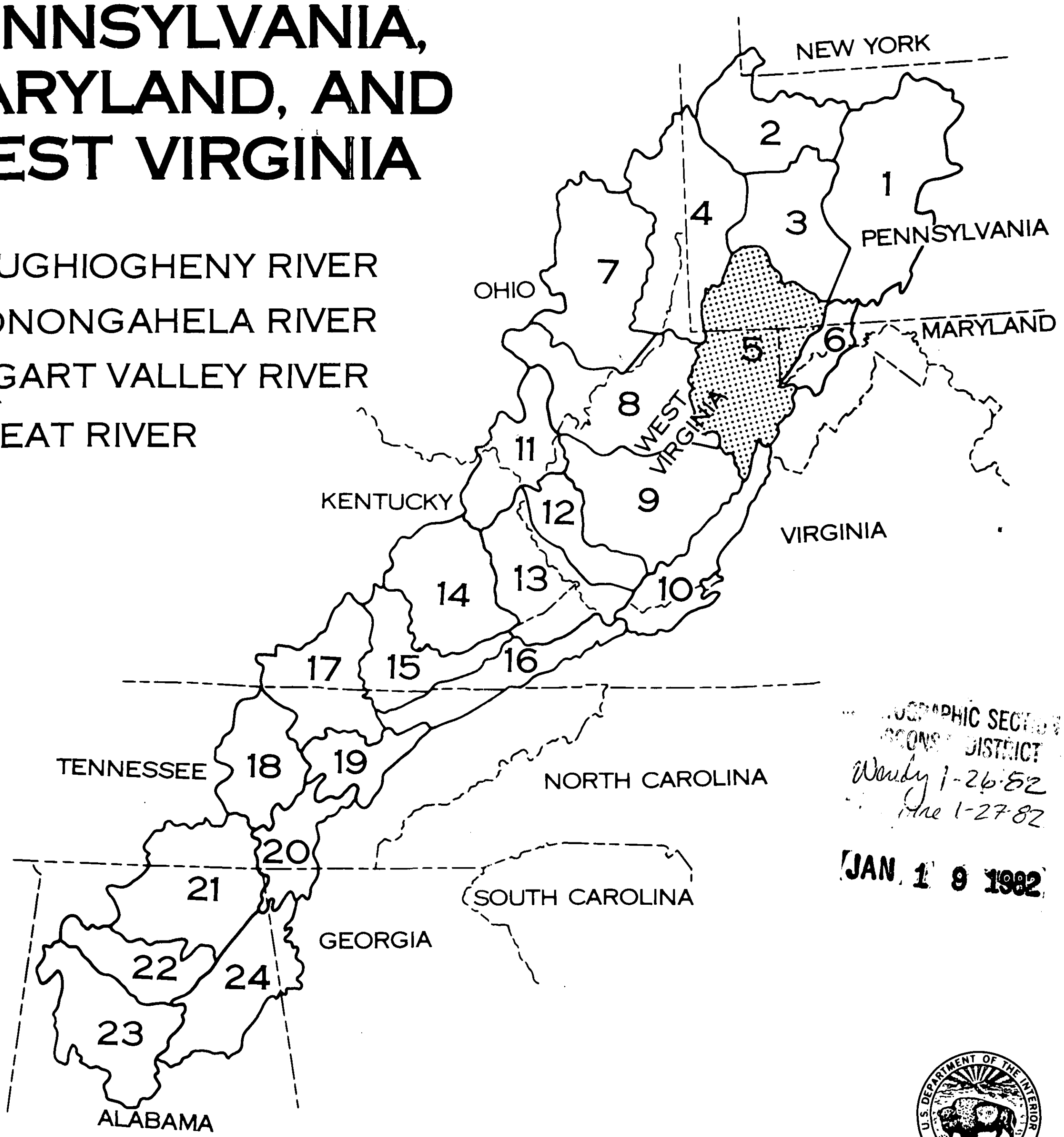
REVIEW DRAFT

HYDROLOGY OF AREA 5, EASTERN COAL PROVINCE, PENNSYLVANIA, MARYLAND, AND WEST VIRGINIA

- YOUGHIOGHENY RIVER
- MONONGAHELA RIVER
- TYGART VALLEY RIVER
- CHEAT RIVER



UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

WATER-RESOURCES INVESTIGATIONS
OPEN-FILE REPORT 81-538

HYDROLOGY OF AREA 5, EASTERN COAL PROVINCE, PENNSYLVANIA, MARYLAND, AND WEST VIRGINIA

BY
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U.S. GEOLOGICAL SURVEY
WATER-RESOURCES INVESTIGATIONS 81-538

drainage/culture flaps not registered well throughout

1965, 1966, 1967 base maps??

HARRISBURG, PENNSYLVANIA
SEPTEMBER 1981

UNITED STATES DEPARTMENT OF THE INTERIOR

JAMES G. WATT, *SECRETARY*

GEOLOGICAL SURVEY

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CONTENTS

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

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

Multiply inch-pound units	By	To obtain SI units
inches (in)	25.4	millimeters (mm)
inches per hour (in/h)	25.4	millimeters per hour (mm/h)
	2.54	centimeters per hour (cm/h)
feet (ft)	0.3048	meters (m)
feet per mile (ft/mi)	0.1894	meters per kilometer (m/km)
miles (mi)	1.609	kilometers (km)
square miles (mi^2)	2.590	square kilometers (km^2)
gallons per minute (gal/min)	0.06309	liters per second (L/s)
million gallons per day (mgal/d)	0.04381	cubic meters per second (m^3/s)
	3,785	cubic meters per day (m^3/d)
cubic feet per second (ft^3/s)	0.02832	cubic meters per second (m^3/s)
cubic feet per second per square mile [$(ft^3/s)/mi^2$]	0.01093	cubic meters per second per square kilometer [$(m^3/s)/km^2$]
tons per square mile per year [$(tons/mi^2)/yr$]	0.03753	metric tons per square kilometer per year [$(t/km^2)/a$]

ABSTRACT

The Eastern Coal Province is divided into 24 separate reporting areas. The divisions are based upon hydrologic factors, location, size, and mining activity. Hydrologic units (drainage basins) or parts of units are combined to form each area. Area 5, in the northern part of the Eastern Coal Province, is comprised of the 7,384 square-mile Monongahela River basin.

This report is designed to be useful to mine owners, mine operators, consultants, and regulatory authorities by presenting information concerning existing hydrologic conditions and identifying additional sources of hydrologic information. The hydrology of the area is presented in the format of a brief text and accompanying graphic on a single water-resources related topic.

Area 5 is in the Unglaciated Allegheny Plateaus and Allegheny Mountain sections of the Appalachian Plateaus physiographic province. Rocks of the Pennsylvanian system are common in most of the area, but Mississippian and Devonian rocks are common in the southeastern corner. Major streams in Area 5 in addition to the Monongahela River are the Youghiogheny, Cheat, Tygart Valley, and West Fork Rivers. Slopes in the area generally range from 3 to 35 percent and soils are generally acidic to neutral. The climate of the area is humid continental, and the mean annual precipitation is 36 to 66 inches, depending upon altitude.

Coal production in Area 5 counties gradually declined from 70 million tons in 1975 to 67 million tons in 1977, and then dropped to 57 million tons in 1978. Almost 50 percent of the 1978 production came from surface mines. Approximately 87,000 acres in Area 5 counties have been disturbed by surface mining to an extent requiring reclamation, but only 24,000 acres has a legal requirement for reclamation.

A special network was established to collect hydrologic data in coal-bearing areas. One hundred thirty-four synoptic sites and 11 continuous-record stations were established in Area 5. Streamflow, water-quality, and sediment data are generally collected two or three times per year at the synoptic sites and six to nine times per year at the continuous-record sites. Samples are analyzed for specific conductance, pH, acidity, alkalinity, dissolved and total iron, dissolved and total manganese, dissolved sulfate, residue on evaporation, suspended sediment, common constituents, minor elements, bed-material metals, and coal in bed material. Benthic invertebrates are identified.

Streams high in constituents which indicate acid-mine drainage were most common in the Tygart Valley River basin. Only 11 of the 134 synoptic sites in Area 5 had pH, acidity-alkalinity, total iron, total manganese, and dissolved sulfate indicative of acid-mine drainage. Most of the manganese in Area 5 streams is transported in the dissolved phase, but much iron is transported in suspension. Sulfate concentrations in Area 5 streams are generally high. Specific conductance, pH, total iron, total manganese, and dissolved sulfate can show considerable variation from stream to stream and with time in a single stream. No benthic invertebrates were found in 25 of 129 streams sampled in Area 5. Streams lacking benthic invertebrates were most common in the Cheat and Tygart Valley River basins.

Recent streamflow data have been collected at 50 continuous-record gaging stations, 4 crest-stage partial-record stations, and 13 low-flow partial-record stations in addition to 126 miscellaneous sites. Low-flow, mean-flow, peak-flow, and flow-duration data are presented for gaging stations in Area 5. Techniques and sources of information are presented to enable estimates of these flow characteristics at ungaged sites.

Water levels in observation wells in Area 5 fluctuate throughout the year. Levels are generally lowest during late summer and early fall and highest during early spring. The U.S. Geological Survey identifies and improves access to existing water data through: the National Water Data Exchange, the National Water Data Storage and Retrieval System, and the Office of Water Data Coordination.

1.0 INTRODUCTION

1.1 Objective

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 the applications.

A need for hydrologic information and analysis on a scale never before required nationally resulted when the "Surface Mining Control and Reclamation Act of 1977" was signed into law as Public Law 95-87, August 3, 1977. This report broadly characterizes the hydrology of Area 5 in Pennsylvania, Maryland, and West Virginia (fig. 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 of the area in the vicinity of the mine and the anticipated hydrologic consequences of the mining operation.

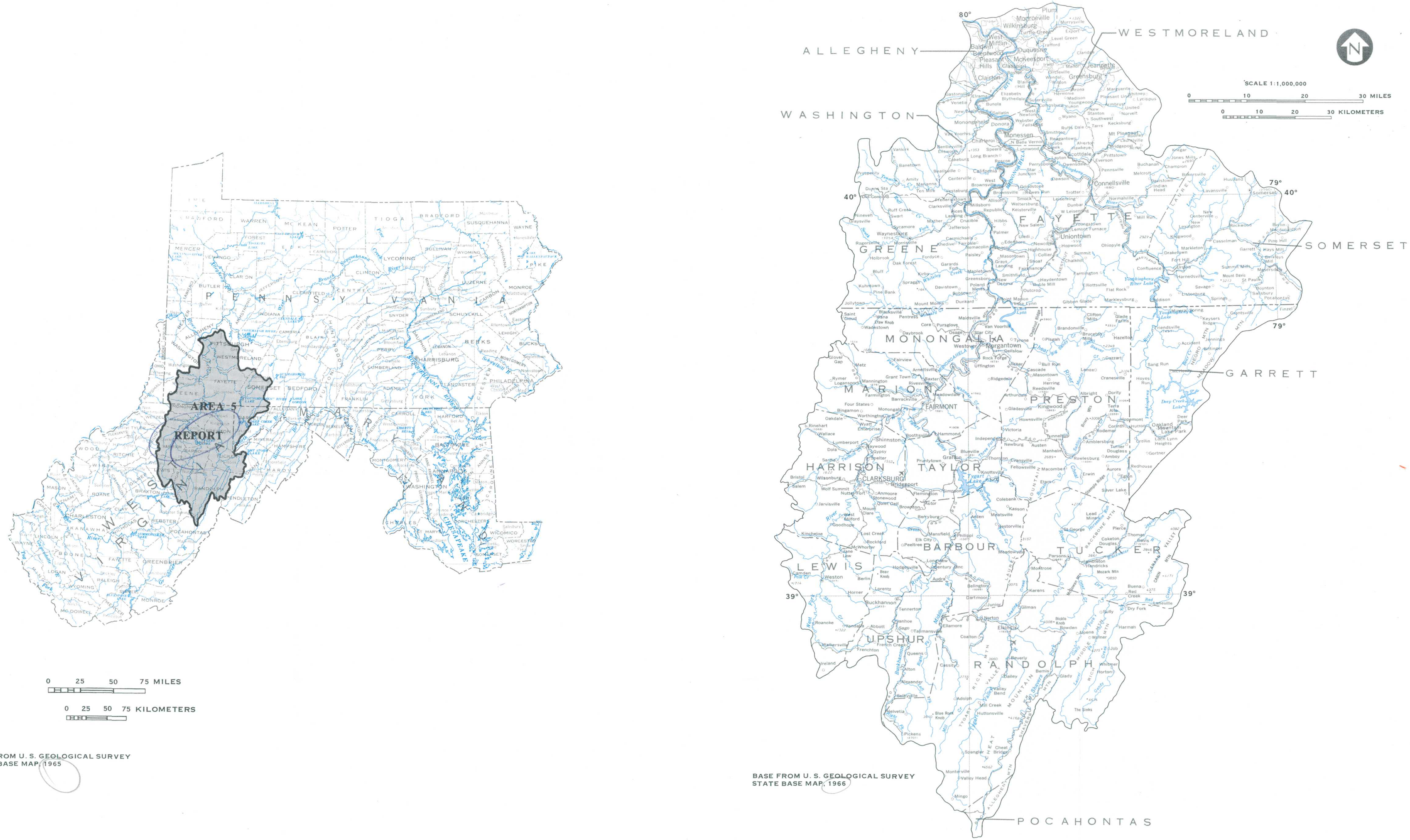


Figure 1.1-1 Location of study area.

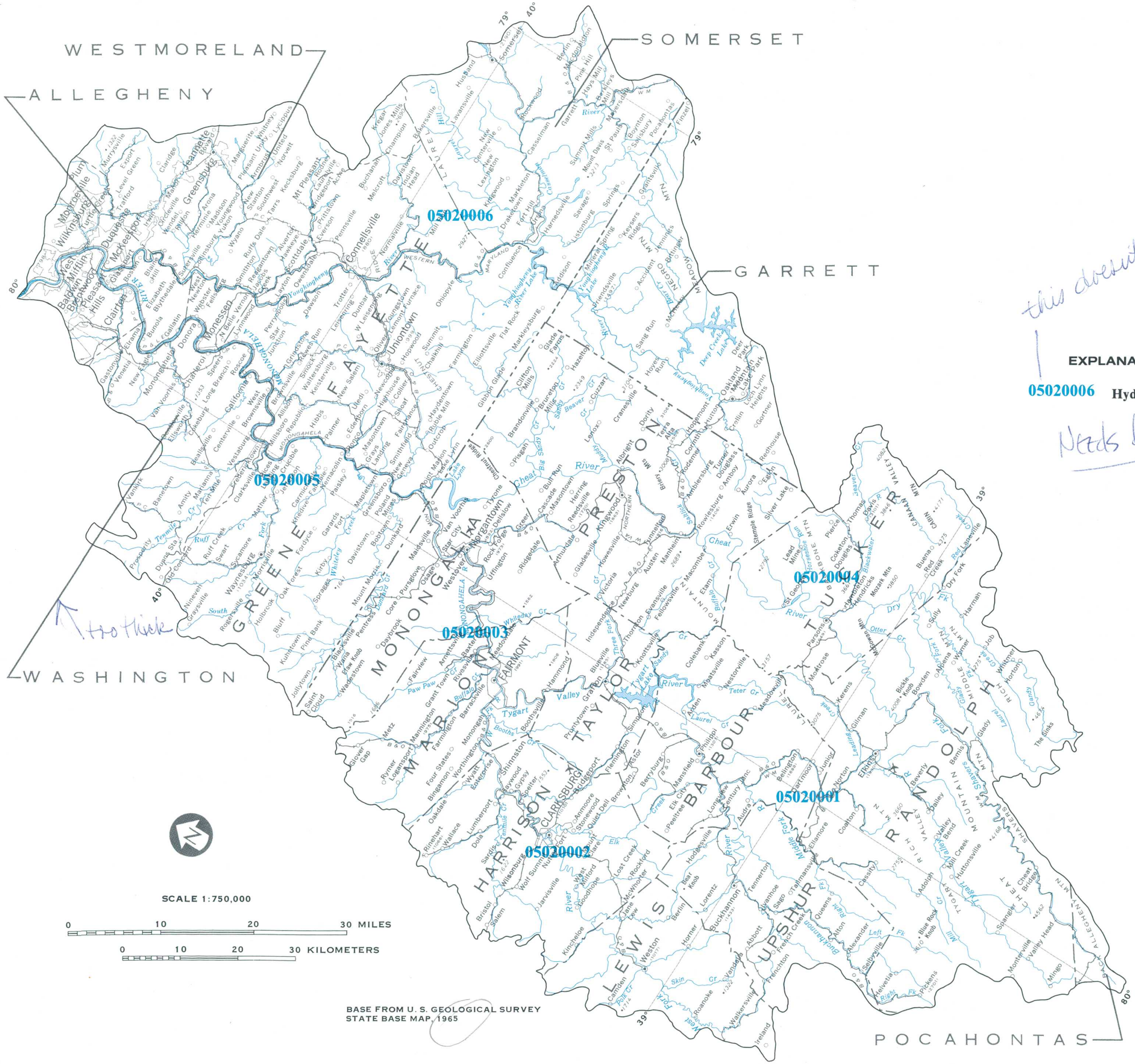
HYDROLOGY AND WATER RESOURCES SUMMARIZED FOR PARTS OF WEST VIRGINIA, MARYLAND, AND PENNSYLVANIA

This report summarizes the hydrology and water resources of Area 5 in the northern end of the Eastern Coal Province in West Virginia, Maryland, and Pennsylvania.

The Eastern Coal Province is divided into 24 reporting 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 (fig. 1.2-1) (see front cover for areas in the Eastern Coal Province).

Area 5 is in the northern third of the Eastern Coal Province in north-central West Virginia, western Maryland, and southwestern Pennsylvania. The area includes all or part of Barbour, Harrison, Lewis, Monongalia, Preston, Randolph, Tucker, and Upshur Counties, W. Va.; Garrett County, Md.; and Allegheny, Fayette, Greene, Somerset, and Westmoreland Counties, Pa.

The area includes the entire Monongahela River basin from the head-waters of the Tygart Valley River in West Virginia to the mouth of the Monongahela at Pittsburgh, Pa. Major tributaries in the area are the Tygart Valley, Youghiogheny, Cheat, and West Fork Rivers. The surface area is 7,384 mi^2 (square miles).



too thick

this doesn't look like a year(?)

EXPLANATION

05020006 Hydrologic Unit

Needs boundaries!

Figure 1.2-1 Hydrologic units.

2.0 DEFINITION OF TERMS

TERMS USED IN HYDROLOGIC REPORTS DEFINED

Technical terms that occur in this Hydrologic Report are defined.

Bed material is the unconsolidated material of which a streambed, lake, pond, reservoir, or estuary bottom is composed.

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

Bottom material specifically includes anthropogenic matter in addition to natural solid material in bed material.

Cubic feet per second per square mile [$(ft^3/s)mi^2$] is the average number of cubic feet of water flowing per second from each square mile of area drained, assuming that the runoff is distributed uniformly in time and area.

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

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

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

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

Dissolved refers to the amount of substance present in true chemical solution. In practice, however, the term includes all forms of substance that will pass through a 0.45-micrometer membrane filter, and thus may include some very small (colloidal) suspended particles. Analyses are performed on filtered samples.

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

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

Gage height (G.H.) is the water-surface elevation referred to some arbitrary gage datum. Gage height is often used interchangeably with the more general term "stage", although gage height is more appropriate when used with a reading on a gage.

Gaging station is a particular site on a stream, canal, lake, or reservoir where systematic observations of hydrologic data are obtained.

Hydrologic unit is a geographic area representing part or all of a surface drainage basin or distinct hydrologic feature as delineated by the Office of Water Data Coordination on the State Hydrologic Unit Maps; each hydrologic unit is identified by an 8-digit number.

Micrograms per gram ($\mu g/g$) is a unit expressing the concentration of a chemical element as the mass (micrograms) of the element per unit mass (gram) of sediment.

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

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

Partial-record station is a particular site where limited streamflow and/or water-quality data are collected systematically over a period of years for use in hydrologic analyses.

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

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

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

Specific conductance is a measure of the ability of water to conduct an electrical current. It is expressed in micromhos per centimeter (μmho/cm) at 25°C. Specific conductance is related to the type and concentration of ions in solution and can be used for approximating the dissolved-solids concentration of the water. Commonly, the concentration of dissolved solids (in milligrams per liter) is about 65 percent of the specific conductance (in micromhos). This relation is not constant from stream to stream, and it may vary in the same source with changes in the composition of the water.

Stage-discharge is the relation between gage height (stage) and volume of water per unit of time, flowing in a channel.

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

Substrate is the physical surface upon which an organism lived.

Natural substrate refers to any naturally occurring emersed or submersed solid surface, such as a rock or tree, upon which an organism lived.

Taxonomy is the division of biology concerned with the classification and naming of organisms. The classification of organisms is based upon a hierarchical scheme beginning with Kingdom and ending with Species at the base. The higher the classification level, the fewer features the organisms have in common. For example, the taxonomy of a particular mayfly, *Hexagenia limbata* is the following:

Kingdom---Animal

Phylum---Arthropoda

Class---Insecta

Order---Ephemeroptera

Family---Ephemeridae

Genus---*Hexagenia*

Species---*Hexagenia limbata*

NEW REGULATIONS SET EFFLUENT LIMITATIONS FOR IRON, MANGANESE, PH, AND SUSPENDED SOLIDS

Standards have been set for iron, manganese, pH, and suspended solids in water discharged from areas disturbed by surface mining.

The Permanent Regulatory Program of the Office of Surface Mining sets specific standards for water leaving a mine site. Section 816.42 (a) (7) of the Permanent Regulatory Program states that "discharges of water from areas disturbed by surface mining shall be made in compliance with all Federal and State laws and regulations . . . ." This same section also sets certain specific numerical effluent limitations. The specific effluent limitations are for total iron, total manganese, total suspended solids, and pH. Table 3.0-1 lists these numerical standards.

The effluent limitations for iron and manganese are considerably higher than those recommended for drinking water by the U.S. Environmental Protection Agency which sets limits of 300 $\mu g/L$ (micrograms per liter) iron and 50 $\mu g/L$ manganese.

bad placement on pg.

Table 3.0-1 Mine effluent limitations.

Effluent limitations in milligrams per liter (mg/L) except for pH[1]

Effluent characteristics	Maximum allowable	Average of daily values for 30 consecutive discharge days
Iron, total	7.0	3.5
Manganese, total[2]	4.0	2.0
Total suspended solids	70.0	35.0
pH[3]	Within range of 6.0 to 9.0	

[1]Federal Register, Volume 44, No. 50, Tuesday, March 13, 1979, p. 15398.

[2]Shall not apply to untreated alkaline discharges.

[3]pH may exceed 9.0, to a small extent, if needed to achieve manganese limit.

AREA 5 IS IN THE APPALACHIAN PLATEAUS PHYSIOGRAPHIC PROVINCE

The area, underlain mainly by rocks of Pennsylvanian age, is in the Unglaciated Allegheny Plateaus and Allegheny Mountain sections of the Appalachian Plateaus province.

Physiographically, Area 5 is in the Unglaciated Allegheny Plateaus and Allegheny Mountain sections of the Appalachian Plateaus province (Fenneman, 1938). Rock types in Area 5 are primarily sandstones and shales that contain thin beds of limestone and coal. The rocks are divided into 10 stratigraphic units, 1 in the Permian and Pennsylvanian systems, 4 in the Pennsylvanian system, 2 in the Mississippian system, and 3 in the Devonian system. From youngest to oldest in stratigraphic order, the rock units are the Dunkard Group of Permian and Pennsylvanian age; the Monongahela, Conemaugh, and Allegheny Groups, and Kanawha Formation of Pennsylvanian age; Greenbrier Limestone and Pocono Group of Mississippian age; and the Hampshire, Chemung, and Brallier Formations of Devonian age. Coal beds and limestones are numerous in the Pennsylvanian system. The Allegheny Group has 12 feet of workable coal and the Monongahela Group has 3 feet of workable coal (Clifford Dodge, oral communication, 1980). The Conemaugh Group has thin beds of coal that are generally not workable.

The Conemaugh Group is areally the largest unit in the area and the Dunkard Group is the second largest. The Monongahela Group, Allegheny Group, and the Kanawha Formation cover almost equal areas. Thus the Pennsylvanian system covers the northwest 75 percent of the area. The Greenbriar Limestone, Pocono Group, Hampshire, Chemung, and Brallier Formations are limited to the southeastern part of Area 5 along the Allegheny Front.

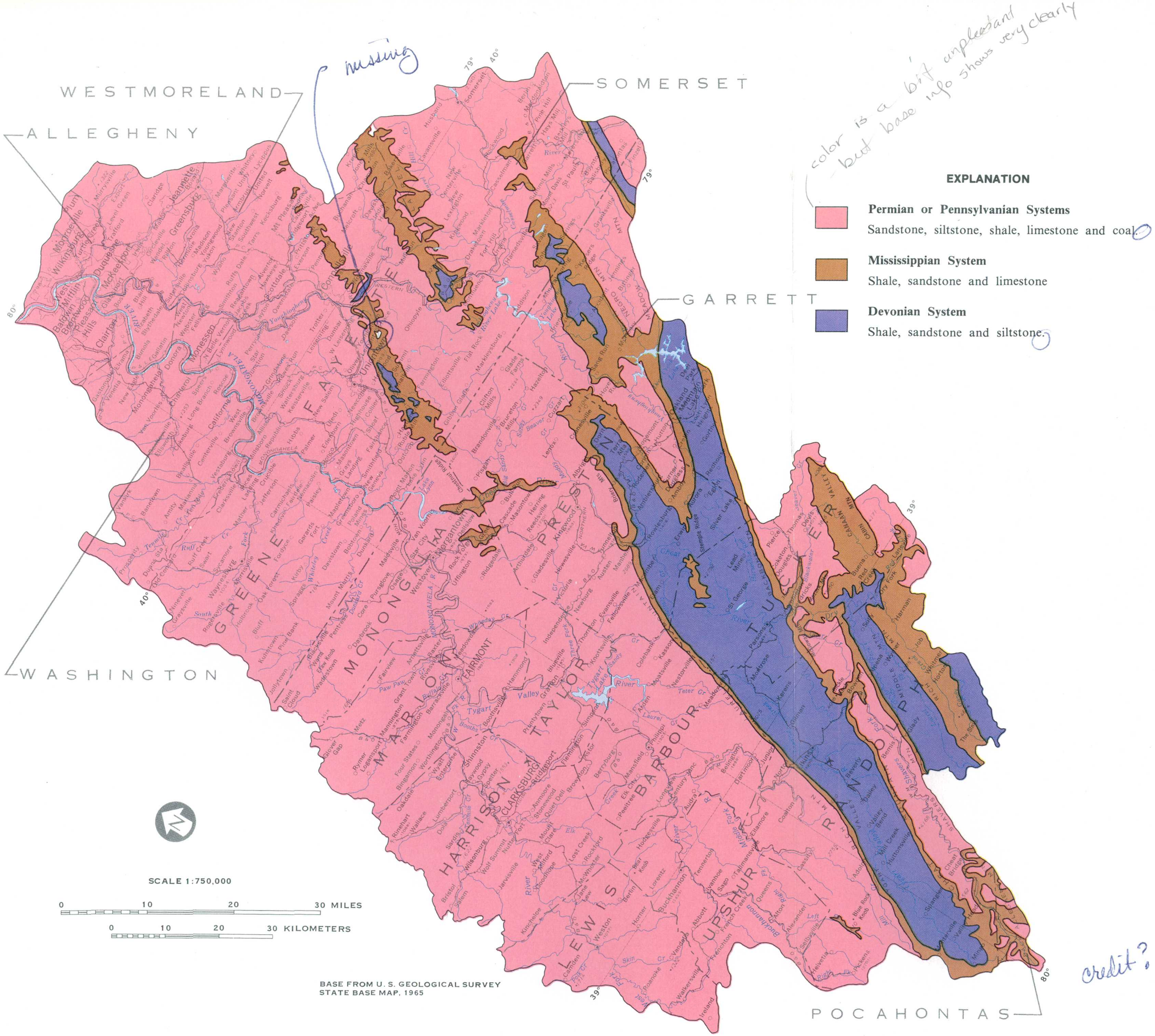


Figure 4.1-1 Surface geology.

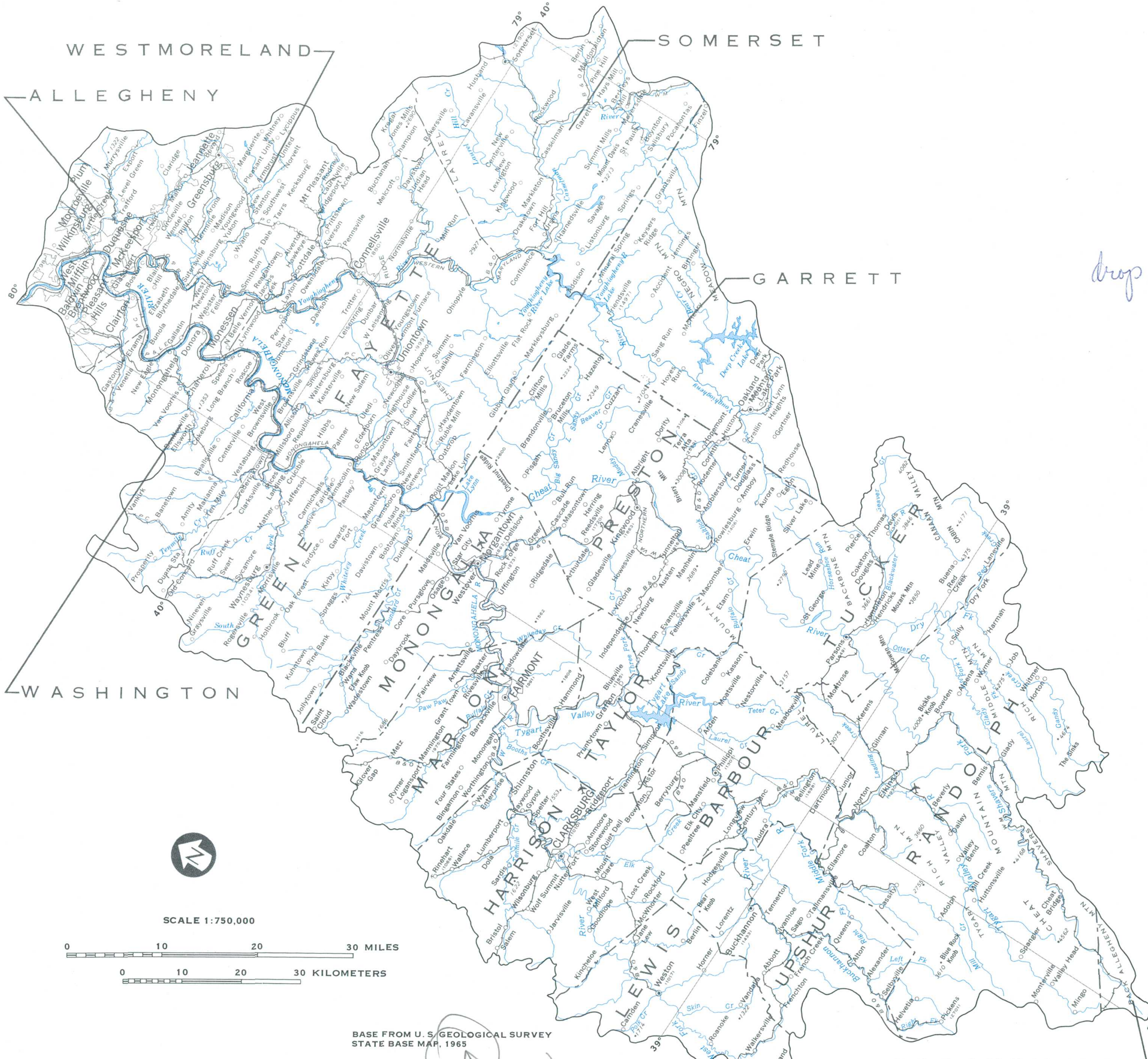
MONONGAHELA RIVER DRAINS ENTIRE AREA

Area 5 consists of the entire Monongahela River basin. Four major tributaries to the Monongahela, the Youghiogheny, Cheat, Tygart Valley, and West Fork Rivers drain 74 percent of the area's 7,384 square miles.

Eastern Coal Province Area 5 consists of the entire 7,384 mi^2 (square miles) of the Monongahela River basin. Four major tributaries to the Monongahela account for 5,440 mi^2 or about 74 percent of the drainage area (fig. 4.2-1). The major tributaries are the Youghiogheny, Cheat, Tygart Valley, and West Fork Rivers which drain 1,763; 1,422; 1,374; and 881 mi^2, respectively. The rest of Area 5 is drained by smaller streams tributary to the Monongahela. Tenmile Creek and Dunkard Creek are the largest of the minor tributaries with drainage area of 338 and 235 mi^2, respectively.

Each of the major tributaries includes several major subbasins. Major subbasins of the Youghiogheny include the Casselman River and Laurel Hill Creek. Shaver Fork, Dry Fork, and Big Sandy Creek are the major subbasins of the Cheat River. Major subbasins in the Tygart Valley River basin include the Buckhannon and Middle Fork Rivers. Elk and Tenmile Creek are the major subbasins of West Fork River.

The Monongahela River basin (Area 5) is comprised of parts of Pennsylvania, West Virginia, and Maryland. The West Virginia part of the basin occupies 58 percent of the area, while Pennsylvania accounts for 36 percent of the area. The remaining 6 percent, in the upper Youghiogheny River basin, is in Garrett County, Maryland.



drop culture

limit is 1967

Figure 4.2-1 Major streams.

more than "major" streams appear on map

4.0 GENERAL FEATURES OF STUDY AREA (CONTINUED)

4.2 SURFACE DRAINAGE

SOILS IN AREA ARE VARIED

Soils in Area 5 are grouped into 35 associations composed of combinations of 31 major soils.

The distribution of 35 soil associations in Eastern Coal Province Area 5 is shown in figure 4.3-1. Figure 4.3-1 was developed from general soils maps of Pennsylvania, West Virginia, and Maryland (Soil Conservation Service; 1972, 1979, 1967). The individual soils maps use different series concepts, and do not agree in names and boundary placements at the State borders. Therefore, it will be necessary to use care when using figure 4.3-1.

The 35 soil associations found in the area are formed from various combinations of 31 major soils. Slopes in the area generally range from 3 to 35 percent, but in some areas slopes exceed 35 percent. Many of the major soils have pH values in the 4.0-7.0 range. These pH values range from extremely acidic to neutral (Miller, 1967). More detailed data on soils can be obtained from soil surveys of the individual counties prepared by the Soil Conservation Service.

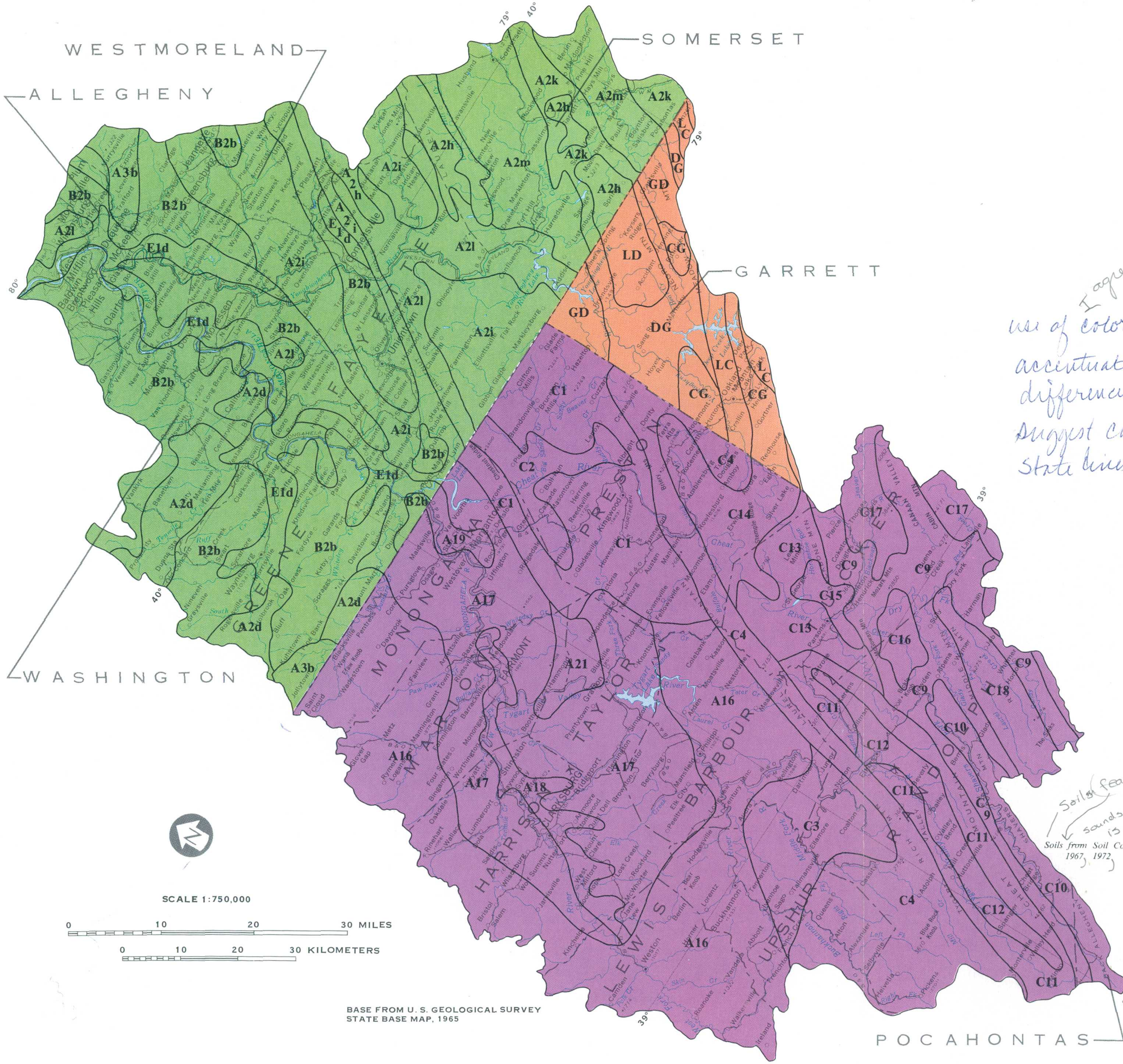


Figure 4.3-1 Soil associations.

use of color? I agree
accentuates wrong differences
suggest color accent state lines not areas

EXPLANATION

A2d **PENNSYLVANIA SOIL ASSOCIATIONS**

Noncarbonate sedimentary parent material

A2d	Culleoka-Weikert
A2h	Gilpin-Hazleton-Calvin
A2i	Gilpin-Ernest-Wharton
A2j	Gilpin-Upshur-Weikert
A2k	Hazleton-Cookport
A2l	Hazleton-Gilpin-Ernest
A2m	Rayne-Wharton-Ernest

Substrate of reddish, yellowish and brownish clay shale

A3b	Upshur-Gilpin-Clarksburg

Substrate of calcareous shale, limestone and sandstone

B2b	Guernesey-Culleoka

Soils formed in unconsolidated water-sorted materials

E1d	Monongahela-Philo-Melvin

A16 **WEST VIRGINIA SOIL ASSOCIATIONS**

A16	Gilpin-Culleoka-Upshur
A17	Culleoka-Westmoreland-Clarksburg
A18	Monongahela-Lindside-Clarksburg
A19	Monongahela-Zoar-Allegheny
A21	Gilpin-Ernest
C1	Gilpin-Ernest
C2	Dekalb-Buchanan-Ernest
C3	Gilpin-Dekalb-Ernest
C4	Gilpin-Dekalb-Buchanan
C9	Calvin-Belmont-Meckesville
C10	Dekalb-Buchanan
C11	Berks-Calvin-Weikert
C12	Ernest-Atkins-Monongahela
C13	Gilpin
C14	Calvin-Gilpin
C15	Barbour-Pope-Chavies
C16	Dekalb-Brinkerton Variant
C17	Ernest-Dekalb-Brinkerton
C18	Dekalb-Ernest-Buchanan
E1	Dekalb-Lehew-Teas

Soils (features, data, info) sounds a bit like the SCS is a mail order house?

Soils from Soil Conservation Service; 1967, 1972, 1979

GD **MARYLAND SOIL ASSOCIATIONS**

GD	Gilpin-Dekalb
DG	Dekalb-Gilpin-Ernest
CG	Cookport-Gilpin
LC	Lehew-Calvin
LD	Lehew-Calvin-Dekalb

AREA HAS HUMID CONTINENTAL CLIMATE

The climate in Area 5 may be termed humid continental, humid because of the even precipitation, and continental because of the yearly temperature range.

Area 5 is in or close to the highest average mountain elevations east of the Mississippi River. The southeastern third of Area 5 has a cooler mountain climate because of the higher elevation. The central and western two-thirds generally slope westward to the Ohio and Mississippi Rivers. Area 5's location places it in the path of a number of the major storm tracks that cross the area from the north, west, and south. Winter storms originate in polar Canada and travel due south from the Hudson Bay or east from the Rocky Mountains. At times in the winter, warm air from the Gulf travels north causing alternate thawing and freezing. Summer storms from the south bring heavy rains and hot humid weather.

