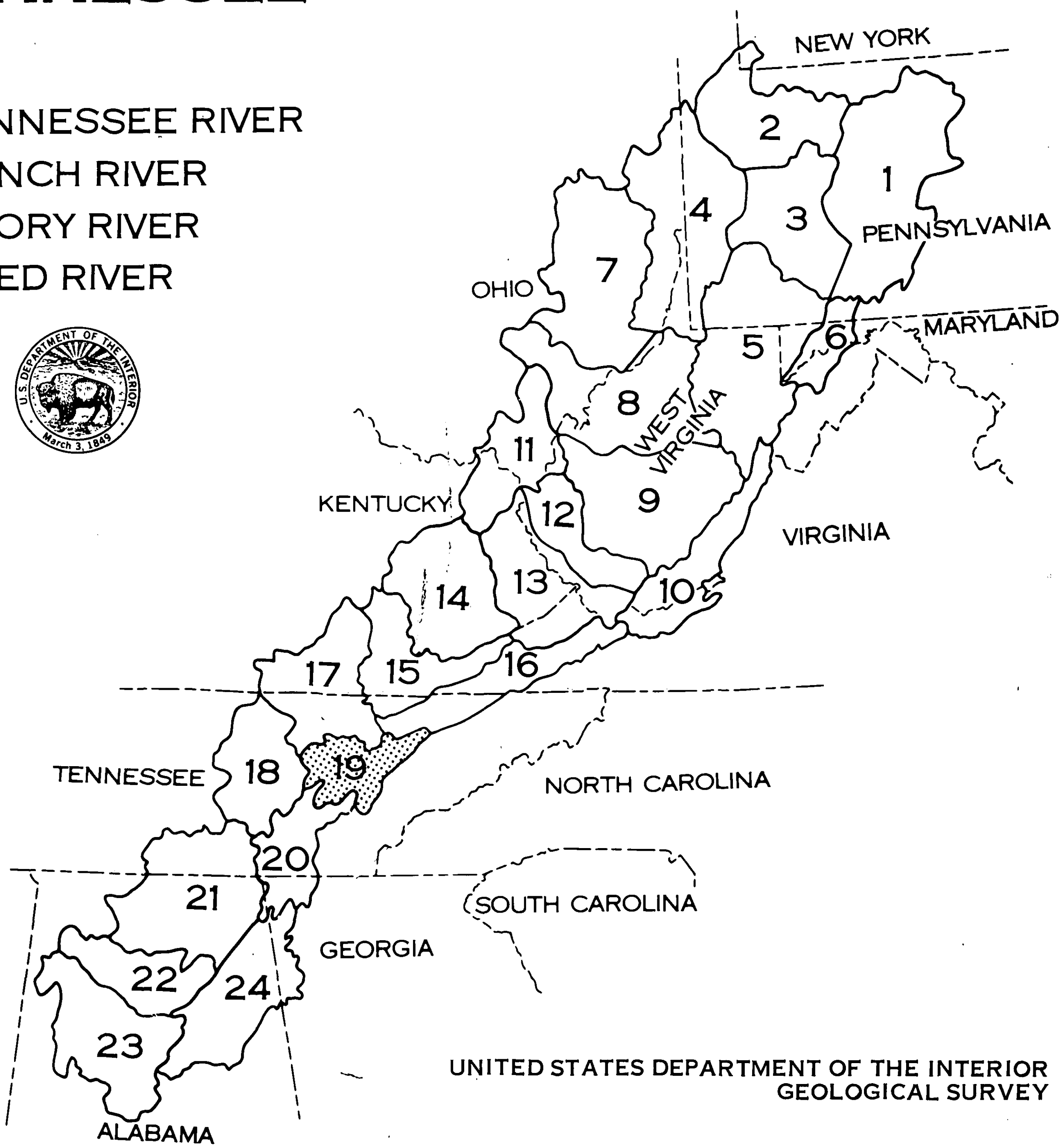
HYDROLOGY OF AREA 19, EASTERN COAL PROVINCE, TENNESSEE

- TENNESSEE RIVER
- CLINCH RIVER
- EMORY RIVER
- OBED RIVER



UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

WATER-RESOURCES INVESTIGATIONS
OPEN-FILE REPORT 81-901

HYDROLOGY OF AREA 19, EASTERN COAL PROVINCE, TENNESSEE

BY
MICHAEL W. GAYDOS AND OTHERS

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NASHVILLE, TENNESSEE
JANUARY 1982

UNITED STATES DEPARTMENT OF THE INTERIOR

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GEOLOGICAL SURVEY

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CONTENTS

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

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

Multiply inch-pound units	By	To obtain SI units
inches (in)	25.4	millimeters (mm)
inches per hour (in/h)	25.4	millimeters per hour (mm/h)
	2.54	centimeters per hour (cm/h)
feet (ft)	0.3048	meters (m)
feet per mile (ft/mi)	0.1894	meters per kilometer (m/km)
miles (mi)	1.609	kilometers (km)
square miles (mi^2)	2.590	square kilometers (km^2)
gallons per minute (gal/min)	0.06309	liters per second (L/s)
million gallons per day (mgal/d)	0.04381	cubic meters per second (m^3/s)
	3,785	cubic meters per day (m^3/d)
cubic feet per second (ft^3/s)	0.02832	cubic meters per second (m^3/s)
cubic feet per second per square mile [(ft^3/s)/mi^2]	0.01093	cubic meters per second per square kilometer [(m^3/s)/km^2]
tons per square mile per year [(tons/mi^2)/yr]	0.3503	metric tons per square kilometer per year [(t/km^2)/a]

HYDROLOGY OF AREA 19, EASTERN COAL PROVINCE, TENNESSEE

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Abstract

The need for hydrologic information on coal-mining areas has intensified because of the recent increase in surface-mining activity and its potentially adverse impact on the hydrologic environment. The Surface Mining Control and Reclamation Act of 1977 (Public Law 95-87) contains specific requirements regarding hydrologic information prior to mining, evaluation of the potential effects of proposed mines, measures to control these effects, and measures to provide land reclamation. The Act establishes specific limits for selected chemical constituents and physical properties of mine effluents.

