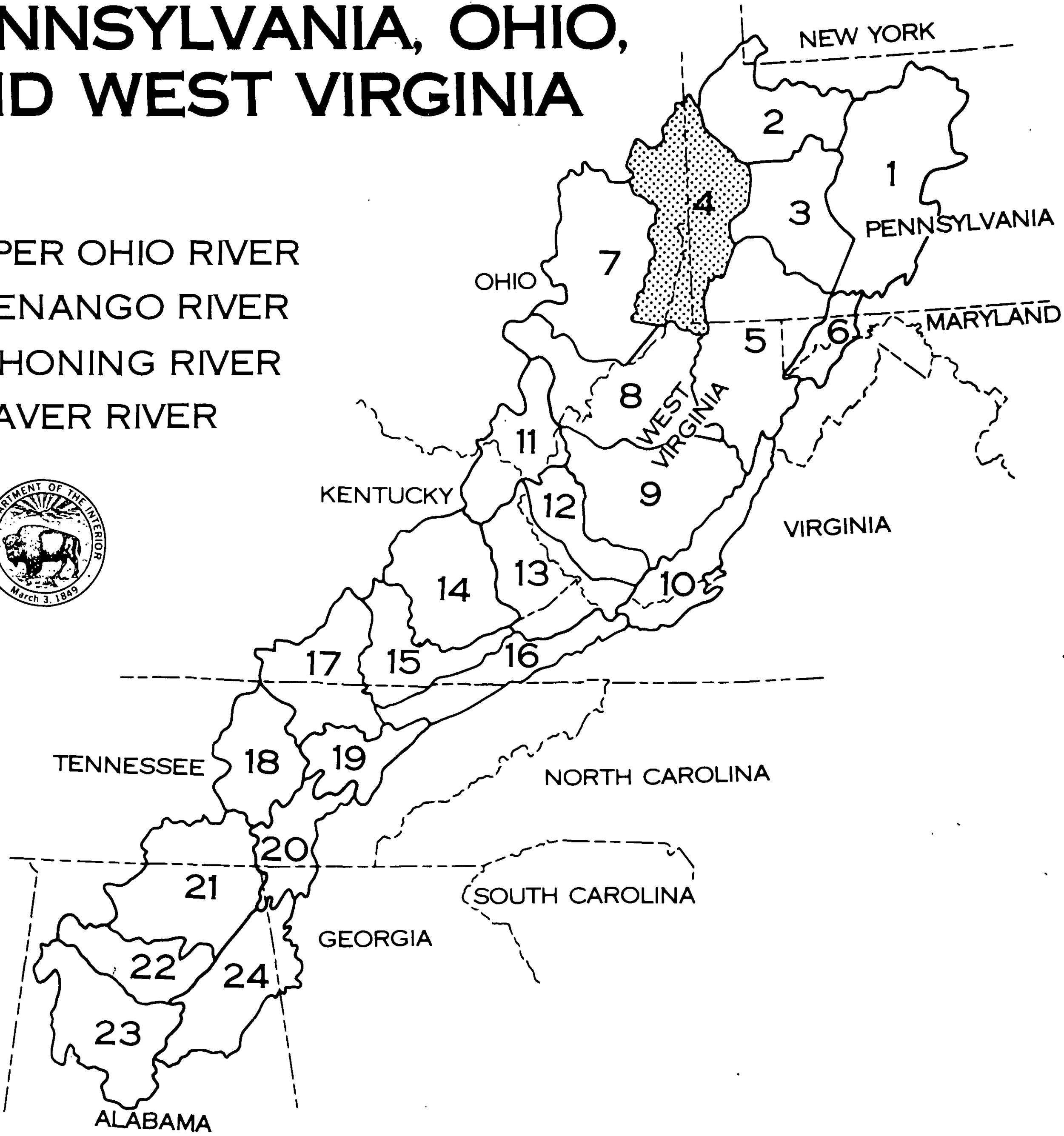
HYDROLOGY OF AREA 4, EASTERN COAL PROVINCE, PENNSYLVANIA, OHIO, AND WEST VIRGINIA

- UPPER OHIO RIVER
- SHENANGO RIVER
- MAHONING RIVER
- BEAVER RIVER



UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

WATER-RESOURCES INVESTIGATIONS
OPEN-FILE REPORT 81-343

HYDROLOGY OF AREA 4, EASTERN COAL PROVINCE, PENNSYLVANIA, OHIO, AND WEST VIRGINIA

BY
DONALD K. ROTH, MORRIS J. ENGELKE, JR., AND OTHERS

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COLUMBUS, OHIO
JULY 1981

UNITED STATES DEPARTMENT OF THE INTERIOR

JAMES G. WATT, *SECRETARY*

GEOLOGICAL SURVEY

Doyle G. Frederick, *Acting Director*

For additional information write to:
U.S. Geological Survey
975 West Third Avenue
Columbus, OH 43212

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)
feet (ft)	0.3048	meters (m)
feet per mile (ft/mi)	0.1894	meters per kilometer (m/km)
miles	1.609	kilometers (km)
square miles (mi^2)	2.590	square kilometers (km^2)
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 ton per square kilometer per year [(metric ton/km^2)/yr]

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ABSTRACT

Area 4, one of the 24 hydrologic areas defining the Eastern Coal Province, is located at the northern end of the Eastern Coal Province in eastern Ohio, northern West Virginia, and western Pennsylvania. It is part of the upper Ohio River basin, which includes the Beaver, Mahoning, and Shenango Rivers, and is underlain by rocks of the Pottsville, Allegheny, Conemaugh, Monongahela Groups (or Formations), and Dunkard Groups.

The land has been deeply dissected by erosion, but many of the narrow, steep-sided ridges have broad, gentle crests underlain by flat lying, resistant formations.

Area 4 has a temperate climate with an annual average rainfall of from 38 to 42 inches, with most of the area covered by forest. The soils have a high erosion potential when the vegetation cover is removed.

In response to Public Law 95-87, 132 sites were added to the existing surface-water data-collection network in Area 4. At these added sites, data collected included discharge, water quality, sediment, and biology. The data is available from computer storage through the National Water Data Exchange (NAWDEX) of the published annual Water Resources Data reports for Ohio, Pennsylvania, and West Virginia.

Hydrologic problems related to mining are: (1) Erosion and increased sedimentation, and (2) degradation of water quality.

Erosion and sedimentation are surface mining problems. Sediment yields increase drastically when vegetation is removed from the highly erosive soils.

Degradation of water quality can result from drainage of underground and surface mines. The major part of all acid mine drainage into streams in Area 4 comes from underground mines. The rest seeps from abandoned surface mines. Usually with reclaimed surface mines the overburden is replaced in such a short time after the coal is taken out, that oxidation of acid-forming minerals, commonly pyrite or marcasite, is not complete or is neutralized by the buffering action of calcareous minerals in the soils. The acid water from mines usually decreases in acidity downstream from its source because it is neutralized by the buffering action of calcareous minerals. Dissolved-iron concentrations are high near the source of drainage but also decrease rapidly downstream due to dilution and aeration. Sulfate usually is the highest dissolved constituent in water from mined areas and is highest at low flow.

1.0 INTRODUCTION

1.1 OBJECTIVE

Area 4 Report Submitted in Support of Public Law 95-87

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

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

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

In recognizing the potentially adverse impact that coal mining may have on water resources, Public Law 95-87 requires (1) that each mining-permit applicant make an analysis of the potential effects of the proposed mine on the hydrology of the mine site and adjacent area, (2) that "an appropriate Federal or State agency" provide to each mining-permit applicant "hydrologic information on the general area prior to mining," and (3) that measures be taken by mining permittees to control adverse effects of mining on the "hydrologic balance" and reclamation of the land.

This report broadly characterizes the hydrology of Area 4 in Ohio, Pennsylvania, and West Virginia as delineated in Figure 1.1-1. The hydrologic information presented or available through sources identified in this report, may be used in describing the hydrology of the "general area" of any proposed mine. Furthermore, it is expected that this hydrologic information will be supplemented by the lease applicant's specific site data as well as data from other sources to provide a more detailed picture of the hydrology of the area in the vicinity of the mine and the anticipated hydrologic consequences of the mining operation.

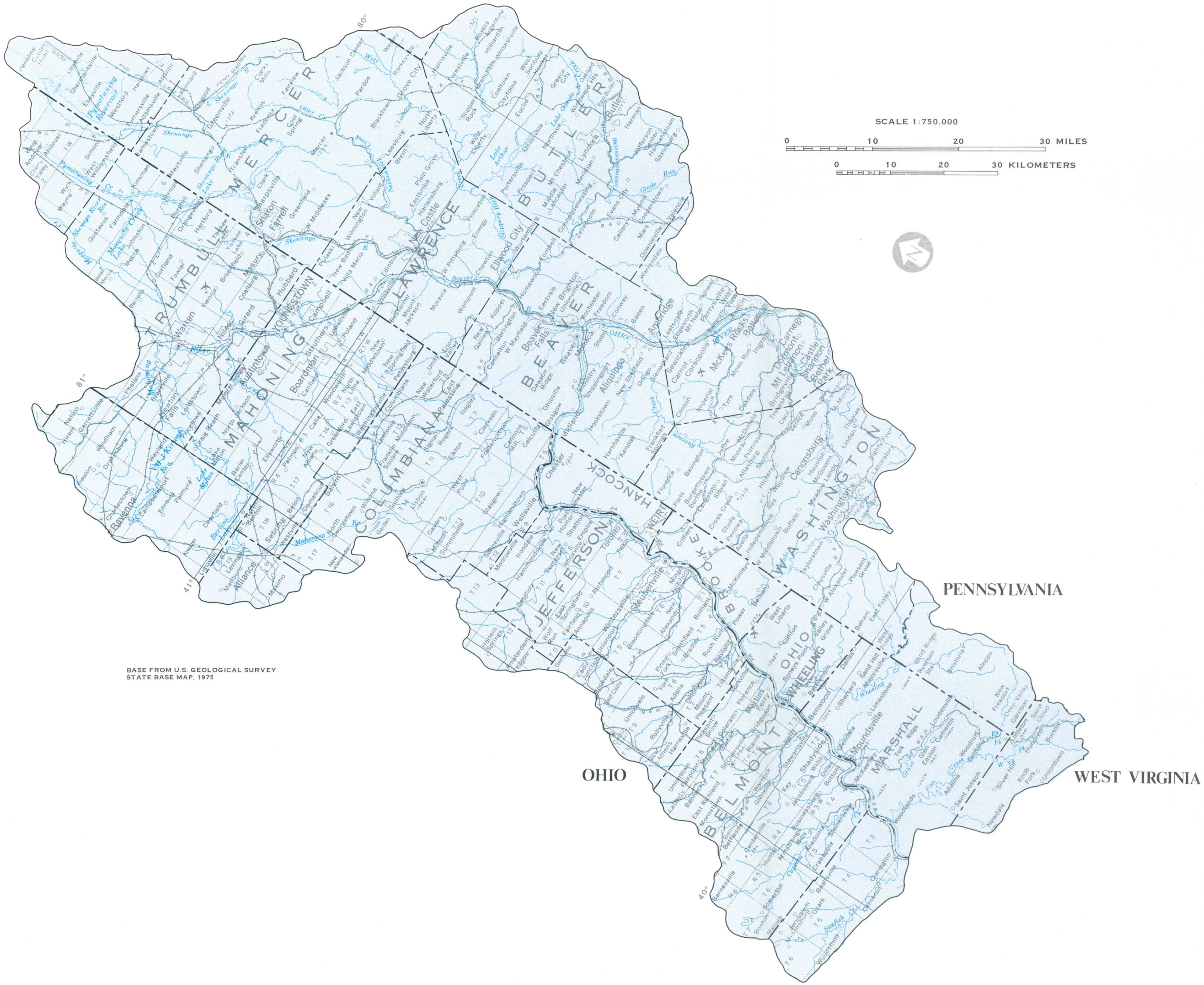


Figure 1.1-1 Outline of Area 4

Hydrology and Water Resources for Area 4

This report describes the hydrology and water resources of Area 4 in the upper end of the Northern Appalachian Coal Field in Ohio, West Virginia, and Pennsylvania.

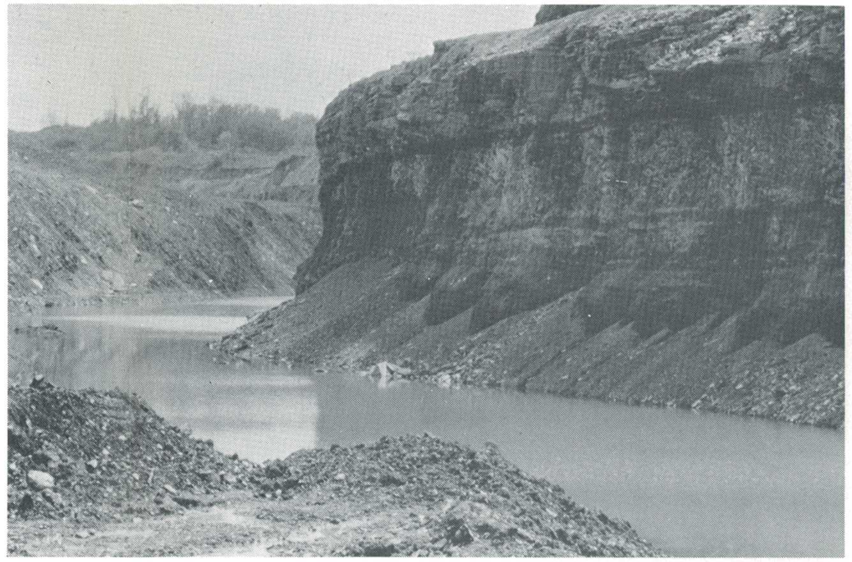
The Eastern Coal province is divided into 24 hydrologic reporting areas. Figure 1.2-1 shows the location of Area 4 in the northern end of the Eastern Coal Province in eastern Ohio, northern West Virginia, and western Pennsylvania, in the Appalachian Plateaus physiographic province. The area is drained by streams of the upper Ohio River basin, the main tributaries being the Mahoning, Beaver, and Shenango Rivers. The terrane is mainly rolling hills.

Area 4 contains 6,709 square miles and includes parts or all of 36 counties in Ohio, 4 counties in West Virginia, and 8 counties in Pennsylvania.

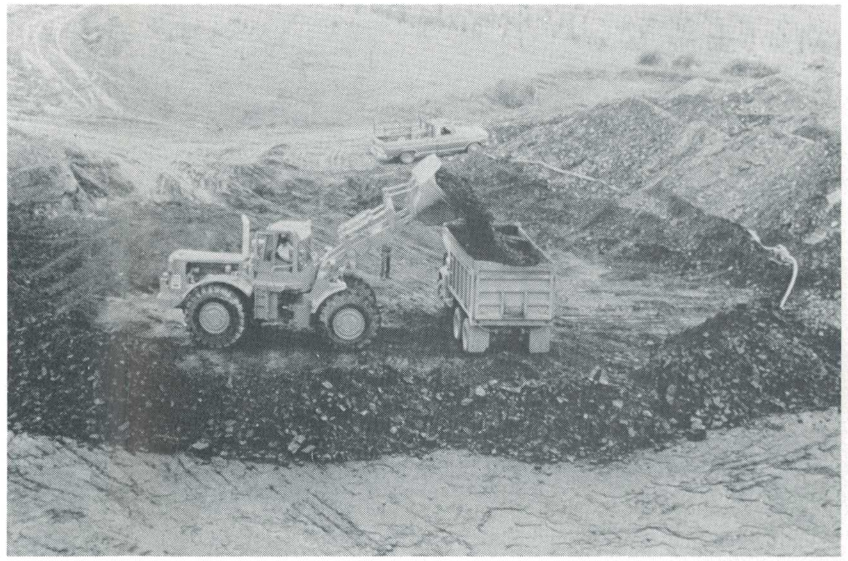
The climate is temperate with an average temperature of 22°F (-5.6°C) in the winter and 72°F (22.2°C) in the summer. The average annual precipitation is about 40 inches.

Population is concentrated in cities along the major streams. Mining in Area 4 includes strip mining and underground mining, as shown in examples in figure 1.2-2.

Figure 1.2-1 Location of Area 4 in the Eastern Coal Province.



A. Abandoned mine in Moxahala Creek Basin.



B. Area strip mining in Ohio.

C. Air shaft with fan and drive wheel at abandoned underground mine in Moxahala Creek Basin.

Figure 1.2-2 Types of mining in Area 4.

Hydrologic Environment Can be Adversely Altered by Surface Coal Mining

Erosion, sedimentation, and degradation of water-quality are problems associated with surface mining.

Sediment can be eroded from strip mine surfaces at rates many times greater than for sediment eroded from similar undisturbed land (Ohio Board on Unreclaimed Strip Mined Land, 1974). The sediment from stripped area mines chokes receiving streams, reduces channel size and water-carrying capacity and increases flood potential. Sediment also disrupts the ecosystem of streams by smothering and choking bottom life and destroying vital components of the aquatic food chain (Ohio Division of Water, 1977).

Physical and chemical characteristics of the spoil also have major effects on the vegetation of strip mined lands. Without adequate treatment spoils may render a strip mine surface temporarily sterile. The toxic materials may be sufficiently leached over a period of time to permit only sparse vegetative growth, provided erosion does not continually expose unleached materials. Steep spoil slopes have a detrimental effect on revegetation because of severe erosion and slope instability.

About one quarter of the acid mine drainage into streams in Appalachia originates from strip mines (Ohio Board on Unreclaimed Strip Mine Lands, 1974). Surface runoff frequently accumulates in the pits of unreclaimed contour strip mines. The hydrolosis products of the pyritic material in the spoil and bench material accumulate in the ponded water. Eventually this water seeps through the spoil and flows into streams as acidic ground-water inflows.

Extensive erosion and increased sediment in streams. Pyrite oxidation can also occur on the exposed surface of strip mine soil and coal refuse piles. Surface water runoff washes oxidized chemicals into streams. Figure 1.3-1 has photographs of erosion and of sediment and acid mine seepage from abandoned surface mines.

A. Sediment from abandoned strip mine in eastern Ohio.

B. Erosion in abandoned strip mine in eastern Ohio.

C. Mine drainage from abandoned strip mine, headwaters of Moxahala, Ohio.

Figure 1.3-1 Sedimentation, erosion, and acid-mine seepage from abandoned strip mines.

Hydrologic Environment Can be Adversely Altered by Underground Coal Mining

Acid mine drainage is the major problem in areas of abandoned underground mines.

Three quarters of the acid mine drainage produced in Appalachia originate in underground mines (Ohio Environmental Protection Agency, 1979). The most common problem from abandoned underground mines is pollution of the streams by the addition of acidity, hardness, iron, sulfates, aluminum, manganese, and other dissolved and suspended solids. Coal and associated rocks contain sulfur compounds including iron disulfide (pyrite). When exposed to the air by mining acitivities, the iron disulfide oxidizes to form sulfuric acid and iron sulfate, which are eventually flushed from the mines into the streams. The iron oxidizes and a red-yellow precipitate called "yellow boy" results. Photographs of mine drainage from underground coal mines are shown in figure 1.4-1.

A. Drainage from abandoned underground mine in western Pennsylvania

B. Tributary of Short Creek near Dillonvale, Ohio. Note underground mine at top of photograph.

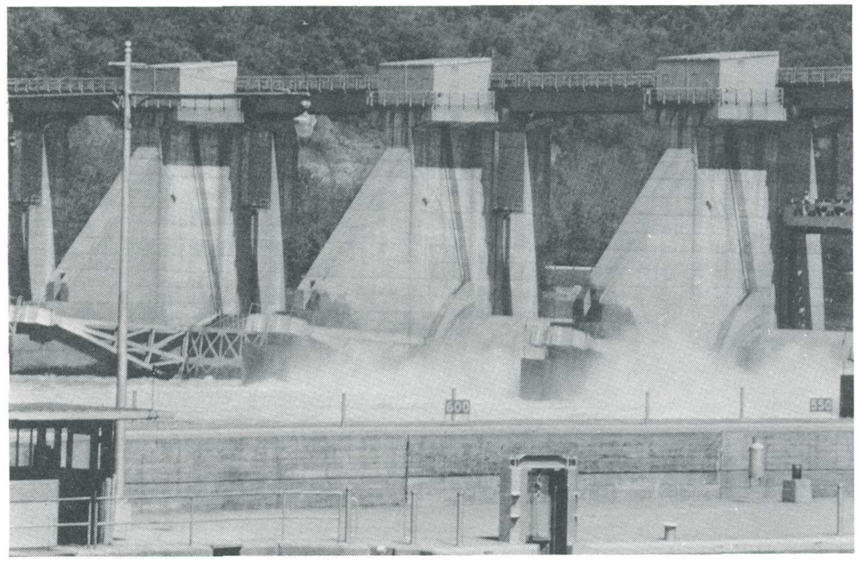
Figure 1.4–1 Mine drainage from abandoned underground mines.

Economy Based on Coal Production

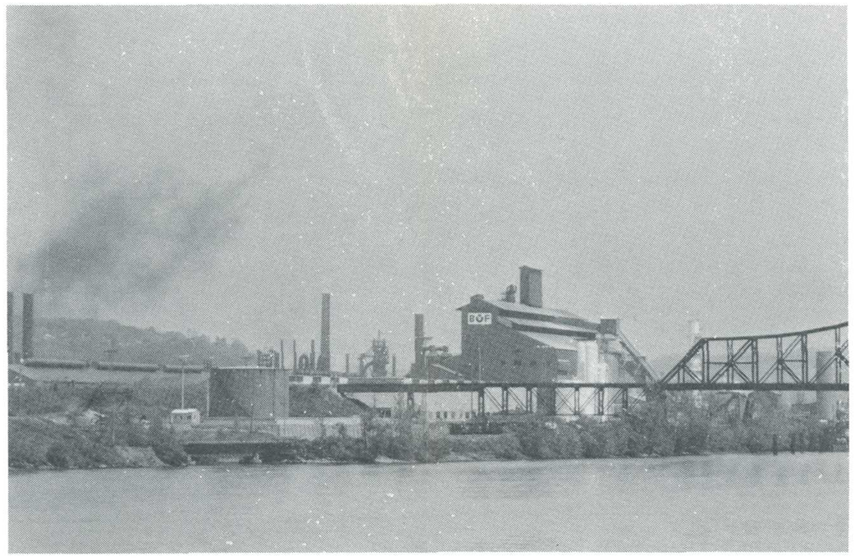
Coal is the Upper Ohio River basin's most important mineral resource.

In the early 1920's, the U.S. Army Corps of Engineers began construction of several locks along the upper Ohio River to improve boat transportation and barging. Today much of the industrial complexes along the river are coal related. Photographs (figure 1.5-1) illustrate a few of these developments. Coal is transported by trucks and conveyors to the loading facilities along the river. Barges move the coal to the steel mills, coal burning electric power plants, and other industrial and municipal facilities. Limestone which is crushed (rock dust) and used to reduce the explosive potential of coal dust in underground mining is barged to unloading docks and stockpiled.