Precipitation is fairly evenly distributed throughout the year, lowest during the fall, and somewhat higher during the spring and summer. Snow usually begins in October and ends in May. The amount of snow varies with elevation, ranging from 30 to 125 inches per year. The weather station at Pickens, West Virginia, in the southern part of Area 5, records the highest average (125 inches) snowfall in the State. Average annual precipitation increases from the Ohio and Mississippi Rivers eastward to the Appalachian Mountains. The northern part of Area 5 has a mean annual precipitation of 36 inches (elevation 765 feet) while the southern section has 66 inches (elevation 2,700 feet). Temperatures and precipitation peak during July.

Mean annual precipitation, in inches, is shown by isolines on figure 4.4-1; the base period is 1941-70. The recorded normals at several weather stations are shown in figure 4.4-2.

Temperatures have been recorded as high as 105°F during the month of July and as low as -30°F in the month of January. Because of the differences in topography, the mean annual freeze-free period ranges from 110 days to 185 days. The recorded normal temperatures at Donora, Pa., Morgantown, W. Va., and Elkins, W. Va., weather stations are shown in figure 4.4-2.

Daily precipitation data are published monthly as "Local Climatological Data for Pennsylvania" by the National Oceanic and Atmospheric Administration, National Climatic Center, Ashville, North Carolina. Statistical information on analysis and data are presented by the U.S.Department of Commerce (1973).

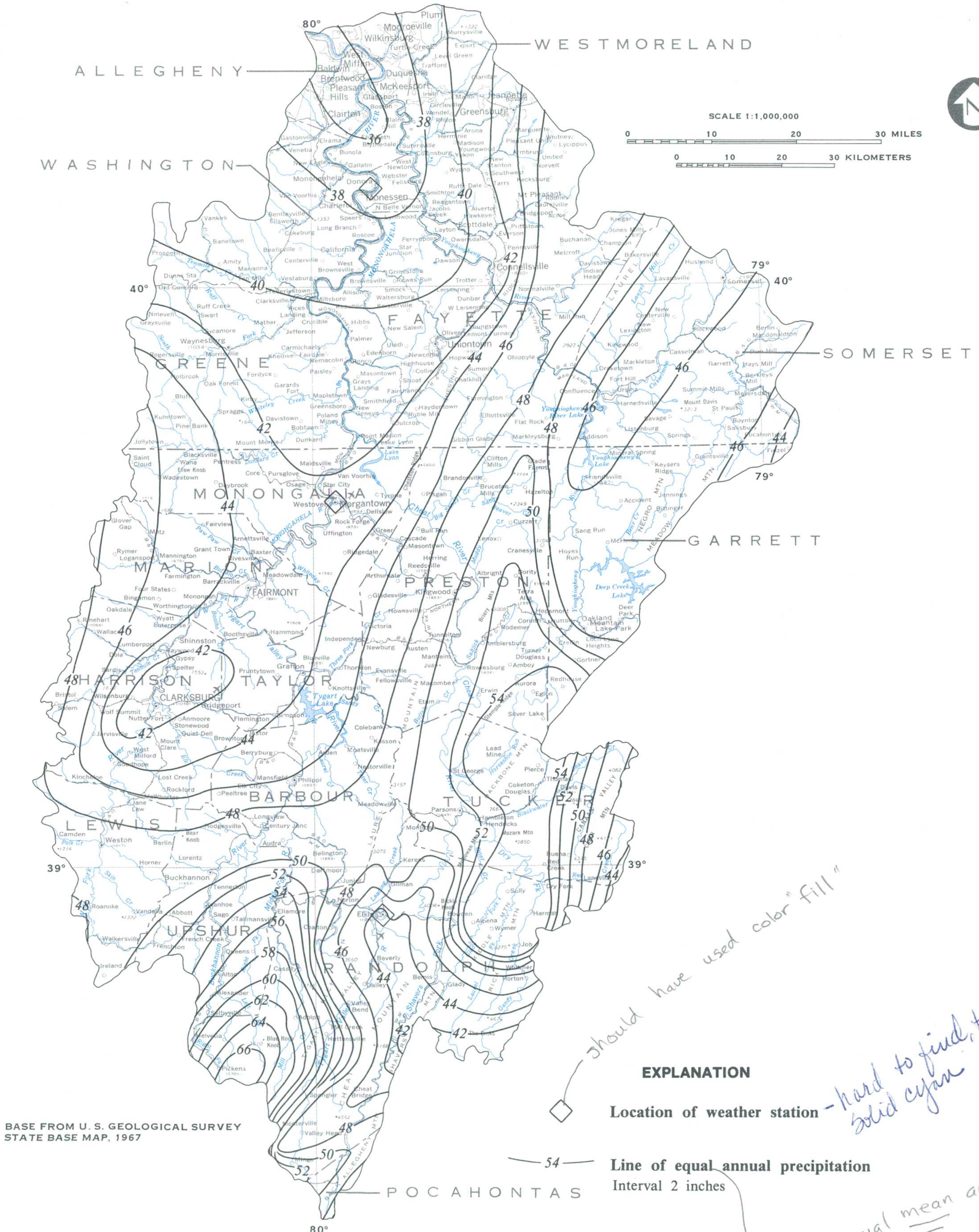


Figure 4.4-1 Mean annual precipitation.

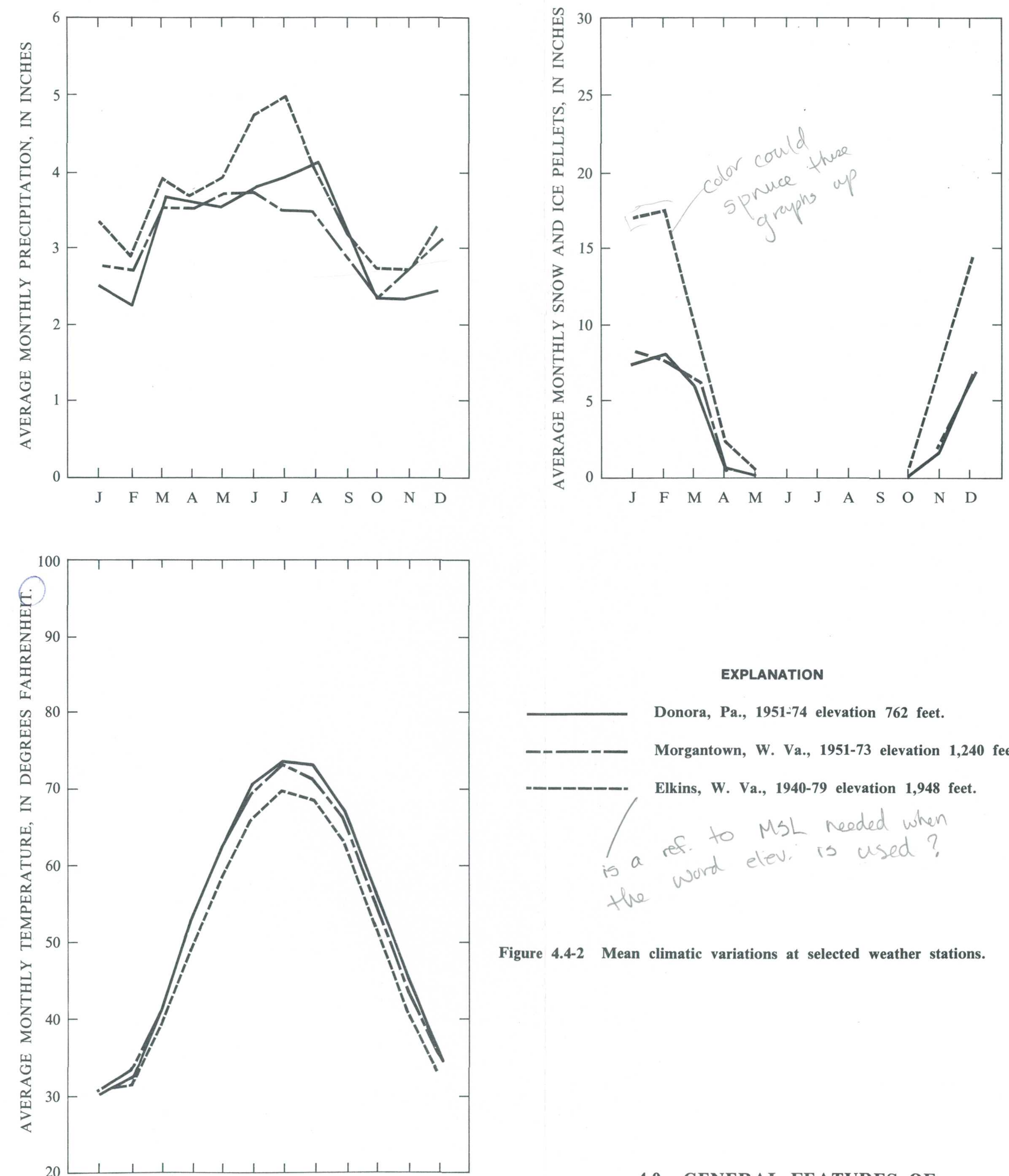


Figure 4.4-2 Mean climatic variations at selected weather stations.

4.0 GENERAL FEATURES OF STUDY AREA (CONTINUED)

4.4 CLIMATE

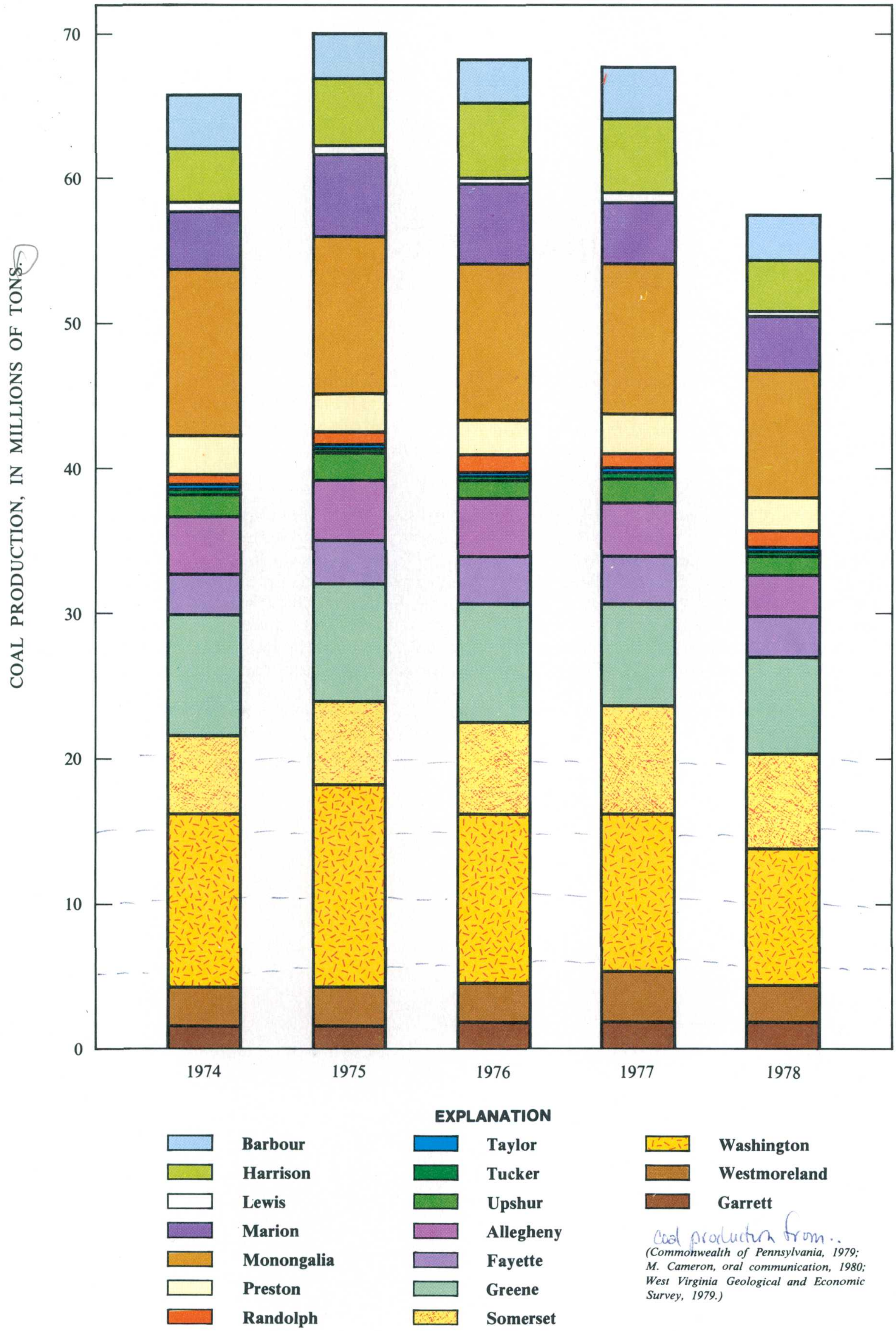
AREA COUNTIES PRODUCED 64 MILLION TONS OF COAL ANNUALLY DURING 1974-78

Annual coal production in Area 5 counties during 1974-78 averaged 63,658,000 tons. Washington County, Pennsylvania, produced an annual average of 11,917,000 tons.

Coal production from counties in Eastern Coal Province Area 5 averaged 63,658,000 tons per year during 1974-78 (Commonwealth of Pennsylvania, 1979; M. Cameron, oral communication, 1980; West Virginia Geological and Economic Survey, 1979). Figure 5.1-1 illustrates the total production and the county-by-county production for the period. Annual production ranged from 70 million tons in 1975 to 57 million tons in 1978. During 1975-77 there was a gradual decline in coal production followed by a precipitous drop in 1978 (fig. 5.1-1).

Four of the 17 counties in Area 5 accounted for about 55 percent of the total production. Washington County, Pa., was the leading coal producer of the Area 5 counties, having an average annual production of 11,917,000 tons during 1974-78. Monongalia County, W. Va., and Greene and Somerset Counties, Pa., rounded out the top four, having average annual productions of 10,495,000; 7,600,000; and 6,220,000 tons, respectively. The production from the Area 5 counties in Pennsylvania and West Virginia accounted for over 35 percent of those States' combined bituminous coal production. Owing to the fact that some of the listed counties are only partly in Area 5, the actual production in the area is somewhat less than these figures indicate.

could fit small county map here w/ corresponding color coding to the right graph



not useful for measurement

Figure 5.1-1 Coal production in Area 5 counties, 1974-78.

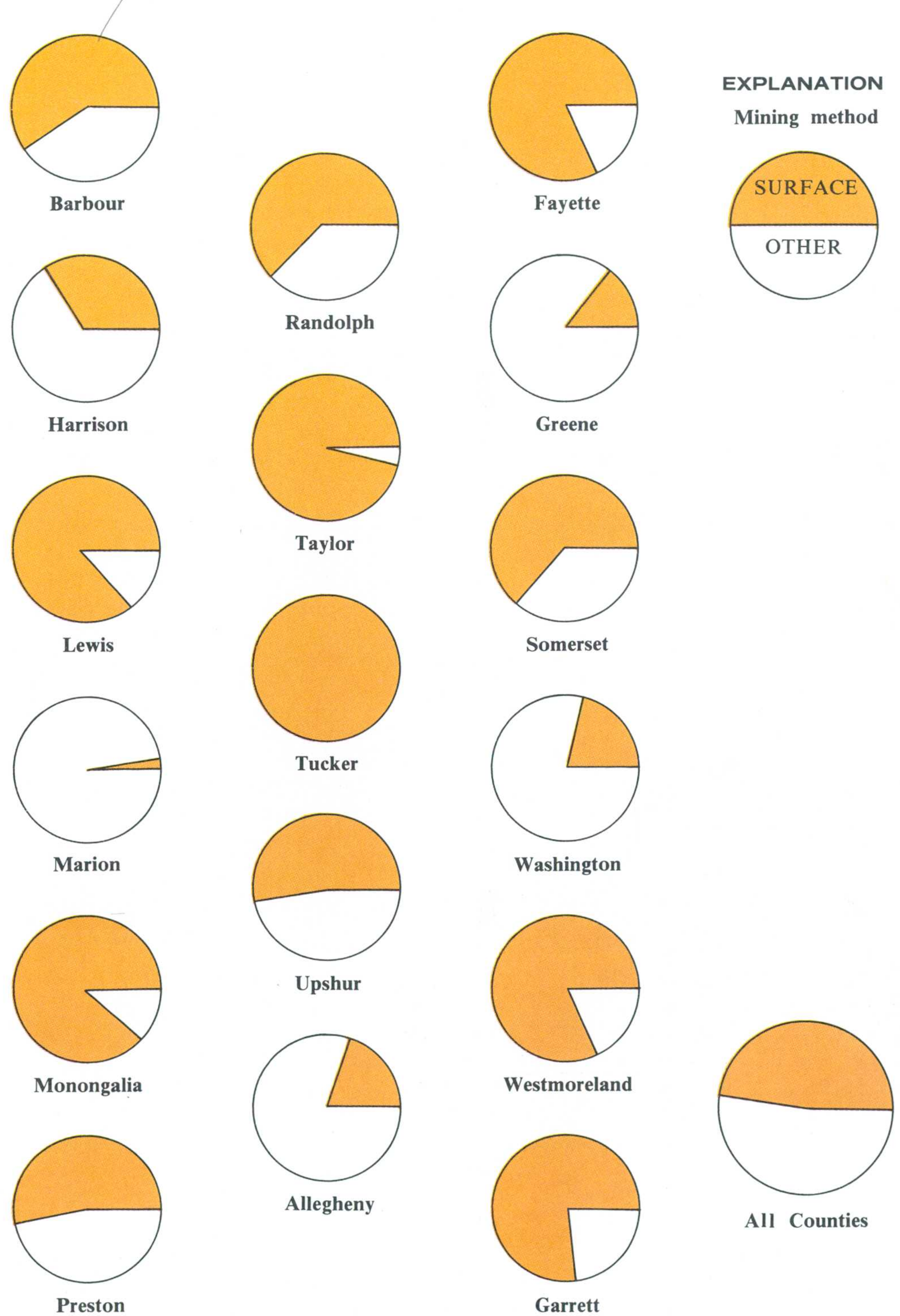
SURFACE MINING IMPORTANT IN AREA

Fifty percent of the coal mined in Area 5 counties comes from surface mines. Counties in the area have 136 square miles of coal-mining disturbed land which is in need of reclamation.

During 1978 about 57 million tons of coal were mined in counties in Eastern Coal Province Area 5 (Commonwealth of Pennsylvania, 1979; West Virginia Geological and Economic Survey, 1979; M. Cameron, oral communication, 1980). Almost 50 percent of the total came from surface mines. Figure 5.2-1 illustrates the contribution of surface mining to total coal production in Area 5 counties. Almost 60 percent of the surface-mined coal came from Monongalia, Somerset, Fayette, and Westmoreland Counties.

Almost 2 percent of the land area in the counties of Area 5 has been disturbed by surface coal mining to an extent that requires reclamation. The U.S. Department of Agriculture (1977) indicates that about 87,000 acres or 136 mi^2 (square miles) are in need of reclamation. Coal-mining disturbed land in Fayette, Somerset, and Washington Counties, Pennsylvania, account for about 50 percent of this area (fig. 5.2-2). Almost 30 percent of the disturbed land has a legal requirement for reclamation, but 70 percent or 63,000 acres lacks such a requirement. Once again, Fayette, Somerset, and Washington Counties account for about 50 percent of the disturbed area having no legal reclamation requirements.

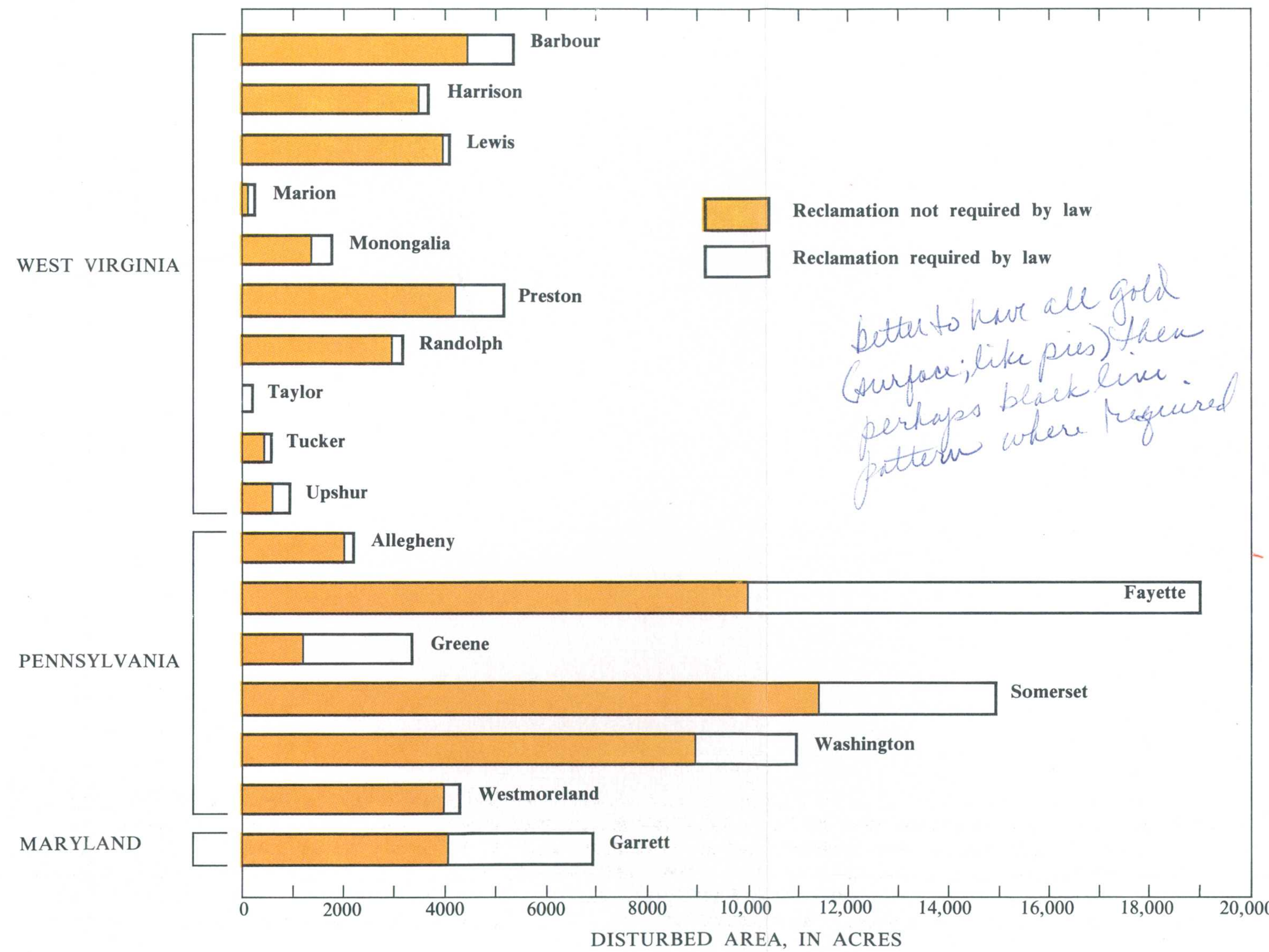
have room for county map here



Data from Commonwealth of Pennsylvania (1979), West Virginia Geological and Economic Survey (1979), and M. Cameron oral communication (1980).

Figure 5.2-1 Surface mining contribution to total coal production in counties.

nice idea



Data from U.S. Dept. of Agriculture (1977)

better to have all gold (surface; like pies) then perhaps black line pattern where required

Figure 5.2-2 Land disturbed by surface coal mining in need of reclamation ~~in~~ counties. ~~only~~ or by county

RECENT STREAMFLOW DATA COLLECTED AT 193 LOCATIONS IN AREA

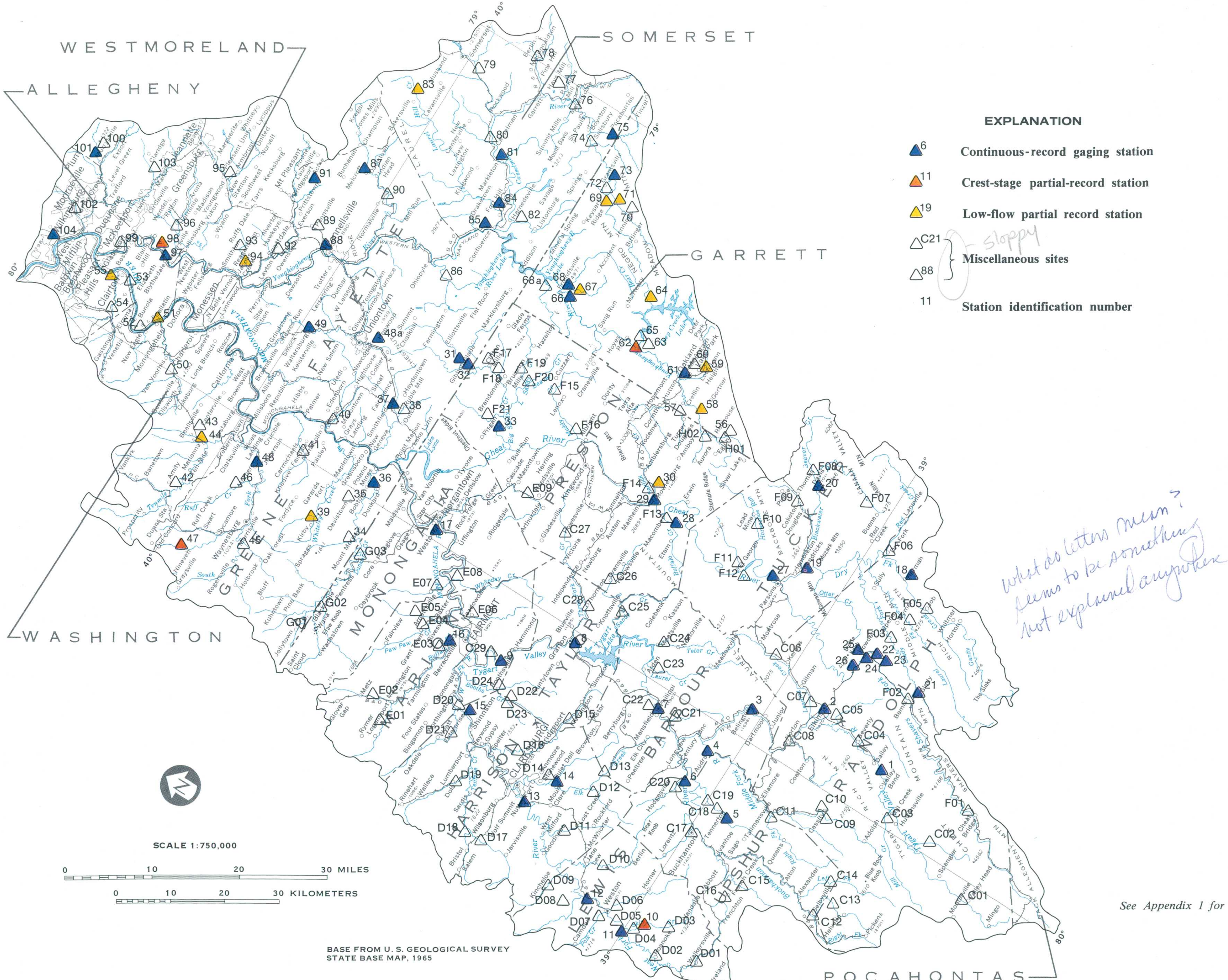
Streamflow data have recently been collected at 50 continuous-record gaging stations, 4 crest-stage partial-record stations, 13 low-flow partial-record stations, and 126 miscellaneous sites in Area 5.

Systematic collection of streamflow data at an established network of stations is a key ingredient in the assessment of the hydrology of any area. If streamflow data are collected over a period of time, it is possible to make estimates of certain streamflow characteristics at the stations. Such systematic data collection also provides hydrologists with the necessary tools to make estimates of streamflow characteristics for sites where data are not collected. Surface-water data are collected at continuous-record stations, partial-record stations, or miscellaneous sites. Appendix 1 lists the 67 streamflow stations and 126 miscellaneous sites in Area 5 and figure 6.1-1 shows their locations.

Continuous-record stations are locations where a continuous record of stream stage (height of the water surface above an arbitrary datum) is collected. The stage information is generally collected and recorded by a variety of automatic recorders. Periodic measurements of actual streamflow or discharges relate specific stages to specific discharges. The continuous record of stage, combined with the stage-discharge relation, provides a continuous record of streamflow. Such continuous streamflow data are usually converted to yield a mean daily discharge, although instantaneous discharges at specific times during the day can also be determined. Continuous-record stations provide the most detailed streamflow data.

Partial-record stations supplement the networks of continuous-record stations. They provide additional data at a much lower cost than that provided by a continuous-record station although much detail is lost. Low-flow partial-record stations have no recording devices, but rather are measured directly during low flow. Relationships between concurrent flows at the partial-record and continuous-record stations extend the areal coverage of low-flow data. Crest-stage partial-record stations, on the other hand, utilize a simple gage to record the maximum stage reached by a stream during a runoff event. A stage-discharge relation, developed through a series of direct discharge measurements and indirect discharge determinations, is then used to compute the peak flow during the event. Such peak-flow data can be analyzed to determine the flood-frequency characteristics of a stream.

Miscellaneous sites are locations at which occasional discharge measurements are made without attempts to measure at extremely high or low flows. Discharge data at miscellaneous sites can be combined with water-quality data to compute instantaneous loads of various dissolved or suspended constituents.



See Appendix 1 for detailed station description

Figure 6.1-1 Locations of surface-water quantity stations.

WATER-QUALITY DATA AVAILABLE FOR 157 SITES IN AREA

Water-quality data have recently been collected at 27 daily streamflow stations and 130 miscellaneous sites in Area 5.

The locations of 27 gaging stations where recent water-quality data and daily-streamflow data have been collected in Eastern Coal Province Area 5 are shown in figure 6.2-1. The gaging stations are identified by downstream order number and name in Appendix 1.

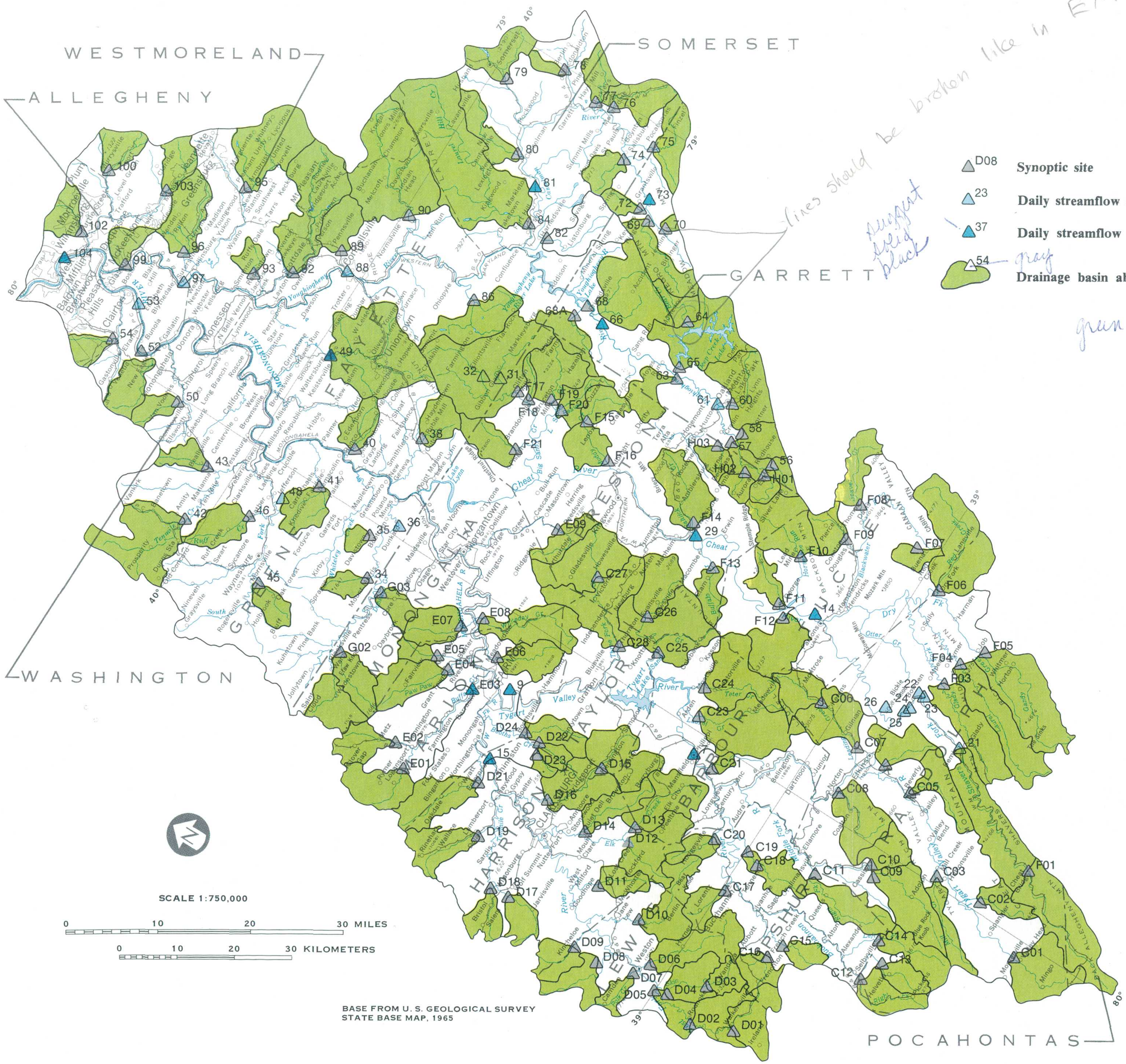
Water-quality data were collected at 19 of the 27 stations 4 to 9 times annually for several years in the latter half of the 1970's. Typical data collected during the period include, in addition to streamflow: specific conductance, pH, temperature, turbidity, dissolved oxygen, suspended sediment, acidity, alkalinity, dissolved sulfate, dissolved iron, total iron, and hardness.

Three of the 19 gaging stations sampled during the 1970's, plus eight others, were selected for continued water-quality sampling as part of a program for the hydrologic study of coal areas. These 11 sites, circled on figure 6.2-1, will be sampled 6 to 9 times annually.

In order to more fully describe the hydrology of the area, sampling was initiated or continued at 134 additional monitoring sites. Figure 6.2-1 shows the location of these monitoring sites, known as synoptic sites and Appendix 1 provides the identification number and name of each site. The map also shows the drainage basin that is monitored at each synoptic site. Any activity affecting water quality or quantity taking place in one of the shaded areas should be reflected at the downstream synoptic site. However, if the change is small or transitory, it may not be detected at the synoptic site.

All first order streams in coal-bearing sections of Area 5 were initially considered for a synoptic site. First order streams were defined as those unbranched streams appearing on a 1:500,000 scale Hydrologic Unit map. A subset of these first order streams was selected for actual synoptic site location. The final site selection was designed to provide broad coverage in Area 5.

Synoptic sites were located on 134 streams having drainage areas ranging from 3.82 to 1,366 mi^2 (square miles). The median drainage area for all streams was about 21 mi^2. Almost 40 percent of the streams have drainage areas between 10 and 20 mi^2 while about 15 percent of the streams have drainage areas larger than 50 mi^2.



EXPLANATION

D08 Synoptic site

23 Daily streamflow station having water-quality data.

37 Daily streamflow station where coal-hydrology data are being collected.

54 Drainage basin above synoptic site.

lines should be broken like in EXP.

suggest solid black

gray

green drainage basin?

Figure 6.2-1 Locations of surface-water quality stations.

SAMPLING NETWORK IS DESIGNED TO DEFINE COAL-RELATED WATER QUALITY IN AREA

A network of 134 synoptic sites and 11 continuous-record stations is being sampled to collect water-quality data which may be related to the presence of coal or coal mining. The sampling schedule is designed to collect data over a range of flow conditions.

The present sampling program of the coal hydrology network utilizes two types of sampling stations, each having a distinct purpose. A large network of synoptic sites is designed to provide broad areal coverage, while a smaller network of continuous-record stations is designed to provide more detailed information on changes in water quality over time.

Water-quality samples and measurements of discharge (streamflow) are planned for at least three different flow conditions at synoptic sites. Samples have been collected under high and intermediate base flow conditions at most synoptic sites. Climatic conditions prevented adequate low base-flow sampling prior to preparation of this report. Future plans include sampling at low base flow.

Table 6.3-1 lists the types and frequencies of data collection at the 134 synoptic sites. These data were selected to concentrate on information which may be useful in coal-bearing areas. Many of the water-quality constituents listed in table 6.3-1 are specifically mentioned in the surface mining regulations. These water-quality data are published by U.S.Geological Survey (1980a, b, c; 1981a, b, c).

Similar data are being collected at the six continuous-record stations in Area 5's coal hydrology network. Samples are being collected more frequently than at the synoptic sites and additional samples are being collected. Table 6.3-2 lists the types and frequencies of sampling at the continuous-record stations. The data collected at these sites have been published by U.S. Geological Survey (1980a, b, c; 1981a, b, c).

Table 6.3-1 Types and frequency of water-data collection at synoptic sites.

Each visit (low, medium, and high flows)

Discharge	Dissolved iron
Temperature	Total manganese
Specific conductance	Dissolved manganese
pH	Sulfate
Alkalinity	Residue, dissolved
Acidity	Suspended sediment
Total iron	

Annually (low flow)

Identification of benthic invertebrates

One time only (low flow)
Bottom materials

Arsenic	Manganese
Cadmium	Mercury
Chromium	Selenium
Cobalt	Zinc
Copper	Organic carbon
Iron	Inorganic carbon
Lead	Coal

Storm events (high flow)
selected sites

Suspended sediment and discharge

Table 6.3-2 Types and frequency of water-data collection at continuous-record stations.

Each visit (6-9, times annually)

Discharge	Dissolved iron
Temperature	Total manganese
Specific conductance	Dissolved manganese
pH	Sulfate
Alkalinity	Residue, dissolved
Acidity	Suspended sediment
Total iron	

Annually (low flow)

Identification of benthic invertebrates

One time only (low flow)[1]
Bottom materials

Arsenic	Manganese
Cadmium	Mercury
Chromium	Selenium
Cobalt	Zinc
Copper	Organic carbon
Iron	Inorganic carbon
Lead	Coal

Common constituents[1]

Sodium absorption ratio	Dissolved fluoride
Sodium percent	Residue, dissolved
Dissolved calcium	Dissolved silica
Dissolved manganese	Dissolved sulfate
Dissolved potassium	Nitrite plus nitrate
Dissolved sodium	Total phosphorus
Dissolved chloride	Total alkalinity

Minor elements[1]

Total barium	Total manganese
Total cadmium	Total silver
Total chromium	Total zinc
Total copper	Total arsenic
Total iron	Total selenium
Total lead	Cyanide
	Total mercury

[1]At continuous-record sites designated trend or reference collection is annually at low flow. Storm sediment data are also collected at trend and reference sites.

STREAMS IN THREE PARTS OF AREA HAVE SPECIFIC CONDUCTANCES IN EXCESS OF 1,000 MICROMHOS PER CENTIMETER

Specific conductances in excess of 1,000 μmho/cm (micromhos per centimeter) were found in 13 streams in 3 sections of Area 5. High conductances were found in the lower West Fork River basin, in tributaries to the Monongahela River in West Virginia and Pennsylvania, and in a group of streams in the vicinity of McKeesport, Pennsylvania.

The highest specific conductances observed at synoptic sites in Eastern Coal Province Area 5 during the 1979 and 1980 water years were found in 13 streams in 3 general locations. Figure 7.1-1 illustrates the maximum specific conductances found at synoptic sites in the area. Streams having maximum specific conductances in excess of 1,000 μmho/cm at 25°C were found in the lower West Fork River basin, in tributaries to the Monongahela River on both sides of the Pennsylvania--West Virginia State line, and in five streams in the vicinity of McKeesport, Pennsylvania. High specific conductances near McKeesport and in the West Fork basin ranged from 1,000 to 1,499 μmho/cm, whereas high specific conductances near the State line ranged from 1,500 to 8,000 μmho/cm.

Figure 7.1-1 also shows that streams having specific conductances lower than 300 μmho/cm were most common in the southeastern half of Area 5. Specific conductances less than 100 μmho/cm were almost entirely limited to streams in the headwaters of the Tygart Valley, Cheat, and Youghiogheny Rivers.

The mean maximum specific conductance observed at 134 sites in Area 5 was 465 μmho/cm, and the range was 20-8,000 μmho/cm. The median specific conductance value of 220 μmho/cm indicates the effect of several high conductances on the mean. Figure 7.1-2 illustrates the numerical distribution of maximum specific conductances.

Specific conductance determinations were generally made three times at each synoptic site during June 1979 to April 1980 according to procedures outlined by Skougstad and others (1979). The determinations were generally made during periods of moderate to high base flow. Low baseflow sampling is scheduled for the future. Data for the 1979 and 1980 water years are published by U.S. Geological Survey (1980a, b, c; 1981a, b, c).

Specific conductance data collected at four daily streamflow stations during the 1977 and 1978 water years illustrate the stream-to-stream and within-stream variability which may be encountered. Figure 7.1-3 shows mean specific conductance values ranging from 32 μmho/cm to 1,080 μmho/cm. Within individual streams the observed specific conductances varied by nearly a factor of 2. In spite of the specific-conductance variations within streams, a 2-sample t-test indicates that the means for all four stations are significantly different. At the daily streamflow sites there was a general negative correlation between specific conductance and the log(base10) of instantaneous discharge. This tends to indicate a relatively constant source of dissolved solids which is diluted to a greater or lesser extent as streamflow increases or decreases.

