleftharpoons Fe(OH)_3 + 2H^+$$

If sufficient pyrite is present, this reaction releases free hydrogen ions in such large quantities that it overwhelms the neutralization capacity of the carbonate system and results in a lowering of the pH of the stream. As shown in figure 6.3-2, the mean pH of streams draining mined areas is 1.7 units lower than that of streams draining unmined areas.

The mean pH values measured at sites located along the North Branch Potomac River are shown in figure 6.3-3. The pH of the upper North Branch which drains the Upper Potomac Coal Field, is consistently below the recommended pH levels for domestic water supply (5.0) and freshwater aquatic life (6.5) (U.S. Environmental Protection Agency, 1976 [1977]). These low pH values indicate the important influence of mine drainage on the North Branch. As the river reaches site 38 at river mile 63, the pH has risen to 7.8, which is in the near-neutral range. This rise in pH is due to dilution and neutralization by the Savage River, New Creek, and other alkaline tributaries, and to discharge of alkaline, industrial and domestic waste at Westernport, Md.

pH is an important factor in the chemical and biological systems of natural waters. It affects the solubility and toxicity of metals; the dissociation of weak acids and bases; the disinfection, water softening, and corrosion processes in water treatment; and the suitability of water as habitat for aquatic organisms. Recommended ranges of pH are 5 to 9 for domestic water supplies and 6.5 to 9 for freshwater aquatic life (U.S. Environmental Protection Agency, 1976[1977]). Minimum, mean, and maximum pH values measured at sites in Area 6 are listed in section 10.4.



BASE FROM U.S. GEOLOGICAL SURVEY
1966, 1974, 1975; 1:500,000

Figure 6.3-1 Mean pH values measured at selected sites.

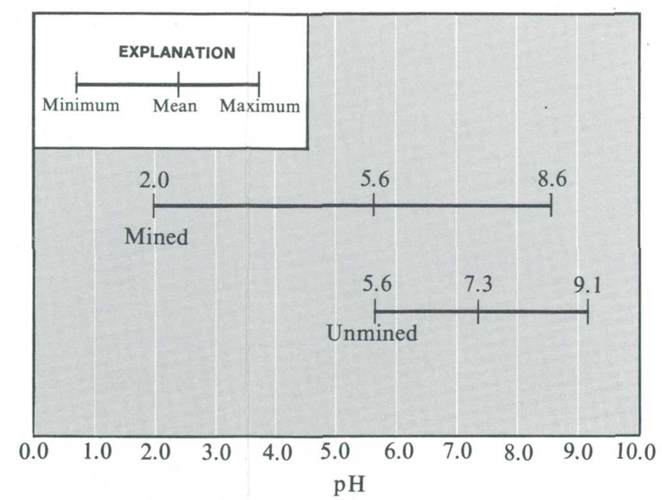


Figure 6.3-2 Range of mean pH values measured at sites draining mined and unmined areas.

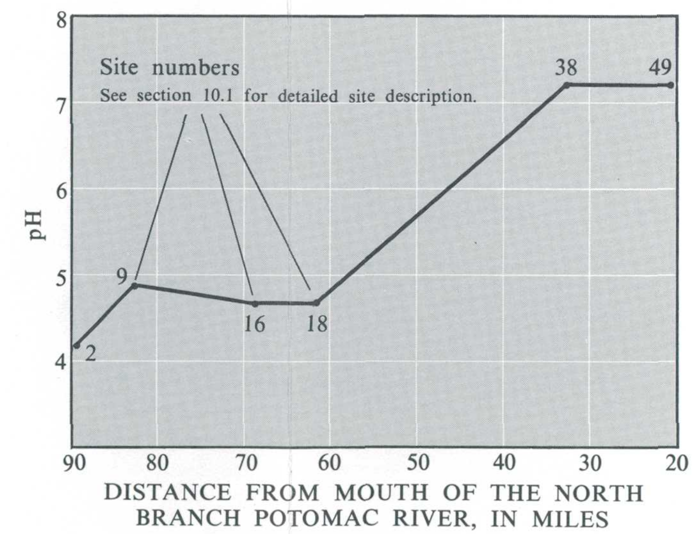


Figure 6.3-3 Mean pH values measured at sites along the North Branch Potomac River.

Iron Concentrations Higher in Streams Draining Coal-Mining Areas

Both total- and dissolved-iron concentrations tend to be higher in streams draining coal mining areas than in those draining unmined areas.

Iron, a common element generally found in insoluble form in soils and sedimentary rocks, is naturally present in low concentrations in the streams of Area 6. Figure 6.4-1 and 6.4-2 show the areal distributions of dissolved and total iron in the area. Total-iron concentrations measured at streams draining unmined areas ranged from 30 to 16,000 micrograms per liter (μg/L) and had a mean value of 536 μg/L (fig. 6.4-3).

Pyrite and marcasite are ferrous-sulfide minerals commonly associated with coal-bearing strata. Coal mining exposes large surface areas of these rocks to oxygen and water, thereby accelerating the oxidation of ferrous sulfide, ultimately to form ferric iron and sulfuric acid. Ferric iron is soluble in low-pH water and is leached from deep mines and spoil piles, thereby increasing the iron content of streams draining coal mining areas. Total-iron concentrations, measured in streams draining coal mining regions in Area 6, ranged from 80 to 44,000 μg/L and had a mean value of 2,660 μg/L (fig. 6.4-3).

Ferric iron, resulting from the oxidarion of ferrous sulfide, can occur in mine drainage as Fe^{+3}, $FeOH^{+2}$, and $Fe(OH)_2^{+}$. The predominant form and solubility of these iron species is dependent on the pH of the solution, and the redox potential, and the dissolved carbon dioxide and sulfur species present. Above a pH of 4.8 the solubility of ferric species is less than 10 μg/L (Hem, 1970).

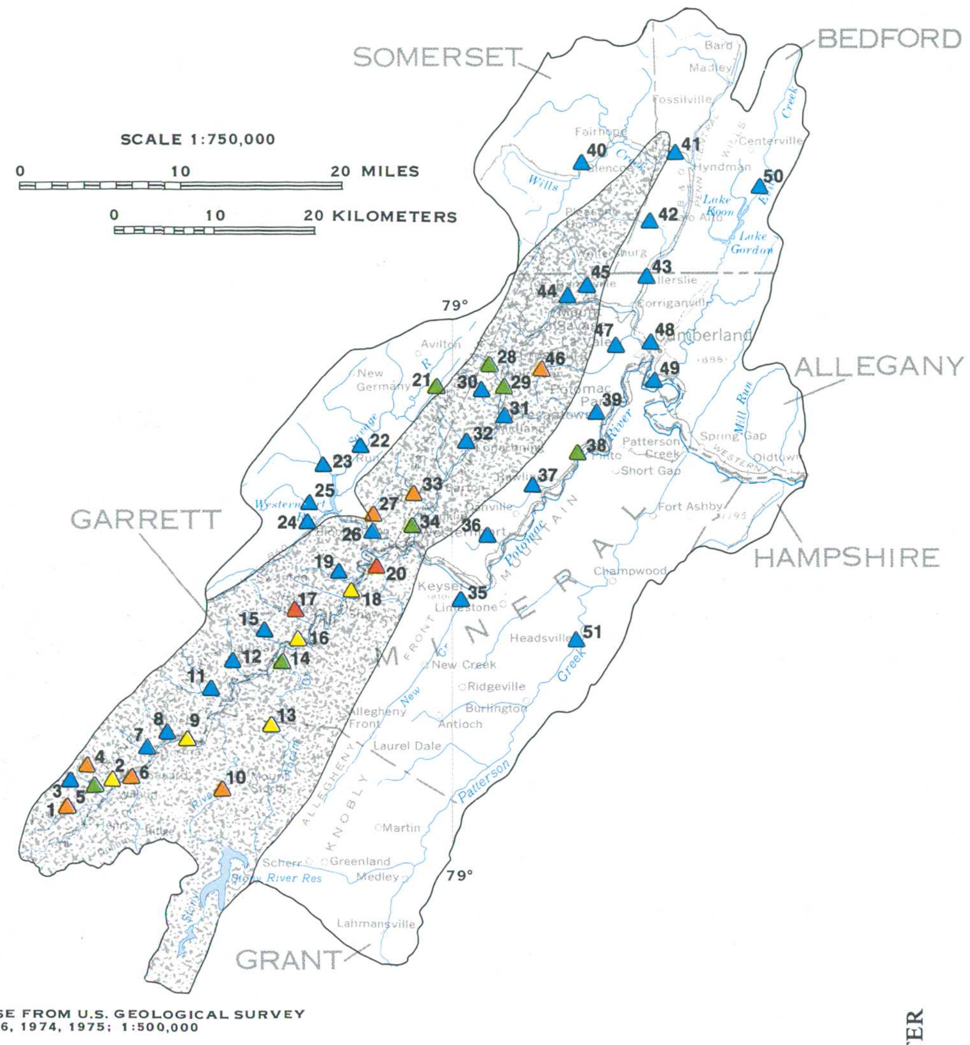
Streams draining coal mining areas generally have much lower pH's than streams that are unaffected by mining. The solubility of iron and the portion of total iron in the dissolved state, are greater in streams having low pH's. Dissolved-iron concentrations in streams draining coal mining areas ranged from 0 to 44,000 μg/L and had a mean value of 1568 μg/L (fig. 6.4-3). For streams draining unmined areas, the dissolved-iron concentrations ranged from 0 to 190 μg/L and had a mean value of 30 μg/L (fig. 6.4-3). The mean concentration of dissolved iron for all streams draining unmined regions amounted to only 5 percent of the mean concentration of total iron for those streams. However, the mean concentration of dissolved iron for all streams draining coal mining areas amounted to more than 65 percent of the mean total-iron concentration for those streams.

The concentration of total and dissolved iron gradually declines downstream from sources of mine drainage. As the stream is neutralized by alkaline ground water, alkaline tributaries, and contact with carbonate rocks, the pH gradually rises, and insoluble ferric hydroxide precipitates from solution. Figure 6.4-4 shows the downstream decline in the average concentration of total and dissolved iron measured at sites on the North Branch Potomac River.

Figure 6.4-4 also shows the average total-iron load of streams tributary to the North Branch Potomac River. The streams contributing the largest amounts of total iron to the North Branch Potomac River are Stony River and Georges Creek. These two streams, which contribute about 14 percent of the average annual water discharge of the North Branch Potomac River at Cumberland, produce over 50 percent of the total-iron inflow to the North Branch above that site. The sum of the average total-iron loads measured a selected tributaries to the North Branch Potomac River upstream from Cumberland amounted to 7,000,000 pounds per day. The average total iron load to the North Branch measured at Cumberland amounted to about 4,500,000 pounds per day. The 2,500,000 pounds per day difference between the load measured as inflow to the North Branch above Cumberland and the load that the river carries at Cumberland probably can be attributed to the deposition of insoluble iron hydroxide onto the steam bed. During periods of high flow, the iron that has been deposited is likely to be resuspended and carried by the river as a very large suspended-iron load.

The ferric hydroxide that precipitates from solution forms a bright orange floc, commonly known as "yellow boy". The floc may completely blanket a stream bed and make it unhabitable for many aquatic organisms. The iron precipitates reduce the standing crops of algae and vascular plants that provide food and shelter for benthic invertebrates, a prime food source for certain species of fish (Gale and others, 1976).

A recommended standard for dissolved iron has been set at 300 μg/L for domestic water supplies and at 1 milligram per liter (mg/L) for freshwater aquatic life (U.S. Environmental Protection Agency 1976[1977]). Concentrations of dissolved iron in excess of 300 μg/L can detrimentally affect the taste of water and can cause staining to laundry and plumbing fixtures. The minimum, mean, and maximum dissolved- and total-iron concentrations measured at selected sites are listed in section 10.4.



BASE FROM U.S. GEOLOGICAL SURVEY
1966, 1974, 1975; 1:500,000

EXPLANATION

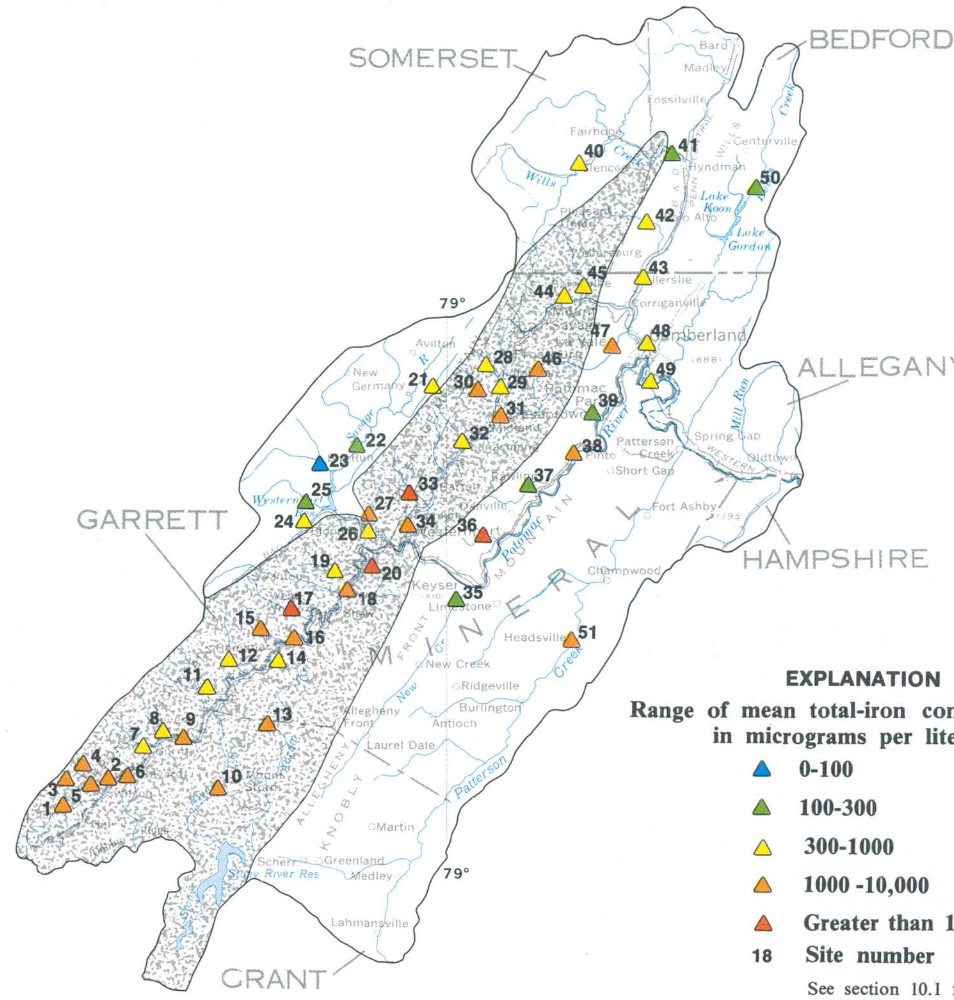
Range of mean dissolved-iron in micrograms per liter:

- ▲ 0-100
- ▲ 100-300
- ▲ 300-1000
- ▲ 1000-10,000
- ▲ Greater than 10,000
- **18** Site number

See section 10.1 for detailed site description.

Coal-mining area

Figure 6.4-1 Mean dissolved-iron concentrations measured at selected sites.



EXPLANATION

Range of mean total-iron concentrations in micrograms per liter:

- ▲ 0-100
- ▲ 100-300
- ▲ 300-1000
- ▲ 1000 -10,000
- ▲ Greater than 10,000
- **18** Site number

See section 10.1 for detailed site description.

Coal-mining area

Figure 6.4-2 Mean total-iron concentrations measured at selected sites.

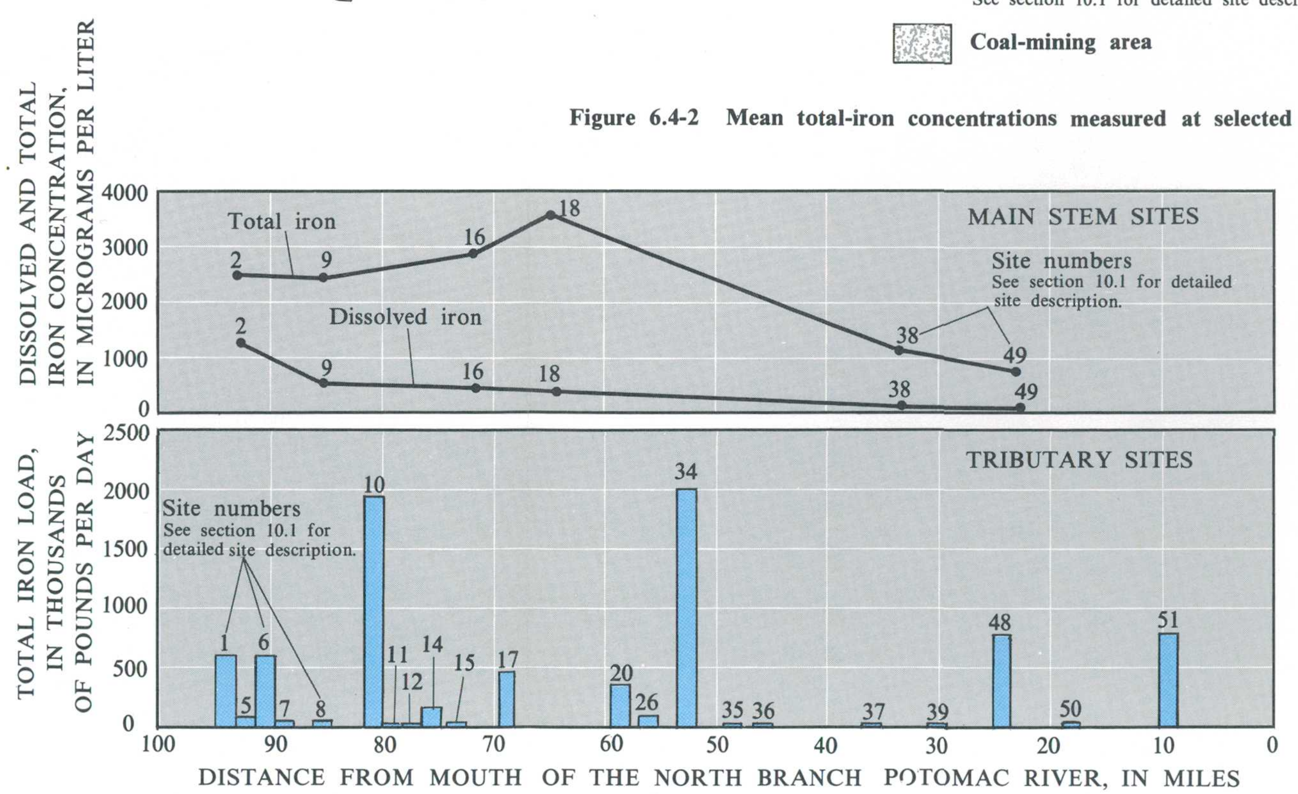


Figure 6.4-4 Dissolved and total-iron concentrations measured at sites on the North Branch Potomac River and total-iron loads of selected tributaries.