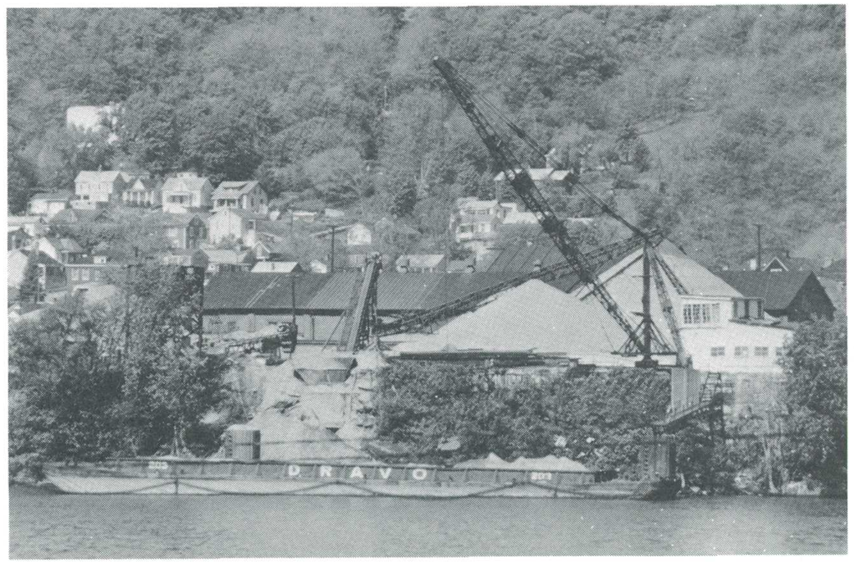
(Figure 1.5-2) illustrates coal production in Ohio from 1875 to 1979. Although the graph applies only to Ohio, the general trend of coal production during this period is thought to be similar throughout Area 4. The consumption of goods and services in the upper Ohio River basin is affected by the increase or decrease of the workforce earnings from strip and underground mining operations (Samuelson, 1958).



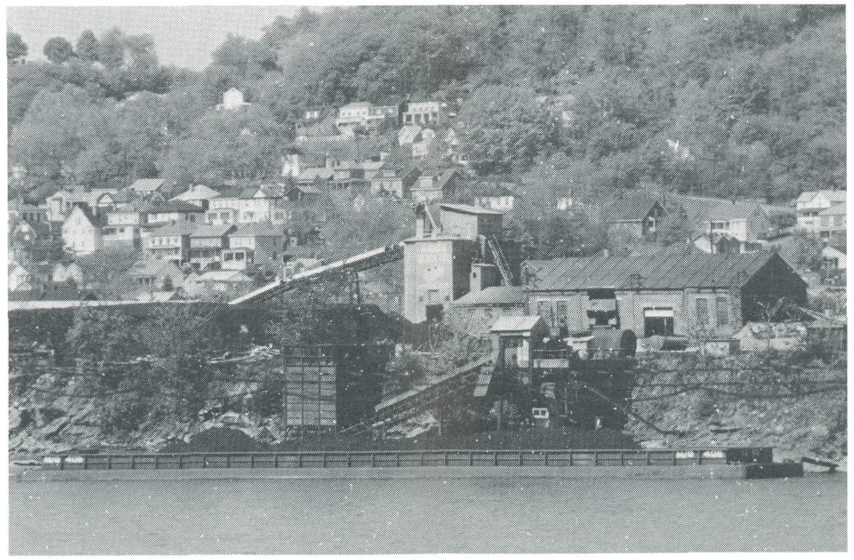
A. Long Island Lock near Wheeling, West Virginia.



B. Steel mill at Steubenville, Ohio.



C. Unloading limestone at storage facilities near Steubenville, Ohio.



D. Loading coal onto barge near Steubenville, Ohio, for journey to steel mill.

Figure 1.5-1 Coal related industries.

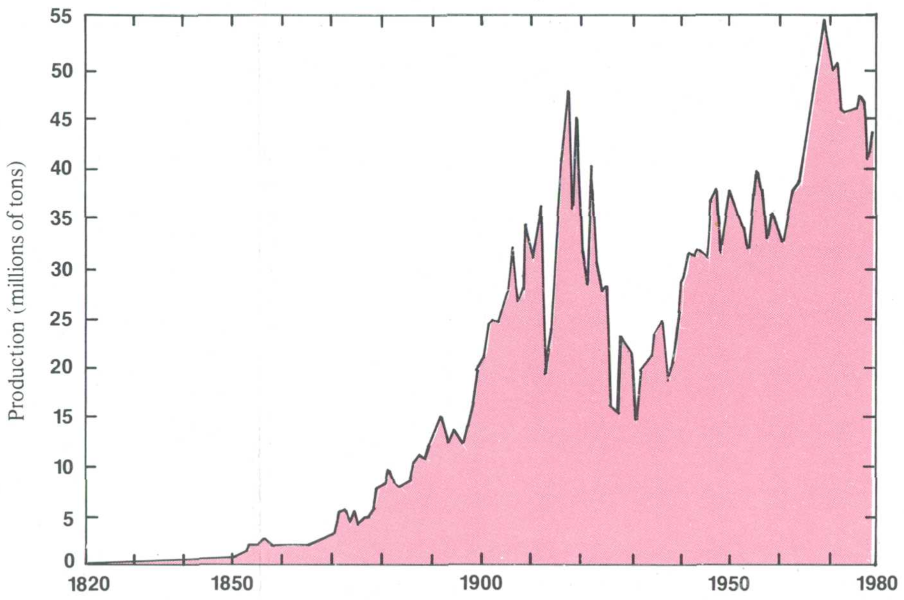


Figure 1.5-2 Coal production in Ohio, 1820–1979

Seven Major Rock Units Are Exposed in Area 4

The strata exposed in Area 4 can be subdivided into seven units within four systems, which are: The Ohio Shale of the Devonian System; undifferentiated rocks of the Mississippian System; the Pottsville, Allegheny, Conemaugh, and Monongahala Groups (or Formations) of the Pennsylvanian System; and the Dunkard Group of the Pennsylvanian and Permian Systems.

The Ohio Shale is a black carbonaceous shale that outcrops in the northern part of Area 4. The Ohio Shale represents the oldest strata in Area 4 and is more than 1,500 feet thick in northeastern Ohio. The Ohio Shale has a gentle southerly dip and is barren of coal (Lamborn, 1938). Because of its small areal distribution in Area 4, the Ohio Shale has been omitted from figure 2.1-1.

Mississippian strata crop out in the northern part of Area 4 and consist of sandstone and shale. These strata also have a gentle southerly dip and are barren of coal deposits.

The Pennsylvanian System consists of the Pottsville, Allegheny, Conemaugh, and Monogahela Groups (or Formations) which unconformably overlie the Mississippian strata. The Pennsylvanian rocks consist of sandstone, shale, bituminous coal, and limestone, which crop out in the central part of Area 4 in east-west trending belts and have a gentle southeasterly dip. The major coal deposits in Area 4 are shown in figure 2.1-2.

The youngest rocks in Area 4, with the exception of those of the Pleistocene and Holocene Epochs, comprise the Dunkard Group of the Permian System (Lamborn, 1938). Only two minor coal seams, the Waynesburg and Washington coals are found in the Permian strata. Each seam averages about 2 feet in thickness and neither is economically important at this time.

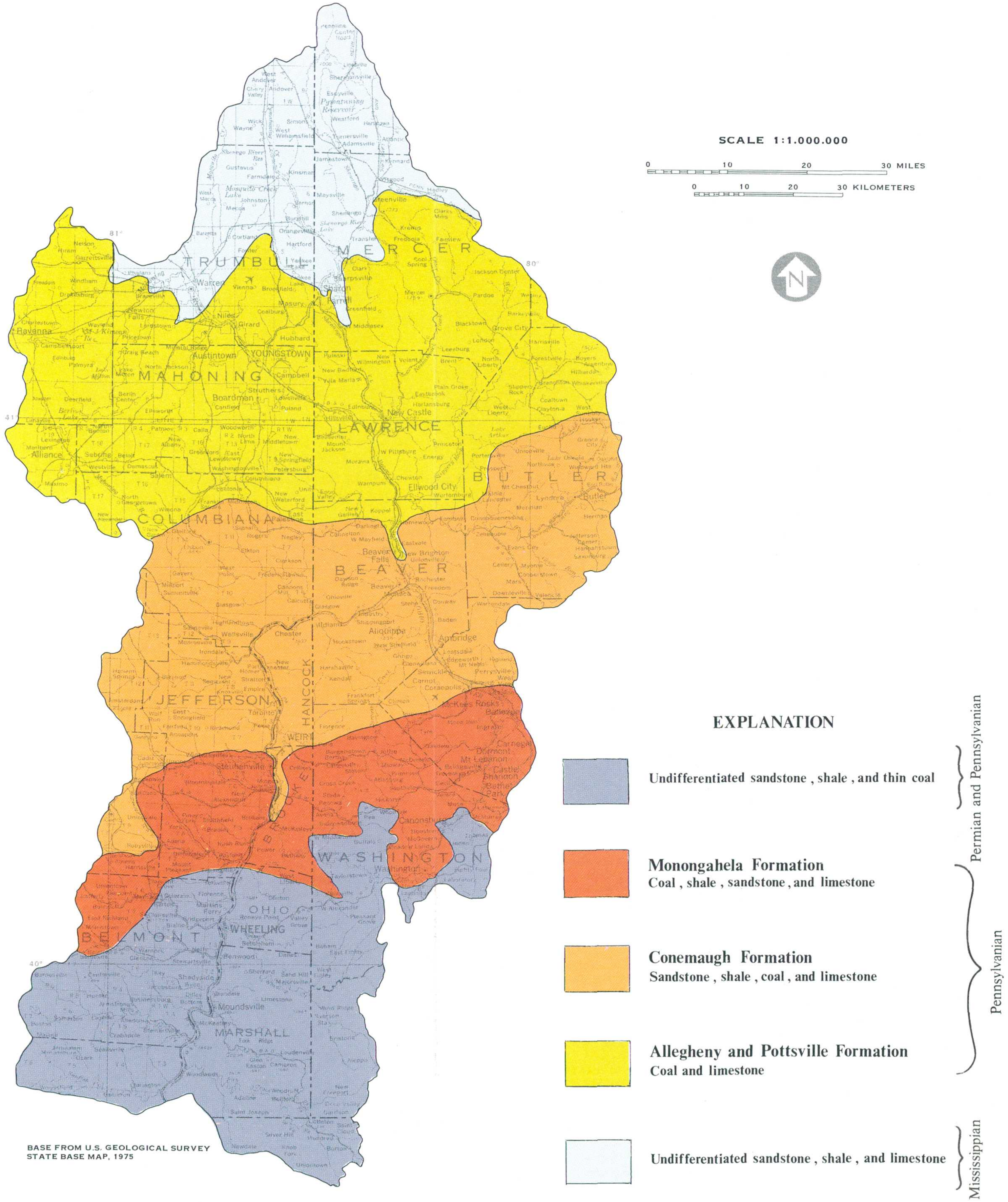


Figure 2.1-1 Generalized geology of study area (Bownocker, 1929, Piper, 1933, and Leggett, 1936).

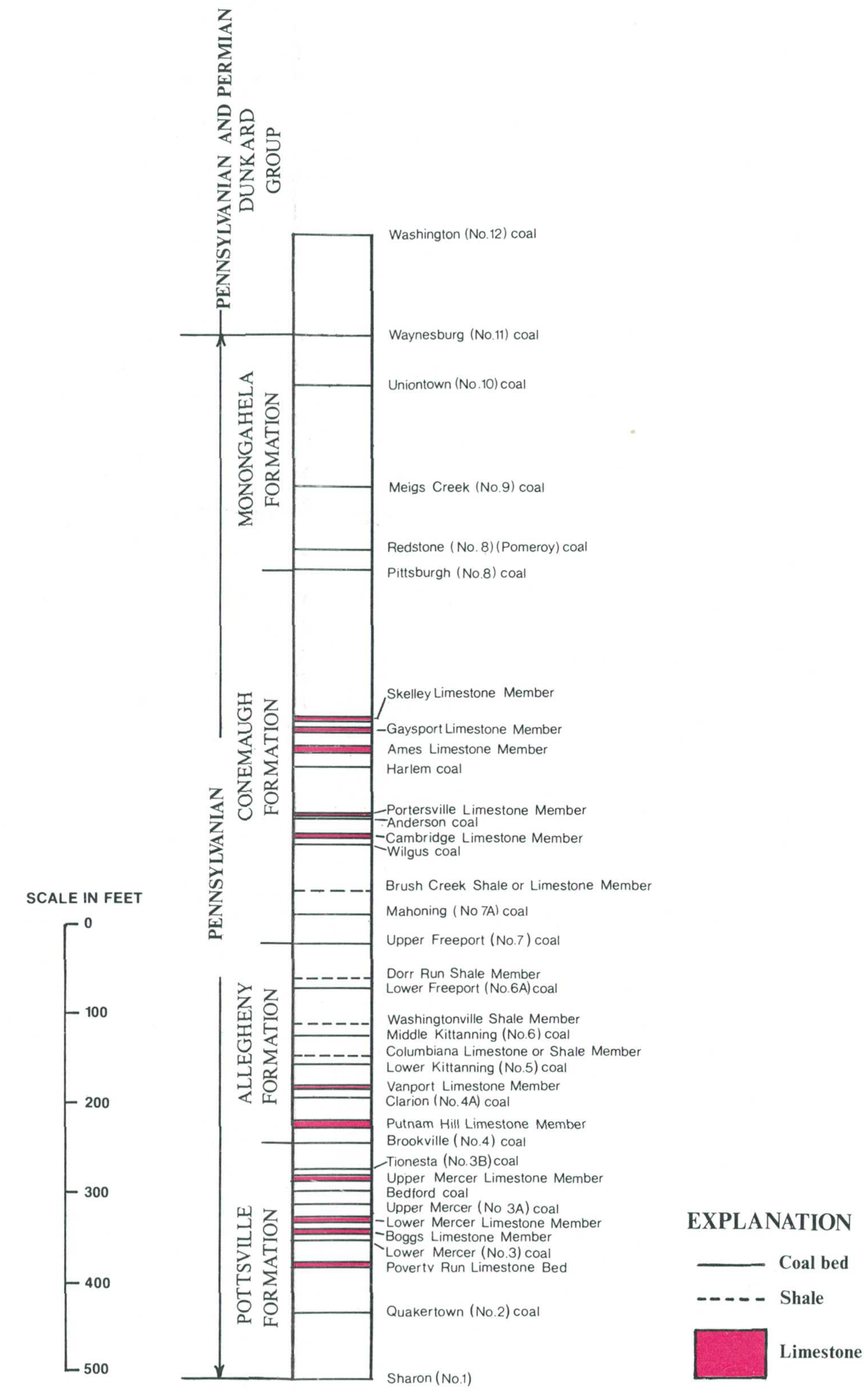


Figure 2.1-2 Coal beds in Ohio (modified from Collins, 1978).

Area 4 Defined By Two Physiographic Regions

Area 4 includes parts of the unglaciated Allegheny Plateau and the glaciated Allegheny Plateau.

The boundary between the glaciated and unglaciated plateaus extends east-west from Lawrence County, Pennsylvania to Columbiana County, Ohio, bisecting Area 4. (See figure 2.2-1.)

The surface of the unglaciated Allegheny Plateau rises slightly to the east, from an altitude of 1,200 feet in eastern Ohio to 1,400 feet in southwestern Pennsylvania. Local relief is 200 to 300 feet. Smooth, rolling hills comprise the surface topography, with the majority of slopes steeper below than above, and with moderately sloping land between the valleys (Fenneman, 1938).

In the glaciated Allegheny Plateau altitudes range from 1,200 to 1,300 feet and relief decreases with altitude. The topography, except for a sag in the northern part of Area 4, which is less than 900 feet in altitude, changes from steep, forested hills in the east to rolling farmlands in the west. The surface is smooth, low, and covered extensively by glacial deposits (Fenneman, 1938).

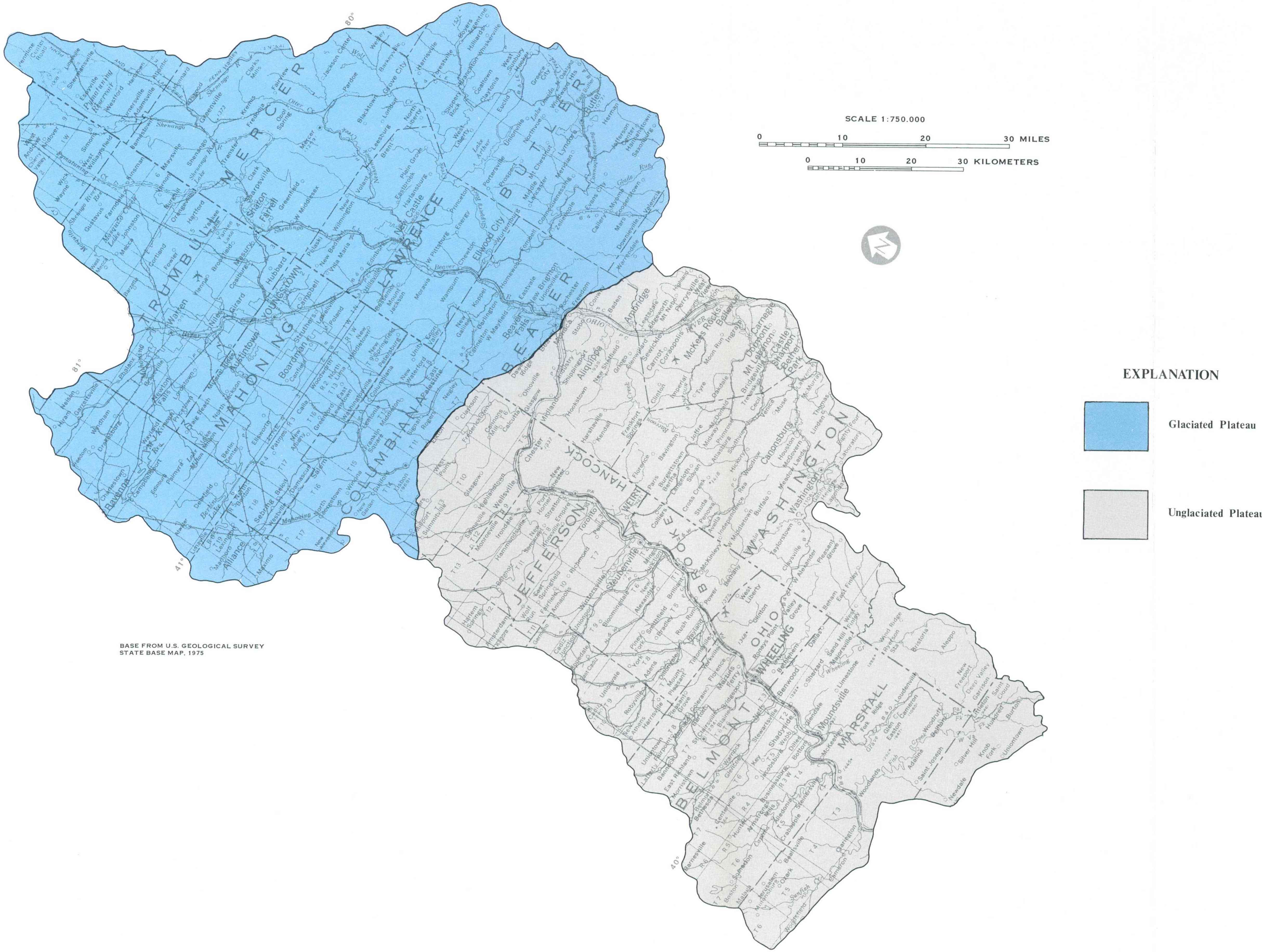


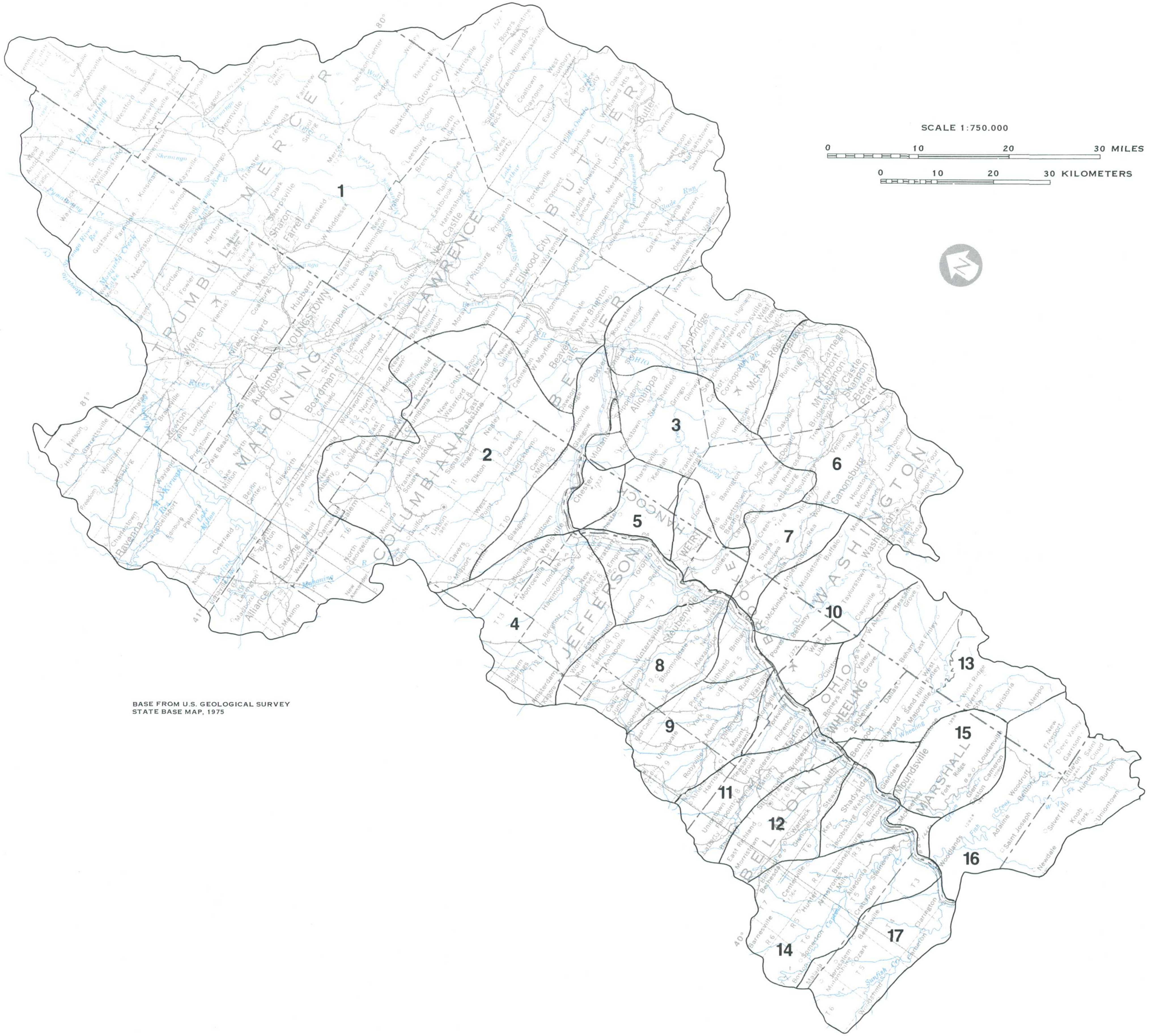
Figure 2.2-1 Land forms in Area 4.