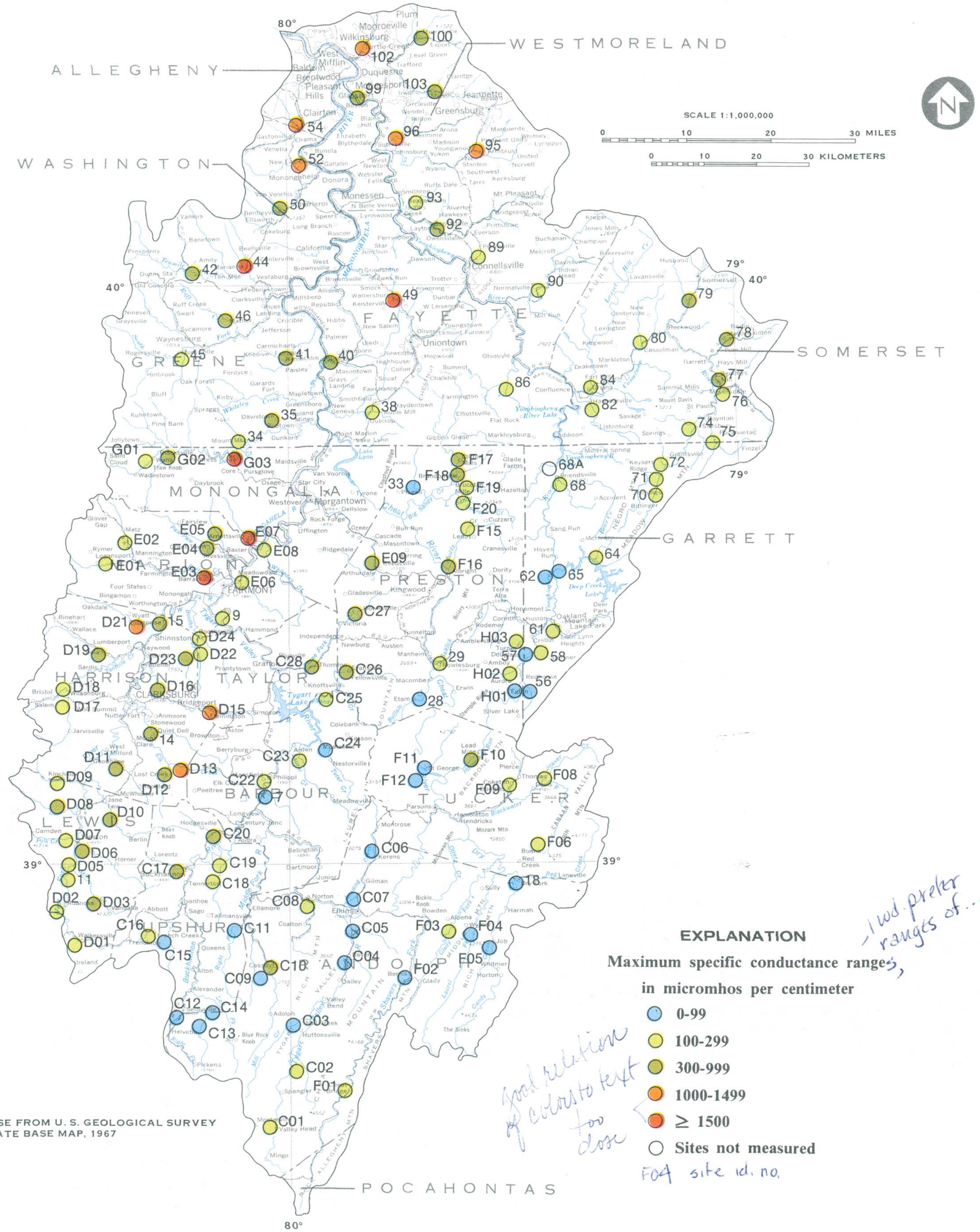


Figure 7.1-1 Maximum specific conductances at selected sites.

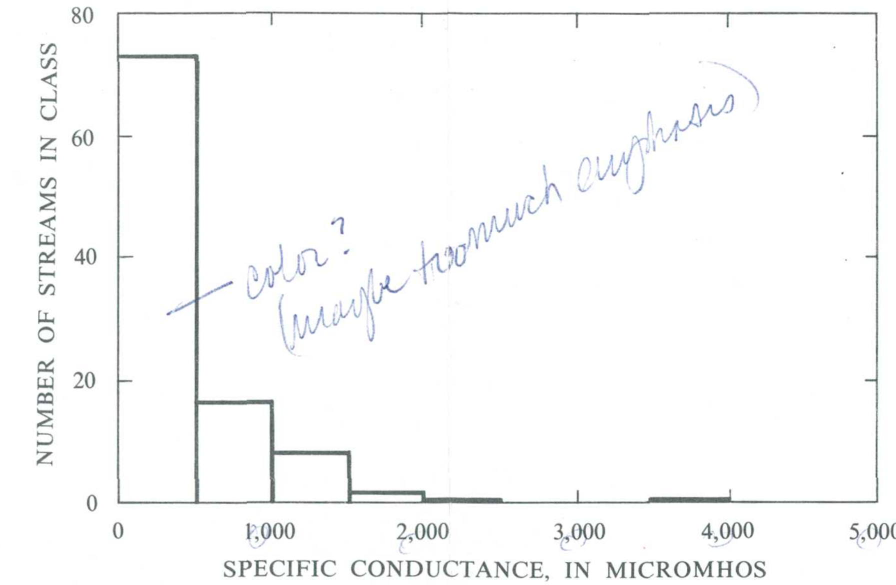


Figure 7.1-2 Histogram of maximum specific conductance in selected streams.

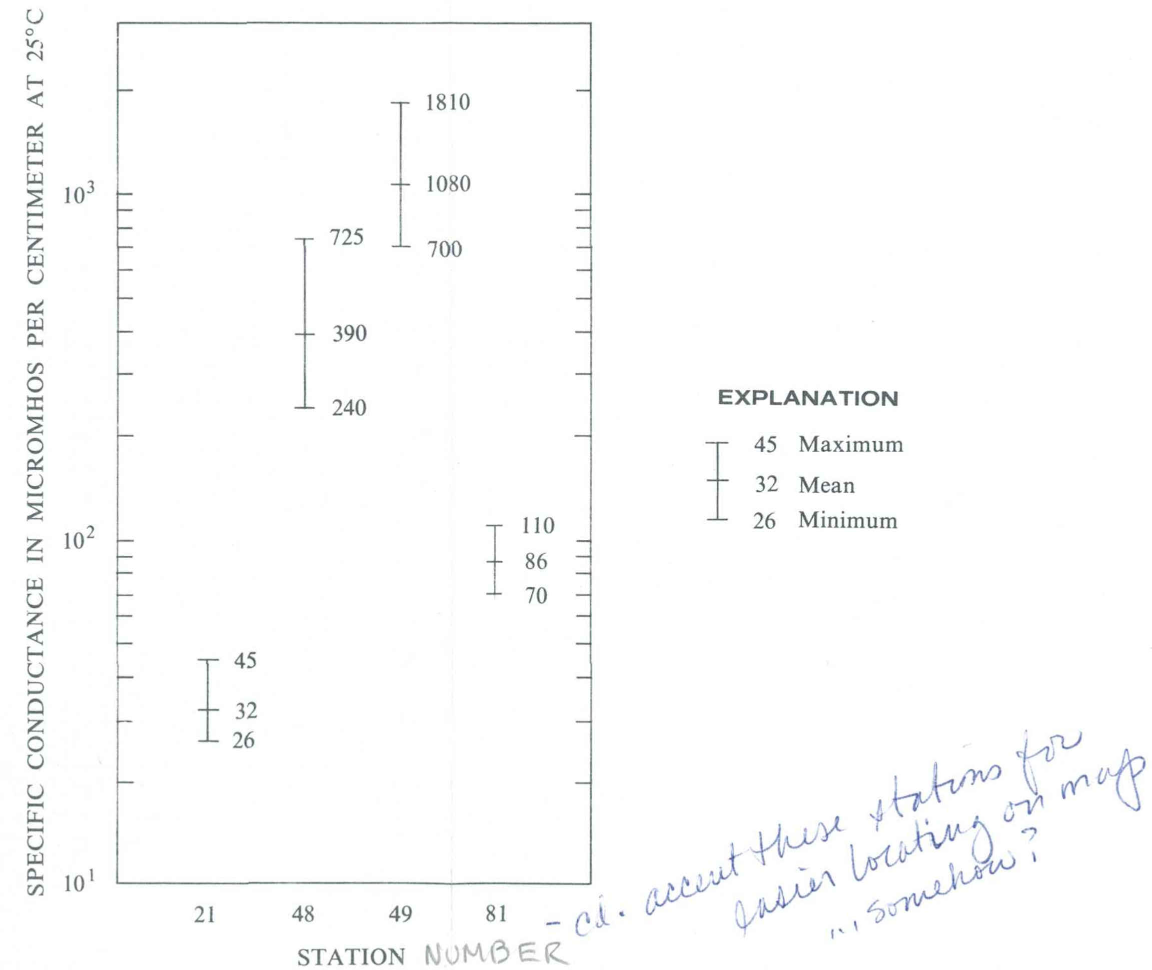


Figure 7.1-3 Ranges and means of specific conductance for selected continuous-record stations, 1977 and 1978 water years.

DISSOLVED-SOLIDS CONCENTRATIONS GREATER THAN 500 MILLIGRAMS PER LITER GENERALLY LIMITED TO WESTERN PART OF AREA

Dissolved-solids concentrations in excess of 500 mg/L (milligrams per liter) are almost exclusively limited to the western part of Area 5. There is a southeast-to-northwest trend of increasing dissolved solids.

Figure 7.2-1 illustrates that there is a southeast-to-northwest trend in maximum dissolved-solids concentrations in Eastern Coal Province Area 5. Dissolved-solids concentrations are generally less than 50 mg/L in the southeast corner of Area 5. A bit to the northwest, concentrations usually range from 50 to 200 mg/L, but a few reach 500 mg/L. From the lower West Fork River to the mouth of the Monongahela River, maximum dissolved-solids concentrations in the 500-999 mg/L are common, and concentrations in excess of 1,000 mg/L are not rare. Northwest of this band of high dissolved solids, concentrations are in the 50-500 mg/L range.

The average maximum dissolved-solids concentration at 134 synoptic sites was 325 mg/L, whereas the median was only 120 mg/L. The range of maximum dissolved-solids concentrations was from 22 to 7,000 mg/L. Figure 7.2-2 shows that about 70 synoptic sites had a maximum dissolved-solids concentration of 300 mg/L or less, whereas only six sites exceeded a concentration of 1,000 mg/L.

Samples for dissolved-solids determinations were generally collected three times during June 1979 to April 1980. Dissolved-solids concentrations were determined by procedures outlined by Skougstad and others (1979). Samples were normally collected during moderate to high base flow. Sampling is scheduled for future low base-flow conditions. Data for the 1979 and 1980 water years are published by U.S. Geological Survey (1980a, b, c; 1981a, b, c).

The relation between specific conductance and dissolved-solids concentration for synoptic sites in Area 5 is shown in figure 7.2-3. The relation was determined from 454 concurrent observations of specific conductance and dissolved-solids concentration. The regression equation defining this relationship is:

$$ROE = 0.83\,(SC) - 34 \qquad (7.2\text{-}1)$$

where ROE = dissolved-solids concentration, in milligrams per liter, and SC = specific conductance, in micromhos per centimeter at 25°C.

Equation 7.2-1 has a multiple correlation coefficient of 96 percent and a standard error of estimate of 88 mg/L dissolved solids. These factors indicate a close relation between dissolved-solids concentration and specific conductance.

The coefficient of 0.83 shown in equation 7.2-1 is rather high. Hem (1970) indicates that the full range of coefficients to be expected for natural waters is about 0.55 to 0.96. Coefficients greater than 0.75 generally are associated with water high in sulfate concentration.

Dissolved-solids concentration for streams in Area 5 is closely related to the concentration of dissolved sulfate. The regression equation for this relation, shown graphically in figure 7.2-4, is:

$$ROE = 1.58\,(SO_4) + 51 \qquad (7.2\text{-}2)$$

where ROE = dissolved-solids concentration, in milligrams per liter, and SO_4 = dissolved-sulfate concentration, in milligrams per liter.

A multiple correlation coefficient of 97 percent and a standard error of estimate of 78 mg/L dissolved solids for equation 7.2-2 indicate the closeness of the relation. The mean sulfate concentration of the 450 samples was about 48 percent of the mean dissolved-solids concentration.

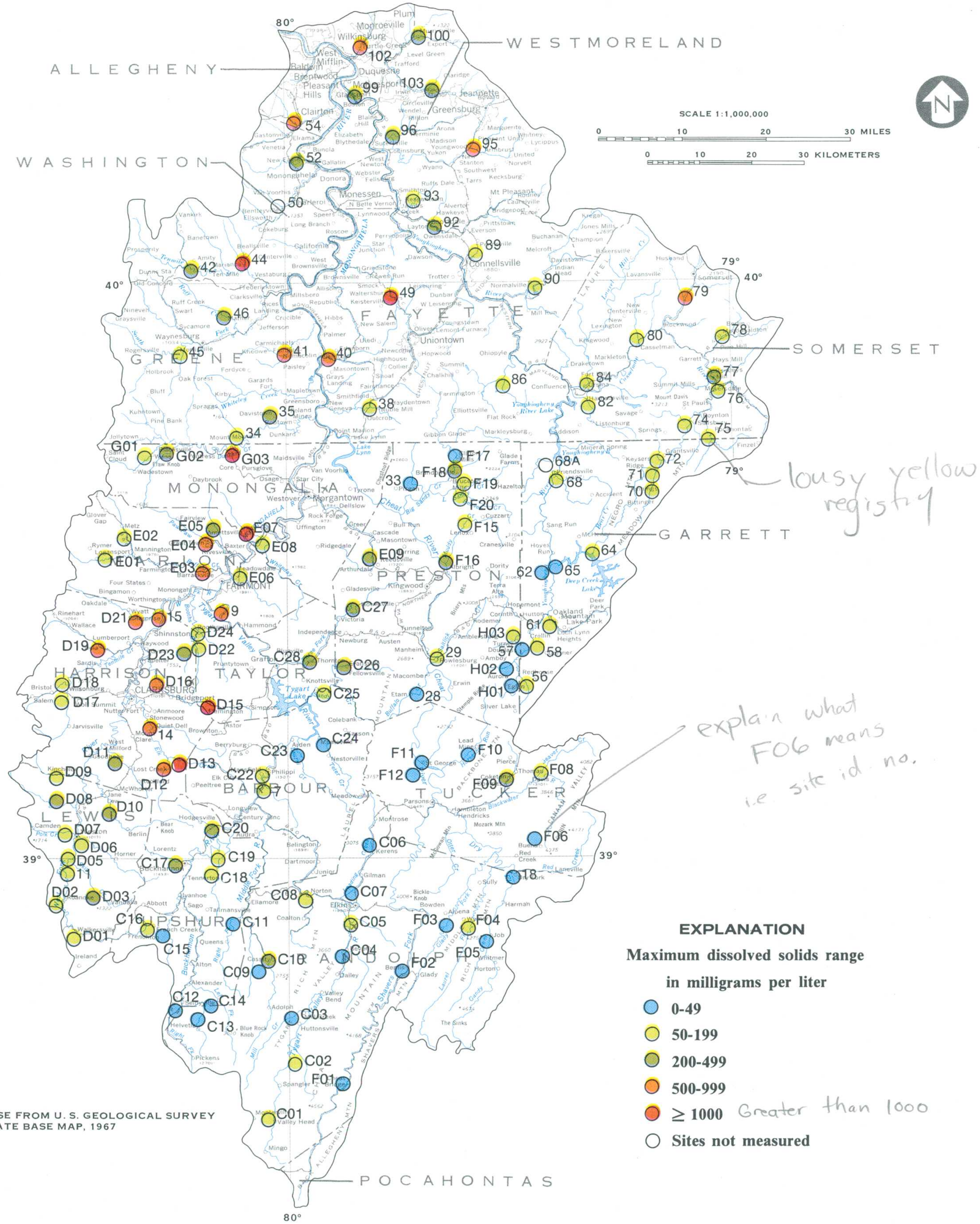


Figure 7.2-1 Maximum dissolved solids at selected sites.

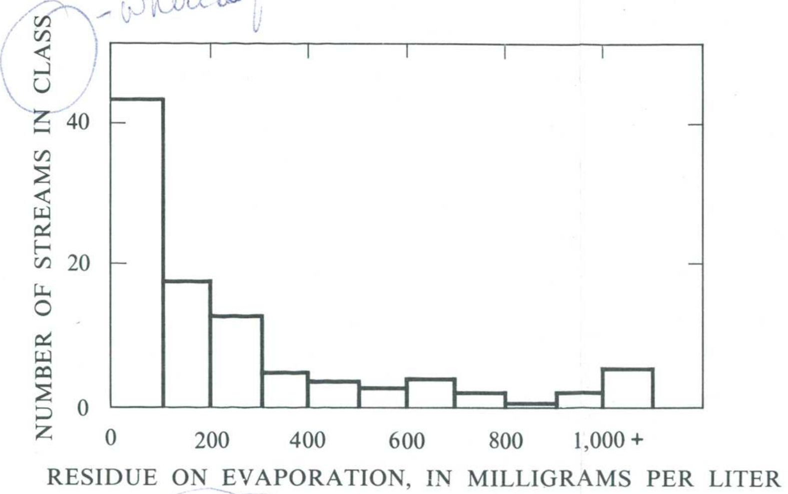


Figure 7.2-2 Histogram of maximum dissolved solids in selected streams.

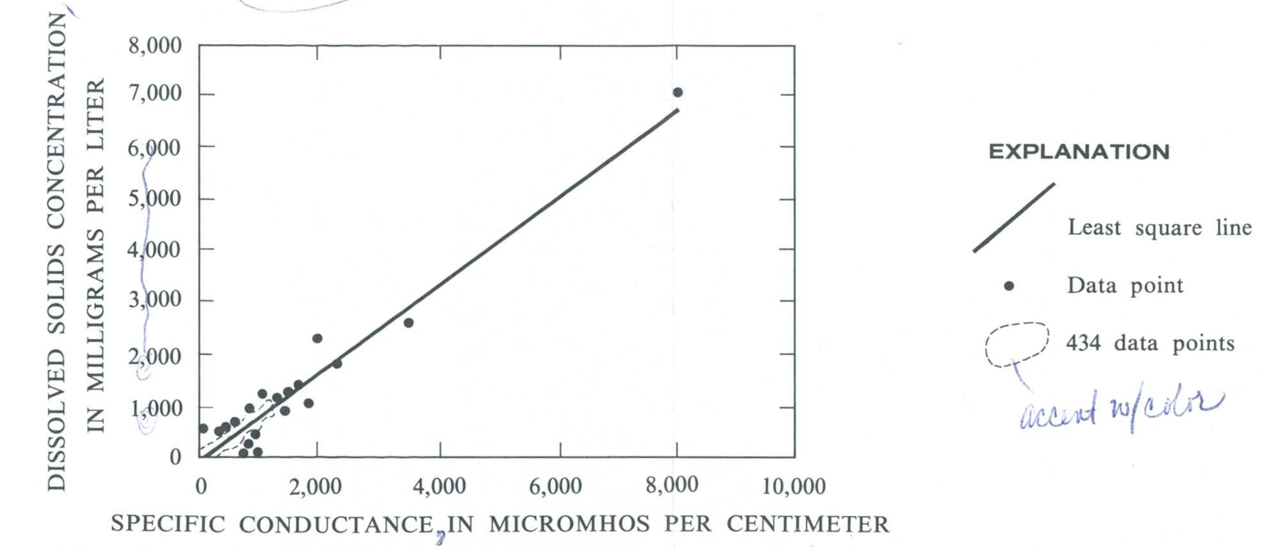


Figure 7.2-3 Relation between dissolved solids and specific conductance for selected streams.

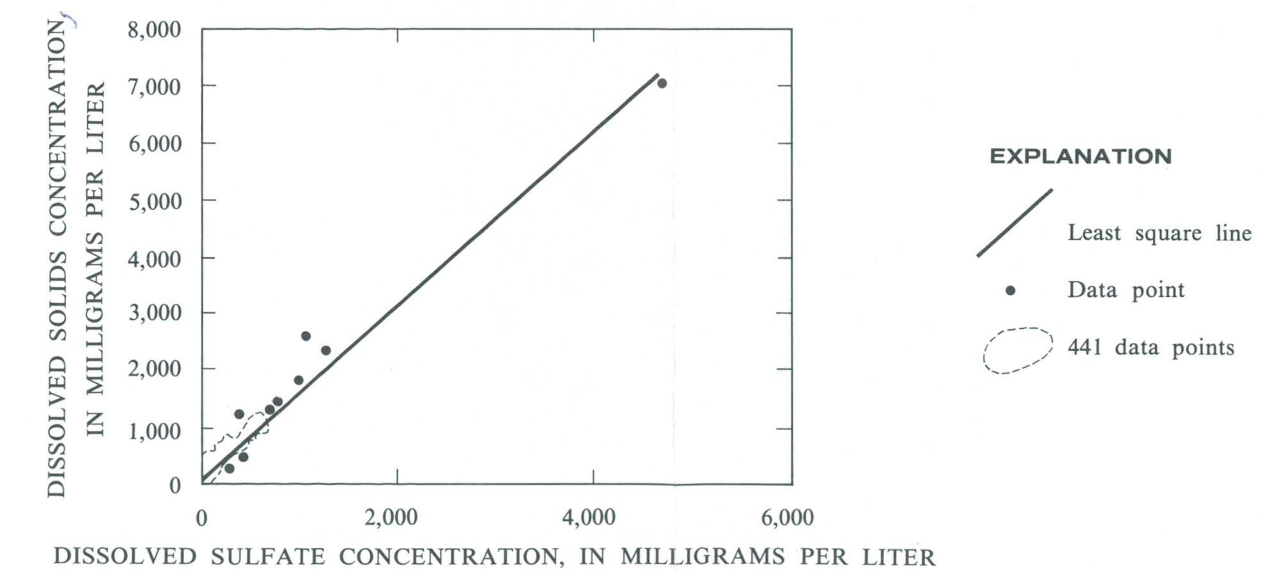


Figure 7.2-4 Relation between dissolved solids and dissolved sulfate for selected streams.

MOST AREA STREAMS HAVING pH VALUES LESS THAN 4.5 WERE FOUND IN THE VICINITY OF PRESTON COUNTY, WEST VIRGINIA

Many streams in the vicinity of Preston County, West Virginia had pH values less than 4.5. Several other streams having low pH values were located near Elkins, West Virginia.

Fourteen of the 134 synoptic sites tested in Eastern Coal Province Area 5 during the 1979 and 1980 water years had a minimum pH of less than 4.5. An additional five sites had minimum pH values in the range of 4.5 to 5.49. Figure 7.3-1 illustrates the distribution of minimum pH values in the area. Most of the streams that had a minimum pH less than 4.5 were found in or near Preston County, West Virginia. Several other streams with pH levels below 4.5 were scattered throughout Area 5. Two sites also having low minimum pH were near Elkins, West Virginia. Figure 7.3-1 also illustrates that minimum pH values are not randomly distributed throughout Area 5. Most of the streams in the northern third of the area have minimum pH in the 6.5-7.5, or approximately neutral range. Streams in the West Fork River basin are also predominately in the neutral pH range. Scattered locations in the upper Tygart Valley River basin exhibited a minimum pH in the 5.5-6.5 range. Only two sites, both in the northern part of Area 5, had minimum pH values greater than 7.5.

The mean minimum pH value at 134 synoptic sites in Area 5 was 6.2 and the median minimum pH was 6.45. Minimum pH values ranged from 2.0 to 7.9. Figure 7.3-2 shows that about 45 synoptic sites had pH in the neutral range of 6.5-7.5 and that more than 90 streams had a minimum pH value within one pH unit of neutral. Only 14 streams had a minimum pH value of less than 4.5.

Determinations of pH were generally made three times during June 1979 to April 1980 using procedures outlined by Skougstad and others (1979). Determinations were generally made during periods of moderate to high base flow. Future plans include low base-flow pH determinations. Data for the 1979 and 1980 water years are published by U.S. Geological Survey (1980a, b, c; 1981a, b, c).

Figure 7.3-3 illustrates that pH measurements at different times in the same stream can vary widely (2.6 pH units for site 21). The mean pH values at the four selected daily streamflow stations during the 1977 and 1978 water years were not significantly different from one another except when comparing site 21 with site 48 and site 48 with site 81. Figure 7.3-3 also demonstrates that some pH values for sites 21 and 81 fell below the Office of Surface Mining (1979) effluent limit of pH 6.0; however, the mean pH for all four streams was at or above the effluent standard.

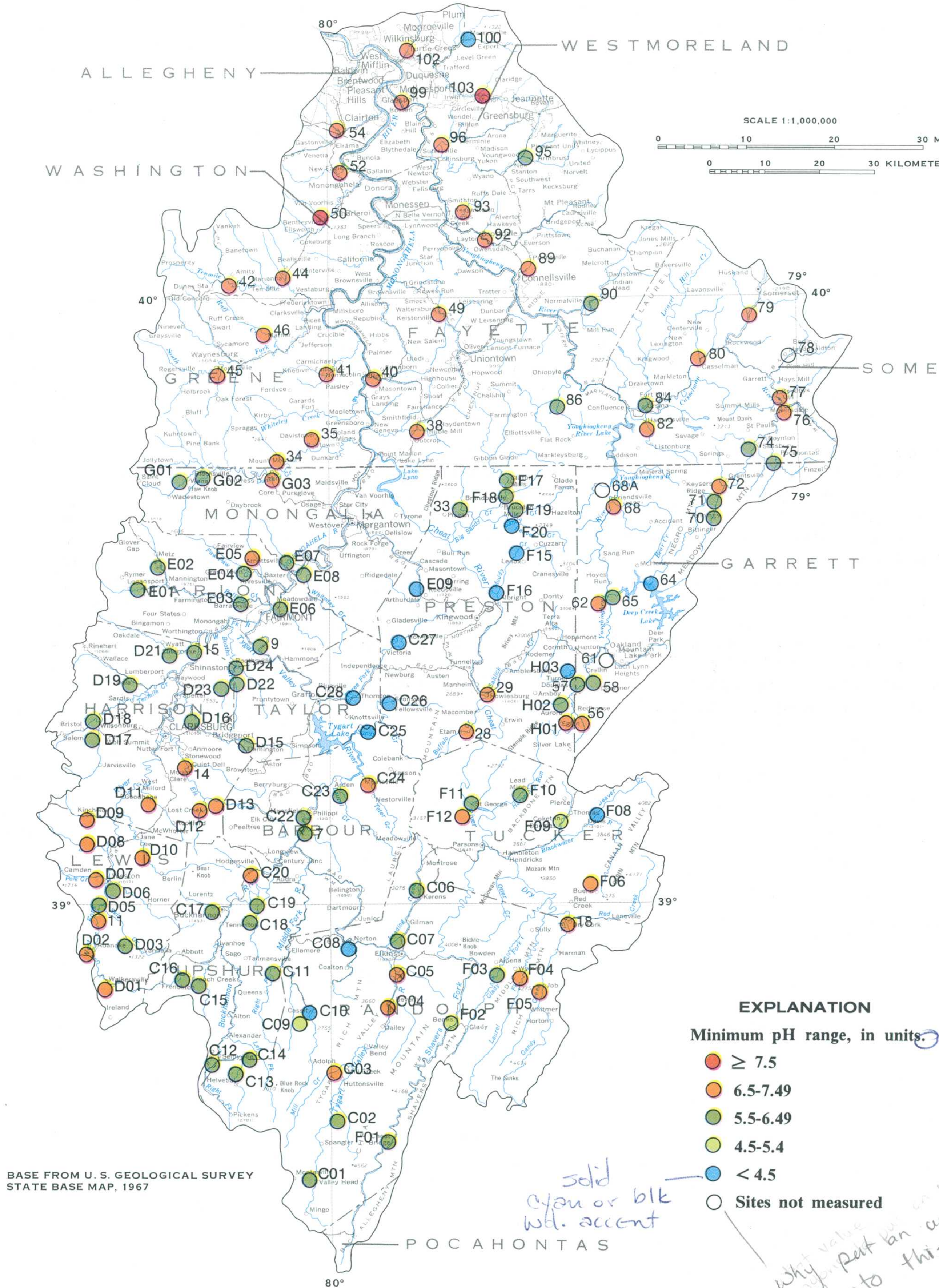


Figure 7.3-1 Minimum pH at selected sites.

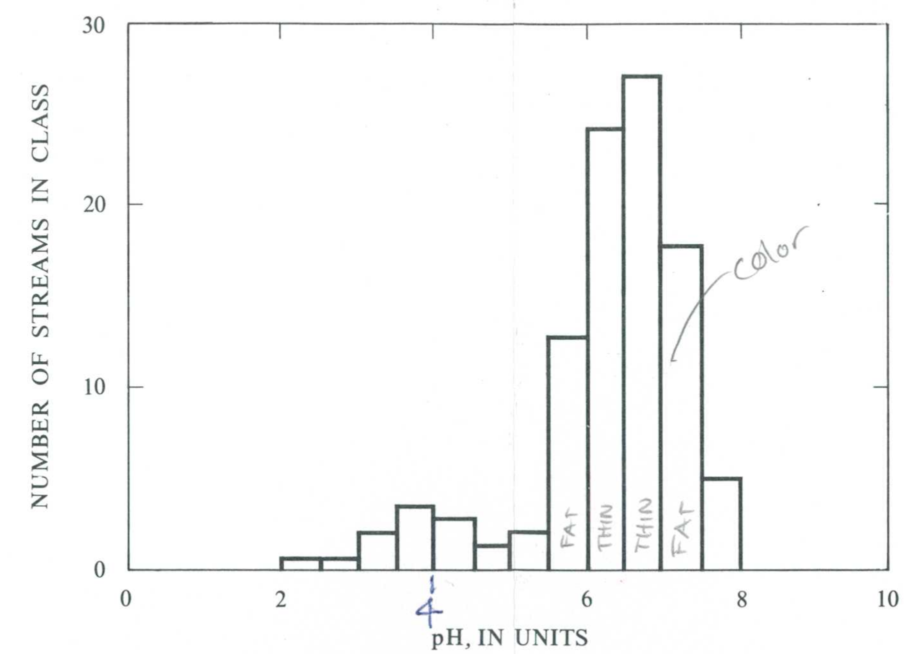


Figure 7.3-2 Minimum pH in selected streams.

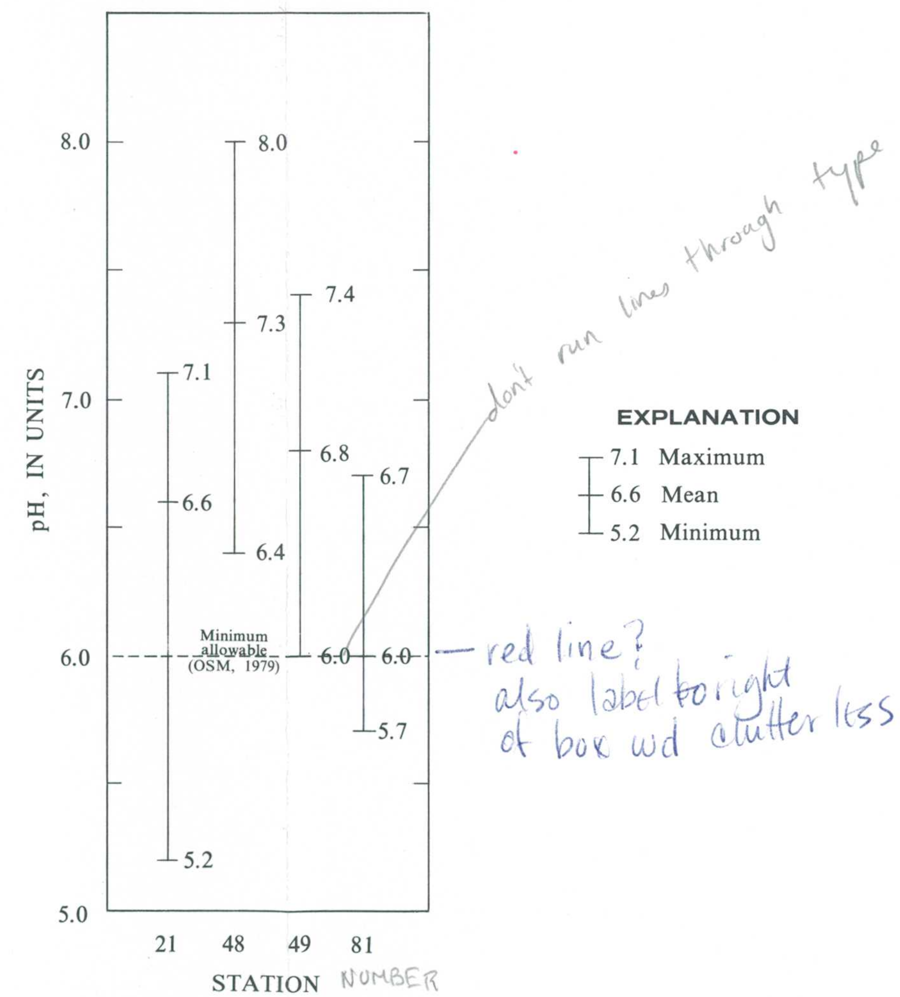


Figure 7.3-3 Ranges and means of pH for selected continuous-record stations, 1977 and 1978 water years.

ACIDITY EXCEEDS ALKALINITY AT 36 OF 134 STREAMS IN AREA

Concurrent acidity exceeded alkalinity at 36 of 134 synoptic sites in Area 5. These sites were limited to the eastern part of the area.

When concurrent acidity and alkalinity determinations were compared for 134 synoptic sites in Eastern Coal Province Area 5 during the 1979 and 1980 water years, acidity was found to exceed alkalinity at 36 streams. If a stream's acidity exceeded its alkalinity in just one of the 3-5 samples collected during January 1979 to April 1980, it was included in this classification.

Figure 7.4-1 shows the locations of the 36 synoptic sites in Area 5 where acidity exceeded alkalinity. All but one of the sites are located in the eastern part of the area. Most of the sites where acidity exceeds alkalinity are in the Buckhannon, Cheat, and upper Youghiogheny River basins.

Samples for acidity and alkalinity determinations were generally collected 3-5 times during January 1979 to April 1980. Determinations of alkalinity and acidity were made according to procedures described by Skougstad and others (1979). Samples were usually collected during intermediate to high base flow. Future plans include low base-flow sampling. Data for the 1979 and 1980 water years are published by U.S. Geological Survey (1980a, b, c; 1981a, b, c).

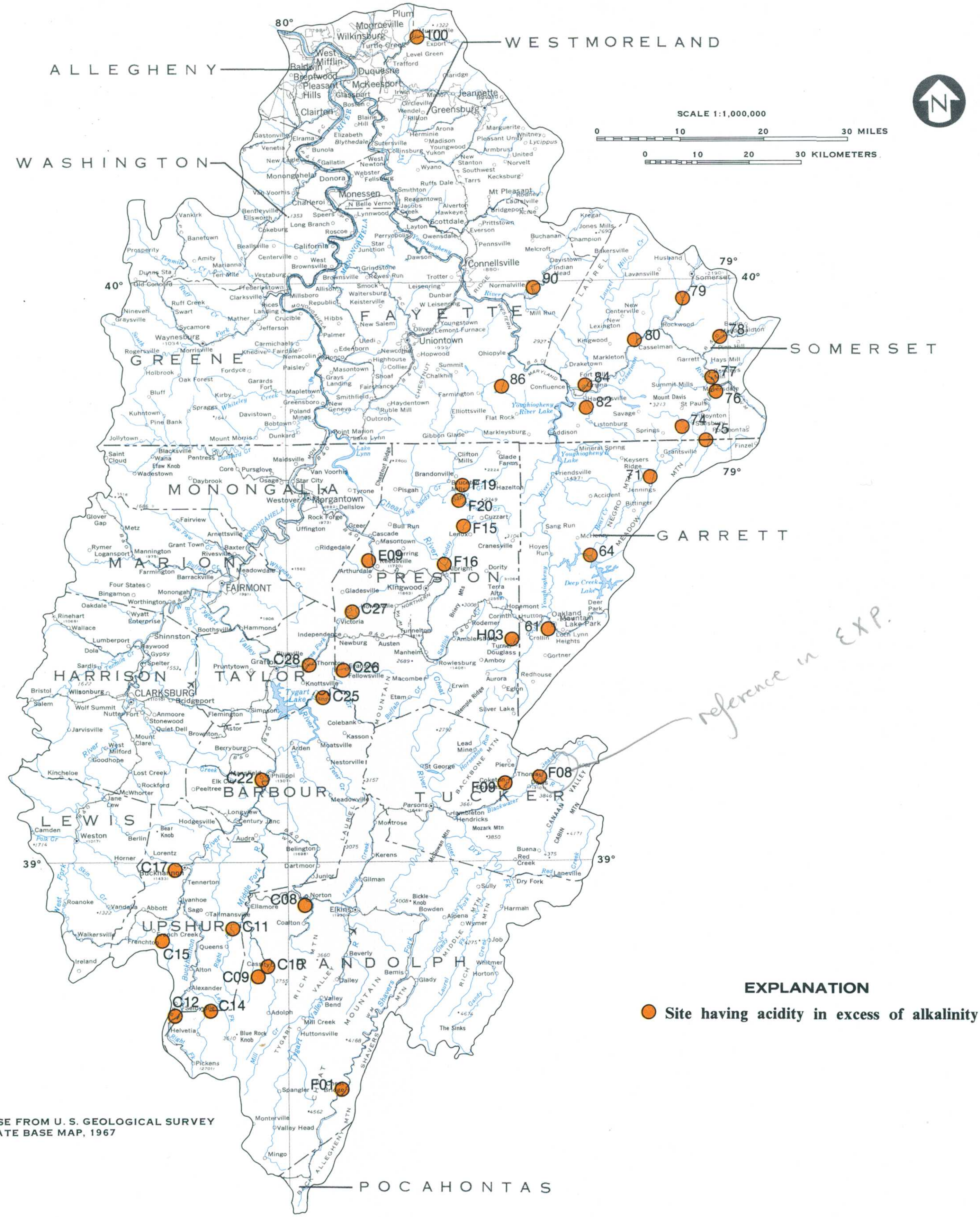


Figure 7.4-1 Location of synoptic sites having acidity in excess of alkalinity.

HIGHEST TOTAL IRON CONCENTRATIONS FOUND IN PENNSYLVANIA PORTION OF AREA

Four of the six streams in Area 5 that had total iron concentrations in excess of 10,000 μg/L (micrograms per liter) were located in Pennsylvania. High total iron concentrations were also common in the Casselman River basin, the lower West Fork River basin, and in Westmoreland County, Pennsylvania.

Six of the 134 synoptic sites in Eastern Coal Province Area 5 sampled during the 1979 and 1980 water years had maximum total-iron concentrations in excess of 10,000 μg/L (fig. 7.5-1). Four of these streams were in Pennsylvania; however, they were scattered over a wide area of three counties. Seven of 12 streams sampled in the Casselman River basin had maximum total-iron concentrations greater than 1,000 μg/L, and 5 of these streams had maximum concentrations greater than 3,000 μg/L. The only other part of Area 5 showing consistently high total-iron concentrations was the lower West Fork River basin, where five streams had maximum total-iron concentrations greater than 3,000 μg/L. The remaining streams having high total-iron concentrations were scattered over the area, although three were in Westmoreland County, Pennsylvania.

Total-iron concentrations of less than 500 μg/L were common in the southern part of Area 5. Low concentrations were most common in the headwaters of the Buckhannon and Tygart Valley Rivers and in the Dry Fork basin. Similarly low total-iron concentrations were found throughout Area 5.

Maximum total-iron concentrations at 134 synoptic sites in Area 5 averaged 2,350 μg/L, but the median maximum concentration was only 970 μg/L. The large difference between the mean and median values is a function of a few large total-iron concentrations. Maximum total-iron concentrations at Area 5 synoptic sites ranged from 90 to 35,000 μg/L. Figure 7.5-2 shows that more than 90 streams sampled in Area 5 had maximum total-iron concentrations less than 2,000 μg/L and that only a small percentage had total-iron concentrations in excess of 5,000 μg/L. The geographic distribution of dissolved iron closely followed that of total iron. Maximum dissolved-iron concentrations ranged from 20 to 22,000 μg/L and the median maximum concentration was 160 μg/L.

The relation between total and dissolved iron is not clearcut. Figure 7.5-3 indicates that the total-iron concentration is a function of the dissolved-iron concentration, but there can be wide variations. The regression equation describing this relation, based on 508 concurrent observations is:

$$FET = 1.36(FED) + 752 \qquad (7.5\text{-}1)$$

where FET = total-iron concentration, in micrograms per liter, and FED = dissolved-iron concentration, in micrograms per liter. The multiple correlation coefficient for equation 7.5-1 is a rather low 75 percent, and the standard error of the estimate is a rather high 1,570 μg/L total iron, or about 100 percent of the mean total-iron concentration.

Samples for total- and dissolved-iron determinations were generally collected three times during June 1979 to April 1980. Total and dissolved iron were determined according to procedures described by Skougstad and others (1979). Samples were usually collected during moderate to high base flow. Low base-flow sampling is scheduled for the future. Data for the 1979 and 1980 water years are presented by U.S. Geological Survey (1980a, b, c; 1981a, b, c).