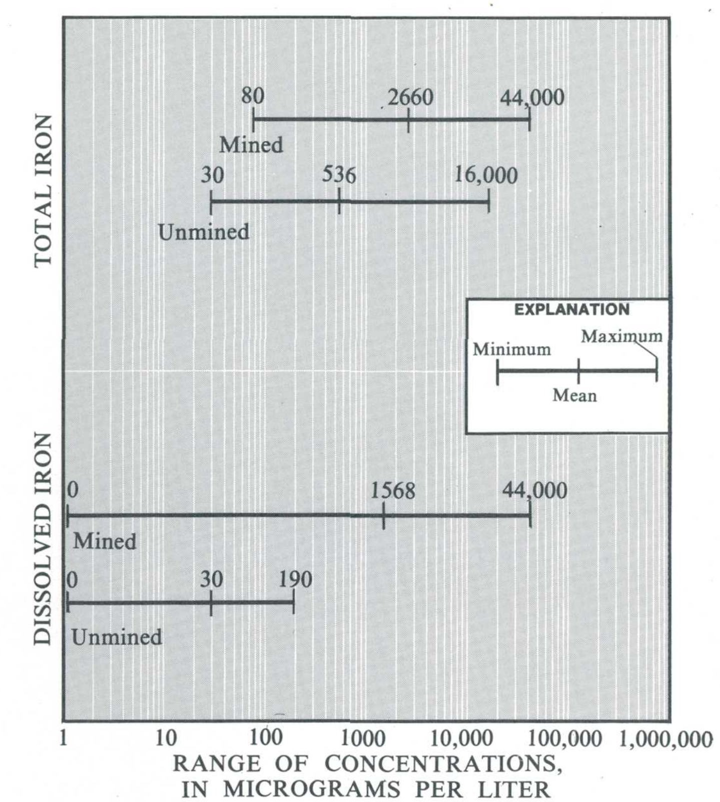


Figure 6.4-3 Range of dissolved - and total-iron concentrations measured at sites draining mined and unmined regions.

High Manganese Concentrations Found in Streams Draining Coal Mining Areas

Both total- and dissolved-manganese concentrations tend to be higher in streams draining coal mining areas than in those draining unmined areas.

Manganese, one of the most common elements in the Earth's crust, is widely distributed in sedimentary rocks and soils. Manganese exists principally as insoluble manganese dioxide, which forms coatings on mineral surfaces such as sediment particles. Lesser amounts of soluble manganese are found in organic complexes and in ferrous-manganese and manganese sulfate minerals (Hem, 1970). Figures 6.5-1 and 6.5-2 show the areal distribution of dissolved and total manganese in Area 6.

The low solubility of manganese in near-neutral water is probably the cause of the low background concentrations of total and dissolved manganese found in the streams of Area 6. For streams draining areas with no coal mining, the total-manganese concentrations ranged for 0 to 410 micrograms per liter (μg/L) and had a mean concentration of 47 μg/L; and dissolved-manganese concentrations ranged from 0 to 210 μg/L and had a mean value of 25 μg/L (fig. 6.5-3).

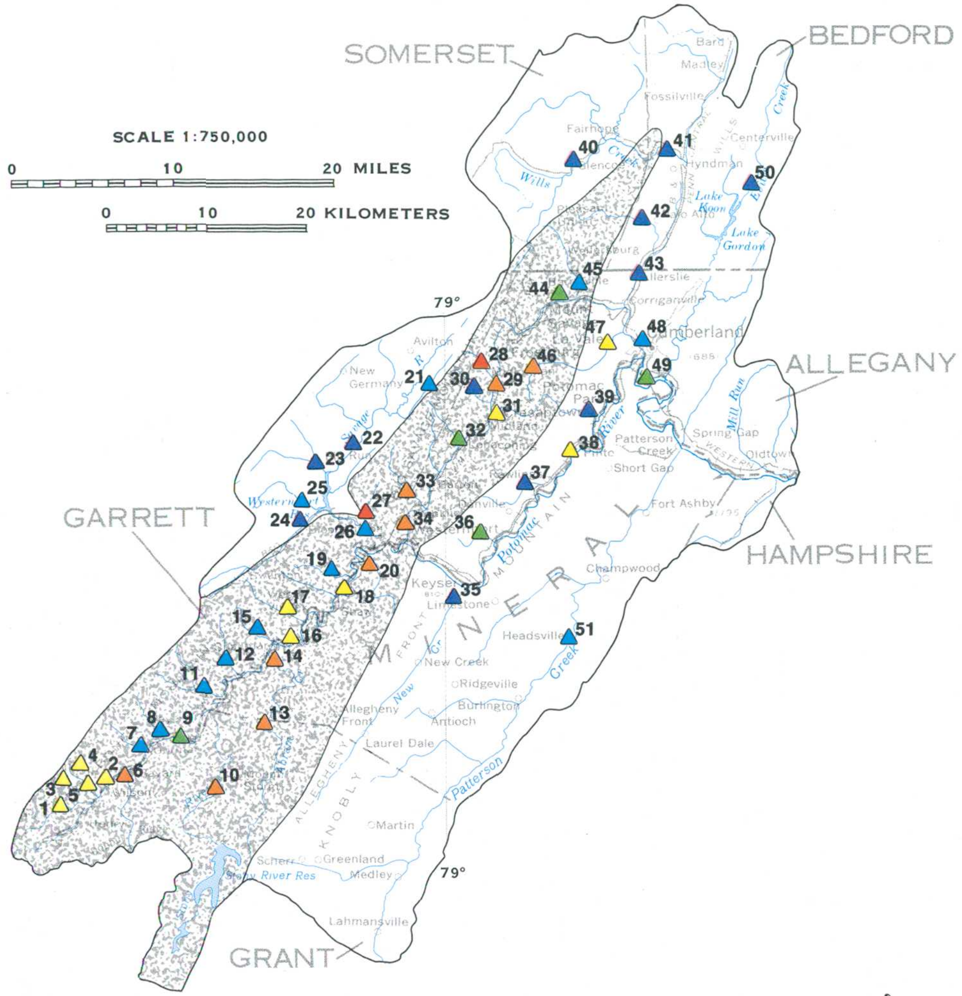
In coal mining areas the oxidation of pyrite depletes the concentration of free oxygen and produces water with a low pH. Under this reducing environment the normally insoluble manganese dioxide has a lower oxidation state and becomes soluble (Sawyer and McCarty, 1978). Once soluble, manganese may be leached from deep mines and from spoil piles and enter streams draining coal mining areas. The total-manganese concentrations for streams draining coal mining areas ranged from 10 to 8,500 μg/L, and had a mean concentration of 1,050 μg/L (fig. 6.5-3).

Although the chemistry of iron and manganese are closely related, differences in solubility are apparent. If the pH of acidic water containing iron and manganese in solution increases slowly, as in the neutralization of mine drainage, iron compounds reach their limit of solubility well before manganese compounds (Hem, 1970). Iron will therefore precipitate while manganese is left in solution. In streams draining coal mining areas, the dissolved-manganese concentrations ranged from 4 to 8,500 μg/L and had a mean concentration of 958 μg/L. This mean dissolved-manganese concentration is 91 percent of the mean total-manganese concentration, measured for all streams draining coal mining areas. In streams draining unmined areas, the mean dissolved-manganese concentration was 25 μg/L. This mean dissolved-manganese concentration is only 53 percent of the mean total-manganese concentration measured for all streams draining unmined areas.

Figure 6.5-4 shows the average total-manganese load of streams tributary to the North Branch Potomac River. The largest sources of total-manganese are Georges Creek, Abram Creek, Stony River, and Wills Creek. These streams contribute only about 46 percent of the average annual flow of the North Branch at Cumberland, but they are sources of more than 86 percent of the measured total-manganese inflow to the North Branch above Cumberland.

Because manganese does not precipitate from solution as readily as iron, manganese will usually persist in river water for greater distances downstream from mine-drainage inflows. Of the 2,600,000 pound total-manganese load measured as inflow to the North Branch Potomac River above Cumberland, 2,300,000 pounds (89 percent) is still carried by the river at Cumberland.

The recommended drinking water standard for dissolved manganese is set at 50 μg/L (U.S. Environmental Protection Agency, 1976[1977]). Concentrations above this level impart an objectionable taste to the water and can cause staining in wash water. No standards have been set for total-manganese concentrations in water. The minimum, mean, and maximum dissolved- and total-iron concentrations measured at selected sites are listed in section 10.4.



BASE FROM U.S. GEOLOGICAL SURVEY
1966, 1974, 1975; 1:500,000

EXPLANATION

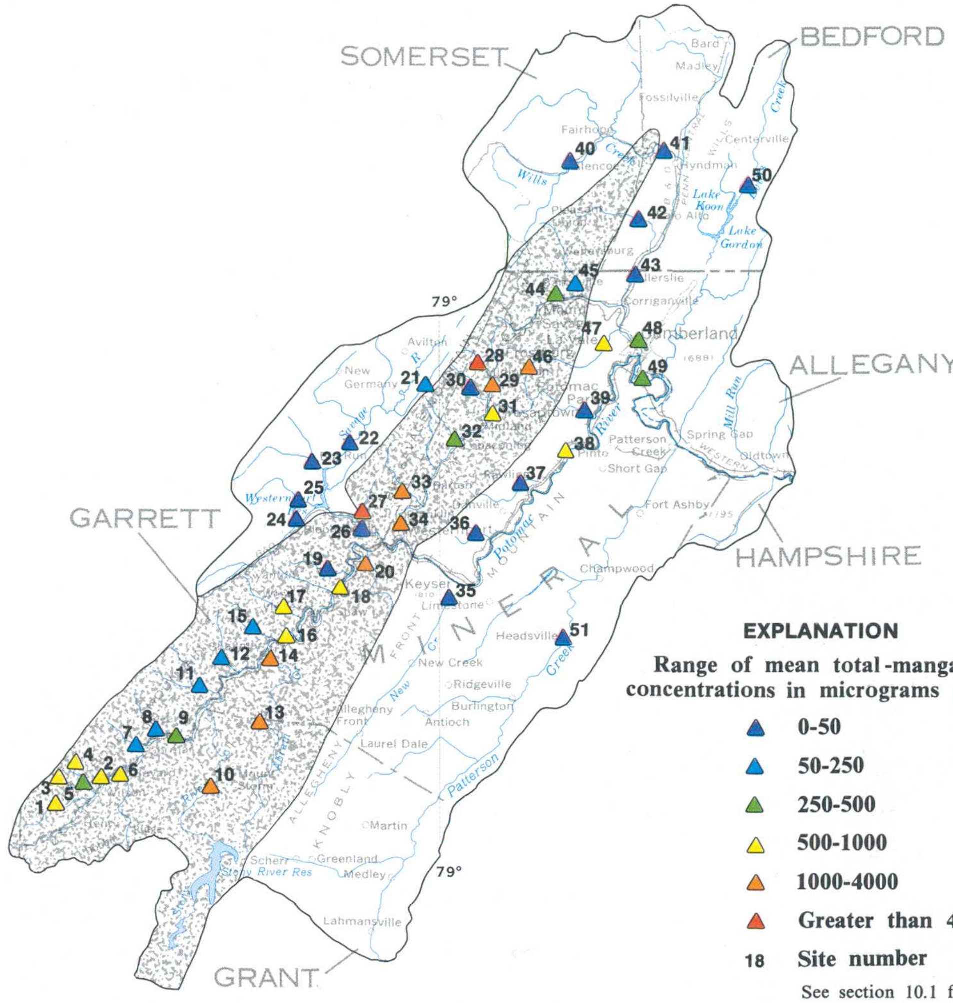
Range of mean dissolved-manganese concentrations in micrograms per liter:

- ▲ 0-50
- ▲ 50-250
- ▲ 50-250
- ▲ 500-1000
- ▲ 1000-4000
- ▲ Greater than 4000
- 18 Site number

See section 10.1 for detailed site description.

Coal-mining area

Figure 6.5-1 Mean dissolved-manganese concentrations measured at selected sites.



EXPLANATION

Range of mean total-manganese concentrations in micrograms per liter

- ▲ 0-50
- ▲ 50-250
- ▲ 250-500
- ▲ 500-1000
- ▲ 1000-4000
- ▲ Greater than 4000
- 18 Site number

See section 10.1 for detailed site description.

Coal-mining area

Figure 6.5-2 Mean total-manganese concentrations measured at selected sites.

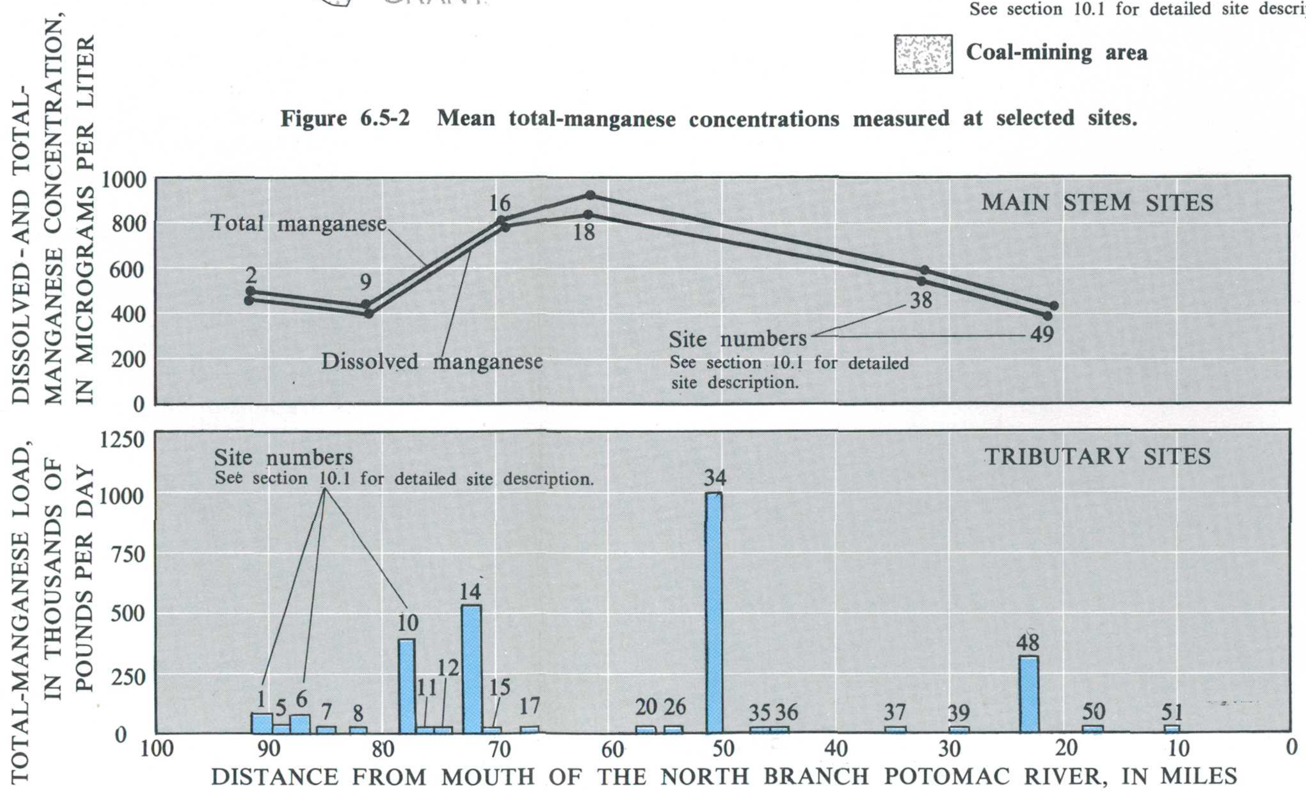


Figure 6.5-4 Dissolved- and total-manganese concentrations measured at sites on the North Branch Potomac River and total-manganese loads of selected tributaries.