Upper Ohio River Basin Drains Area

Area 4 is drained by Beaver River and smaller tributaries of the Ohio River.

Beaver River drains almost half of the 6,709 square miles of Area 4. Major streams tributary to Beaver River are the Mahoning River (Ohio), Shenango River (Ohio and Pennsylvania), Neshannock River (Pennsylvania), and Connoquenessing Creek (Pennsylvania).

Figure 2.3-1 shows the drainage areas of the streams. The largest drainage basins are those of Beaver River and Little Beaver Creek in the northern part of Area 4. Some of the larger Ohio River tributaries are Raccoon Creek, Little Beaver Creek, Wheeling Creek, and Fish Creek. Drainage areas for specific sites are given in Appendix 1 and Appendix 2.



EXPLANATION

1 Beaver River
2 Little Beaver Creek
3 Raccoon Creek
4 Yellow Creek
5 Harmon Creek
6 Chartiers Creek
7 Cross Creek (West Virginia)
8 Cross Creek (Ohio)
9 Short Creek
10 Buffalo Creek
11 Wheeling Creek (Ohio)
12 McMahon Creek
13 Wheeling Creek (West Virginia)
14 Captina Creek
15 Grove Creek
16 Fish Creek
17 Sunfish Creek

Figure 2.3-1 Major drainage basins in Area 4.

Most of Area 4 is Covered by Forest

Sixty percent of Area 4 is forested; 24 percent is agricultural land; 11 percent is surface mining areas; and 3 percent is urban.

The land use maps (figure 2.4-1) show land use areas, from the publication "Land Reborn," Ohio Board on Unreclaimed Strip Mined Land, (1974), and U.S. Geological Survey (1977), "Land Use and Land Cover Series." For additional information on land use and land cover refer to Ohio Department of Natural Resources, Division of Water Miscellaneous Report 20, 1977.

Most surface mining is in the west-central part of Area 4. Forests cover, generally, all but the low-relief agricultural land.

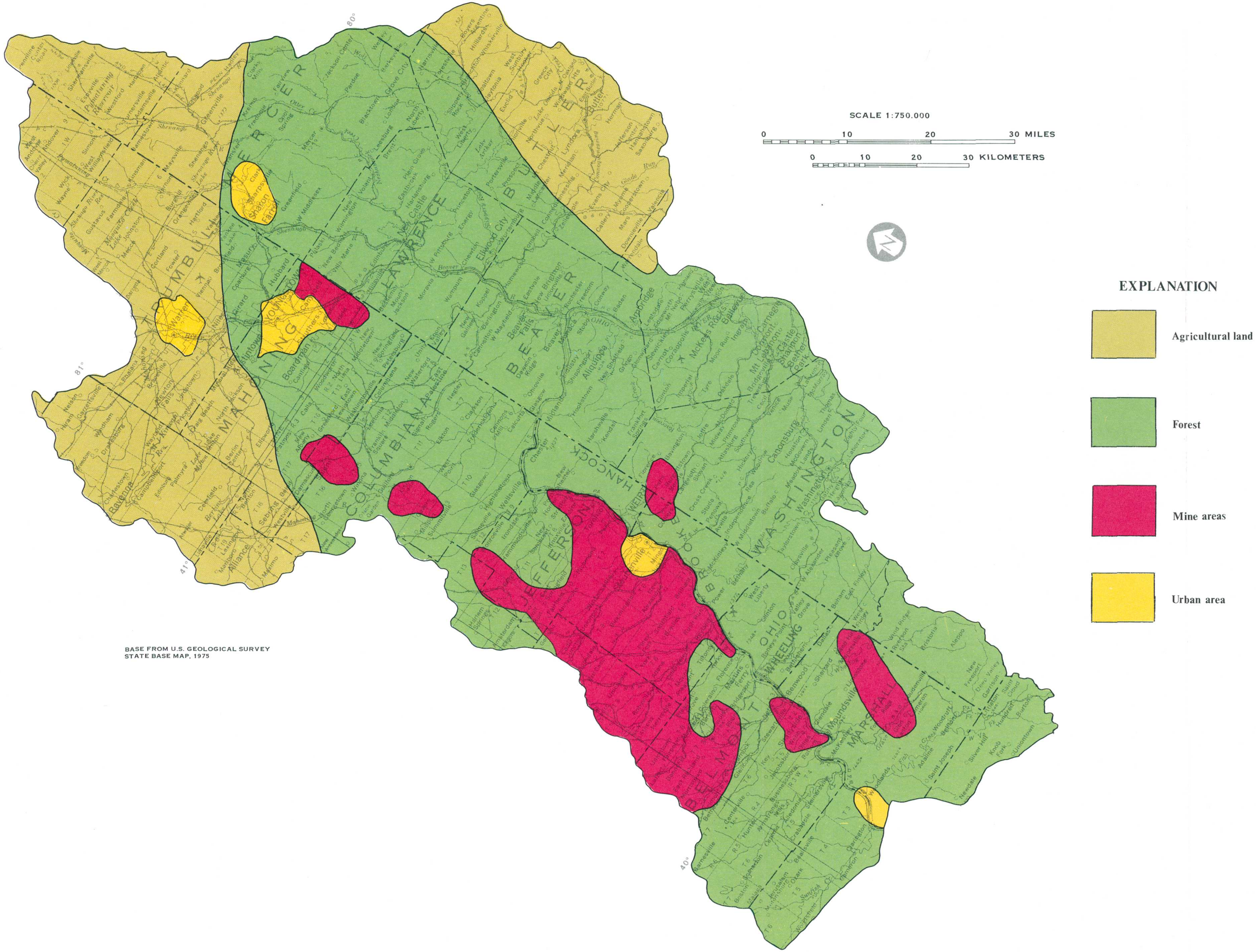


Figure 2.4-1 Area 4 land-use.

2.0 GENERAL FEATURES (Continued)

2.4 LAND USE

Soils in Area 4 Are Acidic and Subject to Erosion

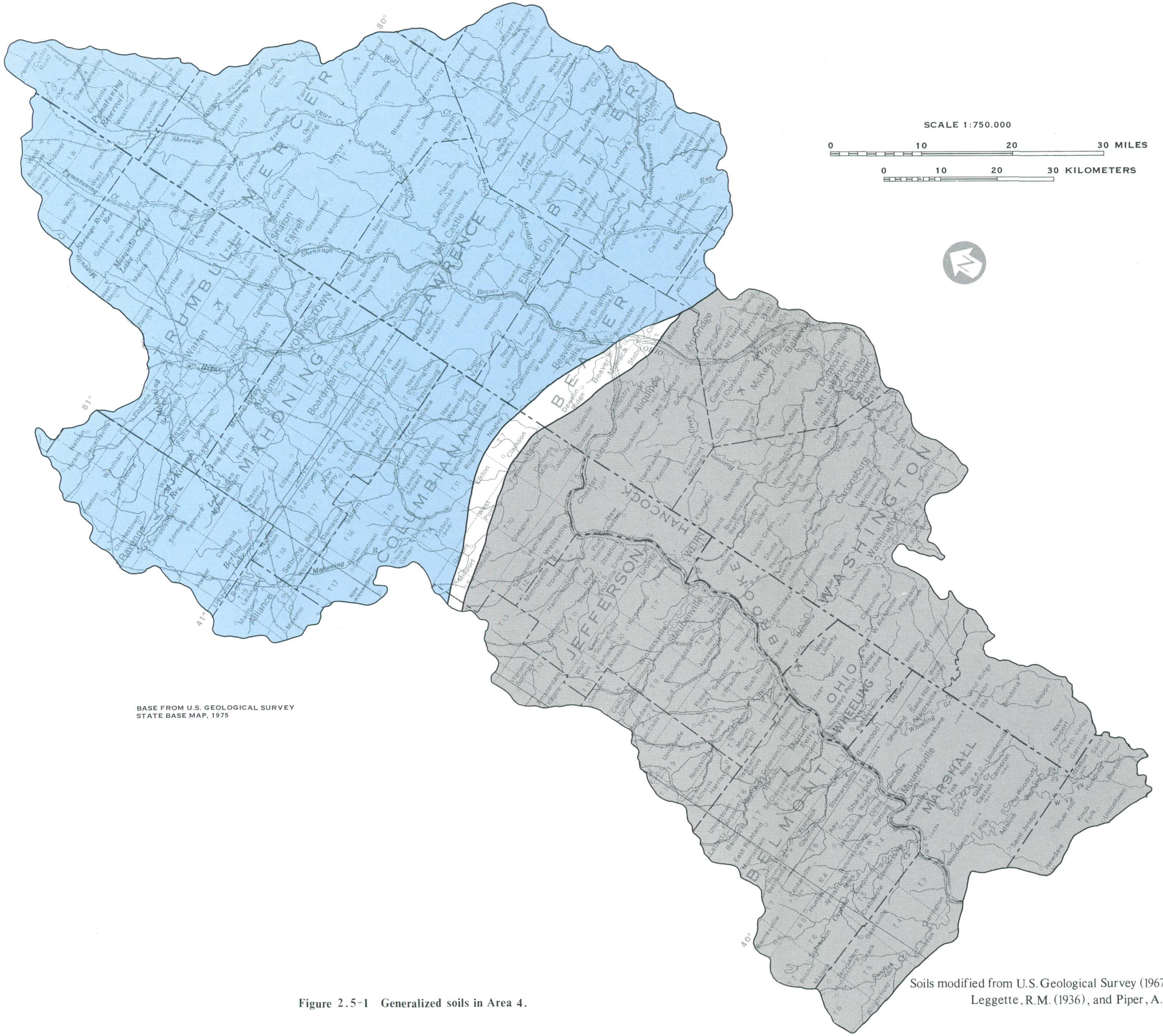
Soils are characterized by moderately high acidity, low organic matter and fertility, and high erosion potential.

Area 4 is glaciated in the northern half and unglaciated in the southern half. Figure 2.5-1 shows the basic soil types. A more detailed description of soils in Area 4 is given by county soils maps of the Ohio Department of Natural Resources, Division of Lands and Soils; West Virginia Geological and Economic Survey; and Pennsylvania Department of Environmental Resources.

Soils developed on low-lime glacial drift of Wisconsin age are characterized by low fertility and moderate to high acidity, with a pH range of 4.5 to 6.5. These soils are derived from sandstone, shale, and small amounts of limestone (usually found near the flood plains). When vegetation is removed, erosion becomes a problem due to the steep terrane and shallow soils. Agriculture in this region includes general farming and dairy farming.

Soils developed in glacial drift of Illinoian age are of medium low fertility, highly erosive, and strongly acidic with a pH range of 5.1 to 5.5. These soils include those of the Hanover-Muskingum-Alford Association, which are well drained and steep, susceptible to erosion when vegetation is removed.

Soils developed on sandstone and shale are the major soil types in the southern or unglaciated part of Area 4. Shallow acidic soils with a pH range of 4.5 to 5.0 and steep terrane, make most of this area poor for cultivation. About 50 percent of the sandstone and shale soils are forested. Erosion is a common problem when vegetation is stripped from the steep slopes. Soils of this zone include Westmore-Guernsey, Upshur-Gilpin-Dekalb and Upshur-Gilpin-Woodsfield.



SCALE 1:750,000

0 10 20 30 MILES

0 10 20 30 KILOMETERS

EXPLANATION

Soil Materials

- Drift of Wisconsin Glaciation
- Drift of Illinoian Glaciation
- Non-glaciated sandstone and shale
- Southern limit of glaciation

BASE FROM U.S. GEOLOGICAL SURVEY STATE BASE MAP, 1975

Soils modified from U.S. Geological Survey (1967), Landers, R.A. (1976), Leggette, R.M. (1936), and Piper, A.M. (1933)

Figure 2.5-1 Generalized soils in Area 4.

Area 4 Characterized by a Continental Climate

Annual precipitation in Area 4 ranges from 38 to 42 inches.

Precipitation is fairly evenly distributed throughout the year, but slightly more occurs during the warm, summer months when thunderstorms are more frequent. There are, on the average, 120 days per year of measurable precipitation.

Mean annual precipitation is shown by the isohyetal map figure 2.6-1 (period 1941-70). Additional information on precipitation and climate can be obtained from the U. S. Weather Bureau or National Oceanic and Atmospheric Administration.

Figure 2.6-2 shows monthly maximum, minimum and average precipitation for Youngstown, Ohio.

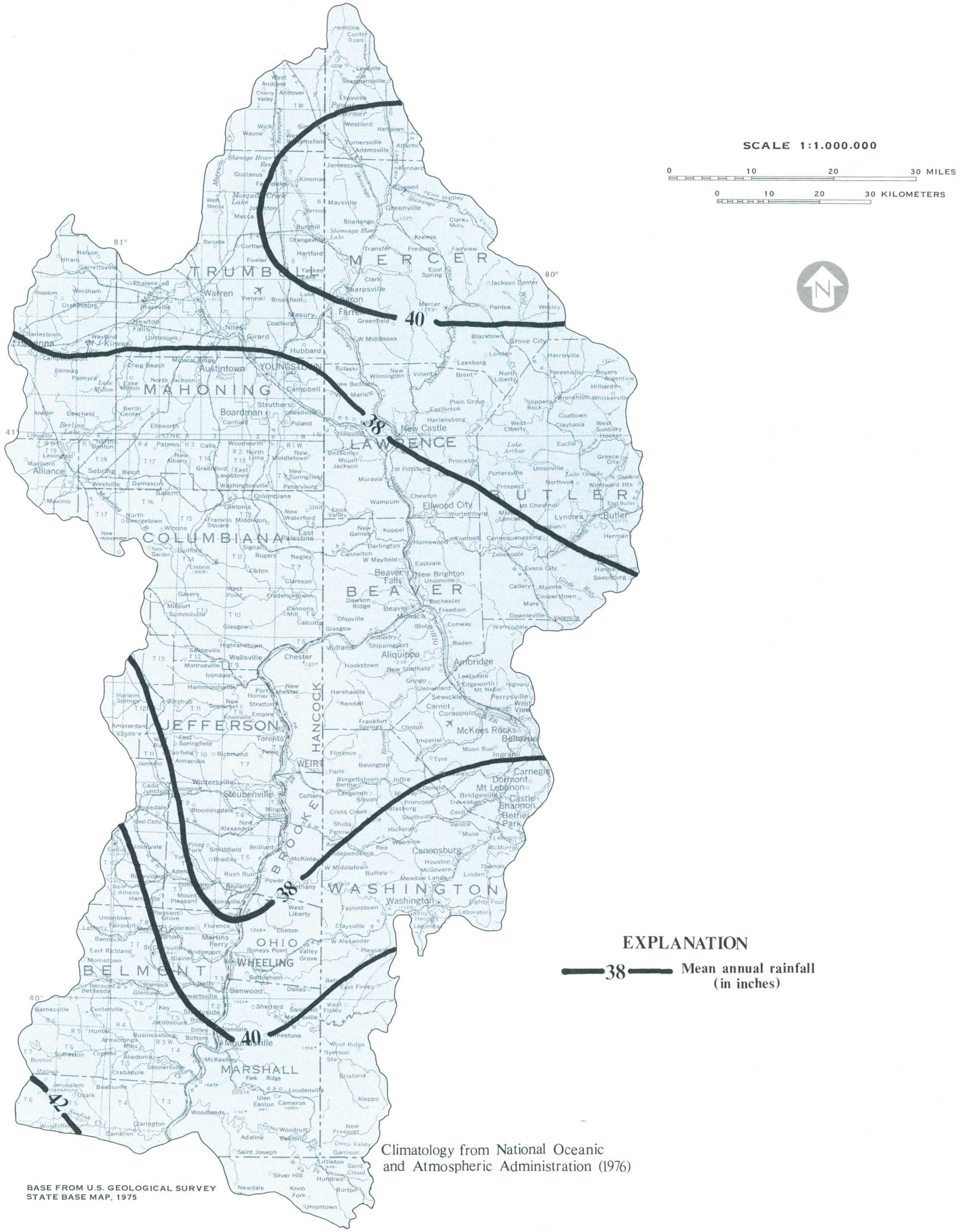


Figure 2.6-1 Mean annual precipitation in Area 4; 1941-1970 period

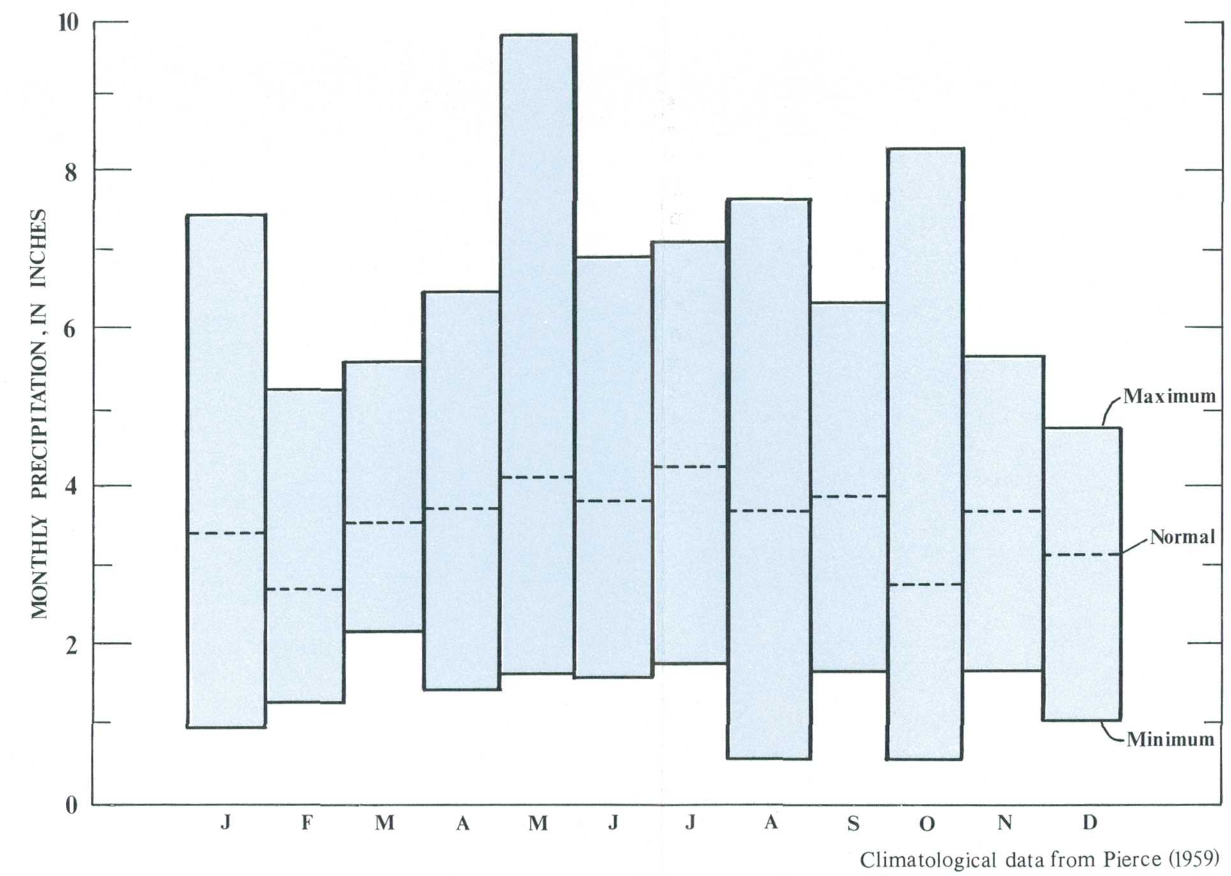


Figure 2.6-2 Precipitation at Youngstown, Ohio (period 1921-1950)

Information on Surface Water is Available for 131 Locations

The surface-water data-collection network for Area 4 was increased in response to PL 95-87.

One hundred thirty-one synoptic sites (a partial record site at which chemical, discharge, and biological data are collected during high and low flow), 8 event sites (a synoptic or partial record site at which suspended sediment data are collected during peak flow), 1 trend station (a continuous record station at which more frequent and comprehensive sampling of sediment, chemical, discharge, and biological data, is done in an area disturbed by mining), and 3 upgraded stations (a continuous surface water station already in operation at which the collection of water quality data is increased), were added to the existing surface-water data-collection network in Area 4. The station locations are shown on figure 3.1-1. Details for the period of record and type of data available are given in Appendix 1 and 2. Ranges of chemical constituents found in selected streams are listed in Appendix 3.

Discharge, water-quality data (see Section 6.0), and benthic invertebrates were collected at all synoptic sites and the trend station. Suspended sediment samples were collected at the event sites. Details of collection and the type of hydrologic data available can be obtained from the National Water Data Exchange (NAWDEX) and from published annual Water Resources Data reports for Ohio, Pennsylvania, and West Virginia.

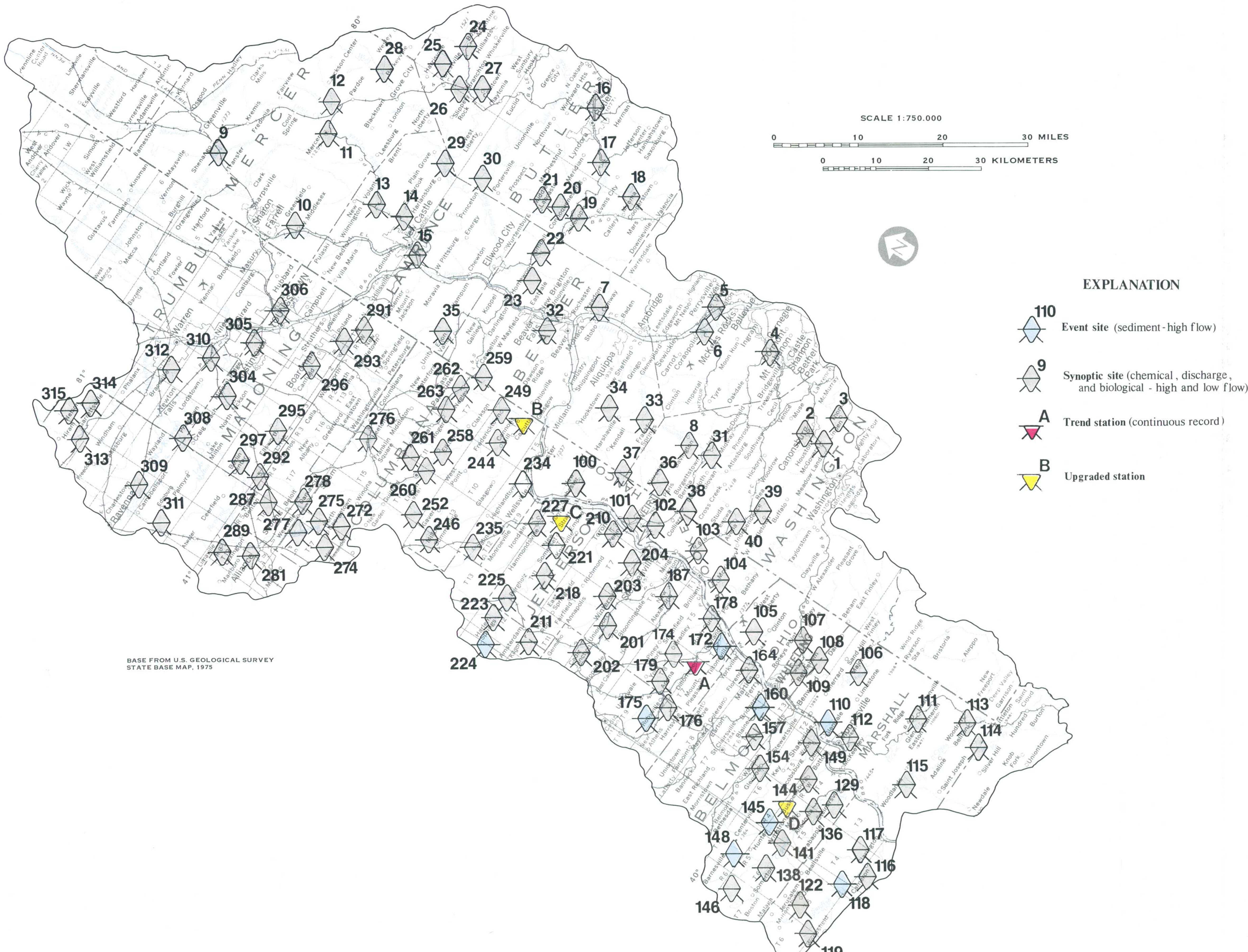


Figure 3.1-1 Sampling sites in Area 4.