Data collected at four selected continuous-record stations (fig.7.5-4) indicate the within-stream and stream-to-stream variability which may occur in total-iron concentrations. In spite of the within-stream variations shown in figure 7.5-4, the mean total-iron concentrations are significantly different for all streams. Most of the streams exhibited a nonsignificant positive correlation between total-iron concentration and the log(base 10) of water discharge, but 49 exhibited a nonsignificant negative correlation. Figure 7.5-4 also indicates that only site 84 did not have total-iron concentrations indicative of acid-mine drainage.

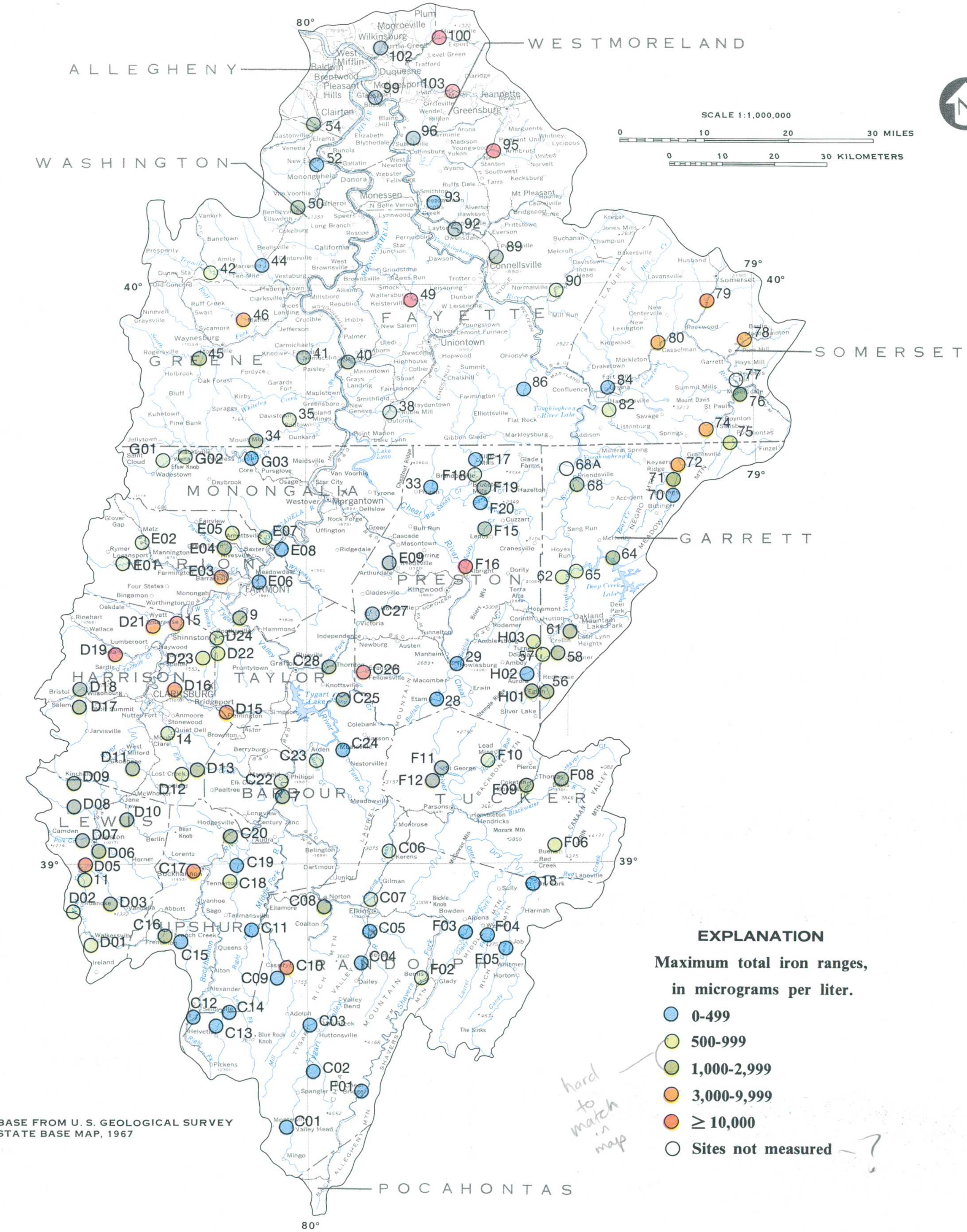


Figure 7.5-1 Maximum total iron at selected sites.

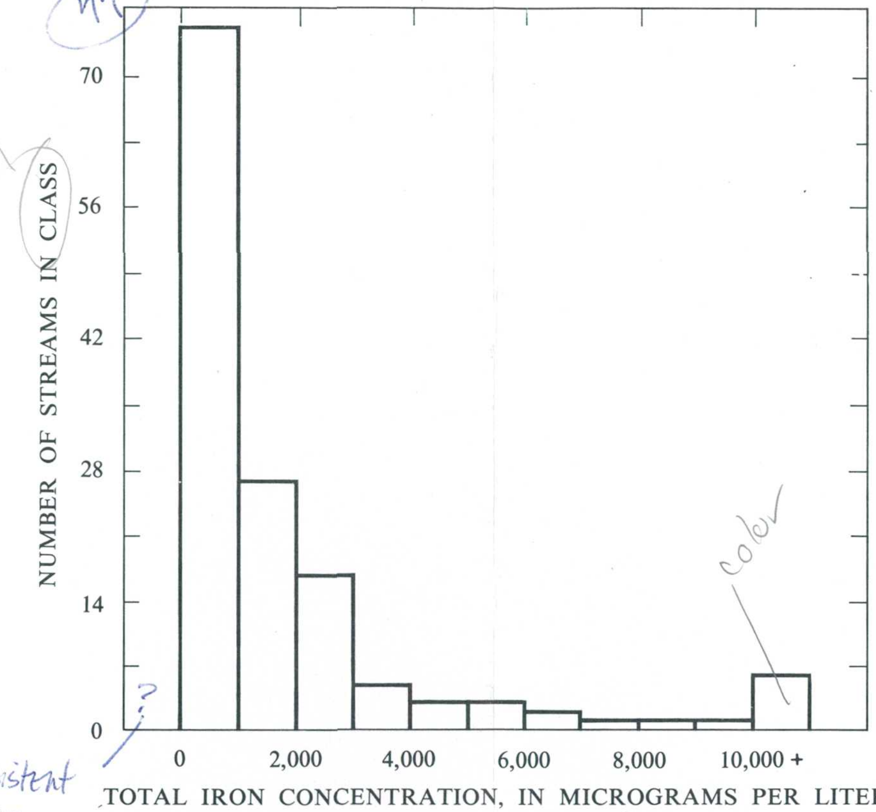


Figure 7.5-2 Maximum total-iron concentration in selected streams.

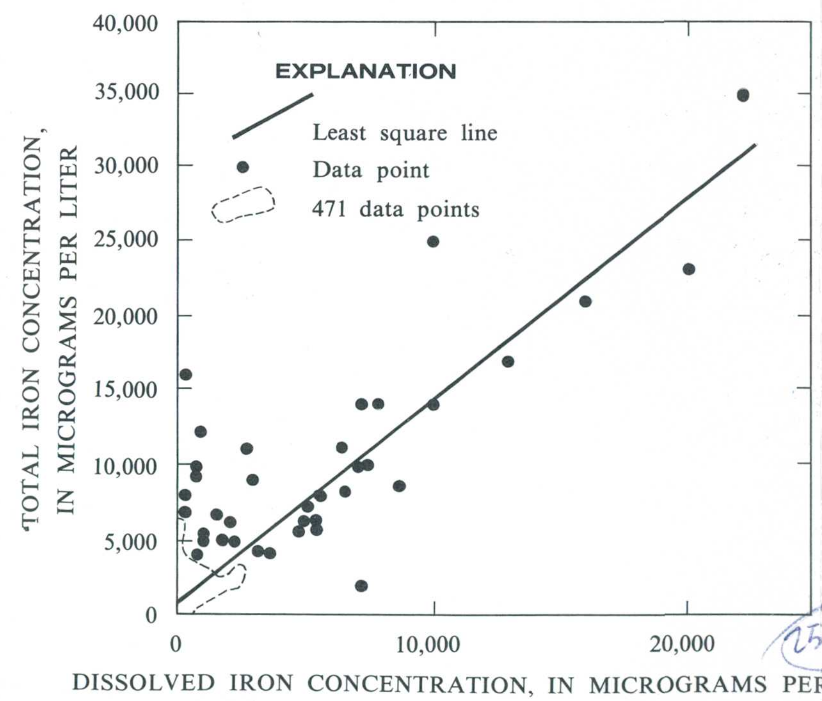


Figure 7.5-3 Relation between dissolved and total iron for selected streams.

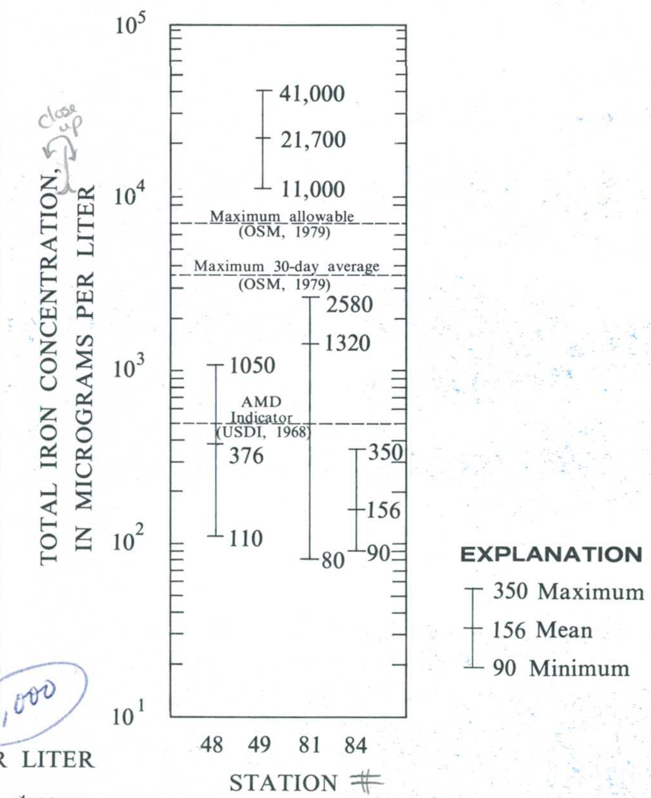


Figure 7.5-4 Ranges and means of total-iron concentrations at selected continuous-record stations, 1977 and 1978 water years.

TOTAL-MANGANESE CONCENTRATIONS IN EXCESS OF 2,000 MICROGRAMS PER LITER FOUND THROUGHOUT AREA

Streams having total-manganese concentrations greater than 2,000 μg/L (micrograms per liter) were common throughout Area 5. Basins with high total-manganese concentrations are the Casselman, Buckhannon, Middle Fork, and lower West Fork River basins.

Figure 7.6-1 illustrates that maximum total-manganese concentrations in excess of 2,000 μg/L were found in streams throughout Eastern Coal Province Area 5 during the 1979 and 1980 water years. The 11 streams having maximum total-manganese concentrations greater than 2,000 μg/L are scattered across eight counties in Pennsylvania, West Virginia, and Maryland.

Several drainage basins within the area have maximum total-manganese concentrations that are in excess of 1,000 μg/L. These basins include the Casselman River in Somerset County, Pa., the Buckhannon River in Upshur County, W. Va., and the lower West Fork River in the vicinity of Clarksburg, W. Va.

Maximum total-manganese concentrations of less than 300 μg/L were ubiquitous in Area 5, and concentrations less than 100 μg/L were not uncommon.

The maximum total-manganese concentration at 134 synoptic sites ranged from 10 to 4,300 μg/L. The mean maximum concentration was 620 μg/L and the median maximum was 250 μg/L. Figure 7.6-2 indicates that more than 105 synoptic sites in Area 5 had maximum total-manganese concentrations of 1,000 μg/L or less, whereas only 11 sites had concentrations greater than 2,000 μg/L.

The geographic distribution of dissolved manganese closely followed that of total manganese. Maximum dissolved-manganese concentrations ranged from 1 to 4,300 μg/L and the median maximum concentration was 160 μg/L.

Most of the manganese transported by streams in Area 5 is in the dissolved phase. Figure 7.6-3 shows the relation between dissolved- and total-manganese concentrations based upon 507 concurrent samples. The regression equation describing this relationship is:

$$MNT = 0.98\,(MND) + 36 \qquad (7.6\text{-}1)$$

where MNT = total-manganese concentration, in micrograms per liter, and MND = dissolved-manganese concentration, in micrograms per liter. The standard error of estimate for this relation is 111 μg/L total manganese, and the multiple correlation coefficient is 97 percent. The closeness of the dissolved-manganese coefficient to 1.0 and the relatively small constant (36) indicate that most of the manganese is transported in solution. The mean values of dissolved and total manganese, 351 and 382 μg/L, respectively, also support this hypothesis.

Samples for total- and dissolved-manganese determinations were generally collected three times during June 1979 to April 1980. Total and dissolved manganese were determined by procedures shown in Skougstad and others (1979). The samples were normally taken during periods of moderate to high base flow. Low base-flow sampling is scheduled for the future. Data for the 1979 and 1980 water years are published by U.S. Geological Survey (1980a, b, c; 1981a, b, c).

Total manganese data collected at two continuous-record stations in Area 5 during the 1977 and 1978 water years illustrate the within-stream and stream-to-stream variations in concentration which may be found (fig. 7.6-4). The ratio between the maximum and minimum observed values at both stations was between 3 and 4. Site 48 did not indicate acid-mine drainage, but all observations at 49 did. Total-manganese concentration was negatively correlated with the log(base 10) of water discharge at both sites; but only the correlation for 49 was significant.

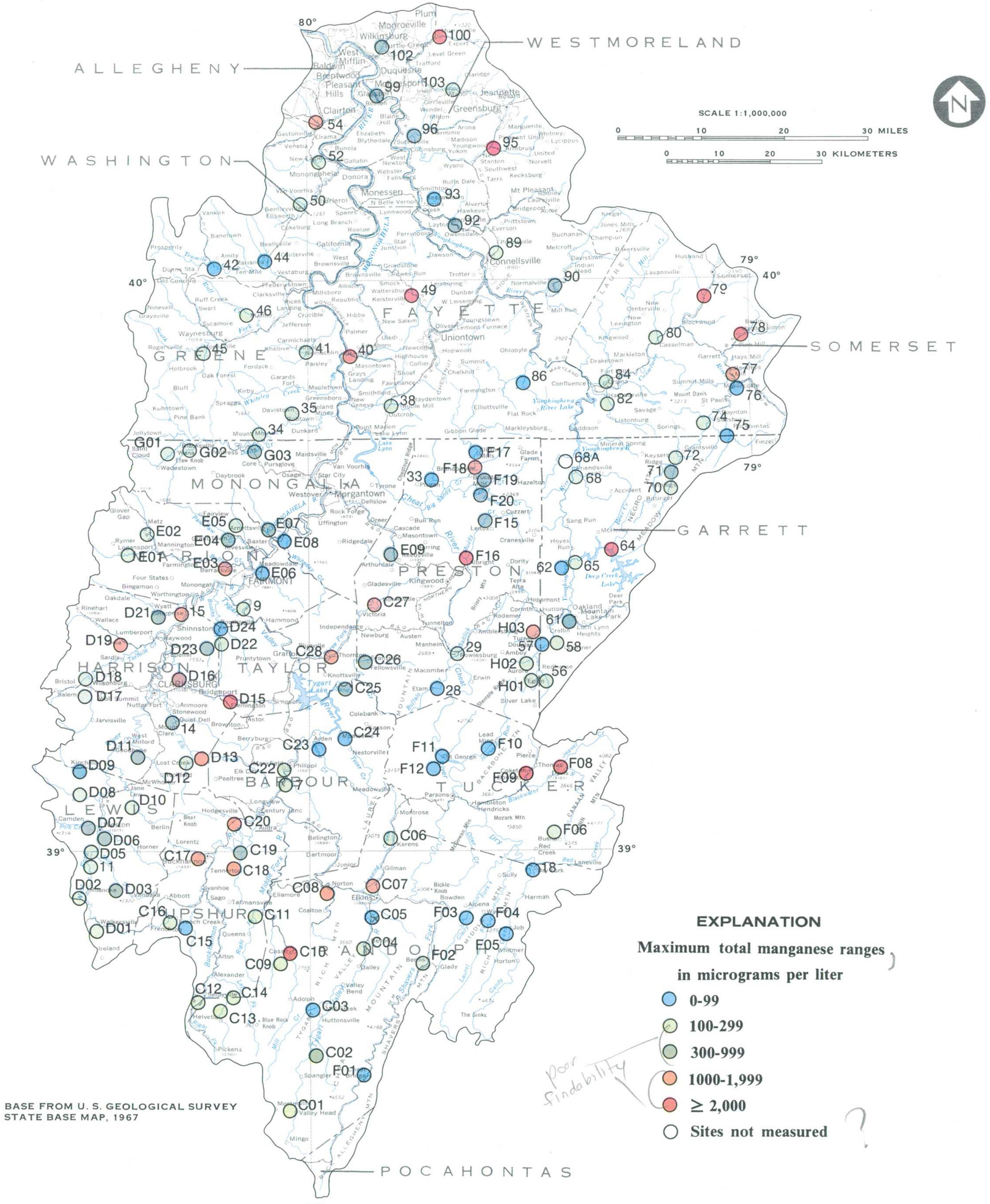


Figure 7.6-1 Maximum total manganese at selected sites.

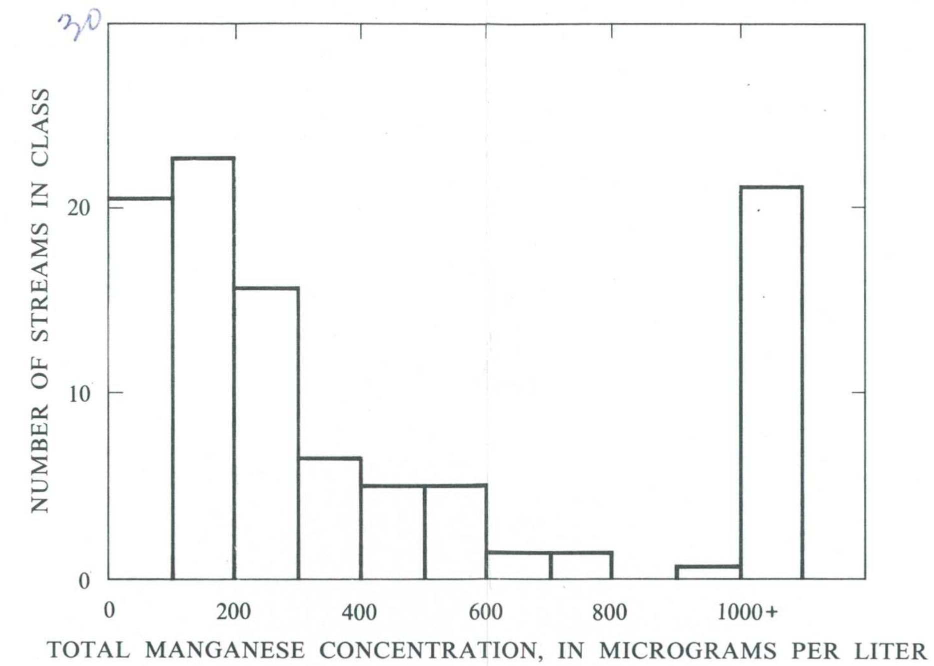


Figure 7.6-2 Maximum total-iron concentrations in selected streams.

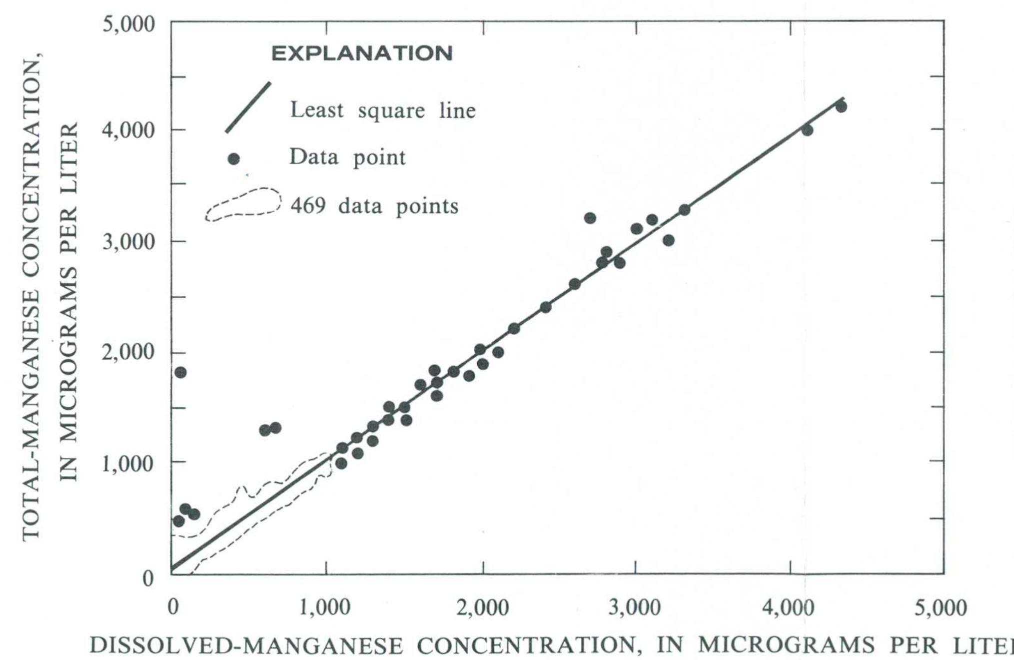


Figure 7.6-3 Relation between dissolved and total manganese for selected streams.

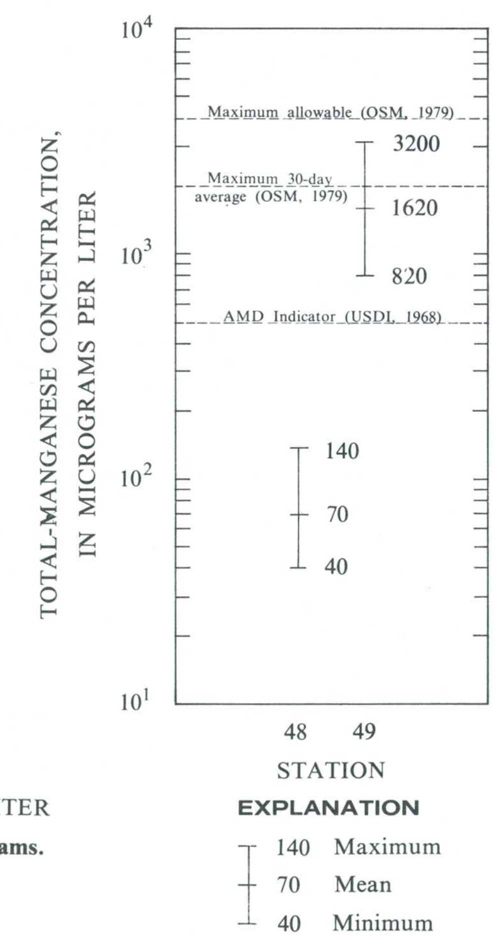


Figure 7.6-4 Ranges and means of total-manganese concentrations at selected continuous-record stations, 1977 and 1978 water years.

DISSOLVED-SULFATE CONCENTRATIONS GREATER THAN 400 MILLIGRAMS PER LITER COMMON IN PARTS OF AREA

Maximum dissolved-sulfate concentrations in excess of 400 mg/L (milligrams per liter) were found in streams tributary to the West Fork and Monongahela Rivers in Harrison, Marion, Taylor, and Monongalia Counties, W. Va. Streams in Washington, Fayette, and Westmoreland Counties, Pa., also had high maximum dissolved-sulfate concentrations.

Maximum dissolved-sulfate concentrations observed during the 1979 and 1980 water years were not randomly distributed areally in Eastern Coal Province Area 5 as shown in figure 7.7-1. The highest dissolved-sulfate concentrations in the Area are limited to two general areas. One area is in Monongalia, Marion, Harrison, and Taylor Counties, W. Va., where 10 tributaries to the lower West Fork and upper Monongahela Rivers have maximum dissolved-sulfate concentrations in excess of 400 mg/L. An additional 5 streams having maximum dissolved-sulfate concentrations of 400 mg/L or greater are widely scattered over Washington, Fayette, and Westmoreland Counties, Pa.

Figure 7.7-1 also shows a general southeast-to-northwest trend in maximum dissolved-sulfate concentrations for Area 5. Most of the streams in the southeastern corner of the area have maximum dissolved-sulfate concentrations in the 0-9.9 mg/L range. Streams to the northwest from that region have maximum dissolved-sulfate concentrations of 10-99 mg/L, but several streams do have concentrations in the 100-400 mg/L range. Further northwest, in the lower West Fork and upper Monongahela River basins, concentrations generally range from 100 to 1,000 mg/L, but some streams have maximum concentrations in excess of 1,000 mg/L. Along the western boundary of Area 5, maximum concentrations are in the 10-99 mg/L range. Although maximum dissolved-sulfate concentrations in streams in the Area ranged from 3.9 to 4,700 mg/L, figure 7.7-2 shows that only 10 streams had maximum concentrations in excess of 500 mg/L. Figure 7.7-2 also shows that only 20 streams exceeded 300 mg/L and only 46 streams exceeded 100 mg/L. The mean maximum dissolved-sulfate concentration in Area 5 was 173 mg/L, but the median was only 44 mg/L.

Samples for dissolved-sulfate determinations were generally collected three times during June 1979 to April 1980. Sulfate concentrations were determined by procedures given by Skougstad and others (1979). Most samples were collected during periods of moderate to high base flow. Low base-flow samples are scheduled for the future. Data for the 1979 and 1980 water years are published by U.S. Geological Survey (1980a, b, c; 1981a, b, c).

Dissolved-sulfate concentrations in individual streams may show considerable variation. Data from four selected daily streamflow stations indicate variations by factors of 3 to 5 during the 1977 and 1978 water years (fig. 7.7-3). Comparisons between the means for the selected streams showed significant differences for all station combinations. The mean dissolved-sulfate concentrations for sites 49 and 81 were greater than the U.S. Department of Interior's (1968) acid-mine drainage indicator of 75 mg/L. All sites except 84 showed a significant negative correlation between dissolved-sulfate concentration and the log(base 10) of concurrent instantaneous discharge.

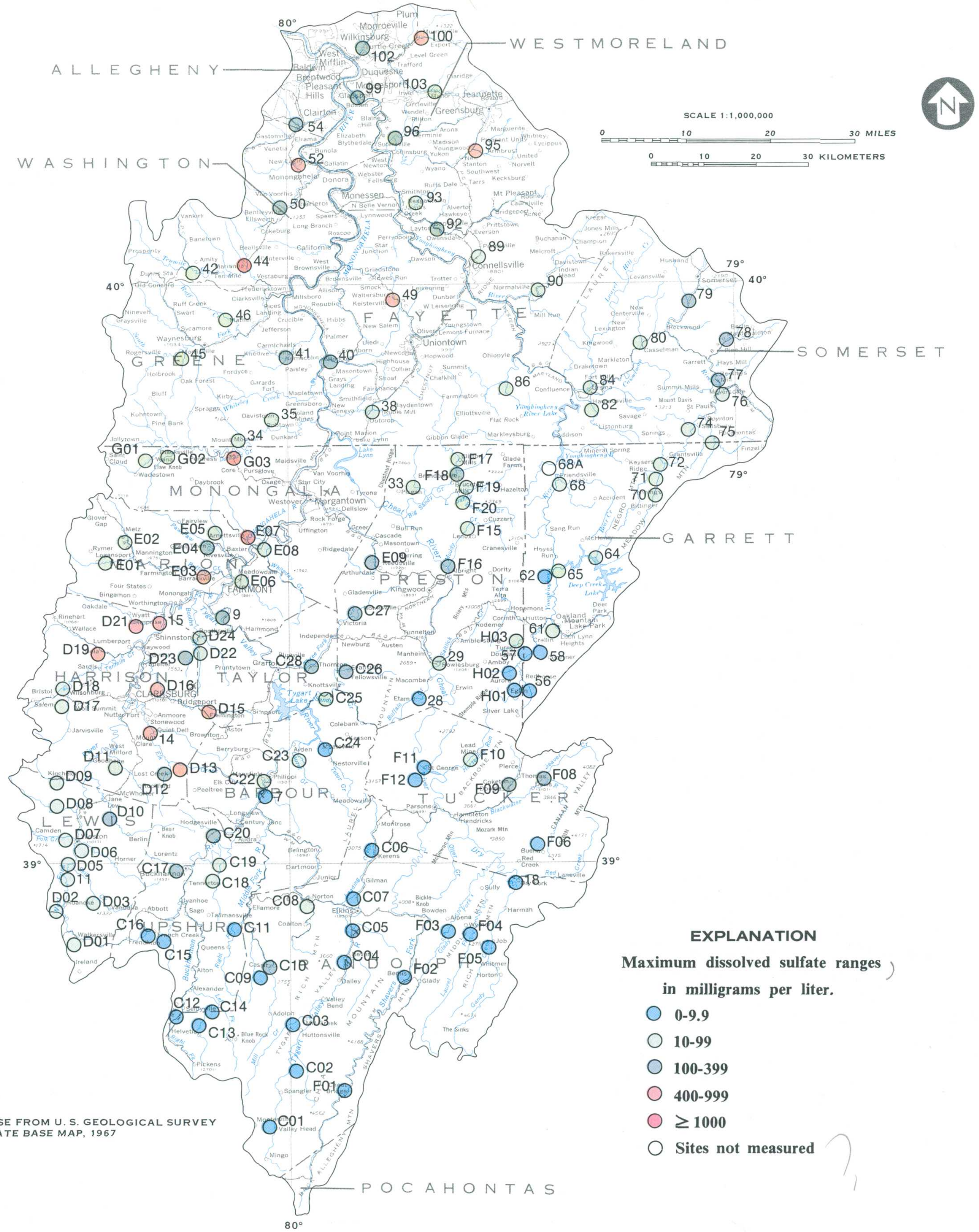


Figure 7.7-1 Maximum dissolved sulfate at selected sites.

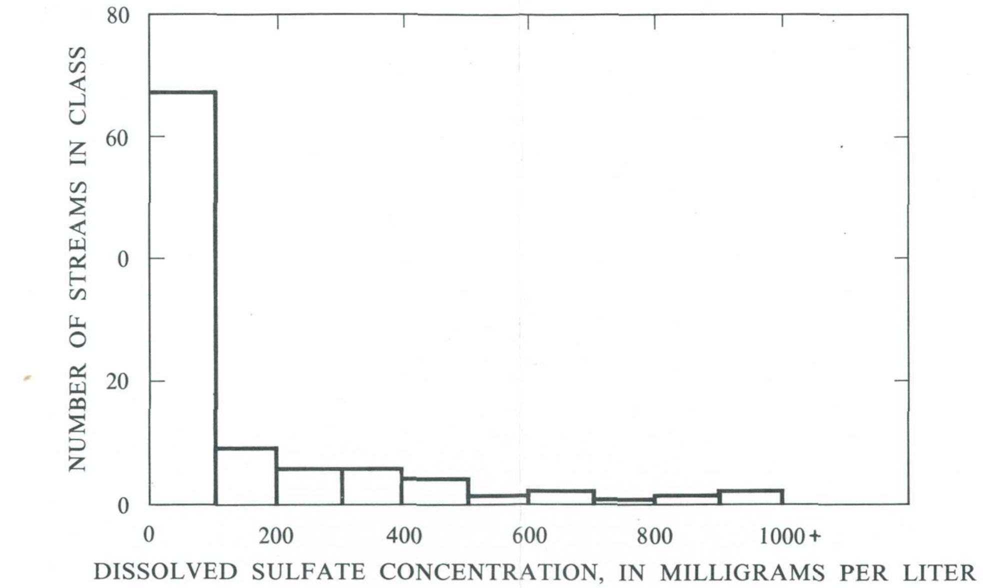


Figure 7.7-2 Maximum dissolved-sulfate concentration in selected streams.

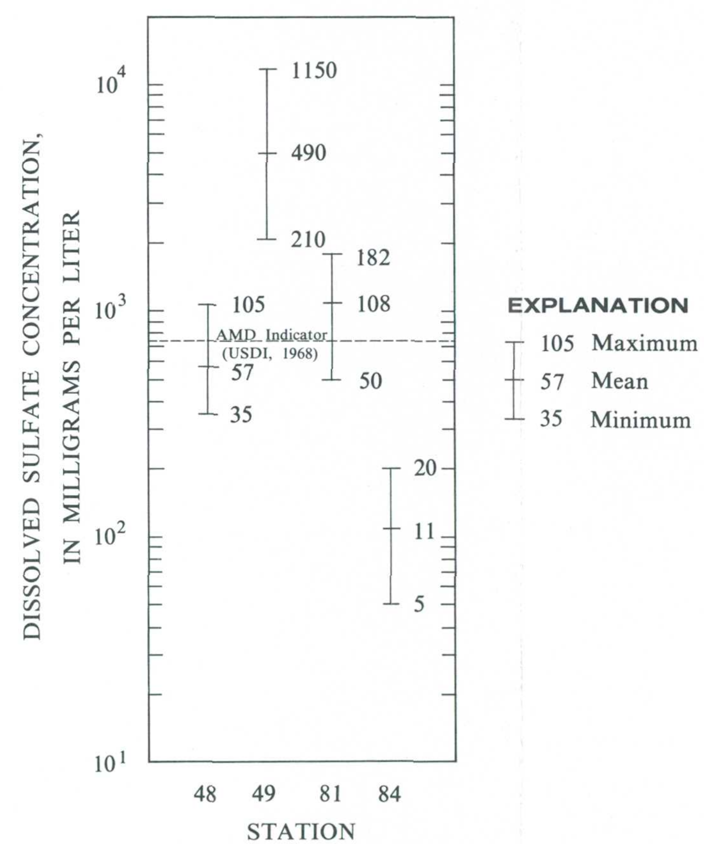


Figure 7.7-3 Ranges and means of dissolved sulfate at selected continuous-record stations, 1977 and 1978 water years.

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SUSPENDED-SEDIMENT DISCHARGE RELATED TO STREAMFLOW

Suspended-sediment discharges in Area 5 streams are related to streamflow, but the relation shows wide variations. The variations are not related to the presence of acid-mine drainage indicators.

The suspended-sediment transport data derived from samples at the synoptic sites in Eastern Coal Province Area 5 are shown in figure 7.8-1. This particular graph relates instantaneous suspended-sediment discharge in tons per day to instantaneous streamflow in $(ft^3/s)/mi^2$ (cubic feet per second per square mile). The shaded portion of figure 7.8-1 encloses 98 percent of the data collected at synoptic sites in Area 5. Note that these data show that for any given instantaneous unit discharge the instantaneous suspended-sediment discharge may vary by a factor of 360. This variability is about 7 times that shown by Wark (1965) for samples from a single large river. The sediment-transport envelope illustrated in figure 7.8-1 should indicate the range of transport values for most streams in Area 5 having drainage areas between 6 and 120 square miles. The wide variability may be a function of the different land uses within the area.

Porterfield (1972) states that an instantaneous transport curve may agree, in practice, with a daily transport curve. If this is the case, it should be possible to compute average annual loads using the flow-duration transport-curve method described by Miller (1951). Under this assumption a minimum annual suspended-sediment discharge for Area 5 streams was computed as shown in table 7.8-1. Average water discharges per square mile for selected time intervals were determined from a composite flow-duration curve for streams in Area 5 (fig. 7.8-2). The development of the composite flow-duration curve is discussed in section 9.5.2. Minimum suspended-sediment discharges corresponding to the selected streamflows were determined from the composite suspended-sediment transport curve for Area 5 streams (fig. 7.8-1) and multiplied by the duration intervals of water discharge to calculate the average annual sediment load. For example, the average water discharge for Area 5 streams for 8.5 to 15 percent of the time is 3.6 $(ft^3/s)/mi^2$. The corresponding suspended-sediment discharge is 0.026 $(tons/mi^2)$ / day (tons per square mile per day). Multiplying the suspended-sediment discharge by the time interval for each interval in table 7.8-1 and dividing the sum of column 6 by 100 (table 7.8-1) yields the mean daily suspended-sediment discharge in $(tons/mi^2)/day$. Multiplying the mean daily suspended-sediment discharge by 365 yields the minimum annual suspended-sediment discharge in $tons/mi^2$.

Table 7.8-1 indicates that the minimum annual suspended-sediment discharge for streams in Area 5 would be about 5.5 $tons/mi^2$. Wark (1965) states that the average annual suspended-sediment yield in Area 5 ranges from 20-250 $tons/mi^2$. Wark's 1965 figures indicate that the average suspended-sediment concentration would range from 11-140 mg/L (milligrams per liter). The concentrations are computed using an average discharge of 1.8 $(ft^3/s)/mi^2$ which is applicable for Area 5 streams. Because relatively large amounts of sediment move in relatively short periods of storm runoff (Wark, 1965), the concentrations must be less than the average values much of the time.

Sediment-transport data for 3 streams exhibiting AMD (acid-mine drainage) indicators fell within the envelope as shown by the solid circles in figure 7.8-1. The distribution of the data was no different from that of all transport data, demonstrating that for the range of flows evaluated to date, those streams containing AMD do not carry larger sediment loads than nearby non-AMD streams. There may be several reasons for a lack of correlation between AMD and suspended sediment. This analysis, based on scant data, does not consider the effects of flows greater than 15 percent duration, nor does it include the effects of significant land disturbance near streams during surface mining. The AMD indicators used to identify AMD streams may have been coming from deep mines which normally produce little sediment;

therefore, the relation may not be valid for surface-mined areas. Additionally, in areas where much sediment is available, as in surface-mined areas, most of the sediment is transported on the rising portion of the hydrograph. The data shown in figure 7.8-1 may have been collected at any point on the hydrograph; therefore, they may not be representative of transport conditions from mined areas. The suspended-sediment and discharge data used to develop the sediment-transport curve are published by the U.S. Geological Survey (1980a, b, c; 1981a, b, c).

Table 7.8-1 Computation of minimum average annual suspended-sediment discharge.

Cumulative time (percent) (1)	Time in interval (percent (2)	Mid-ordinate (percent) (3)	Water discharge [(ft³/s)/mi²)] (4)	Suspended sediment discharge (tons/mi²) (5)	Suspended sediment discharge for interval (tons/mi²)[1] (6)
0.25	0.25	0.125	20	0.5	0.125
.75	.50	.50	15	.3	.15
1.5	.75	1.125	12	.2	.15
2.5	1.0	2.0	11	.17	.17
4.5	2	3.5	8.5	.11	.22
8.5	4	6.5	6.0	.06	.24
15	6.5	11.75	3.6	.026	.17
25	10	20	2.3	.013	.13
35	10	30	1.7	.007	.07
45	10	40	1.2	.004	.04
55	10	50	.84	.002	.02
75	20	65	.50	.001	.02
95	20	85	.16	---	---
100	5	97.5	.05	---	---
TOTAL	---	---	---	---	1.50

Minimum mean daily suspended-sediment discharge = 1.50/100 = 0.015 tons/mi²

Minimum average annual suspended-sediment discharge = 0.015 x 365 = 5.5 tons/mi²

[1] Column 6 = column 2 x column 5

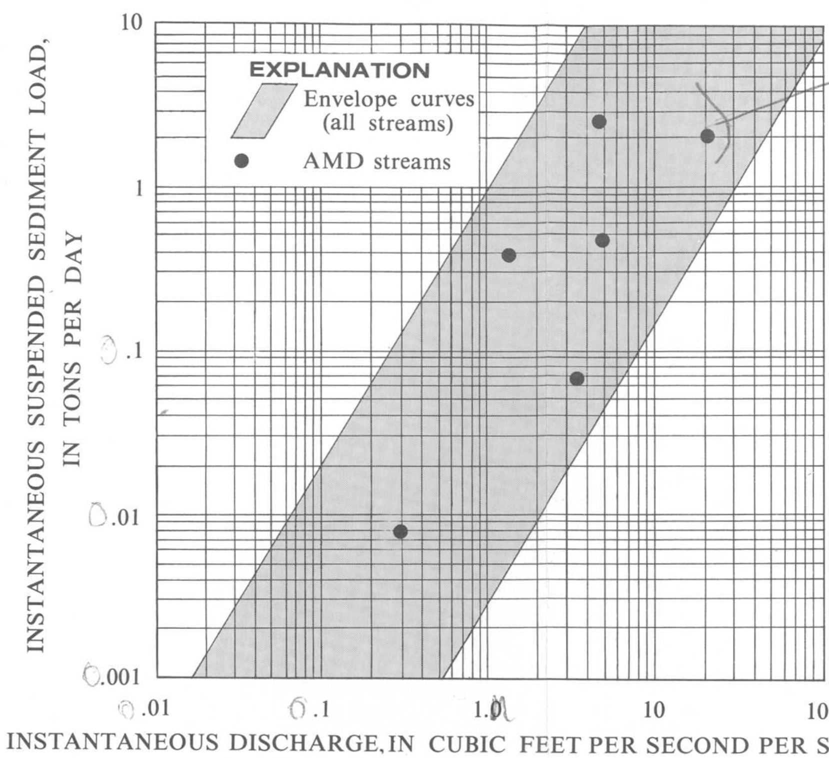

Figure 7.8-1 Instantaneous suspended-sediment transport.

