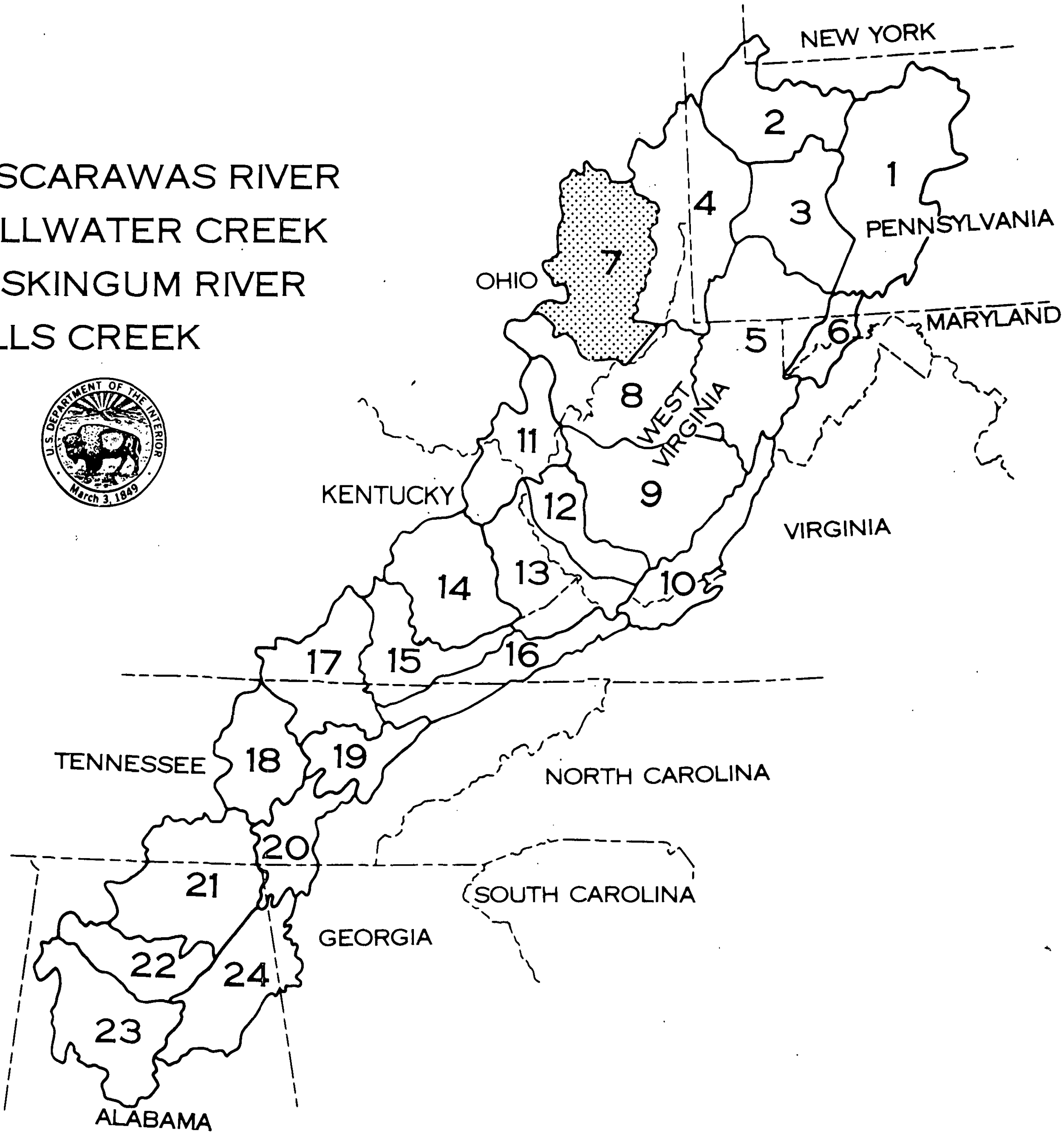
HYDROLOGY OF AREA 7, EASTERN COAL PROVINCE, OHIO

- TUSCARAWAS RIVER
- STILLWATER CREEK
- MUSKINGUM RIVER
- WILLS CREEK



UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

WATER-RESOURCES INVESTIGATIONS
OPEN-FILE REPORT 81-815

HYDROLOGY OF AREA 7, EASTERN COAL PROVINCE, OHIO

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

U.S. GEOLOGICAL SURVEY
WATER-RESOURCES INVESTIGATIONS 81-815

COLUMBUS, OHIO
AUGUST, 1981

UNITED STATES DEPARTMENT OF THE INTERIOR

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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
feet (ft)	0.3048	meters (m)
$feet^3$ (ft^3)	0.03531	liters (L)
$feet^3$ per second (ft^3/s)	0.02832	$meters^3$ per second (m^3)
miles (mi)	1.609	kilometers (km)

HYDROLOGY OF AREA 7, EASTERN COAL PROVINCE, OHIO

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

Abstract

The U.S. Geological Survey established 24 study areas in the Eastern Appalachian Coal Province to appraise the hydrology and water resources from Alabama to Pennsylvania. Chemical, physical, biological, and streamflow data were collected from 138 synoptic sites in Area 7, eastern Ohio. The data are evaluated and presented in this report. Area 7 lies within the drainage basins of Muskingum, Walhonding, Tuscarawas, and Little Muskingum Rivers and Duck and Wills Creeks in eastern Ohio. Walhonding, Tuscarawas, Little Muskingum, and Muskingum Rivers and Wills and Duck Creeks are the major streams draining the study area.

In Ohio, surface and subsurface coal mining has altered the environment. In areas where land has been reclaimed, the environmental stress is expected to be temporary. Hydrologic problems related to coal mining are erosion and sedimentation which degrade water-quality. Based on available sediment data, suspended sediment concentrations were highest in abandoned mine areas, followed by currently mined and reclaimed areas, and lowest in unmined areas.

Low pH, high specific conductance, high concentrations of iron, sulfate and manganese, increased sediment yields, discoloration of streambeds, limited aquatic vegetation and animal life typify streams draining areas with abandoned mines. In abandoned mine areas, the specific conductance of water ranged from 800 to 2,300 micromhos; pH ranged from 2.8 to 5.8; dissolved-iron concentrations ranged from 1,000 to 85,000 micrograms per liter; dissolved-sulfate concentrations ranged from 14 to 1,200 milligrams per liter and dissolved-manganese concentrations commonly exceeded 2,000 micrograms per liter. Red and yellow coloration on the streambeds were precipitates from the hydrolysis of iron, manganese, and sulfate minerals carried into the stream channel by increased sediment erosion from abandoned spoil tailings and drainage from abandoned coal mines. Trace metal concentrations (arsenic, cadmium, chromium, cobalt, copper, lead, mercury, selenium, and zinc) were generally low. Degradation of fish habitat is illustrated by a conceptual model of the aquatic biology related to water chemistry.

1.0 INTRODUCTION
1.1 Objective

Area 7 Submitted to Aid in the Permit Application Process

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. This report broadly characterizes the hydrology of Area 7 in eastern Ohio. 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.

1.0 INTRODUCTION

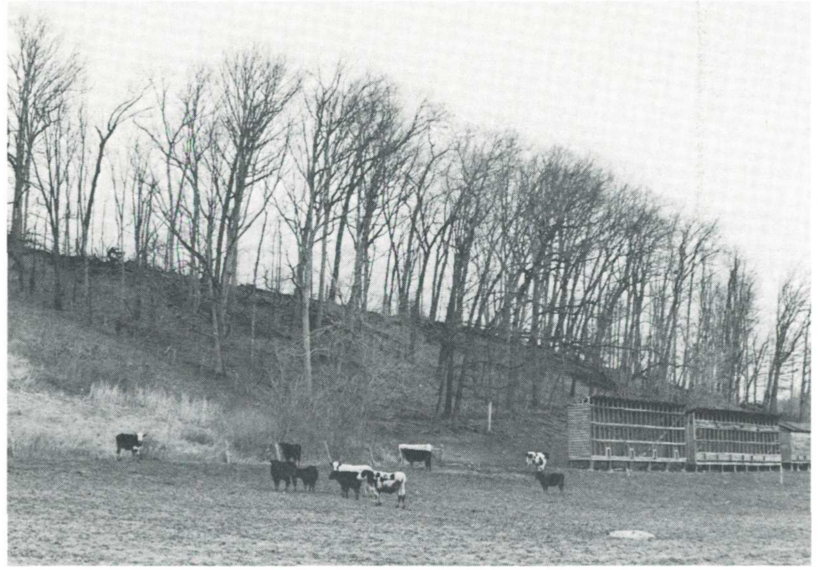
1.1 OBJECTIVE

Hydrology and Water Resources Described for Area 7 in Ohio

The hydrology and water resources of Area 7 are described for three different mining conditions as well as for unmined areas.

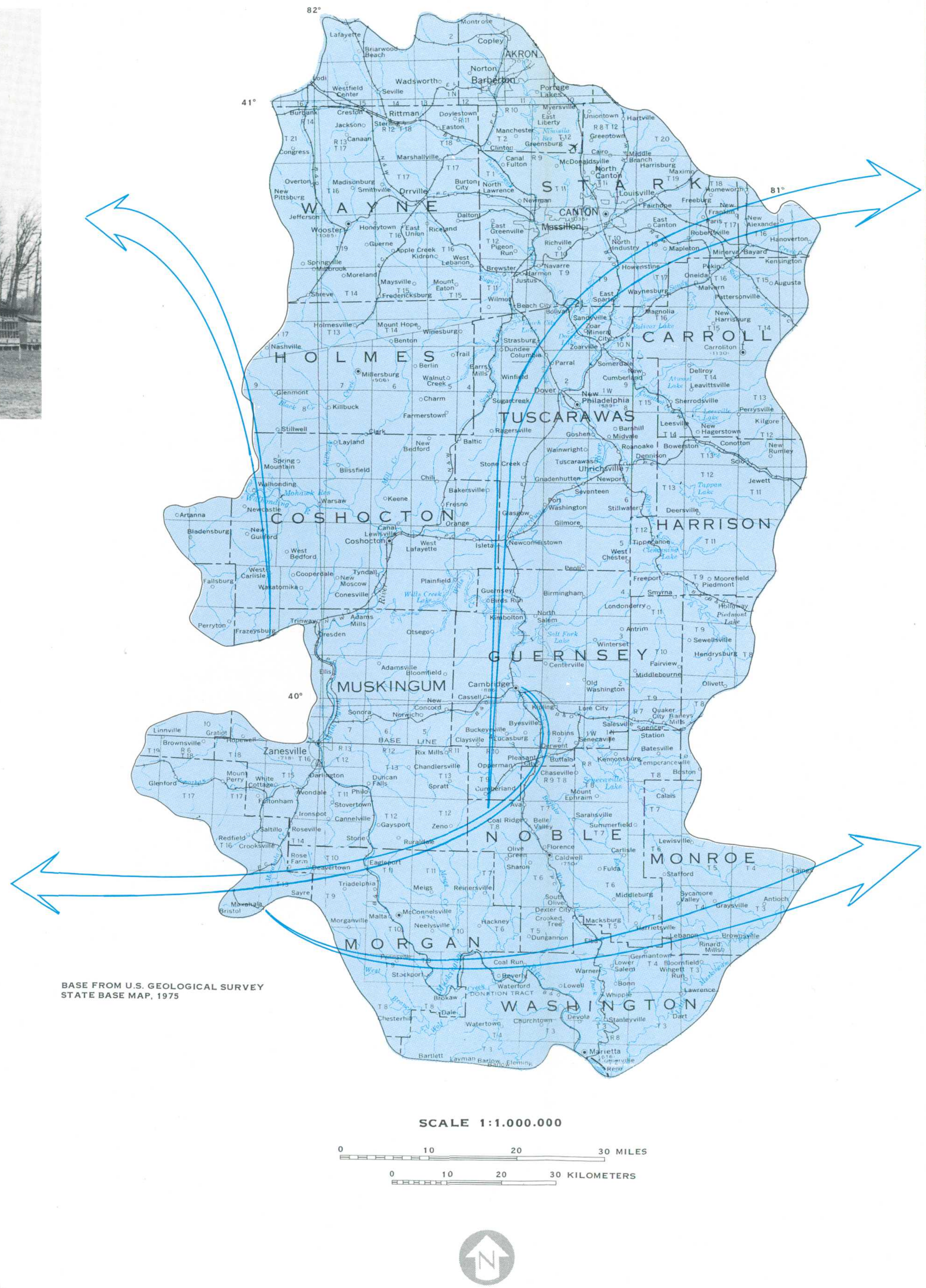
The U.S. Geological Survey in 1979 established a network of data-collection sites on streams in the Eastern Appalachian Coal Province to appraise the hydrology and water resources. The province was divided into 24 study areas. (See cover.) The results of the hydrologic study of streams of Area 7, eastern Ohio, are presented.

Four stream types, used to explain changes in water-quality from different environments, were: (1) Streams draining currently mined land; (2) streams draining previously mined land without land reclamation; (3) streams draining previously mined land with land reclamation; and (4) streams draining unmined land. Typical views of the study area (fig. 1.2-1) show various land use types.

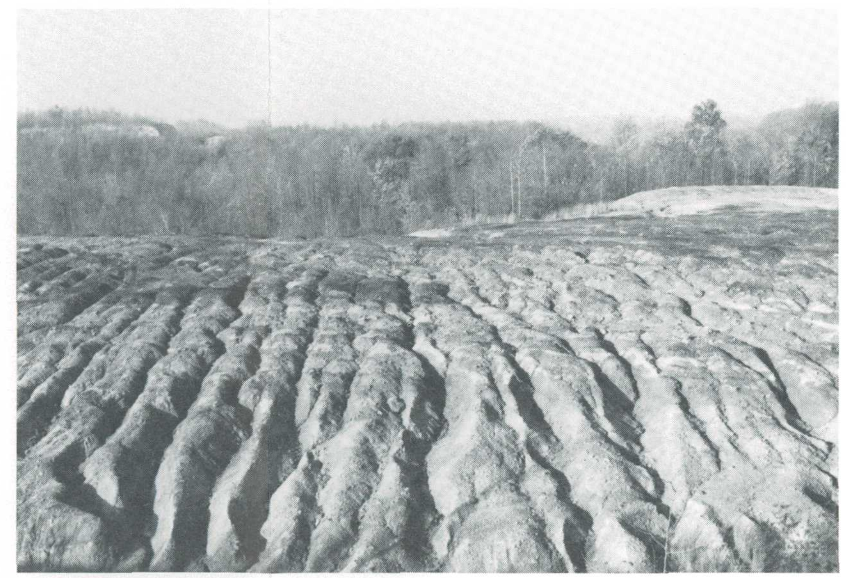


I. Unmined farmland near Frazeysburg, Ohio. View facing north.

II. Current coal strip mining south of Cumberland, Ohio. View facing east.



III. Mined land with reclamation near Cambridge, Ohio. View facing north.



IV. Abandoned strip mining area without reclamation near Moxahela, Ohio. View facing west.

Figure 1.2-1 Views of land use categories in study area.

Hydrologic Environment Can Be Adversely Affected by Drift, Shaft, and Strip Coal Mining

Increased erosion and sediment yields, degradation of biological and chemical water-quality typify problems associated with surface and sub-surface coal mining.

Surface and sub-surface coal mining has altered the environment of many streams in Ohio. In areas where land reclamation is practiced, the environmental stress, at present, has been temporary. But in areas where land has not been reclaimed, long-term environmental damage has occurred (Ohio Board on Unreclaimed Strip Mined Land, 1974). Mining operations such as land excavation, vegetation removal, and the accumulation of large pilings of spoil materials have resulted in increased erosion and sediment yields (Ohio Board on Unreclaimed Strip Mined Land, 1974).

Adverse effects related to coal strip mining in eastern Ohio include high erosion and sediment yields, increased concentrations of dissolved iron, manganese, zinc, sulfate, solids, and low pH. Photographs (figure 1.3-1) show examples of erosion and sediment deposition downstream from an abandoned strip mine. Sediment deposition has partly filled the stream channel and spilled onto farmlands causing loss of cropland and increased flooding due to channel filling. Increased sediment yields and chemical composition of water influenced by the weathering of exposed spoil pilings can adversely affect the stream aquatic environment. Aquatic organism habitats on stream substrates are covered by a fine coating of silt. As stream channels are filled with sediment the depth of water decreases and this results in decreased dissolved oxygen concentrations from warmer water temperatures. Stream channel effects include changes in the number of pools, undercut banks, piles of debris, and shade from streambank vegetation.

A.

EXPLANATION

A. Spoil from abandoned mine.

B. Aerial view of sediment movement.

C, D, and E. Stream channel downstream from abandoned strip mine. Channel has been filled and sediment has spilled into farmfields causing loss of cropland. At the edge of sediment deposition, marshes have formed. (Photos by Ohio Department Natural Resources, Division of Reclamation, 1978).

B.

C.

D.

E.

Figure 1.3 –1 Views of sediment deposition downstream from abandoneded strip mine.

Rocks of Three Geologic Systems Are Exposed in Area 7

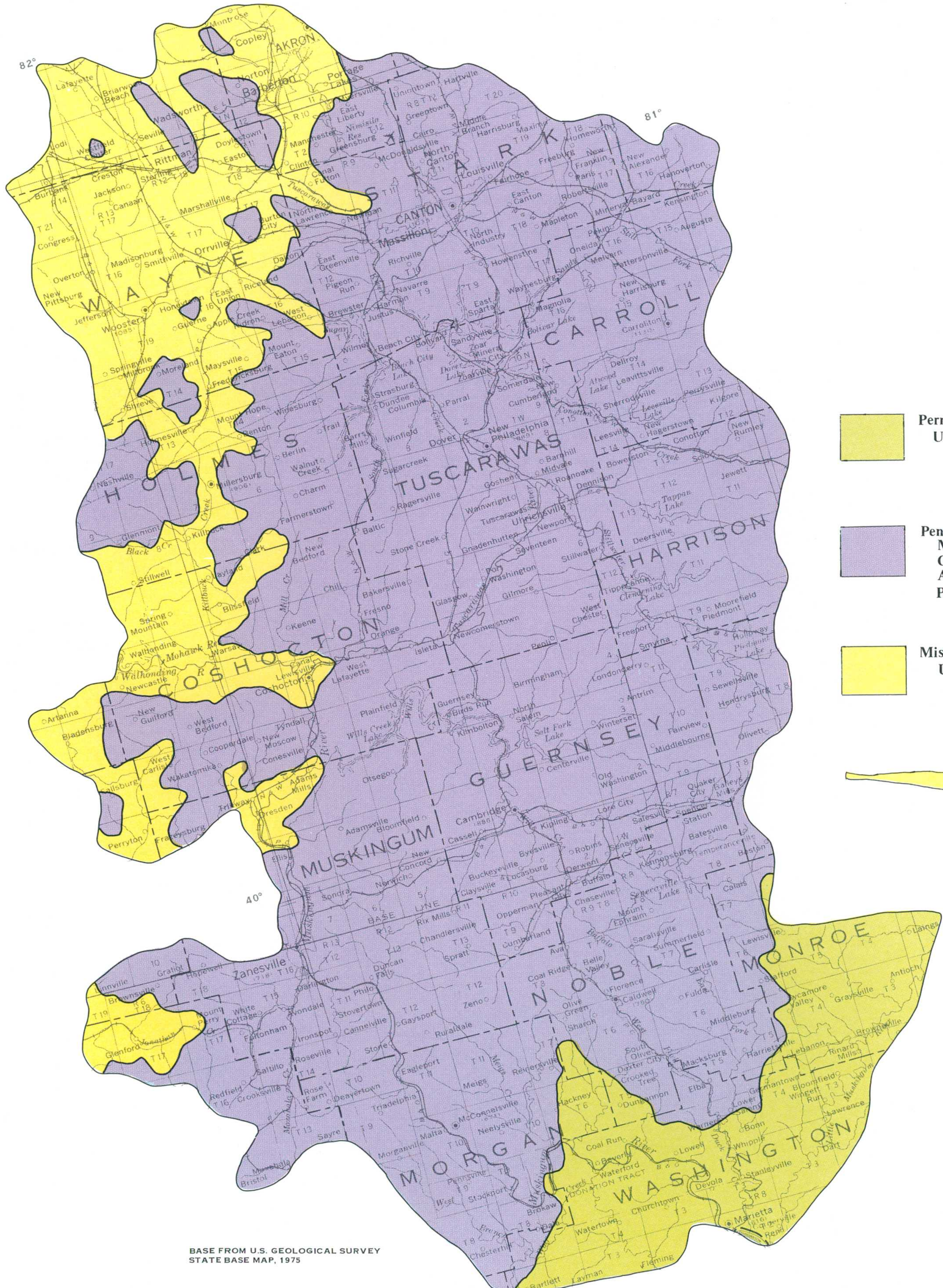
The strata exposed in Area 7 represent the Mississippian, Pennsylvanain, and Permian Systems.

The coal resources of Area 7 are found in the Pennsylvanian and Permian Systems, covering an area of approximately 6,720 square miles (figure 2.1-1). These two geologic systems have an average thickness of approximately 1,750 feet and contain the coal beds of Ohio (Collins, 1978). The vertical sequence of coal seams in the Pennsylvanian and Permian Systems is shown in figure 2.1-2.

The Pennsylvanian System consists of the Pottsville, Allegheny, Conemaugh, and Monongahela Formations and the lower part of the Dunkard Group, which unconformably overlie the Mississippian System. These formations consist of sandstone, shale, bituminous coal, and limestone, which crop out in northeast-southwest trending belts, and dip gently to the southeast approximately 30 feet per mile (Norling, 1958). The major coal fields in eastern Ohio are in the Pennsylvanian System, their distribution and thickness are shown in figure 2.1-2.

The Permian System is represented by part of the Dunkard Group, which crops out in the southeastern part of the area, and consists of sandstone, shale, and thin seams of coal. (See figure 2.1-2.) The only Permian coal seam in the area is the Washington Coal No. 12 which ranges in thickness from 2 inches to 3 feet. It has not been mined in Area 7 during the last decade (Brant and DeLong, 1969).

The Mississippian System is represented by the Cuyahoga and Logan Formations, which consist of massive sandstone, siltstone and shale. No coal deposits are in these formations, which crop out in the northwestern part of the area.