Streamflow Varies Seasonally, Mostly with Precipitation (Snow Melt and Rain) and Evapotranspiration.

Variations in streamflow are related chiefly to the duration and intensity of precipitation (snow melt and rain) and seasonal changes in evapotranspiration.

Streamflow is water that reaches the stream by surface runoff and ground-water discharge. Streamflow is a part of the "hydrologic cycle," in which water moves in a continuous cycle powered by solar energy. This cycle is illustrated in figure 4.1-1.

Figure 4.1-2 shows the mean monthly and yearly mean discharges for a year compared with the mean monthly and yearly discharge for 30 years of record. The hydrograph illustrates typical characteristics of the yearly streamflow cycle: October low flow and low average rainfall; November and December - increased flow as evapotranspiration decreases with lower temperatures; January and February - intermittent low temperatures with some runoff from snow melt; March and April - increased flow due to spring thaw and rains; May and June diminished rainfall and increased evapotranspiration; July and early August - some replenishment of flow by thunderstorms; then a recession of flow in August and September during which ground-water discharge is the main source of streamflow.

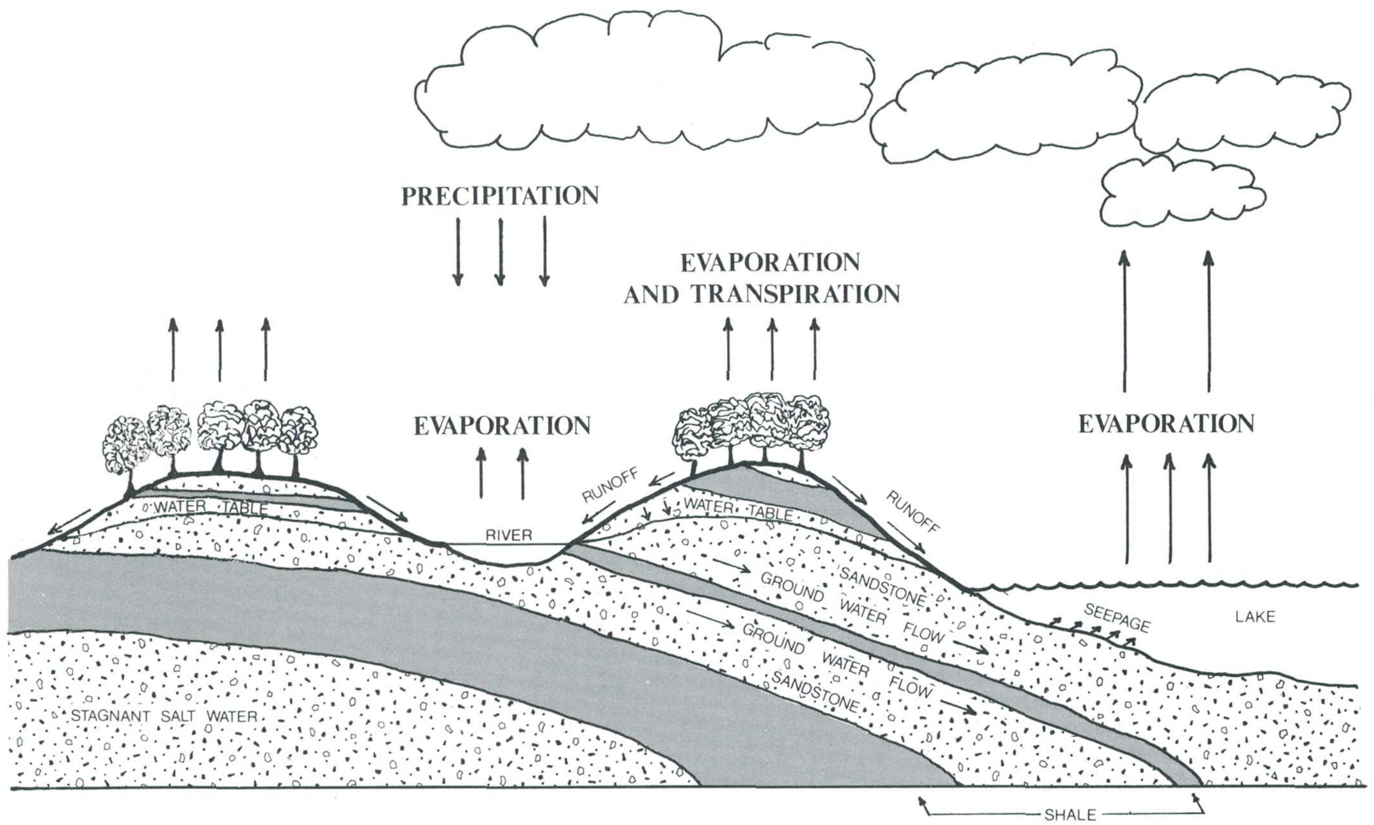


Figure 4.1-1 Hydrologic cycle (modified from Landers, 1976).

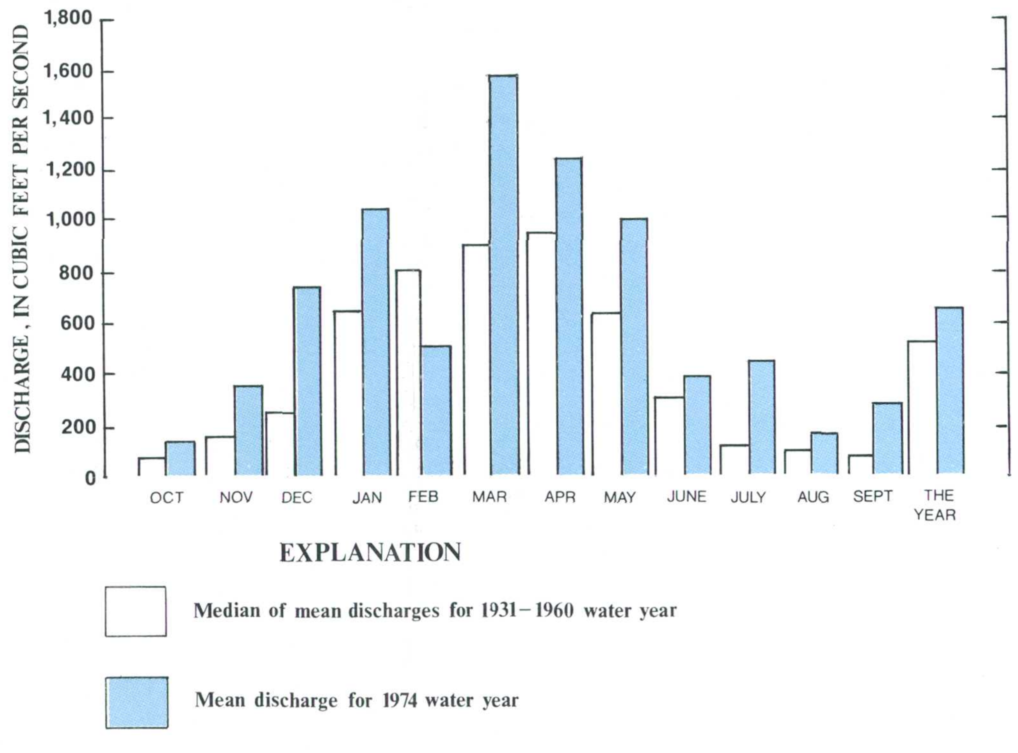


Figure 4.1-2 Seasonal pattern of streamflow, Little Beaver Creek near East Liverpool, Ohio (U.S. Geological Survey, 1974).

Low-Flow Characteristics are Essential in Determining the Adequacy of Streamflow for Periods of Little Rainfall

Streamflow requirements for disposal of solid and liquified wastes, and maintenance of suitable conditions for aquatic life are in terms often evaluated in terms of low flow characteristics.

Low-flow characteristics are a measure of the ability of streams to dilute acidic waste water and to support aquatic life.

Low flow at any location depends in part on: (1) Precipitation over the drainage basin, (2) the temperature regime which controls the storage of water and influences evapotranspiration rates and, (3) the soil and geologic characteristics which control the recharge and discharge of ground water in the basin (Riggs, 1973).

A low-flow frequency curve is a graph showing the magnitude and frequency of annual minimum flows for a given number of consecutive days. Figure 4.2-1 shows low-flow frequency curves for four such periods.

An index of low flow commonly used is the 7-day 10-year low flow, which is the annual minimum 7-day average low at a flow for 10-year recurrence interval. The 7-day 10-year low flow from figure 4.2-1 is about 2.1 ft^3/s.

Unregulated streams in Area 4 vary widely in low flow characteristics. For twelve continuous record stations, the 7-day 10-year low flow ranged from 0.0 $(ft^3/s)/mi^2$ to 0.064 $(ft^3/s)/mi^2$.

In Area 4 the change in land use due to mining affects the natural, low-flow characteristics. Active and abandoned surface contour mining operations usually pond water and reduce infiltration. This tends to reduce low flows. But improved ground water drainage due to abandoned underground mines may increase low flow.

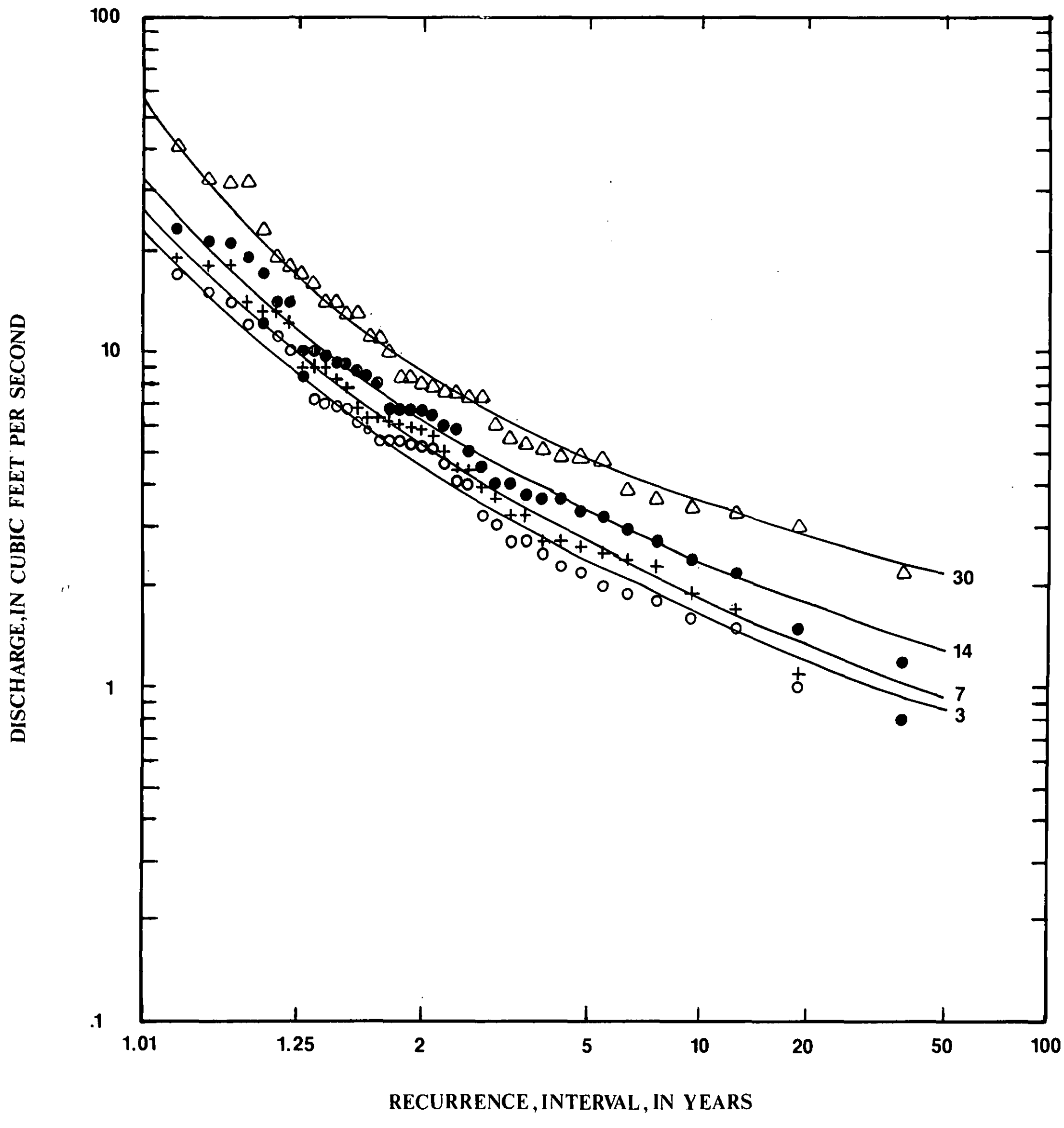


Figure 4.2-1 Low flow frequency curves for 3-, 7-, 14-, and 30-day periods for (03110000) Yellow Creek near Hammondsville, Ohio.

Floods are Natural and Normal Phenomena

They can be catastrophic chiefly because man occupies the flood plain which is the high water channel of a stream.

The extent of flooding depends on topography and weather. Topographic factors include drainage area, slope, soil composition, and elevation. Weather factors are precipitation intensity and distribution.

Area 4 has a diverse terrane. The Ohio River valley consists of moderately wide alluvial plains and rounded hills with low river gradients. These valley characteristics attenuate flood peaks and lengthen the periods of high streamflow in the river. Local relief above the stream valley is about 500 feet, the land rising to an average hill top elevation of about 1,200 feet. The channels of the streams that flow into the Ohio River and its major tributaries are narrow and steep.

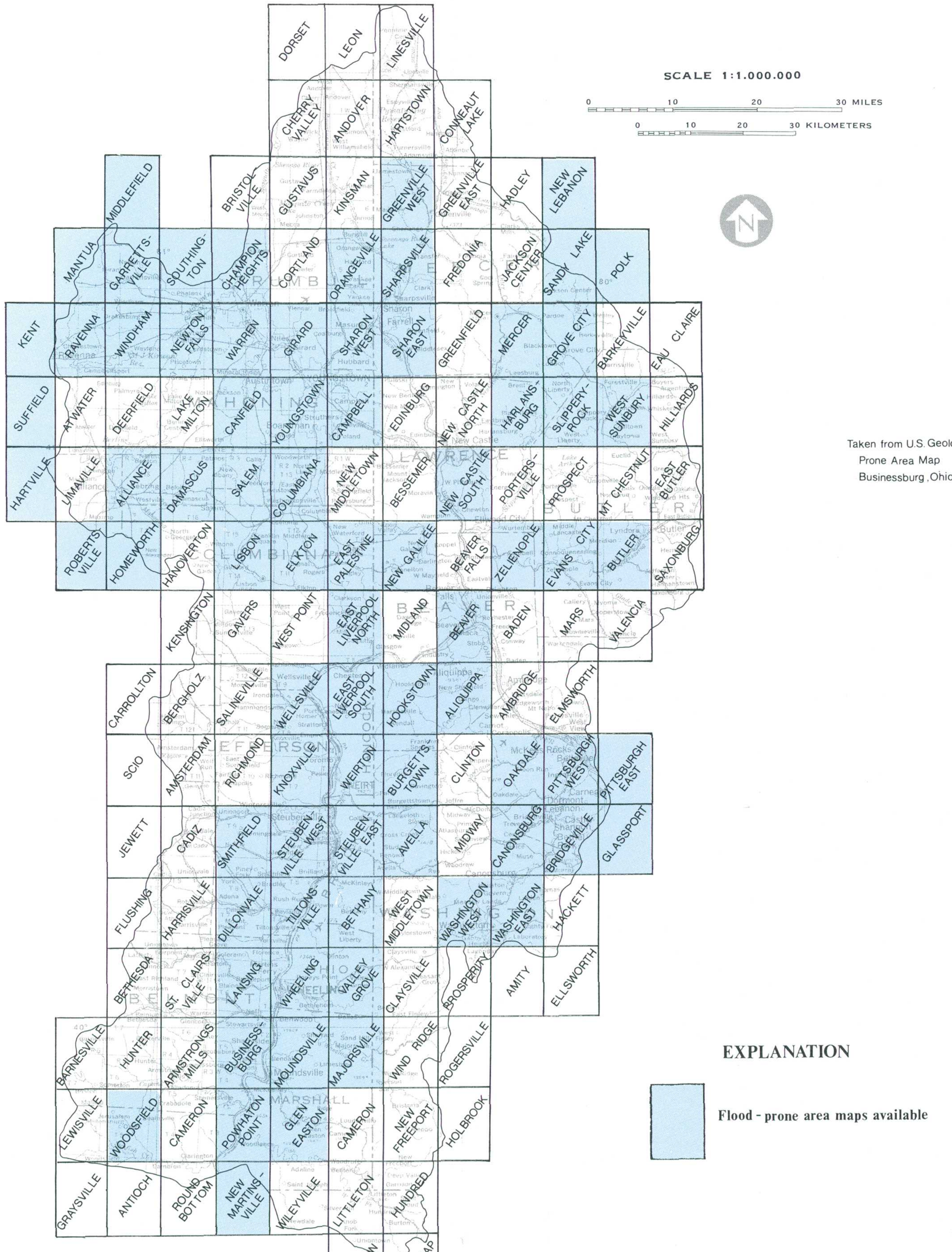
The rest of Area 4, except for the small area in the north above the 41° latitude, is characterized by narrow flood plains and steep slopes, which contribute to rapid storm runoff. The area above 41° latitude is characterized by wider flood plains and moderate stream slopes.

Area 4 is in a region of variable air mass activity, being subject to both polar and tropical continental and maritime air mass invasions. Frequent and rapid changes may result from fronts associated with air mass movements. Flooding in the smaller streams is usually the result of thundershower activity associated with these fronts.

Most flood damage is due to encroachment on the flood plains by industrial, commercial, and residential developments. Areas where flooding may produce significant damage are referred to as "flood prone areas." See example, figure 4.3-2. Many flood prone areas along the Ohio River and its tributaries are occupied by man and his buildings and property. Information on flood-prone areas in Area 4, indicated in figure 4.3-1, can be obtained from the U.S. Geological Survey offices in Ohio, Pennsylvania or West Virginia.

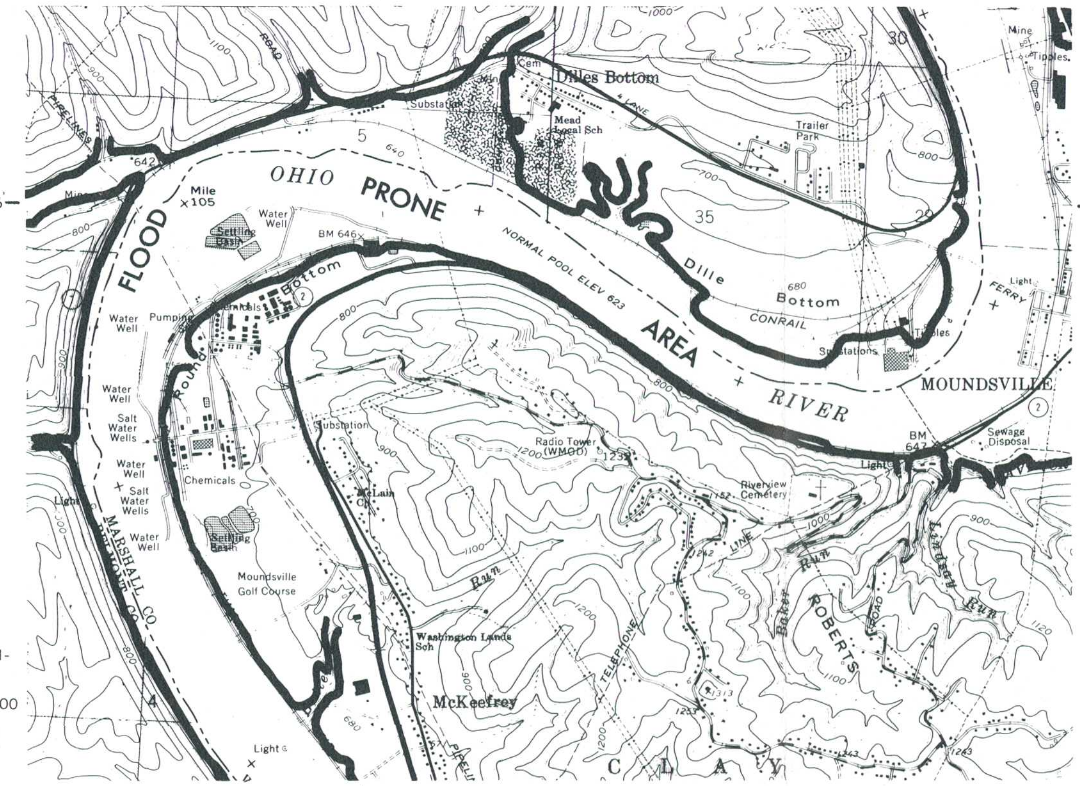
Flood-prone areas are those that would be inundated by a 100-year flood as defined from a frequency curve of annual flood peaks at a gaged site. The 100-year flood has a 1 percent chance of occurring in any year.

Flood profiles of record and for three recurrence intervals are shown in figure 4.3-3 for a short reach of a stream near Area 4. For further information on estimating floods see State publications on magnitude and frequency of floods in Ohio, Pennsylvania, and West Virginia.



BASE FROM U.S. GEOLOGICAL SURVEY
STATE BASE MAP, 1975

Figure 4.3-1 Flood-prone area maps available.



Taken from U.S. Geological Survey Flood-Prone Area Map Businessburg, Ohio-W.Va. 1960, 1:24,000

Figure 4.3-2 Flood-prone area map.