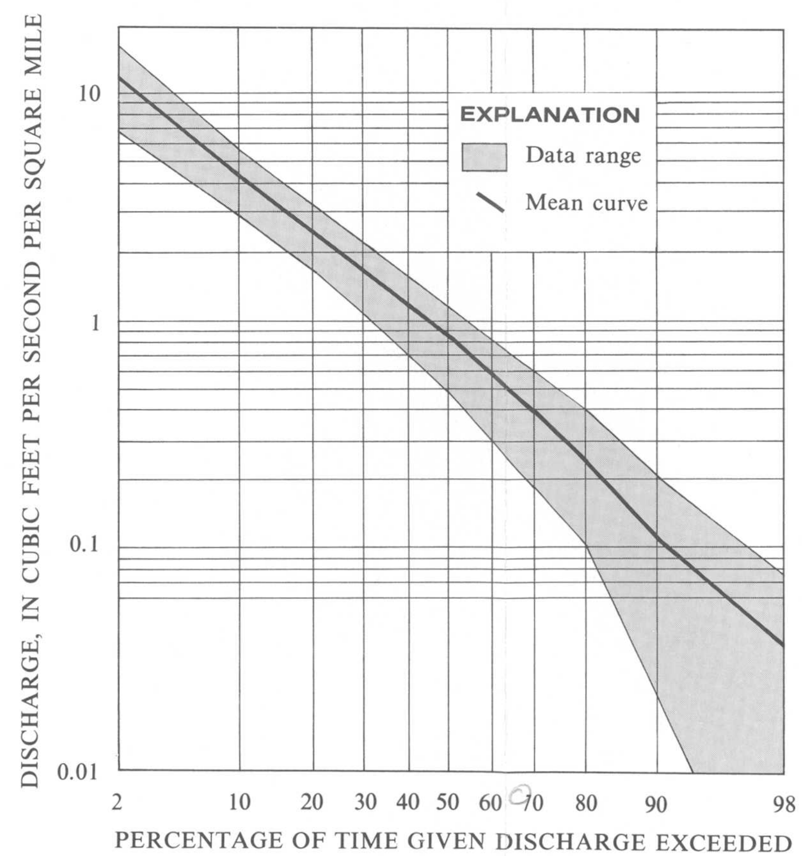

Figure 7.8-2 Composite flow-duration for streams.

BED MATERIAL IRON CONCENTRATIONS HIGH IN MANY PARTS OF AREA

Most Area 5 streams have bed material iron concentrations in excess of 20,000 μg/g (micrograms per gram). Several areas were notable for their low concentrations.

Nearly 50 streams in Eastern Coal Province Area 5 had bed material iron concentrations of 20,000 μg/g or greater during the 1979 water year as shown in figure 7.9.1-1. Thirteen of the streams exceeded bed material iron concentrations of 40,000 μg/g. Areas near Clarksburg, W. Va., and southeast of Pittsburgh, Pa., had characteristically high iron concentrations in bed material.

Although bed material iron concentrations were high over most of Area 5, there were several areas notable for their low iron concentrations. Big Sandy Creek, a tributary of the Cheat River, drains parts of Preston County, W. Va., and Fayette County, Pa. All six streams sampled in the Big Sandy basin had bed material iron concentrations less than 10,000 μg/g. Ten of eleven streams sampled in the Casselman River basin had bed material iron concentrations less than 20,000 μg/g range.

Figure 7.9.1-2 illustrates that about 30 streams sampled in Area 5 had bed material iron concentrations of less than 10,000 μg/g, more than 80 had concentrations less than 20,000 μg/g, but only 6 had concentrations that exceeded 60,000 μg/g.

Bed material samples for iron determination (Skougstad and others, 1979) were collected at 125 sites during the 1979 water year. Bed materials may serve as historical integrators of basin conditions. As conservative materials pass through the stream channel network, they are incorporated into the bed material. Unless extremely high flows scour the bed material and carry it downstream, the deposits may serve as indicators of past water-quality conditions. Although he did not consider iron, Feltz (1980) states that concentrations of heavy metals found in bottom materials confirmed potential contamination in the Schuylkill River although concentrations in the water itself indicated no apparent problem. The concentrations of heavy metals in the bottom materials of the Schuylkill River were several orders of magnitude higher than the concentrations in the water.

Data from the chemical analysis of bed materials are published by U.S. Geological Survey (1980a, b, c).

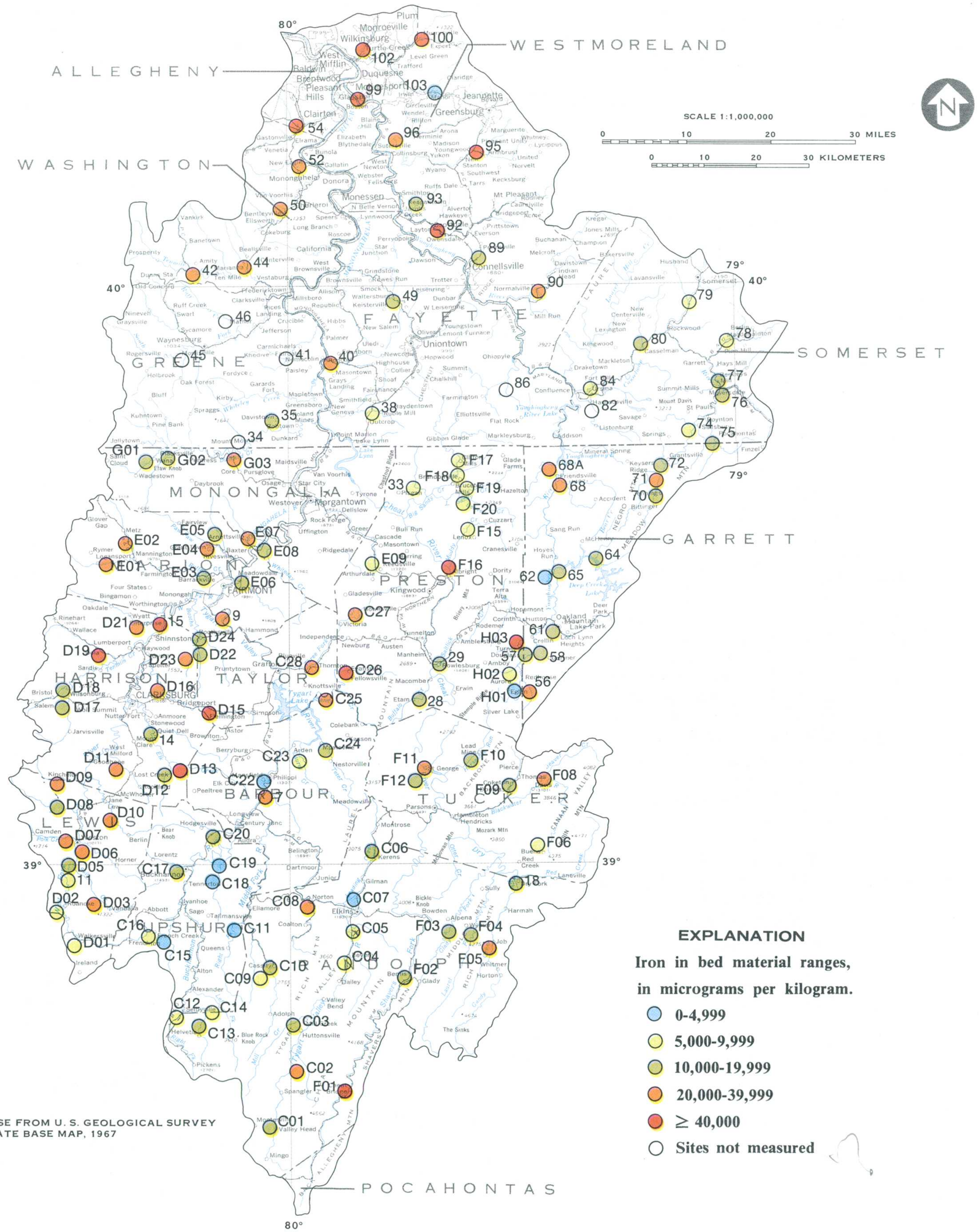

Figure 7.9.1-1 Iron in bed material at selected sites.

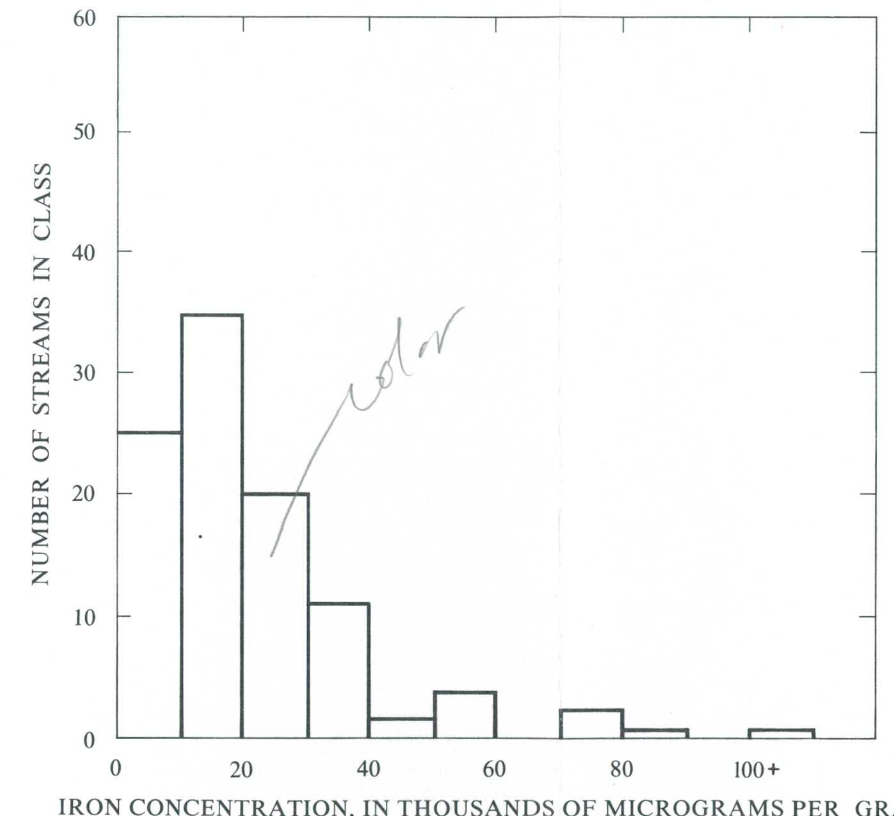

Figure 7.9.1-2 Histogram of bed material iron concentration in selected streams.

BED MATERIAL MANGANESE CONCENTRATIONS HIGHEST IN WEST FORK, YOUGHIOGHENY, AND LOWER MONONGAHELA RIVER BASINS

Bed material manganese concentrations in excess of 1,000 μg/g (micrograms per gram) were most common in the West Fork, Youghiogheny, and lower Monongahela River basins. Low concentrations were most common in the Cheat and Tygart Valley River basins.

Manganese concentrations in bed material of Area 5 streams in excess of 1,000 μg/g are not evenly distributed across the area. Figure 7.9.2-1 shows that most of the high concentrations observed during the 1979 water year were found in the West Fork, Youghiogheny, and lower Monongahela River basins. Many of the remaining streams in these basins had bed material manganese concentrations greater than 500 μg/g. Only 4 of 24 streams sampled in the West Fork River basin had bed material manganese concentrations less than 500 μg/g. In the Youghiogheny River basin 12 of 29 streams had bed material manganese concentrations less than 500 μg/g.

The Tygart Valley and Cheat River basins, on the other hand, are characterized by lower bed material manganese concentrations. Only 7 of 30 streams sampled in the Tygart Valley River basin had concentrations in excess of 500 μg/g, and only 9 of 19 streams in the Cheat River basin exceeded 500 μg/g. Eleven streams in the Tygart Valley River basin had bed material manganese concentrations less than 200 μg/g.

The mean bed material manganese concentration for 125 streams was 800 μg/g whereas the median concentration was 565 μg/g. The difference between the mean and median concentrations is a function of the effect of several high concentrations on the median. Figure 7.9.2-2 indicates that only 9 streams had concentrations in excess of 1,200 μg/g.

Bed material samples for manganese determination (Skougstad and others, 1979) were collected at 125 sites during the 1979 water year. Bed materials may serve as historic integrators of basin conditions. As conservative materials pass through the stream channel network, they are incorporated into the bed material. Unless extremely high flows scour the bed material and transport it downstream, the deposits may serve as indicators of past water-quality conditions. Although he did not consider manganese, Feltz (1980) states that concentrations of heavy metals found in bottom materials confirmed potential contamination in the Schuylkill River even though concentrations in the water itself indicated no apparent problem. The concentrations of heavy metals in the bottom materials of the Schuylkill River were several orders of magnitude higher than the concentrations in the water.

Data from the analyses of bed material samples are published by the U.S. Geological Survey (1980a, b, c).

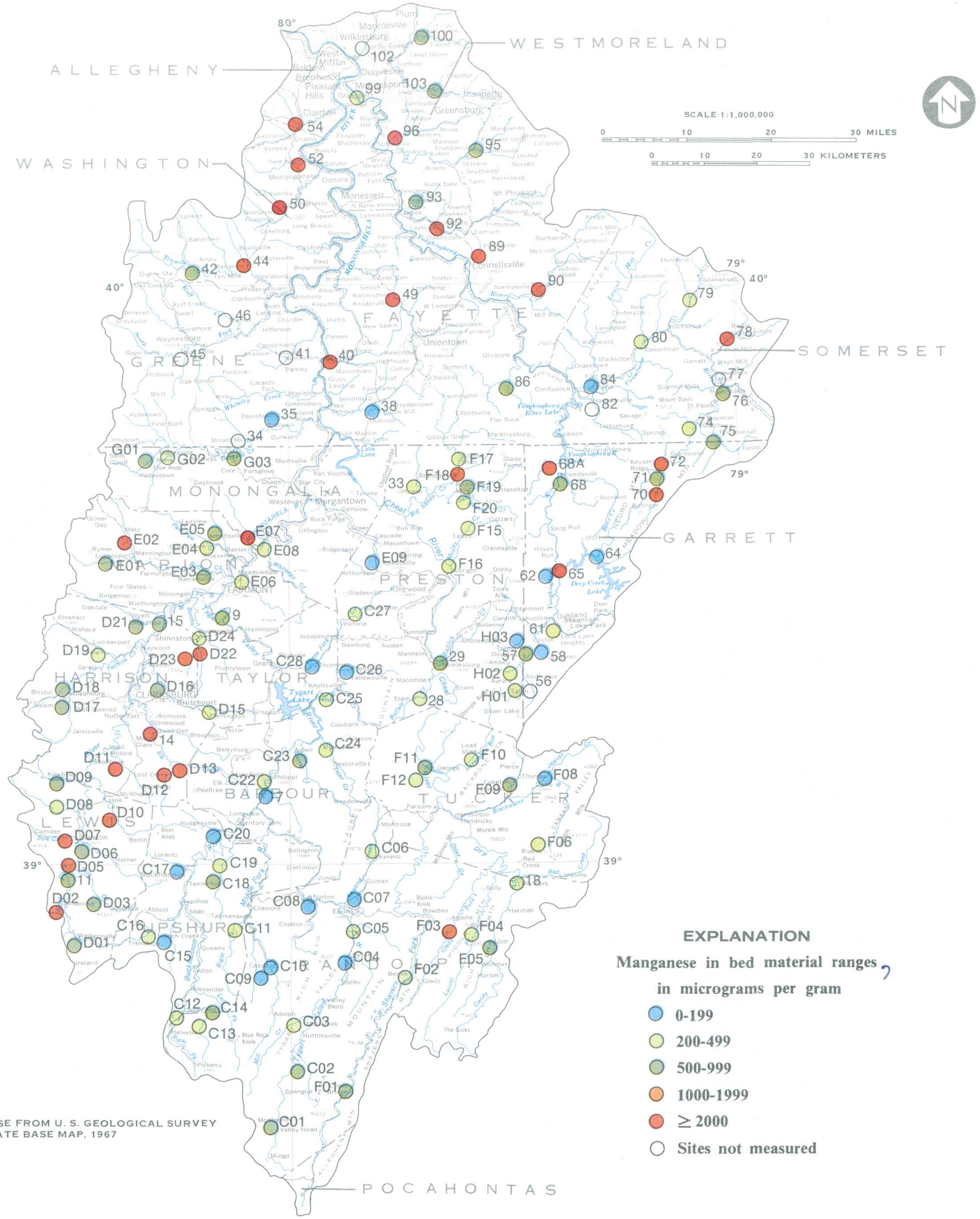

Figure 7.9.2-1 Concentration of manganese in bed material of selected streams.

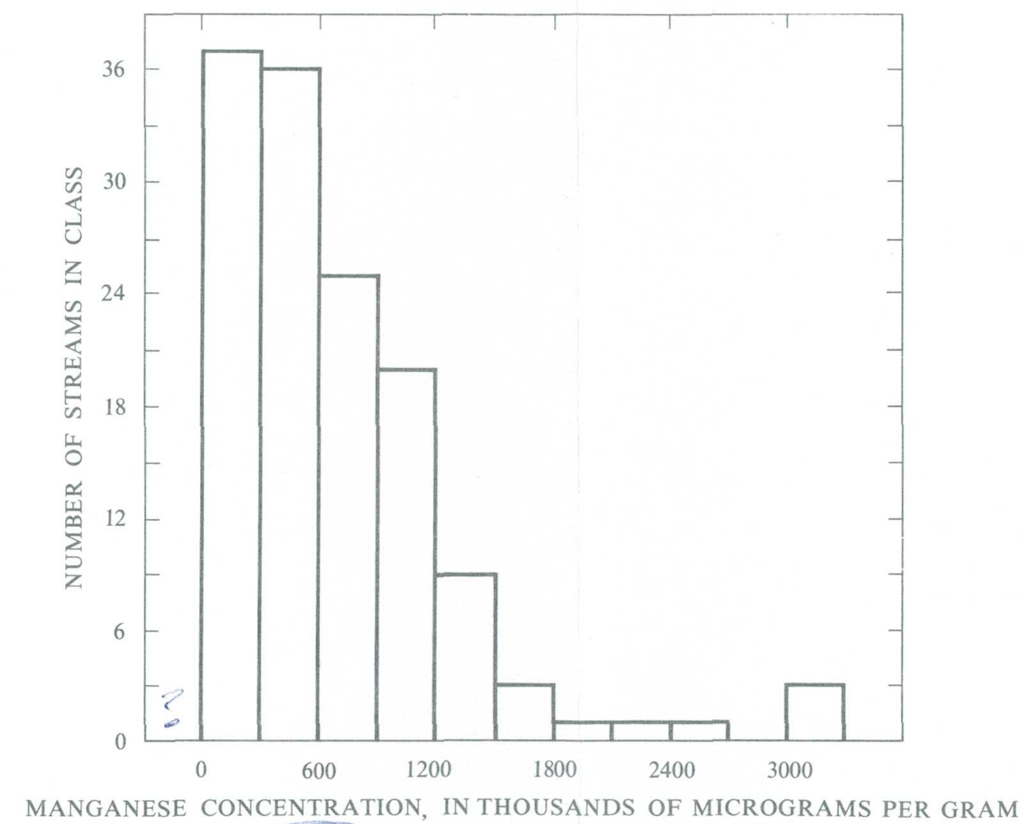

Figure 7.9.2-2 Histogram of bed material manganese concentration in selected streams.

TWENTY-FIVE OF 129 STREAMS SAMPLED IN AREA CONTAINED NO BENTHIC INVERTEBRATES

No benthic invertebrates were found in 25 of 129 streams sampled in Area 5. Streams lacking benthic invertebrates had a mean dissolved sulfate concentration six times greater than streams with five or more benthic invertebrate orders.

Parts of Pennsylvania, Maryland, and West Virginia in Area 5 were sampled in 1979 for benthic invertebrates. Because the level of identification differed in each state, benthic invertebrate data ranges from the more complex taxonomic identification of families to the identification of benthic invertebrate absence or presence.

Benthic invertebrates are used as indicators of water quality because of their relatively long life, restricted mobility, and sensitivity to water contaminants (Britton and Averett, 1974) such as acid-mine drainage (AMD). Although variations in tolerance to AMD may not be evident unless benthic invertebrates are identified to the species level, some broad generalizations can be made on the basis of identification to the order level. Good water quality in a stream can be biologically described by a good variety of benthic invertebrate orders with no dominant population, whereas poor water quality can be described by a small variety of benthic invertebrate orders with one or two dominant populations or very small populations. No populations at all would generally indicate very poor water quality. Biological data cannot be interpreted without regard to chemical constituents or a complete picture of the water quality will not be obtained. Appendix 2 shows the concurrent benthic-invertebrate and chemical water-quality data collected at synoptic sites in Area 5.

Low flow can concentrate contaminants in streams causing benthic invertebrates or their food sources to die. High flow generally dilutes contaminants unless there is runoff from a mining area during a storm and then contaminants may be concentrated in the stream. Area 5 generally had intermediate base flow in August 1979 when benthic invertebrates were collected.

In the central portion of Area 5 there are increased sediment yields and chemical concentrations which may destroy the habitats of benthic invertebrates (Engelke, 1981, written communication). Benthic invertebrates were not found in 25 streams sampled in Area 5 (fig. 7.10-1). These sites do not support a biological community as defined by the Office of Surface Mining (1979). This definition requires at least two species of benthic invertebrates in either of the phylums Arthropoda or Mollusca to be present.

Area 5 streams were found to contain four phyla: Arthropoda, Mollusca, Annelida, and Platyhelminthes. Four orders dominated Area 5 although they varied in rank from basin to basin. Ephemeroptera (mayfly), Decapoda (crayfish), Plecoptera (stonefly), and Trichoptera (caddisfly) were found in 68, 60, 28, and 20 streams, respectively.

The Monongahela basin includes four major subbasins, Youghiogheny River, Cheat River, West Fork River, and Tygart Valley River. Benthic invertebrates were not found in 13 percent of Youghiogheny River basin's 31 sites, 24 percent of Cheat River basin's 29 sites, 38 percent of the Tygart Valley River basin's 21 sites, and 8 percent of the West Fork River basin's 24 sites. Ephemeroptera was collected at most sites within the Tygart Valley, Youghiogheny, and Cheat River basins. Decapoda, collected at the same number of sites as Ephemeroptera in the Cheat River basin, was the dominant order at sites in the West Fork River basin. Trichoptera had established itself at the same number of sites in the Youghiogheny River basin as Ephemeroptera.

Streams in Area 5 having no benthic invertebrate populations had a mean dissolved sulfate concentration of 162 mg/L, whereas streams having five or more benthic invertebrate orders had a mean dissolved sulfate concentration of 24 mg/L. This difference is significant at the 95 percent confidence level.

Forty-eight percent of the streams where benthic invertebrates were not found are in the Cheat River, Tygart Valley River, and the West Fork River basins. These streams had pH values less than 6 and dissolved sulfate values greater than 75 mg/L. Both chemical constituent values are AMD indicators according to the Department of the Interior (1968) and are indicative of poor water quality although the overall benthic invertebrate composition of Area 5 generally showed healthier water quality conditions (Patrick and Grant, 1971).

needs another illustration in this area

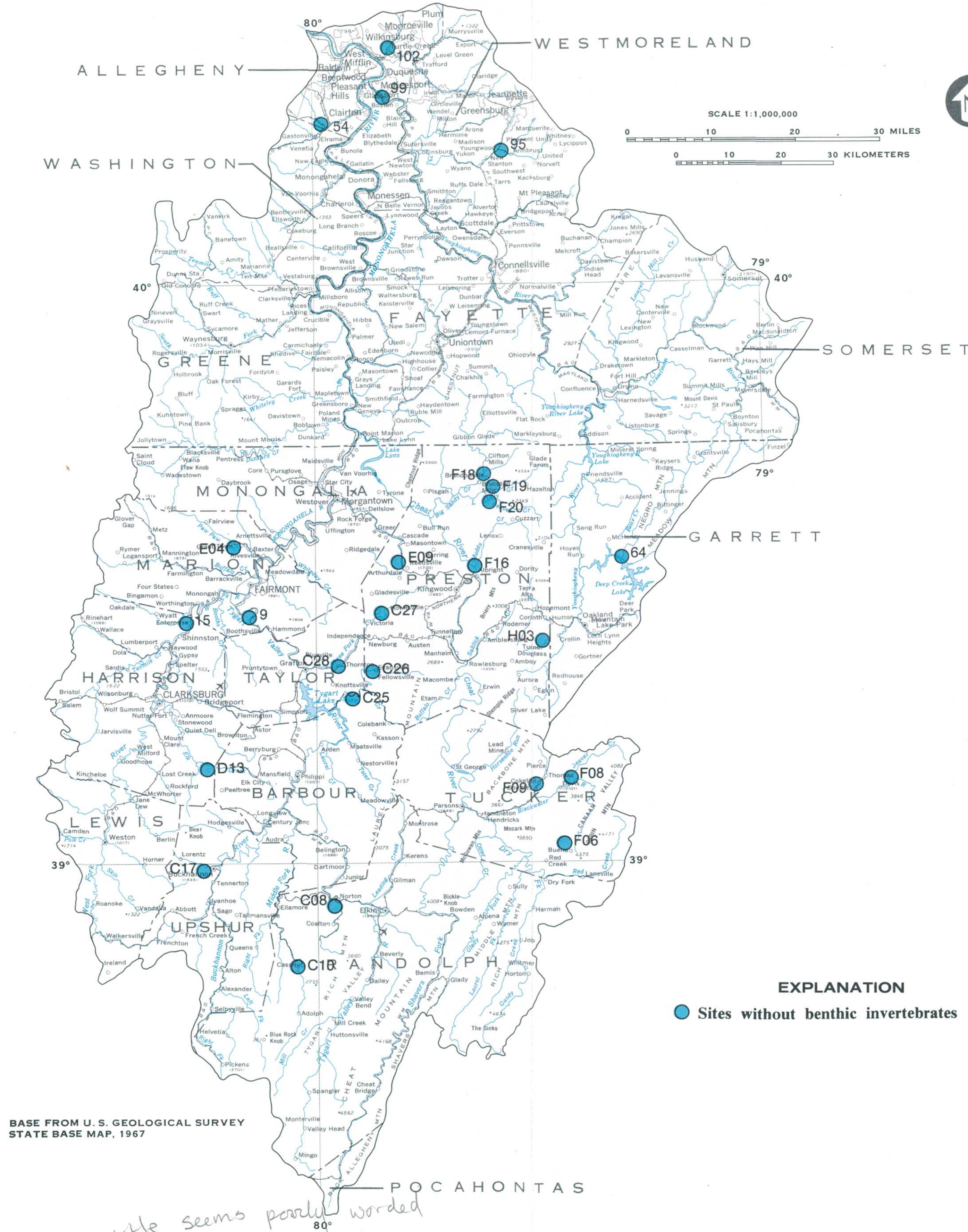

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Figure 7.10-1 Geographical location of the 25 synoptic sites where benthic invertebrates were not found.

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8.0 ACID-MINE DRAINAGE

STRONG INDICATIONS OF ACID-MINE DRAINAGE IN 11 STREAMS

Eleven streams in Area 5 meet or exceed the levels of pH, acidity-alkalinity, total iron, total manganese, and sulfate which are indicators of acid mine drainage. Most of the streams are in the Tygart Valley River basin.

A number of water-quality measures have been proposed as indicators of acid-mine drainage (AMD). Five common indicators are (U.S. Department of the Interior, 1968):

pH < 6.0

acidity > alkalinity

total iron > 0.5 mg/L (milligrams per liter)

total manganese > 0.5 mg/L

sulfate > 75 mg/L

Eleven of the 134 streams in Eastern Coal Province Area 5 that were sampled during January 1979 to April 1980 met or exceeded all five indicator levels. All indicator levels may not have been met or exceeded during a single sampling, nor were all indicator levels necessarily met at every sampling, but each AMD indicator level was met when all samples were considered. Samples for the AMD indicators were generally collected at least three times during periods of moderate or high base flow. Low base-flow sampling is scheduled for the future.

Figure 8.0-1 shows the locations of the 11 synoptic sites meeting all 5 AMD indicator levels. Five of the streams are in the Tygart Valley River basin. The middle Fork River basin has two streams exceeding all five indicator levels, the Cheat and Youghiogheny River basins have one each, and the remaining two streams are tributary to the Monongahela River. Seven of the streams are in the adjoining Taylor, Preston, and Tucker Counties, West Virginia, and the remaining four sites are scattered throughout the Maryland, Pennsylvania, and West Virginia portions of Area 5.

The streams in Area 5 that exceeded all five criteria for acid-mine drainage (AMD) do not exhibit any consistent relations among the AMD indicators. If a stream had a low pH, it did not follow that total iron or total manganese were found in high concentrations. Iron, manganese, and dissolved sulfate concentrations were similarly uncorrelated. In general, low pH values were correlated with high acidities.

Figure 8.0-2 illustrates the relation between dissolved solids and specific conductance based upon 30 concurrent samples at the 11 AMD sites. The regression equation for the relation is:

$$ROE = 0.85(SC) - 84 \qquad (8.0\text{-}1)$$

where ROE = dissolved solids, in milligrams per liter and SC = specific conductance, in micromhos per centimeter at 25°C. The multiple correlation coefficient (R^2) and standard error of estimate (SE) for equation 8.0-1 are 96 percent and 52 mg/L dissolved solids, respectively. The standard error is about 20 percent of the mean dissolved solids.

Hem (1970) states that a specific conductance coefficient greater than about 0.75 is an indication of high sulfate concentrations. This is supported by figure 8.0-3 which shows the relation between dissolved solids and dissolved sulfate based on 30 concurrent samples at 11 sites indicating AMD. The equation for this line is:

$$ROE = 1.70\,(SO_4) - 13 \qquad (8.0\text{-}2)$$

where ROE = dissolved solids, in milligrams per liter, and SO_4 = dissolved sulfate concentration, in milligrams per liter. Equation 8.0-2 has an R^2 of 98 percent and an SE of 34 mg/L dissolved solids. The SE is only 14 percent of the mean dissolved-solids concentration.

The equations showing the relation between dissolved solids and specific conductance and between dissolved solids and dissolved sulfate for streams

Note: 8.0 Acid-Mine Drainage text continued from tip-in at left

having all five AMD indicators are not different from the same equations using data from all streams in Area 5. Compare equations 8.0-1 and 8.0-2 with equations 7.2-1 and 7.2-2. Although the relationships are the same for all streams and for AMD-indicating streams, the average concentrations were different. Streams showing five indicators of AMD had dissolved solids, dissolved sulfate, and specific conductance averages 1.1, 3.7, and 1.3 times greater, respectively, than the average for all streams.

Figure 8.0-4 illustrates the close relation between dissolved-manganese concentration and total-manganese concentration for streams indicating AMD. The regression equation representing this relationship is:

$$MNT = 0.97\,(MND) + 45 \qquad (8.0\text{-}3)$$

where MNT = total-manganese concentration, in micrograms per liter, and MND = dissolved-manganese concentration, in micrograms per liter.

The SE for equation 8.0-3 is 129 μg/L total manganese and the R^2 is 99 percent. The mean dissolved- and total-manganese concentrations are both 1,500 μg/L. This, combined with the closeness of the regression constant to unity, indicates that most of the manganese in streams indicating AMD moves in the dissolved phase. This is the same as the transport characteristics for manganese for all Area 5 streams. However, in the AMD-indicating streams, the mean manganese concentration is almost four times that of the average for all streams in the area.

Figure 8.0-5 indicates that dissolved and total iron are not so closely related as dissolved and total manganese. A sufficiently large number of data points lie outside the trend-line area to prevent any strong statements concerning the dissolved iron-total iron relationship. However, the average dissolved-iron concentration for streams indicating AMD is about 3.9 times the average for all streams, and the average total-iron concentration for streams indicating AMD is 2.5 times the average for all streams.

The relationships shown in this section are based upon relatively scant data, and may not be representative.

The most obvious effect of acid-mine drainage (AMD) on a stream may be aesthetic. If the AMD is partially neutralized, as upon contact with unaffected water, dissolved iron in the AMD begins to precipitate in the form of ferric hydroxide. These ferric hydroxides form the orange coating on the stream bed which we commonly associate with AMD, and when in suspension, can give the water a reddish appearance.

Other effects of AMD may not be as noticeable, but may be of greater consequence than the aesthetic considerations. These effects may alter the ability of a stream to support aquatic life, or may adversely affect the quality of the stream's water for a specific use.

Table 8.0-1 presents some of the effects of pH on aquatic life (International Joint Commission, 1979). Below a pH of about 6.0, damage begins to occur to aquatic life. The first effect is generally a reduction in the number of species. Among the species still remaining, there may be a deterioration in their abilities to withstand additional forms of stress. As pH decreases below 5.5, many pH intolerant species will be eliminated. Air breathing invertebrates, tolerant of low pH, may increase in numbers. In spite of the increasing numbers of low-pH tolerant species, the total invertebrate biomass will be greatly reduced. When pH drops below 5.0, most fish species are eliminated. Because the decomposition of organic matter is greatly reduced, there will be an accumulation of debris. Below a pH of 4.5, all fish life is eliminated.

When pyrite (iron sulfide) is exposed to water and oxygen, it oxidizes to form a weak sulfuric acid solution. When the sulfuric acid contacts rock strata in the vicinity of the pyrite, it dissolves most metals including iron, manganese, aluminum, sodium, calcium, magnesium, and probably some trace metals. The formation of the sulfuric acid can take place under natural conditions, but mining accelerates the process by exposing large amounts of pyrite which naturally occur near coal seams.

Harvard University (1970) presents the following overall reactions for the mine-water system:

$$FeS_2(S) + 7/2\,O_2 + H_2 = Fe^{+2} + SO_4^{-2} + 2H^+ \qquad (8.0\text{-}4)$$

$$Fe^{+2} + \tfrac{1}{4}\,O_2 + H^+ = Fe^{+3} + \tfrac{1}{2}\,H_2O \qquad (8.0\text{-}5)$$

$$Fe^{+3} + 3H_2O = Fe(OH)_3\ (S) + 3H^+ \qquad (8.0\text{-}6)$$

$$FeS_2(S) + 14Fe^{+3} + 8H_2O = 15Fe^{+2} + 2SO_4^{-2} + 16H^+ \qquad (8.0\text{-}7)$$

In the initial step (8.0-4) pyrite is exposed to water and atmospheric oxygen, producing ferrous iron and sulfate and releasing acidity into the water. Reaction 8.0-5 illustrates the oxidation of ferrous iron to ferric iron which hydrolyzes to form the insoluble ferric hydroxide (8.0-6), a step which releases more acidity to the water. Reaction 8.0-7 shows that pyrite itself can reduce ferric iron to ferrous iron accompanied by an additional release of acidity. The ferrous iron formed in the step can reenter the reaction cycle as shown in reaction 8.0-5. In waters having low pH the oxidation of ferrous iron to ferric iron proceeds quite slowly; however, in acidic mine waters, certain bacteria are thought to speed the reaction through bacterial catalysis (Harvard University, 1970).

8.0 ACID-MINE DRAINAGE

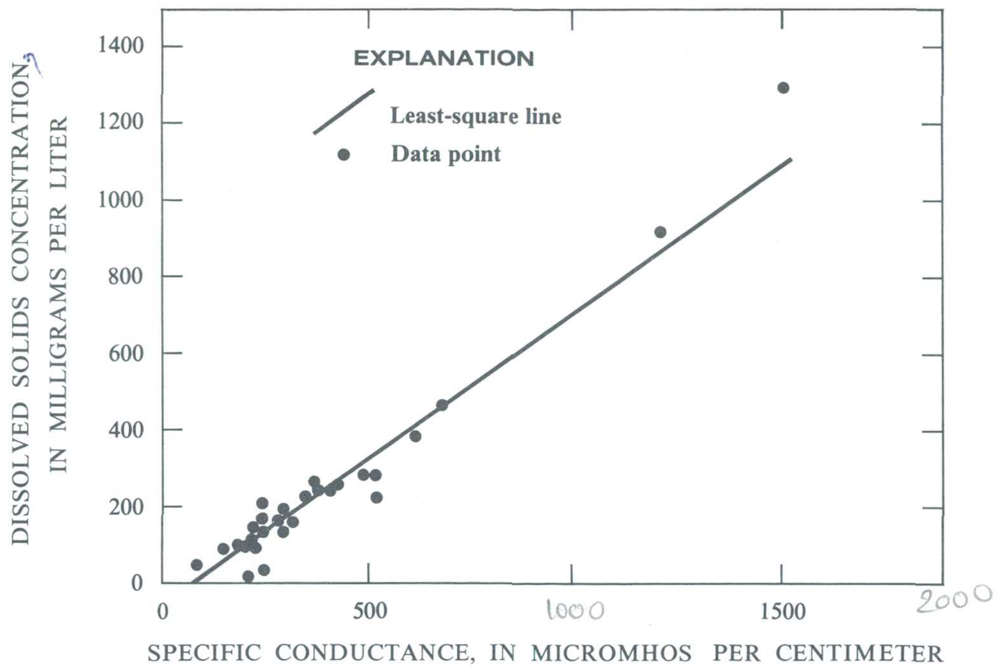

Figure 8.0-2 Relation between specific conductance and dissolved solids for streams indicating acid-mine drainage.

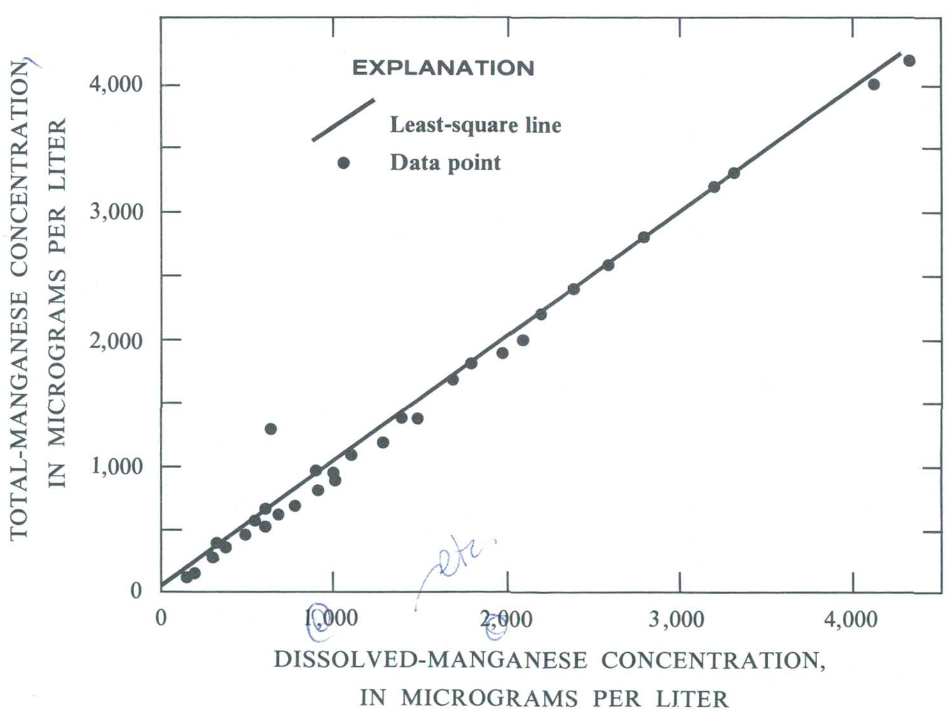

Figure 8.0-4 Relation between dissolved and total manganese for streams indicating acid-mine drainage.

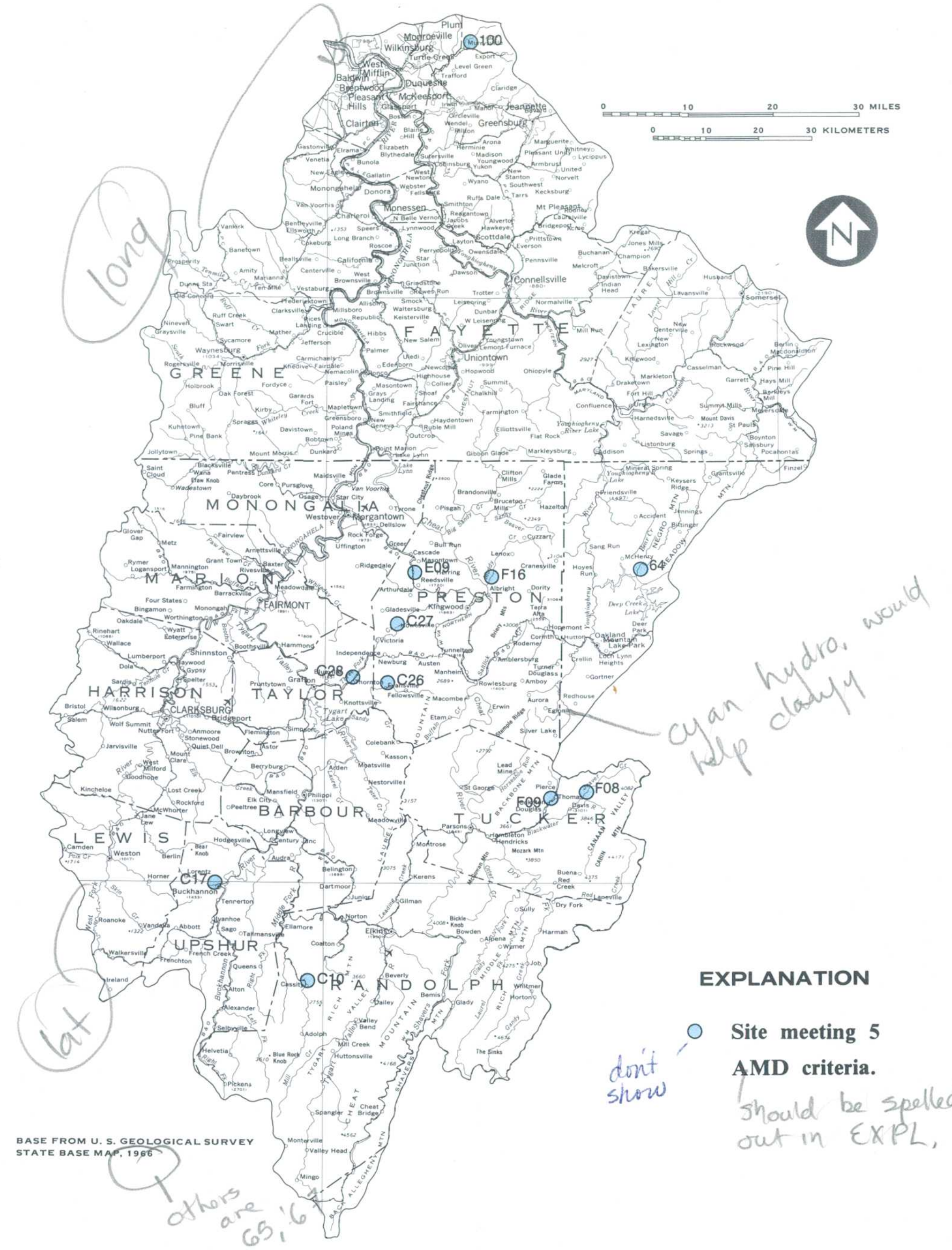

Figure 8.0-1 Location of sites in meeting Acid-Mine Drainage criteria for pH, total iron, total manganese, dissolved sulfate, and alkalinity-acidity.