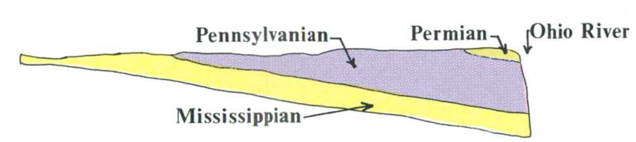
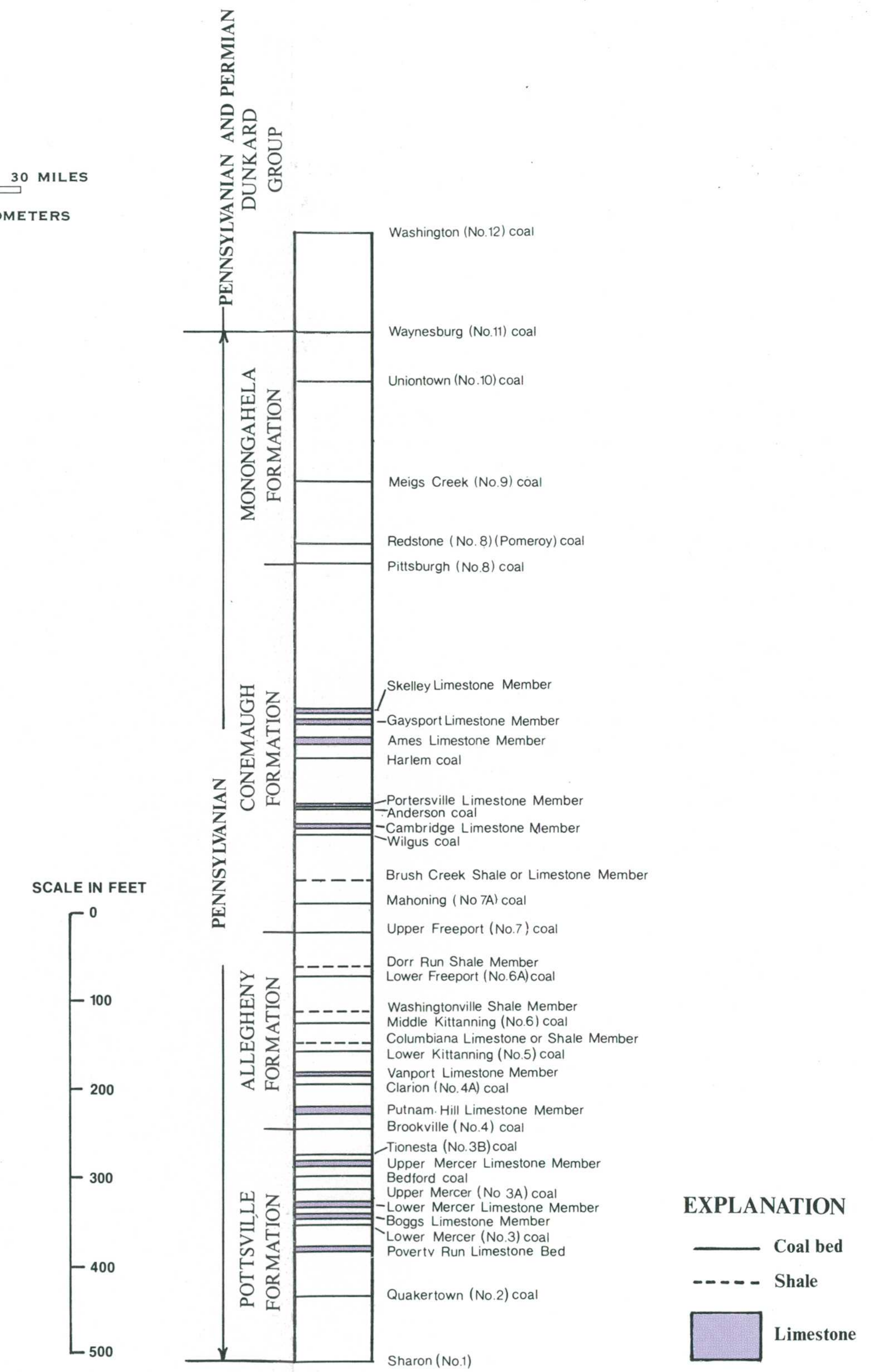


Figure 2.1-1 Geology of Area 7 (Bownocker, 1929).



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

Area Defined by Three Physiographic Provinces

Area 7 lies within three physiographic provinces: Central Allegheny Plateau, Western Allegheny Plateau, and the Eastern Ohio Till Plains. [1]

The central part of Area 7, underlain by the Pennsylvanian System and drained by the Tuscarawas and Muskingum Rivers, lies within the Western Allegheny Plateau (figure 2.2-1). Topographically, this part of the area is typified by flat narrow valley floors, rolling ridgetops, and hilly to steep ridge slopes with local relief of 100 to several hundred feet.

The southern part of the area, underlain by the Permian System and drained by the Little Muskingum River, Wills Creek and Duck Creek, lies in the Central Allegheny Plateau. This part is characterized by narrow valleys and narrow rolling ridgetops separated by long steep slopes with local relief in hundreds of feet.

Northwest of the Western Allegheny Plateau is the Eastern Ohio Till Plains, characterized by gentle to strong dissected plateaus with narrow but not deeply incised stream valleys with local relief of one to tens of feet (Anttila and Tobin, 1978). This area is drained by the Walhonding River and other tributaries to the Muskingum River.

[1] Bier, 1956.

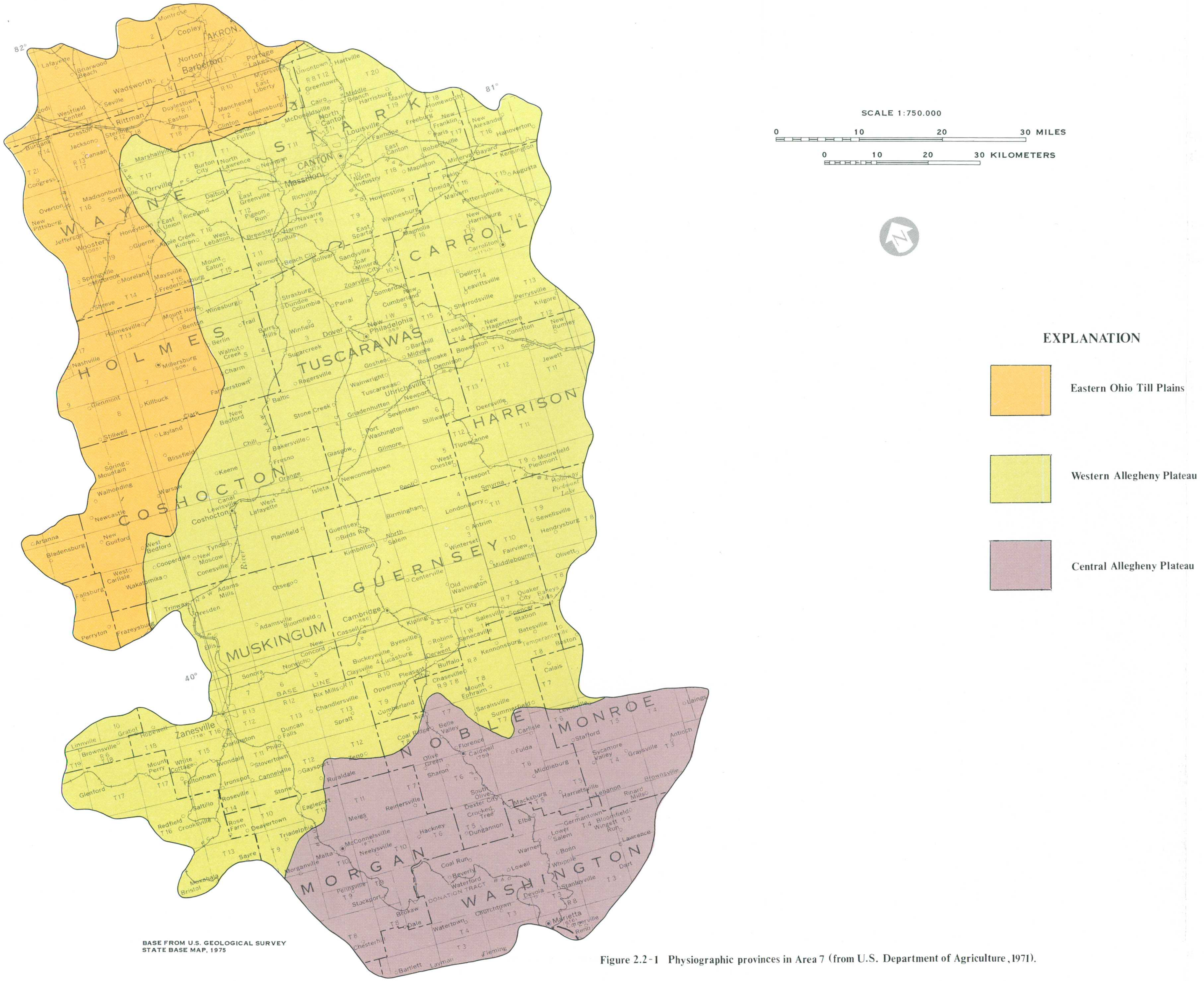
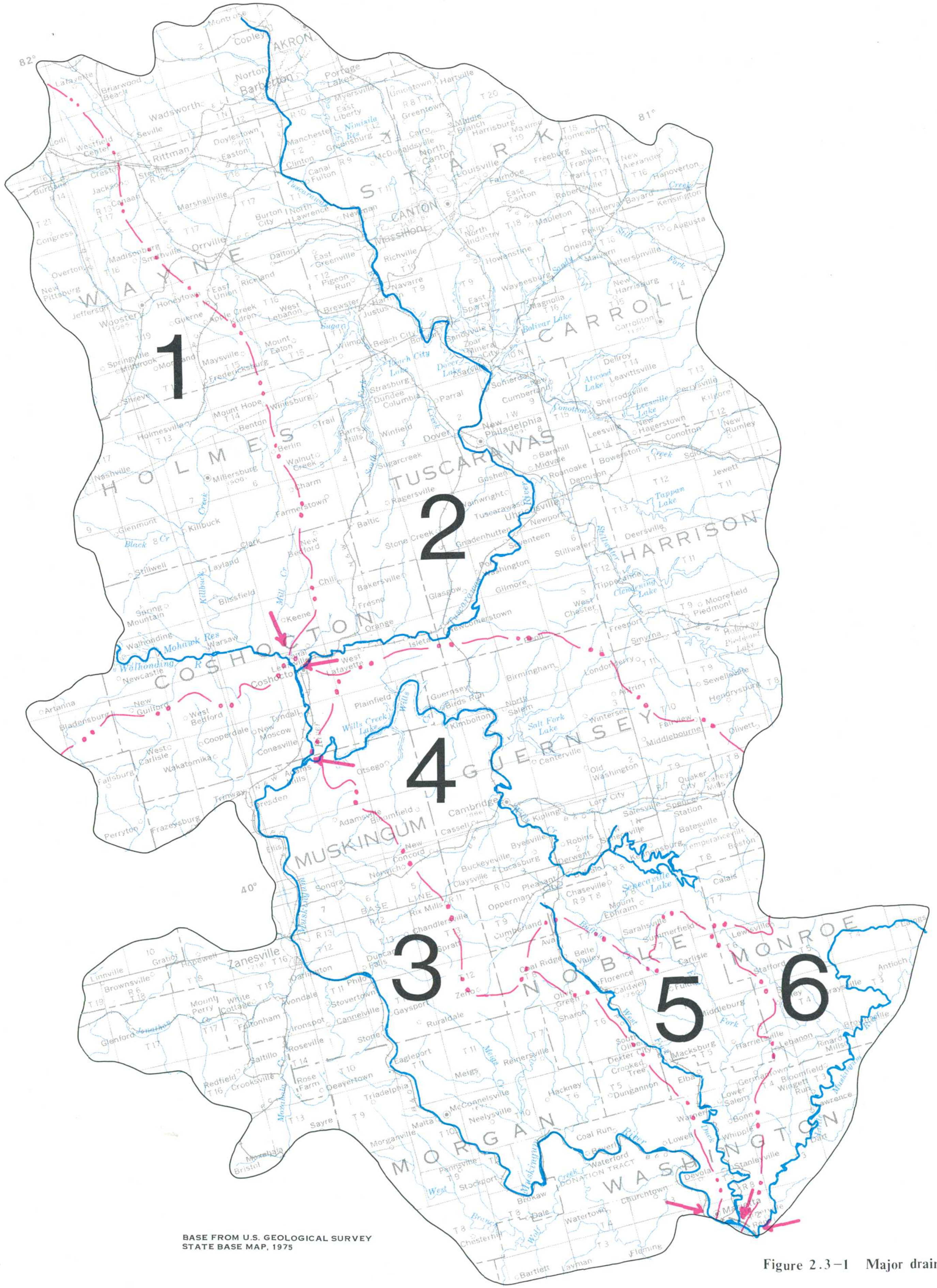


Figure 2.2-1 Physiographic provinces in Area 7 (from U.S. Department of Agriculture, 1971).

Most of the Area is Drained by the Muskingum River and its Tributaries

Major streams draining Area 7 which are tributaries of Muskingum River, include the Walhonding and Tuscarawas Rivers, and Wills Creek. Two streams, which are tributaries to the Ohio River include Little Muskingum River and Duck Creek.

Area 7 has a surface area of 6,720 square miles. The area is drained by the Walhonding, Tuscarawas, Muskingum, and Little Muskingum Rivers, Wills Creek and Duck Creek (figure 2.3-1). Tuscarawas River drains the northeast section of Area 7. Parts of the Walhonding River and Muskingum River basins lie to the west of the area. The drainage area values for those two streams on figure 2.3-1 are the total values (including parts of the basins lying outside of the area). Little Muskingum River and Duck Creek which flow into the Ohio River, drain the southeastern part of the area. Drainage areas for specific sites are given in Appendix 1.



SCALE 1:750,000

0 10 20 30 MILES

0 10 20 30 KILOMETERS

EXPLANATION

← Indicates location of mouth of drainage basin

1 Walhonding River – 2256 square miles

2 Tuscarawas River – 2596 square miles

3 Muskingum River – 8051 square miles

4 Wills Creek – 853 square miles

5 Duck Creek – 287 square miles

6 Little Muskingum River – 315 square miles

Figure 2.3–1 Major drainage basins in Area 7 (from Ohio Division of Water, 1967).

Most of Area is Pasture or Cropland

Most of area is pasture or croplands and the second largest land use is forests. The third major land use is surface mining followed by urban development.

Area 7 was divided into four types of land use, as shown on the land-use map (figure 2.4-1). Streams were classified into four categories: (1) Streams draining currently mined land, (2) streams draining previously mined land without land reclamation, (3) streams draining previously mined land with land reclamation, and (4) streams draining unmined areas. This classification was modified from the land use map, Ohio Division of Planning, 1960. Figure 2.4-2 shows the location and types of mining activities that were determined by Ohio Board on Unreclaimed Strip Mined Land (1974).

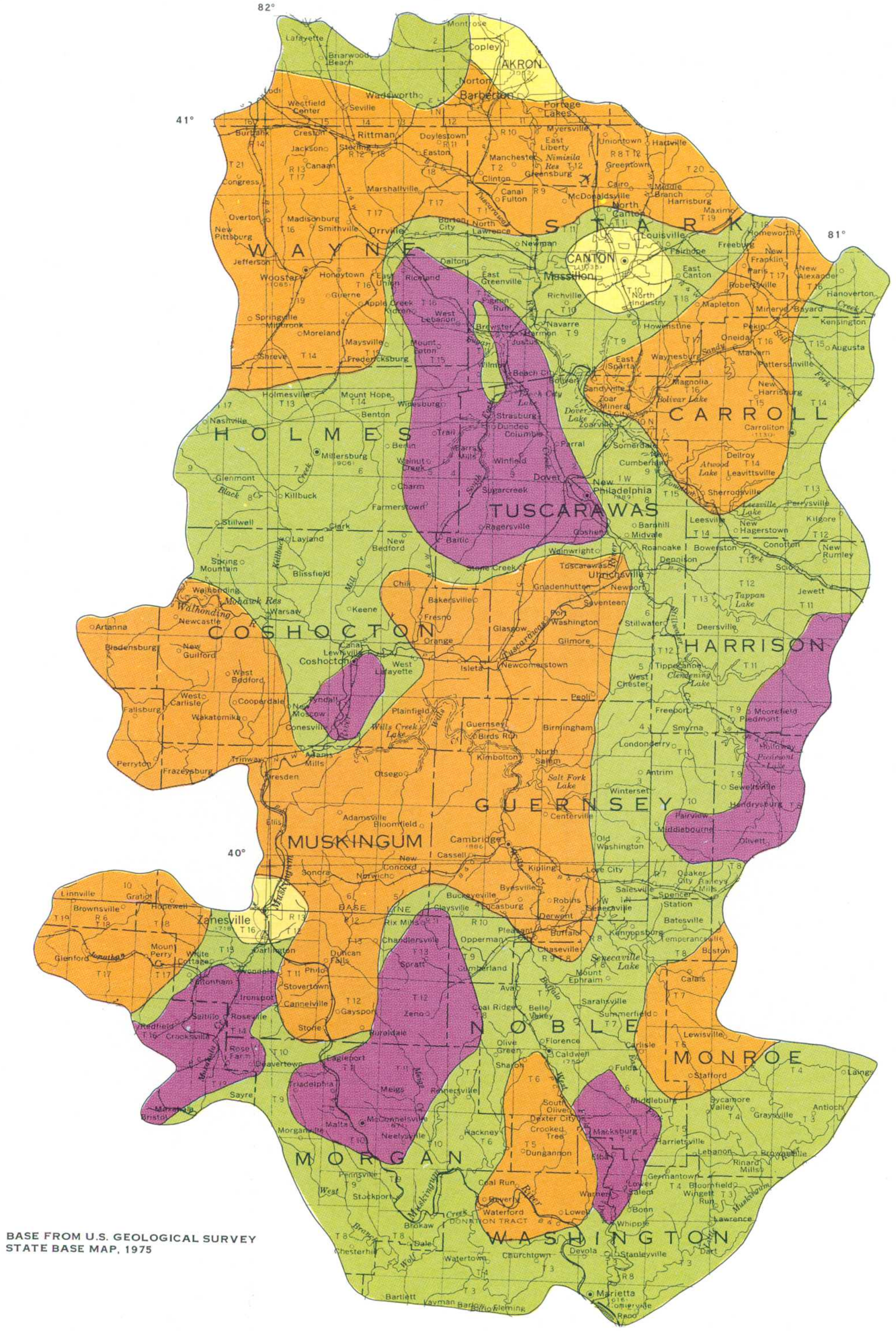


Figure 2.4-1 Land use in Area 7 (from Ohio Division of Planning, 1960).

SCALE 1:1,000,000

0 10 20 30 MILES

0 10 20 30 KILOMETERS

N

EXPLANATION

- Urban
- Agriculture
- Forest
- Surface Mining

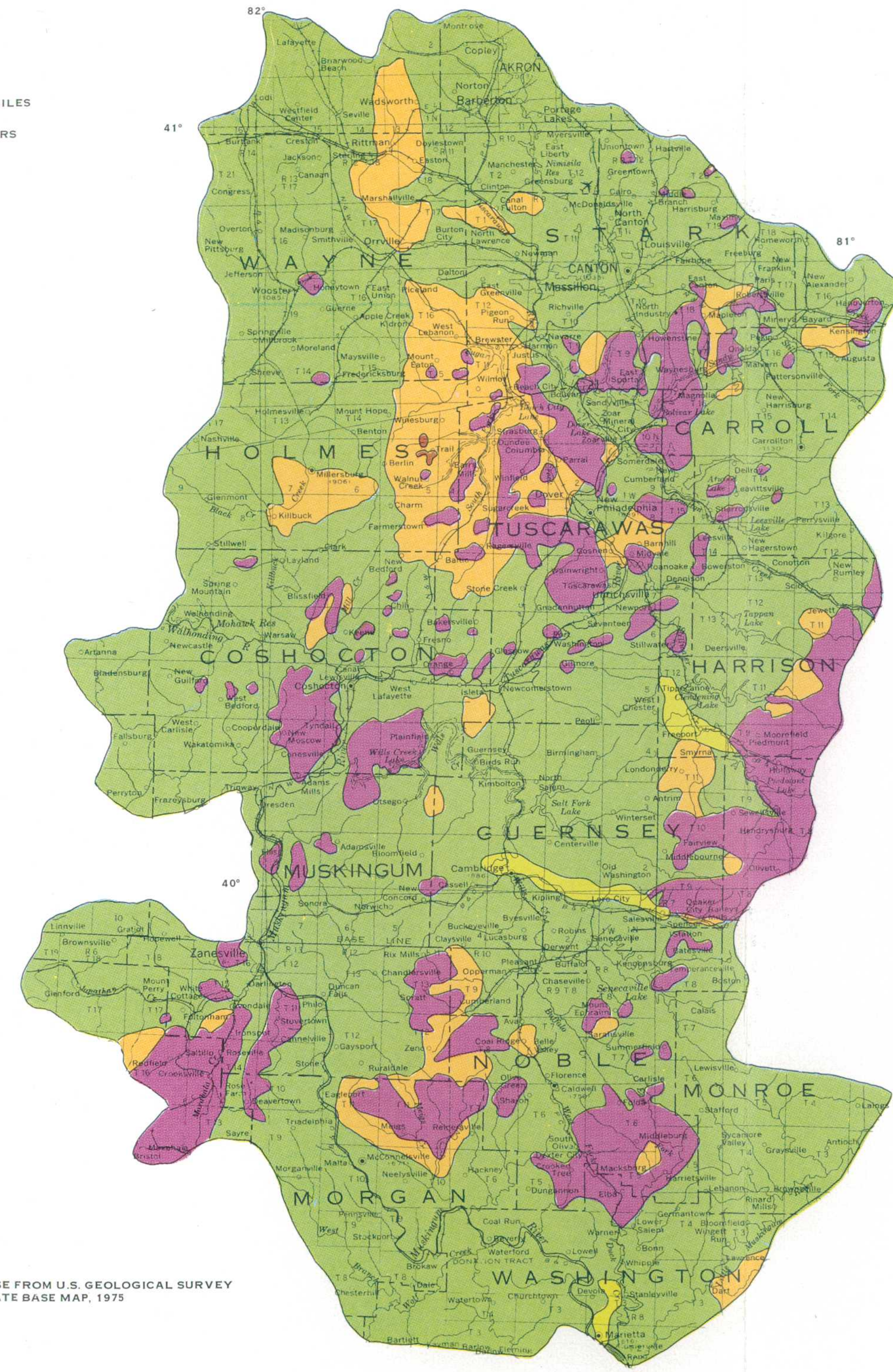


Figure 2.4-2 Land use classification of surface mining in Area 7 (Ohio Board on Unreclaimed Strip Mine Lands, 1974).