This report describes the physical and hydrologic features of Area 19, one of the 24 hydrologic reporting areas in the Eastern Coal province which includes parts of ten states. The report provides a background for the more detailed, site-specific studies required by the Act.

Area 19, including approximately 2,200 square miles, is in two physiographic provinces, the Cumberland Plateau and the Ridge and Valley. Numerous surface mines, about 1 percent of the land use, are in the Cumberland Plateau. No mines are in the Ridge and Valley. During dry periods, streams in the Plateau are not as well sustained as are those in the Ridge and Valley. Therefore, low flows are lower in the Cumberland Plateau, although average annual flows are about 2 cubic feet per second per square mile throughout Area 19. Ground water availability varies widely; well yields in the Cumberland Plateau range from about 5 to 150 gallons per minute, whereas yields in the Ridge and Valley range from about 5 to 600 gallons per minute.

Increased sedimentation and acidic and (or) highly mineralized effluents from mine sites are usually the most severe surface-water problems in coal-mine areas. Although low pH values and concentrations of iron and manganese exceeding limits for mine effluents have been determined at several sites, no widespread water-quality problems have yet been identified. Suspended-sediment loads and total recoverable iron concentrations are related and can be estimated at several sites.

Locally severe water-quality problems may exist and not be detected. No mine drainage or seepage was sampled. Data-collection sites throughout the area were located both upstream and downstream from existing mine effluents.

1.0 INTRODUCTION

Hydrologic Environment can be Adversely Affected by Surface Mining

The net effects of surface mining can cause critical water problems because of degradation of water quality. The magnitude of these effects depends on the methods of mining and reclamation, and the physical and hydrologic characteristics of the general area of the mine.

The importance of coal as a source of energy has increased dramatically in the United States in the last decade caused partly by the rapid rise in the price of oil. Efficient development of coal resources, however, will require expansion of surface mining which can cause detrimental changes to the environment. Surface mining activities such as removal of vegetation and excavation of overburden create spoil piles (unstable areas of loose earth and rock) which erode easily and, if not controlled, contribute additional sediment to streams. Moreover, dissolution of soluble minerals exposed in the spoil piles and mine openings may produce a highly mineralized and acidic effluent (fig. 1.0-1).

The net effects of increased sedimentation and increased mineralization can cause severe water problems. These include limitations on the domestic, municipal, industrial, and recreational use of water because of poor quality. In addition, a decline of ground-water levels can occur in and near surface-mining areas when excavation extends below the water table causing some wells and springs to go dry (fig. 1.0-2). The quality of ground water can also be affected, although the effects may take much longer to determine at points remote from mining acitivites because of the relatively slow movement of water in the subsurface.

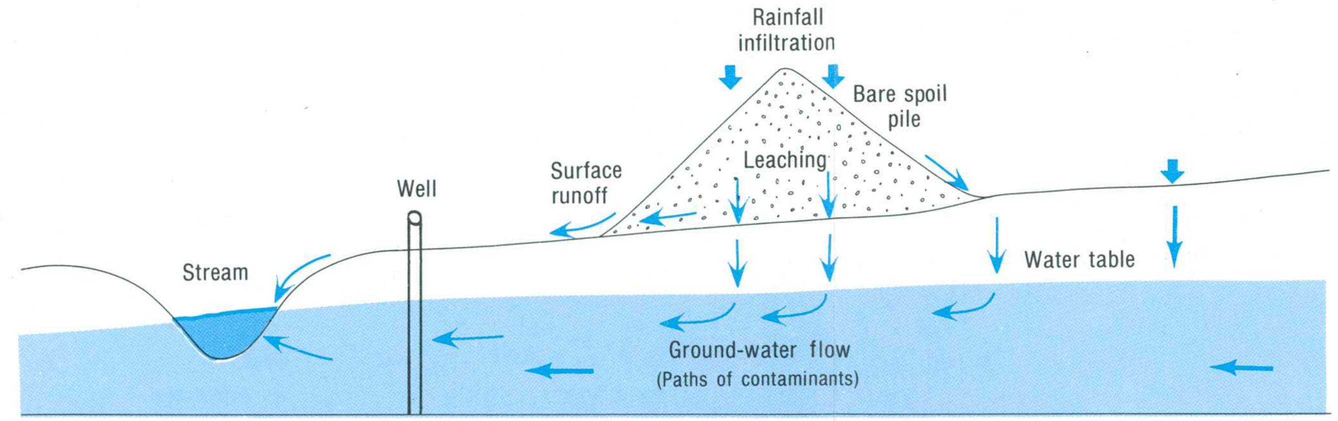
The magnitude of the effects of surface mining on the hydrologic environment depends on several factors. The most important of these include mining and reclamation methods, slope of land, type of rock, amount of rainfall, quality of ground and surface waters, and rate of water movement. The adverse effects are most apparent at or near the mine site. Surface water-quality problems generally will diminish downstream from a mine site due to natural processes, such as dilution. However, additional mining activities downstream can have a cumulative impact.

Recognizing the potentially adverse impact that coal mining could have on the environment, the "Surface Mining Control and Reclamation Act of 1977" was enacted as Public Law 95-87, August 3, 1977. The Act requires (l) 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 both to control adverse effects of mining on the "hydrologic balance" and to provide land reclamation. Hydrologic information, therefore, is needed to enable surface-mine owners and operators, and consultants to prepare the required permit applications and to enable regulatory authorities to appraise the adequacy of the applications.

This report broadly characterizes the hydrology of a part of the Eastern Coal province. In essence, it provides a framework for the more detailed and site-specific studies that will be needed by a mining permit applicant to satisfy the requirements of the Act.

The Eastern Coal province extends from New York to Alabama, covers parts of 10 states, and is divided into 24 hydrologic reporting areas. The division is based primarily on surface hydrologic basins. Additional factors such as location, size, and mining activity were considered when the division was made. Drainage basins or parts of basins are combined to form each reporting area.