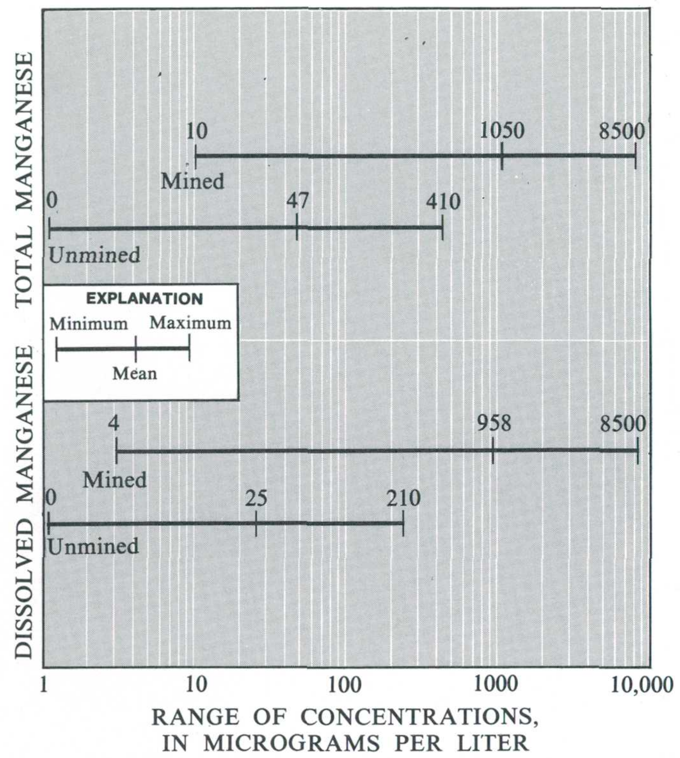


Figure 6.5-3 Range of dissolved- and total-manganese concentrations measured at sites draining mined and unmined regions.

Large Dissolved-Sulfate Concentrations Found in Streams Draining Mined Areas

The mean dissolved-sulfate concentration for streams draining coal mining areas was 10 times greater than for streams draining unmined areas.

In Area 6 streams draining coal mining areas generally had greater dissolved-sulfate concentrations than streams draining unmined areas. As shown in figure 6.6-1, the mean dissolved-sulfate concentration for all streams draining coal mining areas was more than 10 times greater than the mean dissolved-sulfate concentration for all streams draining unmined areas. Figure 6.6-2 shows the areal distribution of dissolved-sulfate. The minimum, mean, and maximum dissolved-sulfate concentrations measured at individual sites in the area are listed in section 10.4.

The principal source of sulfate in the streams of Area 6 is the oxidation of pyrite (Hollyday and McKenzie, 1973). In undisturbed rocks, where oxygen is not readily available, oxidation of pyrite proceeds slowly. Streams draining undisturbed areas, therefore, have low concentrations of sulfate. As seen in figure 6.6-1, the concentration of dissolved sulfate in streams draining unmined areas ranged from 7 to 43 milligrams per liter (mg/L), and had a mean value of 19 mg/L.

Coal mining, however, exposes large surface areas of pyritic rock to the atmosphere and accelerates the oxidation of pyrite and the solution of sulfate. This causes mine drainage, and streams receiving mine drainage, to have larger concentrations of dissolved sulfate. The dissolved-sulfate concentrations of all streams draining coal mining areas ranged from 14 to 1,700 mg/L, with a mean value of 201 mg/L (fig. 6.6-1).

Sulfate remains in solution under normal conditions and at the concentrations found in mine drainage or streams (Hollyday and McKenzie, 1973). Sulfate will therefore persist in solution far downstream from its source. For this reason and because sulfate concentrations are normally low in streams unaffected by mine drainage, sulfate is probably the best indicator of the presence of mine drainage in a stream.

The sulfate loads of the North Branch Potomac River and some of its tributaries are shown in figure 6.6-3. This figure indicates that sulfate load originating from the Upper Potomac Coal Field (upstream of river-mile 54) is nearly equal to the sulfate load originating from the Georges Creek Coal Field (downstream of river-mile 54). Therefore, it appears that net contributions of mine drainage from these two coal fields to the North Branch Potomac River are nearly equal. However, Georges Creek and Wills Creek, which drain the Georges Creek Coal Field, carry the greatest sulfate loads for single tributaries.

Sulfate concentrations correlate well with specific conductance measured in streams in Area 6. Figure 6.6-4 shows the relationship between specific conductance and sulfate. This figure can be used to estimate sulfate concentrations on the basis of specific conductance measurements alone.

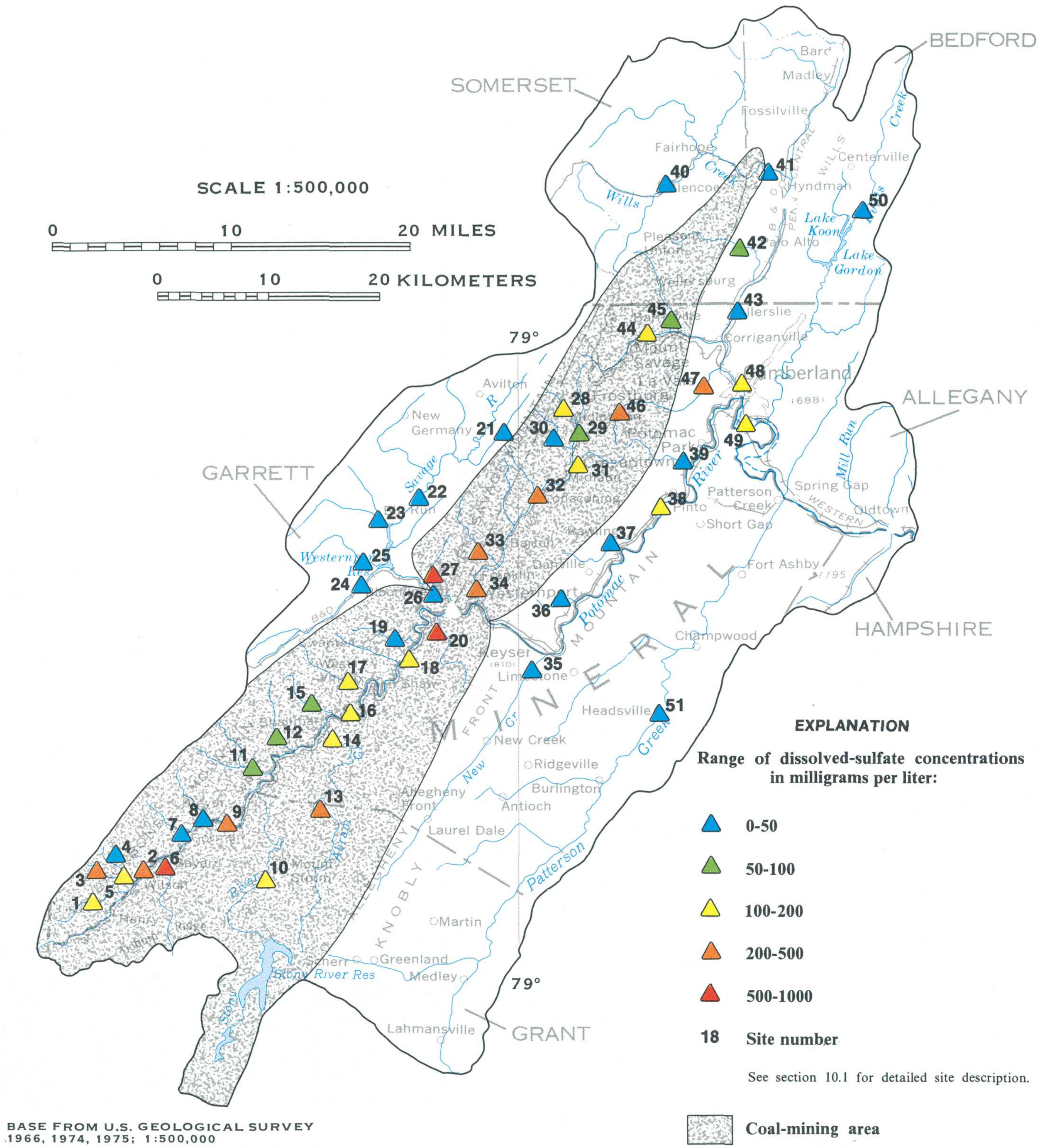


Figure 6.6-2 Mean dissolved-sulfate concentrations measured at selected sites.

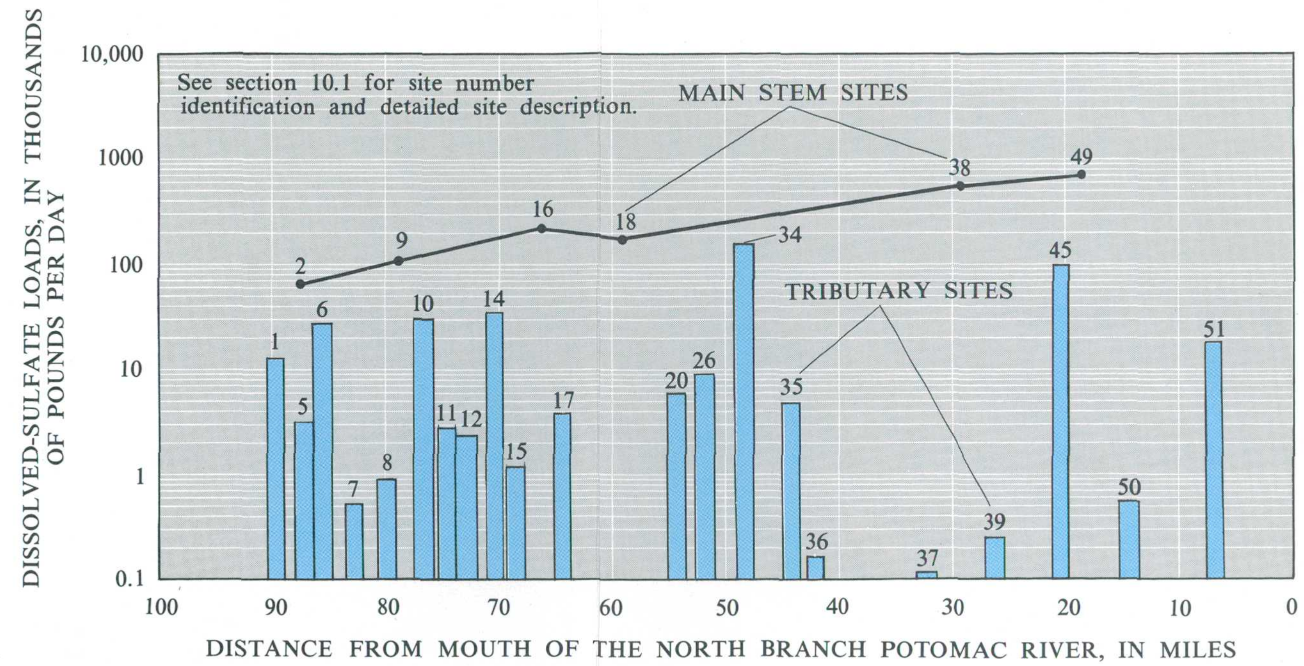


Figure 6.6-3 Dissolved-sulfate loads of the North Branch Potomac River and selected tributaries.

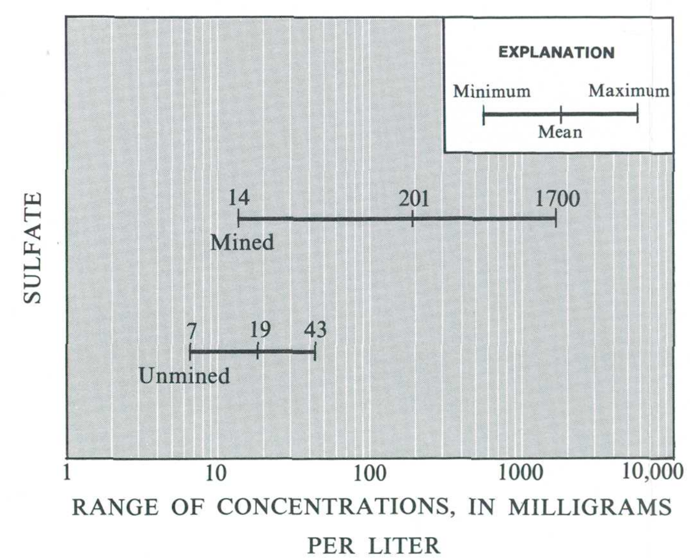


Figure 6.6-1 Range of dissolved-sulfate concentrations measured at sites draining mined and unmined regions.

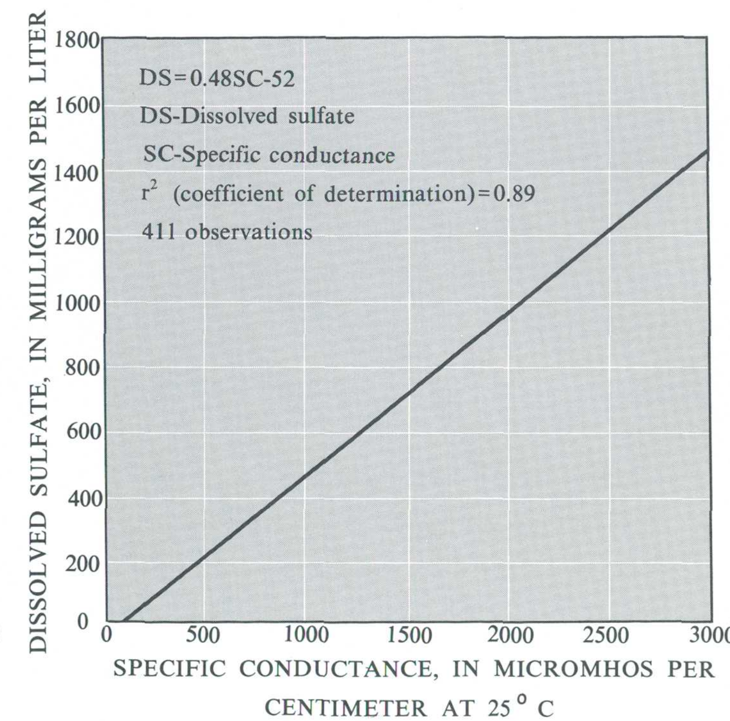


Figure 6.6-4 Relation between specific conductance and dissolved sulfate.

Net-Alkalinity Concentrations Are Variable in Area

Net-alkalinity concentrations of streams draining unmined areas are positive and less variable than the generally negative net-alkalinity concentrations of streams draining mined areas.

Alkalinity is defined as the capacity of a solution to neutralize a strong acid to a defined end-point pH. Several different solute species generally contribute to total alkalinity. However, in most natural freshwater the alkalinity is largely produced by dissolved carbonate and bicarbonate ions. Alkalinity is therefore usually reported as an equivalent quantity of calcium carbonate ($CaCO_3$) (Hem, 1970). The minimum, mean, and maximum alkalinity concentrations measured at selected sites are listed in section 10.4.

Acidity is defined as the capacity of a solution to react with a strong base to a defined end-point pH. Several different solute species can contribute to the total acidity. These species include free H^+, undissociated or partly dissociated acids, and oxidizable metal ions. The by-products of the oxidation of pyrite, sulfuric acid and ferrous iron, both contribute to acidity, and in coal mining areas may be the most important source of acidity. For ease of comparison with alkalinity measurements, acidity is also reported as equivalent concentrations of $CaCO_3$. The minimum, mean, and maximum acidity concentrations measured at selected sites are also listed in section 10.4.

Net alkalinity is determined by subtracting the acidity concentration from the alkalinity concentration. Net alkalinity indicates the neutralization capacity of a stream. If the net alkalinity is less than zero, the water is considered acidic and will have a diminished capacity to neutralize any added acidity. If, however, the net alkalinity is greater than zero, the water is considered alkaline and will be able to neutralize an amount of added acidity. Net alkalinity is therefore an important indicator of a stream's capacity to neutralize acid mine drainage. The minimum, mean, and maximum net-alkalinity concentrations measured at selected sites are listed in section 10.4.

Because of acid mine drainage, streams draining mined areas had a lower mean net-alkalinity concentration than streams draining unmined areas. Streams draining mined areas also tended to have a greater range of net-alkalinity concentrations: from -402 to 136 milligrams per liter (mg/L) as $CaCO_3$, with a mean concentration of -2.5 mg/L. The net alkalinity concentrations of streams draining unmined areas ranged from 0 to 103 mg/L as $CaCO_3$ and had a mean concentration of 30 mg/L as $CaCO_3$. The large variability in net-alkalinity concentrations of streams draining mined areas is due to differences in the quantity and chemical quality of mine drainage reaching a stream; the degree of natural buffering capacity of the stream; and the presence of alkaline domestic or industrial wastes in the stream. Figure 6.7-1 shows the areal distribution of net alkalinity in Area 6, and figure 6.7-2 graphically depicts ranges and means in mined and unmined areas.

The net-alkalinity loads of the North Branch Potomac River and some of its tributaries are shown in figure 6.7-3. The North Branch Potomac River at Barnum, W.Va., site 18 (river mile 62), carries a negative net-alkalinity load due to acid mine drainage from the Upper Potomac Coal Field. The net-alkalinity load of the North Branch Potomac River becomes positive further downstream due to alkaline discharges from Savage River, Georges Creek, New Creek, and from industrial and domestic wastes discharged at Westernport, Md. Georges and Wills Creeks, which drain the Georges Creek Coal Field, both carry positive net-alkalinity loads. Acid mine drainage in these two streams is evidently neutralized by alkaline tributaries and domestic wastes.