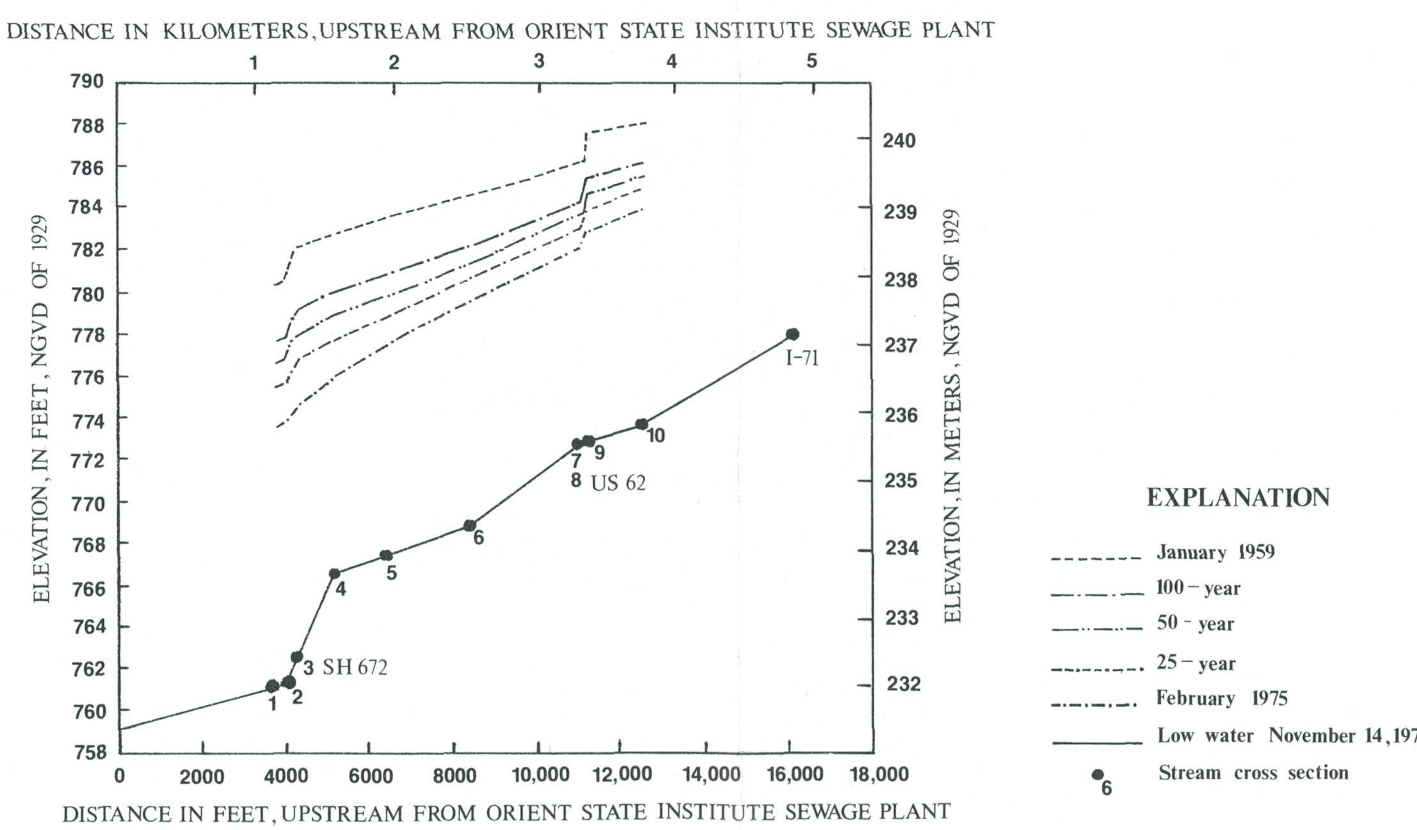


Figure 4.3-3 Flood profiles, Big Darby Creek at Orient, Ohio (Mayo, 1977).

The Flow-Duration Curve is the Distribution of Daily Discharges Over a Period of Years

The flow-duration curve, is a cumulative frequency curve that shows the percentage of time that specified discharges are equaled or exceeded (Langbein and Iseri, 1960).

Figure 4.4-1 shows flow duration curves for two stations in Area 4. As an example from the curve, a discharge of 0.6 $(ft^3/s)/mi^2$ for Brush Run near Buffalo, Pennsylvania is expected to be equaled or exceeded about 50 percent of the time.

The shape of the flow-duration curve is indicative of the hydrologic and geologic characteristics of the drainage basin. A curve with a steep slope denotes highly variable streamflows caused mainly by direct surface runoff. A curve with a flat slope indicates a large flow from surface or ground water storage. A flat slope at the lower end of the curve indicates sustained base flow, whereas a steep slope indicates negligible base flow (Searcy, 1959).

The duration curves in figure 4.4-1 show the extremes in ground water contribution for Area 4. The topography of both basins consists of rolling hills with slopes that vary from gentle to steep. However, Brush Run basin is underlain mostly by sandstone and shale that are low in ground water storage. The basin of Short Creek includes buried valley systems partly filled with sand and gravel which serve as good ground water reservoirs. The village of Dillonvale obtains its water supply from two wells drilled into these sand and gravel aquifers (Nichols, 1980). Buried valley systems are the major sources of ground water storage in the area and are more common north of the glacial boundary.

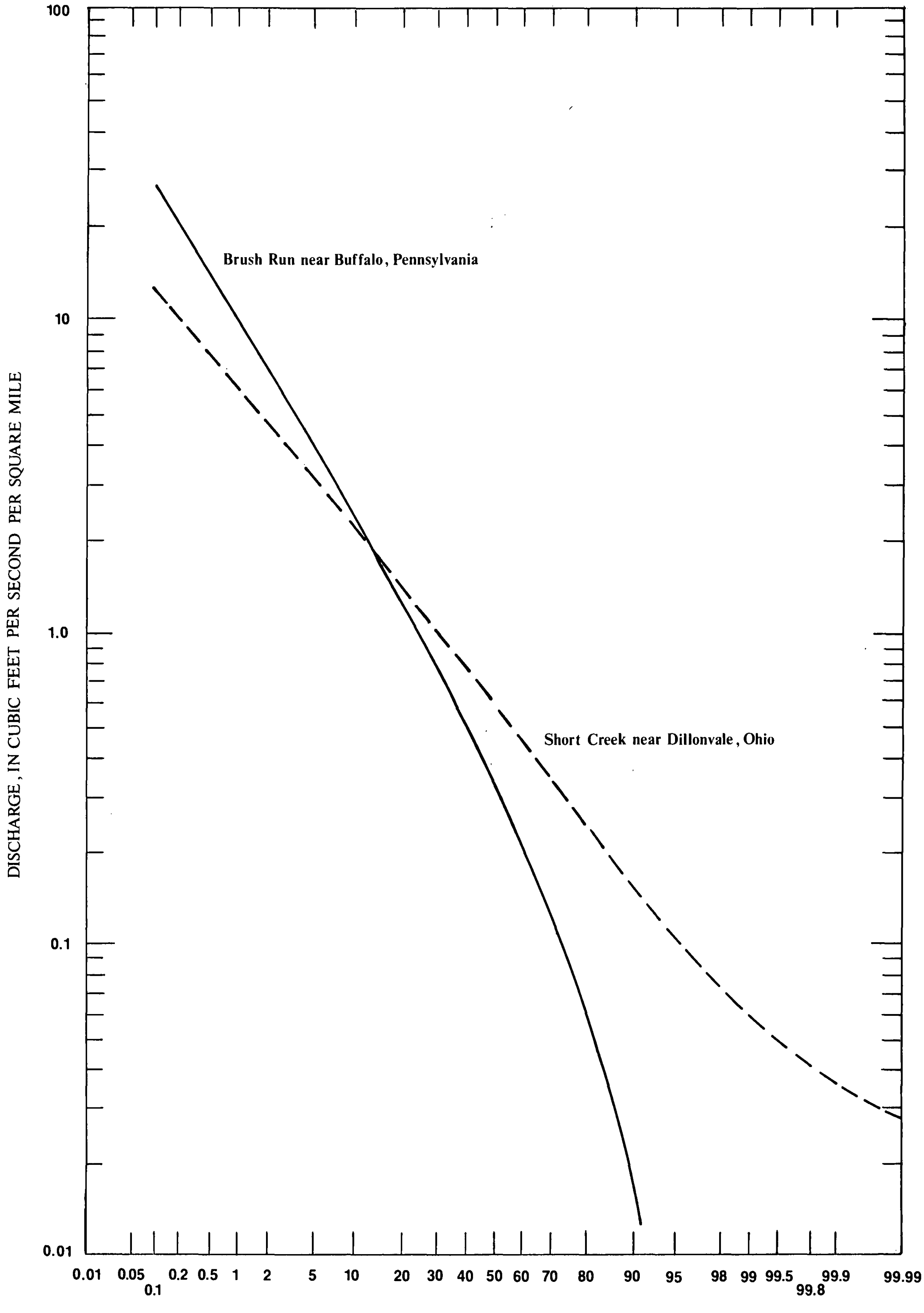


Figure 4.4-1 Flow duration curves of Brush Run near Buffalo, Pennsylvania and Short Creek near Dillonvale, Ohio.

Specific Conductance is High in Streams Draining Coal Mining and Industrialized Areas

High specific conductance commonly results from coal mining and industrial effluents.

Specific conductance of a stream is the property of the water to conduct an electric current and is expressed in micromhos (μmhos) per centimeter at 25° Celsius. Because specific conductance is related to the ion concentration or dissolved solids content, it acts as an indicator of the ionic concentration or dissolved solids in a stream (Hem, 1970). Figure 5.1-1 shows the relationship between specific conductance and the concentration of sulfate (SO_4^{--}) ion.

As a general rule, as streamflow increases the dissolved-solids concentration is lowered by dilution (Anderson, 1963); therefore specific conductance is usually highest during low flow periods.

The high specific conductance in coal mined areas is due to the weathering of pyrite and other minerals when exposed to the air in underground mines and spoil piles of surface mines. Oxidation results in the formation of sulfuric acid and soluble mineral salts. The acidic drainage reacts with other minerals as it enters the stream producing high dissolved-solids concentrations. The higher sulfate concentrations shown in figure 5.1-1 are from sample sites where mining activity has been intense. Generally, the highly mineralized water draining from a mined area decreases rapidly downstream due to dilution by tributary streams.

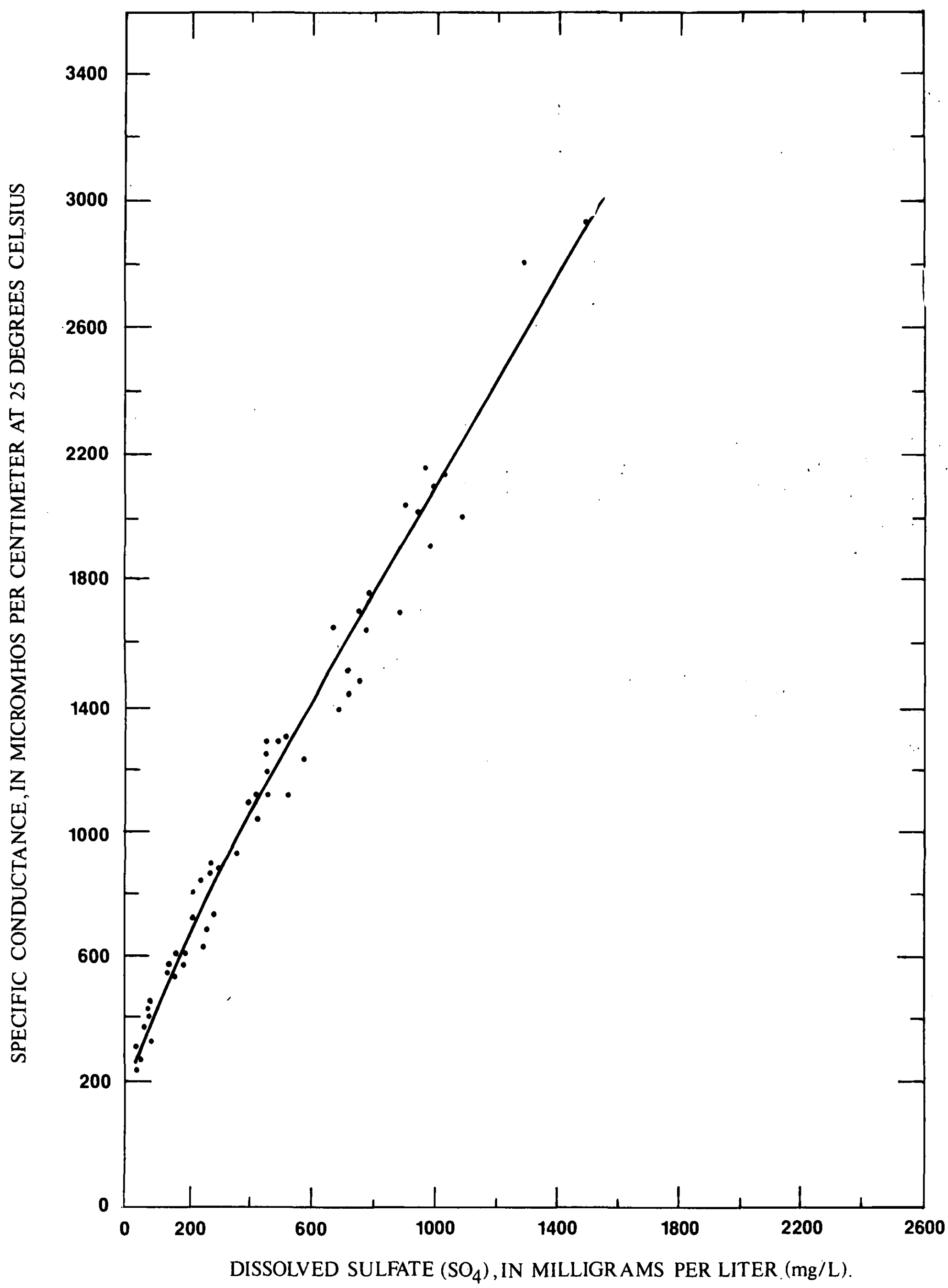


Figure 5.1-1 Relation between dissolved sulfate concentrations and specific conductance at sites in Area 4.

Streams in Areas Not Influenced by Pollution Generally Have a pH Value Between 6.5 and 8.5 (Hem, 1970)

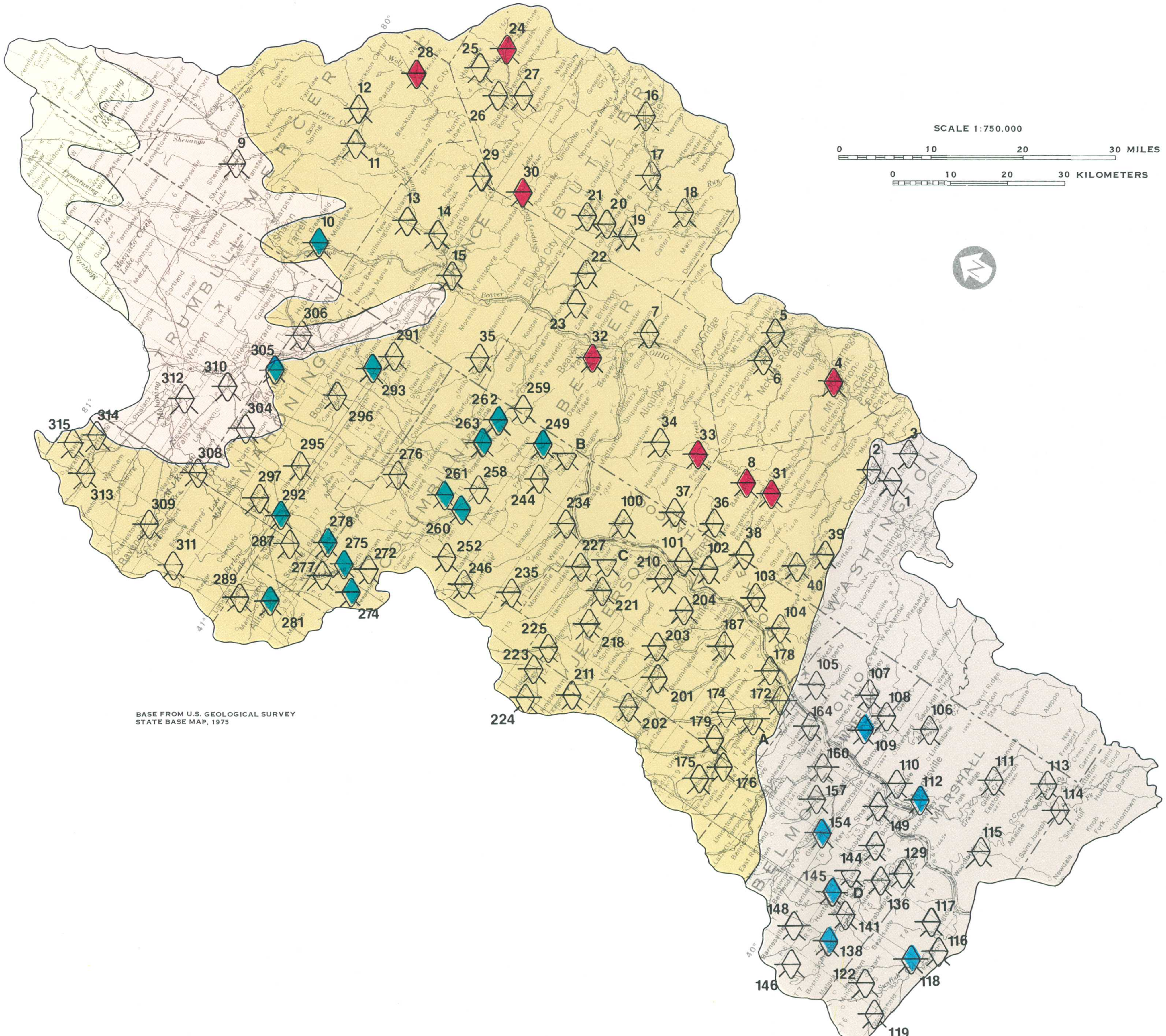
The pH of most streams in Area 4 is in the normal range of 6.5 to 8.5.

Acidity is generally expressed as pH. A pH value of 7.0 represents neutral water. Values above 7.0 denote alkaline water and those below 7.0 denote acidic water. Natural acidity is usually caused by the presence of dissolved carbon-dioxide and the hydrolysis of salts of weak acids and strong bases. Sources of these substances include rainfall, weathered geologic strata and organic matter in soils (Hem, 1970).

The pH values for streams draining undisturbed basins underlain by sandstone and shale is generally in the near neutral range (6.5 to 8.5).

Another source of alkalinity in streams draining coal mining areas is "rock dust," which is ground up limestone. Rock dust is used in underground coal mines to reduce the possibility of explosion of coal dust. It also helps to neutralize the acid discharge (Ohio EPA, 1979).

Low pH values, below 6.5, indicate acidic conditions and in coal mining areas usually indicate acid mine drainage. See figure 5.2-1 for range of pH values found at sites in Area 4.



EXPLANATION

pH	Range
9	3.3 → 6.4
4	6.5 → 8.5
10	8.6 → 9.2

DEVONION
Shale, sandstone, and conglomerate

MISSISSIPPIAN
Coarse sandstone, and shale

PENNSYLVANIAN
Coal, shales, coarse sandstones, and limestone

PENNSYLVANIAN AND PERMIAN
Shale, coarse sandstone, coal, and thin limestone

Figure 5.2-1 Range of pH values in streams at synoptic sites and underlying rocks in Area 4.

Sediment and Erosion Are Problems Associated With Surface Mining

Sediment yield in streams draining abandoned strip mining areas is higher than in streams draining areas of undergroung mining.

Increased sediment in streams is the result of certain land-use activities such as forest clearing, farming, road construction, urban development, and surface mining which results in increased erosion.

The increased sediment yield from surface mining areas usually comes from the erosion of the exposed, unconsolidated spoil piles during high intensity storms. The increase in sediment is usually of short duration if the area has been reclaimed. In unreclaimed areas, the continued erosion and sedimentation are a local problem. See figure 5.3-1 and figure 1.3-1 for examples of erosion and sediment filling of stream channels and culverts. Sediment concentrations are generally lowered by dilution of larger receiving streams. Usually the lowest suspended-sediment concentration occurs during low flows and the highest during high flows.

Several factors influence the sediment runoff in Area 4, including climate, soils, size of drainage basin, and topography. Area 4 ranges from hilly topography in the south to flat in the north. Streambeds range from shale and sandstone to clay, sand and silt. Both the observed and limited collected data showed a greater sediment yield from streams draining abandoned and active strip mines than undisturbed land.

Goose Run near Pattersonville, Ohio

Guernsey County, Ohio

Figure 5.3-1 Sediment deposited from surface mining in eastern Ohio. (Photograph by Ohio Department of Natural Resources)

Iron Concentrations are Mostly Below 300 Micrograms Per Liter in Area 4

Dissolved iron concentrations are high at coal mines, but decrease rapidly downstream.

Dissolved iron concentrations exceeding 300 micrograms per liter ($\mu g/L$) impart objectional qualitites to water, such as bad taste and staining and limit the water's use for domestic and industrial purposes (Ohio EPA, 1979). Streams draining undisturbed areas generally have a dissolved iron concentration less than 300 $\mu g/L$, while streams draining mined areas, may have a dissolved iron concentration in excess of 1,200 $\mu g/L$.

Dissolved iron concentrations are high in streams draining coal mine areas, but decrease rapidly downstream, and are similar to those of unmined streams a short distance downstream from the mined areas. Figure 5.4-1 shows the range of dissolved iron at sites in Area 4. Most values are in the range of 0-300 $\mu g/L$, even those where acid mine drainage was observed running into the streams in the headwaters. The reason very few sites showed dissolved iron above 300 $\mu g/L$ was probably due to the fact that the sites were near the mouths of the streams, well downstream from the sources of acid mine drainage.

Dissolved iron concentrations in streams draining coal-mine areas are the result of weathering and oxidation of iron bearing minerals (pyrite and marcasite). These exposed minerals are washed into the stream channels from coal mining operations and as a result of hydrolysis form insoluble iron precipitates known as "yellow boy" (figure 5.4-2)(Ohio Board on Unreclaimed Strip Mined Land, 1974).