Area 19, which is in the southern part of the Eastern Coal province, is located in eastern Tennessee and includes parts of 15 counties (fig. 1.0-3). This report describes the physical and hydrologic features of the area with emphasis on the quality of the surface and ground water. It also identifies the network of hydrologic stations for which data are available. Much of the data used in this report was collected prior to enactment of Public Law 95-87, but some additional surface-water data have been collected since the law was enacted. Although the Act establishes specific limits for selected chemical constituents or properties in mine effluents, data were collected throughout Area 19 at sites both upstream and downstream from existing effluents and mine seepages. These data should provide hydrologic information for the general area, but not for specific mine sites. Few ground-water data have been acquired in the area since 1979.



From SYNTHETIC FUELS DEVELOPMENT by U.S. Dept. of Int. and U.S.G.S.

Figure 1.0-1 Leaching from spoil material.

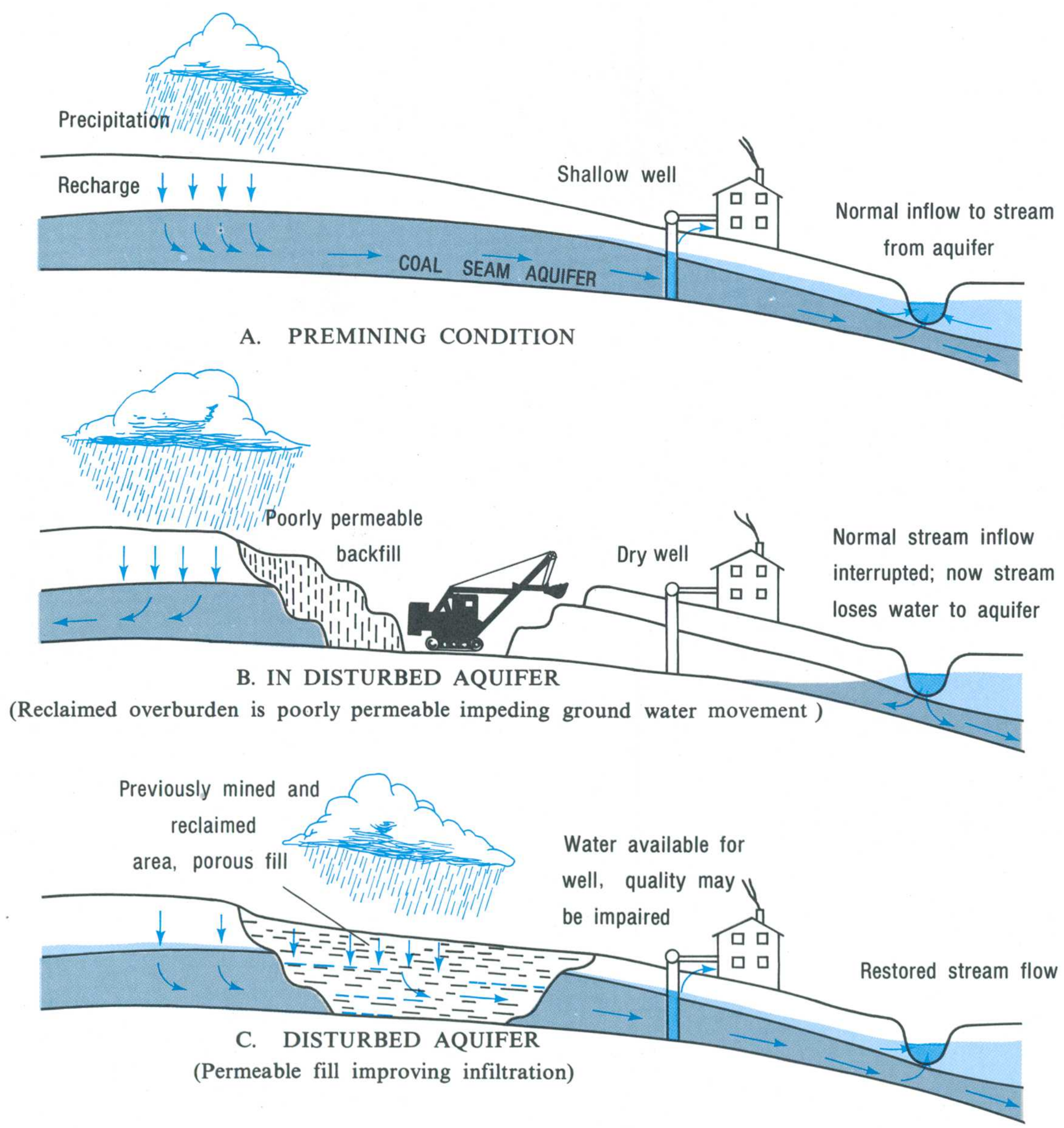


Figure 1.0-2 Potential impact of mining on aquifers.