EXPLANATION

- Currently Mined Areas
- Abandoned Mine Areas
- Reclaimed Areas
- Unmined Areas

Soils are Formed Over Sandstone and Shale and Have High Erosion Potential

Soils in the area are generally moderately deep, low in natural fertility and organic material, and are acidic, with pH ranging from 3.5 to 6.0. When denuded the soils are easily eroded.

Soils in Area 7 are generally classified by physiographic regions, such as, the Eastern Ohio Till Plains, the Central Allegheny Plateau, and the Western Allegheny Plateau (Bier, 1956).

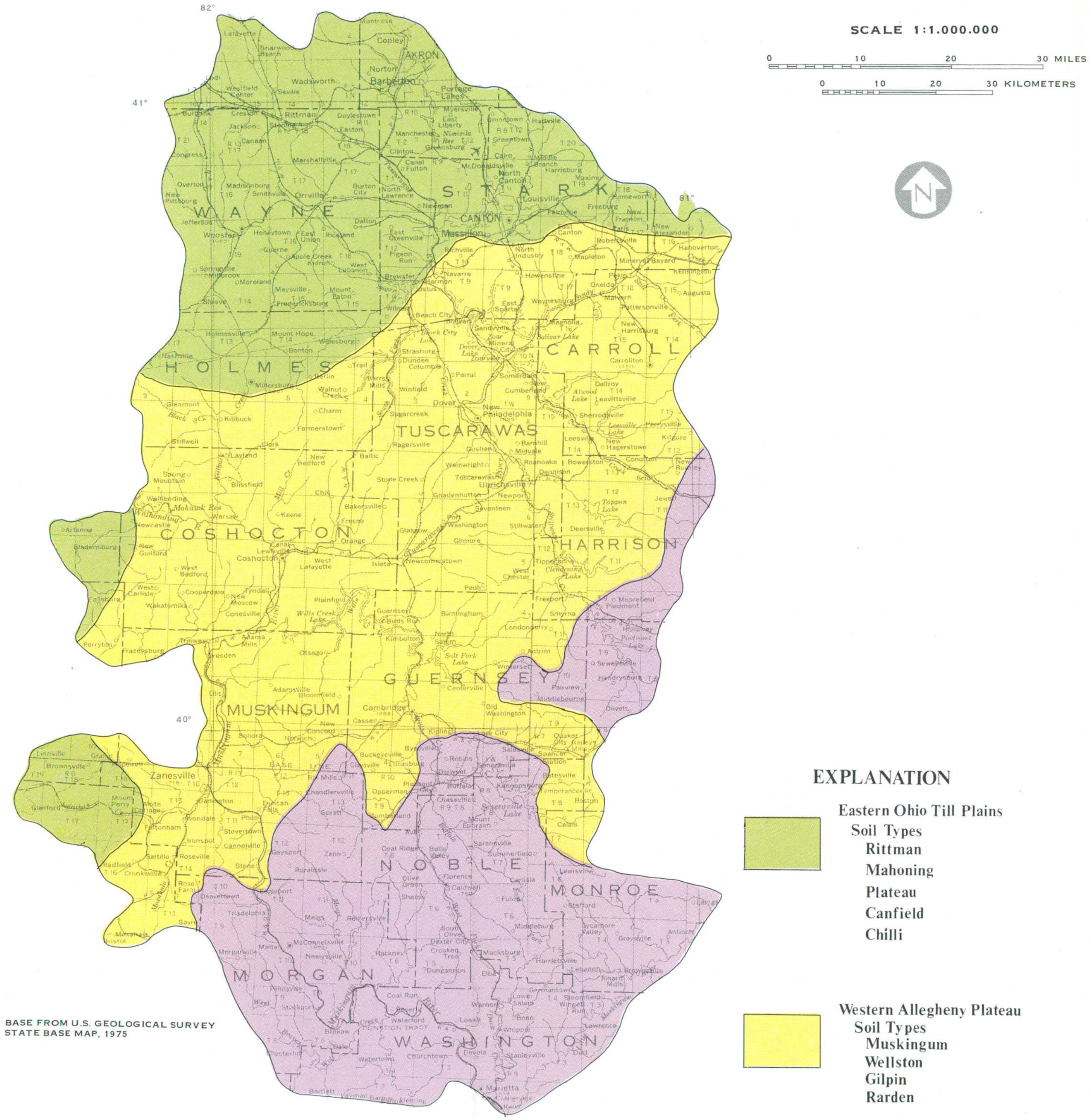
The generalized soils map (figure 2.5-1) shows the distribution of the soil by types (Ohio Division of Lands and Soils, 1973).

Land in the Western and Central Allegheny Plateaus has undergone strip mining since the turn-of-the-century. Most mining operators abandoned the shaft, drift, and excavated surface mined areas. These abandoned mines have eroded and increased yields of sediment, dissolved iron, sulfate, and trace metal concentrations have been discharged into stream channels and onto the adjacent land. Figure 2.5-2 illustrates the type of environmental damage that can result from an abandoned shaft coal mine. The strip mine spoil materials are acidic. Steep slopes, loss of topsoil by erosion, high clay and stone content of the remaining soil, and acidity of spoil material limit land use. Most of the abandoned strip mines are in areas of eastern Ohio.

Soils in the Eastern Ohio Till Plains were formed in glacial drift of Wisconsin age derived mainly from sandstone, shale, and small amounts of limestone. They include the Rittman, Mahoning, Plateau, Canfield, and Chili soils which are low in fertility and organic matter, and are acidic. If the vegetation is removed, the soils are easily eroded. Land is used mainly for farming and dairying.

Soils in the Western Allegheny Plateau are formed over sandstone and shale. The Muskingum, Wellston, Gilpin, and Rarden soils are low in organic matter and natural fertility and are acidic. Soils in this area have a severe erosion potential owing to steep topography and shallow depth to bedrock. Changes in land use could cause landslides. General land use classifications are livestock pasturing, farming, forests, and strip mining of coal.

Soils in the Central Allegheny Plateau are the Gilpin, Upshur, Guernsey, and Westmoreland soils which were formed in silty material overlying red clay. The clay overlies red shale bedrock on steep sideslopes that are benched. These steep slopes are subject to severe erosion owing to the shallowness of the topsoil. Most of the area is woodland with some pasturing on the ridgetops. Strip mining of coal is common in some areas, such as Moxahala, McConnelsville, and Coal Ridge in eastern Ohio.



EXPLANATION

Eastern Ohio Till Plains
Soil Types
- Rittman
- Mahoning
- Plateau
- Canfield
- Chilli

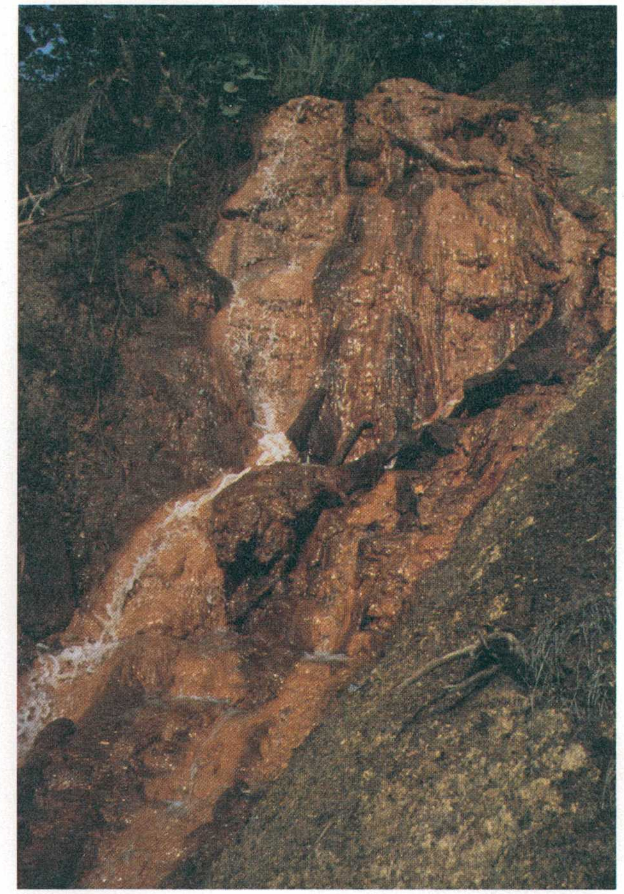
Western Allegheny Plateau
Soil Types
- Muskingum
- Wellston
- Gilpin
- Rarden

Central Allegheny Plateau
Soil Types
- Gilpin
- Upshur
- Guernsey
- Westmoreland

Figure 2.5-1 Soil types in the physiographic provinces of Area 7.(Soil types by Ohio Division of Lands and Soils, 1973)

A. Abandoned shaft mine with ground water carrying large concentrations of iron and sulfate onto the surrounding terrain.

Note: Iron (yellow boy) deposits.



B.

C.

B. and C. Loss of vegetation from high iron and sulfate concentrations subjecting barren ground to erosion.

Figure 2.5-2 Mine drainage from an abandoned shaft mine in eastern Ohio. (Photos by Ohio Department of Natural Resources, Division of Reclamation.)

Area Characterized by Continental Climate

Area 7 has a continental climate with the heaviest rainfall occurring in April and the least rainfall occurring in October.

Area 7 has a continental climate with a mean annual precipitation ranging from 36 inches in the northern part to 42 inches in the southern part (Pierce, 1959). Spring is the wettest season; April is the wettest month; autumn is the driest season and October is the driest month (Pierce, 1959). Average snowfall ranges from 60 inches in the northern part of Area 7 to 16 inches or less in the southern part (Pierce, 1959).

Mean annual precipitation for Ohio is given in figure 2.6-1.

Daily precipitation data are published monthly in "Climatological Data for Ohio" by the National Oceanic and Atmospheric Administration, National Climatic Center, Ashville, North Carolina.

Statistical information is presented in U.S. Department of Commerce, Weather Bureau, Technical Paper No. 40, titled, "Rainfall Frequency Atlas of the United States."

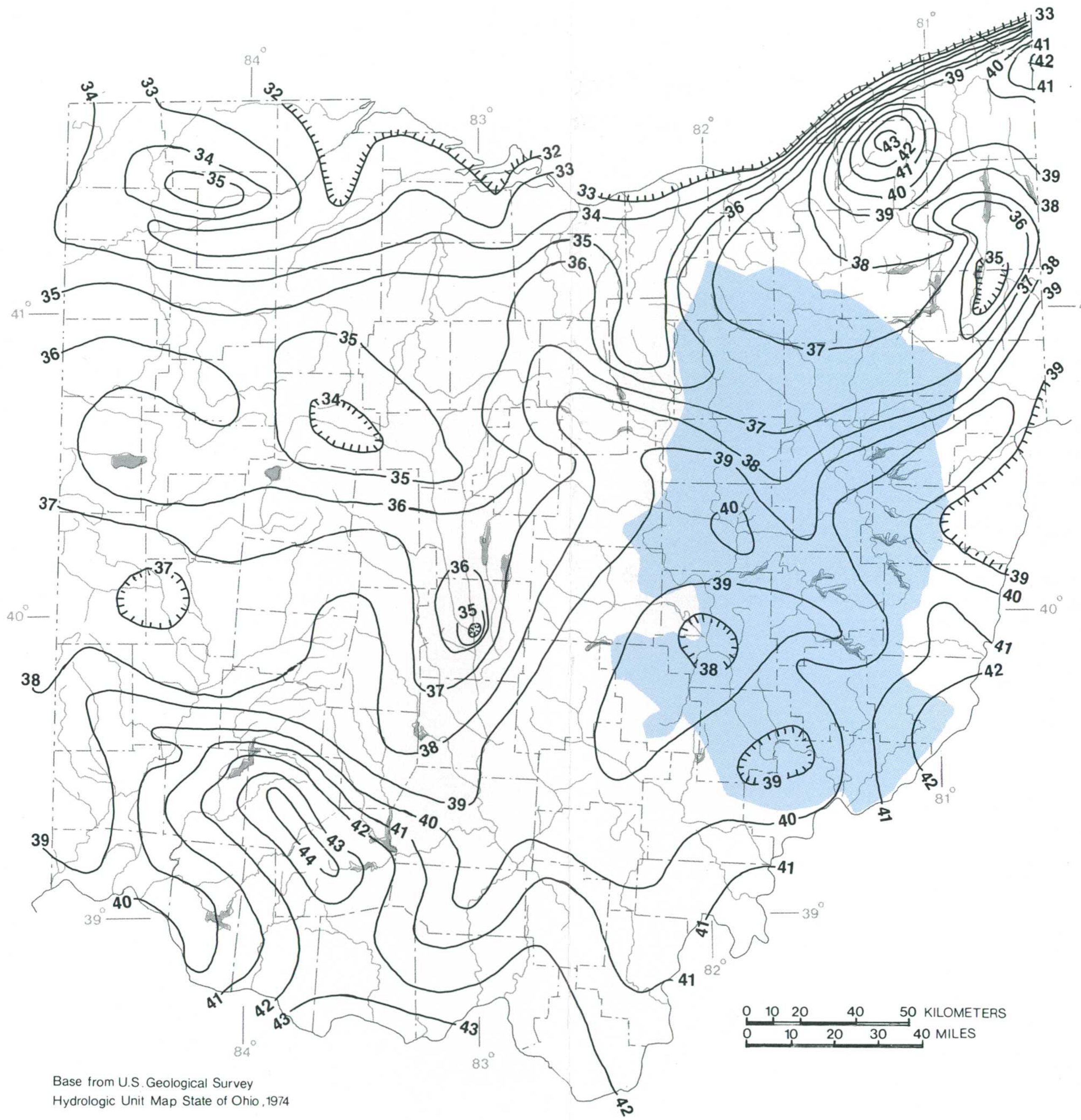


Figure 2.6-1 Mean annual precipitation, in inches, in Area 7, 1931-1960 (from Ohio Division of Water, 1962).

Surface Water Information is Available for 142 Locations

The U.S. Geological Survey surface-water data-collection network was intensified in response the Surface Mining Control and Reclamation Act.

Water-quality, biological, and discharge data are available for 138 synoptic sites and 4 continuous record stations in Area 7. Their locations are shown on figure 3.1-1 and listed in Appendix 1. Ten of the synoptic sites are event sites, at which suspended-sediment data are available. Their locations are also shown on figure 3.1-1. The kinds of data and collection dates are published in "Water Resources Data for Ohio, 1979, Appendix A, Coal Areas," U.S. Geological Survey Water-Data Report OH-79-A. The network was upgraded in 1979 to monitor streamflow and determine baseline data in eastern Ohio coal regions. Area 7 was divided into four land-use categories, charaterized by (1) currently mined areas, (2) abandoned mine areas, (3) reclaimed areas, and (4) unmined areas. The listing of stations in each of these land-use categories are shown in Appendix 1. The matching of sites to different land-use types was determined from "Land Reborne" (Ohio Board on Unreclaimed Strip Mine Land, 1974). Water-quality, streamflow and biological data were collected at all synoptic sites and suspended-sediment data at event sites in Area 7. This data can be retrieved from computer storage through National Water Data Exchange (NAWDEX) and are published in U.S. Geological Survey Water-Data Report OH-79-A.

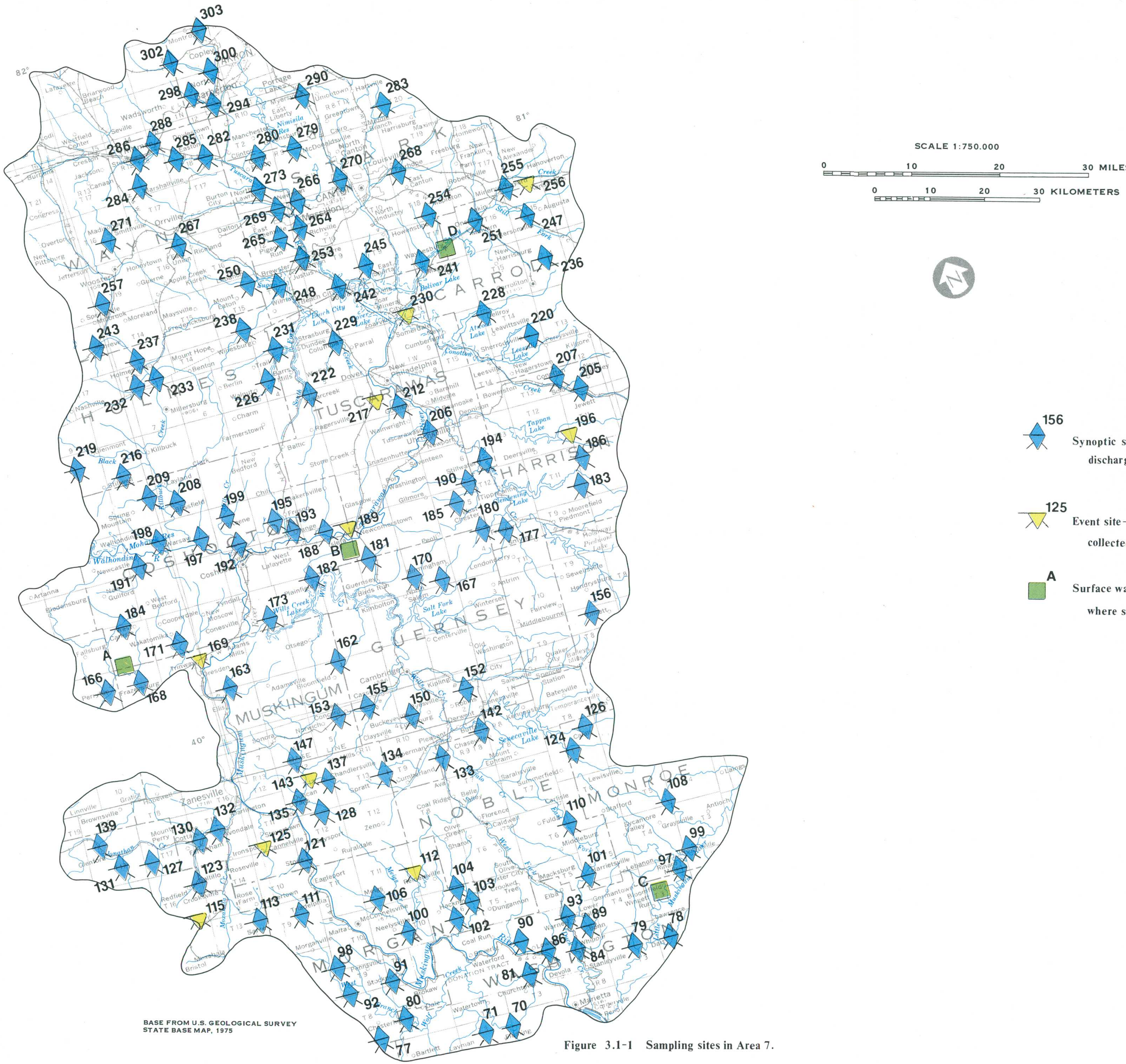


Figure 3.1-1 Sampling sites in Area 7.

EXPLANATION

156 Synoptic site - A partial-record site at which chemical, biological, and discharge data are collected twice a year at high and low flow.

125 Event site - A synoptic site at which suspended-sediment data are collected during peak flow.

A Surface water station - A gaging station at a particular site on a stream where systematic observation of hydrologic data are obtained.

3.0 HYDROLOGIC NETWORK

3.1 SURFACE WATER STATIONS

Streamflow Varies With Time and Location

Streamflow variation is related to rainfall and evapotranspiration.

Streamflow variations with time at a given location are due to changes in precipitation occurrences and their intensity and duration, air temperature, relative humidity, and other weather factors. Variations in streamflow with location are due to differences in climate, topography, and geology.

Two of the most important meteorological factors affecting streamflow are precipitation and air temperature. Figure 4.1-1 shows a typical streamflow hydrograph for Wakatomika Creek near Frazeysburg, Ohio, (site A), (Water Year 1979). The variations in this hydrograph are caused by short-term weather fluctuations and seasonal trends.

Short-term fluctuations are caused by precipitation occurrences. In figure 4.1-1 precipitation is the cause of day-to-day streamflow variations. When precipitation occurs streamflow rapidly rises, reaches a peak, falls rapidly, and gradually decreases to a point where most of the flow is derived from ground water inflow.

Annual streamflow variations are caused by largely predictable seasonal changes in the weather. The seasonal streamflow variations shown in figure 4.1-1 are similar to those of most streams in Area 7. The hydrograph illustrates a yearly cycle of streamflow: The characteristic low flow of October; increase in streamflow through November as evapotranspiration decreased; the effects of winter rains and snowfalls of December, January, and February; the flood season of March and April resulting from rainfall and snowmelt; and recession of flow in May and June as rainfall decreased and evapotranspiration increased, some surface runoff and ground water activity replenished by thunderstorms of July and early August; and recession of flow in late August and early September which was interrupted by precipitation associated with Hurricane Frederick.