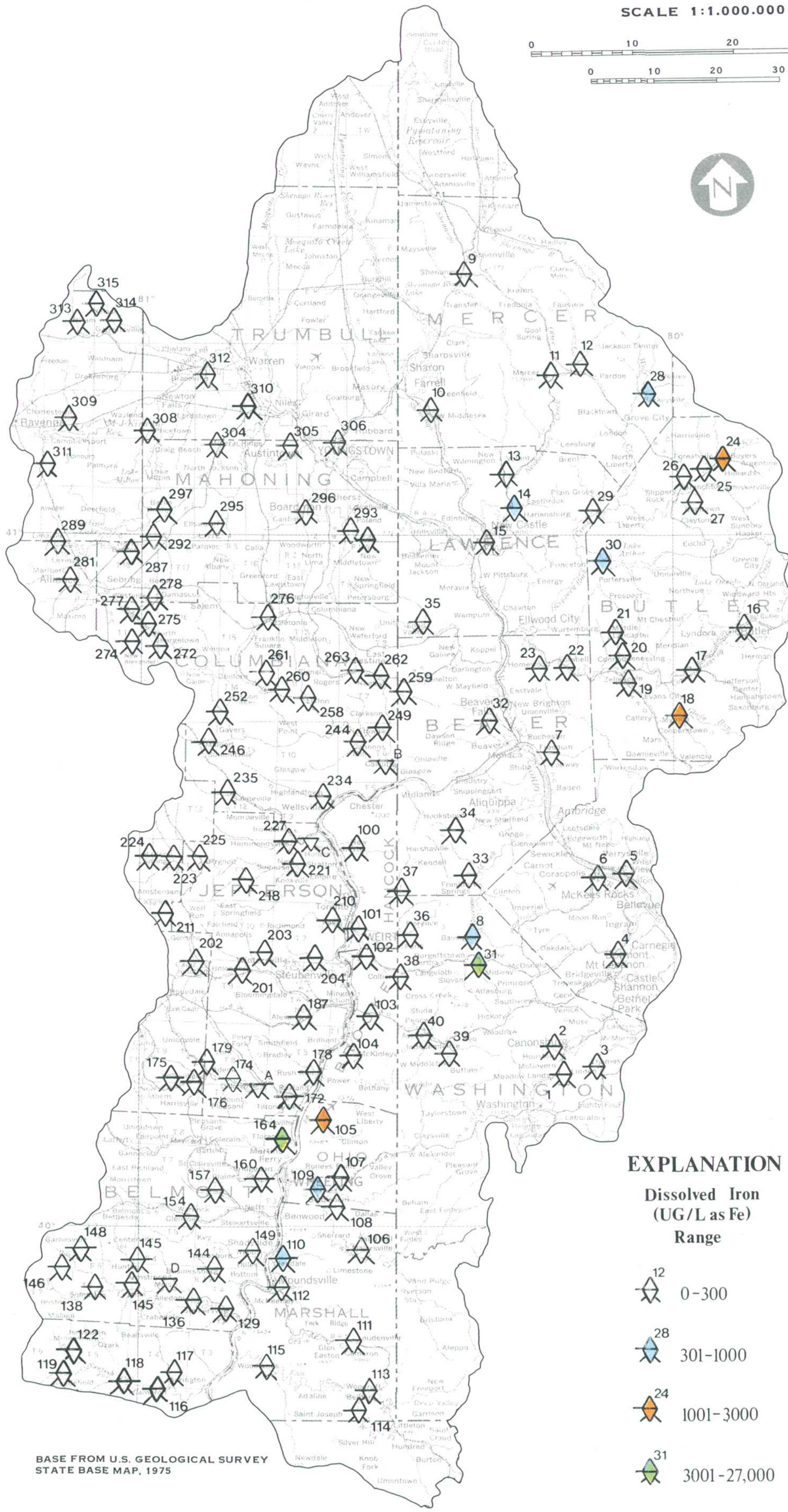


Figure 5.4-1 Range of dissolved iron concentrations at synoptic sites in Area 4.

A. Stream near Burgesstown, Pennsylvania.

C. Tributary stream near Youngstown, Ohio.

Figure 5.4-2 Reddish yellow precipitates, "Yellow Boy," in Area 4.

B. Tributary stream in Belmont County, Ohio.

D. Stream in northern West Virginia.

5.0 QUALITY OF SURFACE WATER (Continued)

5.4 IRON

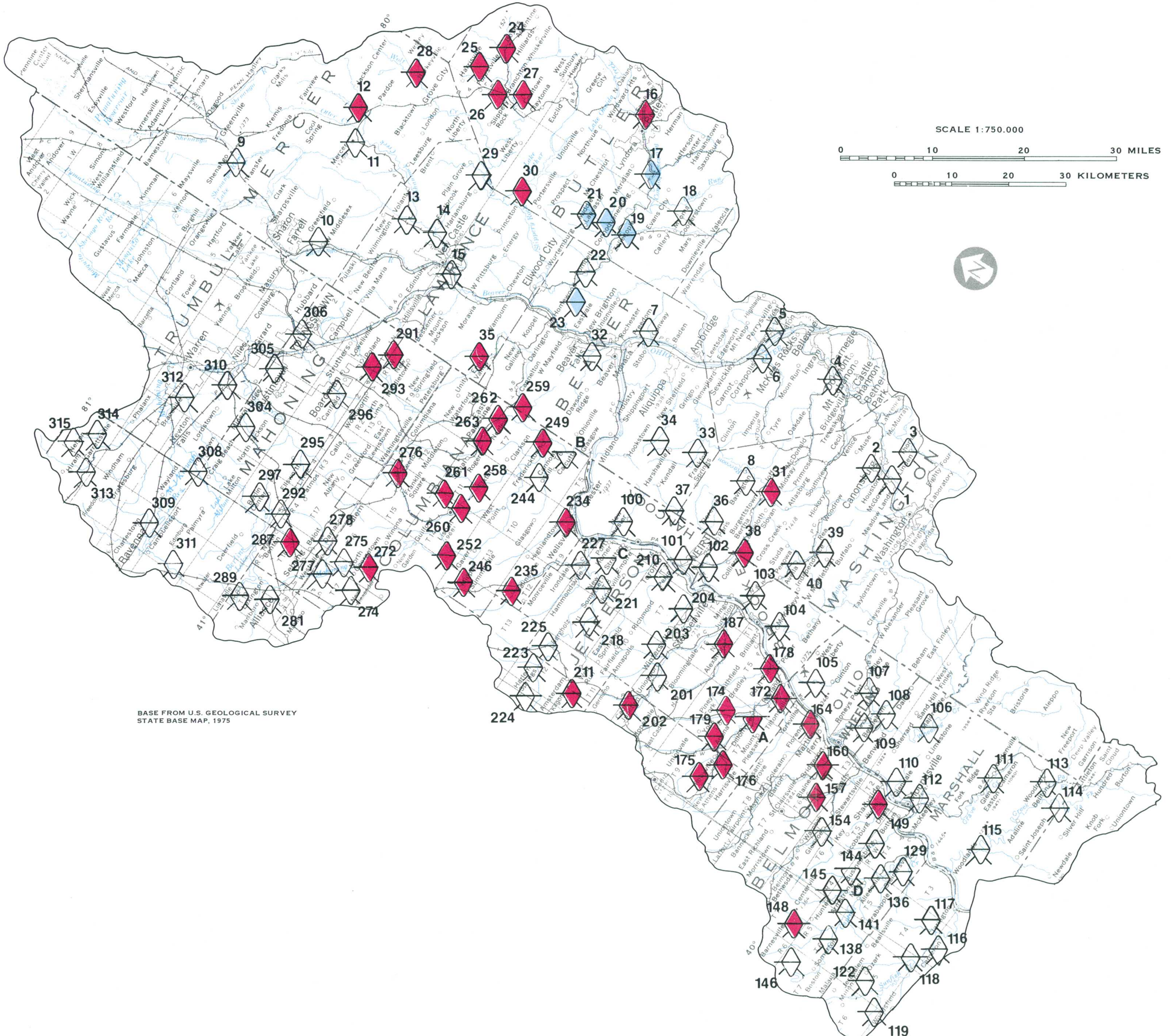
Stream Drainage From Currently, Abandoned, and Reclaimed Mined Areas Have High Concentration of Manganese

Concentrations of dissolved manganese in Area 4, from abandoned mines, often exceed 500 μg/L. Concentrations from reclaimed and currently mined areas typically exceed 200 μg/L. Concentrations in undisturbed areas are usually less than 150 μg/L.

Soils enriched in organic matter, and rock strata containing ferro-magnesian minerals, are sources of small concentrations of manganese in natural water. Dissolved manganese concentrations less than 50 μg/L (micrograms per liter) are safe levels for domestic and industrial use (Biesecker, 1966, and National Academy of Sciences and National Academy of Engineering, 1972).

Soils contain manganese in the form of manganese dioxide, which is insoluble in water containing carbon dioxide. Under low pH conditions the manganese is reduced, allowing soluble manganese salts to enter the water system (Sawyer and McCarty, 1978). In mined areas, oxygen consumed in the oxidation of pyrite produces a reducing environment which, with low pH, increases the concentration of soluble manganese.

In Area 4, manganese concentrations ranged from 90-490 μg/L in abandoned mine areas, due to the accelerated weathering of manganese-rich minerals exposed in the mine spoils. (See figure 5.5-1.) However, concentrations in undisturbed areas ranged from 60-4100 μg/L, due most likely to urban and industrial runoff.



EXPLANATION

9 Concentrations of manganese less than 50 ug/L

12 Concentrations of manganese more than 50 ug/L

17 Questionable sites due to lack of information about the area

Figure 5.5-1 High manganese concentrations in mined areas.

Sulfate Concentrations are High in Streams Draining Mined Areas

The most common dissolved constituent in streams draining coal mine areas in Area 4 is sulfate.

Sulfates occur in streams draining coal mining areas as the result of oxidation and weathering of pyrite and marcasite which are carried by surface runoff and ground water discharge into the streams.

Sulfate concentrations are highest during low flows, due to lack of dilution by rainfall and the infiltration of sulfates from ground water discharge. In general, sulfate concentrations decrease downstream from the source, due to dilution by tributary streams.

Sulfate concentrations can be related directly to specific conductance, an indicator of the degree of mineralization in water. Figure 5.6-1 shows the relationship between sulfates and specific conductance. The highest specific conductance occurred during low flow and the lowest during high flow.

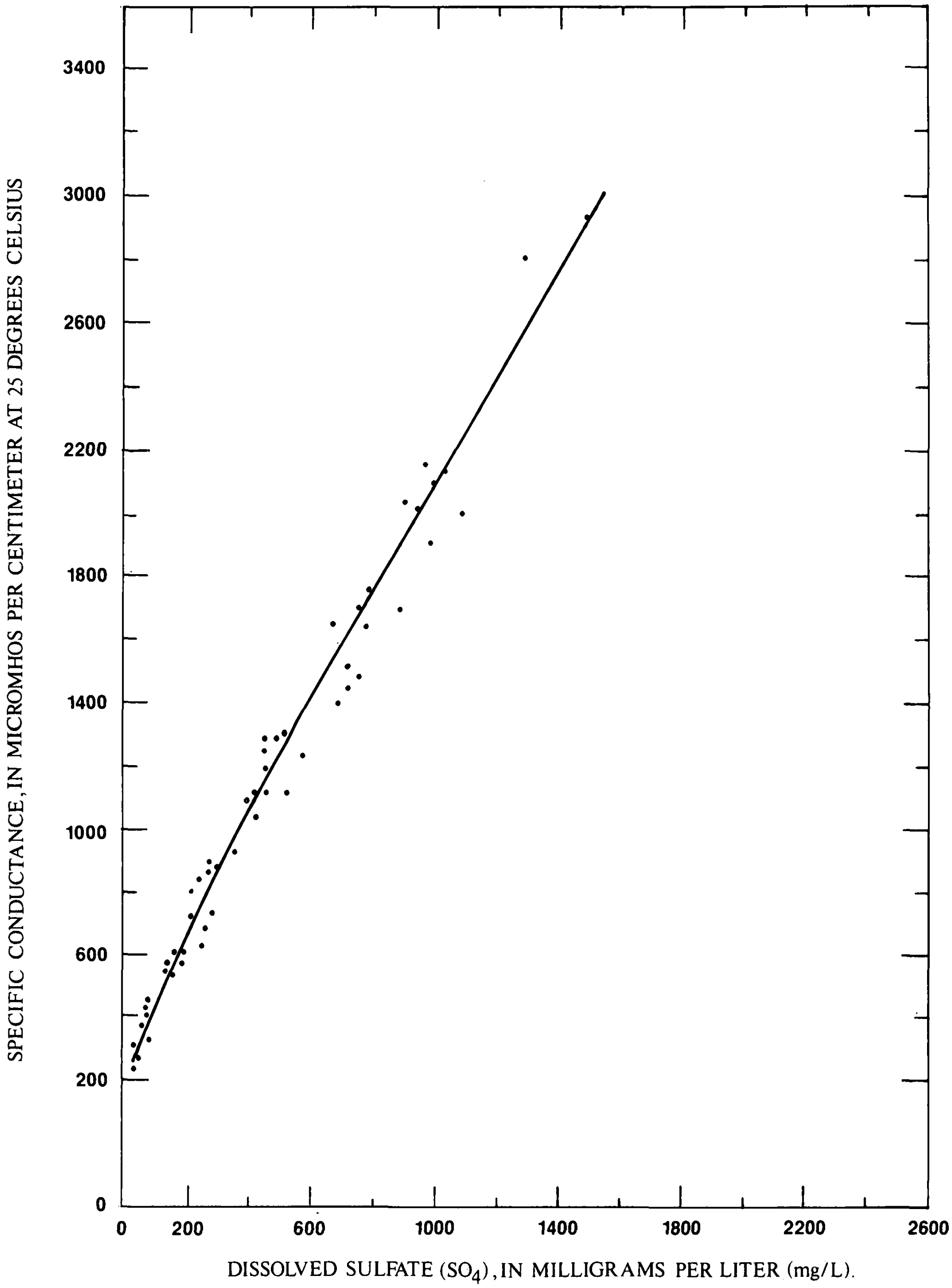


Figure 5.6-1 Relation between dissolved sulfate concentrations and specific conductance at sites in Area 4.

Trace Elements Occur in Small Concentrations in Bottom Materials

Trace elements are present in small concentrations in natural water, and generally do not contribute to water-quality problems of streams.

Trace elements are primarily derived from soils, rock strata within the stream basin, and atmospheric fallout. In low concentrations, trace elements provide a source of nutrients to plants and animals. As concentrations increase some trace elements can become toxic (Harkins, 1980). Although high concentrations may occur naturally, they are usually associated with the discharge of industrial wastes. In mined areas, pyritic material in spoil banks is rapidly weathered producing acidic water and minerals, resulting in higher concentrations of trace elements than normally occur.

In Area 4, trace elements under consideration were arsenic, cadmium, chromium, cobalt, copper, lead, zinc, selenium, and mercury. All of the trace elements concentrations, recovered from the bottom material, fell within the drinking water standards established by the Ohio Environmental Protection Agency (1977), with the exception of chromium and lead. Safe levels for both chromium and lead are 50 μg/L (Ohio Environmental Protection Agency, 1977). The range of concentration for chromium was 10-60 μg/L, and that of lead ranged from 10-2300 μg/L. (See figure 5.7-1.)

The only high analysis of chromium, of a sample recovered from the bottom material, was found near Burgesstown, Pennsylvania, at an abandoned zinc mine. From 1913-1948 coal was mined there from underground, and zinc was shipped in by rail to burn in the smelters. Nearby acid seepage suggests that the mine could be the source of the chromium. Chromium is a by-product of zinc ore. (See figure 5.7-1). No reclamation had been done except for the removal of clinkers (by-product from the burning of coal in smelters) from pilings.

High concentrations of lead in bottom material characterized both mined and undisturbed areas. The undisturbed sites were within urban areas, suggesting the source of the lead could be urban runoff or industrial waste. Mined areas included current, abandoned, and reclaimed surface and underground mines.

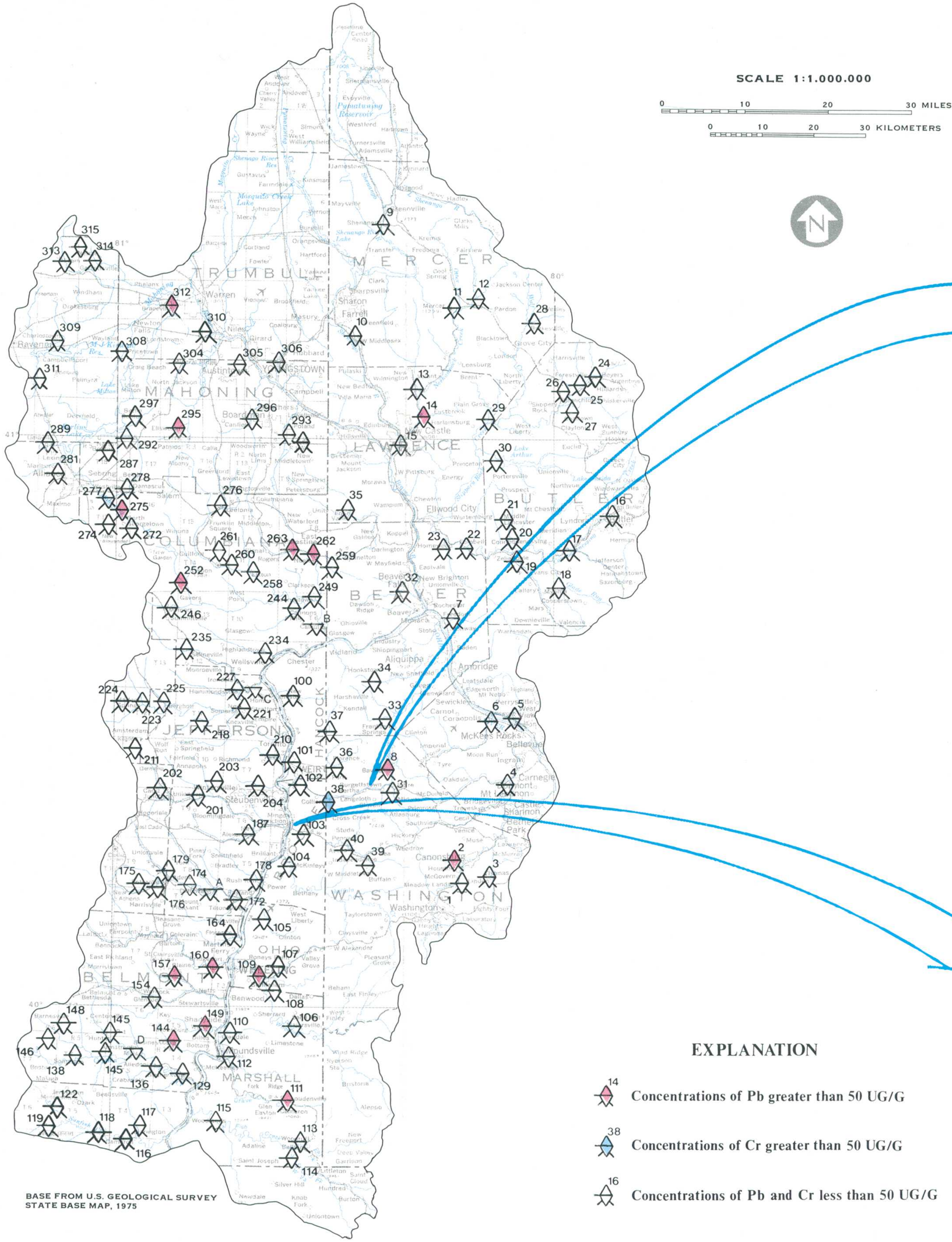


Figure 5.7-1 High lead and chromium concentrations recoverable from bottom materials.

A. Tailings from the smelter near Burgesstown, Pennsylvania.

B. Acid seepage from coal seam.

Aquatic Life in Area 4 Sparse in Streams Draining Abandoned Mines

Habitat degradation explained by use of flow diagram, chemical tolerance ranges of benthic invertebrates, and conceptual model.

The ecology of aquatic communities and their relation to mine development alternatives in streams draining Area 4 are described by a flow diagram, chemical tolerance ranges of benthic invertebrates, and a conceptual model. According to Trautman (1977), no virgin streams exist in eastern Ohio today. Most streams in the Ohio section of Area 4 are characterized by increased sediment yields from strip mines, organic enrichment from sewage outfalls, and increased chemical yields from industrial effluents and abandoned sub-surface and surface coal mines.

In Pennsylvania and West Virginia, most coal is mined underground. Acid-mine drainage products from abandoned underground mines leaves a yellow to red precipitate on the stream channel. (See figures 1.4-1 and 5.4-2.) Aquatic animal life is almost entirely destroyed in such an environment.

A flow diagram (figure 6.1-1) was developed to show the difference in benthic invertebrates, dissolved iron, and dissolved sulfate concentrations with various mining development.

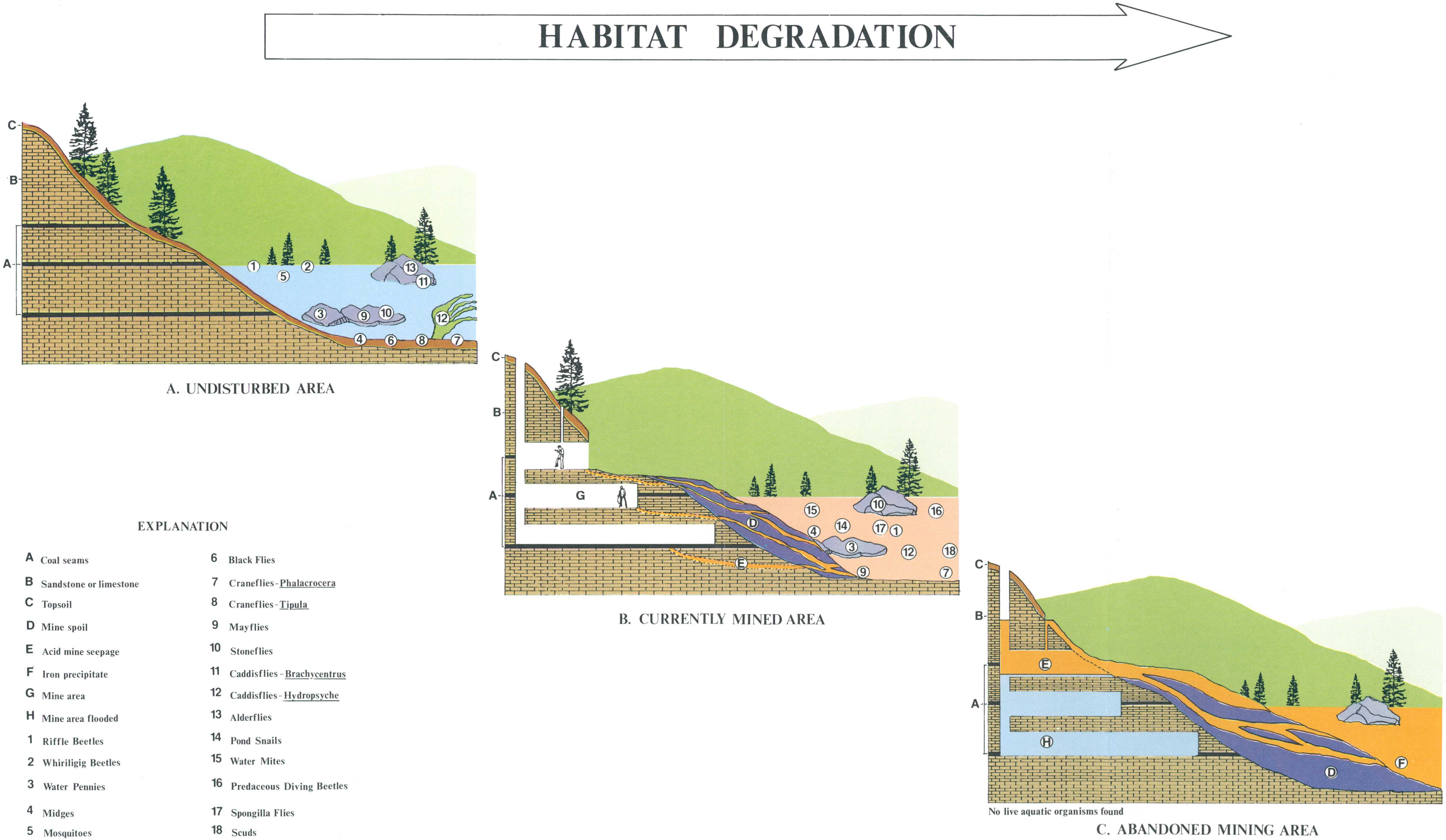


Figure 6.1-1 Flow diagram relating benthic invertebrates, dissolved sulfate and iron concentrations to selected mining activities (Engelke and others, 1980).