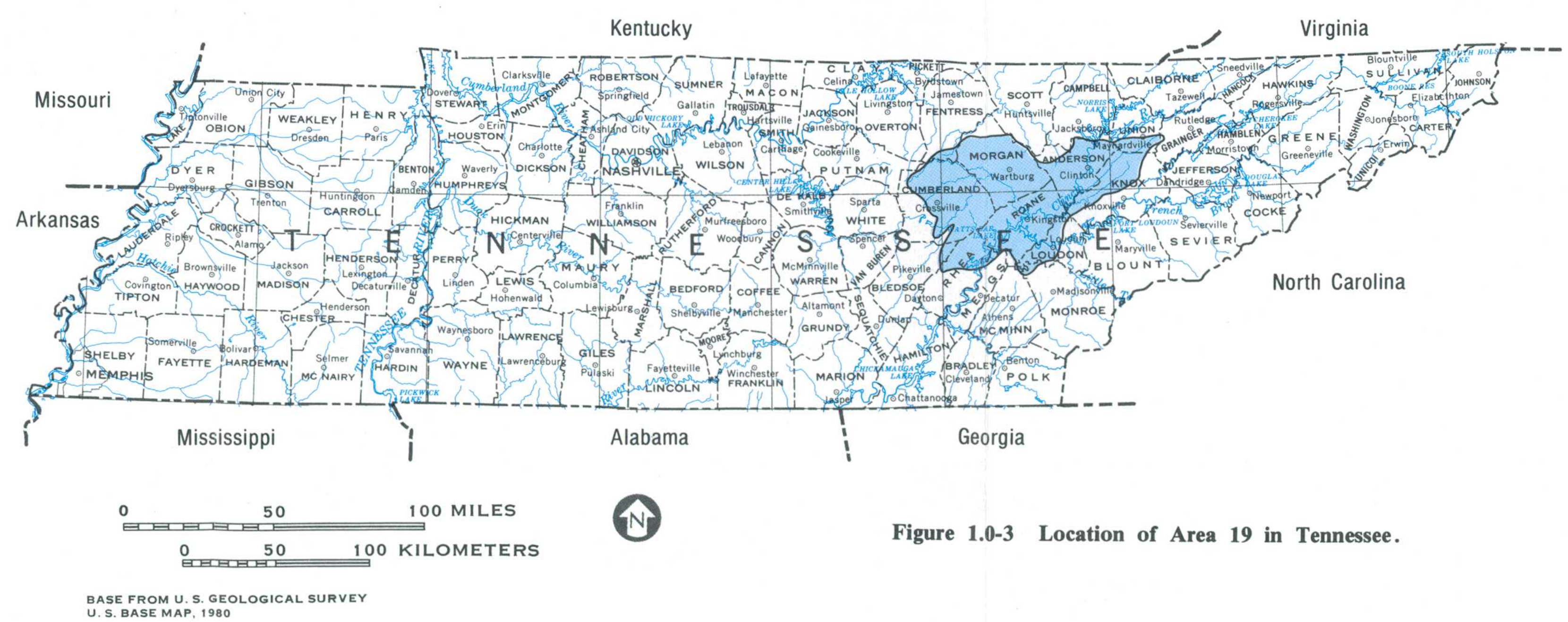


Figure 1.0-3 Location of Area 19 in Tennessee.

Area is in Two Physiographic Provinces

Area 19 lies in parts of two physiographic provinces, the Cumberland Plateau (a section of the Appalachian Plateau province) and the Ridge and Valley province.

The Cumberland Plateau in the northwest part of the area is differentiated from the Ridge and Valley in the southeast on the basis of altitude and topography. The Cumberland Plateau is a rolling upland area with an escarpment separating it from areas of lower altitude in the Ridge and Valley (fig. 2.1-1).

The Cumberland Plateau in Area 19 has a general altitude of 1,500-1,700 feet and an area of more than 1,100 mi^2. The terrain is mostly rolling hills with slopes of 10 percent or less. Toward the eastern edge of the Cumberland Plateau, a line of mountains including the Crab Orchard Mountains stretches northeast with altitudes more than 1,000 feet higher than the surrounding plateau. Streams are deeply incised into the Cumberland Plateau. The Emory River has cut more than 600 feet below the plateau surface. The northern three-fourths of the Cumberland Plateau are drained by the Emory and Obed Rivers. The remainder is drained by Piney Creek in the south. Emory River and Piney Creek eventually flow into Watts Bar Lake on the Tennessee River.

Separating the Cumberland Plateau from the Ridge and Valley is Walden Ridge, a highly dissected, southeast-facing escarpment. The escarpment has 700 to 900 feet of relief in most areas, but has only 400 to 500 feet of relief where the Emory River crosses it at Harriman. Slopes range from 50 to 80 percent with cliffs sometimes present in the upper 100 feet.

The Ridge and Valley includes about 1,000 mi^2 in the southeast part of Area 19. It is characterized by long ridges separated by valleys trending in a northeast-southwest direction with a trellis drainage pattern. The valleys are generally flat with a general altitude of 800 to 900 feet. Intervening ridges reach altitudes of 1,000 to 1,300 feet with slopes averaging 20-35 percent, although slopes of 60-70 percent occur along some of these ridges. The Tennessee River in the southeast and the Clinch River in the north drain this part of Area 19; the Clinch River flows into the Tennessee River at Watts Bar Lake in the south-central part.