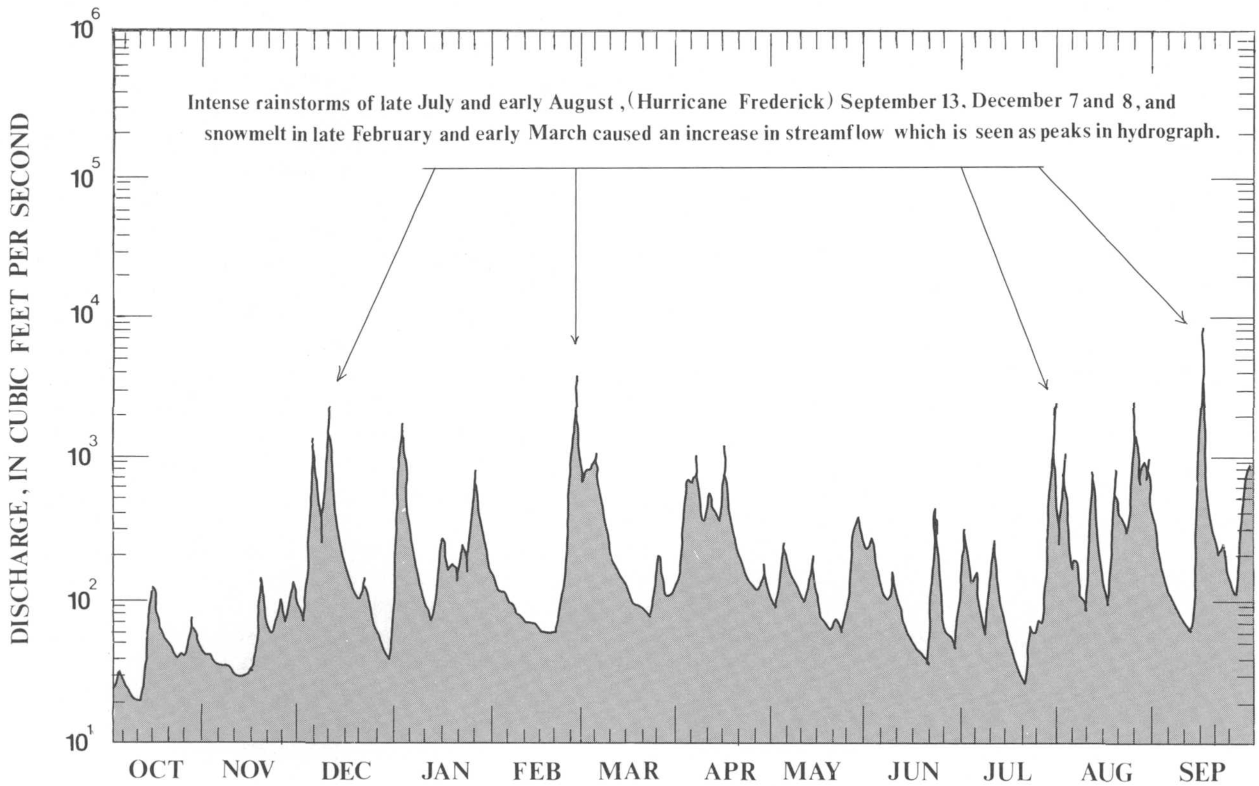


Figure 4.1-1 Hydrograph of site A, at Wakatomika Creek near Frazeysburg, Ohio (Water year 1979).

The Flow-Duration Curve Shows the Percentage of Time that Various Rates of Flow Are Exceeded

Streams draining areas south of the glacial boundary have less sustained flow than those draining areas north of the glacial boundary.

Flow duration curves are used to show streamflow variability. Figure 4.2-1 shows a flow duration curve for Tuscarawas River at Newcomerstown (site B) and Little Muskingum River at Bloomfield (site C). The flow-duration curve shows the percentage-of-time that a specific discharge can be expected to be equaled or exceeded. For example, a discharge of 0.28 $(ft^3/s)/mi^2$ is expected to be equaled or exceeded about 70 percent of the time, at the Tuscarawas River station.

The shape of the flow-duration curve is determined by the hydrologic and geologic characteristics of the drainage basin. A curve with a steep slope denotes highly variable streamflows derived largely from direct surface runoff. A curve with a flat slope is caused by surface or groundwater storage such as permeable rock, lakes, and reservoirs. A flat slope at the lower end of the curve indicates dependable base flows, whereas a steep slope indicates negligible base flows (Searcy, 1959).

The value of flow duration curves for comparative purposes can be seen in figure 4.2-1 where curves for the two sites shown, site B Tuscarawas River at Newcomerstown, and site C Little Muskingum River at Bloomfield differ. The curve for the Little Muskingum River at Bloomfield shows a steep slope at the lower end, which typifies streams in the area, and indicates a lack of surface and (or) ground-water storage. The Tuscarawas River at Newcomerstown has a gentle slope that becomes flat at the lower end, indicating ground-water storage. The basin of the Little Muskingum River consists of gently rolling hills, underlain by massive sandstones and shales with little ground-water storage. The Tuscarawas River above Newcomerstown drains an area with a large amount of ground-water storage due to buried valley systems partly filled with sand and gravel.

Most of Area 7 is similar to the basin of Little Muskingum River at Bloomfield although the area north of the glacial boundary, shown in figure 4.2-2, displays high ground-water storage as the result of localized buried valley systems. Some preglacial valleys occur south of the glacial boundary. These buried valley systems extend no farther than 50 miles south of the boundary and are less extensive than the buried valley systems of the glaciated region.

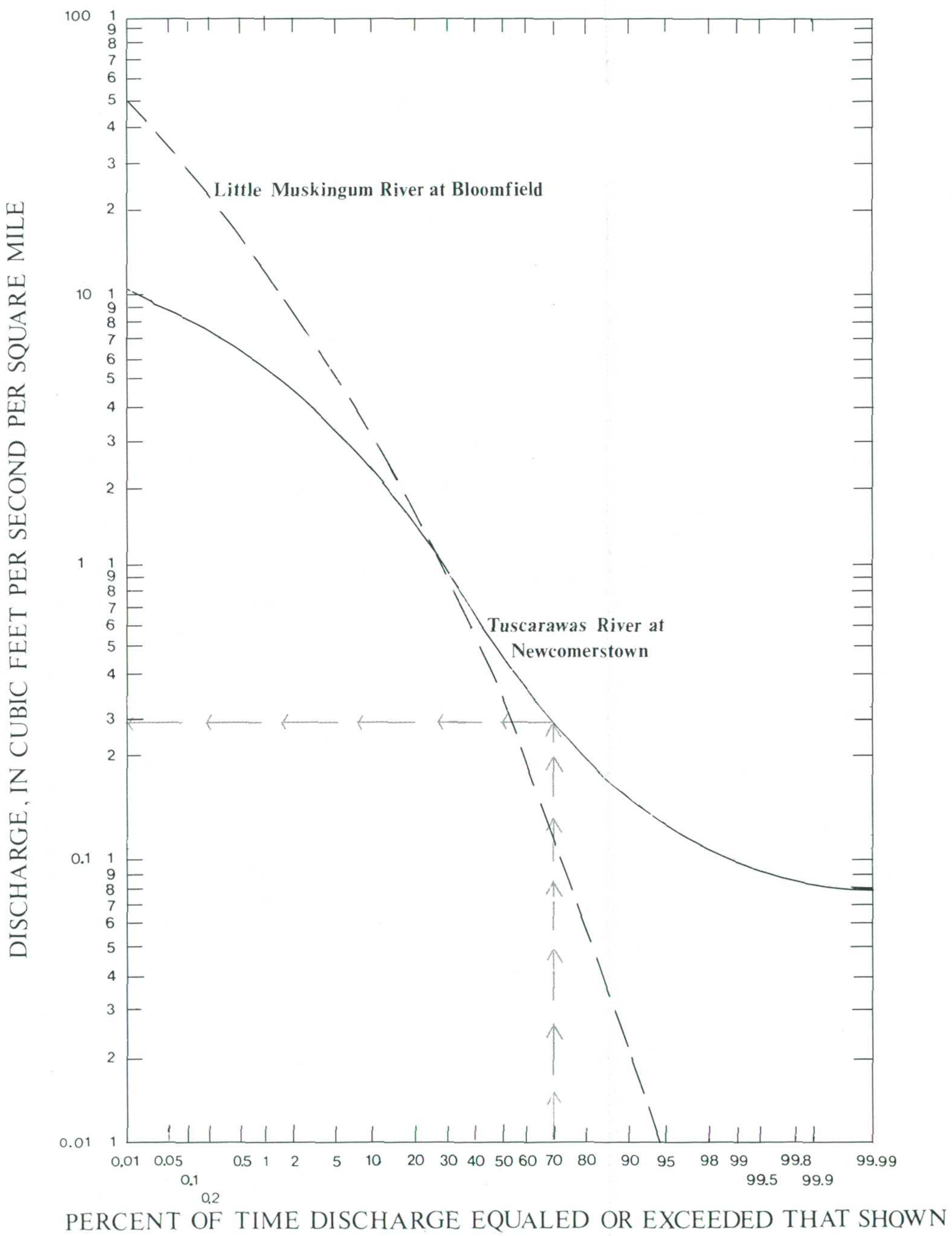


Figure 4.2-1 Duration curve for site B, Tuscarawas River at Newcomerstown and site C, Little Muskingum River at Bloomfield, Ohio.

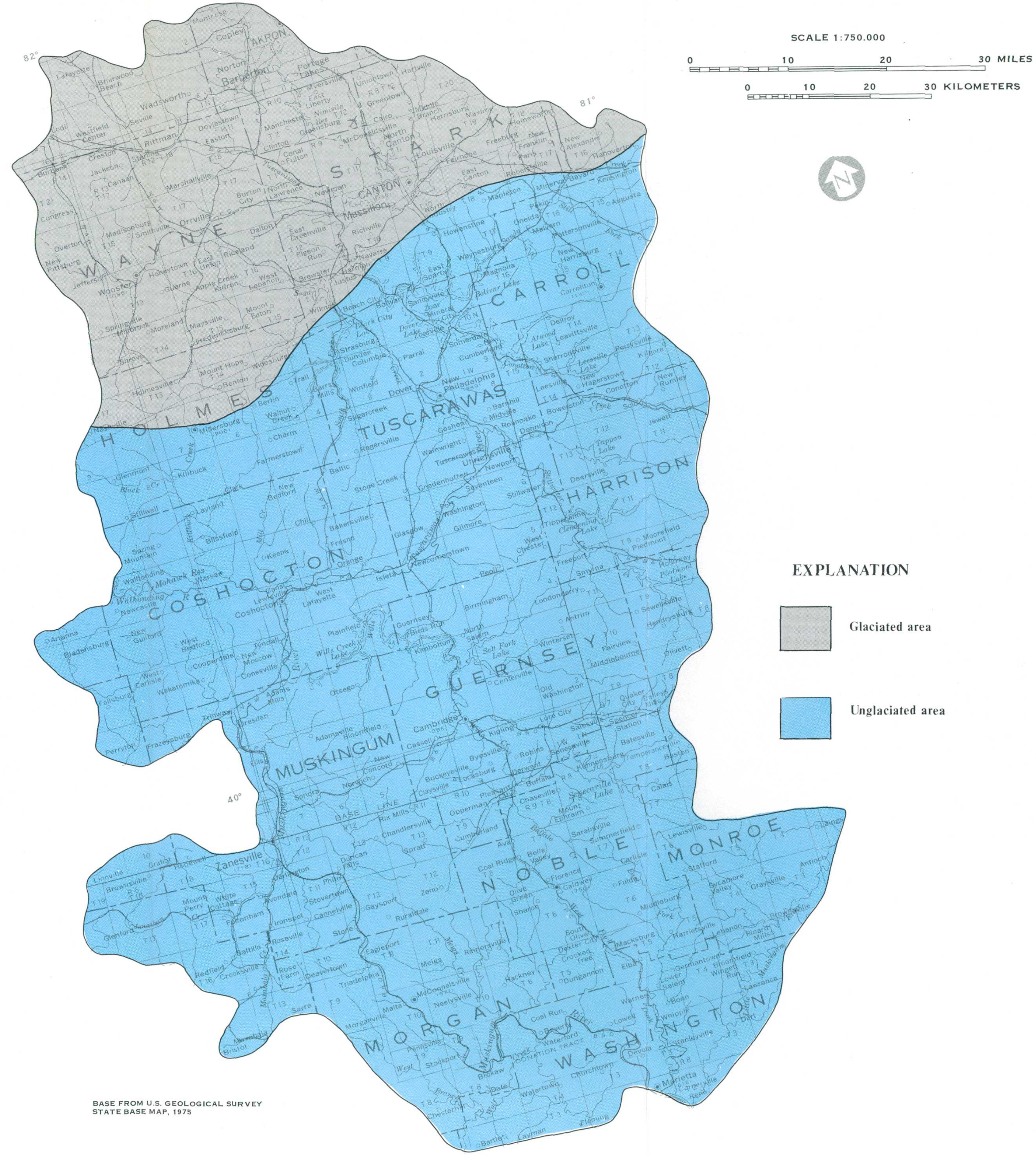


Figure 4.2-2 Glacial boundary in Area 7.

Low-Flow Characteristics of Streams in the Area Vary Widely

Aquifers in Area 7 display substantial variation in discharge of ground-water during dry periods.

Low flow at any specific location depends on precipitation over the basin and the soil and geologic characteristics which control the recharge and discharge rates in the basin (Riggs, 1972).

The most often used low-flow index is the 7-day 10-year. The annual 7-day low flow will be less than the 7-day 10-year low flow at intervals averaging 10 years in length. In any given year the 7-day low flow has a 10 percent chance of being less than the 7-day 10-year low flow.

Figure 4.3-1 shows a typical set of low-flow frequency curves for site D, Sandy Creek at Waynesburg. The graph shows four curves of 3-, 7-, 14-, and 30-day periods. The 7-day 10-year low flow is 17 ft^3/s.

Streams in Area 7 vary widely in low-flow characteristics. The continuous record stations in the area ranged from 0.001 $(ft^3/s)/mi^2$ to 0.104 $(ft^3/s)/mi^2$ for the 7-day 10-year low flow. It was found in comparing these sites that geology was the major controlling factor. Some of the sites had relatively high low flows while other sites were low. The sites with relatively high low flows are on streams draining buried valley systems that have high ground-water storage characteristics. The other sites are in the unglaciated region and drain areas typified by fairly impermeable sandstones, shales, coals, and limestones of the Pennsylvanian System.

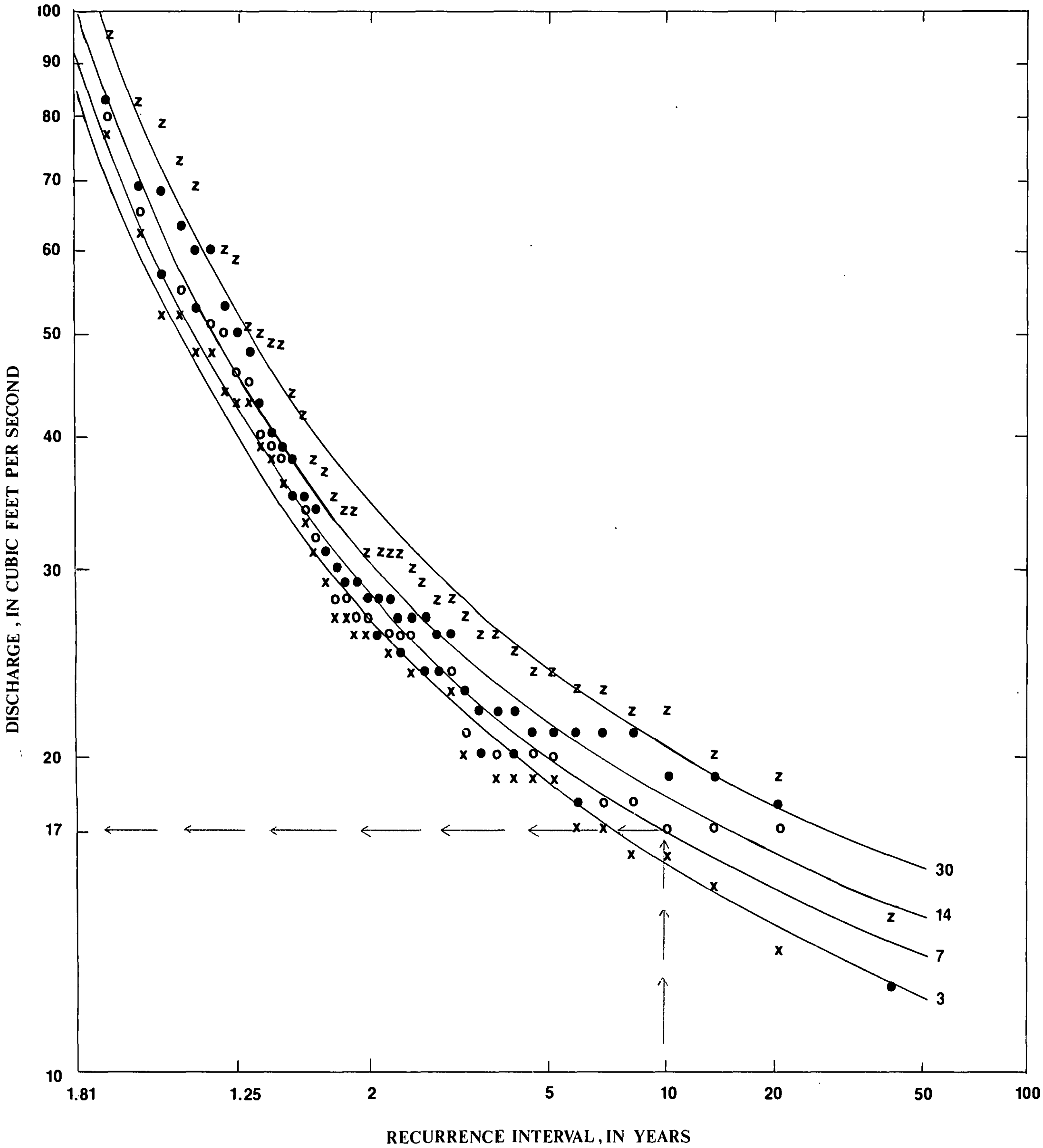


Figure 4.3-1 Low flow frequency curves for 3-, 7-, 14-, and 30 -day periods for Sandy Creek at Waynesburg, Ohio, (site D).

Floods Have a More Rapid Rise in the Southern Part of Area 7 Than in the Northern Part

Floods in the unglaciated region of Area 7 occur more suddenly and last for shorter time periods than those in the glaciated region of the area.

Floods can be related to basin and climatic characteristics. Basin characteristics include elevation, slope, area, soil type, geology, vegetation, drainage pattern, cultural influences, and land use. Climatic factors include seasonal distribution of precipitation and intensity and duration of storms.

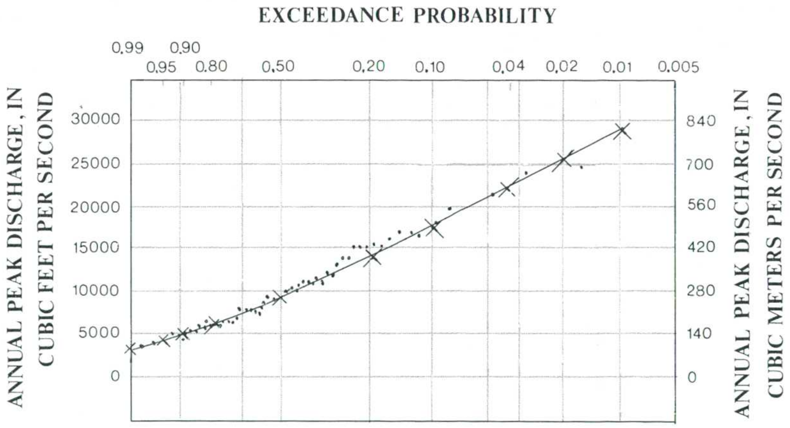
Narrow flood plains and steep slopes are charcteristic of the unglaciated region of the southern part of the area. These characteristics cause runoff to be more rapid than in the northern glaciated region.

Generally speaking, the more rugged topography of unglaciated areas produces sharper flood peaks than the flatter glaciated areas. However, the main channel slopes are sometimes steeper in the glaciated areas because the streams are younger. Thus, the effect from flooding is sometimes not predictable.

A means of computing the frequency of a flood at a gaged stream is by the use of a flood frequency curve. A typical flood frequency curve for Ohio, developed for the gaged stream Little Beaver Creek near East Liverpool (site E, Appendix 1) is shown in figure 4.4-1. This shows computed annual peak discharges for a range of recurrence intervals and exceedance probabilities. Recurrence interval and exceedence probability are reciprocals. Exceedance probability is the probability of a given flow being exceeded in any 1 year (Webber and Bartlett, 1976). An example is the 100-year flood, which has a 1 percent chance of occurring in any year.

Also, in Webber and Bartlett's report (1976) information is given for estimating floods on ungaged streams. Regression equations for estimating flood frequencies at ungaged sites were given and regionalized in relation to basins. These geographic areas were designated with a number from 1 to 5. Figure 4.4-2 shows the geographic areas in Area 7 with the regression equation to be used in computing flood frequencies at ungaged sites.

Figure 4.4-3 shows areas covered by Flood Prone Area maps available at the U.S. Geological Survey, 975 West Third Avenue, Columbus, Ohio, 43212.



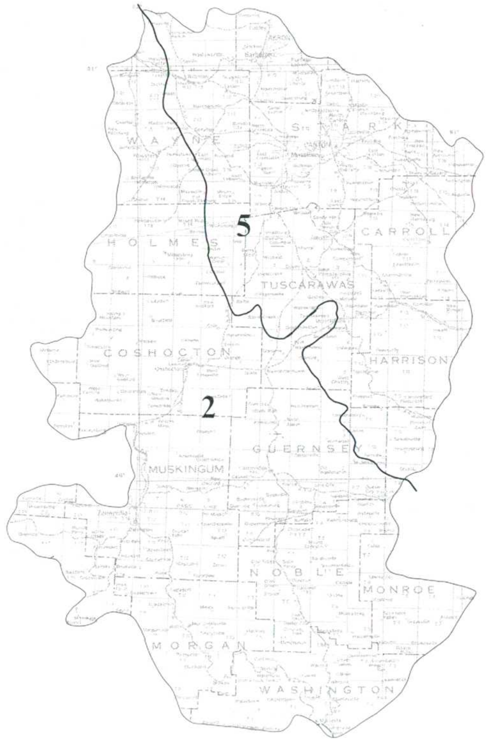
EXPLANATION

Observed station data × Log-Pearson Type III computation

Site E Drainage area – 496 square miles

Period of record – 60 years, 1916–75

Figure 4.4-1 Flood frequency curve for the gaged stream Little Beaver Creek near East Liverpool, Ohio. (Webber and Bartlett, 1976)



EXPLANATION

$$Q_T = aA^x Sl^y$$

Q_T = discharge in ft^3/s for the T year recurrence interval,

A = drainage area in mi^2

Sl = main-channel slope in ft/mi,

a = regression constant, and

x, y = regression exponents

Summary of regression equations for area 5

Peak flow characteristic Q_T	Regression constant a	Drainage area A (x)	Main channel slope Sl (y)	Standard error of estimate, percent*
Q_2	25.1	0.775	0.317	36
Q_{10}	51.9	.733	.356	38
Q_{50}	91.2	.697	.346	40
Q_{100}	114	.682	.336	41

Summary of regression equations for area 2

Peak flow characteristic Q_T	Regression constant a	Drainage area A (x)	Main channel slope Sl (y)	Standard error of estimate, percent*
Q_2	42.6	.802	.225	33
Q_{10}	47.4	.830	.447	27
Q_{50}	50.9	.850	.575	29
Q_{100}	52.6	.857	.619	32

*Standard error of estimate, in percent, is the average of the positive and negative percent error, within which lie two-thirds of the observed values.