The recommended minimum standard for alkalinity has been set at 20 mg/L as $CaCO_3$ for freshwater aquatic life. Alkalinity is important for freshwater aquatic life because it buffers susceptability to pH changes. Components of alkalinity such as carbonate and bicarbonate will also complex some toxic heavy metals and markedly reduce their toxicity (U.S. Environmental Protection Agency, 1976 [1977]).

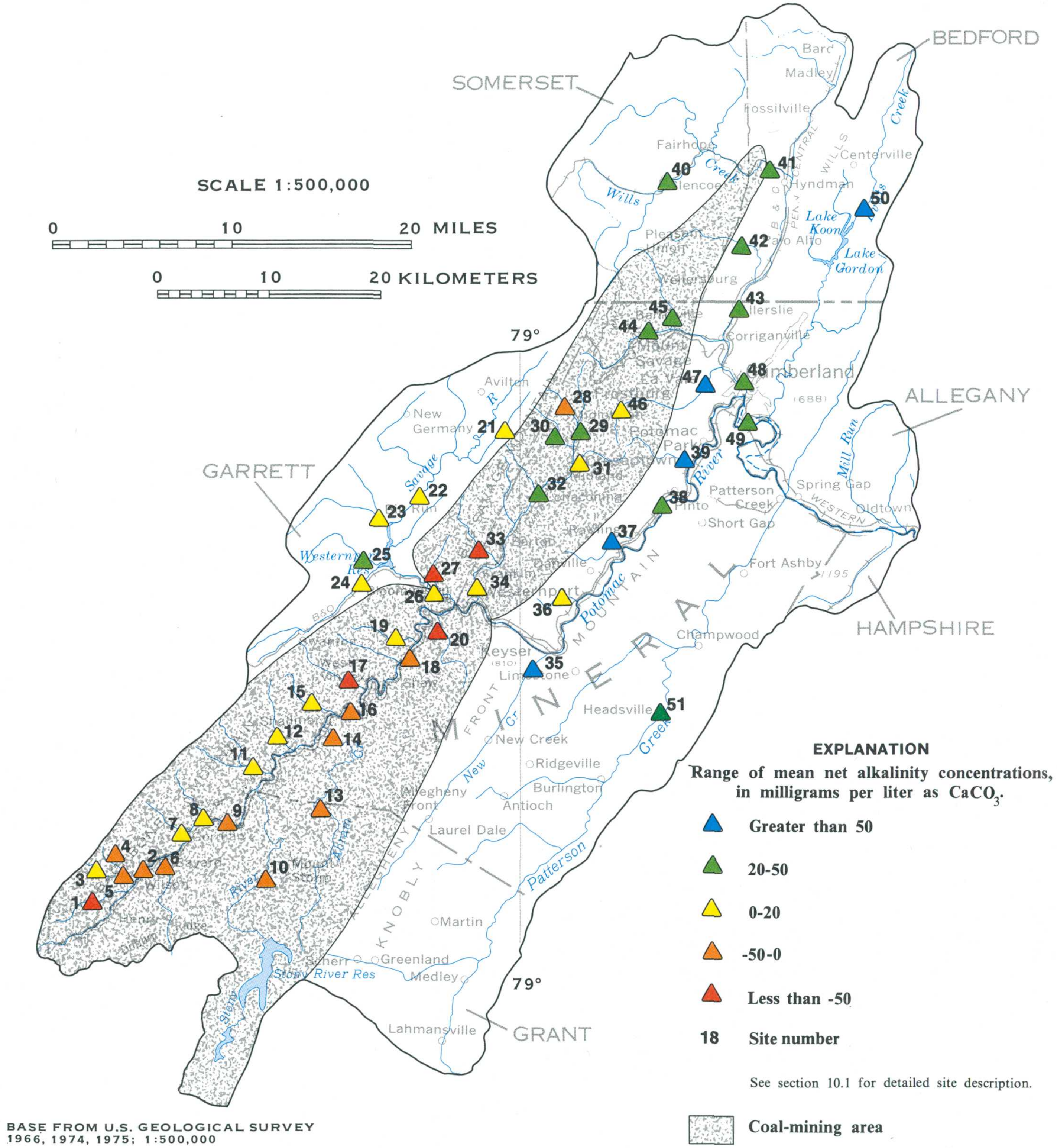


Figure 6.7-1 Mean net-alkalinity concentrations measured at selected sites.

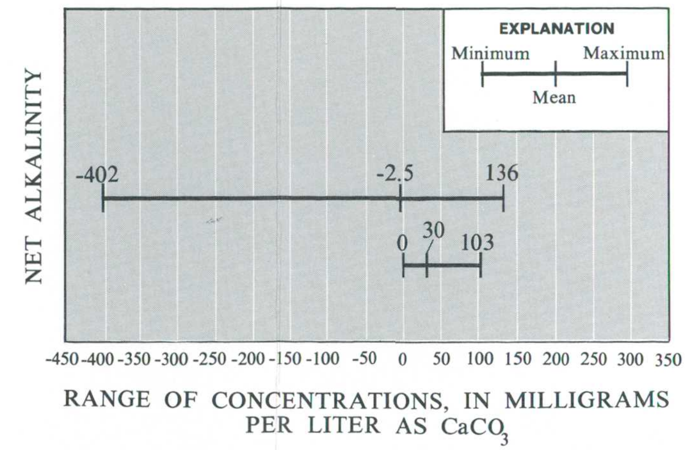


Figure 6.7-2 Range of net-alkalinity concentrations measured at sites draining mined and unmined regions.

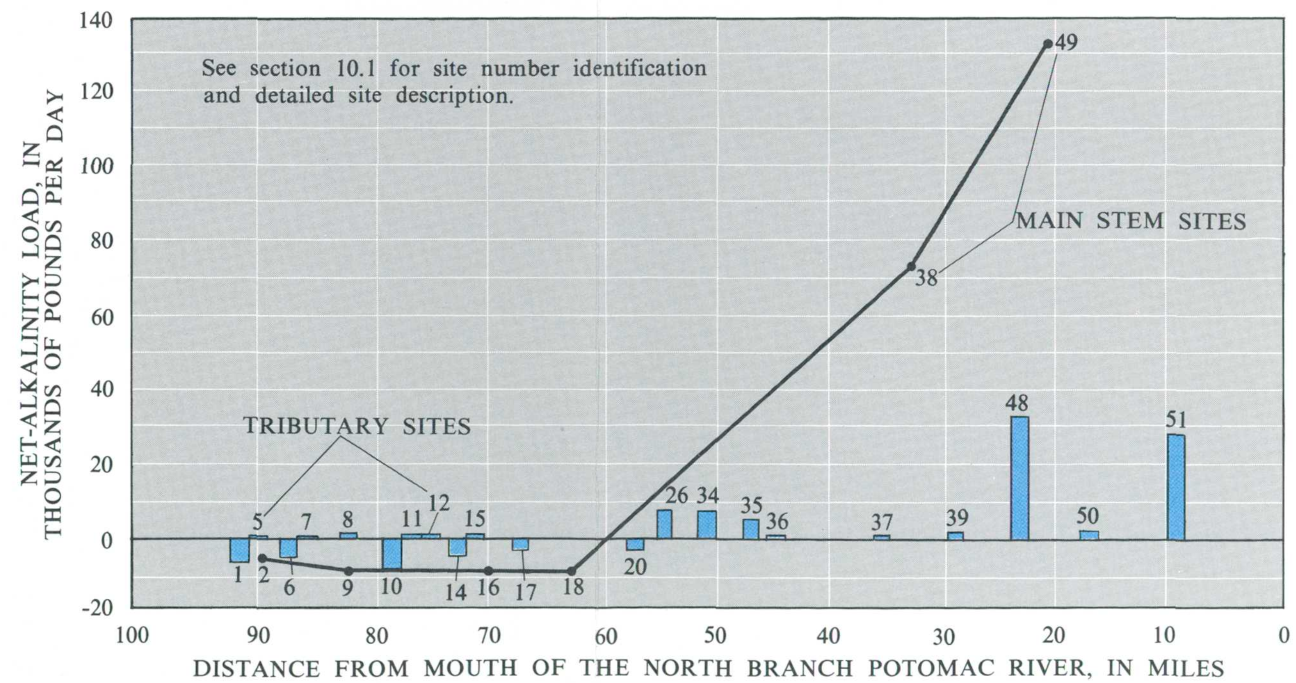


Figure 6.7-3 Net-alkalinity loads of the North Branch Potomac River and selected tributaries.

Trace-Metal Concentrations Generally Low

Trace-metal concentrations measured in the water column and in the bottom material of streams in the area are generally low.

Trace metals are generally found in low concentrations in most streams. The concentration of trace metals in streams is largely dependent on their presence in the rocks and soils of the area, the erosion and weathering processes occurring in the area, waste discharges to the stream or atmosphere, and runoff from developed or disturbed areas. Although large concentrations of some trace metals in stream water may occur naturally, most large concentrations of trace metals are usually associated with waste discharges. Trace metals are generally found in low concentrations in sedimentary rocks such as those found in Area 6. This may account for the usually low concentrations of trace metals found in the streams of the area.

Water-quality samples from selected streams were analyzed for selected trace metals during low-flow periods. As seen in figure 6.8-1, streams draining unmined areas had uniformally low trace-metal concentrations, which in no cases exceeded the U.S. Environmental Protection Agency recommended drinking water standards (U.S. Environmental Protection Agency, 1976 [1977]). Streams draining coal mining areas generally had mean and maximum trace-metal concentrations greater than streams draining unmined areas. The U.S. Environmental Protection Agency drinking water standards for chromium and lead were exceeded in streams draining coal mining areas. Chromium standards were exceeded at 5 sites. Three of the sites are located on streams draining populated areas, and it is possible that the large lead concentrations measured at these sites result from the use of leaded gasoline in automobiles.

Trace metals are readily sorbed to sediment particles. When stream energy cannot support the suspension and transport of sediment, the particles and their associated trace metals are deposited on the streambed. Once deposited, the sediments in the streambed continue to chemically interact with the passing water and continue to adsorb trace metals. The streambed sediment, therefore, acts as an integrator of long-term chemical processes occurring in a stream, and chemical analysis of bottom sediment gives an indication of the quality of water carried by the stream between periods of bottom scour (Feltz, 1980). In comparison, water-quality samples of stream water only measure the quality of water at the particular instant of sampling.

Bottom-material samples from selected streams in Area 6 were analyzed for a limited number of trace metals, and the results reported as micrograms of constituent per gram of dry sample. As observed in figure 6.8-1, bed-material samples collected from streams draining coal mining areas generally had greater mean and maximum trace metal concentrations than streams draining unmined areas. This indicates that over the long term, stream water from coal mining areas generally contains greater concentrations of trace metals than stream water from unmined areas. Arsenic, however, was an exception to this trend. The mean and maximum concentrations of arsenic are greater for streams draining areas with no coal mining. These values are influenced by a single large concentration measured at site 35, New Creek at Keyser, W. Va. All other arsenic concentrations measured at sites on streams draining unmined areas ranged from 0 to 1 microgram per gram.

Trace metal	Mined or unmined	Number of sites with observations	Number of observations
Arsenic, recoverable from water column	Mined	17	32
	Unmined	3	4
recoverable from bottom material	Mined	35	46
	Unmined	8	10
Cadmium, recoverable from water column	Mined	17	32
	Unmined	3	4
recoverable from bottom material	Mined	35	46
	Unmined	9	11
Chromium, recoverable from water column	Mined	17	32
	Unmined	3	4
recoverable from bottom material	Mined	35	46
	Unmined	9	11
Cobalt, recoverable from water column	Mined	17	6
	Unmined	1	4
recoverable from bottom material	Mined	35	46
	Unmined	9	11
Copper, recoverable from water column	Mined	17	32
	Unmined	3	4
recoverable from bottom material	Mined	35	46
	Unmined	9	11
Iron, recoverable from water column	Mined	37	373
	Unmined	11	81
recoverable from bottom material	Mined	35	46
	Unmined	9	11
Lead, recoverable from water column	Mined	17	32
	Unmined	3	4
recoverable from bottom material	Mined	35	46
	Unmined	9	11
Manganese, recoverable from water column	Mined	37	373
	Unmined	11	81
recoverable from bottom material	Mined	35	46
	Unmined	9	11
Mercury, recoverable from water column	Mined	17	34
	Unmined	3	4
recoverable from bottom material	Mined	35	46
	Unmined	8	10
Zinc, recoverable from water column	Mined	17	32
	Unmined	3	4
recoverable from bottom material	Mined	35	46
	Unmined	9	11

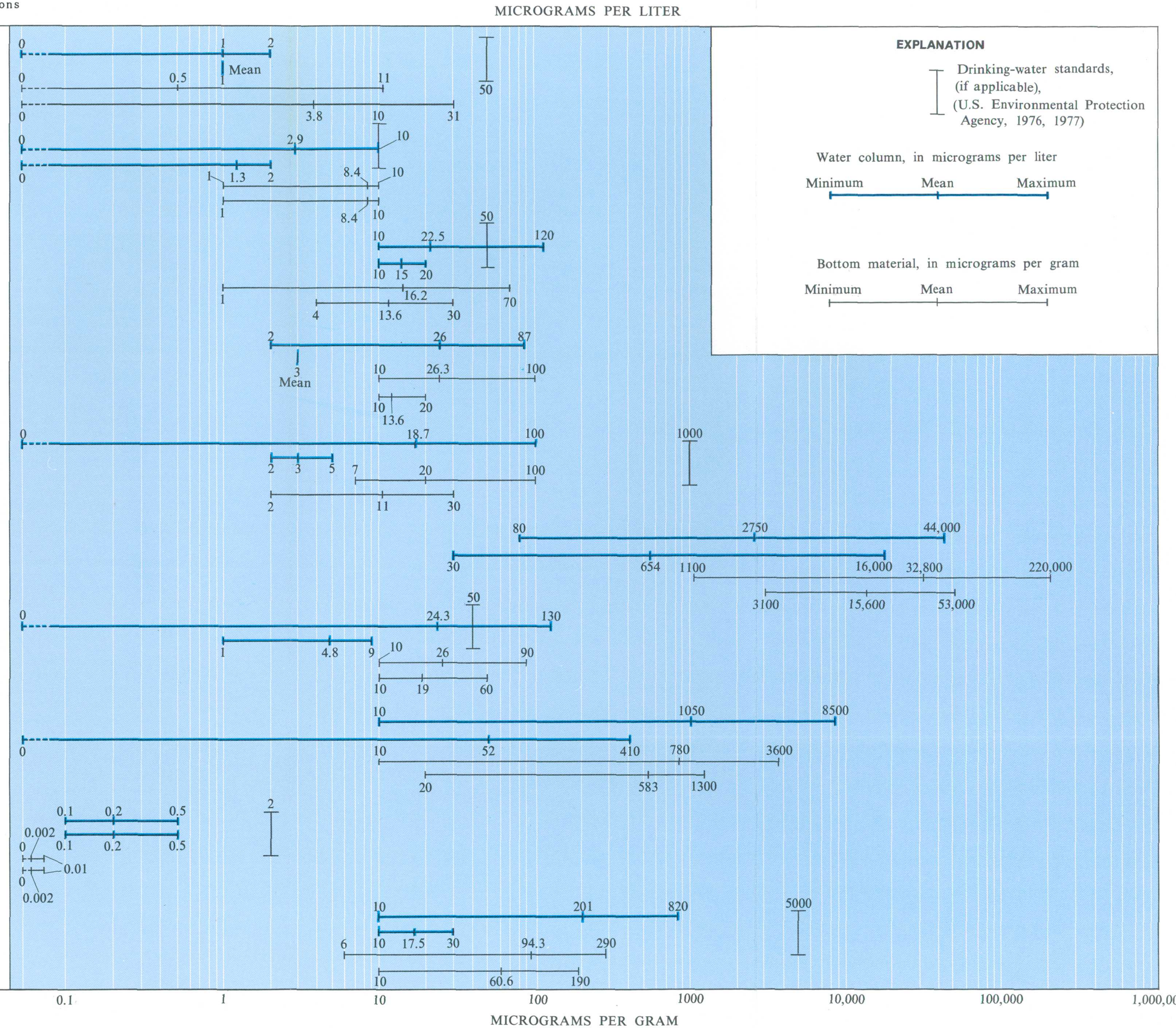


Figure 6.8-1 Range and mean concentrations of trace metals in water column ($\mu g/L$) and in bottom material ($\mu g/g$) and U.S. Environmental Protection Agency (1976a) drinking water standards.

Daily Suspended-Sediment Samples Collected at Three Sites

Suspended-sediment loads were generally higher for mined areas than for unmined areas and ranged from 78 to 233 tons per square mile.

Suspended-sediment samples were collected daily and during storms at three sites in Area 6 during a 20-month period from February 1980, to September 1981. Using the relationships developed in figures 6.9-1, -2, and -3, the sediment record at each site was extended to 24 months, and annual sediment loads were estimated (table 6.9-1). The North Branch Potomac River at Kitzmiller, Md., site 16, which has had 6.6 percent of its drainage area surface mined, had an estimated annual-sediment load of 233 tons per square mile. This sediment load is about three times greater than the 78 tons per square mile estimated annual-sediment load from Crabtree Creek near Swanton, Md., site 24, which is undisturbed by mining. The North Branch Potomac River near Cumberland, Md., site 49, which has had 2.3 percent of its drainage area surface mined and includes all of the surface mining region in Area 6, had an estimated annual-sediment load of 88 tons per square mile during the study period.