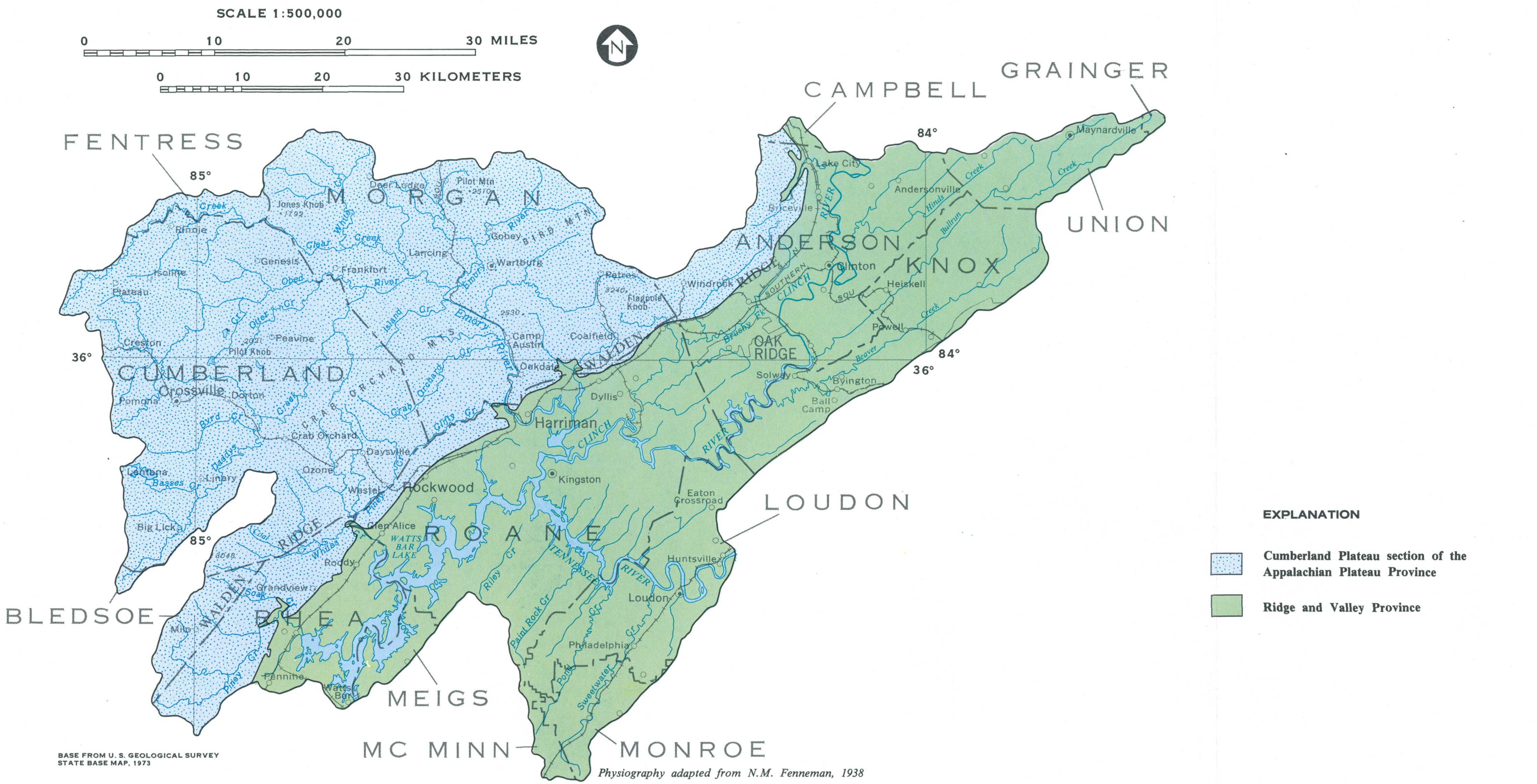


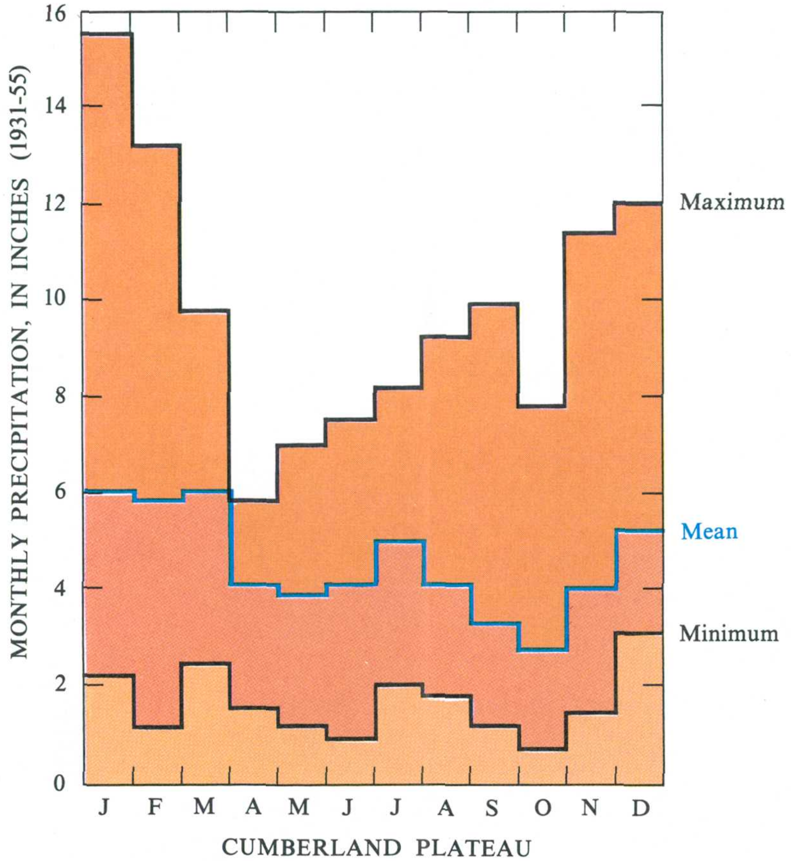
Figure 2.1-1 Physiographic provinces.

Climate of Area Varies Seasonally

Mean annual precipitation averages about 52 inches with extremes of about 35 and 70 inches. Average annual temperature is about 58°F.

Area 19 is in parts of two climatological divisions, Eastern Tennessee and the Cumberland Plateau (fig. 2.2-1). The average annual precipitation for the area is about 52 inches, but ranges from about 35 inches in dry years to about 70 inches in wet years (U.S. Weather Bureau, 1960). Thunderstorms which often produce locally heavy rainfall occur on about 56 days per year and are sometimes accompanied by damaging winds and extreme changes in temperature. The 10-year 24-hour rainfall, shown in figure 2.2-1, is about five inches (U.S. Weather Bureau, 1961). Maximum, minimum, and mean monthly precipitation for each climatological division are also shown. Data shown for the Cumberland Plateau are representative of that entire division. Five long-term precipitation stations and an unspecified number of short-term stations were used to determine these values. One of the long-term stations in the division, Crossville, is in Area 19. Data shown for the Eastern Tennessee division are also representative of the entire division. Nineteen long-term and an unspecified number of short-term precipitation stations were used to determine these values. Two of the long-term stations in the division, Kingston and Oak Ridge, are in Area 19.

The average annual temperature for Area 19 is about 58°F with extremes seldom above 100°F or below -5°F. Temperatures are above 90°F about 75 days per year. There is a frost-free season of about 180 days from late April to late October. Average annual temperature varies with altitude; temperature generally decreases about 3°F per 1,000 feet of increased altitude.