Figure 4.4-2 Geographic areas with regression equations used in Area 7 Report. (Webber and Bartlett, 1976)

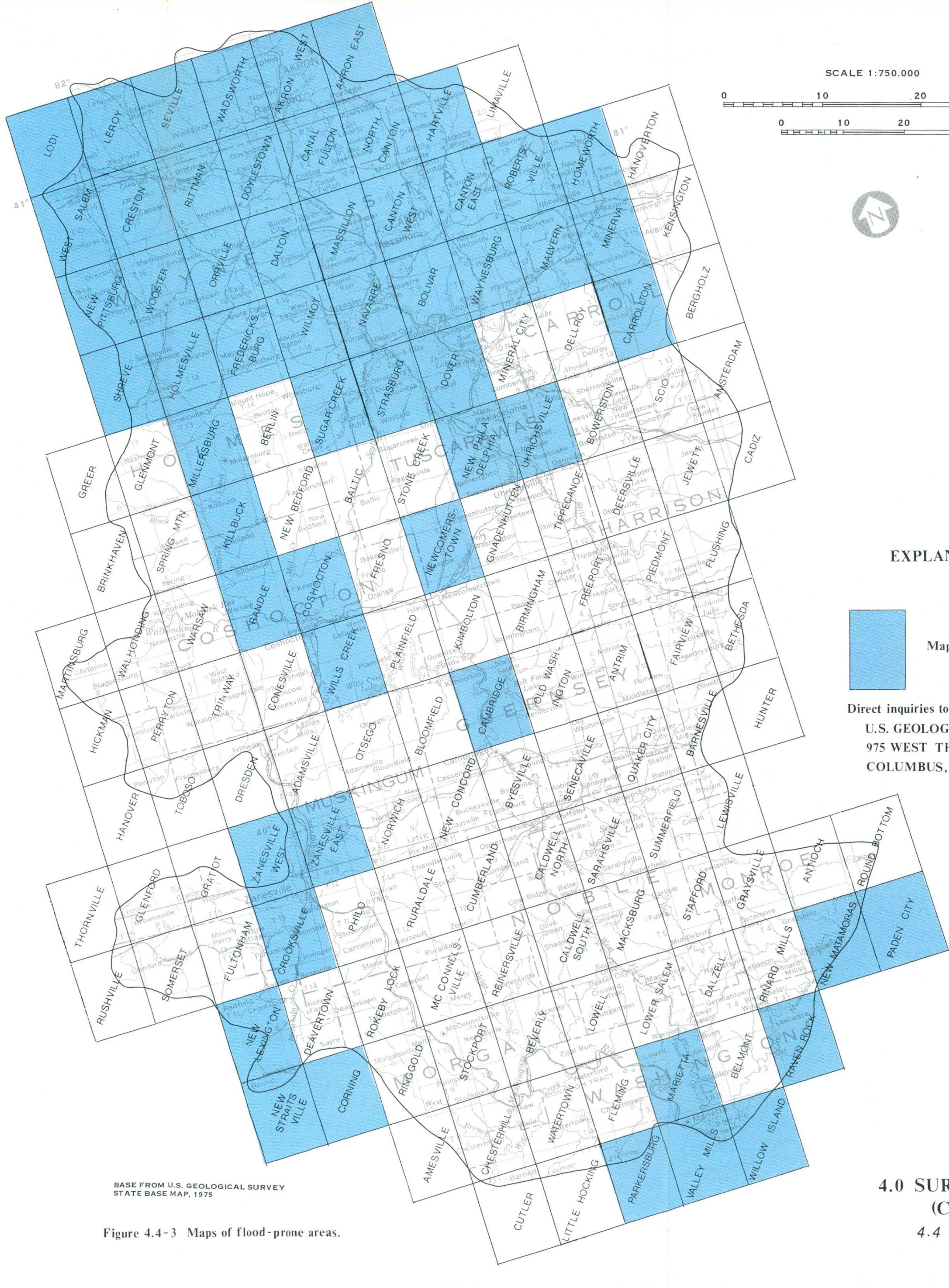


Figure 4.4-3 Maps of flood-prone areas.

EXPLANATION

Maps available in 1980

Direct inquiries to:

U.S. GEOLOGICAL SURVEY
975 WEST THIRD AVENUE
COLUMBUS, OHIO 43212

4.0 SURFACE WATER (Continued)

4.4 FLOOD FLOW

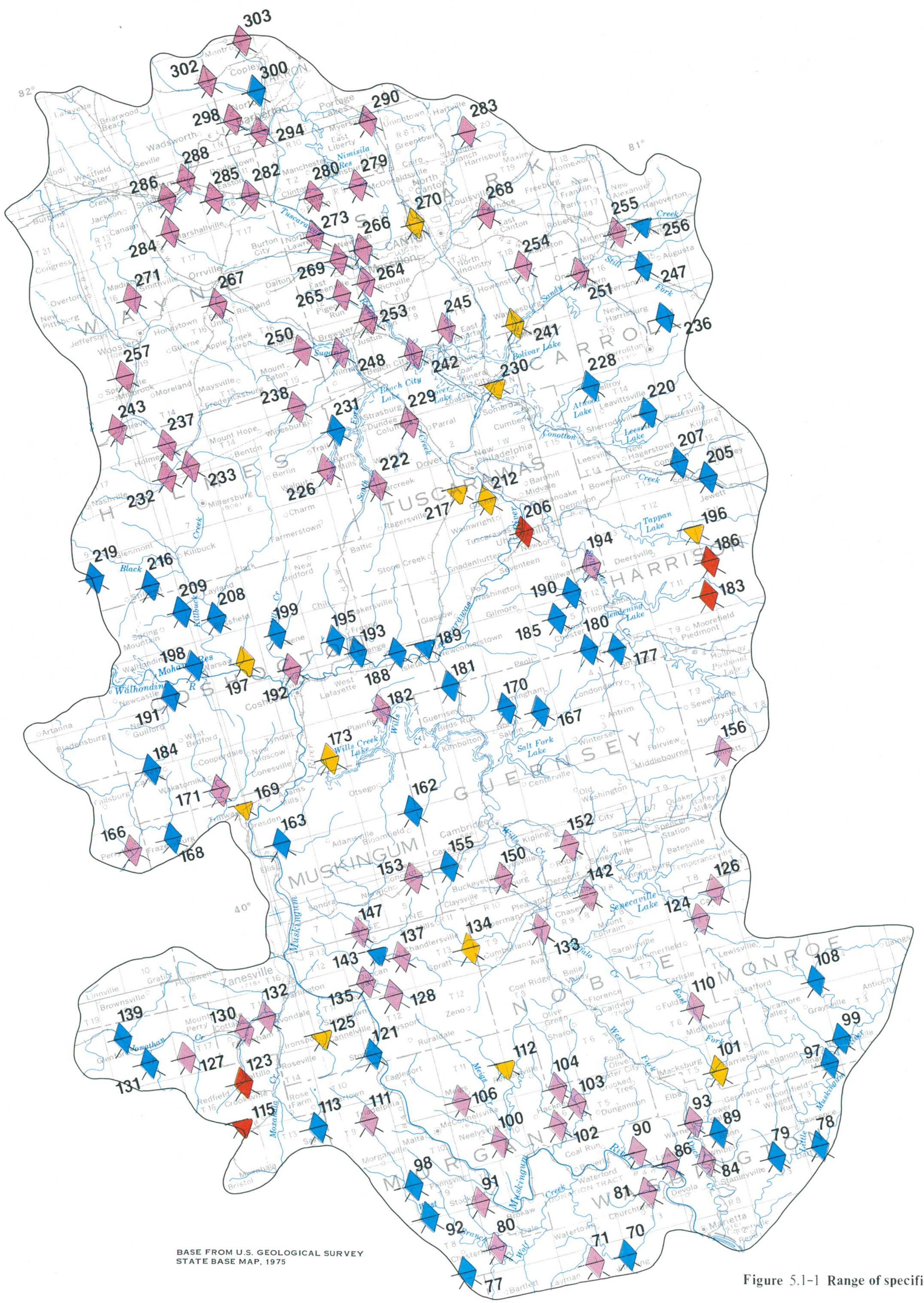
Specific Conductance of Water is High in Abandoned and Active Strip Mining Areas

High specific conductance results from underground-mine drainage and increased dissolved-solids from abandoned strip mines.

The specific conductance is generally low (185 to 650 micromhos at 25 degrees Celsius) in streams draining undisturbed lands in Area 7. Large reservoir-regulated rivers, such as the Walhonding, Tuscarawas, and Muskingum Rivers have relatively high specific conductances (900 to 1,600 micromhos at 25 degrees Celsius) that reflect urban and industrial waste discharges (Ohio Board on Unreclaimed Strip Mined Land, 1974).

According to Hem (1970) "Specific conductance of water is a measure of the ability of water to transmit an electrical current and is expressed in micromhos (μmhos) per centimeter at 25°C." Since specific conductance is related to dissolved-solids content, it can be used to indicate the degree of water mineralization and estimate specific ion concentrations.

Dissolved-solids concentrations in streams are usually derived from soluble-mineral salts of the soil and underlying strata. Figure 5.1-1 shows the range in specific conductance values found at synoptic sites in the area. The specific conductance of streams draining undisturbed areas in Area 7 ranged from 150 to 1,580 micromhos. The higher ranges were found in streams which drained urban areas such as Akron and Canton, Ohio. Streams which drain current coal mining areas in Area 7 ranged from 210 to 2,150 micromhos. Streams which drain abandoned strip mines ranged from 302 to 2,300 micromhos. Specific conductance was highest during low flows, due to less water available for dilution. Streams characterized by acid mine drainage in Area 7 do not show a large range in specific conductance between high and low flows.



SCALE 1:750.000

0 10 20 30 MILES

0 10 20 30 KILOMETERS

EXPLANATION

Specific conductance in micromhos per centimeter at 25° Celsius.

300 — 0 - 400

283 — 401 - 900

270 — 901 - 1500

186 — Over 1500

Figure 5.1-1 Range of specific conductance values at synoptic sites in Area 7.

The pH of Most Streams in Area 7 are in the Neutral Range

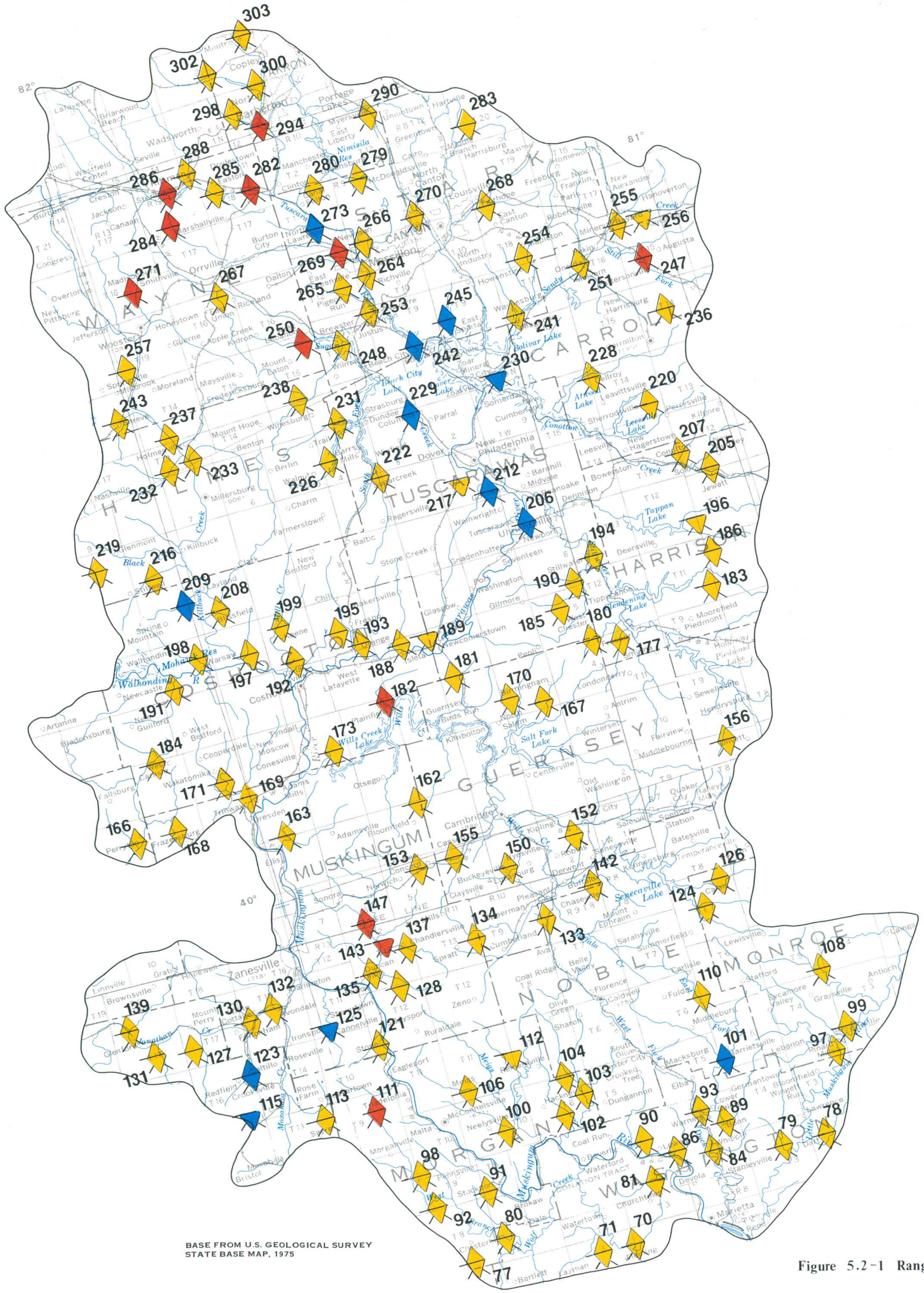
Streams in areas not influenced by mining generally have a pH between 6.5 and 8.5.

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).

A 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, 1978).

pH values below 6.5 in coal mining areas usually indicate acid mine drainage. The range of pH values found at sites in Area 7 are shown in figure 5.2-1. The range of pH for the four land-use types is shown in Appendix 2. Most of the acid streams receive discharge from underground mines (Ohio Board on Unreclaimed Strip Mined Land, 1974).



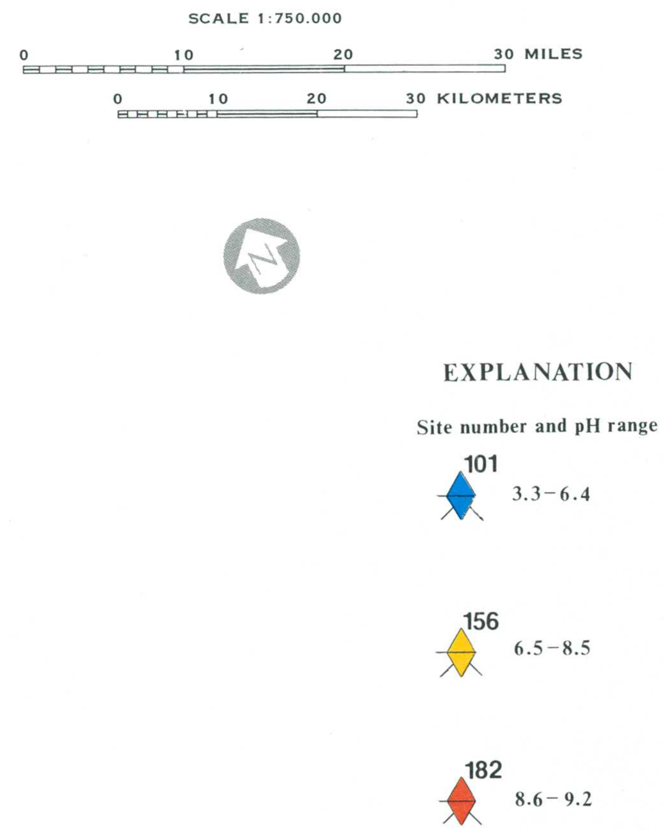


Figure 5.2-1 Range of pH values at synoptic sites in Area 7.

5.0 QUALITY OF SURFACE WATER (Continued)

5.2 pH

Iron Concentrations are High in Streams Draining Mined Areas

Dissolved iron concentrations are highest in streams draining areas where there are abandoned underground mines.

Dissolved-iron concentrations in streams draining reclaimed land and undisturbed parts of Area 7 are less than 730 μg/L. Dissolved-iron concentrations range from 1,000 to 8,500 μg/L (micrograms per liter) from streams draining areas where there are abandoned underground mines. Where there are abandoned strip mines, dissolved-iron concentrations are not as much a concern in terms of environmental damage as the sediment yields from erosion of the tailings. The range of dissolved iron concentrations in streams draining abandoned strip mines in Area 7 was 10 to 85,000 μg/L. Iron concentrations in streambottom material from abandoned strip mines are much higher than dissolved-iron concentrations. The high iron of the sediment is due to the large quantity of iron-bearing minerals (pyrite) in sediment which is washed downstream from the abandoned strip mine spoils and deposited in bottom material. Table 5.3-1 shows the range of dissolved iron and total recoverable iron concentrations observed in the four land-use types.

Dissolved-iron precipitates and concentrations decrease downstream from sources due to aeration and dilution. In Ohio, much of the "yellow-boy" comes from improperly sealed or unsealed air vents in underground mines (Ohio Board on Unreclaimed Strip Mined Land, 1974). Total recoverable-iron concentrations in bottom material are high in streams draining active and abandoned strip mined areas which have increased suspended-sediment concentrations due to erosion from spoil tailings. The range of dissolved-iron concentrations are shown in figure 5.3-1.

Table 5.3-1 Range of dissolved iron and recoverable iron in bottom material in Area 7.

Land-use categories	Range of dissolved-iron concentrations	Range of total recoverable iron concentrations in bottom material
Streams draining unmined areas	0 to 730 µg/L	5,100 to 62,000 µg/g
Streams draining currently mined areas	0 to 1,100 µg/L	4,900 to 89,000 µg/g
Streams draining previously mined areas with land reclamation	0 to 600 µg/L	2,000 to 57,000 µg/g
Streams draining previously mined areas without land reclamation	10 to 85,000 µg/L	8,300 to 120,000 µg/g

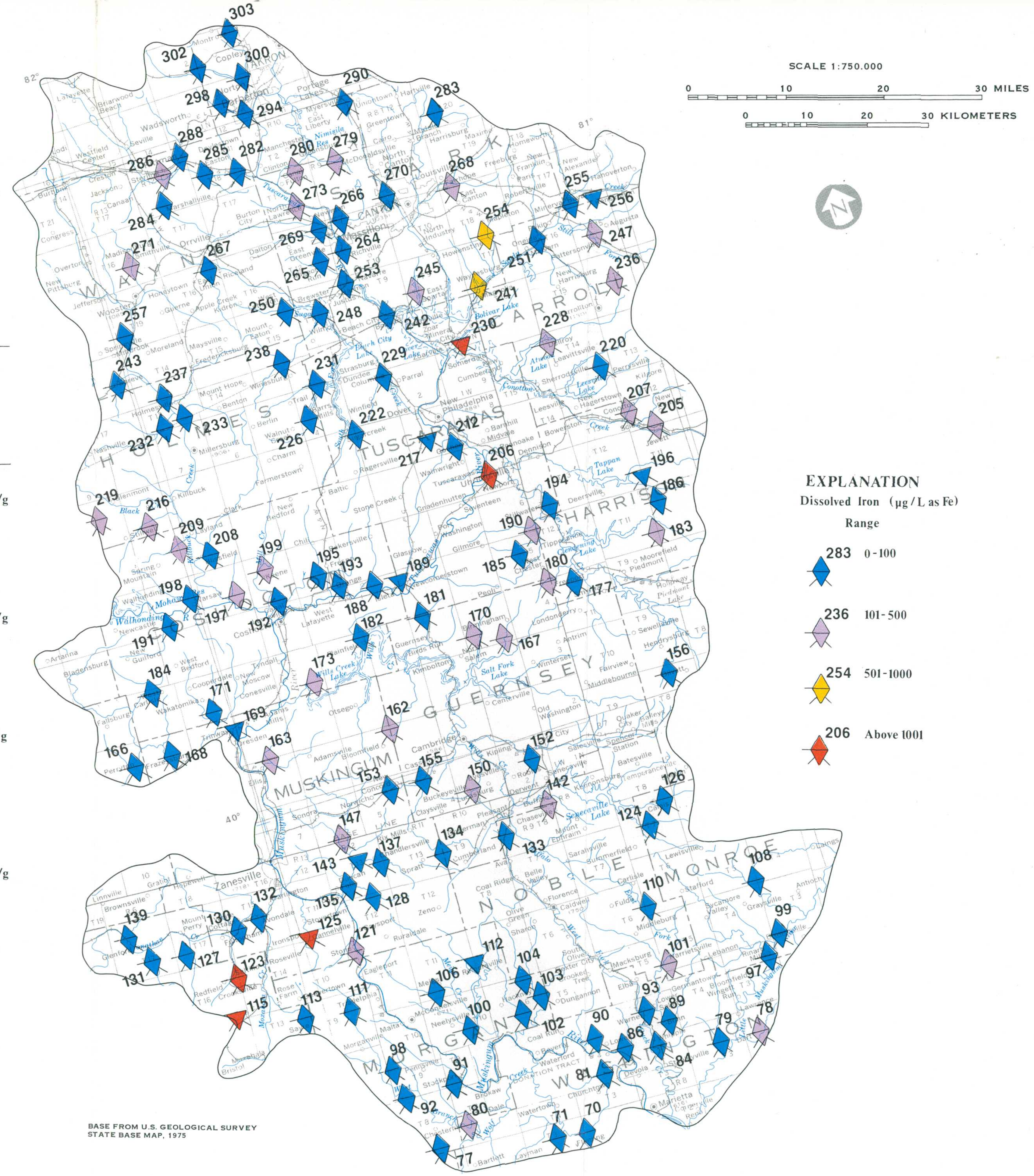


Figure 5.3-1 Range of dissolved iron concentrations in Area 7.