Daily- and storm-sediment samples have been collected at site 49 since 1964. During the period of 1964-1980, the mean-annual-sediment load was 190 tons per square mile. This is more than twice the annual-sediment load measured during the study period. However, during the study period discharges were lower than normal, which would account for lower-than-normal sediment yields. Probably the sediment loads measured at sites 16 and 24 during the study period are also less than their long-term averages.

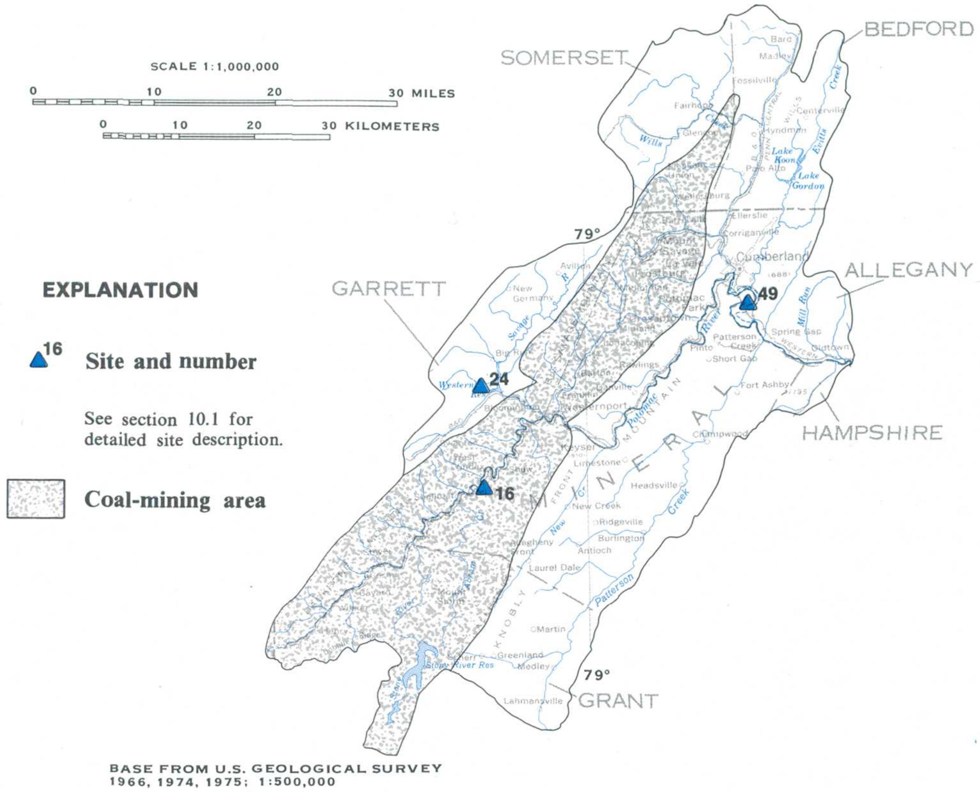
Stream discharge is an important factor affecting the sediment yield of a given watershed. Sediment concentrations and loads are generally greatest during high flows and smallest during low flows. Increased precipitation not only increases the stream's discharge and its ability to carry sediment, but also increases erosion rates and, therefore, the supply of transportable material. Figures 6.9-1, 6.9-2, and 6.9-3 show the relationships between monthly mean discharges and monthly sediment loads measured at sites 16, 24, and 49, respectively.

Sediment concentrations tend to be largest in small streams directly receiving mine drainage. Curtis (1971) and Collier and others (1970) reported sediment concentrations in the 30,000-40,000 milligrams per liter (mg/L) range to be common in Kentucky for small streams (less than 1.5 mi^2) directly below surface mines that had no sediment controls. Further downstream sediment concentrations tend to decrease as sediment is deposited in the stream channel and flood plain, and as cleaner streams dilute the large concentrations. Sediment concentrations measured at sites 16, 24, and 49 ranged from 1-1,150 mg/L, 1-359 mg/L, and 1-852 mg/L, respectively.

Sediment yields of streams are affected by numerous factors, including physiography, soils, climate, and land use. Land-use activities that disturb the land surface, such as surface mining, construction, agriculture, and silviculture, increase erosion and sediment yields. As a land use, active surface mining has one of the highest rates of erosion (U.S. Environmental Protection Agency, 1976).

Surface mining operations yield sediment from newly cleared areas, haul roads, spoil piles, and newly reclaimed land. Strip mine spoil is a mixture of freshly exposed sandstone, limestone, shale, and soil. Spoil rapidly weathers and breaks into unconsolidated particles that are easily erodible (Curtis, 1971). If a mine site is not reclaimed, spoil piles may remain sources of large sediment yields for many years. However, after a mine site is properly reclaimed, erosion decreases significantly, and sediment yield from the mine site becomes a short-term problem.

Increased sediment yields can be detrimental to streams in the immediate vicinity and to those much further downstream. In the local reaches, sediment destroys aquatic habitat by covering it, decreases photosynthetic activity by increasing turbidity, and increases flooding by filling stream channels. Further downstream, sediment fills valuable storage space in reservoirs, increases water treatment and dredging costs, and serves as a carrier of other pollutants.



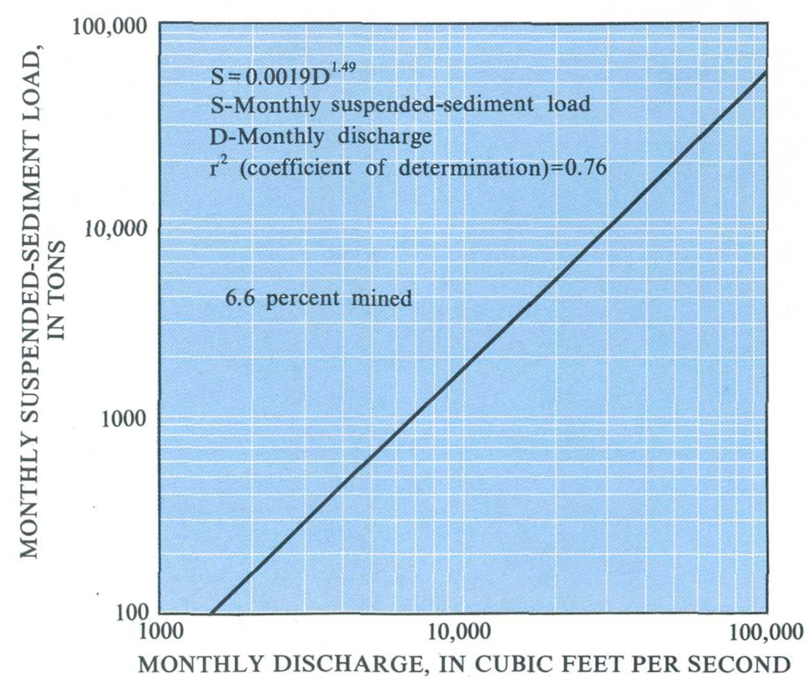


Figure 6.9-1 Relation between monthly discharge and monthly suspended-sediment load at site 16, North Branch Potomac River at Kitzmiller, Md.

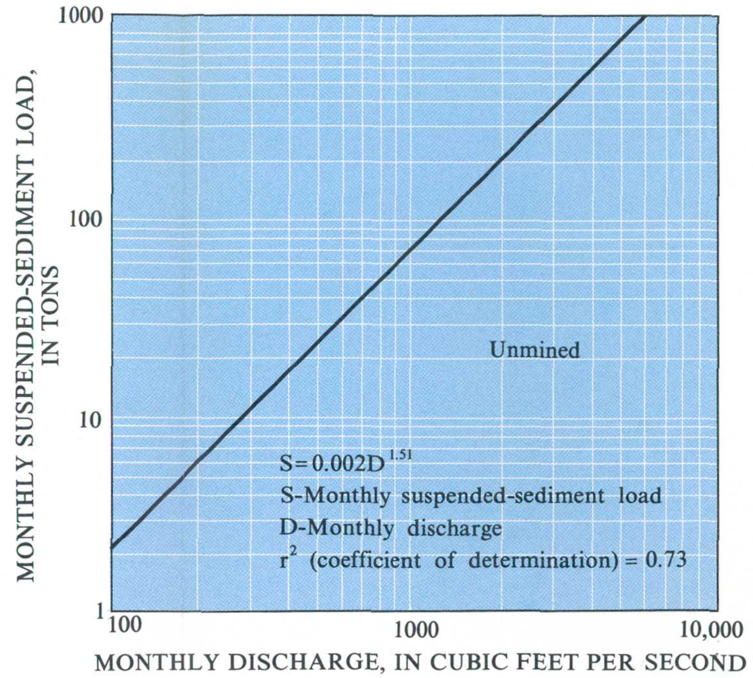


Figure 6.9-2 Relation between monthly discharge and monthly suspended-sediment load at site 24, Crabtree Creek near Swanton, Md.

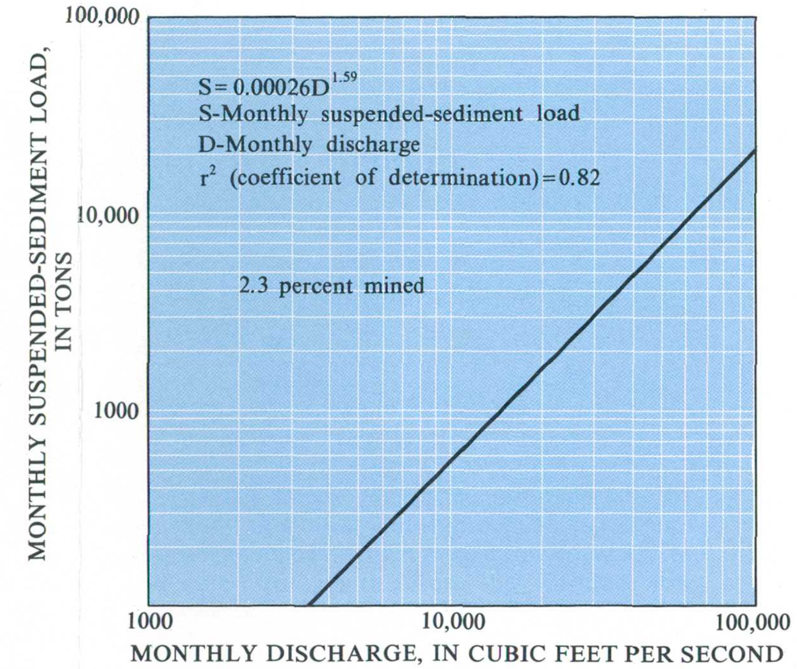


Figure 6.9-3 Relation between monthly discharge and monthly suspended-sediment load at site 49, North Branch Potomac River near Cumberland, Md.

Table 6.9-1 Estimated annual suspended-sediment loads and range of suspended-sediment concentrations measured at three sites in Area 6.

Site number	Station name	Drainage area (square miles)	Surface-mined area (percent)	Estimated annual suspended-sediment loads (tons per square mile)	Period of record	Range of suspended-sediment concentrations (milligrams per liter)
16	North Branch Potomac River at Kitzmiller, Md.	225	6.6	233	February 1980 to September 1981	1-1150
24	Crabtree Creek near Swanton, Md.	16.7	0	78	February 1980 to September 1981	1-359
49	North Branch Potomac River near Cumberland, Md.	875	2.3	88	October 1964 to September 1981	1-852

7.0 GROUND WATER

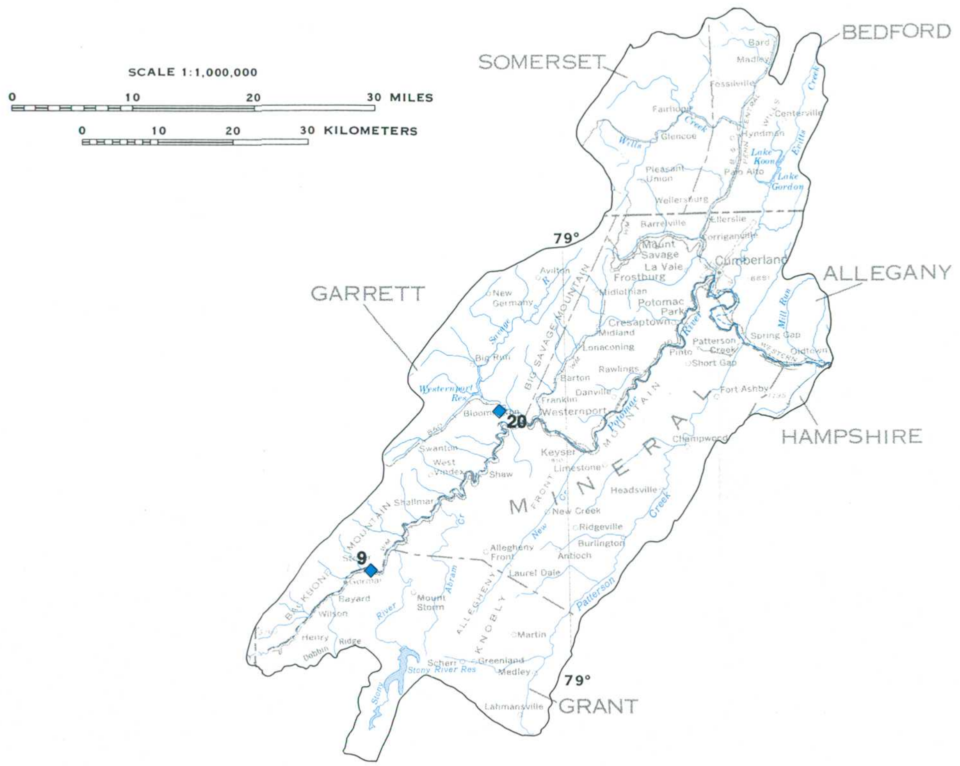
Ground-Water Supplies Are Variable

The largest ground-water supplies available in Area 6 are from sandstone and carbonate rock aquifers.

The availability of ground water varies widely in different aquifers and locations in Area 6. Well yields are influenced by several factors including lithology, geologic structure, bed thickness, and depth. Generally, water occurs in secondary openings such as joints, faults, fractures, bedding-plane partings, and solution cavities. In some sandstone beds, water may occur in the primary openings of intergranular pore spaces (Nutter and others, 1980). The largest ground-water supplies in the area are available from sandstone and carbonate rock aquifers, containing secondary openings within the zone of saturation. Lesser supplies are available from shale and siltstone aquifers, containing almost no secondary openings. All rocks contain fewer secondary openings with increased depth below land surface, resulting in diminished ground-water supplies. This decrease in ground-water supply with depth is most marked in shale (Hobba and others, 1972). Descriptions of the geologic formations commonly used as aquifers in the area, their generalized water-bearing properties, mean and median well yields, and mean and median specific capacities are listed in table 7.0-1.

Ground-water levels measure relative changes in the volume of ground-water storage and identify periods of ground-water recharge and dewatering. Ground-water levels vary with well depth, the timing and quantity of precipitation and evapotranspiration, and manmade influences, such as impounding, pumping, and surface and deep mining. Figure 7.0-1 shows ground-water levels measured at a shallow well in the Conemaugh Formation and illustrates that the time of year in which precipitation occurs is critical to ground-water recharge. Precipitation that falls on unfrozen ground during the dormant growth season can infiltrate to the water table and increase ground-water levels. This is observed in figure 7.0-1; recharge resulted from increased precipitation during the winter, spring, and fall of 1979 and the spring of 1980. However, if the bulk of annual precipitation occurs during the summer months, much of the precipitation is evaporated at the ground surface, or transpired by plants, and never reaches the water table. This can be seen in figure 7.0-1 during the summer of 1980 when ground-water levels dropped, even though precipitation was the greatest it had been in two years. On the average, precipitation in Area 6 occurs fairly uniformly throughout the year, resulting in ground-water recharge in the winter and spring. Ground-water levels, therefore, tend to be highest in the spring and lowest in the fall.

The effect of deep mining on the ground-water level of a well located in the Conemaugh Formation is shown in figure 7.0-2. This figure illustrates the dewatering of an aquifer located above a newly mined side cut. In January 1981, a side cut was begun over 1200 feet from well site number 9. By July 1 the side cut was within 300 feet of the well, and mining was suspended. Figure 7.0-2 shows the concurrent drop in water level of the well (M. T. Duigon, Hydrologist, Maryland Geological Survey, Towson, Md., oral communic., 1982).

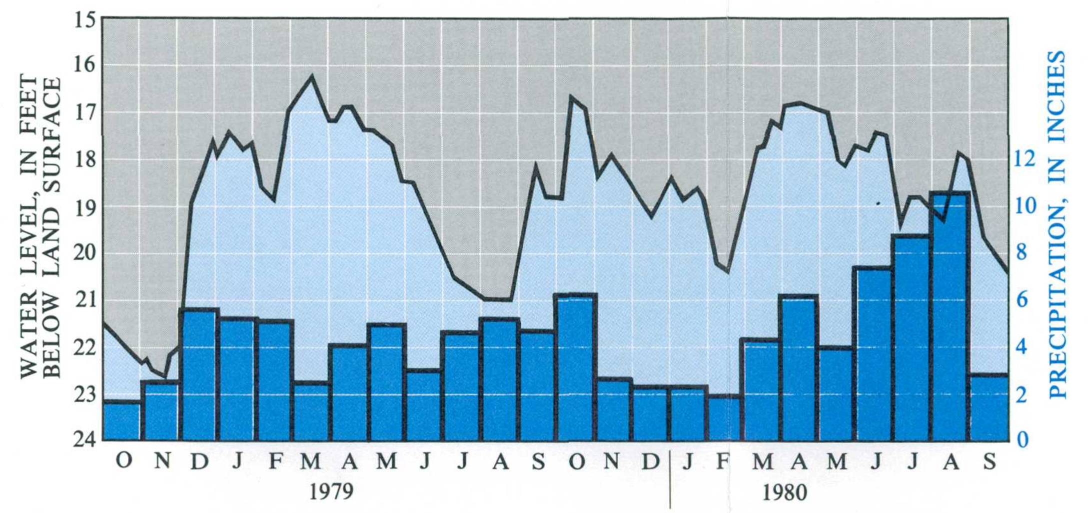


BASE FROM U.S. GEOLOGICAL SURVEY
1966, 1974, 1975: 1:500,000

EXPLANATION

20 **Site and number**

See section 10.2 for detailed site description.