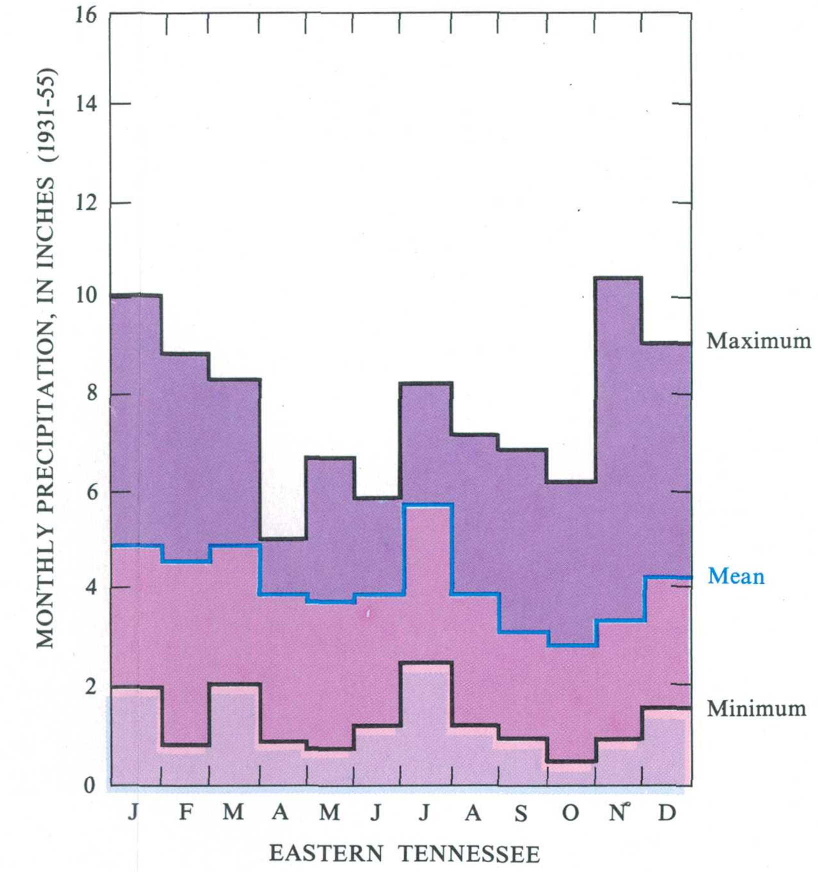


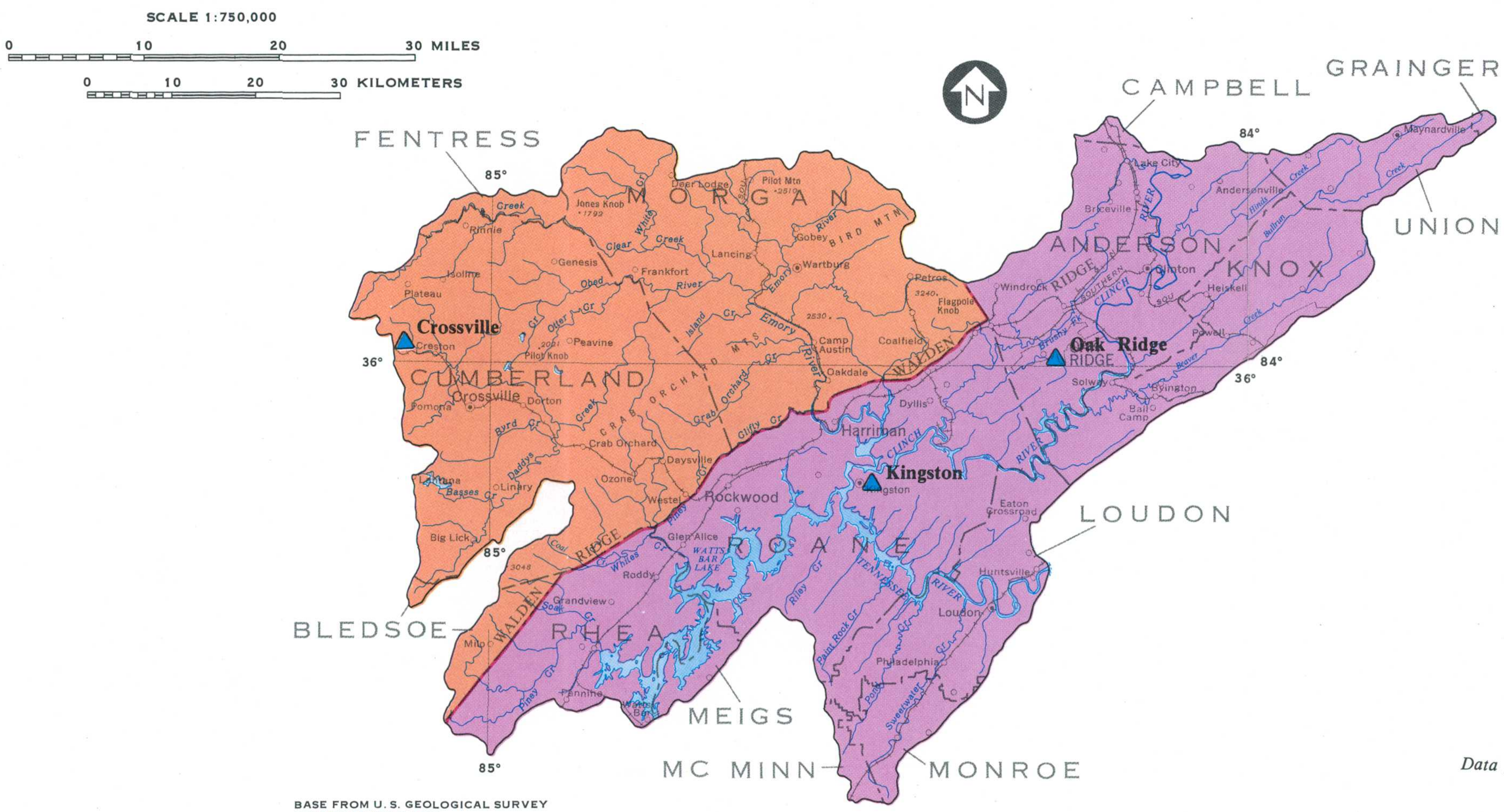
EXPLANATION

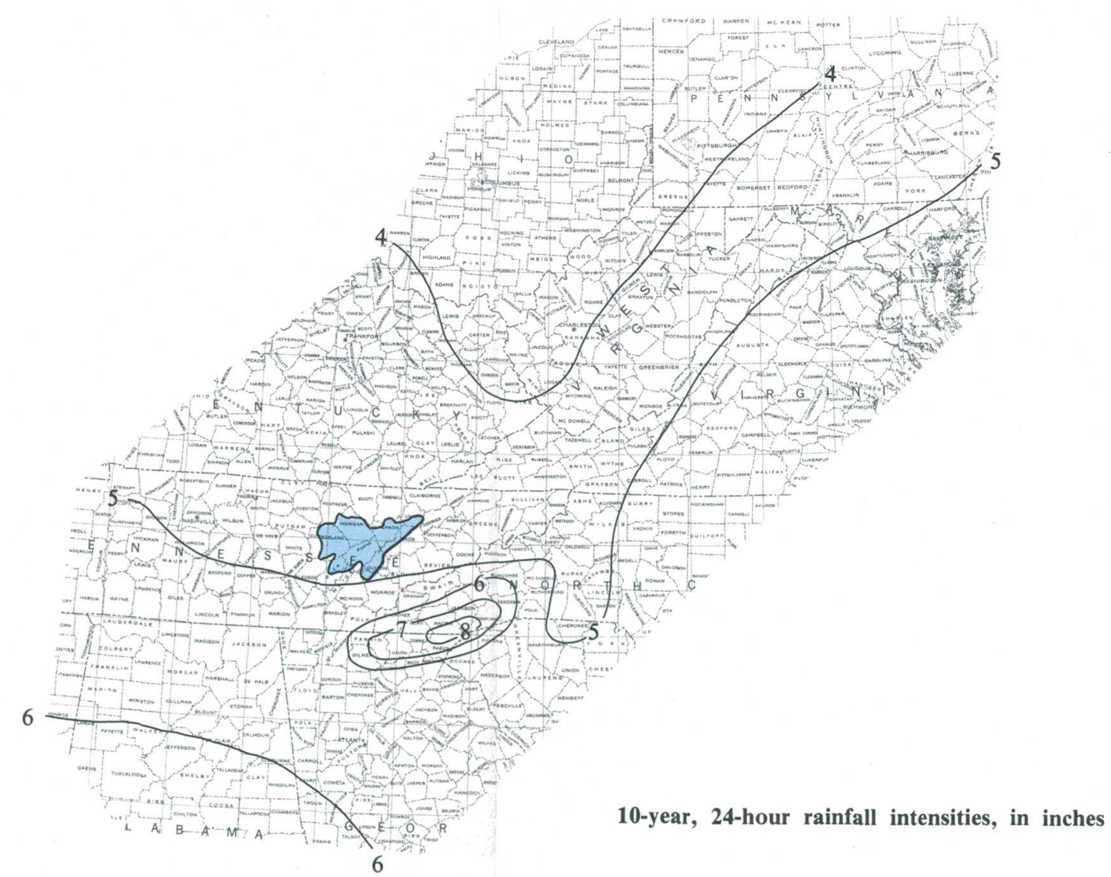
Long-term precipitation station

Cumberland Plateau

Eastern Tennessee







10-year, 24-hour rainfall intensities, in inches

Data from U.S. Department of Commerce, 1960 and 1961

Figure 2.2-1 Precipitation data for the two climatological divisions of Area 19.