Sulfate Concentrations in Streams Draining Mined Areas Are Higher Than in Streams Draining Unmined Areas

In Ohio, sulfate concentrations were found to exceed drinking water standards at 25 sites.

Sulfate concentrations in streams draining undisturbed basins in Area 7 are usually low with concentrations ranging from 16 to 870 mg/L. Streams draining current and abandoned mine areas are variable and the sulfate content of streams ranges from 14 to 1,200 mg/L. Sulfate has been used as an indicator of acid mine drainage. The Ohio Environmental Protection Agency (1978) has determined that concentrations above 250 mg/L exceed safe drinking water standards.

Streams draining undisturbed basins with sulfate concentrations above 250 mg/L were observed to be receiving sewage effluent from municipal sewage outfalls. Appendix 2 lists the range of sulfate concentrations from streams studied in the different land-use categories. During moderate flow conditions, sulfate concentrations did not vary greatly.

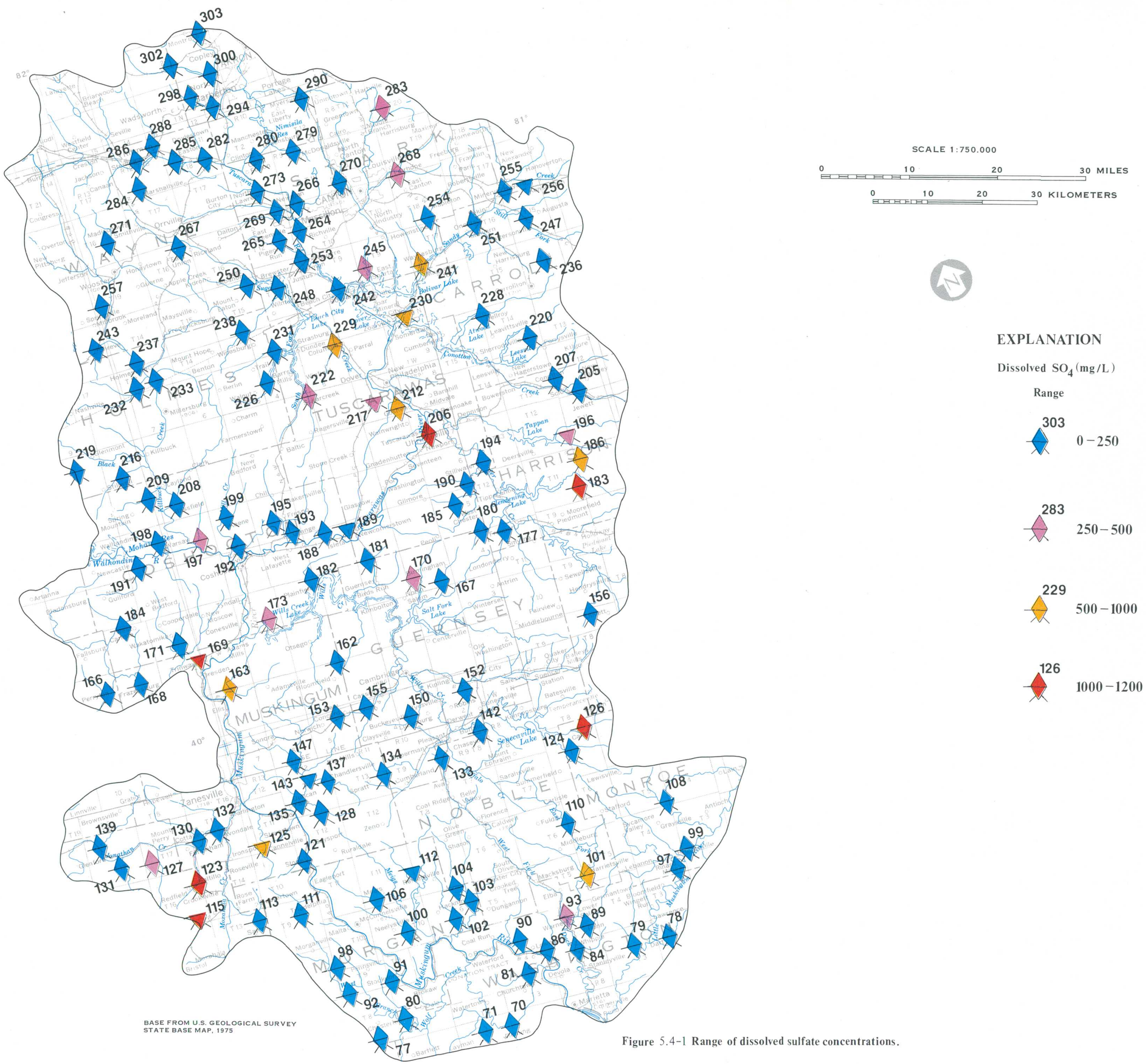


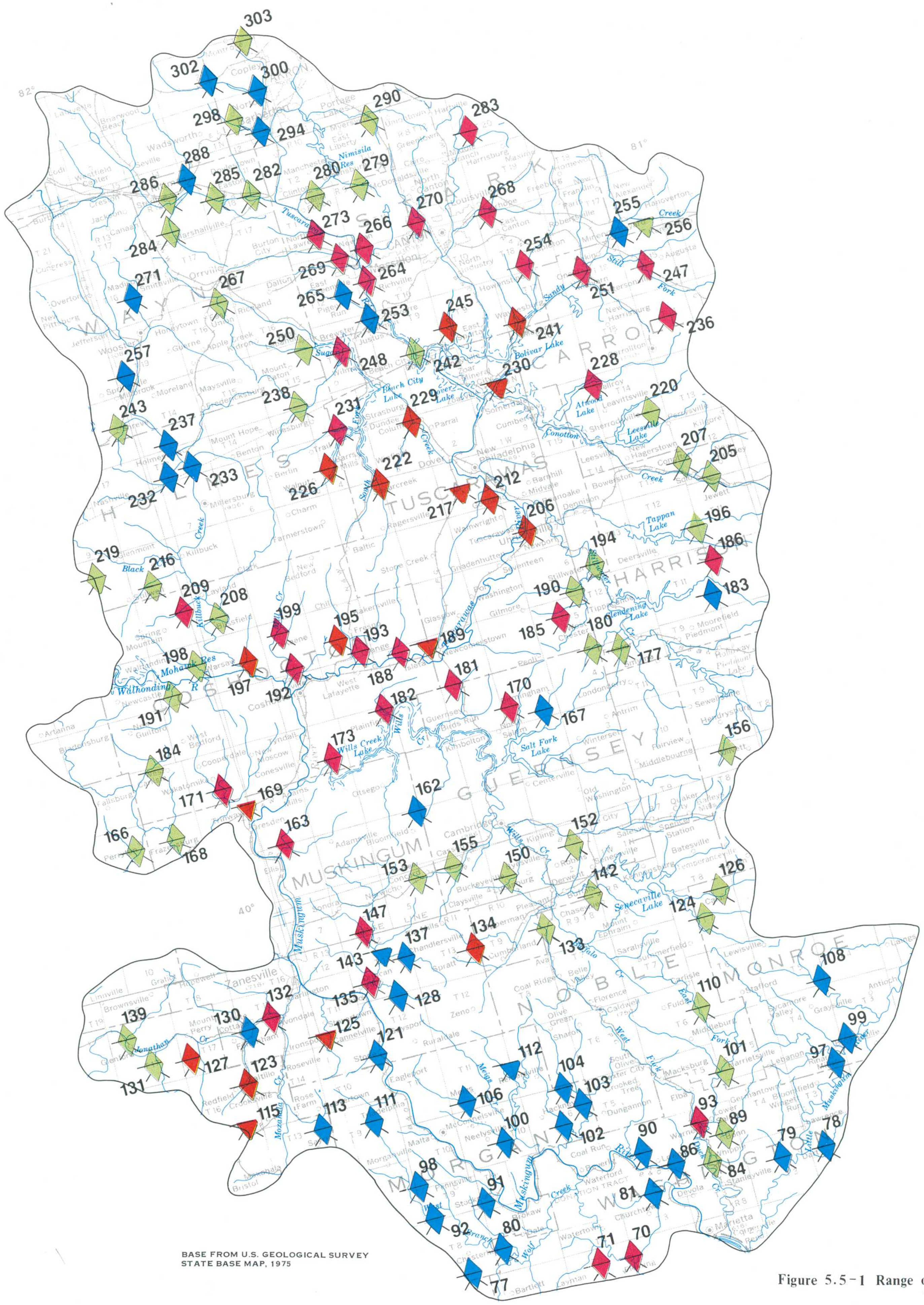
Figure 5.4-1 Range of dissolved sulfate concentrations.

Manganese Concentrations Are High in Streams Draining Abandoned Drift, Shaft, and Strip Mined Areas

Dissolved-manganese concentrations in streams: (1) often exceeding 2,000 μg/L in abandoned coal mining areas; (2) often exceeded 100 μg/L in current mining areas; (3) are often below 100 μg/L in areas of past mining with land reclamation; and (4) are also often below 100 μg/L in undisturbed areas.

Dissolved-manganese concentrations exceeding 50 μg/L are unsafe for domestic and industrial use (Ohio Environmental Protection Agency, 1978). Dissolved manganese occurred naturally in streams in small amounts and ranged from 10 to 5,700 μg/L for undisturbed areas and 0 to 31,000 μg/L for abandoned mine areas.

The high dissolved-manganese concentrations in streams draining mined areas in Area 7 were probably produced by accelerated weathering of manganese minerals present in mine spoils. The range of dissolved manganese concentrations found in study area are shown in figure 5.5-1.



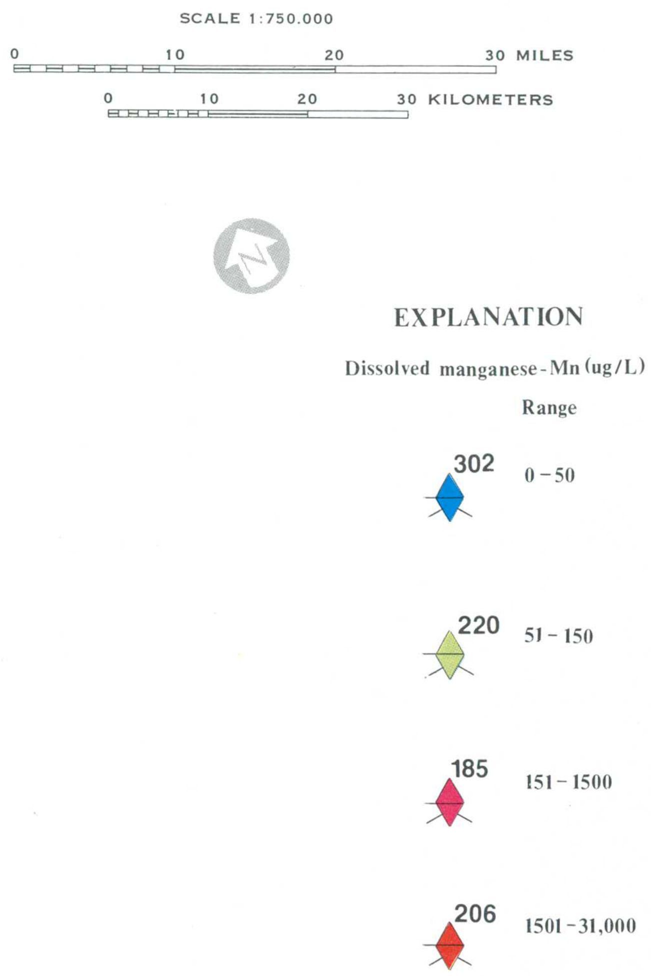


Figure 5.5-1 Range of dissolved manganese in Area 7.

Trace Metals in Bottom Material are Low in Concentration

Trace metals occur naturally in streams but generally are found in low concentrations and are not a water-quality problem in this area.

Trace metals which occur naturally in soils and geologic formations, and as atmospheric fallout are usually washed into streams by surface runoff. Most trace metals in low concentrations, are nutrients essential to the metabolisn of life processes. Sometimes such high concentrations occur in streams below industrial effluents and are usually toxic to aquatic plants and animals. Most trace metals (arsenic, cadmium, chromium, cobalt, copper, lead, mercury, selenium, and zinc) in Area 7 are produced by hydrolysis of minerals in mine spoils. Concentrations of trace metals in Area 7 are very low in mined and unmined areas. The concentrations of trace metals in bottom materials are within the maximum limits recommended by the Ohio Environmental Protection Agency (1978).

Abandoned tipple – Huff Run basin near Mineral City, Ohio.

Moxahala Creek basin near Crooksville, Ohio.

Increased Sediment Discharge from Abandoned Strip Mined Areas Has Been Observed

When strip mining occurs the land surface is denuded (no vegetation) and large areas of unconsolidated spoil that are created contribute to increased sediment discharges.

High sediment discharges can be expected from abandoned strip-mine areas (Ohio Board on Unreclaimed Strip Mined Land, 1974). Barren areas (or areas with limited vegetation) exposed to weathering and intensive rainfall have the highest discharges. Other factors affecting sediment transport are slope, intensity and duration of rainfall. High sediment discharges occur during spring and late summer high intensity rainstorms. This is probably caused by the scouring of land surface and stream channels from runoff.

Several factors such as climate, soils, physiography, drainage basin size, duration of rainfall, and land-use activities influence the sediment discharge of streams. Topography controls the rate and direction of surface runoff. Hilly areas in eastern Ohio have rapid surface-water runoff due to high gradients and the character of the soils. Streambeds are usually shale or slate with few pools for retention of sediment.

Sediment discharges from areas of subsurface mining are not as great as the sediment discharges from areas of surface strip, contour, and auger coal operations (Ohio Board on Unreclaimed Strip Mined Land, 1974). Figure 5.7-1 shows the sediment discharges, in tons per square mile, for a single hydrologic event, produced in drainages of different land use types. Mean suspended-sediment concentrations were determined using the graphical method and converted to sediment discharge using the mean-interval method (Porterfield, 1972). The results are from a single hydrologic event for a single stream in each land use category. These events may or may not have been hydrologically similar. The illustration tentatively suggests that unreclaimed strip mine areas have greater sediment discharges than reclaimed or undisburbed areas. Despite the limited data, the general trend shows that surface mining (past and present) contributes to increased sediment discharge.

Coal-loading operation found in eastern, Ohio.

Abandoned contour mine in headwaters of Moxahaha Creek basin near Crooksville,Ohio.

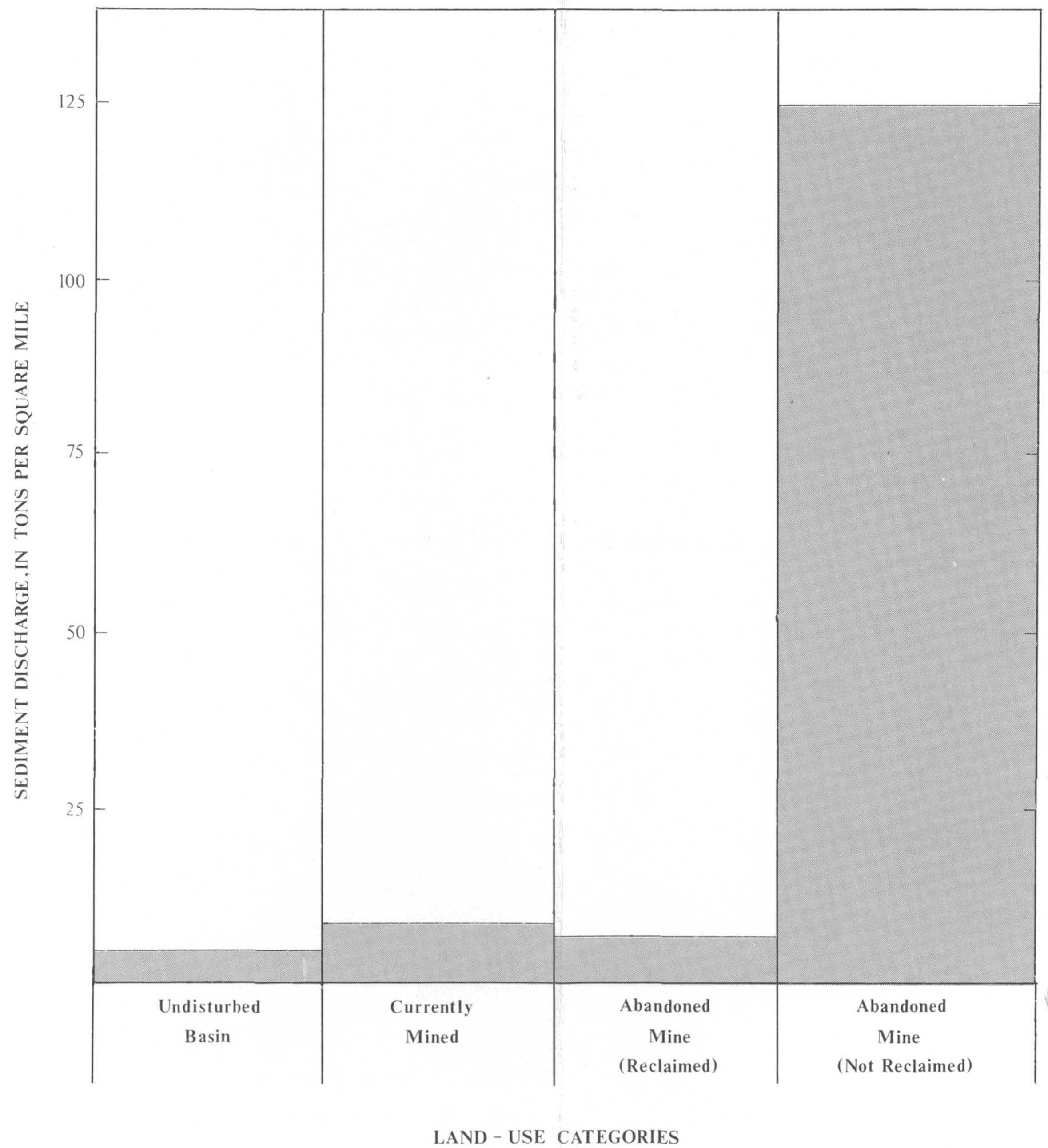


Figure 5.7-1 Sediment discharge, in tons per day, for selected land-use categories, and land-use activities.

Conceptual Model Shows Changing Habitat Characteristics Associated With Coal Mining

High iron and sulfate concentrations from abandoned drift and and shaft coal mines and sediment discharges from abandoned strip mines destroy aquatic life.

The ecosystem ecology of aquatic communities and its relation to land use in streams draining Area 7 is described by the development of the conceptual model, ranges of chemical tolerance levels for benthic invertebrates and habitat discussion.

A conceptual model which shows three aquatic habital communities associated with coal related land-use activities was developed (figure 5.8.1-1). Land use A shows the aquatic community in streams draining undisturbed areas in Area 7. Land use B shows the aquatic community in streams draining areas of current and past mining with land reclamation. Land use C shows the aquatic communities associated with streams draining abandoned drift, shaft, and strip coal mines.

Streams draining areas not disturbed by coal mining activities have a more stable substrate and diverse aquatic community. When strip-mining of coal is initiated in a drainage basin, sediment discharge has been observed to increase. If the mines are abandoned, heavy sediment discharges occur. The ecosystem of substrate beds in streams draining Area 7 are extremely delicate and complex. Aquatic organisms inhabiting streambeds can be destroyed by a thin covering of sand, silt, or clay. Streambeds are usually rich in animal and plant life and are the prime producers of aquatic food. These streambeds also provide a breeding and nesting area and shelter for many species of terrestrial and aquatic animals. According to Trautman (1977) no virgin stream exists in eastern Ohio today. Most streams in Area 7 receive sediment from strip mines, organic enrichment from sewage outfalls, and chemical contamination from industrial wastes and acid drainage from abandoned coal mines. Streams draining undisturbed areas are characterized by rocky substrates without deep deposits of sand, silt, and clay, or buildup of red iron precipitate. Organic enrichment from the numerous outhouses that dot the landscape in Area 7 were observed.

Benthic invertebrates are important food sources for fish and serve as indicators of environmental quality. Benthic invertebrates classified to the order level for the synoptic sites and composition, relative abundance, and diversity index for event sites are published in "Water Resources Data for Ohio, Water Year 1979, Appendix Coal Areas," U.S. Geological Survey Water-Data Report OH-79-A.