Table 8.0-1 Effects of pH on aquatic life (International Joint Commission, 1979).

6.0	Reduction in species numbers among remaining species, alterations in ability to withstand stress.
5.5	Elimination of many species such as mayflies, stoneflies, and molluscs. Air-breathing pH tolerant invertebrates may become abundant. Greatly reduced invertebrate biomass.
5.0	Most fish species eliminated. Decomposition of organic detritus will be impaired and debris will accumulate.
4.0	All fish eliminated.

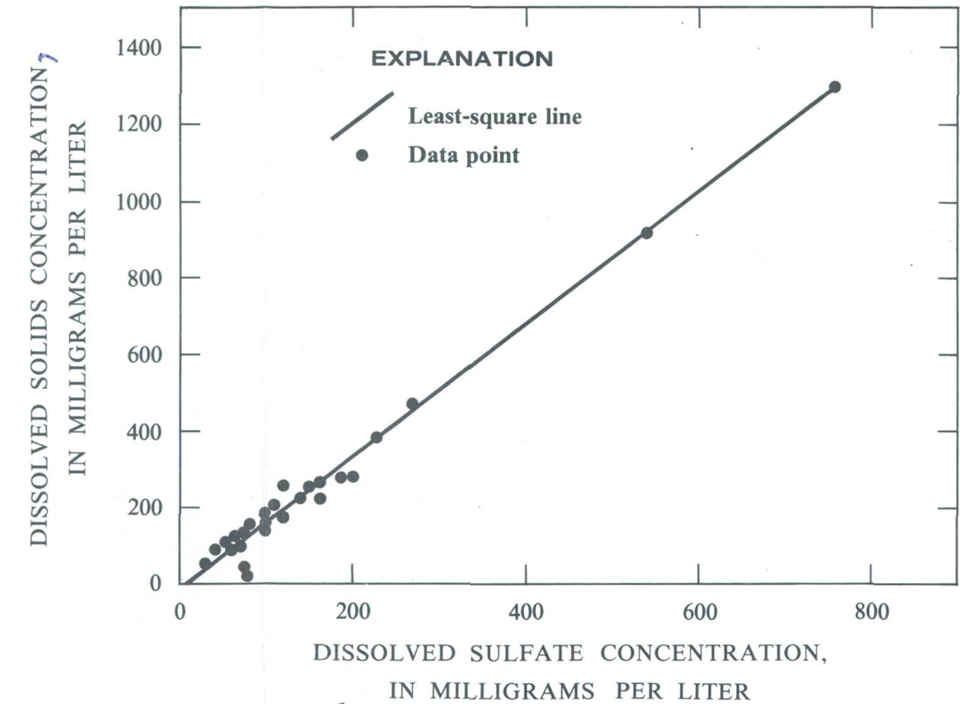

Figure 8.0-3 Relation between dissolved sulfate and dissolved solids for streams indicating acid-mine drainage.

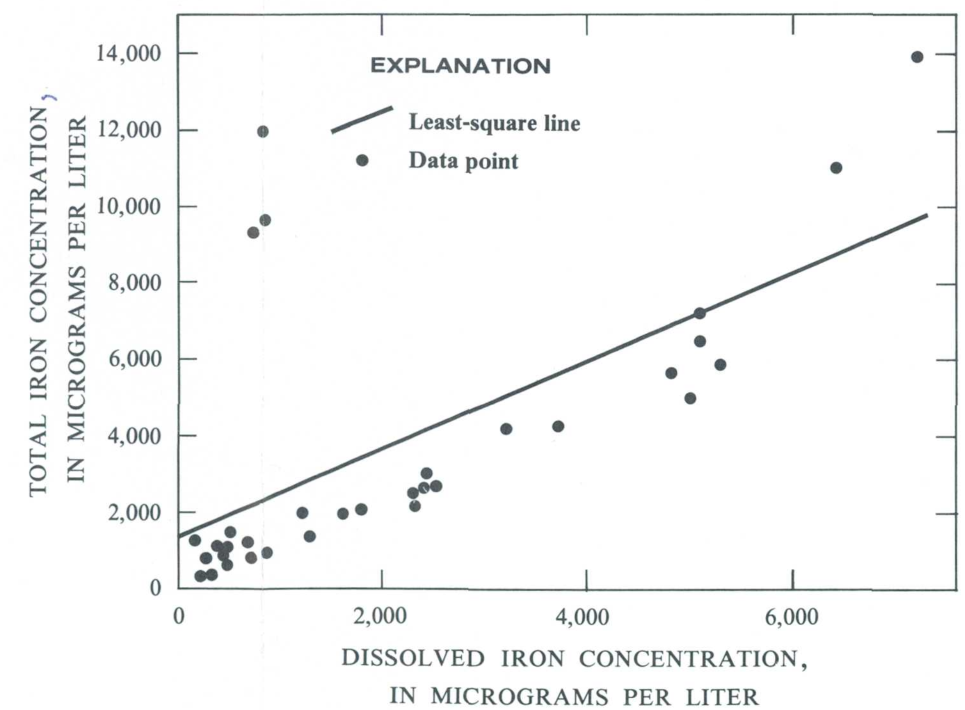

Figure 8.0-5 Relation between dissolved and total iron for streams indicating acid-mine drainage.

DAILY DISCHARGE IS BASIC HYDROLOGIC DATA

Daily discharge is the average flow rate during each day. It is used in the computation of many hydrologic indices.

The basic reporting unit of streamflow data is mean daily discharge in cubic feet per second. Mean daily discharge is the rate of flow, if it were constant throughout the day, that would have produced the volume of flow measured during the day. Mean daily discharge is determined by measuring stream stage (fig. 9.1-1) at intervals generally ranging from 5 minutes to 1 hour, and applying a stage-discharge relation.

Mean daily discharge, although a convenient unit of flow measurement, does not show the variation of flow throughout the day. Figure 9.1-2 is a discharge hydrograph for site 101, computed from the stage hydrograph shown in figure 9.1-1, and the appropriate stage-discharge relationship. Although the mean discharge for the day is 20 ft^3/s (cubic feet per second), the actual recorded instantaneous discharges ranged from a low of 1.0 ft^3/s to a high of 152 ft^3/s.

Mean daily discharges during a period can be presented in tabular form, such as table 9.1-1 for site 9 for October 1977. The daily discharges can also be presented graphically, as shown in figure 9.1-3 for site 11 for the 1978 water year.

Mean daily discharge data have greater utility than simply reporting average discharges for individual days. Daily discharge data are used in the computation of mean flows, low flows, and flow-duration curves or tables.

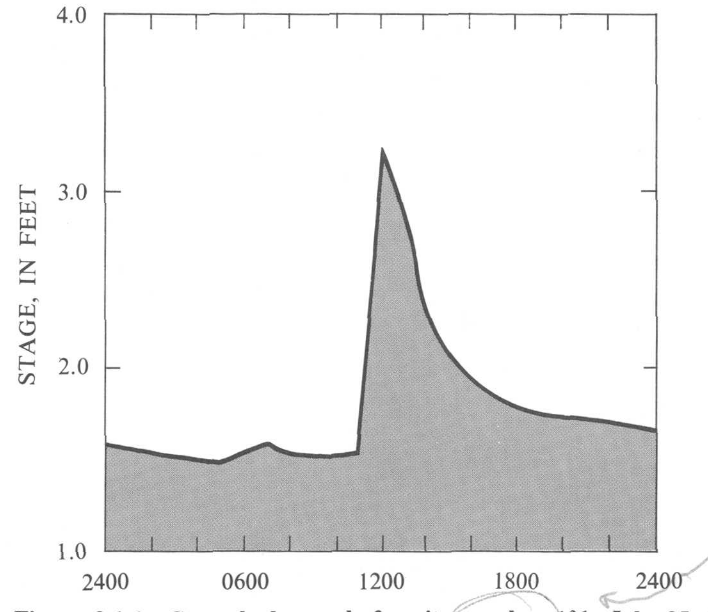

Figure 9.1-1 Stage hydrograph for site number 101, July 25, 1977.

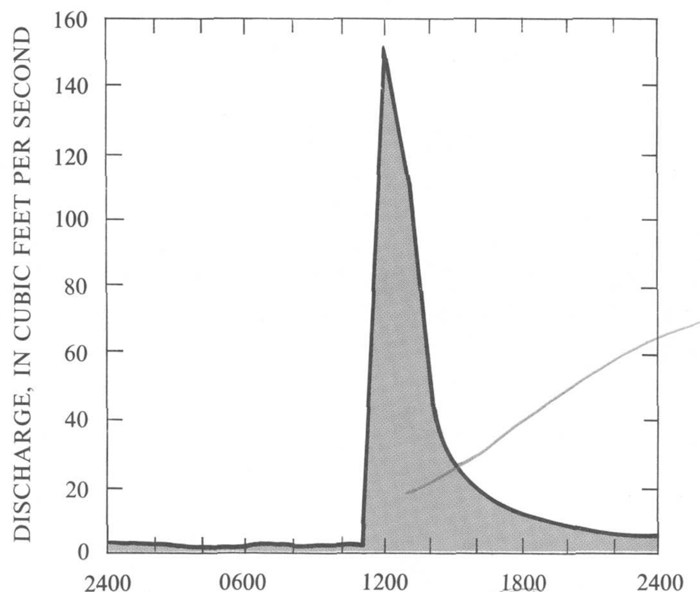

Figure 9.1-2 Discharge hydrograph for site number 101, July 25, 1977.

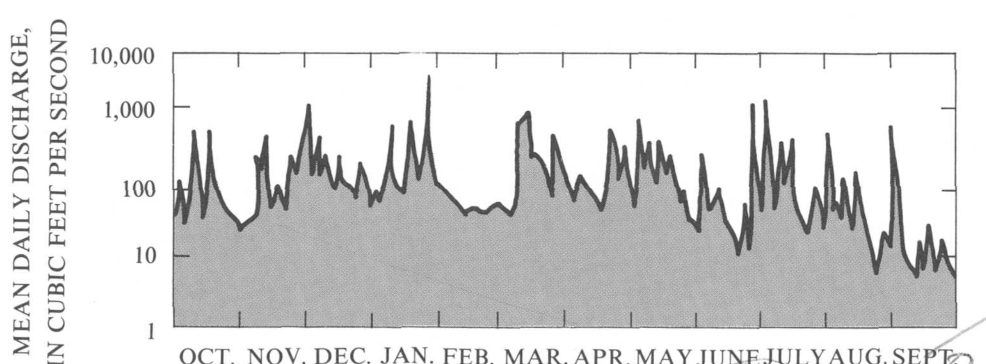

Figure 9.1-3 Daily discharge hydrograph for site number 11, 1978 water year.

Table 9.1-1 Mean daily discharge, in cubic feet per second, for site 9 during October 1978.

Day	October
1	926
2	1,740
3	1,910
4	1,690
5	1,600
6	1,620
7	1,680
8	1,640
9	2,430
10	3,420
11	6,230
12	6,010
13	5,790
14	5,590
15	4,640
16	2,920
17	2,840
18	1,890
19	3,000
20	3,000
21	3,330
22	4,260
23	4,170
24	4,040
25	3,930
26	3,640
27	2,140
28	1,470
29	2,480
30	2,440
31	2,380

LOW-FLOW DATA PRESENTED FOR 33 GAGING STATIONS IN AREA

Low-flow data are presented for 33 gaging stations in Area 5. Data are presented for 1, 3, 7, 30, and 120 consecutive-day periods and for non-exceedance probabilities of 50, 20, 10, 5, and 1 percent

Low-flow statistics can be computed for streams having recorded daily discharges. Table 9.2.1-1 presents low-flow data for 33 gaging stations in Eastern Coal Province Area 5. Data are presented for only those stations which are not subject to significant regulation or diversion. Regulation and diversion can unnaturally change flow patterns thereby invalidating the low-flow estimates.

Although it contains many figures, table 9.2.1-1 is not difficult to interpret. For example, find the value 12 in row 61 under column heading 50 percent, and sub-column heading 1 day. It is interpreted that for site 61, there is a 50 percent chance that the lowest mean daily flow will be less than 12 ft^3/s (cubic feet per second). Similarly, the value 6.0 in row 84, column 20 percent, sub-column 3 days is interpreted that for site 84, there is a 20 percent chance that the lowest mean flow for 3 consecutive days will be less than 6.0 ft^3/s.

Although table 9.2.1-1 is based on all daily streamflow data collected at the gaging stations, similar analyses can be done for flows for individual months. The consecutive-day periods for monthly low flows would then have an upper limit of 30 days for most months.

Table 9.2.1-1 Average flows, in cubic feet per second, which have the specified probability of not being exceeded in the specified number of consecutive days for gaging station.

		Probability of observed value not exceeding the tabular value (percent)																							
		50					20					10					5					1				
		Number of Consecutive Days																							
Site Number	Station Number	1	3	7	30	120	1	3	7	30	120	1	3	7	30	120	1	3	7	30	120	1	3	7	30	120
1	03050000	6.5	7.2	8.5	18	9.4	2.3	2.5	3.1	7.4	36	1.2	1.3	1.6	4.5	15	0.67	0.73	0.94	3.0	6.2	0.20	9.21	0.29	1.3	0.66
2	03050500	7.2	8.7	12	22	99	1.9	2.3	3.2	8.0	43	.82	.98	1.4	4.6	26	.38	.45	.63	2.8	16	.07	.09	.12	1.1	6.0
3	03051000	18	20	24	47	200	6.9	7.7	9.0	17	90	3.5	4.0	4.6	8.9	49	1.8	2.2	2.4	4.9	27	.39	.55	.56	1.4	6.6
4	03052000	3.5	4.1	5.5	15	66	1.1	1.3	1.7	4.4	28	.56	.66	.88	2.1	17	.33	.38	.47	1.1	10	.12	.13	.15	.30	3.9
5	03052500	.22	.24	.26	.79	4.8	.06	.06	.07	.26	2.1	.03	.03	.15	1.2	.02	.02	.02	.02	.09	.76	.005	.004	.01	.03	.28
6	03053500	12	13	16	35	170	4.3	4.7	5.4	12	73	2.3	2.4	2.8	5.5	36	1.3	1.3	1.5	2.7	18	.36	.37	.39	.58	3.3
7	03054500	37	40	48	97	410	15	16	19	36	190	8.8	9.3	11	20	120	5.7	6.0	7.0	12	79	2.4	2.4	2.9	4.8	33
11	03058000	1.5	1.6	1.9	4.3	23	.41	.51	.56	1.2	6.8	.19	.27	.29	.55	3.1	.10	.15	.16	.29	1.5	.03	.05	.05	.08	.31
14	03059500	1.8	1.9	2.4	5.3	19	.70	.77	.99	2.4	8.7	.41	.46	.60	1.5	5.5	.26	.29	.39	1.0	3.7	.10	.12	.16	.44	1.6
15	03061000	35	38	42	75	250	17	18	21	40	130	11	12	14	29	84	7.2	8.2	10	22	59	3.1	3.8	4.9	13	28
16	03061500	1.9	2.2	2.7	5.1	20	.78	.94	1.2	2.2	8.0	.47	.58	.80	1.4	4.9	.30	.38	.54	.95	3.2	.13	0.16	.25	.44	1.4
17	03062400	.07	.09	.07	.35	2.5	.03	.03	.02	.10	.85	.02	.02	.01	.05	.42	.01	.01	.01	.02	.22	.01	.01	.01	.01	.01
18	03063600	.13	.15	.22	.59	1.9	.07	.06	.09	.28	1.0	.04	.03	.06	.18	.78	.03	.02	.04	.12	.63	.01	.01	.02	.01	.43
19	03065000	25	27	32	58	200	13	14	16	27	110	8.7	9.3	11	18	72	6.3	6.7	7.7	12	51	3.2	3.4	3.9	5.7	25
20	03066000	9.1	9.7	11	19	61	5.2	5.6	6.5	10	33	3.7	4.1	4.8	7.0	22	2.7	3.0	3.6	5.1	15	1.4	1.7	2.1	2.7	6.5
27	03069500	75	81	95	180	580	41	44	50	87	310	22	31	34	57	200	21	22	24	38	130	11	11	12	17	50
28	03069880	.22	.26	.41	1.3	6.2	.10	.12	.19	.81	3.5	.07	.08	.14	.67	2.7	.05	.06	.10	.59	2.2	.03	.04	.06	.49	1.5
29	03070000	94	98	110	210	720	49	51	55	98	380	33	34	36	62	240	23	24	25	42	150	11	11	12	18	57
33	03070500	8.8	9.6	11	19	73	3.6	3.9	4.4	7.9	30	1.9	2.0	2.3	4.4	17	1.0	1.1	1.2	2.5	10	.26	.28	.28	.75	3.5
36	03072000	2.5	2.8	3.3	6.2	24	1.3	1.4	1.7	2.9	9.2	.97	1.1	1.3	2.0	5.4	.78	.85	1.0	1.5	3.5	.54	.58	.68	.85	1.5
37	03072590	.39	.31	.37	.75	2.1	.21	.13	.16	.35	.94	.14	.07	.11	.24	.63	.10	.05	.08	.18	.46	.05	.02	.04	.11	.26
48	03073000	.89	1.0	1.2	3.0	17	.36	.39	.46	1.1	5.6	.22	.24	.28	.70	2.9	.15	.16	.18	.47	1.6	.09	.07	.08	.22	.50
48a	03074300	.14	.15	.18	.33	1.2	.06	.06	.09	.23	.73	.03	.03	.05	.19	.55	.02	.02	.04	.16	.44	.004	.004	.02	.12	.29
49	03074500	14	16	18	21	30	10	11	12	15	21	7.9	8.7	9.5	12	18	6.50	7.0	7.6	70	16	4.3	4.4	4.7	7.0	12
61	03075500	12	13	14	23	65	6.5	6.9	7.6	12	32	4.6	4.9	5.3	8.3	22	3.4	3.6	3.8	6.2	15	1.8	1.9	2.0	3.4	7.2
68	03076600	5.4	5.6	6.2	8.4	17	3.1	3.3	3.6	5.1	9.7	2.3	2.4	2.7	4.0	7.2	1.7	1.8	2.1	3.2	5.7	.94	1.0	1.2	2.3	3.7
73	03078000	3.6	3.6	4.0	7.0	20	1.6	1.6	1.9	3.4	9.9	.96	.99	1.2	2.2	6.7	.61	.65	.87	1.6	4.7	.24	.27	.43	.81	2.4
75	03078500	.40	.43	.52	1.01	4.1	.17	.18	.20	.40	1.7	.11	.11	.13	.25	1.1	.07	.10	.09	.17	.73	.04	.04	.04	.08	.35
81	03079000	28	29	32	50	130	18	19	20	29	69	14	15	16	22	49	12	12	13	17	36	8.7	9.0	9.4	11	20
84	03080000	8.9	10	12	20	60	5.3	6.0	7.0	11	31	4.1	4.6	5.2	8.1	21	3.2	3.6	4.0	6.1	15	2.0	2.3	2.5	3.5	7.4
87	03082200	.25	.26	.28	.55	2.2	.10	.09	.08	.24	.90	.06	.05	.04	.15	.56	.04	.03	.02	.11	.38	.02	.01	.004	.06	.19
91	03083000	.12	.13	.15	.26	.86	.08	.09	.10	.16	.40	.07	.07	.08	.12	.26	.06	.06	.07	.10	.18	.04	.05	.05	.07	.09
101	03084000	.14	.18	.16	.35	1.1	.08	.07	.08	.20	.53	.06	.04	.06	.15	.32	.05	.02	.04	.12	.21	.04	.01	.03	.08	.08

LOW-FLOW STATISTICS CAN BE ESTIMATED FOR UNGAGED STREAMS IN AREA

Techniques have been developed which permit the estimation of low-flow statistics for ungaged streams in much of Area 5.

Special techniques have been developed for estimating low flows for unregulated, ungaged streams in much of Eastern Coal Province Area 5. Flippo (1981) presents regression equations for estimating average minimum discharges for 3-, 7-, 30-, and 120-consecutive-day intervals at nonexceedance probabilities of 20, 10, 5, 2, and 1 percent. Flippo also presents equations for estimating minimum discharges for 1, 3, 7, and 30 days at the same nonexceedance probabilities for the 6 individual months of May through October.

Flippo (1981) divided Pennsylvania and portions of surrounding States into a number of low-flow regions. Area 5 in Pennsylvania, Maryland, and part of West Virginia is located in region 12. Region 12 contains all of Area 5 with the exception of the upper Cheat, Tygart Valley, and West Fork Rivers.

Table 9.2.2-1 present Flippo's (1981) equations for annual and May-October low flows for the part of Area 5 covered by his low-flow region 12. The equations use the following conventions:

A:3,5 = Annual low flow for 3 days with 5-year recurrence intervals (20-percent probability), in cubic feet per second,

5:1,10 = May low flow for 1 day with 10-year recurrence interval (10-percent probability), in cubic feet per second,

A = Drainage area, in square miles,

G = Geologic index, dimensionless, and,

PI = Annual precipitation index, in inches.

Prior to the application of the regression equations the reader should consult Flippo (1981) for a discussion of the equations' accuracy and limitations.

Table 9.2.2-1 Summary of regression equations for annual low flows of unregulated streams.

Log Y = Log C + B1 Log A + B2 G + B3 Log PI

Flow Characteristics Y	Regression Constant, Log C	Regression Coefficients B1	B2	B3	Standard Error of estimate, percent	Coefficient of deter-mination, percent
A3,5	-7.140	1.203	1.343	3.371	48	96.6
A3,10	-7.039	1.180	1.304	3.203	42	97.2
A3,20	-6.781	1.131	1.382	2.935	45	96.5
A3,50	-6.444	1.077	1.492	2.573	53	94.5
A3,100	-6.218	1.048	1.578	2.324	62	92.5
A7,5	-7.076	1.127	1.437	3.469	53	95.6
A7,10	-7.051	1.162	1.357	3.279	45	96.8
A7,20	-6.827	1.162	1.378	2.975	46	96.5
A7,50	-6.467	1.116	1.435	2.608	53	94.9
A7,100	-6.266	1.079	1.499	2.397	60	93.2
A30,5	-5.672	1.135	2.316	2.288	52	95.1
A30,10	-6.042	1.124	2.023	2.562	46	96.1
A30,20	-6.309	1.121	1.860	2.716	41	96.9
A30,50	-6.708	1.142	1.565	2.952	42	96.9
A30,100	-6.808	1.142	1.479	2.970	47	96.2
A120,5	-3.665	.981	1.159	1.729	21	98.6
A120,10	-4.123	1.000	1.556	1.782	20	98.8
A120,20	-4.649	1.034	1.991	1.879	23	98.6
A120,50	-5.191	1.081	2.513	1.907	31	97.8
A120,100	-5.616	1.116	2.871	1.972	36	97.2

Log Y = Log C + B1 Log A + B3 Log PI

Flow Characteristics Y	Regression Constant, Log C	Regression Coefficients B1	B3	Standard Error of estimate, percent	Coefficient of deter-mination, percent
5:1,5	-2.511	0.896	1.641	34	95.9
5:1,10	-2.803	.879	1.811	37	95.4
5:1,20	-3.031	.867	1.932	39	94.8
5:1,50	-3.260	.852	2.045	44	93.6
5:1,100	-3.422	.844	2.127	47	92.9
5:3,5	-2.432	.880	1.642	35	95.7
5:3,10	-2.706	.862	1.800	38	95.0
5:3,20	-2.910	.856	1.895	40	94.4
5:3,50	-3.165	.843	2.025	44	93.4
5:3,100	-3.264	.848	2.030	48	92.5
5:7,5	-2.234	.888	1.543	31	96.4
5:7,10	-2.500	.871	1.690	34	95.7
5:7,20	-2.717	.862	1.799	37	95.0
5:7,50	-2.986	.845	1.948	41	94.1
5:7,100	-3.142	.835	2.028	44	93.3
5:30,5	-1.520	.934	1.220	27	97.2
5:30,10	-1.833	.914	1.384	31	96.4
5:30,20	-2.047	.907	1.471	35	95.7
5:30,50	-2.330	.892	1.605	39	94.7
5:30,100	-2.516	.879	1.700	43	93.8

Log Y = Log C + B1 Log A + B3 Log PI

Flow Characteristics Y	Regression Constant, Log C	Regression Coefficients B1	B3	Standard Error of estimate, percent	Coefficient of deter-mination, percent
6:1,5	-3.130	0.926	1.697	40	94.9
6:1,10	-3.457	.922	1.842	46	93.7
6:1,20	-3.735	.915	1.975	51	92.7
6:1,50	-4.114	.915	2.151	58	91.3
6:1,100	-4.397	.913	2.299	63	90.2
6:3,5	-2.984	.928	1.616	39	95.0
6:3,10	-3.301	.920	1.759	43	94.2
6:3,20	-3.569	.911	1.883	48	93.1
6:3,50	-3.964	.909	2.075	55	91.7
6:3,100	-4.204	.905	2.192	60	90.7
6:7,5	-2.850	.918	1.611	35	95.9
6:7,10	-3.122	.901	1.733	40	94.8
6:7,20	-3.345	.887	1.826	44	93.8
6:7,50	-3.635	.874	1.949	50	92.2
3:7,100	-3.836	.865	2.040	54	91.3
6:30,5	-2.161	.942	1.388	31	96.7
6:30,10	-2.490	.911	1.555	35	95.8
6:30,20	-2.784	.883	1.706	39	94.7
6:30,50	-3.140	.854	1.883	46	92.9
6:30,100	-3.390	.832	2.021	50	91.8

Log Y = Log C + B1 Log A + B2 G + B3 Log PI

Flow Characteristics Y	Regression Constant, Log C	Regression Coefficients B1	B2	B3	Standard Error of estimate, percent	Coefficient of deter-mination, percent
7:1,5	-4.251	0.987	1.108	1.837	31	97.3
7:1,10	-4.537	1.002	1.212	1.872	34	96.9
7:1,20	-4.812	1.017	1.293	1.924	37	96.4
7:1,50	-5.161	1.032	1.368	2.011	43	95.6
7:1,100	-5.379	1.043	1.418	2.060	46	95.1
7:3,5	-4.141	.987	1.059	1.806	30	97.5
7:3,10	-4.437	.995	1.100	1.879	32	97.1
7:3,20	-4.707	1.001	1.163	1.946	35	96.7
7:3,50	-5.028	1.025	1.235	1.996	40	95.9
7:3,100	-5.200	1.034	1.300	2.007	45	95.2
7:7,5	-3.828	.981	1.144	1.622	28	97.7
7:7,10	-4.036	.999	1.207	1.599	30	97.3
7:7,20	-4.254	1.012	1.256	1.617	33	96.9
7:7,50	-5.280	.825	.774	2.782	35	96.4
7:7,100	-5.436	.832	.805	2.790	36	96.3
7:30,5	-2.750	.984	.842	1.197	32	96.7
7:30,10	-3.072	1.004	.929	1.242	35	96.2
7:30,20	-3.355	1.016	1.015	1.290	40	95.5
7:30,50	-3.706	1.042	1.097	1.342	47	94.3
7:30,100	-3.928	1.050	1.123	1.397	52	93.4

Log Y = Log C + B1 Log A + B2 G + B3 Log PI

Flow Characteristics Y	Regression Constant, Log C	Regression Coefficients B1	B2	B3	Standard Error of estimate, percent	Coefficient of deter-mination, percent
8:1,5	-5.344	0.910	0.832	2.776	34	97.0
8:1,10	-5.710	.900	.855	2.926	37	96.5
8:1,20	-6.012	.898	.865	3.044	41	95.9
8:1,50	-6.414	.901	.826	3.215	47	95.0
8:1,100	-6.606	.910	.841	3.249	53	94.1
8:3,5	-5.263	.911	.844	2.743	33	97.1
9:3,10	-5.589	.906	.878	2.851	37	96.5
9:3,20	-5.867	.902	.878	2.953	41	95.9
8:3,50	-6.260	.907	.878	3.101	48	94.8
9:3,100	-6.508	.907	.864	3.201	54	93.8
8:7,5	-4.899	.927	.995	2.451	31	97.4
8:7,10	-5.265	.915	1.082	2.583	32	97.2
8:7,20	-5.520	.908	1.135	2.654	34	97.0
8:7,50	-5.895	.907	1.207	2.770	37	96.5
8:7,100	-6.121	.906	1.270	2.830	39	96.2
8:30,5	-3.596	.931	.880	1.838	32	96.9
8:30,10	-3.885	.906	1.037	1.889	33	96.5
8:30,20	-4.107	.889	1.183	1.907	35	96.0
8:30,50	-4.478	.870	1.359	2.001	39	95.2
8:30,100	-4.669	.856	1.438	2.038	42	94.3

Log Y = Log C + B1 Log A + B2 G + B3 Log PI

Flow Characteristics Y	Regression Constant, Log C	Regression Coefficients B1	B2	B3	Standard Error of estimate, percent	Coefficient of deter-mination, percent
9:1,5	-4.595	0.859	1.100	2.057	46	93.4
9:1,10	-5.018	.896	1.245	2.124	51	92.9
9:1,20	-5.386	.921	1.371	2.202	57	91.9
9:1,50	-5.874	.966	1.562	2.280	67	90.5
9:1,100	-6.186	.998	1.766	2.302	73	89.8
9:3,5	-4.527	.857	.975	2.101	43	94.1
9:3,10	-4.964	.885	1.086	2.209	48	93.5
9:3,20	-5.328	.908	1.192	2.299	54	92.5
9:3,50	-5.803	.949	1.350	2.390	65	90.9
9:3,100	-6.053	.974	1.504	2.393	73	89.6
9:7,5	-4.477	.881	1.033	2.073	42	94.7
9:7,10	-4.946	.906	1.161	2.210	46	94.2
9:7,20	-5.287	.927	1.228	2.299	52	93.3
9:7,50	-5.798	.949	1.359	2.463	63	91.4
9:7,100	-6.136	.976	1.461	2.553	68	90.9
9:30,5	-3.674	.926	1.333	1.630	31	96.9
9:30,10	-4.116	.942	1.477	1.746	36	96.0
9:30,20	-4.509	.953	1.573	1.878	42	95.0
9:30,50	-4.995	.974	1.764	1.995	54	92.9
9:30,100	-5.294	.986	1.848	2.083	62	91.6

Log Y = Log C + B1 Log A + B2 G + B3 Log PI

Flow Characteristics Y	Regression Constant, Log C	Regression Coefficients B1	B2	B3	Standard Error of estimate, percent	Coefficient of deter-mination, percent
10:1,5	-4.928	0.820	1.047	2.584	29	97.2
10:1,10	-5.574	.790	1.032	3.003	36	96.2
10:1,20	-6.145	.772	1.019	3.368	44	94.9
10:1,50	-6.943	.743	.982	3.905	54	93.4
10:1,100	-7.334	.729	.984	4.139	61	92.3
10:3,5	-4.709	.830	1.166	2.397	24	98.1
10:3,10	-5.240	.808	1.221	2.696	29	97.4
10:3,20	-5.672	.793	1.257	2.934	34	96.6
10:3,50	-6.241	.771	1.307	3.254	43	95.1
10:3,100	-6.632	.755	1.317	3.492	47	94.3
10:7,5	-4.511	.828	1.260	2.269	24	97.9
10:7,10	-4.969	.809	1.319	2.502	29	97.3
10:7,20	-5.360	.801	1.369	2.692	33	96.6
10:7,50	-5.907	.787	1.444	2.973	39	95.5
10:7,100	-6.229	.767	1.439	3.167	45	94.6
10:30,5	-3.833	.830	1.249	1.983	33	96.1
10:30,10	-4.153	.802	1.359	2.082	33	96.1
10:30,20	-4.396	.792	1.462	2.129	34	95.7
10:30,50	-4.712	.775	1.570	2.205	37	95.2
10:30,100	-4.935	.761	1.624	2.286	40	94.5

MEAN FLOWS PRESENTED FOR 43 GAGING STATIONS IN AREA

Mean and mean monthly flows were computed from records collected at 43 streamflow gaging stations in Area 5.

Table 9.3.1-1 presents mean and mean monthly flows for 43 streamflow gaging stations in Eastern Coal Province Area 5. These particular stations were selected because they had recent streamflow records. The table contains information for both regulated and unregulated streams.

Although they are direct computations from recorded discharges, the mean flows presented in table 9.3.1-1 are only estimates of the long-term mean flows at each station. If the period of record used in the computation of the mean flows in table 9.3.1-1 is representative of long-term mean-flow conditions, the estimates should be satisfactory.

A study of mean flow in Pennsylvania streams (Herb, 1981), which also utilized mean flow data from the West Virginia and Maryland parts of Area 5, found several basin and climatic factors to be related to mean flows. The basin characteristics related to mean flows were drainage area and in some cases, mean basin elevation. The climatic factors related to mean flows were mean annual precipitation and potential annual evapotranspiration which could be combined to yield an annual precipitation excess.

9.0 SURFACE-WATER QUANTITY (CONTINUED)

9.3 MEAN FLOW

9.3.1 GAGED SITES

Table 9.3.1-1 Measured mean discharges at gaging stations.

Site Number	Station Number	Mean discharge for period indicated (cubic feet per second)												
		Annual	October	November	December	January	February	March	April	May	June	July	August	September
1	03050000	349	126	234	453	543	591	712	514	418	234	148	150	81.6
2	03050500	502	179	341	671	790	893	1,047	785	529	331	195	165	122
3	03051000	797	304	547	983	1,311	1,339	1,545	1,171	936	558	380	316	202
4	03052000	347	109	273	480	558	590	674	541	386	232	136	112	85.1
5	03052500	26.3	9.06	19.0	37.3	43.5	46.7	50.3	39.9	24.9	116.7	13.8	9.73	5.73
6	03053500	593	240	462	809	961	1,007	1,122	814	633	388	280	254	158
7	03054500	1,832	647	1,384	2,517	2,895	3,148	3,558	2,738	1,923	1,199	814	764	469
8	03056000	2,309	1,041	1,919	3,251	3,565	4,127	4,450	2,650	2,089	1,528	1,072	1,202	900
9	03057000	2,602	1,160	2,125	3,662	4,062	4,575	5,024	3,044	2,421	1,734	1,160	1,338	1,008
11	03058000	163	40.8	113	241	285	308	315	248	151	98.9	64.4	56.9	38.0
12	03058500	294	115	212	407	478	538	565	424	278	188	121	128	83.0
13	03059000	580	215	404	812	979	1,085	1,116	826	567	343	224	247	171
14	03059500	118	33.0	70.0	166	194	238	251	164	120	60.8	45.6	50.0	28.7
15	03061000	1,149	341	687	1,543	1,969	2,134	2,258	1,741	1,121	740	445	496	369
16	03061500	165	39.3	85.9	202	281	297	350	277	185	116	55.8	57.3	43.3
17	03062400	15.7	4.51	9.16	23.2	23.0	27.0	28.0	25.6	22.3	10.5	6.14	4.51	4.66
18	03063600	9.99	8.31	8.38	16.2	14.8	18.3	16.6	16.2	7.08	6.98	2.12	1.87	3.67
19	03065000	750	356	552	918	1,053	1,200	1,523	1,220	818	530	306	333	221
20	03066000	195	109	147	241	275	312	384	292	202	137	87.4	101	63.0
27	03069500	1,676	898	1,260	2,034	2,370	2,567	3,192	2,529	1,862	1,235	819	838	552
28	03069880	30.1	13.1	32.6	51.5	41.2	46.2	46.8	45.1	31.6	15.7	9.33	15.1	13.4
29	03070000	2,250	1,087	1,667	2,759	3,152	3,520	4,296	3,507	2,603	1,612	1,050	1,117	696
33	03070500	409	147	303	549	637	664	818	647	478	272	157	133	442
33a	03071000	2,988	1,263	1,926	3,603	4,386	4,888	5,566	4,577	3,582	2,217	1,559	1,552	824
36	03072000	272	63.7	135	339	442	517	606	481	302	169	75.6	66.7	77.5
37	03072590	19.1	5.51	8.78	28.3	26.3	31.5	39.3	33.9	24.9	14.6	5.99	3.35	7.93
48	03073000	199	43.4	97.8	229	331	375	459	352	212	118	76.2	51.6	47.4
48a	03074300	6.91	2.02	4.16	9.74	8.10	10.2	13.6	11.4	10.8	6.38	2.30	1.46	2.94
49	03074500	98.2	41.8	50.6	110	135	151	170	159	126	85.3	47.7	42.3	42.6
61	03075500	290	102	201	386	449	478	595	448	312	189	114	132	81.3
66	03076500	612	289	463	793	895	946	1,163	912	656	424	272	312	240
68	03076600	82.6	27.8	51.7	110	114	131	180	147	95.7	45.8	27.9	27.9	35.0
68a	03077500	868	732	727	859	999	1,036	1,173	1,008	1,016	716	622	738	800
73	03078000	116	42.5	67.3	138	171	195	269	213	128	75.3	39.7	35.8	28.7
75	03078500	37.1	15.6	18.4	35.6	50.6	58.8	97.0	74.8	43.6	22.4	9.46	10.9	8.86
81	03079000	652	269	397	738	911	1,033	1,483	1,157	791	449	227	222	171
84	03080000	265	113	197	325	373	393	558	442	315	196	94.7	104	77
85	03081000	1,958	1,076	1,375	2,167	2,584	2,856	3,691	2,923	2,304	1,537	946	1,059	1,032
87	03082200	19.1	6.77	16.7	26.9	27.5	28.0	40.5	31.0	21.4	11.6	5.44	5.16	8.39
88	03082500	2,540	1,278	1,784	2,853	3,440	3,728	5,032	4,034	3,070	1,908	1,159	1,206	1,058
91	03083000	5.56	1.70	3.66	7.20	8.13	8.91	11.3	9.26	7.12	3.80	1.93	1.90	1.91
97	03083500	3,063	1,440	1,984	3,401	4,074	4,533	5,957	4,901	3,644	2,538	1,420	1,503	1,444
101	03084000	5.39	2.26	2.91	6.07	7.71	9.72	11.8	8.86	5.19	3.53	2.86	2.17	1.80

ESTIMATION OF MEAN FLOW AT UNGAGED SITES IN AREA

Equations have been developed to estimate mean flows in the Pennsylvania part of Area 5. Because data from the West Virginia and Maryland parts of the area were used to develop these equations, they should be applicable throughout the area.

A method for estimating mean flows at ungaged sites has been developed for streams in Pennsylvania. Table 9.3.2-1 presents equations for estimating mean and mean monthly flows for streams in the Pennsylvania part of Eastern Coal Province Area 5.

The only data required to use the estimating equations are: drainage area, mean annual precipitation, annual potential evapotranspiration, and, in some cases, mean basin elevation. Herb (1981) more fully explains the use and limitations of the equations.

Although the equations in table 9.3.2-1 were developed for Pennsylvania streams (Herb, 1981), they should be applicable to streams in the Maryland and West Virginia parts of Area 5. The data used to develop the equations came from many streams in the Monongahela basin, and included data for Maryland and West Virginia streams. Therefore, the equations should be reliable throughout Area 5, and can be used until more specific techniques are developed.

The equations in table 9.3.2-1 are applicable to most unregulated streams in Area 5. The estimating equations' reliability for streams having drainage areas less than 2 square miles is unknown. The standard error of estimate presented in table 9.3.2-1 is the percentage error that included about two-thirds of the data used to develop the equation.

Table 9.3.2-1 Regression equations for estimating mean flows at ungaged sites.