Each Physiographic Province is Underlain By a Different Rock Type

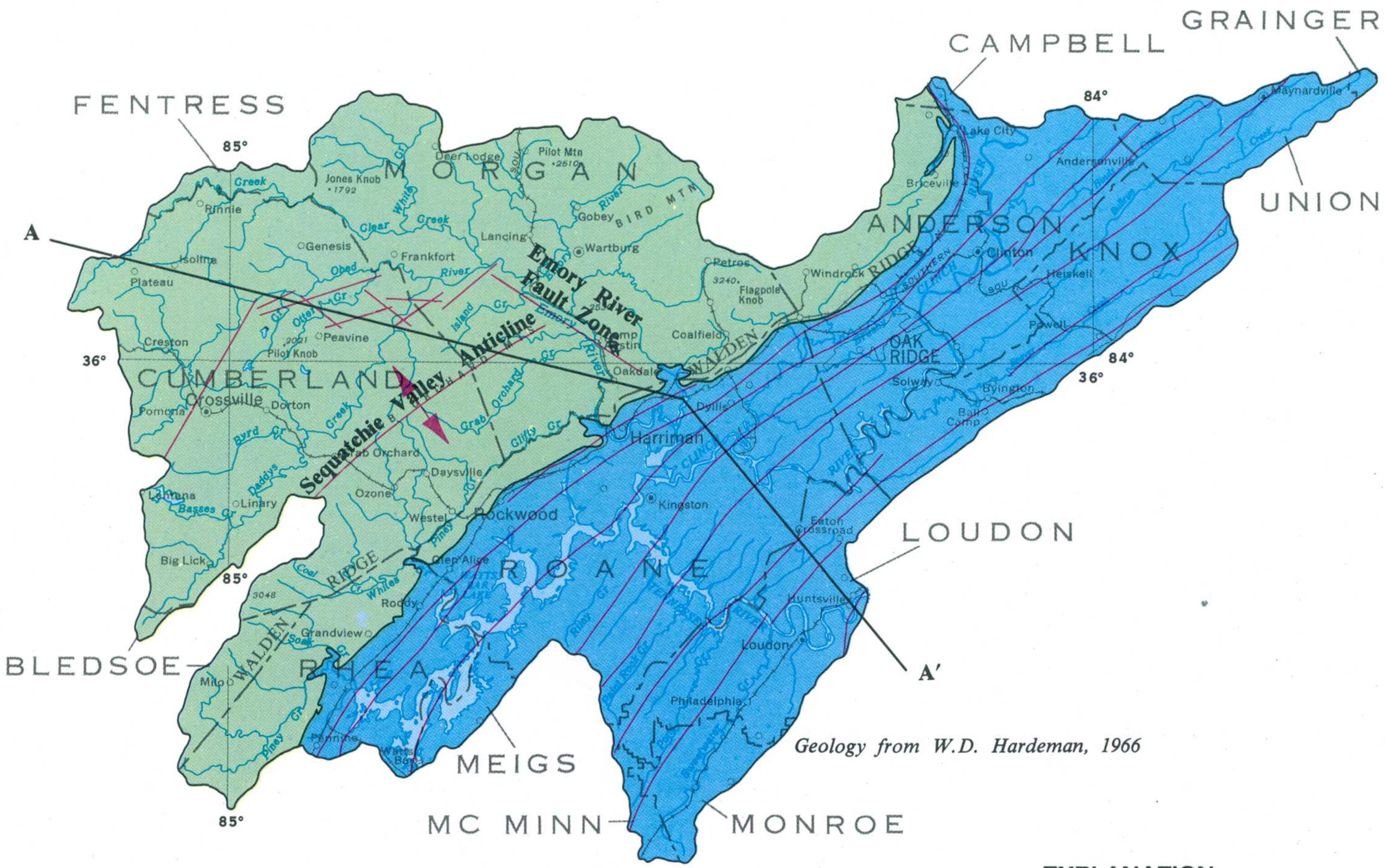
The Cumberland Plateau is underlain by gently dipping Pennsylvanian sandstone and shale. The Ridge and Valley is underlain by Ordovician and Cambrian carbonate rocks and shale which are folded and broken by extensive faulting.