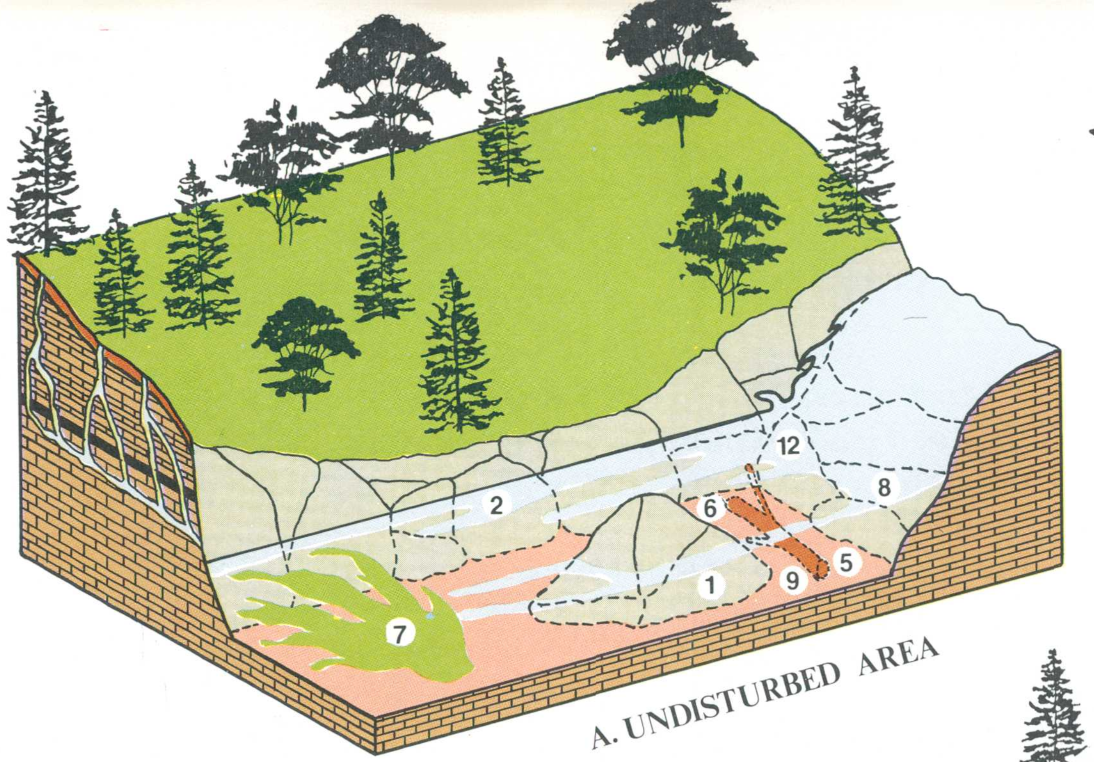
Streams draining undisturbed coal mining areas were observed to have a more stable habitat and are usually enriched in animal life. In Clear Fork near Jewett, Ohio, a stream draining a basin undisturbed by mining activities, large populations and more diverse composition of aquatic organisms were collected. Dominant aquatic insects were caddisflies, stoneflies, hellgrammites, and aquatic beetles. The bed materials consisted of firmly embedded rocks and logs. Stream discharge during sampling was 9.6 ft^3/s (cubic feet per second) and the stream consisted of pools and riffles. There was no bank cutting or deposition in the area. Dense streambank vegetation shaded the stream and water temperature was 14.5°C (degrees Celsius). Specific conductance was 1,100 μmhos (micromhos at 25 degrees Celsius). Specific conductance was 1,100 μmhos (micromhos at 25 degrees Celsius) and the pH 7.6 (near neutral solution). In Horse Run near McConnelsville, Ohio, a stream draining a basin disturbed by strip coal mining, population and composition of aquatic organisms changed. Dominant aquatic insects were midges and black flies. Bed material consisted of cobblestone, sand, and silt with deposition of new gravel and coarse sand on sand bars. Stream discharge during sampling was 4.1 ft^3/s and stream consisted of riffles with some minor pools. Bank erosion was evident. Water temperature (21.5°C) increased as streambank

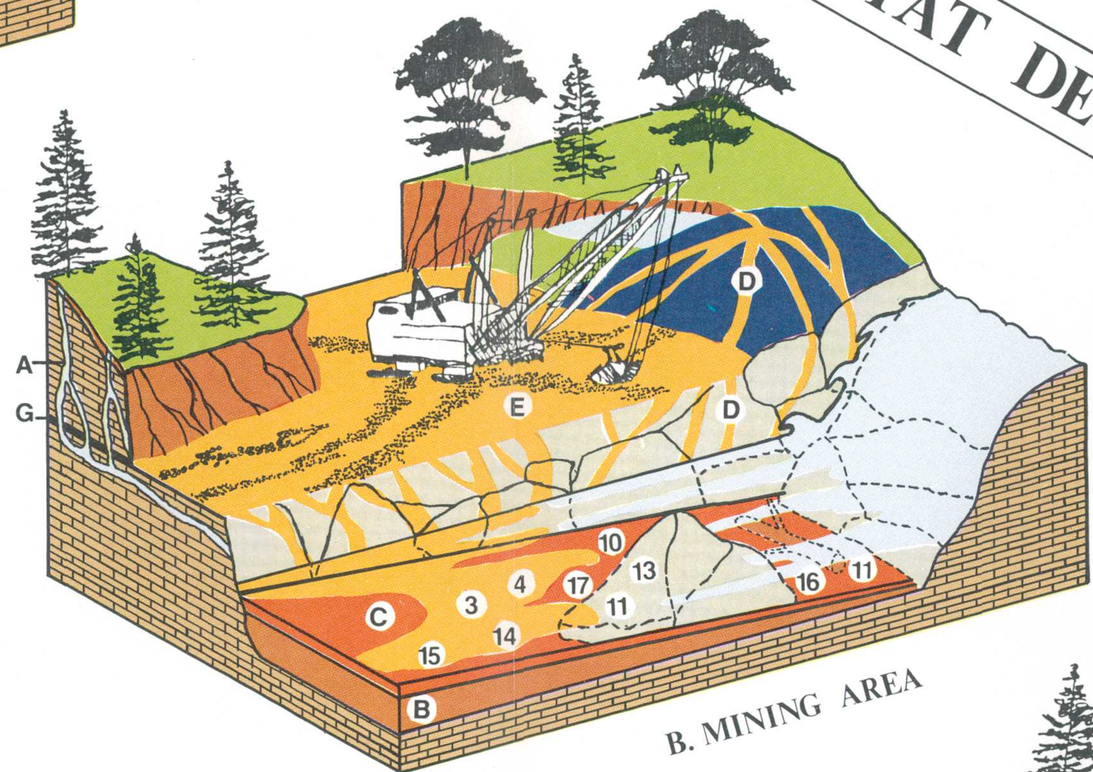
(Text continued on facing page)

(Text continued from page 44)

vegetation decreased. The filling of the stream channel was observed which buried the grasses and smaller shrubs along the streambank. Specific conductance was 1,100 μmhos and pH 7.7. In Bear Creek near Moxahala, Ohio, a stream draining an abandoned strip coal mine, most aquatic life had perished. Aquatic organisms observed were aquatic beetles and midges. These aquatic organisms were migratory (King, C., 1980, oral communication) since aquatic life perishes from severe acid-mine drainage (Olive, J., 1980 oral communication). Bed material consisted of sand, silt, and clay. Scouring, deposition, and bank erosion was observed with heavy silt deposits seen in pooling areas. Streambank vegetation was buried by heavy sediment deposition and water temperature (24°C) was observed to be increasing. Specific conductance was 2,120 μmhos and pH 3.0 (an acid solution).

The caddisfly, *Hydropsyche*, is the most abundant benthic invertebrate in undisturbed streams draining Area 7. The caddisflies are found in trailing algal mats and submerged vegetation below riffle areas. As a group, these caddisflies are widely distributed and are an excellent indicator of clean water receiving only small amounts of sewage effluent (Pennak, 1953).





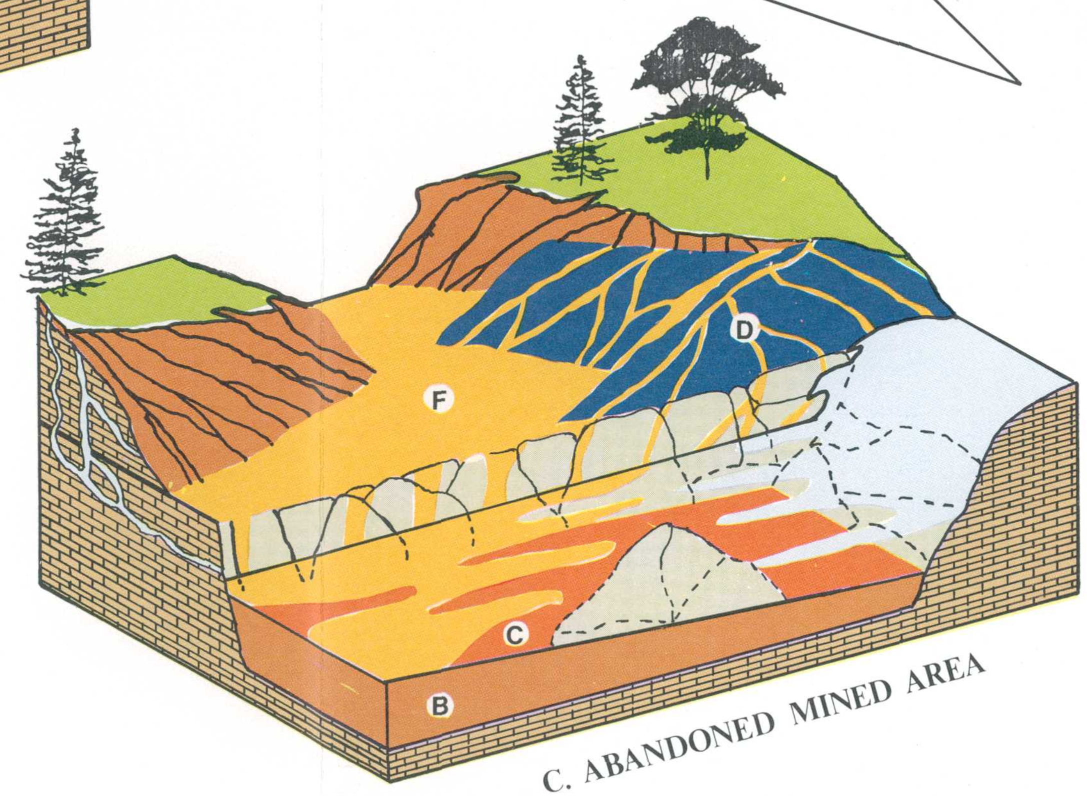


Figure 5.8.1-1 Conceptual model showing habitat degradation (model modified from Ohio Board on Unreclaimed Strip Mined Lands, 1974).

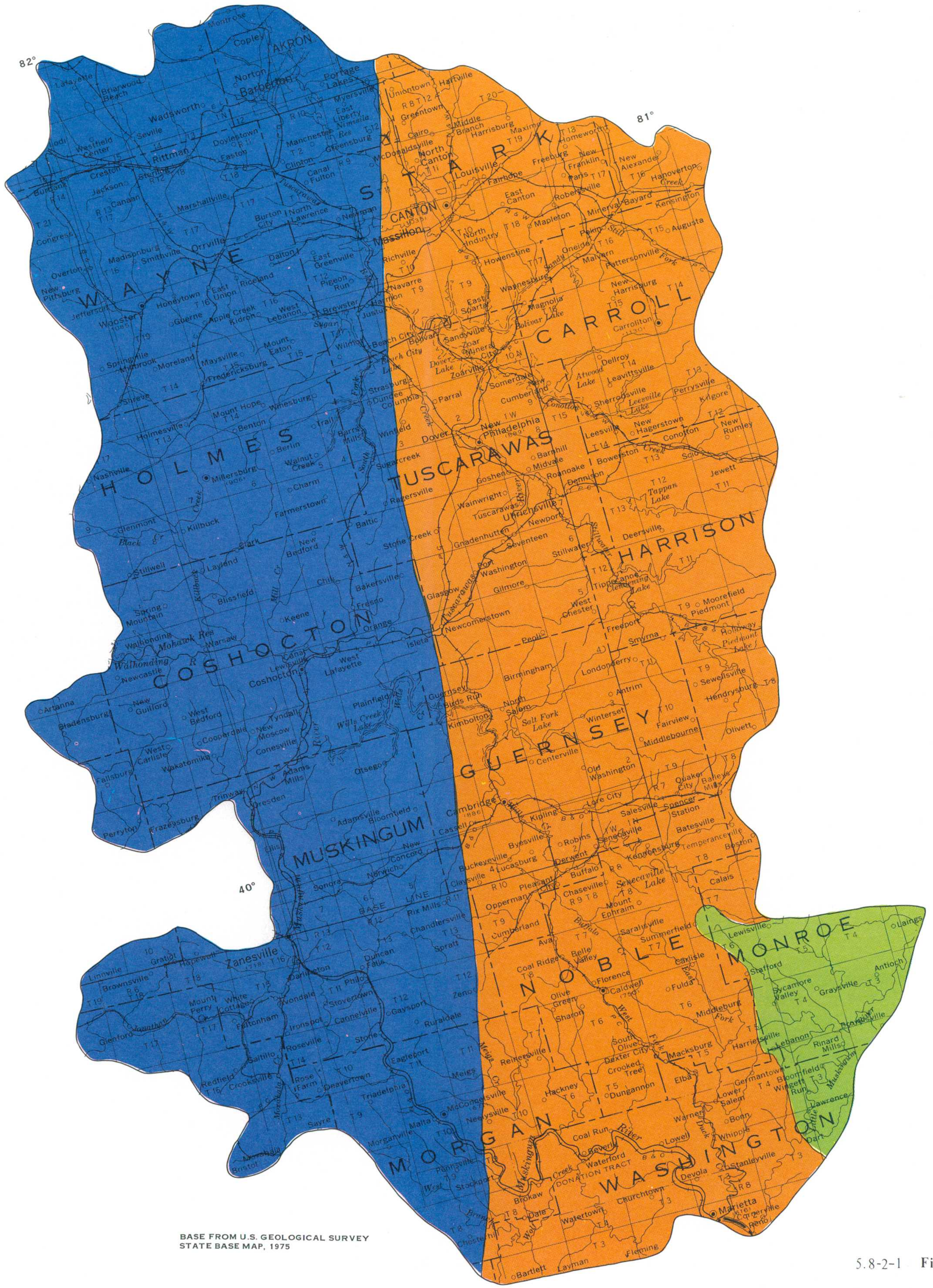
Most Streams in Area Classified Into Three Fish Distribution Classifications

Area 7 is divided into three fish-distribution classes, the Flushing Escarpment, the Glaciated Plateau, and the Darter Streak.

Relief affects stream gradients and land erosion which is a major factor in determining fish distribution in Area 7. Three stream classes, the Flushing Escarpment, the Glaciated Plateau, and the Darter Streak were suggested by Trautman (1957). The Flushing Escarpment (figure 5.8.2-1) parallels the Ohio River from Washington County northward to Columbiana County. Historically, large populations of fish have not been collected from the Flushing Escarpment owing to lack of suitable stream habitat (Trautman, 1957). Streams draining the Flushing Escarpment have a very rapid and flashy type of runoff. The substrata are thin, slate-like fragments of shale or other bedrock which offers little habitat or protection for riffle-inhabiting benthics and fish. During summer, the flow is reduced to a series of widely separated pools (Trautman, 1942). "Since 1900 mine and other industrial and domestic pollutants have been so prevalent in these streams as to affect the fish fauna adversely" (Trautman, 1957).

Most streams of the Glaciated Plateau have moderate runoff with well-developed riffles. The stream substrata are composed of gravel, boulders, and bedrock. The headwaters of these streams are fed by ground water inflow.

Most streams in the Darter Streak have moderate to low runoff and well developed riffles and pools. The substrata are composed of sand, gravel, bedrock and boulders. Streams draining this area contain an abundance of riffle-inhabiting species, especially the darters (Trautman, M. B., 1980, oral communication).



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0 10 20 30 MILES

0 10 20 30 KILOMETERS

EXPLANATION

Darter Streak

Glaciated Plateau

Flushing Escarpment

5.8-2-1 Fish distribution classification of streams in Area 7 (from Trautman, 1957).

NAWDEX, WATSTORE, OWDC Have Water Data Information

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

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 from over 400 organizations and serves as a central focal point to help those in need of water data to determine what information already is available.

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

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

A more detailed explanation of these three activities are given in sections 6.2, 6.3, and 6.4.

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. 6.2-1.) 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 requestor to the organization that retains the data required. To accomplish this service, NAWDEX maintains a computerized Master Water Data Index (fig. 6.2-2), 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. 6.2-3) also is maintained that identifies organizations that are sources of water data and the locations within these organizations from which data may be obtained. In addition NAWDEX has direct access to some large water-data bases of its members and has reciprocal agreements for the exchange of services with others.

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

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

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

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

Hours: 7:45-4:15 Eastern Time

or

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

Telephone: (614) 469-5553
FTS 943-5553

Hours 7:45-4:30 Eastern Time

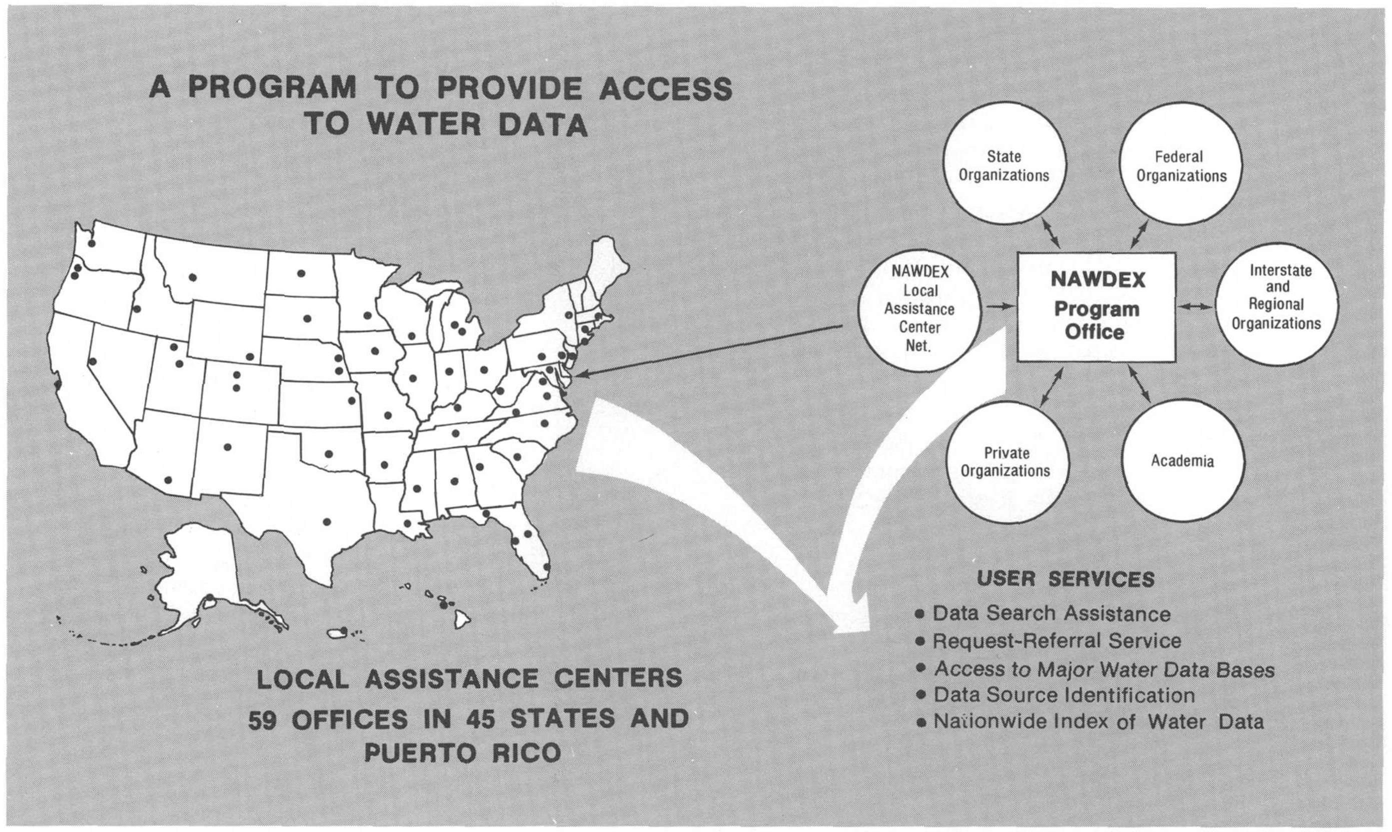

Figure 6.2-1 Access to water data

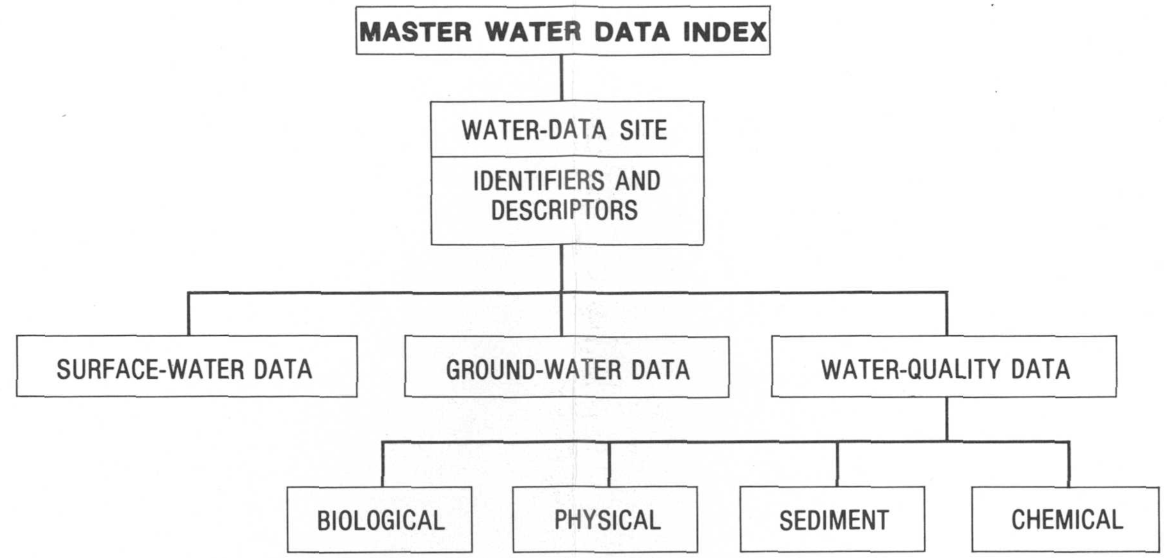

Figure 6.2-2 Master water-data index

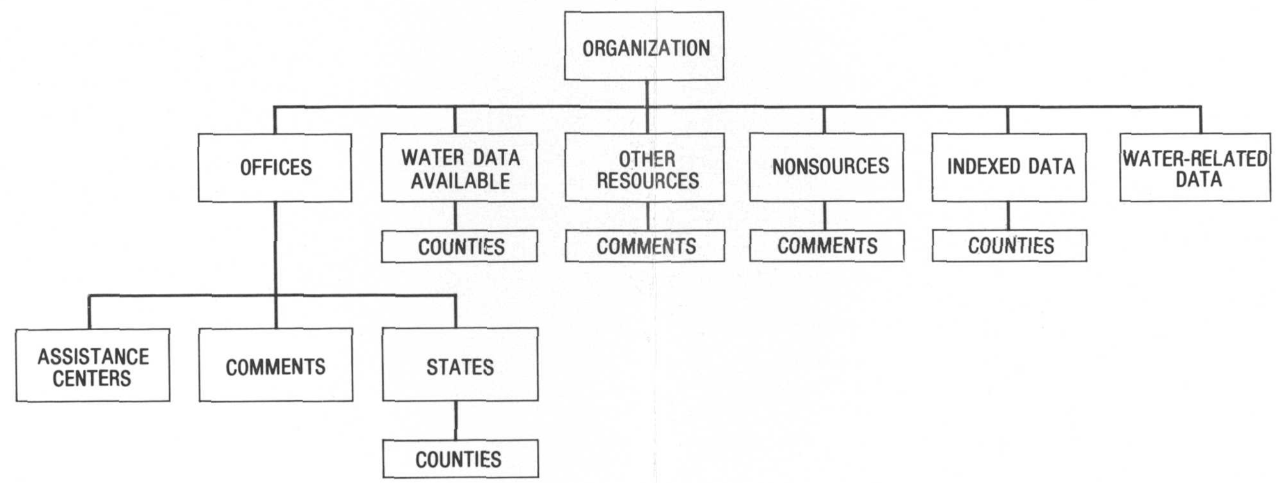

Figure 6.2-3 Water-data sources directory

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, Va. Data may be obtained from WATSTORE through the Water Resources Division's 46 district offices. General inquires about WATSTORE may be directed to:

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

or

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

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

The WATSTORE system consists of several files in which data are grouped and stored by common characteristics and data-collection frequencies. The system 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. 6.3-1). 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 accomodate 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, Colo., and Atlanta, Ga., 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 analysis. 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 capacity 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.