Period	Estimating equation	Standard error of estimate (percent)
Annual	$Q_A = 0.117\ DA^{.99}\ APX^{.91}$	11
October	$Q_{10} = 0.022\ DA^{1.04}\ APX^{1.09}$	33
November	$Q_{11} = 0.022\ DA^{1.00}\ APX^{1.99}$	23
December	$Q_{12} = 0.094\ DA^{.95}\ APX^{1.14}$	14
January	$Q_{01} = 0.150\ DA^{1.09}\ APX^{.89}$	13
February	$Q_{02} = 0.320\ DA^{1.00}\ APX^{.72}$	11
March	$Q_{09} = 0.822\ DA^{.98}\ E^{.38}\ APX^{.44}$	11
April	$Q_{04} = 0.340\ DA^{1.00}\ E^{.21}\ APX^{.67}$	10
May	$Q_{05} = 0.561\ DA^{1.00}\ E^{.48}\ APX^{.91}$	16
June	$Q_{06} = 0.805\ DA^{.99}\ E^{.55}$	26
July	$Q_{07} = 0.012\ DA^{1.02}\ E^{-.54}\ APX^{1.42}$	32
August	$Q_{08} = 0.020\ DA^{1.05}\ APX^{1.07}$[1]	22
	$Q_{08} = 0.005\ DA^{1.17}\ APX^{1.90}$[2]	21
September	$Q_{09} = 0.008\ DA^{1.12}\ APX^{1.12}$	41

DA = drainage area, in square miles

E = mean basin elevation, in thousands of feet

APX = annual precipitation excess, in inches

Q_A - Q_{09} = mean discharge for period, in cubic feet per second. Subscript identifies mouth: 01 = January, 02 = February, and so forth. Subscript A identifies mean flow for entire period of record.

[1]Applicable to all of Area 5 except West Fork River basin.

[2]Applicable to streams in West Fork River basin.

PEAK-FLOW DATA PRESENTED FOR 31 GAGING STATIONS IN AREA

Gaging-stations records were used to compute peak discharges for 31 gaging stations in Area 5. Discharges were computed for exceedance probabilities of 50, 10, 4, 2, and 1 percent.

Table 9.4.1-1 presents peak-flow data for 31 gaging stations in Eastern Coal Province Area 5. These stations are not subject to significant regulation or diversion of peak flows.

Table 9.4.1-1 is easy to interpret. The value of 7,150 in row 2 in the column headed "50-percent exceedance probability" means that for site 2, there is a 50-percent chance that the highest annual instantaneous discharge will be greater than 7,150 ft^3/s (cubic feet per second). Similarly, the value 13,200 in the same row under the column headed "4-percent exceedance probability" means that for site 2, there is a 4-percent chance that the highest instantaneous discharge in any year will be greater than 13,200 ft^3/s.

Exceedance probability percentages are the reciprocals of the previously used "recurrence intervals." An exceedance probability of 4 percent, or .04, is analogous to a recurrence interval of 1.04 or 25 years. A flood with a recurrence interval of 25 years would be expected to be exceeded, on the average, once in 25 years. Because these are estimates of averages, it is entirely possible to have floods with recurrence intervals of 10 and 25 years (exceedance probabilities of 10 and 4 percent), occurring in successive years, or even in the same year.

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Table 9.4.1-1 Peak discharge at selected exceedance probabilities for gaging stations.

Discharge at specified exceedance probability (ft^3/s)					
Station Number	Exceedance probability (percent) 50	10	4	2	1
03050500	7,150	11,100	13,200	14,900	16,600
03051000	10,200	15,100	17,300	19,000	20,600
03052000	5,330	8,810	10,700	12,200	13,800
03052500	714	1,300	1,650	1,930	2,240
03053500	7,300	10,900	12,700	13,900	15,100
03054500	21,200	32,400	37,800	41,800	45,900
03058000	3,250	5,200	6,250	7,050	7,880
03059500	2,590	5,810	7,960	9,800	11,900
03061000	17,400	29,100	35,700	39,700	44,200
03061500	5,090	8,110	9,650	10,800	12,000
03062400	509	1,050	1,380	1,670	1,980
03065000	12,300	22,500	28,900	34,200	40,000
03066000	2,420	4,390	5,570	6,540	7,590
03069500	23,900	39,100	47,000	52,900	58,900
03069880	1,270	2,440	3,170	3,760	4,420
03070000	33,100	53,800	64,000	71,500	78,900
03070500	7,290	13,500	17,700	21,400	25,700
03072000	6,850	12,000	14,800	17,000	19,200
03072590	667	1,240	1,570	1,850	2,130
03073000	6,140	10,100	12,100	13,600	15,100
03074300	154	349	479	591	716
03074500	2,260	4,430	5,780	6,890	8,090
03075500	4,120	7,790	10,000	11,800	13,800
03076600	1,570	2,820	3,550	4,150	4,790
03078000	2,180	3,910	4,960	5,820	6,740
03078500	1,050	2,590	3,720	4,740	5,940
03079000	11,500	20,500	26,400	31,500	37,300
03080000	4,410	7,480	9,130	10,400	11,700
03082200	731	1,250	1,540	1,770	2,010
03083000	249	609	871	1,110	1,380
03084000	417	991	1,370	1,700	2,060

TECHNIQUES AVAILABLE FOR ESTIMATING FLOOD PEAKS AT UNGAGED SITES IN AREA

Several systems have been developed which permit estimation of flood peaks for ungaged streams in Area 5.

Several systems of regression equations, which may be applicable to streams in Eastern Coal Province Area 5, have been developed for estimating flood peaks at ungaged sites. Tables 9.4.2-1 through 9.4.2-4 present these equations.

Currently, the most useful equations are probably those developed by Flippo (1977) which are shown in table 9.4.2-1. Although these equations were developed as part of a Pennsylvania study, Flippo (1977) shows them to be applicable to most Monongahela River basin streams north of the 39th parallel of latitude. The only data required are the drainage area of the basin and the difference between local mean annual precipitation and potential annual evapotranspiration. These equations can be used for unregulated non-urban streams having drainage areas larger than 2 mi^2 (square miles). Flippo (1977) also cautions about the use of these equations in basins that have been extensively strip mined. Such basins may produce anomalously low flood peaks.

Herb (1977) presents regression equations for estimating flood peaks in the Appalachian Plateau of Pennsylvania (table 9.4.2-2). These equations use bankfull channel width as the only independent variable. The equations are applicable to nonregulated streams having drainage areas from 2 to 300 mi^2. The applicability of these equations in extensively strip-mined basins is unknown.

Tables 9.4.2-3 and 9.4.2-4 present regression equations applicable to the West Virginia and Maryland portions of Area 5, respectively (Frye and Runner, 1970; Forrest and Walker, 1970). Both sets of equations utilize combinations of basin and climatic characteristics as the independent variables. Efforts are underway in both States to develop better flood-estimating procedures (D. H. Carpenter, 1980, oral communication; G.S.Runner, 1980, oral communication).

Table 9.4.2-1 Regression equations for estimating peak discharges in selected portions of the Monongahela River basin (from Flippo, 1977).

Exceedance Probability of Peak (percent)	Estimating Equation	Standard Error of Estimate (percent)
43	$39.4\ DA^{.827}\ APX^{.222}$	28
10	$45.4\ DA^{.789}\ APX^{.445}$	25
4	$45.3\ DA^{.772}\ APX^{.566}$	26
2	$44.5\ DA^{.759}\ APX^{.656}$	29
1	$42.2\ DA^{.751}\ APX^{.744}$	31

Table 9.4.2-2 Regression equations for estimating peak discharges in the Appalachian Plateau of Pennsylvania (Herb, 1977).

Exceedance Probability of Peak (percent)	Estimating Equation	Standard Error of Estimate (percent)
10	$7.079\ CWIDE^{1.473}$	50
4	$10.641\ CWIDE^{1.451}$	50
2	$14.028\ CWIDE^{1.437}$	50

Table 9.4.2-3 Regression equations for estimating peak discharges in West Virginia portion of the Monongahela River basin (from Frye and Runner, 1970).

Exceedance Probability of Peak (percent)	Estimating Equation	Standard Error of Estimate (percent)
50	$496\ DA^{.92}\ S^{-.21}\ E^{-.31}\ F^{.43}\ P^{.39}\ Tl^{-.43}$	21
20	$1200\ DA^{.97}\ L^{.13}\ S^{-.26}\ E^{-.40}\ F^{.40}\ Tl^{-1.26}$	22
10	$927\ DA^{1.01}\ L^{.14}\ S^{-.34}\ E^{-.36}\ F^{.38}\ Tl^{-1.08}$	24
4	$982\ DA^{1.04}\ L^{.15}\ S^{-.43}\ E^{-.34}\ F^{.39}\ Tl^{-1.01}$	27
2	$20900\ DA^{1.01}\ L^{.19}\ S^{-.45}\ F^{.33}\ Tl^{-1.40}\ SN^{-.39}$	

Table 9.4.2-4 Regression equations for estimating peak discharge in Maryland streams (from Forrest and Walker, 1970).

Exceedance Probability of Peak (percent)	Estimating Equation	Standard Error of Estimate (percent)
50	$562\ DA^{.769}\ E^{.339}\ F^{-.494}$	41
20	$818\ DA^{.751}\ E^{.325}\ F^{-.446}$	42
10	$1040\ DA^{.737}\ E^{.325}\ F^{-.418}$	44
4	$158\ DA^{.893}\ S^{.356}\ F^{-.357}$	46
2	$19.2\ DA^{.763}\ E^{.573}\ PI^{2.663}$	37

DA = Drainage area, in square miles
APX = Difference between mean annual precipitation and annual potential evapotranspiration, in inches
CWIDE = Top width of bankfull channel, in feet
S = Main channel slope, in feet per mile
L = Main channel length, from point of interest to drainage divide, in miles
E = Mean basin elevation, in feet
F = Forest cover, in percent
Tl = Mean minimum January temperature, in degrees F
SN = Average annual snowfall, in inches
P = Two-year, 24-hour rainfall in inches

FLOOD-PRONE AREA MAPS AVAILABLE FOR AREA

Flood-prone area maps are available for 104 7½-minute topographic maps in Area 5.

The National Flood Insurance Act of 1968 and the Flood Disaster Protection Act of 1973 established programs for identifying towns and streams subject to flood problems and for outlining flood-prone areas on topographic maps by approximate methods. In 1968 the Geological Survey began delineating flood-prone areas of the maximum known flood on 7½-minute topographic quadrangle maps using existing information. After 2 years it was decided that areal uniformity of the flood delineated would be desirable, so the 100-year flood (1-percent exceedance probability flood) was selected for mapping in 1970.

As of 1980, the area inundated by the 1-percent exceedance probability flood had been delineated for selected streams on 104 of the 161 7½-minute topographic quadrangle maps covering Area 5 in West Virginia, Maryland, and Pennsylvania. The delineations were based upon existing flood-depth data and flood depths estimated from the area's flood hydrology. Flood-prone maps within or partially within Area 5 are indicated by shading on figure 9.4.3-1, which also shows the names and locations of all 7½-minute topographic quadrangle maps in the area.

Copies of the flood-prone area maps for individual States' parts of Area 5 may be obtained from:

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

or

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

or

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

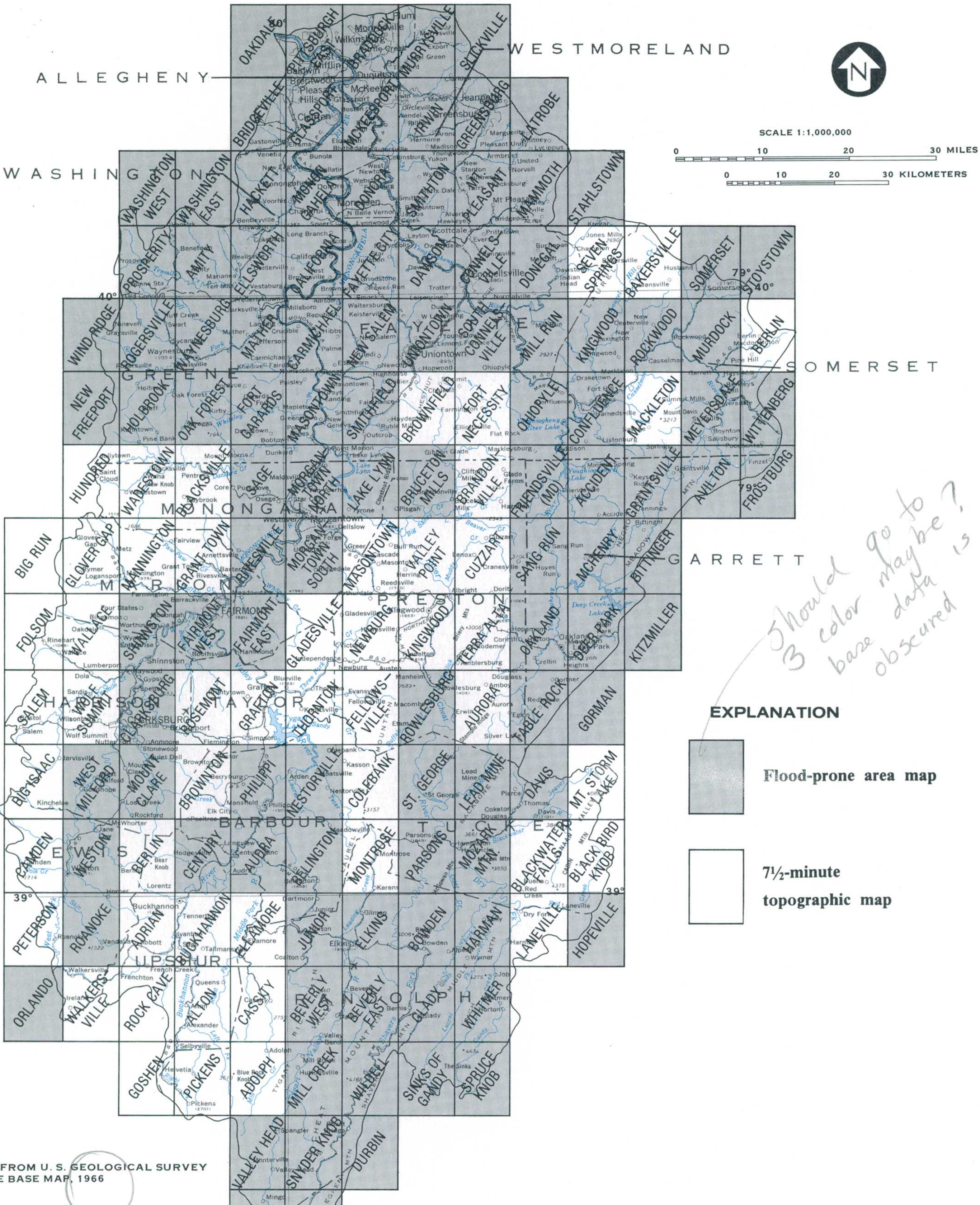

Figure 9.4.3-1 Availability of flood-prone area maps.

FLOW-DURATION CURVES PRESENTED FOR 33 GAGING STATIONS IN AREA

Streamflow data for 33 gaging stations were used to construct flow-duration curves for unregulated streams in Area 5.

Figure 9.5.1-1 presents flow-duration curves for 33 gaging stations on unregulated streams in Eastern Coal Province Area 5. Users of the figure should note that the scales for the individual "boxes" differ.

A flow-duration curve is a cumulative frequency curve that shows the percentage of time a specified discharge was exceeded during a specified period (Searcy, 1959). The flow-duration curve depicts the flow characteristics of a stream over a wide range of discharges without any consideration of the sequence of flows.

A flow-duration curve is useful for more than simply depicting flow characteristics. If the period of record used in developing the curve is representative of long-term conditions, a flow-duration curve can be used in conjunction with the proper transport curve to compute loads of water-borne constituents such as suspended sediment or sulfate.

Figure 9.5.1-1 is easy to use. To find the flow-duration of a specified discharge extend a horizontal line from one of the vertical axes until it intersects the curve for the station of interest. Then drop a vertical line to the lower horizontal axis and read the flow-duration percentage. To find the discharge associated with a specific flow-duration, extend a vertical line from the lower horizontal axis to its intersection with the curve for the stream of interest. A horizontal line extended from that point will intersect one of the vertical axes at the desired discharge. The dashed line in figure 9.5.1-1 indicates that for site 101, the discharge at a flow duration of 50 percent is about 24 cubic feet per second.

I like colors! me too

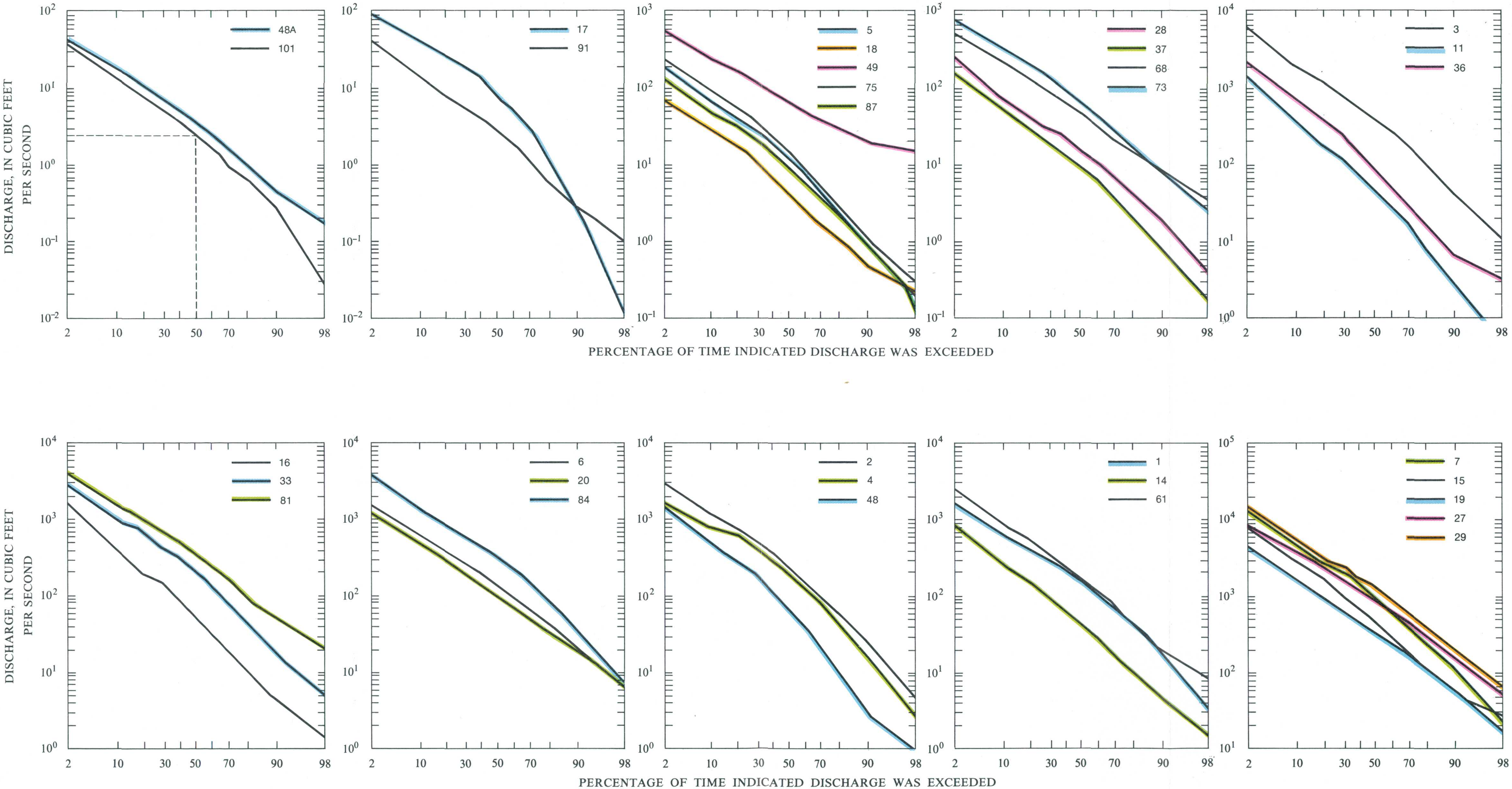

Figure 9.5.1-1 Flow-duration curves for selected stations.

9.0 SURFACE-WATER QUANTITY (CONTINUED)

9.5 FLOW DURATION

9.5.1 GAGED SITES

FLOW-DURATION ESTIMATES CAN BE DETERMINED FOR UNGAGED SITES IN AREA

Flow-duration estimates can be determined for ungaged streams in Area 5 having drainage areas smaller than 90 square miles. The drainage area must be known in order to make the estimate.

Figure 9.5.2-1, combined with a knowledge of an ungaged stream's drainage area, can provide data for a flow-duration curve for an ungaged stream in Eastern Coal Province Area 5. Estimates using this procedure are subject to considerable error, and their reliabilities are not known.

Figure 9.5.2-1 is a composite unit flow-duration curve presenting discharge in $(ft^3/s)mi^2$ (cubic feet per second per square mile) at flow durations from 2 to 98 percent. The composite curve is comprised of individual unit flow-duration curves for nine streams in Area 5 having drainage areas ranging from 6.6 to 86 mi^2 (square miles). The shaded portion of the curve encompasses all nine of the individual curves. The width of the shaded band indicates the uncertainty of unit flow-duration estimates.

The heavy line in the center of the shaded area is the mean of the nine individual flow-duration curves. This mean line can be used to estimate points on a flow duration curve for any unregulated, ungaged stream in Area 5 having a drainage area of 5-90 mi^2 (square miles). For example, try to estimate discharges at the 10-, 20-, 50-, 80-, and 90-percent points on the flow-duration for synoptic site 82 which has a drainage area of 31.9 mi^2. First, use figure 9.5.2-1 to find the appropriate unit discharges of 4.05, 2.30 .86, .14, and .11 $(ft^3/s)/mi^2$, respectively. Multiplying these values by the drainage area for site 82 produces discharges of 129, 73.4, 27.4, 4.5, and 3.5 ft^3/s. Additional points could be computed to produce a smoother curve.

It must be emphasized that this procedure was developed using only scant data and may be subject to large errors. If more reliable techniques are developed, the procedure outlined herein should be discontinued.

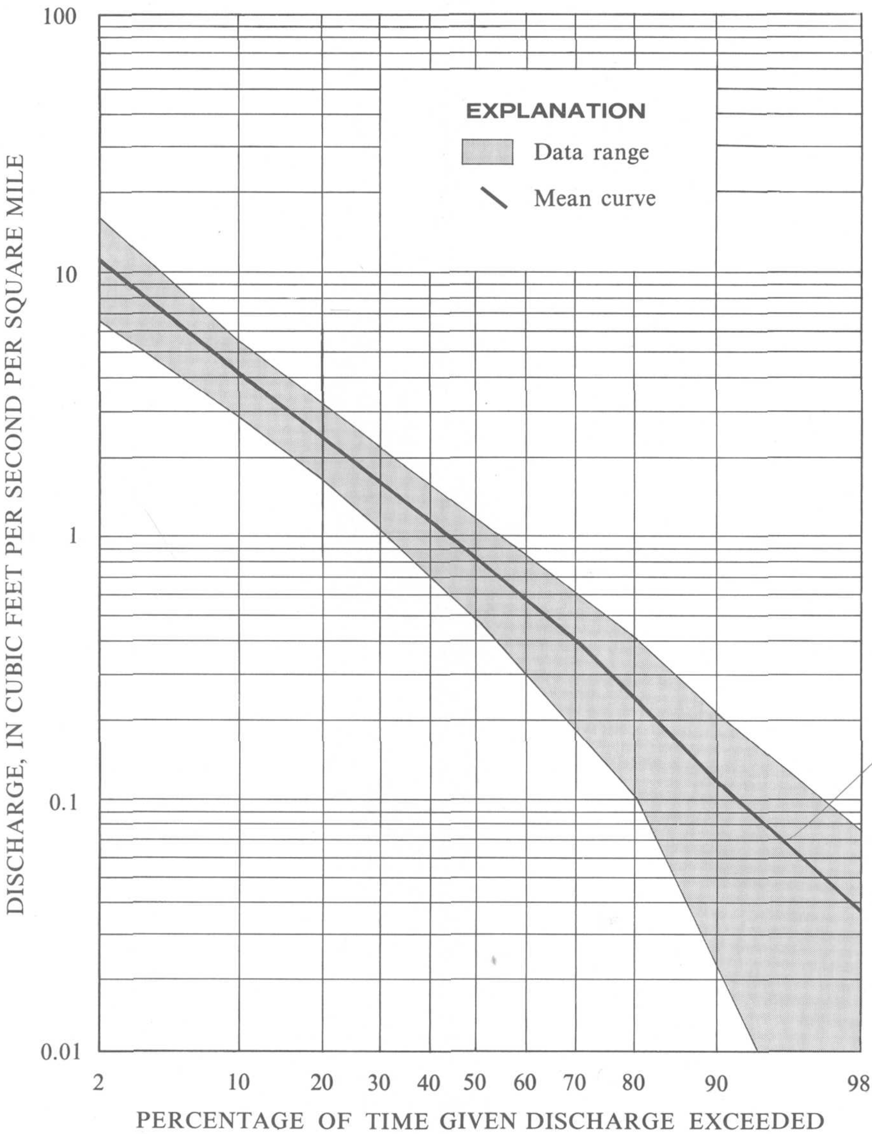

Figure 9.5.2-1 Composite flow-duration for streams.

GROUND-WATER LEVELS MONITORED AT 16 SITES IN AREA

Current monitoring of ground-water levels is being conducted at 16 observation wells within Area 5. Ground-water levels generally vary seasonally.

Figure 10.0-1 shows the location of 16 observation wells in Eastern Coal Province Area 5. Ground-water levels are monitored in these wells on a systematic basis. The periods of record for the wells vary from 1year to more than 40 years (through the 1978 water year).

Ground-water levels generally vary on a seasonal basis. Figure 10.0-2 shows ground-water levels at 5 selected observation wells in Area 5 for the 1977-78 water years. Wells FA17, GR118, and SO2 are artesian wells whereas 9-1-47 and GA-AG-1 are water table wells. As a general rule, ground-water levels are lowest (depth to water greatest) during the late summer and early fall, and are highest (depth to water least) during early spring. Figure 10.0-2 also illustrates the variability that occurs within the overall cyclic pattern. With the exception of wells GA-AG-1 and SO2, the wells show considerable week-to-week variation of water level. Levels at GA-AG-1 are collected too infrequently to show week-to-week variation.

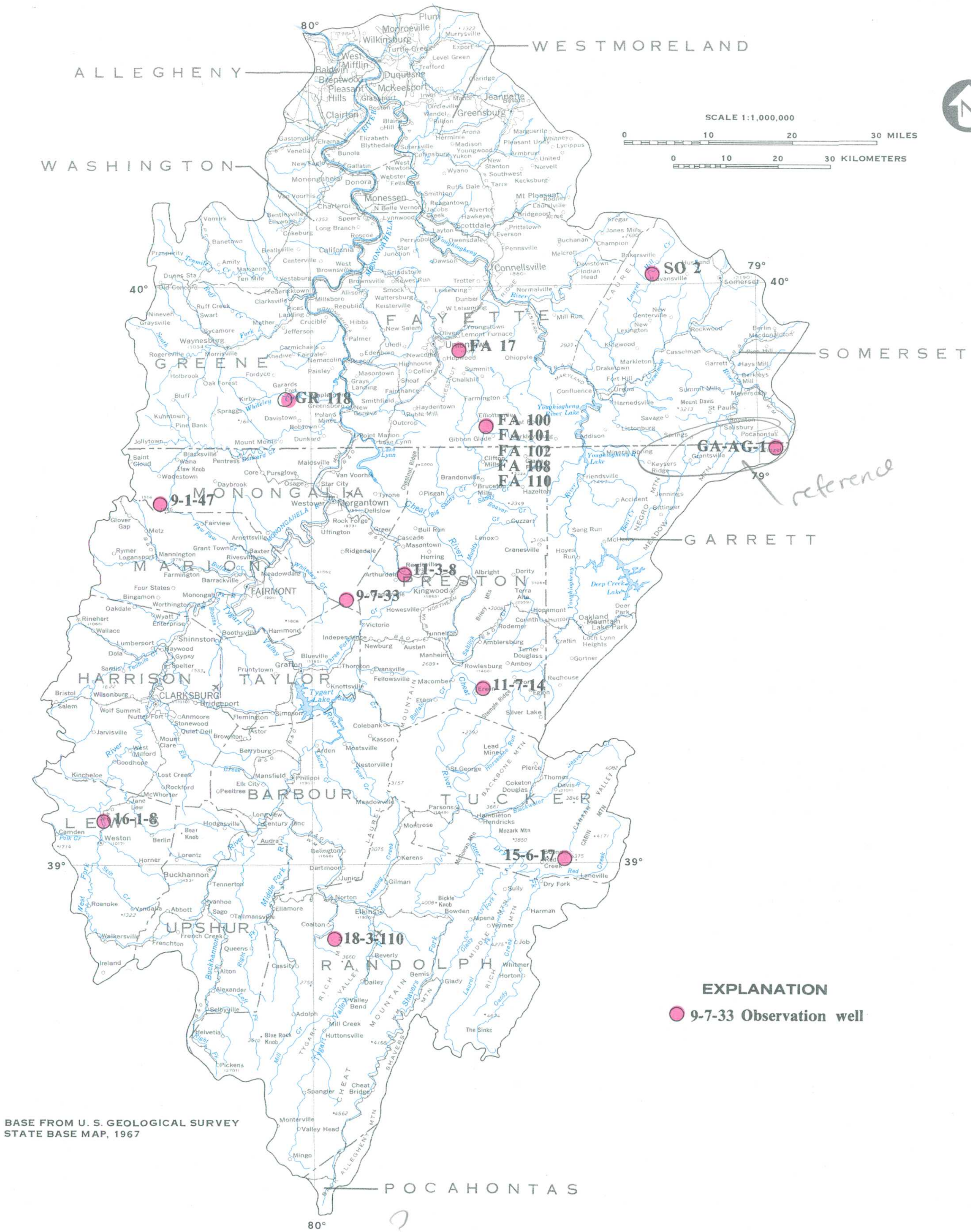

Figure 10.0-1 Locations of recently monitored observation wells.

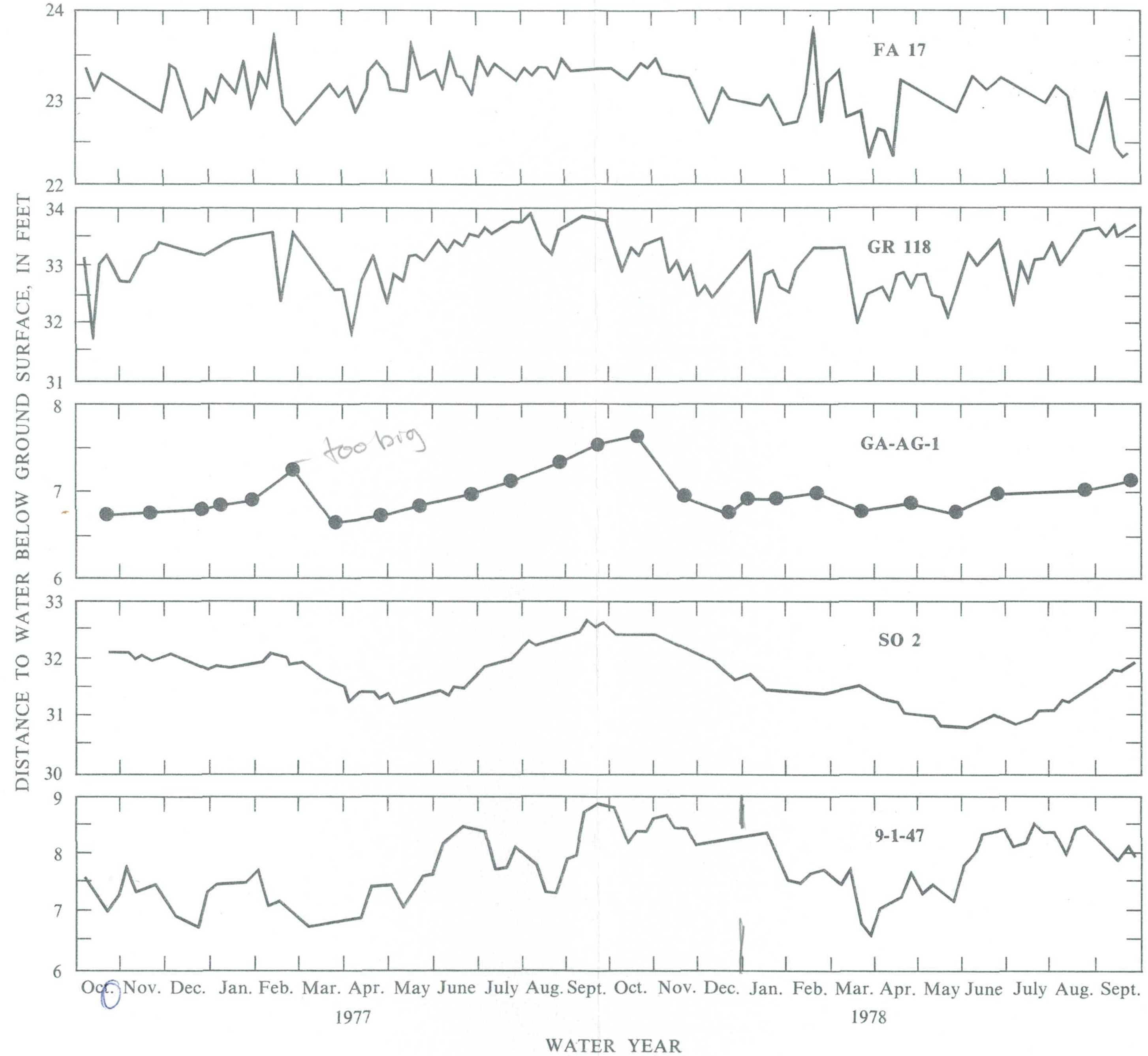

Figure 10.0-2 Variations in groundwater levels, 1977-78 water years.

NAWDEX, WATSTORE, 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:

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

(2) The National Water Data Storage and Retrieval System (WATSTORE), 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 is given in sections 11.2, 11.3, and 11.4.

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 (see fig. 11.2-1). 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. 11.2-2), 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. 11.2-3) 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, Virginia 22092

Telephone: (703) 860-6031
FTS 928-6031

Hours: 7:45-4:15 Eastern Time

or

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

Hours: 8:00-4:00 Eastern Time

or

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

or

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

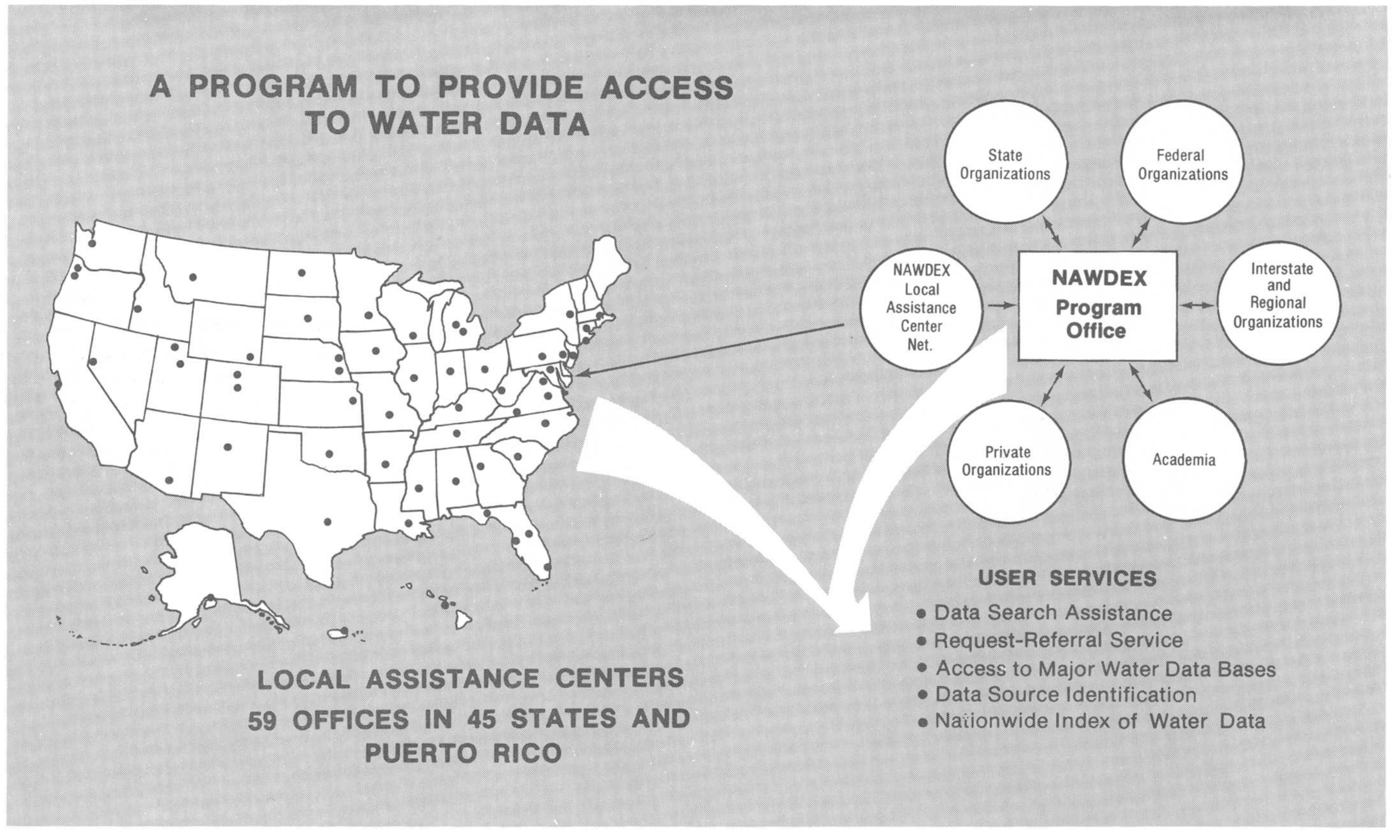

Figure 11.2-1 Access to water data.

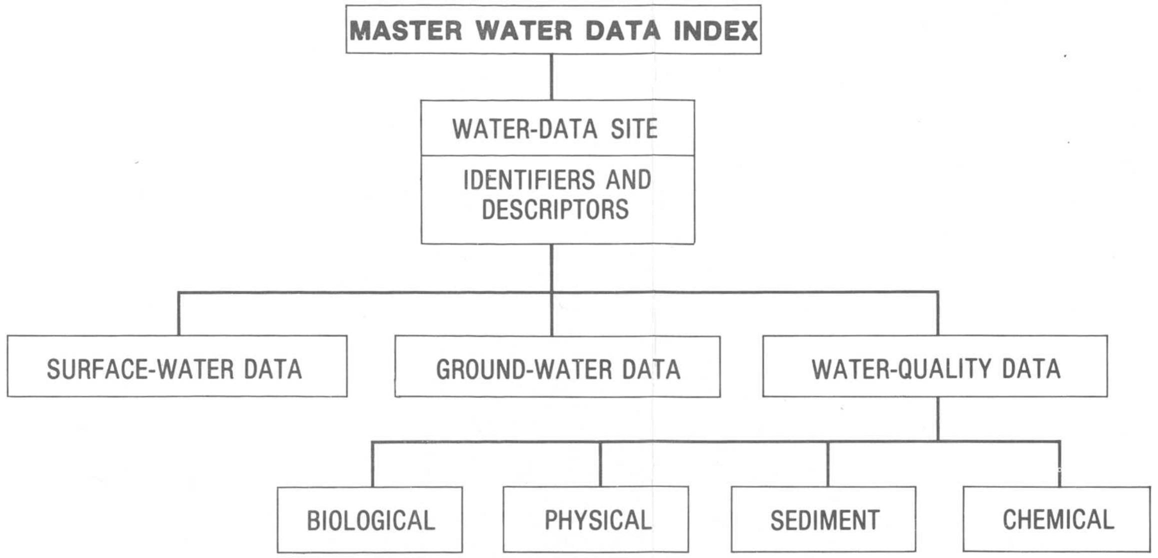

Figure 11.2-2 Master water-data index.

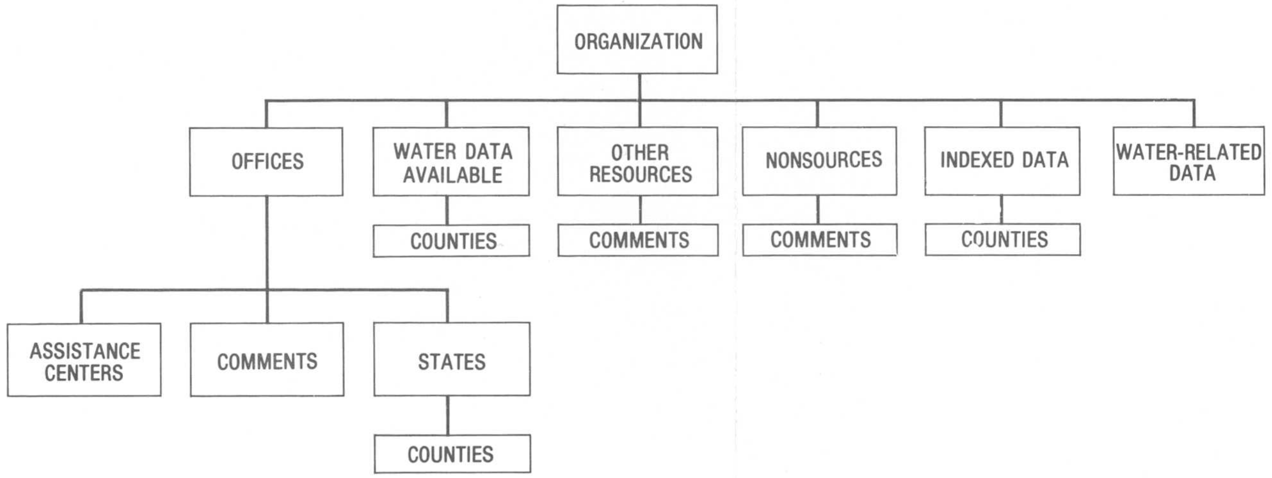

Figure 11.2-3 Water-data sources directory.