Aquatic Habitats Destroyed by Acid Mine Drainage from Abandoned Strip Mines

High iron, manganese, and sulfate concentrations from abandoned underground mines and high sediment yields from abandoned strip mines destroy aquatic life.

The absence or presence of benthic invertebrates classified to the order level for synoptic sites and the composition and relative abundance of benthic invertebrates at the event sites are shown in "Water Resources Data for Ohio 1979, Appendix A, Coal Areas." Most of the benthic invertebrates were collected from undisturbed habitats in streams draining the Ohio section of Area 4. In Pennsylvania and West Virginia, only the composition of benthic invertebrates was determined. Generally, as sediment increases from abandoned strip mines, the habitats in the streambed are destroyed by smothering of the beds with a thin coating of sand, silt, or clay. Streambeds are usually rich in animal and plant life and are the prime producers of aquatic food. Streambeds also provide a breeding and nesting area and shelter for many species of terrestrial and aquatic animals. Most streams that receive acid-mine drainage have a yellowish ("yellow boy") precipitate on the bottom of the stream channel. Usually the high concentrations of iron, manganese, and sulfate kill the animal life.

The caddisflies, *Hydropsyche* and *Brachycentrus*, were associated with fast water and riffles. *Hydropsyche* was attached to twigs, leaf matter, and trailing algal mats. *Brachycentrus* was on or under cobblestones.

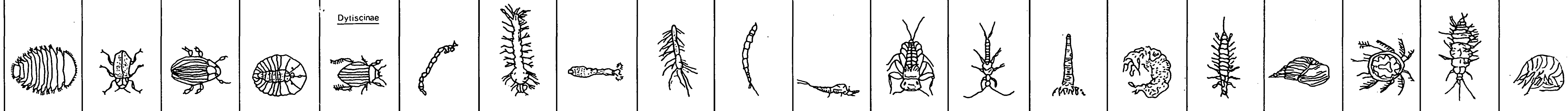
The net-winged midges, Chironominae, were found in ponding and pooling areas burrowing into soft substrate. The cranefly, *Tipula*, was found in ponded areas below sewage outfalls or in areas of organic enrichment. The cranefly, *Phalacrocera*, was found in pools with moving bottoms of fine sediment. The black flies, Simuliidae, were found in streams with moderate flows and moving sediment bottoms. Mosquitoes, Culveidae, were collected from standing pools along the edge of the streambanks.

The mayflies, Baetidae, *Ametropus*, and Capmiidae, were associated with swift water and riffles. Mayflies were collected under rocks, cobblestones, debris, and from submerged twigs, leaves, and logs. The riffle beetle, Elmidae and Dryopidae, the whiligig beetle, Gyrinidae, and the predaceous diving beetle, Dytiscidae, were in moderately flowing streams clinging to trailing algal mats or attached to the water surface of streams. The water pennies, Psephenidae, were collected in swift water or riffles attached to a bottom of cobblestones.

The alderflies, Sialidae, was found in riffles and fast moving water clinging under cobblestones and larger rocks. The spongilla fly, Sisyridae, was found in pooled areas, burrowing into the soft substrate.

Other invertebrate animals include the pond snail, *Lymnaea*, are the scud, Gemmaridae. The pond snails were found in pooling areas with slow moving water. The scud, which is an indicator of clean water environments, was found in pool areas with moderate streamflows.

The values in figure 6.2-1 are comparasions of the reported range of water chemistry to the observed range of water chemistry in Area 4 coal regions (Hart and Fuller, 1974). The observed values for several organisms were significantly higher or lower than the reported values, and these increased or decreased values are underlined. The table shows the most common benthic invertebrates collected during the study, each of which are given a number which identifies its location on the conceptual model.



Parameter	Source	1 Riffle Beetles *Dryopidae*	1 Riffle Beetles *Elmidae*	2 Whiriligig Beetles *Gyrinidae*	3 Water Pennies *Psephenidae*	16 Predaceous Diving Beetle *Dytiscinae*	4 Midges *Chironominae*	5 Culex *Culveidae*	6 Blackflies *Simuliidae*	7 Craneflies *Phalacrocera*	8 Craneflies *Tipula*	9 Mayflies *Baetidae*	9 Mayflies *Ametropus*	9 Mayflies *Capniinae*	11 Caddisflies *Brachycentrus*	12 Caddisflies *Hydropsyche*	13 Alderflies *Sialidae*	14 Pond snails *Lymnae*	15 Water mites *Acarina*	17 Spongilla flies *Sisyridae*	18 Scuds *Gammaridae*
Specific conductance (microhm)	REPORTED HART & FULLER,1974	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	DATA OBSERVED IN STUDY	30-14500	30-14500	30-14500	30-14500	30-14500	30-14500	30-14500	30-14500	30-14500	30-14500	30-14500	30-14500	30-14500	30-14500	30-14500	30-14500	30-14500	30-14500	30-14500	30-14500
Bicarbonate (mg/L)	REPORTED HART & FULLER,1974	N/A	4-213	N/A	N/A	0-206	0-220	N/A	N/A	0-61	0-61	N/A	N/A	N/A	9-20	61-205	N/A	20-360	N/A	N/A	N/A
	DATA OBSERVED IN STUDY	5-788	5-788	5-788	5-788	5-788	5-788	5-788	5-788	5-788	5-788	5-788	5-788	5-788	5-788	5-788	5-788	5-788	5-788	5-788	5-788
Sulfate (mg/L)	REPORTED HART & FULLER,1974	<1.0-313.0	<1.0-450	<1.0-570.0	22.1-370.0	<1.0-450	13.5-370	N/A	N/A	25-322	25-322	<1.0-370.0	N/A	N/A	2.3-2.5	13.3-450	<1.0-370.0	N/A	N/A	2.0-227.8	N/A
	DATA OBSERVED IN STUDY	1.0-2500	1.0-2500	1.0-2500	1.0-2500	1.0-2500	1.0-2500	1.0-2500	1.0-2500	1.0-2500	1.0-2500	1.0-2500	1.0-2500	1.0-2500	1.0-2500	1.0-2500	1.0-2500	1.0-2500	1.0-2500	1.0-2500	1.0-2500
Iron (ug/L)	REPORTED HART & FULLER,1974	<0.01-0.60	<01-2.89	<0.01-2.20	<0.01-0.30	<.01-16.1	0.32-8.75	N/A	N/A	0.74-2.89	0.74-2.89	<0.01-2.89	N/A	N/A	0.3-0.1	<0.01-2.9	0.03-16.10	N/A	N/A	<0.01-0.86	N/A
	DATA OBSERVED IN STUDY	0-27000	0-27000	0-27000	0-27000	0-27000	0-27000	0-27000	0-27000	0-27000	0-27000	0-27000	0-27000	0-27000	0-27000	0-27000	0-27000	0-27000	0-27000	0-27000	0-27000
Mn (ug/L)	REPORTED HART & FULLER,1974	N/A	<1-43	N/A	N/A	N/A	1-11.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	DATA OBSERVED IN STUDY	0-4900	0-4900	0-4900	0-4900	0-4900	0-4900	0-4900	0-4900	0-4900	0-4900	0-4900	0-4900	0-4900	0-4900	0-4900	0-4900	0-4900	0-4900	0-4900	0-4900
pH (units)	REPORTED HART & FULLER,1974	5.5-8.4	5.5-8.8	5.5-8.8	7.6-8.4	3.0-8.8	N/A	N/A	N/A	4.4-7.3	4.4-7.3	5.6-8.8	N/A	N/A	6.3-6.9	5.9-8.5	3.3-8.8	6.7-9.0	N/A	6.5-7.8	N/A
	DATA OBSERVED IN STUDY	3.3-9.2	3.3-9.2	3.3-9.2	3.3-9.2	3.3-9.2	3.3-9.2	3.3-9.2	3.3-9.2	3.3-9.2	3.3-9.2	3.3-9.2	3.3-9.2	3.3-9.2	3.3-9.2	3.3-9.2	3.3-9.2	3.3-9.2	3.3-9.2	3.3-9.2	3.3-9.2
Carbonate (mg/L)	REPORTED HART & FULLER,1974	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3.0-42	N/A	N/A	N/A
	DATA OBSERVED IN STUDY	0-17	0-17	0-17	0-17	0-17	0-17	0-17	0-17	0-17	0-17	0-17	0-17	0-17	0-17	0-17	0-17	0-17	0-17	0-17	0-17
Temperature (deg.C.)	REPORTED HART & FULLER,1974	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0-30	N/A	N/A	N/A
	DATA OBSERVED IN STUDY	0-29.5	0-29.5	0-29.5	0-29.5	0-29.5	0-29.5	0-29.5	0-29.5	0-29.5	0-29.5	0-29.5	0-29.5	0-29.5	0-29.5	0-29.5	0-29.5	0-29.5	0-29.5	0-29.5	0-29.5

Figure 6.2-1 Chemical tolerance range for benthic invertebrates in Area 4.

Aquatic Communities of Area 4 Shown in Model

Conceptual model shows changing habitat characteristics associated with coal mining development.

Figure 6.3-1 shows a conceptual model of benthic invertebrates and its relation to land use in Area 4 during late autumn.

The conceptual model shows three aquatic communities associated with underground coal mines. A on figure 6.3-1 shows the aquatic community found in streams draining unmined areas. B on figure 6.3-1 shows the aquatic community found in streams draining currently mined areas. C in figure 6.3-1 shows the aquatic community in streams draining abandoned underground mine areas.

Hart and Fuller (1974) reported the chemical tollerance range for benthic invertebrates. Appendix 3 shows the observed chemical ranges that were collected for streams that drain coal regions in Area 4 to benthic invertebrates on the conceptual model by use of figure 6.2-1.

The caddisflies, *Hydropsyche*, were the most abundant benthic invertebrates found in streams draining Area 4. *Hydropsyche* are found in trailing algal mats and submerged vegetation below riffle areas. According to Pennak (1953), these caddisflies are widely distributed and are an excellent indicator of clean water receiving small amounts of sewage effluent. The midges, *Chironomus*, were the second most abundant benthic invertebrate and were found in pondlike habitats with deep sediment deposits. *Chironomus* are usually collected below sewage outfalls.

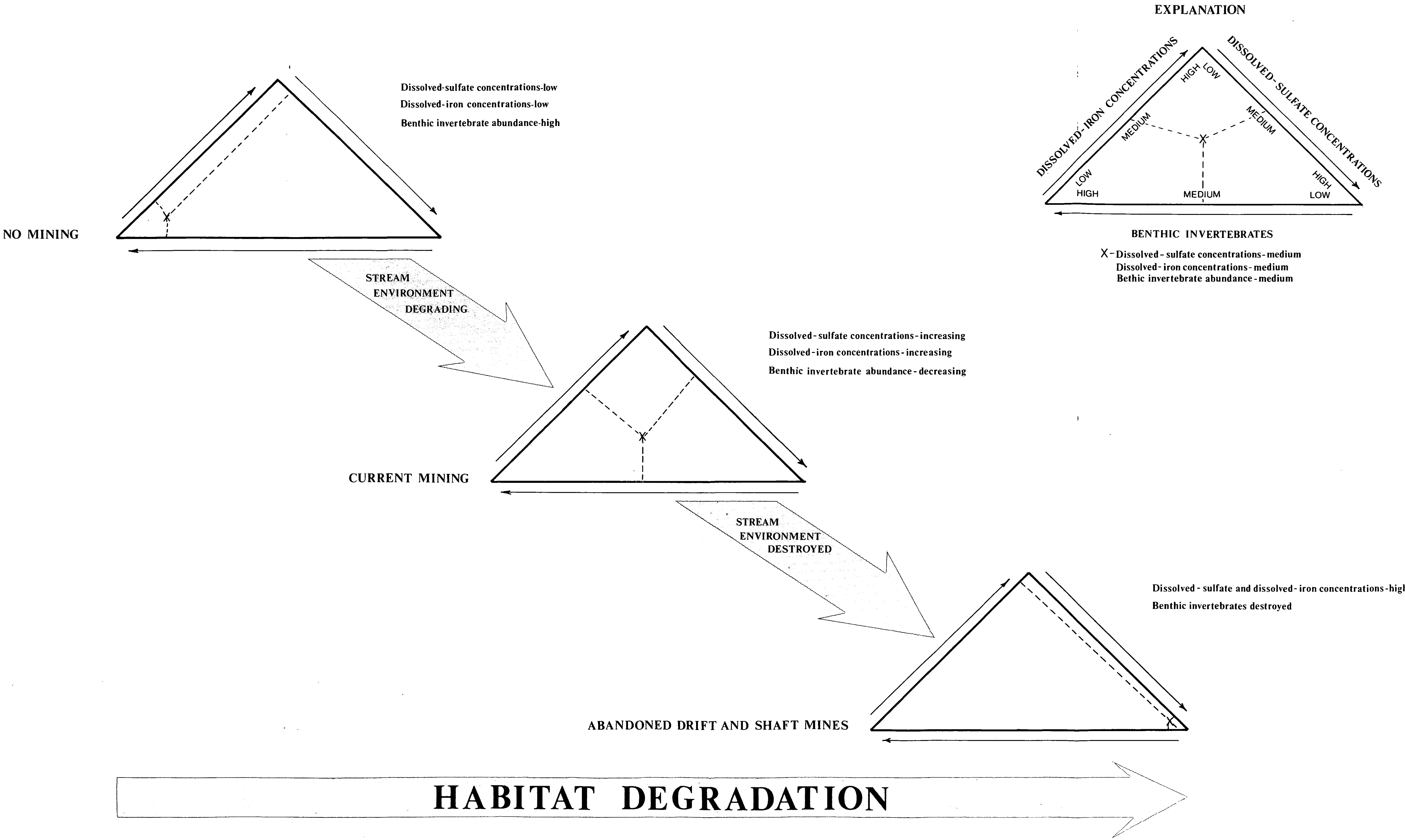


Figure 6.3-1 Conceptual model showing habitat degradation from underground mining.

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.

NAWDEX 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 figure 7.1-1). A free directory is available 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).)

A variety of user services are provided by NAWDEX and are available to any organization or individual. These include assistance in identifying and locating needed water data and referring the requester to the organization that retains the data required. A computerized Master Water Data Index is maintained (figure 7.1-2), 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 (figure 7.1-3) is also 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 instances, charges assessed by NAWDEX Assistance Centers will not exceed the direct costs incurred in responding to the data request. Estimates of cost are provided by NAWDEX upon request and in all cases where costs are anticipated to be substantial.

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

Program Office
National Water Data Exchange (NAWDEX)
U.S. Geological Survey
421 National Center
12201 Sunrise Valley Drive
Reston, VA 22092

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

Hours: 7:45 - 4:15 Eastern Time

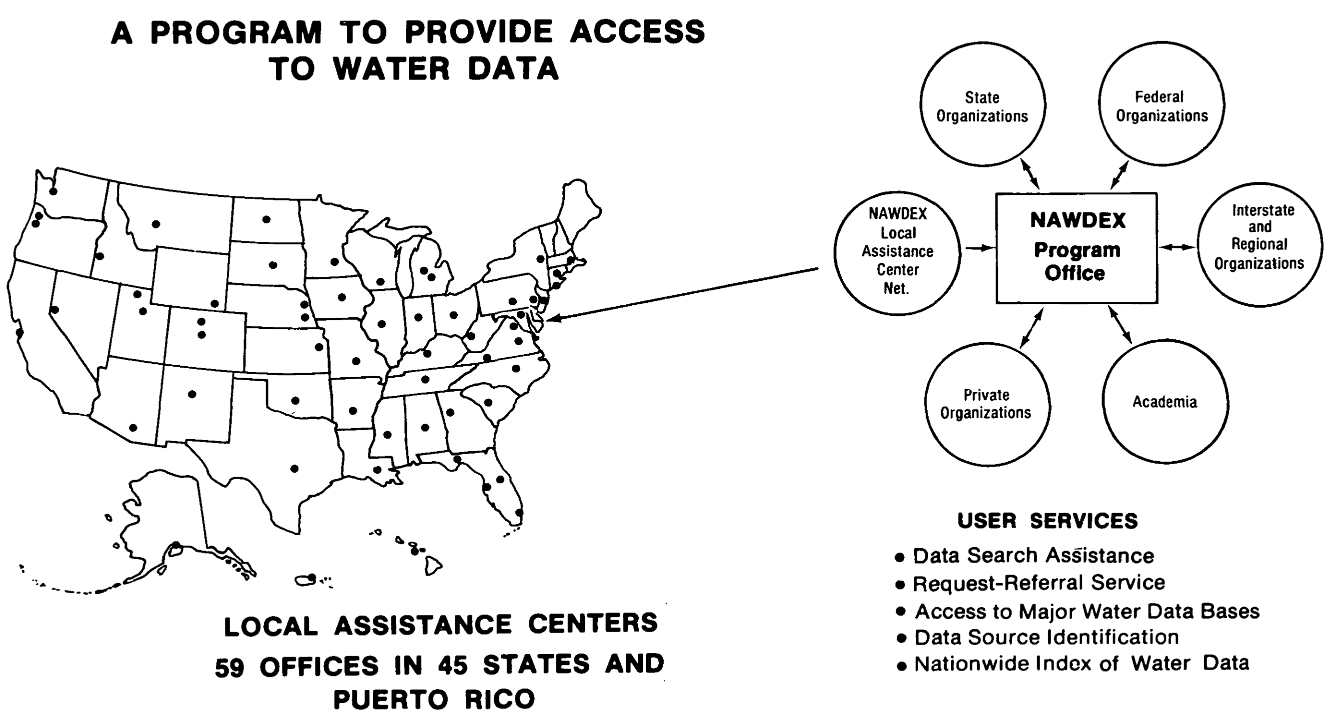


Figure 7.1-1 Access to water data

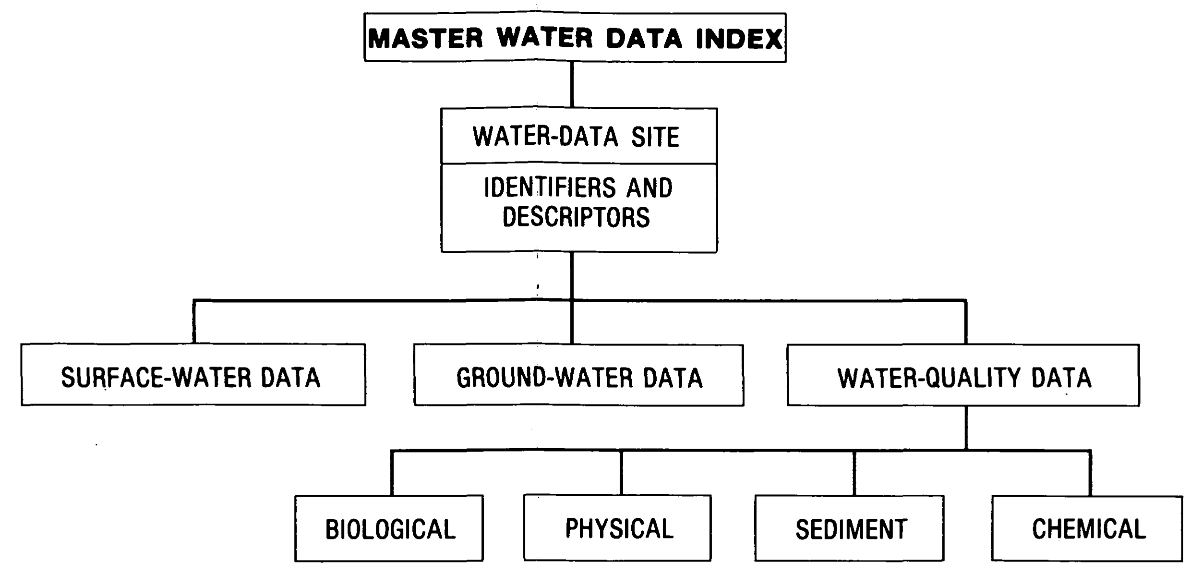


Figure 7.1-2 Master water-data index

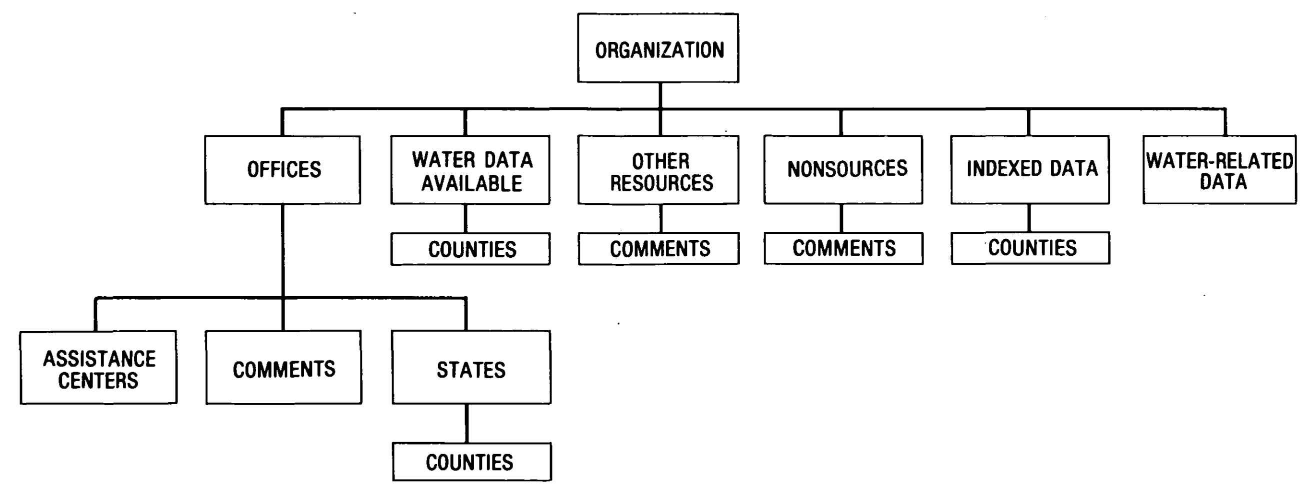


Figure 7.1-3 Water data sources directory

Data for Area 4 Available in District Office

Water-data information for Area 4 may be obtained by contacting District Offices in Ohio, Pennsylvania and West Virginia.