EXPLANATION

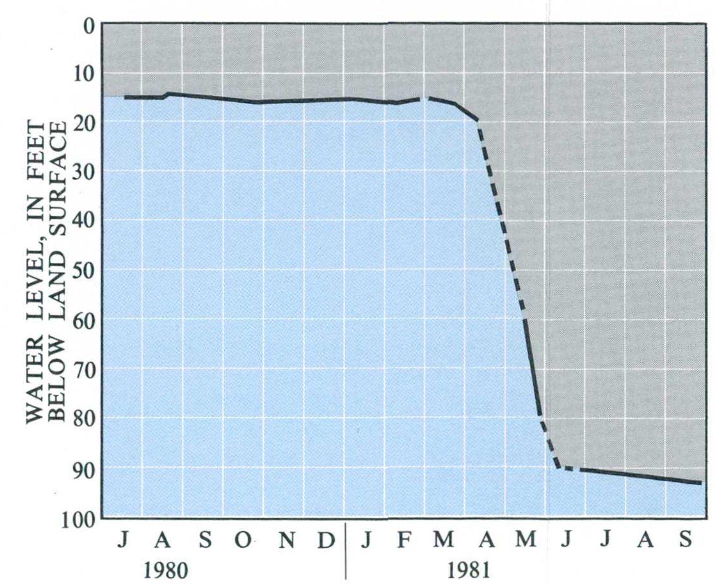
Observed water level
Precipitation

Figure 7.0-1 Water levels measured at Site 20 near Mt. Storm, W.Va., and monthly precipitation measured at Bayard, W.Va.

Table 7.0-1 Geologic formations and their water-bearing properties.

System	Formation	Thickness (feet)	Lithology	Water-bearing properties	Mean yield (gal/min)	Median yield (gal/min)	Sample size	Mean specific capacity (gal/min/ft)	Median specific capacity (gal/min/ft)	Sample size
Quartarnary	Deposits of Holocene and Pleistocene age	0-70	Alluvium, peat deposits slide rock, sand and gravel.	Not important aquifers owing to small areal extent and thickness.	--	--	--	--	--	--
Pennsylvanian	Monongahela	240-270	Shale, siltstone, sandy shale, sandstone, coal seams	Not an important aquifer because of small areal extent, and the formation is is partly drained by mine shafts and drifts.	--	--	--	--	--	--
	Conemaugh	850-950	Sandstone, shale, siltstone, red beds, clay, shaley limestone, coal seams	Important aquifer in the coal basins. Well yields range from 1 to 200 gal/min; mean yield 13.3 gal/min and median yield 7 gal/min.	13.3	7	273	0.65	0.20	168
	Alleghany	275-325	Sandstone, sandy shale, siltstone, clay beds, coal seams	Important aquifer is the coal basins. Formation is not mapped separately in Garrett County.						
	Pottsville	180-250	Sandstone (conglomeratic in lower part), siltstone shale, claystone, a few thin discontinuous coal seams	Moderately important aquifer along the flanks of coal basins. Relatively few wells derive water from this formation, but it has potential for yielding moderately large quantities. Well-yield data combined with Allegheny. Well yields range from 0.5 to 150 gal/min; mean yield 13.1 gal/min and median yield 7 gal/min.	13.1	7	127	.41	.155	80
Mississippian	Mauch Chunk	500-700	Red and green sandy shale, platy sandstone beds	Moderately important aquifer along the flanks of Deer Park and Accident anticlines. Well yields range from 3 to 51 gal/min; mean yield 11.8 gal/min and median yield 10 gal/min.	11.8	10	41	.25	.18	27
	Green Briar	200-300	Red and green shale, lenticular limestone, limy sandstone	Moderately important aquifer along flanks of anticlinal structures. Well yields range from 1 to 300 gal/min; mean yield 32.6 gal/min and and median yield 14 gal/min. Numerous springs used for water water supplies.	32.6	14	48	3.10	.40	31
	Pocono	700-1,300	Coarse-grained sandstone (locally conglomeratic), shale, sandy shale	Important aquifer in Deer Park and Accident anticlines. Many wells and springs in Pocono including several fairly high-yielding wells. Yields range from 0.8 to 130 gal/min; mean yield 13.1 gal/min and median yield 7.5 gal/min.	13.1	7.5	132	.82	.135	94
Devonian	Hampshire	1,400-2,000	Brown and green sandy shale, shale, thin-bedded sandstone, red beds	Important aquifer in Deer Park and Accident anticlines. Well yields range from 1 to 60 gal/min; mean yield 12.0 gal/min and median yield 8 gal/min.	12	8	165	.32	.13	132
	Jennings	4,000-5,000	Gray and green shale and sandy shale, sandy siltstone, thin-bedded sandstone	Important aquifer in Deer Park anticline area. Well yields range from 0.2 to 50 gal/min; mean yield 8.7 gal/min and median yield 7 gal/min.	8.7	7	186	.41	.13	149

SOURCE: Nutter and others, 1980.



EXPLANATION

Observed water level
Estimated water level

Figure 7.0-2 Water levels measured at site 9 near Wilson, Md.

NAWDEX, WATSTORE, and OWDC Have Water Data Information

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

Within the U.S. Geological Survey there are three activities that help to identify and improve access to the vast amount of existing water data. These activities are:

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

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

(3) The Office of Water Data Coordination (OWDC), which coordinates Federal water-data acquisition activities and maintains a "Catalog of Information on Water Data." To assist in identifying available water-data activities in coal provinces of the United States, special indexes to the Catalog are being printed and made available to the public.

A more detailed explanation of these three activities are given in sections 8.2, 8.3, and 8.4.

NAWDEX Simplifies Access to Water Data

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

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

Services are available through a Program Office located at the U.S. Geological Survey's National Center in Reston, Virginia, and a nationwide network of Assistance Centers located in 45 states and Puerto Rico, which provide local and convenient access to NAWDEX facilities (fig. 8.2-1). A directory is available on request that provides names of organizations and persons to contact, addresses, telephone numbers, and office hours for each of these locations [Directory of Assistance Centers of the National Water Data Exchange (NAWDEX), U.S. Geological Survey Open-File Report 79-423 (revised)].

NAWDEX can assist any organization or individual in identifying and locating needed water data and referring the requester to the organization that retains the data required. To accomplish this service, NAWDEX maintains a computerized Master Water Data Index (fig. 8.2-2), which identifies sites for which water data are available, the type of data available for each site, and the organization retaining the data. A water Data Sources Directory (fig. 8.2-3) also is maintained that identifies organizations that are sources of water data and the locations within these organizations from which data may be obtained. In addition NAWDEX has direct access to some large water-data bases of its members and has reciprocal agreements for the exchange of services with others.

Charges for NAWDEX services are assessed at the option of the organization providing the requested data or data service. Search assistance services are provided free by NAWDEX to the greatest extent possible. Charges are assessed, however, for those requests requiring computer cost, extensive personnel time, duplicating services, or other costs encountered by NAWDEX in the course of providing services. In all cases, charges assessed by NAWDEX Assistance Centers will not exceed the direct costs incurred in responding to the data request. Estimates of cost are provided by NAWDEX upon request and in all cases where costs are anticipated to be substantial.

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

Program Office
National Water Data Exchange (NAWDEX)
U.S. Geological Survey
421 National Center
12201 Sunrise Valley Drive
Reston, VA 22092
Telephone: (703) 860-6031
FTS 928-6031
Hours: 7:45 - 4:15 Eastern Time

Maryland
U.S. Geological Survey
Water Resources Division
208 Carroll Building
8600 LaSalle Road
Towson, Maryland 21204
Telephone: (301) 828-1535
FTS: 922-7872
Hours: 7:45 - 4:15 Eastern Time

West Virginia
U.S. Geological Survey
Water Resources Division
Room 3017, Federal Building and U.S. Courthouse
500 Quarrier Street, East
Charleston, West Virginia 25301
Telephone: (304) 343-6181
FTS: 924-1300

Pennsylvania
U.S. Geological Survey
Water Resources Division
4th Floor, Federal Building
P.O. Box 1107
Harrisburg, Pennsylvania 17108
Telephone: (717) 782-3851
FTS: 590-3851

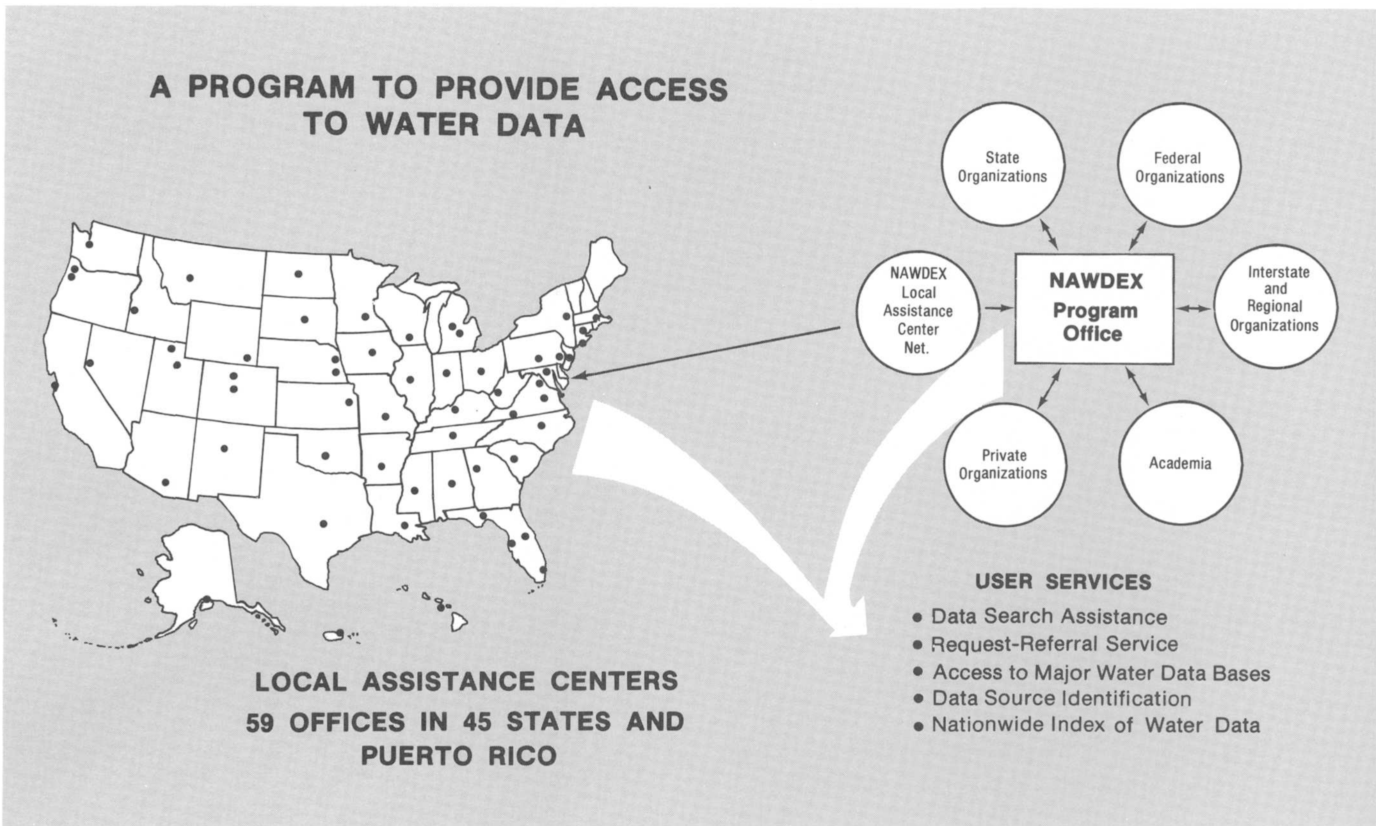


Figure 8.2-1 Access to water data.

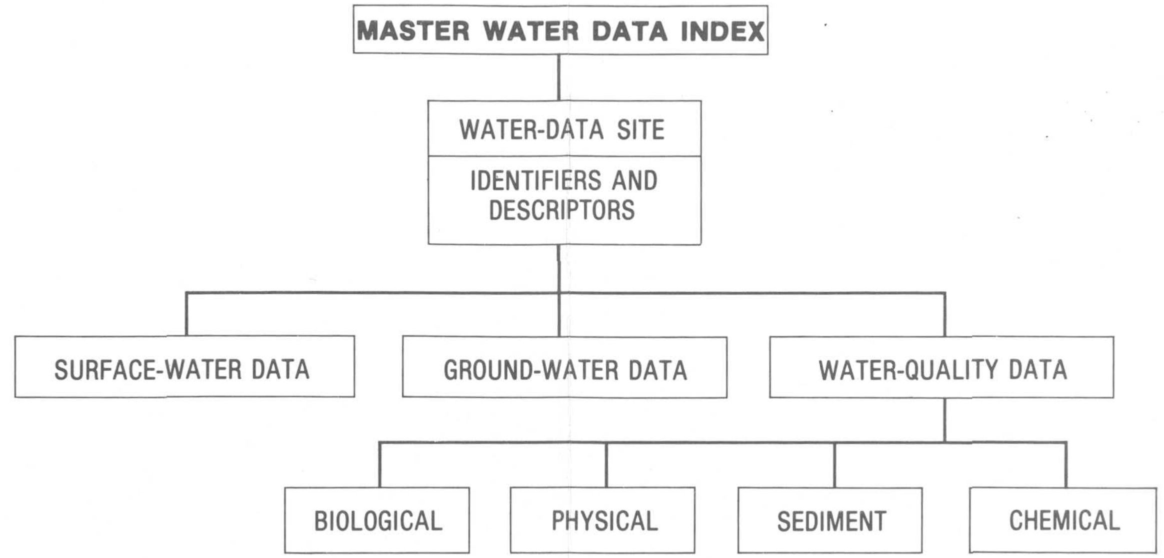


Figure 8.2-2 Master water-data index.

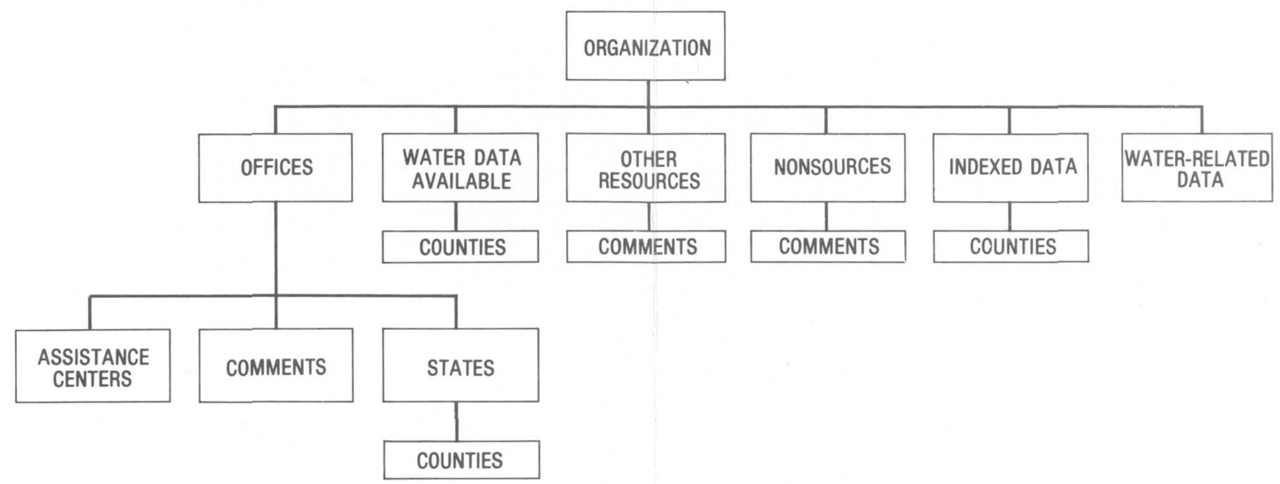


Figure 8.2-3 Water-data sources directory.

WATSTORE Automated Data System

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

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

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

Maryland
U.S. Geological Survey
Water Resources Division
208 Carroll Building
8600 LaSalle Road
Towson, Maryland 21204

West Virginia
U.S. Geological Survey
Water Resources Division
Room 3017, Federal Building and U.S. Courthouse
500 Quarrier Street, East
Charleston, West Virginia 25301

Pennsylvania
U.S. Geological Survey
Water Resources Division
4th Floor, Federal Building
P.O. Box 1107
Harrisburg, Pennsylvania 17108

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

The WATSTORE system consists of several files in which data are grouped and stored by common characteristics and data-collection frequencies. The system is also 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. 8.3-1). A brief description of each file is as follows:

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

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

Peak Flow File: Annual maximum (peak)

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

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

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

Ground-Water Site-Inventory File: This file is 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 70,000 sites.