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, Virgina 22092

or

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

or

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

or

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

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

The WATSTORE system consists of several files in which data are grouped and stored by common characteristics and data-collection frequencies. The system also is designed to allow for the inclusion of additional data files as needed. Currently, files are maintained for the storage of: (1) surface-water, quality-of-water, and ground-water data measured on a daily or continuous basis; (2) annual peak values for streamflow stations; (3) chemical analyses for surface- and ground-water sites; (4) water parameters measured more frequently than daily; and (5) geologic and inventory data for ground-water sites. In addition, an index file of sites for which data are stored in the system is also maintained (fig. 11.3-1). 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 maintained within WATSTORE independent of the files discussed above, but it is cross-referenced to the Water Quality File and the Daily Values File. It contains inventory data about wells, springs, and other sources of ground water. The data included are site location and identification, geohydrologic characteristics, well-construction history, and one-time field measurements such as water temperature. The file is designed to accommodate 255 data elements and currently contains data for nearly 700,000 sites.

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

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

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

Central Laboratory System: The Water Resources Division's two water-quality laboratories, located in Denver, 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.

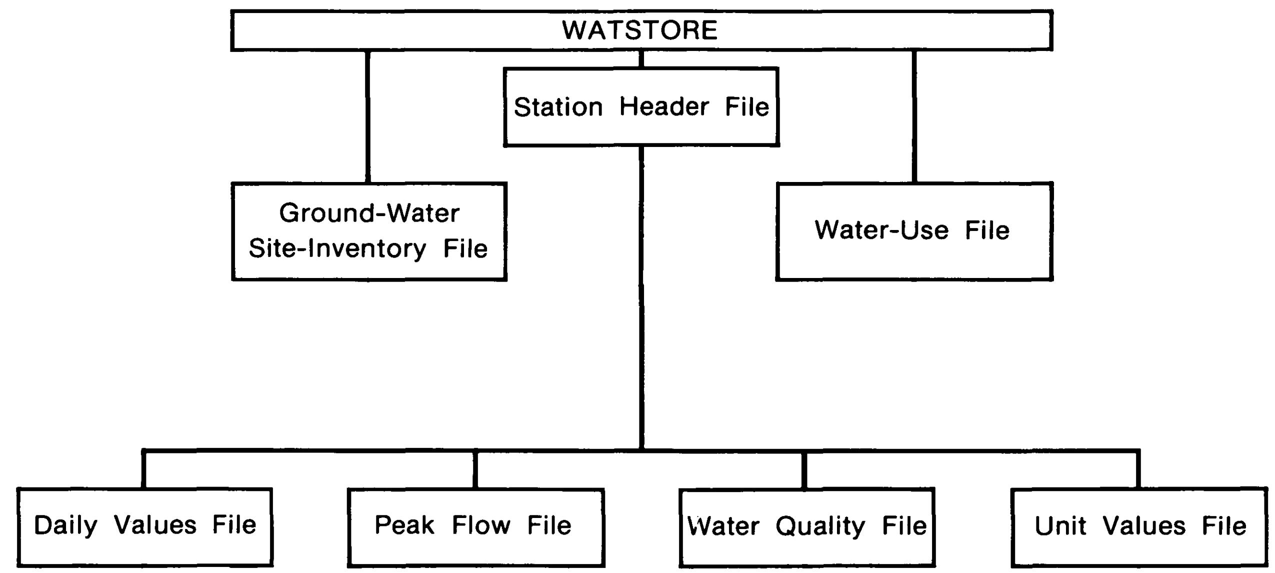

Figure 11.3-1 Index file stored data.

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. 11.4-1): 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 11.2).

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

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

or

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

or

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

or

Office of Surface Mining
U.S. Department of the Interior
603 Morris Street
Charleston, West Virginia 25301

Telephone: (304) 342-8125
FTS 924-7125

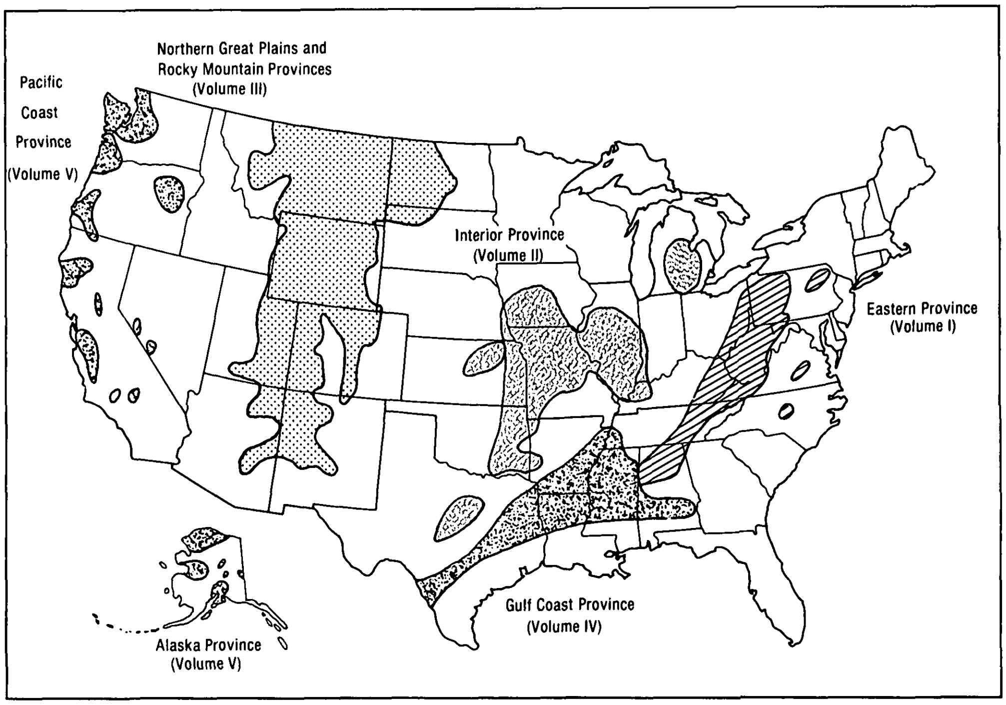

Figure 11.4-1 Index volumes and related provinces.

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Appendix 1 Surface-water stations.

Site Number	Station Number	Name
1	03050000	Tygart Valley River near Darley, W. Va.
2	03050500	Tygart Valley River near Elkins, W. Va.
3	03051000	Tygart Valley River at Belington, W. Va.
4	03052000	Middle Fork River at Audra, W. Va.
5	03052500	Sand Run near Buckhannon, W. Va.
6	03053500	Buckhannon River at Hall, W. Va.
7	03054500	Tygart Valley River at Phillipi, W. Va.
8	03056000	Tygart Valley River at Tygart Dam near Grafton, W. Va.
9	03057000	Tygart Valley River at Colfax, W. Va.
10	03057500	Skin Creek near Brownsville, W. Va.
11	03058000	West Fork River at Brownsville, W. Va.
12	03058500	West Fork River at Butcherville, W. Va.
13	03059000	West Fork River at Clarksburg, W. Va.
14	03059500	Elk Creek at Quiet Dell, W. Va.
15	03061000	West Fork River at Enterprise, W. Va.
16	03061500	Buffalo Creek at Barrakville, W. Va.
17	03062400	Cobun Creek at Morgantown, W. Va.
18	03063600	Horsecamp Run at Harman, W. Va.
19	03065000	Dry Fork at Hendricks, W. Va.
20	03066000	Blackwater River at Davis, W. Va.
21	03068000	Shavers Fork at Bemis, W. Va.
22	03068600	Shavers Fork above Bowden, W. Va.
23	03068610	Taylor Run at Bowden, W. Va.
24	03068690	North Spring at Bowden, W. Va.
25	03068710	South Spring at Bowden, W. Va.
26	03068800	Shavers Fork below Bowden, W. Va.
27	03069500	Cheat River near Parsons, W. Va.
28	03069880	Buffalo Creek near Rowlesburg, W. Va.
29	03070000	Cheat River at Rowlesburg, W. Va.
30	03070200	Salt Lick Creek at Rowlesburg, W. Va.
31	03070420	Stony Fork Tributary near Gibbon Glade, Pa.
32	03070455	Stony Fork near Elliottsville, Pa.
33	03070500	Big Sandy Creek at Rockville, W. Va.
34	03071840	Shannon Run near Mount Morris, Pa.
35	03071920	Meadow Run at Davistown, Pa.
36	03072000	Dunkard Creek at Shannopin, Pa.
37	03072590	Georges Creek at Smithfield, Pa.
38	03072594	Mountain Run at Ruble Mills, Pa.
39	03072700	Whiteley Creek at Kirby, Pa.
40	03072760	Browns Run at Ronco, Pa.
41	03072777	Muddy Creek near Carmichaels, Pa.

Appendix 1 Surface-water stations.

Site Number	Station Number	Site Name
42	03072815	Tenmile Creek near Amity, Pa.
43	03072820	Daniels Run near Marianna, Pa.
44	03072830	Daniels Run at Mariana, Pa.
45	03072865	Pursley Creek near Waynesburg, Pa.
46	03072975	Ruff Creek near Mather, Pa.
47	03072880	Browns Creek near Nineveh, Pa.
48	03073000	South Fork Tenmile Creek at Jefferson, Pa.
49	03074500	Redstone Creek at Waltersburg, Pa.
50	03075035	North Branch Pigeon Creek at Bentlyville, Pa.
51	03075040	Pigeon Run at Monongahela, Pa.
52	03075058	Mingo Creek at River View, Pa.
53	03075070	Monongahela River at Elizabeth, Pa.
54	03075084	Piney Fork at Snowden, Pa.
55	03075090	Peters Creek at Large, Pa.
56	03075250	Youghiogheny River at U.S. 219 near Redhouse, Md.
57	03075340	Youghiogheny River at Underwood Road near Crellin, Md.
58	03075350	Cherry Creek near Crellin, Md.
59	03075475	Little Youghiogheny River at Lock Lynn Heights, Md.
60	03075495	Little Youghiogheny River at 3rd Street at Oakland, Md.
61	03075500	Youghiogheny River near Oakland, Md.
62	03075600	Toliver Run Tributary near Hoyes Run, Md.
63	03075700	Muddy Creek at Swallow Falls State Park
64	03075900	Cherry Creek near McHenry, Md.
65	03076010	Deep Creek Lake Outflow
66	03076500	Youghiogheny River at Friendsville, Md.
67	03076510	South Branch Bear Creek near Friendsville, Md.
68	03076600	Bear Creek at Friendsville, Md.
69	03077925	North Branch Casselman River near Grantsville, Md.
70	03077945	Big Shade Run at Grantsville, Md.
71	03077950	South Branch Casselman River near Grantsville, Md.
72	03077975	South Branch Casselman River at Jennings, Md.
73	03078000	Casselman River at Grantsville, Md.
74	03078200	Tub Mill Run at West Salisbury, Pa.
75	03078500	Big Piney Run near Salisbury, Pa.
76	03078648	Flaugherty Creek at Meyersdale, Pa.
77	03078710	Blue Lick Creek near Meyersdale, Pa.
78	03078720	Tubs Run at Beachdale, Pa.

Appendix 1 Surface-water stations.

Site Number	Station Number	Name
79	03078785	East Bridge Coxes Creek near Somerset, Pa.
80	03078900	Middle Creek near Cassleman, Pa.
81	03079000	Casselman River at Markleton, Pa.
82	03079300	Whites Creek at Hornedsville, Pa.
83	03079600	Laurel Hill Creek near Bakersville, Pa.
84	03080000	Laurel Hill Creek at Ursina, Pa.
85	03081000	Youghiogheny River below Confluence, Pa.
86	03081650	Meadow Run near Farmington, Pa.
87	03082200	Poplar Run near Normalville, Pa.
88	03082500	Youghiogheny River at Connelsville, Pa.
89	03082598	Mounts Creek at Moyer, Pa.
90	03082837	Indian Creek at White Bridge, Pa.
91	03083000	Green Lick Run at Green Lick Reservoir, Pa.
92	03083045	Jacobs Creek near Dawson, Pa.
93	03083095	Barren Run near Smithton, Pa.
94	03083100	Jacobs Creek at Jacobs Creek, Pa.
95	03083150	Sewickley Creek near Youngwood, Pa.
96	03083260	Little Sewickley Creek at Cowansburg, Pa.
97	03083500	Youghiogheny River at Sutersville, Pa.
98	03083600	Gillespie Run near Sutersville, Pa.
99	03083805	Long Run at Versailles, Pa.
100	03083975	Turtle Creek at Murrysville, Pa.
101	03084000	Abers Creek near Murraysville, Pa.
102	03084800	Thompson Run at Turtle Creek
103	03084900	Brush Creek at Westmoreland City, Pa.
104	03085000	Monongahela River at Braddock, Pa.
C01	383309080021539	Tygart Valley River at Highway 15 Bridge at Valley Head, W. Va.
F01	383702079521339	Shavers Fork at Highway 250 Bridge at Cheat Bridge, W. Va.
C02	383936079585339	Becky Creek at Highway 56 Bridge near Huttonsville, W. Va.
C13	384352080084839	Left Fork Right Fork Buckhannon River at Highway 46 Bridge at Czar, W. Va.
C03	384401079584939	Mill Creek at Highway 46 Bridge at Mill Creek, W. Va.
C12	384440080140939	Right Fork Buckhannon River at Highway 48 Bridge at Newlonton, W. Va.
C14	384517080093039	Left Fork Buckahnnon River at Highway 9 Bridge at Palace Valley, W. Va.
F02	384827079441639	Shavers Fork at Bemis, W. Va.
C09	384905080024139	Middle Fork River at Highway 35 Bridge at Cassity, W. Va.

Appendix 1 Surface-water stations.

Site Number	Station Number	Site Name
C10	384933080020639	Cassity Fork at Highway 35 Bridge at Cassity, W. Va.
C04	385015079523339	Files Creek at Highway 219 Bridge at Beverly, W. Va.
F05	385152079332839	Dry Fork downstream from Stinking Run at Job, W. Va.
D01	385207080272939	West Fork River at Highway 44 Bridge at Walkersville, W. Va.
C15	385232080155239	Laurel Fork at Highway 20/10 Bridge near Adrian, W. Va.
F04	385303079355839	Laurel Fork at Highway 33 Bridge at Wymer, W. Va.
C16	385307080175339	French Creek at Highway 20 Bridge at French Creek, W. Va.
F03	385333079384039	Glady Fork at Highway 33 Bridge at Evenwood, W. Va.
C05	385342079512439	Chenoweth Creek at Highway 23 Bridge at Elkins Airport, W. Va.
C11	385346080065239	Right Fork at Highway 28/1 Bridge near Kedron, W. Va.
D02	385603080294039	West Fork River at Highway 19 Bridge at Roanoke, W. Va.
C08	385605079570039	Roaring Creek at Highway 21/1 Bridge at Norton, W. Va.
D03	385633080252339	Skin Creek at Highway 30/12 Bridge near Vandalia, W. Va.
C07	385646079512439	Leading Creek at Highway 219 Bridge at Elkins, W. Va.
C18	385750080091039	Sand Run near Buckhannon, W. Va.
F06	385835079293639	Red Creek at Highway 32 Bridge at Dry Fork, W. Va.
D04	385925080283239	Skin Creek at Highway 30/3 Bridge near Brownsville, W. Va.
C17	385946080142139	Fink Run at Highway 119 Bridge at Buckhannon, W. Va.
D05	390010080283539	West Fork River at Brownsville, W. Va.
C19	390020080083539	Sand Run at Highway 3/2 Bridge near Mouth, W. Va.
C06	390134079491139	Leading Creek at Highway 3 Bridge near Kerns, W. Va.
D06	390210080265639	Stonecoal Creek at Highway 119 Bridge at Weston, W. Va.
F07	390212079264239	Blackwater River at Highway 32 Bridge at Canaan Valley State Park

Appendix 1 Surface-water stations.

Site Number	Station Number	Site Name
D07	390253080283839	Polk Creek at Highway 33 Bridge at Weston, W. Va.
C20	390334080091839	Pecks Run at Highway 1/13 Bridge at Teter, W. Va.
D10	390520080232239	Hackers Creek at Highway 14 Bridge near Jane Lew, W. Va.
D08	390627080294039	Freemans Creek at Bridge at Valley Chapel, W. Va.
C21	390723080023139	Little Laurel Run at Highway 30 Bridge South Philippi, W. Va.
F09	390820079304039	North Fork Blackwater River at Highway 27 Bridge at Coketon, W. Va.
F12	390853079424839	Clover Run at Highway 21 Bridge at St. George, W. Va.
D09	390855080295539	Kinchfloe Creek at Bridge near Valley Chapel, W. Va.
F08	390856079261839	Beaver Creek at Highway 93 Bridge near Davis, W. Va.
C22	390900080022539	Tygart Valley River at Philippi, W. Va.
D12	390947080154239	Gnatty Creek at Highway 20/20 Bridge at Romines Mills, W. Va.
F11	391000079421039	Minear Run at Highway 5 Bridge at St. George, W. Va.
D11	391000080220739	Lost Creek at Highway 27/2 Bridge at Lost Creek, W. Va.
D13	391023080140539	Elk Creek at Highway 57/2 Bridge near Romines Mills, W. Va.
C23	391100079583139	Laurel Creek at Highway 24 Bridge near Arden, W. Va.
F10	391108079354239	Horseshoe Run at Highway 9 Bridge at Lead Mine, W. Va.
C24	391212079545339	Teier Creek at Highway 92 Bridge near Nestorville, W. Va.
D14	391353080172039	Brushy Fork at Highway 42 Bridge near Stonewood, W. Va.
D15	391605080094739	Simpson Creek at Highway 13/13 Bridge at Rosemont, W. Va.
D17	391632080292039	Tenmile Cr at Highway 31 Bridge at Maken, W. Va.
F13	391719079421639	Buffalo Creek at Highway 72/3 Bridge near Rowlesburg, W. Va.
C25	391722079543439	Sandy Creek at Highway 1 Bridge at Claude, W. Va.

Appendix 1 Surface-water stations.

Site Number	Station Number	Site Name
H01	391752079293039	Maple Run at Highway 24/1 Bridge near Eglon, W. Va.
D18	391817080291539	Salem Creek at Highway 5/9 Bridge near Maken, W. Va.
D16	391842080170139	Simpson Creek at Highway 24/1 Bridge near Bridgeport, W. Va.
H02	391952079303339	Rhine Creek at Highway 108 Bridge at Brookside, W. Va.
C26	391958079520739	Little Sandy Creek at Highway 92/14 Bridge at Evansville, W. Va.
C28	392041079563739	Three Fork Creek at Highway 50 Bridge at Thornton, W. Va.
F14	392105079394839	Saltlick Creek at RR Bridge at Rowlesburg, W. Va.
D23	392149080123139	Thomas Fork at Highway 73/73 Bridge at Santiago, W. Va.
D19	392203080243739	Little Tenmile Creek at Highway 20 Bridge at Rosebud, W. Va.
D22	392212080120339	Corbin Branch at Highway 1/1 Bridge at Santiago, W. Va.
H03	392258079293139	Laurel Run at Highway 94/2 Bridge at Turner Douglas, W. Va.
D24	392335080114839	Hustead Fork at Highway 3/16 Bridge at Boothsville, W. Va.
D21	392457080192939	Bingamon Creek at Highway 8 Bridge at Pine Bluff, W. Va.
D20	392520080164039	West Fork River at Enterprise, W. Va.
C29	392615080075539	Tygart Valley River at Colfax, W. Va.
C27	392617079505539	Three Fork Creek at Highway 33 Bridge near Gladesville, W. Va.
E06	392947080054139	Pricketts Creek at Highway 73 Bridge at Meadowdale, W. Va.
E03	393014080102139	Buffalo Creek at Barrackville, W. Va.
F16	393052079384239	Muddy Creek at Highway 26/23 Bridge at Ruthbelle, W. Va.
E09	393059079483739	Deckers Creek at Highway 27 Bridge at Reedsville, W. Va.
E01	393114080232039	Buffalo Creek at Highway 1/10 Bridge at Deep Valley, W. Va.
E08	393250080023439	Whiteday Creek at Highway 36 Bridge near Smithtown, W. Va.
E04	393308080100339	Paw Paw Creek at Highway 17 Bridge at Grant Town, W. Va.

Appendix 1 Surface-water stations.

Site Number	Station Number	Site Name
E02	393320080212239	Pyles Fork at Highway 250/5 Bridge near Metz, W. Va.
E07	393408080045039	Indian Creek at Highway 45/2 Bridge at Osgood, W. Va.
E05	393423080091339	Little Paw Paw Creek at Highway 25 Bridge at Hoodsville, W. Va.
F15	393518079355639	Muddy Creek at Highway 3 Bridge near Cuzzart, W. Va.
F20	393736079355839	Beaver Creek at Highway 3/4 Bridge near Brandonville, W. Va.
F19	393838079361239	Little Sandy Creek at Highway 3/4 Bridge near Brandonville, W. Va.
F21	393903079432039	Laurel Run at Highway 73/73 Bridge near Laurel Run, W. Va.
F18	394036079373539	Glade Run at Highway 8 Bridge at Brandonville, W. Va.
F17	394149079370839	Big Sandy Creek at Highway 4 Bridge at Clifton Mills, W. Va.
G01	394208080180239	West Virginia Fork at Highway 7 Bridge at Wanna, W. Va.
G02	394212080152739	Miracle Run at Highway 7 Bridge at Bula, W. Va.
G03	394227080065739	Dolls Run at Highway 7 Bridge near Core, W. Va.

Appendix 2 Numbers of Taxonomic Benthic-Invertebrate and Water-Quality Data.

Site Number	Station Number	Station Name	Trichoptera caddisfly	Epemeroptera mayfly	Decapoda crayfish	Plecoptera stonefly	Diptera flies midges mosquitoes	Megaloptera alderflies dobsonflies fishflies	Pelecypoda clams	Coleoptera beetles	Basomatophora snails	Odonata dragonflies damselflies	Amphipoda scud	Collembola spring tails	Lepidoptera aquatic caterpillars	Unknown order Hirudinea leeches	Unknown order Tubellaria flatworms	Hemiptera bugs	Oligochaeta Aquatic earthworms	Benthic invertebrates	pH	SO_4 Dissolved mg/L	Fe Total µg/L	Fe Dissolved µg/L	Conductivity µmhos
35	03071920	Meadow Run at Davistown, Pa.	1	2	0	0	2	2	0	1	0	0	0	0	0	0	0	1	0	0	8.0	56	2.9k	50	480
38	03072594	Mountain Run at Ruble Mills, Pa.	13	4	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	8.0	28	600	40	160
40	03072760	Browns Run at Ronco, Pa.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7.8	360	1.7k	30	960
42	03072815	Tenmile Creek near Amity, Pa.	4	4	0	1	2	0	0	2	0	0	0	2	1	0	0	1	0	0	7.7	39	660	30	420
43	03072820	Daniels Run near Marianna, Pa.	11	0	0	0	4	2	0	0	0	0	1	0	0	0	0	0	0	0	8.3	1.1k	260	60	3.5k
49	03074500	Redstone Creek at Waltersburg, Pa.	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	6.8	800	35k	22k	1.7k
50	03075035	N. Br. Pigeon Creek at Bentlyville, Pa.	17	1	0	0	5	0	0	0	0	0	1	0	0	0	0	0	0	0	7.9	190	1.7k	30	770
52	03075058	Mingo Creek at River View, Pa.	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	8.1	870	330	0	1.0k
54	03075084	Piney Fork at Snowden, Pa.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7.8	290	490	20	1.2k
74	03078200	Tub Mill Run at West Salisbury, Pa.	1	2	1	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6.9	24	5.2k	40	108
76	03078648	Flaugherty Creek at Meyersdale, Pa.	6	7	0	4	1	1	0	0	0	0	0	0	0	0	0	0	0	0	7.2	13	440	160	100
77	03078710	Blue Lick Creek near Meyersdale, Pa.	2	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7.1	230	1.8k	90	600
78	03078720	Tubs Run at Beachdale, Pa.	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5.5	88	360	110	279
79	03078785	E. Br. Coxes Creek near Somerset, Pa.	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	7.0	350	23k	20k	450
80	03078900	Middle Creek near Cassleman, Pa.	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	7.6	17	560	60	160
82	03079300	Whites Creek at Hornedsville, Pa.	3	1	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	7.2	22	550	30	140
84	03080000	Laurel Hill Creek at Ursina, Pa.	1	1	2	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7.0	11	390	60	81
86	03081650	Meadow Run near Farmington, Pa.	4	2	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7.3	11	490	30	190
89	03082598	Mounts Creek at Moyer, Pa.	4	0	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	7.9	50	1.6k	50	272
90	03082837	Indian Creek at White Bridge, Pa.	0	1	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6.8	39	700	30	178
92	03083045	Jacobs Creek near Dawson, Pa.	9	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	7.3	80	1.3k	50	342
93	03083095	Barren Run near Smithton, Pa.	8	2	0	0	3	9	0	5	0	0	0	0	0	0	0	0	0	C	7.8	36	370	50	273
95	03083150	Sewickley Creek near Youngwood, Pa.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6.8	480	25k	10k	1.1k
96	03083260	L. Sewickley Creek at Cowansburg, Pa.	1	1	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	8.1	270	1.7k	70	980
99	03083805	Long Run at Versailles, Pa.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7.9	180	2.1k	0	840
102	03084800	Thompson Run at Turtle Creek	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8.5	58	1.7k	0	1.0k
103	03084900	Brush Creek at Westmoreland City, Pa.	0	0	0	0	0	0	0	0	1	0	0	0	0	2	1	0	0	0	8.3	71	570	40	600
69	03077925	N. Br. Casselman R. nr. Grantsville, Md.	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	P	7.4	19	740	200	98
70	03077945	S. Br. Casselman R. at Jennings, Md.	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	P	7.6	33	470	100	138
72	03077975	Big Shade Run at Grantville, Md.	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	P	7.2	25	670	40	117
56	03075250	Youghiogheny R. at U.S. 219 nr. Redhouse, Md.	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	P	7.2	7.4	1.6k	490	72
57	03075340	Youghiogheny R. at Underwood Rd. nr. Crellin, Md.	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	P	7.3	7.0	940	210	75
58	03075350	Cherry Creek near Crellin, Md.	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	P	7.0	6.9	2k	240	100
60	03075495	L. Youghiogheny R. at 3rd Str. at Oakland, Md.	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	P	7.2	11	1.9k	500	125
65	03076010	Deep Creek Lake Outflow, Md.	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	P	6.8	8.7	680	170	40
63	03075700	Muddy Creek at Swallow Falls State Park, Md.	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	P	6.5	7.4	590	230	35
64	03075900	Cherry Creek near McHenry, Md.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	A	4.0	98	1.1k	470	280
68	03076600	Bear Creek at Friendsville, Md.	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	P	7.3	9.6	310	30	115
75	03078500	Big Piney Run near Salisbury, Pa.	0	0	0	0	0	P	0	0	0	0	0	0	0	0	0	0	0	0	7.3	10	820	250	97
C01	383309080021539	Tygart Vly R at Hwy 15 Br at Valley Head, WV	P	P	P	0	0	0	0	0	P	0	0	0	0	0	0	0	0	0	8.3	5.3	70	0	115
C02	383936079585339	Becky C at Hwy 56 Br nr Huttonsville, WV	0	P	P	0	P	0	0	0	P	0	0	0	0	0	0	0	0	0	8.2	5.5	60	10	75
C03	384401079584939	Mill C at Hwy 46 Br at Mill Creek, WV	0	P	0	0	0	0	0	0	0	P	0	0	0	0	0	0	P	0	6.8	3.1	120	40	10
C04	385015079523339	Files C at Hwy 219 Br at Beverly, WV	0	P	P	0	P	0	0	0	0	0	0	0	0	0	0	0	0	0	7.0	5.8	110	40	45
C05	385342079512439	Chenoweth C at Hwy 23 Br at Elkins Airport, WV	0	P	P	0	0	0	0	0	0	0	0	0	0	P	0	0	0	0	7.6	9.8	170	70	75
C06	390134079491139	Leading C at Hwy 3 Br nr Kerns, WV	0	P	P	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7.1	6.4	890	190	35
C07	385646079512439	Leading C at Hwy 219 Br at Elkins, WV	0	0	P	0	0	0	0	0	P	0	0	0	0	0	0	0	0	0	6.8	7.0	850	130	40
C08	385605079570039	Roaring C at Hwy 21/1 Br at Norton, WV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.6	74	1.4k	950	255
C09	384905080024139	Middle Fk R at Hwy 35 Br at Cassity, WV	0	P	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7.3	6.7	110	30	5
C10	384933080020639	Cassity Fk at Hwy 35 Br at Cassity, WV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.9	150	1.1k	370	375
C11	385346080065239	Right Fk at Hwy 28/1 Br nr Kedron, WV	0	P	P	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6.8	5.4	320	80	50
C12	384440080140939	R F Buckhannon R at Hwy 48 Br at Newlonton, WV	P	P	0	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5.5	6.1	260	100	<50
C13	384352080084839	L F R F Buckhannon R at Hwy 46 Br at Czar, WV	P	P	0	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6.4	6.2	280	50	<50
C14	384517080093039	L F Buckahnnon R at Hwy 9 Br at Palace Vly, WV	P	P	0	P	0	0	P	0	0	0	0	0	0	0	0	0	0	0	6.4	8.5	170	30	<50
C15	385232080155239	Laurel Fk at Hwy 20/10 Br nr Adrian, WV	0	P	P	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7.1	5.6	450	140	60
C16	385307080175339	French C at Hwy 20 Br at French Creek, WV	0	P	P	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7.2	5.7	1.2k	210	100
C17	385946080142139	Fink Run at Hwy 119 Br at Buckhannon, WV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6.4	110	980	440	325
C18	385750080091039	Sand Run nr Buckhannon, WV	0	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6.8	54	280	40	195
C19	390020080083539	Sand Run at Hwy 3/2 Br nr Mouth, WV	0	P	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7.1	36	230	40	145
C20	390334080091839	Pecks Run at Hwy 1/13 Br at Teter, WV	0	P	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7.4	240	500	10	585
C21	390723080023139	L Laurel Run at Hwy 30 Br South Philippi, WV	0	P	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7.1	6.2	1.2k	230	80
C22	390900080022539	Tygart Valley R at Philippi, WV	0	0	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7.1	23	350	70	115
C23	391100079583139	Laurel C at Hwy 24 Br nr Arden, WV	0	P	0	0	0	P	0	0	0	0	0	0	0	0	0	0	0	0	7.2	16	500	180	100
C24	391212079545339	Teter C at Hwy 92 Br nr Nestorville, WV	0	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7.6	8.7	230	90	85
C25	391722079543439	Sandy C at Hwy 1 Br at Claude, WV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.6	63	710	550	195
C26	391958079520739	L Sandy Cr at Hwy 92/14 Br at Evansville, WV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.1	160	5.9k	5.3k	510
C27	392617079505539	Three Fk C at Hwy 33 Br nr Gladesville, WV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.7	200	2.9k	2.4k	510
C28	392041079563739	Three Fk C at Hwy 50 Br at Thornton, WV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.8	150	370	250	400
C29	392615080075539	Tygart Valley R at Colfax, WV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6.2	23	690	90	100
D01	385207080272939	West Fk R at Hwy 44 Br at Walkersville, WV	0	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7.2	9.3	970	210	130
D02	385603080294039	West Fk R at Hwy 19 Br at Roanoke, WV	0	P	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6.7	32	800	170	165
D03	385633080252339	Skin C at Hwy 30/12 Br nr Vandalia, WV	0	P	P	0	0	0	P	0	0	0	0	0	0	0	0	0	0	0	6.9	9.3	1.2k	160	395
D04	385925080283239	Skin C at Hwy 30/3 Br nr Brownsville, WV	0	P	P	0	0	0	P	0	0	0	0	0	0	0	0	0	0	0	7.3	44	640	100	200
D05	390010080283539	West Fk R at Brownsville, WV	0	P	P	0	0	0	P	0	0	0	0	0	0	0	0	0	0	0	6.6	32	800	130	165
D06	390210080265639	Stonecoal Cr at Hwy 119 Br at Weston, WV	0	0	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6.4	33	1.0k	210	165
D07	390253080283839	Polk C at Hwy 33 Br at Weston, WV	0	P	P	0	0	0	P	0	0	0	0	0	0	0	0	0	0	0	7.6	65	1.2k	260	285
D08	390627080294039	Freemans C at Br at Valley Chapel, WV	0	0	P	0	0	0	P	0	0	0	0	0	0	0	0	0	0	0	7.8	80	830	80	325
D09	390855080295539	Kinchfloe C at Br nr Valley Chapel, WV	0	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7.6	12	630	190	160
D10	390520080232239	Hackers C at Hwy 14 Br nr Jane Lew, WV	0	P	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7.8	130	800	30	400
D11	391000080220739	Lost C at Hwy 27/2 Br at Lost Creek, WV	0	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7.2	77	1.2k	50	345
D12	390947080154239	Gnatty C at Hwy 20/20 Br at Romines Mills, WV	0	P	P	0	0	0	P	0	0	0	0	0	0	0	0	0	0	0	7.6	340	760	40	840
D13	391023080140539	Elk C at Hwy 57/2 Br nr Romines Mills, WV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7.4	610	940	40	1.3k

Appendix 2 Numbers of Taxonomic Benthic-Invertebrate and Water-Quality Data.

Site Number	Station Number	Station Name	Trichop-tera caddisfly	Epemer-optera mayfly	Decapoda crayfish	Plecop-tera stonefly	Diptera flies midges mosquitoes	Megaloptera alderflies dobsonflies fishflies	Pelecy-poda clams	Coleop-tera beetles	Basomat-ophora snails	Odonata dragonflies damselflies	Amphi-poda scud	Collem-bola spring tails	Lepidop-tera aquatic caterpillars	Unknown order Hirudinea leeches	Unknown order Tubellaria flatworms	Hemip-tera bugs	Oligo-chaeta Aquatic earthworms	Benthic inverte-brates	pH	SO_4 Dissolved mg/L	Fe Total µg/L	Fe Dissolved µg/L	Conduc-tivity µmhos
D14	391353080172039	Brushy Fk at Hwy 42 Br nr Stonewood, WV	0	P	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7.6	360	420	20	820
D15	391605080094739	Simpson C at Hwy 13/13 Br at Rosemont, WV	0	0	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6.0	580	6.1k	2.1k	1.2k
D16	391842080170139	Simpson C at Hwy 24/1 Br nr Bridgeport, WV	0	0	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7.4	430	530	20	900
D17	391632080292039	Tenmile Cr at Hwy 31 Br at Maken, WV	0	0	P	P	0	0	0	0	0	0	0	0	0	0	0	0	P	0	7.8	28	870	100	240
D18	391817080291539	Salem C at Hwy 5/9 Br nr Maken, WV	0	P	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7.6	19	670	60	240
D19	392203080243739	L Tenmile C at Hwy 20 Br at Rosebud, WV	0	0	P	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7.0	400	4.9k	2.3k	810
D20	392520080164039	West Fr R at Enterprise, WV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6.4	220	2.2k	230	545
D21	392457080192939	Bingamon C at Hwy 8 Br at Pine Bluff, WV	0	0	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7.4	490	1.1k	40	1.0k
D22	392212080120339	Corbin Branch at Hwy 1/1 Br at Santiago, WV	0	P	P	P	0	0	P	0	0	0	0	0	0	0	0	0	0	0	7.6	17	630	130	180
D23	392149080123139	Thomas Fk at Hwy 73/73 Br at Santiago, WV	0	P	P	P	P	0	0	0	0	0	0	0	0	0	0	0	0	0	6.9	97	670	50	440
D24	392335080114839	Hustead Fk at Hwy 3/16 Br at Boothsville, WV	0	P	P	P	0	0	P	0	0	0	0	0	0	0	0	0	0	0	7.9	28	380	90	170
E01	393114080232039	Buffalo C at Hwy 1/10 Br at Deep Valley, WV	0	P	P	0	0	0	0	0	0	0	0	0	0	0	0	0	P	0	7.2	23	700	190	170
E02	393320080212239	Pyles Fk at Hwy 250/5 Br nr Metz, WV	0	P	0	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7.3	18	970	210	185
E03	393014080102139	Buffalo C at Barrackville, WV	0	0	P	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8.2	180	400	60	580
E04	393308080100339	Paw Paw C at Hwy 17 Br at Grant Town, WV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7.9	220	1.0k	20	720
E05	393423080091339	L Paw Paw C at Hwy 25 Br at Hoodsville, WV	0	0	P	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7.5	52	540	70	360
E06	392947080054139	Prickets C at Hwy 73 Br at Meadowdale, WV	0	P	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9.5	200	2.9k	2.4k	510
E07	393408080045039	Indian C at Hwy 45/2 Br at Osgood, WV	0	0	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7.4	1.3k	460	40	2.1k
E08	393250080023439	Whiteday C at Hwy 36 Br nr Smithtown, WV	0	P	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7.9	14	210	70	100
E09	393059079483739	Deckers C at Hwy 27 Br at Reedsville, WV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5.0	160	850	300	370
F01	383702079521339	Shavers Fk at Hwy 250 Br at Cheat Bridge, WV	0	P	P	P	0	0	0	0	0	0	0	0	0	P	0	0	0	0	6.8	5.3	370	80	10
F02	384827079441639	Shavers Fk at Bemis, WV	0	P	P	0	0	P	0	0	0	0	0	0	0	0	0	0	0	0	7.3	5.6	190	90	50
F03	385333079384039	Glady Fk at Hwy 33 Br at Evenwood, WV	0	P	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6.8	3.6	280	140	25
F04	385303079355839	Laurel Fk at Hwy 33 Br at Wymer, WV	0	P	P	0	0	0	0	0	P	0	0	0	0	0	0	0	0	0	7.1	4.4	350	150	65
F05	385152079332839	Dry Fk D/S Stinking Run at Job, WV	0	P	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7.6	5.2	200	60	50
F06	385835079293639	Red C at Hwy 32 Br at Dry Fork, WV	0	P	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6.7	6.3-	130	30	25
F07	390212079264239	Blackwater R at Hwy 32 Br at Canaan Vly St Pk	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6.9	5.3	910	280	50
F08	390856079261839	Beaver C at Hwy 93 Br nr Davis, WV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.7	100	2.7k	2.4k	290
F09	390820079304039	N Fk Blackwater R at Hwy 27 Br at Coketon, WV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.7	120	2.1k	140	290
F10	391108079354239	Horseshoe Run at Hwy 9 Br at Lead Mine, WV	0	P	P	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6.6	5.7	100	30	980
F11	391000079421039	Minear Run at Hwy 5 Br at St. George, WV	0	P	P	0	P	0	0	0	0	0	0	0	0	0	0	0	0	0	6.4	5.9	90	20	20
F12	390853079424839	Clover Run at Hwy 21 Br at St. George, WV	0	P	P	0	0	0	0	0	P	P	0	0	0	0	0	0	0	0	6.5	6.1	90	10	25
F13	391719079421639	Buffalo C at Hwy 72/3 Br nr Rowlesburg, WV	0	P	P	P	0	0	0	0	P	P	0	0	0	0	0	0	0	0	7.0	6.1	120	20	70
F14	392105079394839	Saltlick C at RR Br at Rowlesburg, WV	0	0	P	0	0	0	0	0	P	0	0	0	0	0	0	0	0	0	7.5	13	150	60	105
F15	393518079355639	Muddy C at Hwy 3 Br nr Cuzzart, WV	0	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5.4	37	640	60	115
F16	393052079384239	Muddy C at Hwy 26/23 Br at Ruthbelle, WV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.0	270	14k	7.2k	680
F17	394149079370839	Big Sandy C at Hwy 4 Br at Clifton Mills, WV	0	P	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5.8	12	450	160	60
F18	394036079373539	Glade Run at Hwy 8 Br at Brandonville, WV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6.4	140	170	40	345
F19	393838079361239	L Sandy C at Hwy 3/4 Br nr Brandonville, WV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5.6	63	320	150	185
F20	393736079355839	Beaver C at Hwy 3/4 Br nr Brandonville, WV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.2	56	410	120	165
F21	393903079432039	Laurel Run at Hwy 73/73 Br nr Laurel Run, WV	0	P	P	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7.0	13	120	30	60
G01	394208080180239	West Virginia Fk at Hwy 7 Br at Wanna, WV	P	P	0	P	P	P	0	0	0	P	0	0	0	0	0	0	0	0	7.0	22	460	170	215
G02	394212080152739	Miracle Run at Hwy 7 Br at Bula, WV	P	P	0	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7.5	75	520	50	370
G03	394227080065739	Dolls Run at Hwy 7 Br nr Core, WV	P	P	P	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7.8	1.0k	270	40	2.4k
H01	391752079293039	Maple Run at Hwy 24/1 Br nr Eglon, WV	0	P	P	0	P	0	P	0	0	0	0	0	0	0	0	0	0	0	6.7	5.1	1.1k	310	75
H02	391952079303339	Rhine C at Hwy 108 Br at Brookside, WV	0	P	P	0	P	0	0	0	0	0	0	0	0	0	0	0	0	0	6.0	5.9	460	170	70
H03	392258079293139	Laurel Run at Hwy 94/2 Br at Turner Douglas, WV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.2	49	800	700	160

[1]Where value is 0, the taxon was not found.
Where value is NI, no attempt was made to identify taxon.
Where value is P, taxon was present but not enumerated.
Where value is A, no taxa were found.
K take values times 1000

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