Location of stations and sites in Area 4 are found in Appendix 1 and Appendix 2 of this report. Range of chemical constituents found in selected streams in Area 4 are listed in Appendix 3 of this report. Discharge, chemical, sediment, and biological data collected at coal sites are found in 1979 WY Water Resources Data reports for Ohio (Appendix A); for Pennsylvania (Volume 4); and West Virginia (Volume 2). For information on these reports contact the appropriate state U.S. Geological District office listed below:

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

or

U.S. Geological Survey
Water Resources Division
Post Office Box 1107
4th Floor, Federal Bldg.
228 Walnut Street
Harrisburg, PA 17108

or

U.S. Geological Survey
Water Resources Division
Room 3017, Federal Bldg. and
U.S. Courthouse
500 Quarrier Street, East
Charleston, W.VA 25301

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Appendix 1. Coal Hydrology Sites.

(See location map figure 3.1-1; data collected were published in "Water Resources Data, Water Year 1979" reports for Ohio, Pennsylvania, and West Virginia.)

Sites: Synoptic is a partial-record site at which chemical, discharge, and biological data were collected during high and low flow. Those marked by an asterisk (*) were also called event sites which were partial-record sites where suspended sediment data were collected at peak flows.

Trend is a continuous record station at which more frequent and comprehensive sediment, chemical, discharge, and biological data were collected in an area disturbed by mining.

Upgraded is a continuous record station where more frequent collections of chemical, discharge, and biological data were made for this project.

Type and period of record: Discharge and chemical quality data collected twice a year; biological data collected once a year since 1979.

Sites	Station number	Latitude/Longitude	Station name	Drainage area (mi^2)
			Synoptic Sites	
1	03085237	40 14 26 080 12 31	Chartiers C at Houston, PA	54.5
2	03085240	40 14 54 080 12 39	Chartiers Rn at Houston, PA	22.3
3	03085300	40 14 14 080 08 20	Little Chartiers C at Linden, PA	37.0
4	03085497	40 23 38 080 06 40	Robinson Rn at Ewingsville, PA	40.2
5	03085950	40 30 46 080 05 30	Lowries Rn at Emsworth, PA	16.3
6	03085960	40 30 18 080 08 42	Montour C at Coraopolis, PA	36.2
7	03086400	40 40 52 080 13 20	Crows Rn nr Freedom, PA	10.5
8	03102500	40 25 19 080 22 35	Little Shenango R at Greenville, PA	104
9	03102810	41 21 52 080 24 30	Big Rn nr Reynolds Heights, PA	26.3
10	03104100	41 10 55 080 27 20	Hogback Rn at West Middlesex, PA	7.38
11	03104550	41 13 34 080 13 28	Otter C at Mercer, PA	48.7
12	03104584	41 15 00 080 10 21	Yellow C nr Jackson Center, PA	21.1
13	03104900	41 05 21 080 18 58	L Neshannock C nr Neshannock Falls, PA	50.4
14	03104996	41 02 21 080 17 42	Hottenbaugh Rn at Eastbrook, PA	13.3
15	03105248	40 59 04 080 21 00	Big Run at New Castle, PA	28.5
16	03105700	40 52 34 079 51 02	Bonnie Bk at East Butler, PA	18.1
17	03105808	40 48 18 079 57 14	Thorn C at Renfrew, PA	42.3
18	03105845	40 44 22 079 58 34	Glade Rn nr Glade Mills, PA	16.8
19	03105920	40 47 38 080 05 39	Breakneck C at Eidenau, PA	41.5
20	03105930	40 49 26 080 05 52	L Connoquenessing C nr Harmony, PA	45.3
21	03105938	40 51 20 080 06 03	L Yellow C nr Middle Lancaster, PA	5.15
22	03105995	40 48 32 080 12 05	Camp Rn at Fombell, PA	14.8
23	03106018	40 48 14 080 14 27	Brush C nr Hazen, PA	42.8
24	03106030	41 06 34 079 54 30	Slippery Rock C at Boyers, PA	28.4
25	03106035	41 06 00 079 55 59	N B Slippery Rock C at Alwells Crossing, PA	16.1
26	03106040	41 05 11 079 58 03	McMurray Rn nr Branchton, PA	12.6
27	03106045	41 03 43 079 57 52	S B Slippery Rock C nr Branchton, PA	38.8
28	03106108	41 12 33 080 02 18	E B Wolf C nr Grove City, PA	13.8
29	03106160	41 02 06 080 08 29	Jamison Rn at Elliot Mills, PA	12.8
30	03106300	40 57 47 080 07 41	Muddy C nr Portersville, PA	51.2
31	03107600	40 23 01 080 22 05	Raccoon C at Raccoon, PA	18.9
32	03107612	40 43 57 080 20 11	Brady Rn at Patterson Heights, PA	8.45
33	03107711	40 30 26 080 22 42	Traverse C below Raccoon C State Park Dam, PA	19.5
34	03107800	40 34 10 080 24 07	Service C nr Shippingport, PA	4.50
35	03109380	40 52 50 080 28 02	Honey C nr Enon Valley, PA	0.30
36	03110812	40 25 26 080 29 22	Kings C nr Florence, PA	7.10
37	03110825	40 29 24 080 30 38	N Fork at Hughes Lake, PA	7.14
38	03110920	40 21 56 080 30 34	Harmon C nr Hanlin Station, PA	19.9
39	03111003	40 15 04 080 24 49	Cross C nr Evella, PA	10.1
40	03111005	40 16 38 080 27 41	N Fk Cross C at Avella, PA	16.3
114	394403080345039	39 44 03 080 34 50	J11.0 W V Fk Fish C at Hwy 89 bridge at Bannen, WV	86.4
113	394533080334839	39 45 33 080 33 48	J10.0 Penn Fk Fish C at U.S. 250 bridge at Bellton, WV	43.3
116	394624080563600	39 46 24 080 56 36	041 Ackerson Rn nr Cameron, OH	6.47
117	394627080561900	39 46 27 080 56 19	041 Paine Rn nr Cameron, OH	7.90
118	394645081004100	39 46 45 081 00 41	041 Piney F nr Woodsfield, OH	15.2
119	394706081082000	39 47 06 081 08 20	041 Wheeler Rn nr Woodsfield, OH	6.95
115	394713080445839	39 47 13 080 44 58	J12.0 Whetstone C at Hwy 74/1 bridge nr Meighen, WV	15.0
122	394827081065300	39 48 27 081 06 53	041 Baker F nr Woodsfield, OH	8.09
111	395005080360239	39 50 05 080 36 02	J08.0 Grave C at Hwy 62 bridge at Loudenville, WV	7.50
129	395201080514000	39 52 01 080 51 40	041 Cat Rn nr Powhattan Point, OH	12.1
136	395333080541300	39 53 33 080 54 13	041 Pea Vine C nr Armstrongs Mills, OH	9.79
138	395419081044800	39 54 19 081 04 48	041 S Fk Captina C nr Somerton, OH	33.3
141	395441081000000	39 54 41 081 00 00	041 Piney C nr Armstrongs Mills, OH	9.92
112	395447080434239	39 54 47 080 43 42	J09.0 M Grave C at Hwy 54 bridge at Moundsville, WV	28.4
144	395550080505900	39 55 50 080 50 59	041 Pipe C nr Jacobsburg, OH	8.06
145*	395618080592700	39 56 18 080 59 27	041 Bend F nr Armstrongs Mills, OH	19.8
146	395639081083200	39 56 39 081 08 32	041 Unnamed stream nr Barnesville, OH	2.89
148*	395709081062900	39 57 09 081 06 29	041 Long Rn nr Barnesville, OH	6.53
110	395717080443539	39 57 17 080 44 35	J07.0 L Grave C at Hwy 10 bridge at Glendale Height, WV	10.7
149	395727080461400	39 57 27 080 46 14	041 Wegee C nr Shadyside, OH	9.91
106	395744080352939	39 57 44 080 35 29	J03.0 Wheeling C at Hwy 7 bridge at Viola, WV	181
154	400013080533000	40 00 13 080 53 30	041 Williams C at Glenco, OH	12.3
157	400225080504100	40 02 25 080 50 41	041 L McMahon C nr Neffs, OH	11.1
108	400235080373639	40 02 35 080 37 36	J05.0 M Wheeling C 1/4 mi U.S. 170 bridge Triadelphia, WV	33.8
109	400240080394039	40 02 40 080 39 40	J06.0 Wheeling C at Elm Grove, WV	232

Sites	Station number	Latitude/Longitude	Station name	Drainage area (mi^2)
			Synoptic Sites--Continued	
107	400326080371039	40 03 26 080 37 10	J04.0 L Wheeling C at U.S. 40 bridge at triadelphia, WV	19.8
160	400402080460200	40 04 02 080 46 02	041 Wheeling C nr Lansing, OH	105
164	400710080430900	40 07 10 080 43 09	041 Glenns Rn nr Martins Ferry, OH	8.82
105	400908080385939	40 09 08 080 38 59	J02.0 Short C at Hwy 1 bridge nr Clearview, WV	16.5
172	401104080423000	40 11 04 080 42 30	041 L Short C nr Tiltonsville, OH	17.6
174	401211080462100	40 12 11 080 46 21	041 Piney F at Dillonvale, OH	22.2
175	401227080551201	40 12 27 080 55 12	041 S F Short C at Georgetown, OH	9.64
176	401247080532800	40 12 47 080 53 28	041 M F Short C nr Adena, OH	24.3
178	401313080401800	40 13 13 080 40 18	041 Rush Rn nr Tiltonsville, OH	12.3
179	401314080522300	40 13 14 080 52 23	041 N F Short C at Adena, OH	22.1
104	401436080355039	40 14 36 080 35 50	J01.0 Buffalo C at Hwy 27/4 bridge at McKinleyville, WV	53.3
187	401803080410400	40 18 03 080 41 04	041 McIntyre C nr Mingo Junction, OH	24.2
103	401823080335739	40 18 23 080 33 57	I04.0 Cross C at Hwy 7/6 bridge at Louise, WV	70.6
201	402214080474600	40 22 14 080 47 46	041 Salem C nr Bloomingdale, OH	15.2
202	402245080532300	40 22 45 080 53 23	041 N B Cross C nr Hopedale, OH	5.00
203	402258080455800	40 22 58 080 45 58	041 Cedar Lick C nr Richmond, OH	5.56
204	402309080401000	40 23 09 080 40 10	041 Wills C at Steubenville, OH	5.46
102	402333080340739	40 23 33 080 34 07	I02.0 Harmon C at Hwy 1 bridge at Weirton, WV	32.3
101	402608080353439	40 26 08 080 35 34	I02.0 Kings C at Hwy 11/5 bridge at Weirton, WV	49.0
210	402610080375700	40 26 10 080 37 57	041 Island C nr Toronoto, OH	22.5
211	402705080565600	40 27 05 080 56 56	041 Elk Lick nr Amsterdam, OH	5.01
218	403001080474700	40 30 01 080 47 47	041 Long Rn nr East Springfield, OH	6.51
221	403102080435200	40 31 02 080 43 52	041 Town F nr Hammondsville, OH	25.9
223	403133080560800	40 31 33 080 56 08	041 Strawcamp Rn nr Bergholz, OH	4.98
224*	403144080585500	40 31 44 080 58 55	041 Center F nr Harlem Springs, OH	10.2
225	403150080531200	40 31 50 080 53 12	041 Upper N F at Bergholz, OH	18.7
100	403253080354639	40 32 53 080 35 46	I01.0 Tomlinson Run at Hwy 3 bridge in State Park, WV	23.4
227	403257080430600	40 32 57 080 43 06	041 Brush C at Hammondsville, OH	15.3
234	403715080391400	40 37 15 080 39 14	041 L Yellow C nr Wellsville, OH	22.0
235	403724080500700	40 37 24 080 50 07	041 Riley Rn at Salineville, OH	16.7
244	404140080351100	40 41 40 080 35 11	041 Longs Rn nr Calcutta, OH	13.1
246	404206080520000	40 42 06 080 52 00	041 Williard Rn nr Lisbon, OH	6.31
249	404254080324000	40 42 54 080 32 40	041 N F L Beaver C at Fredericktown, OH	193
252	404423080502900	40 44 23 080 50 29	041 Cold Rn nr Lisbon, OH	31.7
258	404544080415400	40 45 44 080 41 54	041 Elk Rn at Elkton, OH	11.2
259	404554080301700	40 45 54 080 30 17	041 Brush Rn nr Negley, OH	12.6
260	404629080453500	40 46 29 080 45 35	041 Lisbon C at Lisbon, OH	6.61
261	404655080455301	40 46 55 080 45 53	041 Lisbon C at Lisbon, OH	6.18
262	404722080325700	40 47 22 080 32 57	041 Leslie Rn nr Negley, OH	13.7
263	404756080355800	40 47 56 080 35 58	041 L Bull C nr Rogers, OH	15.0
272	405035080592300	40 50 35 080 59 23	041 Unnamed C at N Georgetown, OH	9.44
274	405128081011500	40 51 28 081 01 15	041 Beaver Rn nr Homeworth, OH	4.91
275	405116080593900	40 51 16 080 59 39	041 Unnamed C nr N Georgetown, OH	10.2
276	405233080452401	40 52 33 080 45 24	041 Cherry Valley Rn at Leetonia, OH	11.8
277	405322081004400	40 53 22 081 00 44	041 Naylor D nr Sebring, OH	3.96
278	405405080583200	40 54 05 080 58 32	041 Naylor D nr Damascus, OH	4.83
281	405606081082200	40 56 06 081 08 22	041 Beech C nr Alliance, OH	17.7
287	405823081004700	40 58 23 081 00 47	041 Island C nr N Benton, OH	4.89
289	405843081094600	40 58 43 081 09 46	041 Deer C nr Limaville, OH	32.5
291	405926080345800	40 59 26 080 34 58	041 Burgess Rn nr New Middletown, OH	2.34
292	410001080580701	41 00 01 080 58 07	041 Mill C nr Berlin Center, OH	19.0
293	410010080363700	41 00 10 080 36 37	041 Burgess Rn at Poland, OH	7.32
295	410049080512800	41 00 49 080 51 28	041 W B Meander C at Ellsworth, OH	7.09
296	410128080415700	41 01 28 080 41 57	041 Indian Rn nr Broadman, OH	14.3
297	410128080571600	41 01 28 080 57 16	041 Turkey Broth C at Berlin Center, OH	5.45
304	410705080512000	41 07 05 080 51 20	041 Morrison Rn nr N Jackson, OH	5.46
305	410715080440500	41 07 15 080 44 05	041 Fourmile Rn at Wickliffe, OH	2.59
306	410720080380801	41 07 20 080 38 08	041 Crab C at Youngstown, OH	14.0
308	410823080594301	41 08 23 080 59 43	041 Kale C nr Newton Falls, OH	21.9
309	410916081085101	41 09 16 081 08 51	041 Hinkley C at Charlestown, OH	7.85
310	411034080481800	41 10 34 080 48 18	041 Mud C nr Niles, OH	13.3
311	410554081111500	41 05 54 081 11 15	041 Barrel Rn nr Rootstown, OH	9.53
312	411249080525100	41 12 49 080 52 51	041 L Duck C nr Leavittsburg, OH	4.09
313	411738081072700	41 17 38 081 07 27	041 Silver C nr Garrettsville, OH	9.00
314	411807081032600	41 18 07 081 03 26	041 Tinker C nr Garrettsville, OH	4.35
315	411836081055000	41 18 36 081 05 50	041 Camp C nr Garrettsville, OH	3.96
			Trend Station	
A	03111500	40 11 36 080 44 04	Short C nr Dillonvale, OH	123
			Upgraded Stations	
B	03109500	40 40 33 080 32 27	L Beaver C nr E Liverpool, OH	496
C	03110000	40 32 16 080 43 31	Yellow C nr Hammondsville, OH	147
D	03114000	39 54 31 080 55 27	Captina C nr Armstrong Mills, OH	134

Appendix 2. Existing Surface Water Stations in Area 4.

(See U.S. Geological Survey, Water Resources Data reports of years included for Ohio, Pennsylvania, and West Virginia for data collected.)

Sites: Continuous record is a site where streamflow and (or) water-quality data are collected systematically over a period of years for use in hydrologic analyses.
Trend is a surface-water site at which more frequent and comprehensive sampling was done and was intended to show broad trends in areas disturbed by mining.
Upgraded is a continuous record station where more frequent collection of chemical, discharge, and biological data was collected for this project.

Station number	Latitude/Longitude	Station name	Drainage area (mi^2)	Type and period of record: Discharge	Chemical quality	Sediment	Biological
		Continuous Record Stations					
03091500	41 07 53 080 58 17	Mahoning R at Pricetown, OH	273	1929--	--	--	--
03086500	40 55 58 081 05 41	Mahoning R at Alliance, OH	89.2	1941--	--	--	--
03092090	41 09 41 081 11 50	W B Mahoning R nr Ravenna, OH	21.8	1965--	--	--	--
03092500	41 10 18 081 01 16	W B Mahoning R nr Newton Falls, OH	96.3	1926--	--	--	--
03093000	41 15 40 080 57 16	Eagle C at Phalanx Station, OH	97.6	1952-53, 1967-68	1967--	--	--
03093800	41 14 22 080 52 56	Mahoning R above Duck C at Leavittsburg, OH	542	1968--	--	--	--
03094000	41 14 21 080 52 51	Mahoning R at Leavittsburg, OH	575	1940--	--	--	--
03098000	41 06 40 080 40 23	Mahoning R at Youngstown, OH	898	1921--	--	--	--
03099500	41 02 12 080 32 11	Mahoning R at Lowellville, OH	1,073	1942--	--	--	--
03099510	41 01 53 080 31 10	Mahoning R at OH-PA state line below Lowellville, OH	1,075	1967--	1967--	--	--
03102950	41 52 34 080 35 18	Pymatuning C at Kinsman, OH	96.7	1965--	--	--	--
03109320	40 47 33 080 31 20	Stateline C nr Negley, OH	3.09	1977-78	1977-78	--	--
03110830	40 26 08 080 35 34	Kings C at Weirton, WV	49.0	1976-78	1977-78	1977-78	1977-78
03110815	40 25 36 080 30 43	Kings C nr Paris, PA	10.0	1976-78	1976-78	--	1976-78
03110820	40 25 39 080 30 43	Aunt Clara Fk nr Paris, PA	14.2	1976-78	1976-78	--	1976-78
03112000	40 02 40 080 39 40	Wheeling C at Elm Grove, WV	282	1940--	--	--	--
03112510	40 00 54 080 44 20	Ohio R at Benwood nr Wheeling, WV	25,070	1977-78	1977-78	1977-78	1977-78
03113706	39 55 45 080 44 54	L Grave C at Moundsville, WV	11.9	1977-78	1977-78	1977-78	1977-78
03113708	39 55 35 080 44 34	Par Run at Moundsville, WV	1.30	1977-78	1977-78	1977-78	1977-78
03113732	39 53 07 080 38 29	M Grave C at Knoxville, WV	7.73	1977-78	1977-78	--	1977-78
03113738	39 54 46 080 43 43	M Grave C at Moundsville, WV	28.6	1977-78	1977-78	1977-78	1977-78
03102500	41 25 19 080 22 35	L Shenango R at Greenville, PA	104	1913--	1975--	--	--
03102850	41 21 13 080 23 53	Shenango R nr Transfer, PA	337	1965--	--	--	--
03103500	41 15 58 080 28 22	Shenango R at Sharpsville, PA	584	1938--	1975--	--	--
03104500	41 00 00 080 21 05	Shenango R at New Castle, PA	--	1975--	1975--	--	--
03104760	41 11 10 080 19 38	Harthegig Run nr Greenfield, PA	2.26	1965--	--	--	--
03105500	40 53 19 080 20 14	Beaver R at Wampum, PA	2,235	1914-18, 1933-40, 1946, 1951-52, 1960--	1970-73, 1975--	--	--
03105810	40 48 21 079 57 55	Connoquenessing C at Renfrew, PA	--	1975--	1975--	--	--
03106000	40 49 01 080 14 33	Connoquenessing C nr Zelienople, PA	356	1919--	1970-73, 1975--	--	--
03106153	41 02 11 080 06 32	Slippery Rock C at Moores Corners, PA	--	1976--	1976--	--	--
03106300	40 57 47 080 07 41	Muddy C nr Portersville, PA	51.2	1963--	--	--	--
03106500	40 53 02 080 14 02	Slippery Rock C at Wurtemburg, PA	398	1911--	1966, 1968, 1970-73, 1975--	--	--
03107500	40 45 48 080 18 55	Beaver R at Beaver Falls, PA	3,106	1935--	1966, 1972-73, 1975--	--	--
03107615	40 42 05 080 17 45	Beaver R at Rochester, PA	--	1975--	1975--	--	--
03108000	40 37 40 080 20 16	Raccoon C at Moffatts Mill, PA	178	1941--	1976--	--	--
03109390	40 51 28 080 26 27	L Beaver C at Enon Valley, PA	--	----	1975--	--	--
03109650	40 37 10 080 35 25	Ohio R at E Liverpool, OH-Newell, WV bridge	--	----	1975--	--	--
03111150	40 11 54 080 24 28	Brush Run nr Buffalo, PA	10.3	1960--	--	--	--
03085260	40 16 33 080 08 37	Chartiers C nr Cannonsburg, PA	--	----	1975--	--	--
03085500	40 24 02 080 05 48	Chartiers C at Carnegie, PA	257	1919-33, 1940--	1975--	--	--
03086000	40 31 53 080 11 21	Ohio R at Sewickley, PA	19,500	1933--	1945-47, 1956, 1961-73, 1975--	--	--
03086100	40 36 27 080 09 49	Big Sewickley C nr Ambridge, PA	15.6	1963-67, 1967--	--	--	--
03099600	41 01 06 080 26 27	Mahoning R at North Edinburg, PA	--	----	1975	--	--
		Trend Station					
03111500	40 11 36 080 44 04	Short C nr Dillonvale, OH	123	1941--	1964-77	1969-74	1979--
		Upgraded Stations					
03109500	40 40 33 080 32 27	L Beaver C nr E Liverpool, OH	496	1915--	1964-78, 1979--	1969-74	--
03110000	40 32 16 080 43 31	Yellow C nr Hammondsville, OH	147	1940--	1965-77, 1979--	1969-74	--
03114000	39 54 31 080 55 27	Captina C nr Armstrong Mills, OH	134	1926-35, 1958--	1965-77, 1979--	1969-74	--

Appendix 3. Chemical Ranges Found in Area 4.

Units of measure: mg/L, milligram per liter; ug/L, microgram per liter; °C, degrees Celsius

	Specific conductance (micromho/ cm at 25°C)	Bicar-bonate (mg/L)	Sulfate (mg/L)	Iron (ug/L)	Man-ganese (ug/L)	pH (units)	Car-bonate (mg/L)	Temper-ature (°C)
Ohio -------------	210-3,700	22-448	23-2,100	0-3,600	0-1,100	6.8-9.2	0-17	9.5-25.5
West Virginia ----	30-1,320	---	23-2,500	0-460	0-810	6.9-8.9	--	0-27
Pennsylvania -----	30-14,500	5-788	1.0-920	0-27,000	0-4,900	3.3-8.9	0-0	0-29.5
Range for Area 4 -	30-14,500	5-788	1.0-2,500	0-27,000	0-4,900	3.3-9.2	0-17	0-29.5

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