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

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

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

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

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

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

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

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

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

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

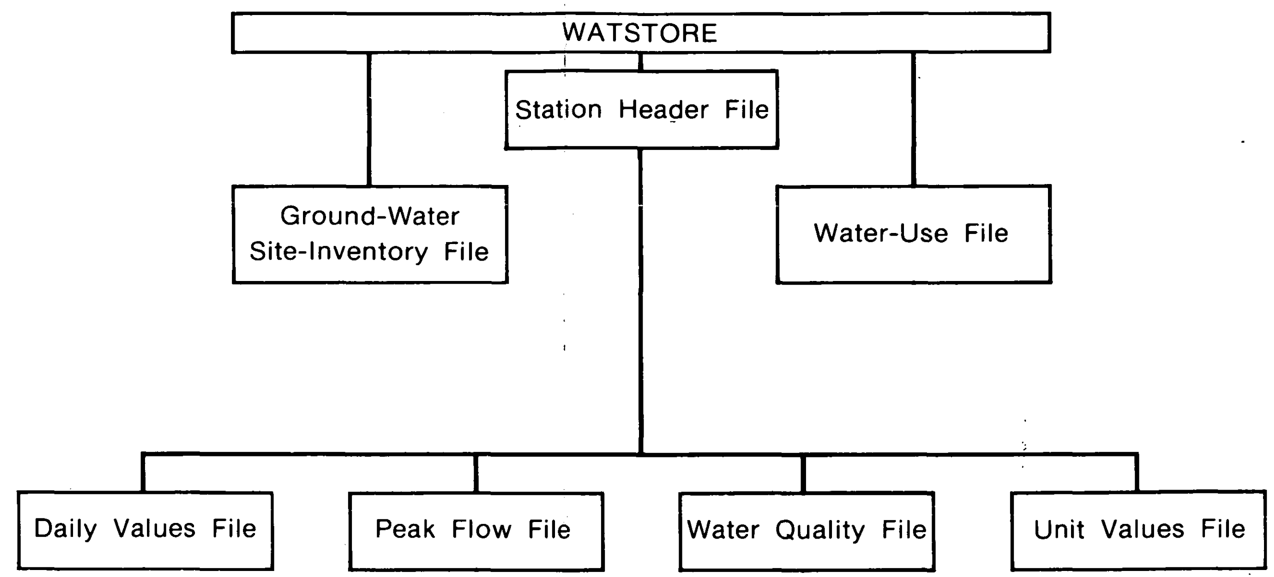


Figure 8.3-1 Index file stored data.

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. 8.4-1): 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 a table.

Those who need additional information from the Catalog file or who need assistance in obtaining water data should contact the National Water Data Exchange (NAWDEX) (see section 8.2).

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

Maryland
U.S. Geological Survey
Water Resources Division
208 Carroll Building
8600 LaSalle Road
Towson, Maryland 21204
Telephone: (301) 828-1535
FTS: 922-7872
Hours: 7:45 - 4:15 Eastern Time

West Virginia
U.S. Geological Survey
Water Resources Division
Room 3017, Federal Building and U.S. Courthouse
500 Quarrier Street, East
Charleston, West Virginia 25301
Telephone: (304) 343-6181
FTS: 924-1300

Pennsylvania
U.S. Geological Survey
Water Resources Division
4th Floor, Federal Building
P.O. Box 1107
Harrisburg, Pennsylvania 17108
Telephone: (717) 782-3851
FTS: 590-3851

Office of Surface Mining
U.S. Department of the Interior
603 Morris Street
Charleston, West Virginia
Telephone: (304) 342-8125
FTS: 924-7125

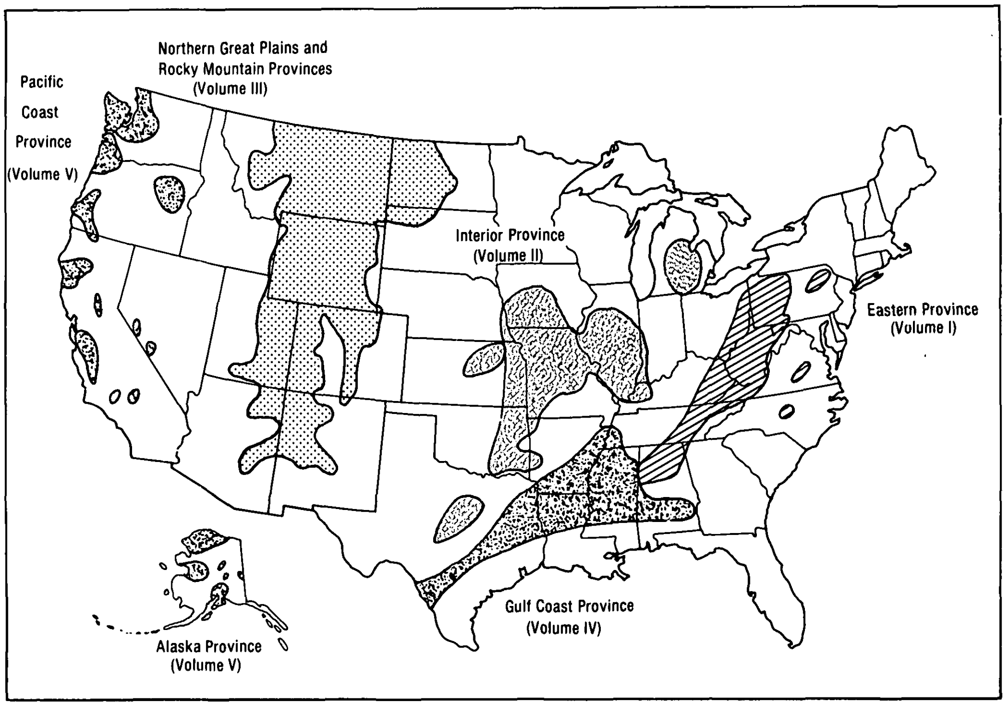


Figure 8.4-1 Index volumes and related provinces.

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Table 10.1-1 Surface-water station data.

Site number	Station identification number	Station type[1]	Station name	Drainage area (square miles)	Latitude ° ' "	Longitude ° ' "	Period of discharge record	Period of water-quality record
1	01594930	S	Laurel Run at Dobbin Rd. nr. Wilson, Md.	8.3	39 14 37	79 24 43	1979-1981	1979-1981
2	01594931	S	North Branch Potomac River at Wilson, Md.	25.9	39 15 10	79 23 56	1979-1981	1979-1981
3	01594934	S	South Fork Sand Run nr. Wilson, Md.	1.6	39 15 31	79 24 40	1979-1981	1979-1981
4	01594936	S	North Fork Sand Run nr. Wilson, Md.	1.9	39 15 36	79 24 36	1979-1981	1979-1981
5	01594942	S	Sand Run at Wilson, Md.	3.9	39 15 13	79 24 04	1979-1980	1979-1980
6	01594960	S	Buffalo Creek at Bayard, W. Va.	9.9	39 16 23	79 21 58	1980-1981	1980-1981
7	01594965	S	Nydegger Run at Gorman, Md.	5.2	39 17 51	79 20 54	1980-1981	1980-1981
8	01594975	S	Glade Run at Steyer, Md.	8.8	39 18 08	79 19 33	1977-1981	1979-1981
9	01595000	R	North Branch Potomac River at Steyer, Md.	72.7	39 18 07	79 18 26	1956-1981	1979-1981
10	01595200	R	Stony River nr. Mt. Storm, W. Va.	48.4	39 16 10	79 15 45	1961-1981	1962-1981
11	01595225	S	Laurel Run at Riley Rd. nr. Steyer, Md	9.2	39 20 54	79 17 26	1980-1981	1980-1981
12	01595250	S	Lostland Run at Lostland Run Rd. nr. Taskers Corners, Md.	9.6	39 22 14	79 15 14	1980-1981	1980-1981
13	01595275	S	Abram Cr. at Rt.50 Bridge nr.Mt.Storm,W.Va.	21.5	39 18 45	79 12 43	1979-1980	1979-1980
14	01595300	R	Abram Cr. at Oakmont, W. Va.	47.3	39 22 00	79 10 45	1956-1981	1960-1961 1965,1969-71
15	01595495	S	Wolfden Run at Kitzmiller, Md.	4.5	39 23 32	79 11 57	1979-1980	1979-1980
16	01595500	S	North Branch Potomac River at Kitzmiller, Md.	227.3	39 23 38	79 10 55	1949-1981	1961-1981
17	01595550	S	Three Forks Run at Vindex, Md.	7.3	39 24 53	79 10 55	1980-1981	1980-1981
18	01595800	S	North Branch Potomac River at Barnum, W. Va.	267.9	39 26 44	79 06 39	1966-1981	1979-1980
19	01595810	S	Folly Run nr. Barnum, W. Va.	4.8	39 27 00	79 06 32	1980	1980
20	01595900	S	Piney Swamp Run at Hampshire, W. Va.	6.1	39 28 17	79 05 00	1980-1981	1980-1981
21	01596200	S	Little Savage River nr. Avilton, Md.	2.0	39 36 59	79 01 29	1979-1980	1979-1980
22	01596500	S	Savage River nr. Barton, Md.	48.3	39 34 05	79 06 10	1948-1981	1979-1981
23	01596600	S	Big Run nr. Swanton, Md.	13.0	39 32 45	79 08 31	1977-1980	1979-1980
24	01597000	S	Crabtree Creek nr. Swanton, Md.	17.1	39 30 00	79 09 35	1948-1981	1979-1981
25	01597100	S	Middle Fork nr. Swanton, Md.	10.8	39 30 46	79 09 17	1977-1981	1979-1981
26	01597500	R	Savage River below Savage River Dam nr. Bloomington, Md.	105.9	39 30 05	79 07 25	1948-1981	1979-1981
27	01597900	S	Aaron Run at Bloomington, Md.	3.5	39 29 11	79 05 01	1979-1981	1979-1981
28	01598750	S	Winebrenner Run at Midlothian, Md.	3.0	39 38 03	78 57 05	1980-1981	1980-1981
29	01598770	S	Georges Creek at Ocean, Md.	13.1	39 36 11	78 56 46	1979-1981	1979-1981
30	01598775	S	Woodland Creek at Ocean, Md.	5.5	39 36 12	78 56 46	1979-1981	1979-1980
31	01598820	S	Neff Run at Midland, Md.	5.5	39 35 26	78 56 56	1979-1981	1979-1980
32	01598870	S	Koontz Run at Lonaconing, Md.	3.7	39 34 33	78 59 14	1980-1981	1980-1981
33	01598980	S	Mill Run at Morrison, Md.	7.4	39 31 03	79 01 44	1979-1981	1979-1981
34	01599000	R	Georges Creek at Franklin, Md.	73.3	39 29 38	79 02 42	1905-1906 1929-1981	1979-1981
35	01599600	S	New Creek at Keyser, W. Va.	51.2	39 25 49	78 59 05	1931,1948-1963, 1965-1969	1979-1981
36	01599700	S	Deep Hollow at Dawson Church, Md.	1.7	39 29 01	78 56 37	1979-1980	1979-1980
37	01599800	S	Mill Run at Rawlins, Md.	2.8	39 32 01	78 56 37	1979-1981	1979-1981
38	01600000	R	North Branch Potomac River at Pinto, Md.	597.2	39 33 59	78 50 25	1938-1981	1969-1974 1976-1981

Table 10.1-1 Surface-water station data--continued.

Site number	Station identification number	Station type[1]	Station name	Drainage area (square miles)	Latitude ° ' "	Longitude ° ' "	Period of discharge record	Period of water-quality record
39	01600500	S	Warrior Run at Cresaptown, Md.	6.6	39 35 44	78 50 05	1979-1981	1979-1981
40	01600490	S	Wills Creek at Glencoe, Pa.	--	39 49 12	78 50 41	1980-1981	1980-1981
41	01600498	S	Wills Creek nr. Hyndman, Pa.	--	39 50 04	78 44 54	1980-1981	1980-1981
42	01601080	S	Gladdens Run nr. Hyndman, Pa.	--	39 44 42	78 45 15	1980-1981	1980-1981
43	01601100	S	Wills Creek at Ellerslie, Md.	184.6	39 43 04	78 46 17	1979-1981	1979-1981
44	01601280	S	Jennings Run at Barrelville, Md.	19.9	39 42 02	78 50 42	1979-1981	1979-1981
45	01601300	S	North Branch Jennings Run at Barrelville, Md.	11.7	39 42 14	78 50 39	1979-1981	1979-1981
46	01601420	S	Hoffman Drainage Tunnel at Clarysville,Md.		39 38 18	78 53 35	1979-1981	1979-1981
47	01601490	S	Braddock Run at Narrows Park, Md.	17.1	39 40 12	78 47 37	1979-1981	1979-1981
48	01601500	R	Wills Creek nr. Cumberland, Md.	246.6	39 40 07	78 47 18	1905-1906 1929-1981	1979-1981
49	01603000	T	North Branch Potomac River nr. Cumberland, Md.	874.8	39 37 16	78 46 24	1929-1981	1965-1981
50	01603500	S	Evitts Creek near Centerville, Pa.	30.2	39 47 23	78 38 48	1932-1981	1979-1981
51	01604500	S	Patterson Creek nr. Headsville, W. Va.	219.0	39 26 35	78 49 20	1938-1981	1979-1981
52	01596005	Q	Savage River nr. Frostburg, Md.	1.5	39 40 56	78 57 54	1971-1981	---------
53	01598500	Q	North Branch Potomac River at Luke, Md.	404	39 28 45	79 03 55	1899-1906 1949-1981	---------
54	01600700	Q	Little Wills Creek at Bard, Pa.	10.2	39 55 35	78 39 40	1961-1981	---------
55	01601000	Q	Wills Creek bl. Hyndman, Pa.	146	39 48 43	78 43 00	1951-1967 1968-1980	---------
56	01605475	Q	Seven Springs Run at Oldtown, Md.	9.16	39 32 29	78 36 28	1975-1981	---------

[1]S - Synoptic
R - Regular
T - Trend
Q - Surface-water-quantity data only

Table 10.2-1 Observation well data.

Site number	Local identification number	Latitude and longitude (o ' ")	Water-bearing unit	Period of record	Frequency of measurement[1]	Depth of well (feet)
1	GA-FA 25	39 15 59 79 26 09	Conemaugh	1978-	P	315
2	GA-FA 26	39 15 59 79 26 09	Conemaugh	1978-	P	170
3	GA-FA 27	39 15 11 79 26 50	Conemaugh	1978-	P	215
4	GA-FA 28	39 15 12 79 27 09	Conemaugh	1978-	P	341
5	GA-FA 29	39 15 12 79 27 09	Conemaugh	1978-	P	226
6	GA-FA 31	39 15 39 79 25 46	Allegheny	1980-	C	606
7	GA-FA 32	39 15 39 79 25 46	Conemaugh	1979-	C	473
8	GA-FA 33	39 15 39 79 25 46	Conemaugh	1979-	C	391
9	GA-FA 34	39 15 39 79 25 46	Conemaugh	1979-	C	115
10	GA-FA 36	39 15 59 79 26 12	Conemaugh	1978-	P	210
11	GA-FB 22	39 15 30 79 24 44	Allegheny	1980-	C	640
12	GA-FB 23	39 15 30 79 24 44	Conemaugh	1980-	C	495
13	GA-FB 24	39 15 30 79 24 44	Conemaugh	1980-	C	400
14	GA-FB 25	39 15 30 79 24 44	Conemaugh	1980-	C	180
15	GA-FB 26	39 15 13 79 24 36	Allegheny	1980-	C	832
16	GA-FB 27	39 15 13 79 24 36	Conemaugh	1980-	C	656
17	GA-FB 28	39 15 13 79 24 36	Conemaugh	1980-	C	556
18	GA-FB 29	39 15 13 79 24 36	Conemaugh	1980-	C	360
19	GA-FB 30	39 15 13 79 24 36	Conemaugh	1980-	C	85
20	--------	39 16 52 79 18 14	Conemaugh	1978-	C	24
21	22-5-23	39 21 11 79 08 11	Conemaugh	1968-	P	37
22	GA-AG 1	39 41 16 78 58 16	Pocono or Greenbrier	1946-	P	30
23	ALL-BD 2	39 39 30 78 46 09	Tonoloway	1946-	P	85
24	ALL-CA 19	39 30 09 79 02 52	Conemaugh	1974-	P	85

[1]C - Continuous
P - Periodic

Table 10.3-1 Peak discharge of record, estimated peak discharge, and estimated flood volume for gaged streams.