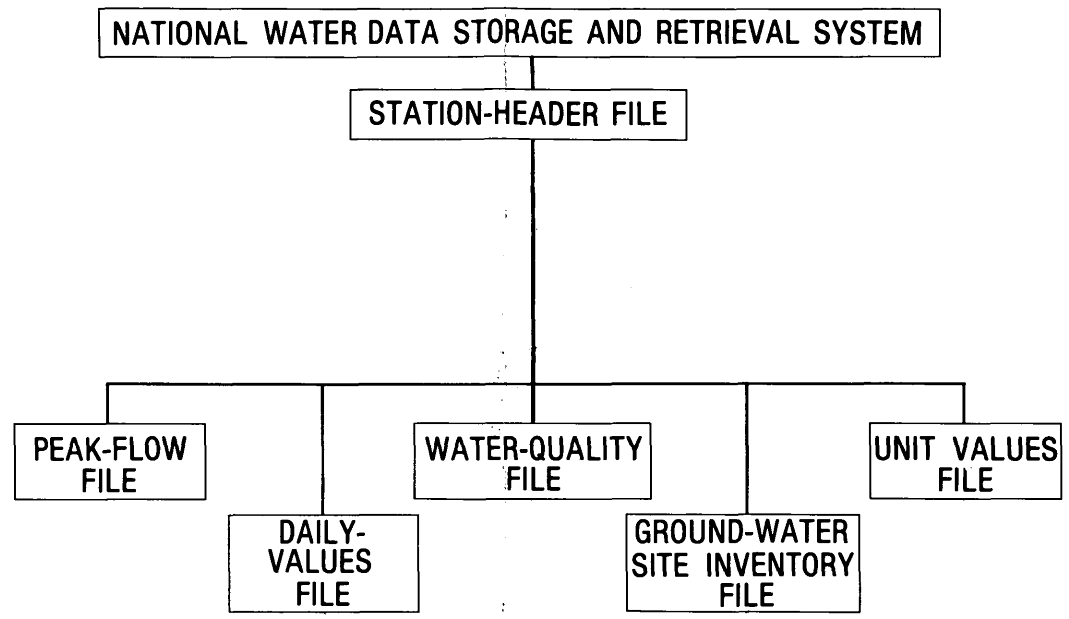

Figure 6.3-1 Index file stored data

Water Data Indexed for Coal Provinces

A special index, "Index to Water-Data Activites 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. 6.4-1): 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 Coal provinces; 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 6.2.)

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

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

Telephone: (614) 469-5553
FTS 943-5553

or

Office of Surface Mining
U.S. Department of the Interior
1st Floor, Thomas Hill Bldg.
950 Kanawha Blvd., East
Charleston, WV 25301

Telephone: (304) 344-3481

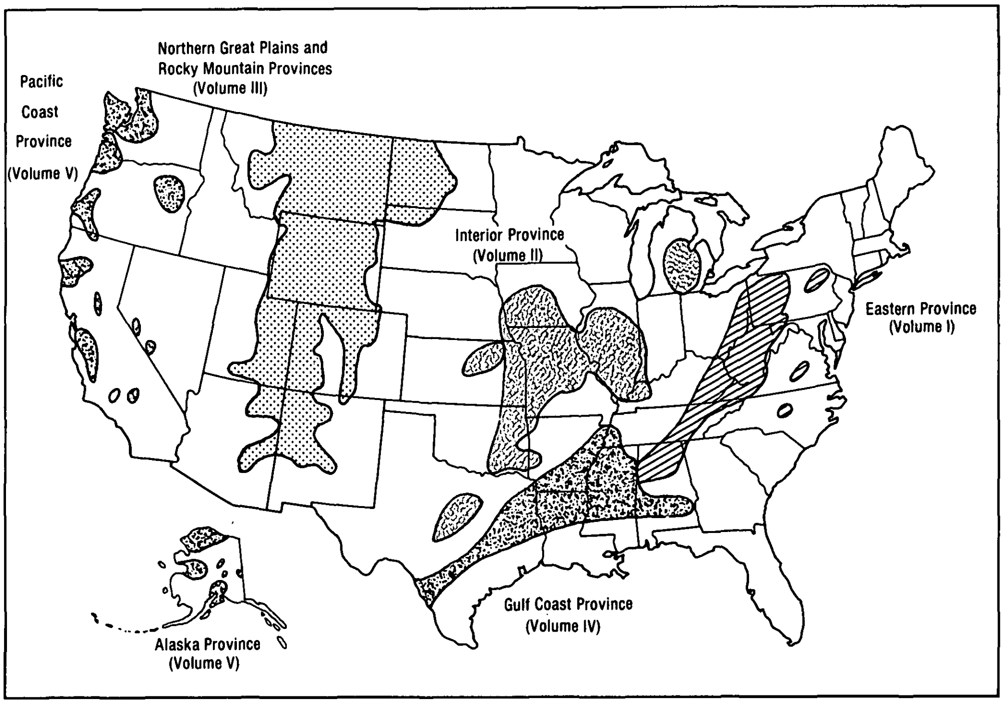

Figure 6.4-1 Index volumes and related provinces

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Appendix 1. Synoptic site for streams draining Area 7, selected land-use categories and miscellaneous surface water stations used throughout the report.

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.

Selected land-use categories: I, unmined areas; II, currently mined areas; III, reclaimed areas; IV, abandoned mine areas.

Site numbers and letters: Map numbers given to all sites and letters to miscellaneous surface-water stations used throughout the report.

Station numbers: The first six digits denote degrees, minutes, and seconds of latitude; the next seven digits denote degrees, minutes, and seconds of longitude.

Miscellaneous stations: Continuous record gaging station at a particular site on a stream where systematic observations of hydrologic data were obtained.

Data collected: Published in U.S. Geological Survey Water Data Report, OH-79-1, and U.S. Geological Survey Water Data Report, OH-79-A.

Site	Station number	Station name	County	Drainage area (mi^2)
		I Unmined areas		
70	392503081351300	Horse Run near Barlow, OH	Washington	13.04
71	392557081384900	South Fork Wolf Creek near Watertown, OH	Washington	7.54
77	392756081512000	North Branch Coal Run at Chesterhill, OH	Morgan	2.60
79	392840081174000	Fifteenmile Creek at Dart, OH	Washington	20.20
80	392914081474200	Aldridge Run near Chesterhill, OH	Washington	11.23
81	392947081314000	Rainbow Creek near Devola, OH	Washington	13.68
91	393317081475100	Bald Eagle Run at Stockport, OH	Morgan	10.15
92	393343081554600	Unnamed Creek Little Wolf Creek near Pennsville, OH	Morgan	7.87
93	393400081252100	West Fork Duck Creek at Warner, OH	Washington	30.55
97	393609081094600	Clear Fork near Rinard Mills, OH	Monroe	197.80
98	393620081554200	Buck Run near Pennsville, OH	Morgan	5.51
99	393657081091500	Straight Fork near Rinard Mills, OH	Monroe	11.36
102	393729081382200	Little Olive Green Creek near McConnelsville, OH	Morgan	15.18
108	394232081091900	Town Fork near Graysville, OH	Monroe	9.66
111	394310081570000	Island Run near McConnelsville, OH	Morgan	5.57
121	394735081545600	Blue Rock Creek near Philo, OH	Muskingum	9.88
124	394953081182800	Skin Creek near Summerfield, OH	Monroe	7.10
126	395115081163800	Seneca Fork Wills Creek near Barnesville, OH	Monroe	17.78
128	395140081504600	Kent Run near Chandlersville, OH	Muskingum	7.43
131	395210082165600	Painter Creek near Somerset, OH	Perry	17.96
137	395411081492500	Williams Fork at Chandlersville, OH	Muskingum	6.47
139	395419082184400	Valley Run near Glenford, OH	Perry	28.71
*143	395522081514100	White Eyes Creek near Chandlersville, OH	Muskingum	12.37
150	395801081350200	Chapman Run near Byesville, OH	Guernsey	11.36
163	400601081573600	North Branch Symmes Creek near Adamsville, OH	Muskingum	12.22
166	400817082120400	Brushy Fork Wakatomika Creek near Frazeysburg, OH	Licking	14.76
167	400932081265100	Clear Fork near Birmingham, OH	Guernsey	11.23
168	400945082094600	Nickel Valley Run near Frazeysburg, OH	Muskingum	4.10
*169	401005082001700	Mill Fork Wakatomika Creek near Trinway, OH	Coshocton	23.17
170	401028081294100	Rocky Fork near Birmingham, OH	Guernsey	12.26
181	401342081343200	Postboy Creek near Kimbolton, OH	Tuscarawas	5.00
184	401417082085000	Winding Fork Wakatomika Creek near Walhonding, OH	Coshocton	16.90
185	401645081215300	Fallen Timber Creek near Tippecanoe, OH	Tuscarawas	7.60
191	401914082042600	Mohawk Creek near Walhonding, OH	Coshocton	22.25
194	401953081163100	Skull Fork near Freeport, OH	Guernsey	38.83
*196	402012081051200	Clear Fork near Jewett, OH	Harrison	21.53
198	402058082004800	Beaver Run near Warsaw, OH	Coshocton	12.90
205	402415081025500	Irish Creek near Scio, OH	Harrison	16.02
207	402520081050600	Dining Fork near Scio, OH	Harrison	12.70
208	402548082560600	Doughty Creek near Clark, OH	Coshocton	55.75
209	402559081592100	Big Run near Killbuck, OH	Coshocton	10.46
219	403041082062900	Black Creek Tributary at Glenmont, OH	Holmes	5.40
220	403047081064700	North Fork McGuire Creek near Carrollton, OH	Carroll	11.24
232	403641081565100	Paint Creek near Holmesville, OH	Holmes	27.20
233	403655081550200	Martins Creek near Holmesville, OH	Holmes	22.88
236	403755081022200	Pipes Fork near Carrollton, OH	Carroll	6.12
237	403807081552700	Salt Creek at Holmesville, OH	Holmes	7.99
243	404136082001800	Shreve Creek near Shreve, OH	Wayne	10.58
253	404434081315500	Pigeon Run near Navarre, OH	Stark	9.52
255	404505081041100	Middle Branch Sandy Creek near Minerva, OH	Columbiana	20.31
*256	404507081022000	Conser Run near Minerva, OH	Columbiana	15.44
257	404512081584800	Unnamed Creek near Shreve, OH	Wayne	5.79
264	404808081302600	Sippo Creek at Massillon, OH	Stark	17.27
265	404818081331700	West Branch Sippo Creek at Massillon, OH	Stark	9.78
266	404831081301000	Sippo Creek at Massillon, OH	Stark	16.16
267	404858081464900	Little Sugar Creek near Orrville, OH	Wayne	17.93
268	404909081163100	Unnamed Creek near Louisville, OH	Stark	13.17
269	404922081330601	Newman Creek near Massillon, OH	Stark	38.28
270	405022081242200	Unnamed Creek at Avondale, OH	Stark	15.52
279	405432081294900	Nimisila Creek near North Canton, OH	Stark	8.26
282	405610081403300	Silver Creek near Clinton, OH	Wayne	8.39
283	405620081171300	Swartz Ditch near Hartville, OH	Stark	9.74
290	405919081261300	Unnamed Creek near Uniontown, OH	Summit	12.97

Appendix 1. (Continued)

Site	Station number	Station name	County	Drainage area (mi^2)
		II Currently mined areas		
90	393240081310500	Cat Creek at Lowell, OH	Washington	10.91
103	393840081360300	Keith Fork near Caldwell, OH	Morgan	14.87
104	393950081361700	Sharon Fork near Caldwell, OH	Morgan	19.60
110	394310081215200	Schwab Run near Summerfield, OH	Noble	3.74
*112	394311081425700	Horse Run near McConnelsville, OH	Morgan	4.50
132	395255082040900	Thompson Run near White Cottage, OH	Muskingum	15.32
133	395313081324300	Buffalo Creek near Pleasant City, OH	Noble	42.15
134	395320081401200	Yoker Creek near Cumberland, OH	Guernsey	12.00
156	400224081093300	Spencer Creek near Hendrysburg, OH	Belmont	8.75
171	401100082015200	Sand Fork Wakatomika Creek near Trinway, OH	Coshocton	8.79
173	401106081500500	No Name Tributary Wills Creek near Conesville, OH	Coshocton	3.00
182	401357081435800	Center Creek near Plainfield, OH	Coshocton	5.50
183	401505081061800	Brusky Fork near Cadiz, OH	Harrison	18.54
186	401756081050800	Standing Stone Fork near Cadiz, OH	Harrison	9.45
188	401805081394500	Evans Creek near West Lafayette, OH	Coshocton	21.02
190	401829081192601	Crooked Creek near Tippecanoe, OH	Tuscarawas	47.50
192	401936081504900	Spoon Creek near Coshocton, OH	Coshocton	7.70
195	402011081450500	West Fork White Eyes Creek near Fresno, OH	Coshocton	20.00
199	402137081505300	Little Mill Creek near Keene, OH	Coshocton	7.43
226	403242081413800	Goose Creek near Walnut Creek, OH	Holmes	6.09
228	403440081113400	Willow Run near Dellroy, OH	Carroll	7.85
241	404026081174100	Pleasant Valley Run near Waynesburg, OH	Stark	9.98
251	404310081090800	Hugle Run near Malvern, OH	Carroll	21.00
		III Reclaimed areas		
78	392814081135000	Archers Fork Little Muskingum River near Newport, OH	Washington	15.45
86	393129081281800	Bear Creek near Whipple, OH	Washington	5.55
100	393707081441400	Fourmile Run near McConnelsville, OH	Morgan	12.16
106	394125081481500	Mans Fork near McConnelsville, OH	Morgan	11.82
127	395128082121600	Turkey Run near Somerset, OH	Perry	11.73
135	395329081530800	Boggs Creek near Duncan Falls, OH	Muskingum	17.90
142	395444081273400	Opossum Run near Senecaville, OH	Noble	10.72
147	395659081522700	Little Salt Creek near Norwich, OH	Muskingum	13.19
152	395908081273400	Leatherwood Creek at Lore City, OH	Guernsey	57.45
153	395941081432900	North Crooked Creek at New Concord, OH	Guernsey	8.81
155	400037081392700	Peters Creek near New Concord, OH	Guernsey	10.36
162	400520081411700	Indian Camp Run near New Concord, OH	Guernsey	6.65
177	401237081172700	Craborchard Creek near Freeport, OH	Harrison	11.47
180	401314081191700	Atkinson Creek near Freeport, OH	Harrison	8.55
197	402023081553800	Bucklew Run near Coshocton, OH	Coshocton	5.90
216	402843082012600	Wolf Creek near Killbuck, OH	Homes	23.13
231	403555081393700	Indian Trail Creek near Winesburg, OH	Tuscarawas	13.50
238	403851081414500	Crabapple Creek near Mount Eaton, OH	Holmes	10.77
242	404052081281900	Unnamed Creek near Bolivar, OH	Stark	8.58
247	404210081023700	Muddy Fork near Minerva, OH	Carroll	11.81
248	404229081342300	Elm Run at Brewster, OH	Stark	6.25
250	404300081395000	North Fork near West Lebanon, OH	Wayne	16.83
254	404444081142700	Black Run near Robertsville, OH	Stark	16.39
271	405027081554200	Little Apple Creek near Wooster, OH	Wayne	9.07
273	405120081345100	Fox Run near Massillon, OH	Stark	13.17
280	405457081334301	Nimisila Creek near Canal Fulton, OH	Summit	23.14
284	405645081484300	Little Chippewa Creek near Rittman, OH	Wayne	26.55
285	405709081440300	Mill Creek at Easton, OH	Wayne	7.18
286	405758081485600	Tommy Run near Rittman, OH	Wayne	6.30
288	405830081462000	River Styx at Rittman, OH	Wayne	28.37
294	410024081380400	Hudson Run at Barberton, OH	Summit	7.32
298	410132081394400	Hudson Run near Norton, OH	Summit	4.83
300	410318081363200	Wolf Creek near Barberton, OH	Summit	28.80
302	410517081411500	Wolf Creek near Copley, OH	Summit	20.67
303	410644081365300	Schocalog Run near Fairlawn, OH	Summit	3.20
		IV Abandoned mine areas		
84	393112081245600	Whipple Run at Whipple, OH	Washington	9.50
89	393235081225500	Paw Paw Creek at Lower Salem, OH	Washington	21.44
101	393720081212100	Middle Fork Duck Creek near Germantown, OH	Noble	30.55
113	394331082021000	Ogg Creek near New Lexington, OH	Morgan	8.15
*115	394508082092800	McLuney Creek near New Lexington, OH	Perry	2.28
123	394836082081600	Buckeye Fork near Fultonham, OH	Perry	8.62
*125	395029081590700	Brush Creek near Philo, OH	Muskingum	18.57
130	395217082055300	Kent Run at White Cottage, OH	Muskingum	22.82
*189	401812081362400	Lick Run at Newcomerstown, OH	Tuscarawas	1.90
193	401940081441400	East Fork White Eyes Creek near Fresno, OH	Coshocton	12.41
206	402431081234300	Mud Run at Tuscarawas, OH	Tuscarawas	9.20
212	402738081262300	Old Town Creek at New Philadelphia, OH	Tuscarawas	18.60
*217	402859081290700	Crooked Run at New Philadelphia, OH	Tuscarawas	7.70
222	403108081364900	East Branch at Sugarcreek, OH	Tuscarawas	28.20
229	403445081313200	Broad Run at Strasburg, OH	Tuscarawas	19.50
*230	403550081213400	Huff Run at Mineral City, OH	Tuscarawas	12.10
245	404155081241400	Bear Run near Canton, OH	Stark	5.07

Miscellaneous surface-water stations used throughout report

Site	Station number	Station name	Drainage area (mi^2)	Period of record
A	03144000	Wakatomika Creek near Frazeysburg, OH	140	Sept. 1936 to present
B	03129000	Tuscarawas River at Newcomerstown, OH	2,443	Sept. 1921 to present
C	03115400	Little Muskingum River at Bloomfield, OH	210	Oct. 1950 to present
D	03117500	Sandy Creek at Waynesburg, OH	253	Oct. 1938 to present
E	03109500	Little Beaver Creek near East Liverpool, OH (not shown on map)	496	May 1915 to present

Appendix 2. Chemical ranges for selected land use categories

(Explanation: deg C, degrees Celsius; mg/L, milligrams per liter; ug/g, micrograms per gram; ug/L, micrograms per liter.)

Water quality data, water year October 1978 to 1979

Land use categories	Temperature (deg C)	Specific conductance (micromhos)	pH (units)	Carbon dioxide dissolved (mg/L as CO_2)	Alkalinity (mg/L as $CACO_3$)	Bicarbonate (mg/L as HCO_3)	Carbonate (mg/L as CO_3)	Sulfate dissolved (mg/L as SO_4)	Arsenic total in bottom material (µg/g as AS)	Cadmium recov. from bottom material (µg/g as CD)	Chromium recov. from bottom material (ug/g)	Cobalt recov. from bottom material (µg/g as CO)	Copper recov. from bottom material (µg/g as CU)
I Unmined areas													
Maximum	24.0	1,580	9.3	61.0	250	308	26	870	-	<10	40	50	46
Minimum	8.0	150	6.3	0.2	32	32	0	16	-	<10	<10	<10	<10
II Currently mined areas													
Maximum	26.5	2,150	8.8	12.0	240	294	2	1,200	-	<10	50	60	30
Minimum	11.5	210	6.5	0.2	15	18	0	14	-	<10	<10	<10	<10
III Reclaimed areas													
Maximum	25.5	936	9.2	32.0	320	308	55	500	-	<10	20	70	30
Minimum	11.0	185	6.4	0.1	0	0	0	23	-	<10	<10	<10	<10
IV Abandoned mine areas													
Maximum	23.5	2,300	8.5	56	200	240	0	1,200	-	<10	30	30	440
Minimum	14.0	302	2.8	0	0	0	0	26	-	<10	<10	<10	<0

Land use categories	Iron suspended recoverable (µg/L as FE)	Iron total recoverable (µg/L as FE)	Iron dissolved (µg/L as FE)	Lead recov. from bottom material (µg/g as PB)	Manganese recov. from bottom material (ug/g)	Manganese suspended recov. (µg/L as MN)	Manganese total recoverable (µg/L as MN)	Manganese dissolved (µg/L as MN)	Zinc recov. from bottom material (µg/g as ZN)	Selenium total in bottom material (µg/g)	Iron recov. from bottom material (µg/g as FE)	Mercury recov. from bottom material (µg/g as HG)
I Unmined areas												
Maximum	2,900	6,400	730	1,100	13,000	400	6,900	6,800	130	-	62,000	0.25
Minimum	50	70	0	<10	110	0	10	0	10	-	5,100	0.00
II Currently mined areas												
Maximum	3,000	3,000	1,100	40	21,000	300	5,900	5,700	170	-	8,900	0.00
Minimum	110	170	0	<10	290	0	20	10	20	-	4,900	0.00
III Reclaimed areas												
Maximum	9,100	9,100	600	490	2,100	400	6,000	6,000	140	-	57,000	0.12
Minimum	60	50	0	<10	160	0	0	0	10	-	2,000	0.00
IV Abandoned mine areas												
Maximum	1,400	99,000	85,000	70	1,600	6,600	31,000	31,000	130	-	120,000	0.00
Minimum	250	80	10	<10	190	0	10	10	20	-	8,300	0.00

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