Site number	Drainage area (mi^2)	Discharge in cubic feet per second								
		Peak of record	Peak discharge					Flood volume		
			Q_2	Q_{10}	Q_{25}	Q_{50}	Q_{100}	$Q_{1,2}$	$Q_{1,10}$	$Q_{1,25}$
9	72.7	6,900	3,430	5,140	6,060	6,760	7,480	2,170	3,410	4,000
14	47.3	2,310	1,320	2,280	2,840	3,290	3,770	829	1,260	1,420
16	227.3	33,400	7,310	13,400	17,200	20,300	23,700	4,690	7,650	9,540
18	267.9	27,100	8,390	16,200	21,000	25,100	29,500	5,530	8,650	10,400
22	48.3	7,510	1,530	3,100	4,120	4,980	5,940	1,050	1,530	1,700
24	17.1	3,260	485	1,180	1,700	2,160	2,710	344	563	622
34	73.3	8,500	1,890	4,090	5,580	6,880	8,350	1,040	2,220	3,020
38	597.2	37,000	16,000	36,600	51,100	63,800	78,500	9,020	14,500	17,100
48	246.6	38,100	5,820	12,400	17,200	21,600	26,700	4,100	8,400	11,300
49	874.8	88,200	17,800	38,400	54,100	68,700	86,300	13,700	26,200	34,000
50	30.2	5,240	946	2,260	3,190	4,020	4,960	502	1,070	1,420
51	219.0	16,000	4,320	10,600	15,000	18,800	23,200	3,030	5,910	7,230

Site number	Number of observations	pH (units) Minimum	pH (units) Mean	pH (units) Maximum	Number of observations	Sulfate (milligrams per liter) Minimum	Sulfate (milligrams per liter) Mean	Sulfate (milligrams per liter) Maximum
1	20	2.4	3.1	3.7	16	42	140	200
2	6	3.5	4.2	4.8	5	68	350	800
3	16	4.2	6.4	7.4	15	40	210	470
4	17	3.8	5.3	6.9	15	20	60	220
5	7	4.2	6.0	7.8	5	62	150	240
6	6	3.2	4.0	4.7	7	51	560	1700
7	4	6.2	6.8	7.6	5	19	35	63
8	4	6.1	6.8	7.5	4	19	35	53
9	23	3.9	4.9	6.4	18	78	240	940
10	36	2.8	4.5	6.5	16	48	140	320
11	6	6.1	6.7	7.5	7	38	79	180
12	4	5.5	6.4	7.5	5	37	74	130
13	4	3.2	3.9	4.6	3	150	220	330
14	36	3.9	4.7	6.9	16	97	180	360
15	5	5.0	5.6	6.4	4	20	54	110
16	8	4.0	4.7	5.6	7	43	190	600
17	4	2.3	2.8	3.1	5	41	190	400
18	5	4.0	4.7	5.0	4	52	140	290
19	1	7.3	7.3	7.3	1	22	22	22
20	6	2.0	2.7	3.0	7	210	500	980
21	3	5.6	6.7	8.0	1	9	9	9
22	5	5.9	6.9	7.6	4	13	14	14
23	3	6.7	7.3	7.8	1	13	13	13
24	8	6.3	7.1	8.2	7	13	15	16
25	5	6.1	6.8	7.6	4	12	15	16
26	23	5.9	7.1	8.2	18	13	15	18
27	6	2.6	3.5	4.3	5	250	880	1500
28	5	3.1	4.3	5.4	6	40	130	260
29	4	6.7	7.3	7.8	3	52	64	83
30	2	7.5	7.6	7.7	1	22	22	22
31	3	4.3	5.4	6.7	4	52	140	220
32	3	6.8	7.0	7.1	4	84	210	340
33	8	2.4	3.6	4.3	7	180	410	820
34	23	4.7	6.3	7.7	17	130	370	770
35	4	7.5	8.0	9.1	5	18	26	38
36	2	7.3	7.4	7.5	1	24	24	24
37	5	7.0	7.5	8.0	4	9	16	19
38	26	6.1	7.2	8.4	18	50	150	320
39	5	7.2	7.9	8.6	4	19	23	27
40	5	6.8	7.3	7.8	5	12	14	16
41	5	7.0	7.5	8.1	5	13	15	19
42	5	7.3	7.8	8.4	5	28	51	62
43	8	6.7	7.3	8.0	7	14	17	19
44	5	6.3	6.9	7.2	4	110	140	200
45	5	6.6	7.1	7.7	4	41	63	110
46	5	5.2	5.9	6.4	4	290	360	400
47	6	7.0	7.7	8.1	5	160	290	400
48	23	6.8	7.7	8.2	18	31	110	280
49	29	6.2	7.2	7.9	21	41	140	330
50	2	8.0	8.0	8.0	2	9	13	17
51	21	7.0	7.9	9.1	15	21	34	43

Site number	Number of observations	Specific Conductance (micromhos per centimeter at 25° C) Minimum	Mean	Maximum	Number of observations	Dissolved Solids (milligrams per liter) Minimum	Mean	Maximum
1	16	143	441	745	16	94.0	250	468
2	5	189	847	2000	5	137.0	676	1810
3	14	125	469	959	15	69	356	781
4	14	53	158	547	15	50.0	115	390
5	5	148	376	535	5	106	270	409
6	6	64	759	2600	7	77	899	2680
7	5	72	127	235	5	55	82	141
8	4	63	106	175	4	51	82	125
9	18	140	492	1580	18	135	379	1440
10	25	114	363	804	16	85	235	520
11	7	107	211	410	7	72	145	316
12	5	89	191	340	5	74	132	232
13	3	380	449	584	3	259	350	526
14	88	85	232	790	16	180	304	606
15	4	49	99	152	4	48	90	165
16	7	130	419	1160	6	85	319	907
17	5	168	573	1100	5	88	319	693
18	4	124	330	652	4	104	242	486
19	1	88	88	88	1	63	63	63
20	7	578	1080	1730	7	406	799	1510
21	1	35	35	35	1	26	26	26
22	4	53	70	79	4	50	57	78
23	1	64	64	64	1	39	39	39
24	7	67	96	122	7	56	71	91
25	4	50	59	74	4	38	43	46
26	18	56	76	95	18	46	53	63
27	5	613	1540	2360	5	403	1397	2240
28	6	127	373	752	6	77	262	533
29	3	280	383	524	3	154	235	293
30	1	112	112	112	1	68	68	68
31	4	172	360	555	4	126	258	418
32	4	249	546	795	4	159	427	662
33	7	380	848	1780	7	266	725	1830
34	18	372	750	1310	16	269	583	1180
35	5	148	202	270	4	91	131	166
36	1	116	116	116	1	71	71	71
37	4	71	124	165	4	50	84	104
38	17	160	571	1190	18	120	382	918
39	4	114	214	316	4	79	131	193
40	5	60	84	108	5	42	54	65
41	5	71	91	120	5	41	56	75
42	5	129	207	268	4	58	120	176
43	7	75	104	176	7	52	71	122
44	4	290	375	483	4	216	257	344
45	4	162	222	342	4	126	151	220
46	4	730	871	992	4	620	674	720
47	5	490	722	848	5	366	562	707
48	18	153	340	718	18	88	238	569
49	21	207	522	1180	21	124	354	933
50	2	184	202	221	2	122	138	153
51	19	70	250	317	15	65	146	204

Site number	Manganese, dissolved (micrograms per liter) Number of observations	Minimum	Mean	Maximum	Manganese, total (micrograms per liter) Number of observations	Minimum	Mean	Maximum
1	16	470	910	1400	16	480	910	1400
2	5	240	510	790	5	290	530	790
3	15	340	750	2100	15	440	780	2100
4	15	280	520	1600	15	290	520	1600
5	5	380	470	580	1	610	610	610
6	7	70	610	1700	7	320	1300	5100
7	5	20	88	170	5	20	100	190
8	4	10	63	90	4	20	95	170
9	18	220	450	890	18	250	460	890
10	16	630	1360	2900	16	630	1400	2900
11	7	20	71	150	7	40	110	150
12	5	80	190	260	5	120	210	280
13	3	2700	4000	6300	3	2700	4000	6400
14	16	4	2500	6300	16	1500	3100	6300
15	4	130	170	220	4	130	220	390
16	7	410	850	1700	7	530	860	1700
17	5	60	520	1800	5	270	780	1800
18	4	420	880	1700	4	560	960	1800
19	1	30	30	30	1	110	110	110
20	7	30	2000	4300	7	1200	2600	4300
21	1	90	90	90	1	100	100	100
22	4	0	11	20	4	0	20	50
23	1	10	10	10	1	10	10	10
24	7	0	9	10	7	10	59	310
25	4	0	6	10	4	10	13	20
26	18	4	46	210	18	20	77	210
27	5	1400	5100	8500	5	1500	5100	8500
28	6	940	4200	9200	6	970	4200	9200
29	3	610	1100	1700	3	620	1200	1900
30	1	10	10	10	1	10	10	10
31	4	200	610	1300	4	420	760	1300
32	4	230	270	350	4	270	310	400
33	7	480	1300	2300	7	480	1300	2300
34	17	890	2000	3400	17	910	2000	3500
35	5	10	10	10	5	10	18	30
36	1	10	10	10	1	410	410	410
37	4	0	5	10	4	10	13	20
38	18	270	600	1000	18	350	630	1000
39	4	10	13	20	4	10	18	40
40	5	10	10	10	5	10	20	30
41	5	10	10	10	5	10	10	20
42	5	10	14	20	5	10	28	50
43	7	10	13	10	7	10	30	10
44	4	60	310	400	4	90	340	440
45	4	50	73	90	4	50	88	130
46	4	1600	2500	3100	4	1600	2500	3100
47	5	430	670	860	5	480	710	860
48	18	70	180	510	18	70	200	520
49	21	180	480	970	21	230	500	970
50	2	10	15	20	2	10	15	20
51	15	0	21	66	15	10	61	170

		Iron, dissolved (micrograms per liter)				Iron, total (micrograms per liter)		
Site number	Number of observations	Minimum	Mean	Maximum	Number of observations	Minimum	Mean	Maximum
1	16	1600	5500	10000	16	4400	6100	10000
2	5	180	800	2000	5	1200	2500	3800
3	15	0	89	400	15	390	1500	9000
4	15	110	1400	10000	15	340	1900	10000
5	5	10	150	490	1	2500	2500	2500
6	7	150	6700	30000	7	1400	8500	30000
7	5	30	42	60	5	190	480	1000
8	4	40	53	70	4	300	780	2100
9	18	10	660	3200	18	350	2300	10000
10	16	70	3100	9700	16	270	4300	11000
11	7	20	81	130	7	240	660	1900
12	5	30	52	80	5	170	380	620
13	3	150	540	930	3	790	1400	1900
14	16	60	180	460	16	140	530	930
15	4	50	70	110	4	130	1200	3900
16	7	90	410	930	7	290	2700	12000
17	5	1100	15000	35000	5	5300	17000	36000
18	4	100	370	560	4	1700	7600	3450
19	1	20	20	20	1	960	960	960
20	7	7200	21000	44000	7	9700	23000	44000
21	1	190	190	190	1	600	600	600
22	4	10	25	40	4	120	270	650
23	1	10	10	10	1	50	50	50
24	7	0	9	30	7	100	280	760
25	4	0	8	10	4	60	230	420
26	18	10	31	50	18	70	520	6200
27	5	300	1700	3200	5	420	3500	7500
28	6	90	200	350	6	340	470	800
29	3	30	110	240	3	390	480	580
30	1	20	20	20	1	1500	1500	1500
31	4	30	65	100	4	200	2100	7000
32	4	10	13	20	4	110	340	770
33	7	50	5300	16000	7	2800	11000	27000
34	17	20	240	550	17	1600	3000	8500
35	5	20	26	40	5	30	180	340
36	1	30	30	30	1	16000	16000	16000
37	4	10	28	40	4	80	180	320
38	18	20	110	290	18	310	1100	4200
39	4	0	20	30	4	100	240	570
40	5	0	26	50	5	130	360	550
41	5	0	18	30	5	160	266	500
42	5	10	14	20	5	10	28	50
43	7	10	24	50	7	80	590	3000
44	4	10	18	30	4	210	550	1000
45	4	0	20	40	4	280	730	1200
46	4	170	3200	4600	4	1300	5500	6900
47	5	0	10	20	5	290	1430	4000
48	18	0	22	40	18	80	470	2400
49	21	10	92	230	21	350	460	1400
50	2	40	45	50	2	180	190	200
51	15	10	35	90	15	140	1100	3800

Site number	Alkalinity (milligrams per liter as $CaCO_3$) Number of observations	Alkalinity Minimum	Alkalinity Mean	Alkalinity Maximum	Acidity (milligrams per liter as $CaCO_3$) Number of observations	Acidity Minimum	Acidity Mean	Acidity Maximum
1	9	0.0	2.3	16.0	19	10.0	68.5	149.0
2	5	0.0	0.4	2.0	6	5.0	23.2	41.0
3	8	0.0	15.1	28.0	12	0.0	7.9	20.0
4	8	1.0	3.7	8.0	14	0.0	12.5	60.0
5	3	0.0	2.3	6.0	4	5.0	13.8	30.0
6	6	0.0	0.0	0.0	7	15.0	54.3	131.0
7	5	11.0	19.0	29.0	5	0.0	1.0	5.0
8	5	11.0	17.1	31.0	5	0.0	1.0	5.0
9	23	0.0	2.3	13.0	24	0.0	13.8	74.0
10	15	0.0	1.0	3.0	16	0.0	26.8	75.0
11	7	11.0	19.4	41.0	6	0.0	0.8	5.0
12	5	3.0	6.2	9.0	5	0.0	2.0	5.0
13	3	0.0	1.3	3.0	5	0.0	31.7	52.4
14	14	0.0	1.8	9.0	16	0.0	19.7	40.0
15	4	2.0	3.3	5.0	4	0.0	1.3	5.0
16	9	0.0	1.2	3.3	8	0.0	6.9	15.0
17	4	0.0	0.0	0.0	5	15.0	109.6	248.0
18	4	0.0	5.0	8.0	5	0.0	11.9	30.0
19	1	24.0	24.0	24.0	1	5.0	5.0	5.0
20	7	0.0	0.0	0.0	7	84.0	196.7	402.0
21	1	3.0	3.0	3.0	2	0.0	0.0	0.0
22	5	6.0	13.2	21.0	3	0.0	1.7	5.0
23	1	2.0	2.0	2.0	2	0.0	0.0	0.0
24	6	14.0	24.0	37.0	7	0.0	0.7	5.0
25	3	0.0	6.3	13.0	3	0.0	0.0	0.0
26	21	7.0	13.4	27.0	22	0.0	1.1	5.0
27	5	0.0	1.2	3.0	6	45.0	71.8	104.0
28	6	0.0	1.8	5.0	6	0.0	29.5	55.0
29	3	9.0	30.7	62.0	4	0.0	1.3	5.0
30	1	31.0	31.0	31.0	1	0.0	0.0	0.0
31	4	0.0	8.0	25.0	4	0.0	5.7	13.0
32	4	21.0	50.0	69.0	3	0.0	1.6	4.8
33	9	0.0	.44	2.0	8	15.0	66.5	199.0
34	22	0.0	11.6	45.0	23	0.0	2.9	15.0
35	5	42.0	59.5	78.7	3	0.0	0.0	0.0
36	1	11.0	11.0	11.0	1	0.0	0.0	0.0
37	5	18.0	52.6	85.0	5	0.0	1.0	5.0
38	22	8.0	28.5	73.8	23	0.0	1.5	10.0
39	4	34.0	76.0	136.0	4	0.0	0.0	0.0
40	5	10.0	20.0	32.0	1	0.0	0.0	0.0
41	5	9.0	60.8	206.0	1	0.0	0.0	0.0
42	5	21.0	50.0	70.0	1	0.0	0.0	0.0
43	7	2.0	22.1	57.0	8	0.0	.63	5.0
44	6	8.0	21.0	33.0	4	0.0	0.0	0.0
45	4	18.0	34.4	52.0	3	0.0	0.0	0.0
46	5	49.0	71.1	98.0	5	0.0	45.2	117.0
47	7	20.0	57.6	79.0	5	0.0	0.0	0.0
48	21	2.0	35.9	74.0	18	0.0	.28	5.0
49	28	9.0	32.6	66.0	20	0.0	1.0	10.0
50	2	80.4	91.7	103.0				

Site number	Number of observations	Net Alkalinity (milligrams per liter as $CaCO_3$) Minimum	Mean	Maximum
1	7	-103.0	-56.4	-20.0
2	5	- 41.0	-21.4	- 3.0
3	5	- 15.0	6.0	22.0
4	5	- 13.0	- 2.9	3.3
5	2	- 29.0	-22.0	-15.0
6	6	- 70.0	-41.5	-15.0
7	5	11.0	18.0	29.0
8	4	6.0	17.4	31.0
9	23	- 73.0	-11.4	13.0
10	14	- 75.0	-25.8	1.0
11	6	11.0	19.0	41.0
12	5	- 2.0	4.2	9.0
13	3	- 37.0	-23.7	1.0
14	13	- 40.0	-17.3	9.0
15	3	- 2.0	2.0	5.0
16	8	- 14.2	- 5.8	1.0
17	4	-248.0	-97.0	-15.0
18	4	- 9.5	- 2.4	5.0
19	1	19.0	19.0	19.0
20	7	-402.0	-196.7	-84.0
21	1	3.0	3.0	3.0
22	3	1.0	11.3	20.0
23	1	2.0	2.0	2.0
24	6	14.0	23.2	37.0
25	2	0.0	6.5	13.0
26	21	2.0	12.5	27.0
27	3	45.0	69.3	99.0
28	6	- 55.0	- 27.7	5.0
29	3	9.0	29.0	62.0
30	1	31.0	31.0	31.0
31	4	- 13.0	2.2	25.0
32	3	21.0	48.1	69.0
33	8	-199.0	- 66.1	-15.0
34	22	- 11.0	9.2	45.0
35	3	63.0	68.6	78.7
36	1	11.0	11.0	11.0
37	5	13.0	51.6	85.0
38	22	4.0	27.1	73.8
39	3	55.0	90.0	136.0
40	1	20.0	20.0	20.0
41	1	30.0	30.0	30.0
42	1	48.0	48.0	48.0
43	7	2.0	21.4	57.0
44	4	8.0	20.7	33.0
45	2	18.0	26.2	34.4
46	4	- 46.0	7.9	62.0
47	5	20.0	56.8	79.0
48	17	2.0	33.5	74.0
49	19	9.0	34.2	66.0
50	2	80.4	91.7	103.0
51	10	10.0	68.2	99.0

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