The Cumberland Plateau is underlain by gently dipping Pennsylvanian sandstone and shale, some conglomerate, and coal. These rocks have a thickness of about 1,500 feet. The main coal seams in Pennsylvanian rocks are the Big Mary, Rock Spring, and Coal Creek. The Pennington Formation of Mississippian age is a transition from the basal Pennsylvanian sandstone and shale which overlie the Mississippian carbonate rocks. The Mississippian rocks are predominately limestone, calcareous shale, and siltstone, with a maximum thickness of about 1,000 feet. These rocks crop out along the escarpment formed by Walden Ridge. The Chattanooga Shale of Devonian age and the Rockwood Formation of Silurian age underlie the Mississippian rocks and crop out along the base of the escarpment. Gently east-dipping rocks underlying the plateau are warped upward along the escarpment and dip steeply to the northwest as a result of thrusting from the southeast (fig. 2.3-1).

The most prominent structural feature in this part of the Cumberland Plateau of Area 19 is the Sequatchie Valley anticline. At the northeastern end of the anticline, massive sandstone forms the Crab Orchard Mountains. The anticline dies out to the northeast and disappears at the Emory River fault zone. This fault zone is part of a long belt of structural deformation which lies to the north and northwest of the Crab Orchard Mountains. The belt is largely a series of thrust faults which are connected by cross faulting and anticlines (fig. 2.3-1).

Ordovician and Cambrian rocks that underlie the Ridge and Valley are predominately carbonate, siltstone, shale, and some sandstone. Northeast-trending ridges are formed by resistant formations such as the Cambrian Rome Formation. The valleys are underlain by less resistant formations such as the Cambrian Conasauga Shale and the Ordovician Chickamauga Limestone. The formations within the Ridge and Valley have been deformed by folding and intense faulting which occurred during the development of the Appalachian Mountains.

Karst topography formed by the solution of carbonate rocks occurs within both the Cumberland Plateau and the Ridge and Valley of Area 19. In the Cumberland Plateau, karst occurs along the Sequatchie anticline, just southwest of the Crab Orchard Mountains. The collapse of sinkholes in these areas contributes to the headward advance of the Sequatchie Valley. Karst is developed in those areas of the Ridge and Valley that are underlain by limestone. These areas are long narrow belts which trend to the northeast (fig. 2.3-2).



EXPLANATION

Pennsylvanian

pre-Pennsylvanian

Fault

Anticline

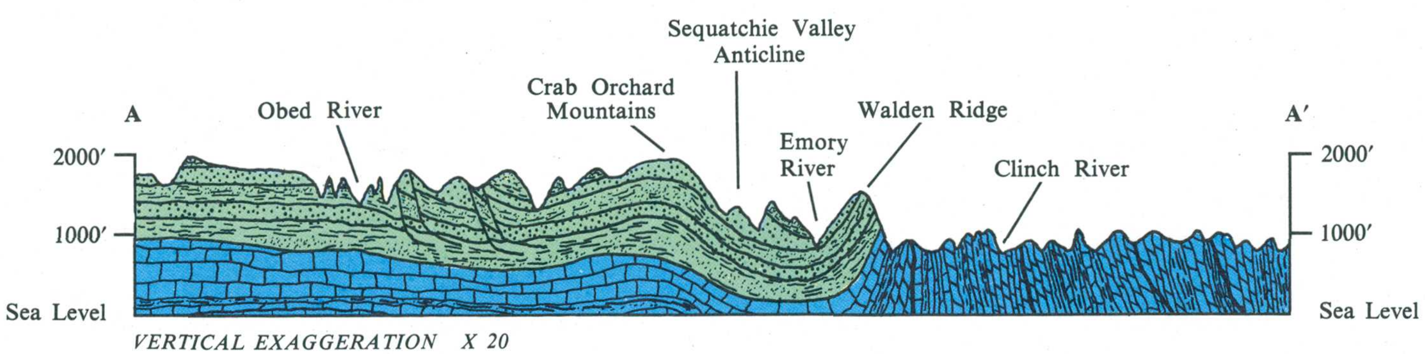
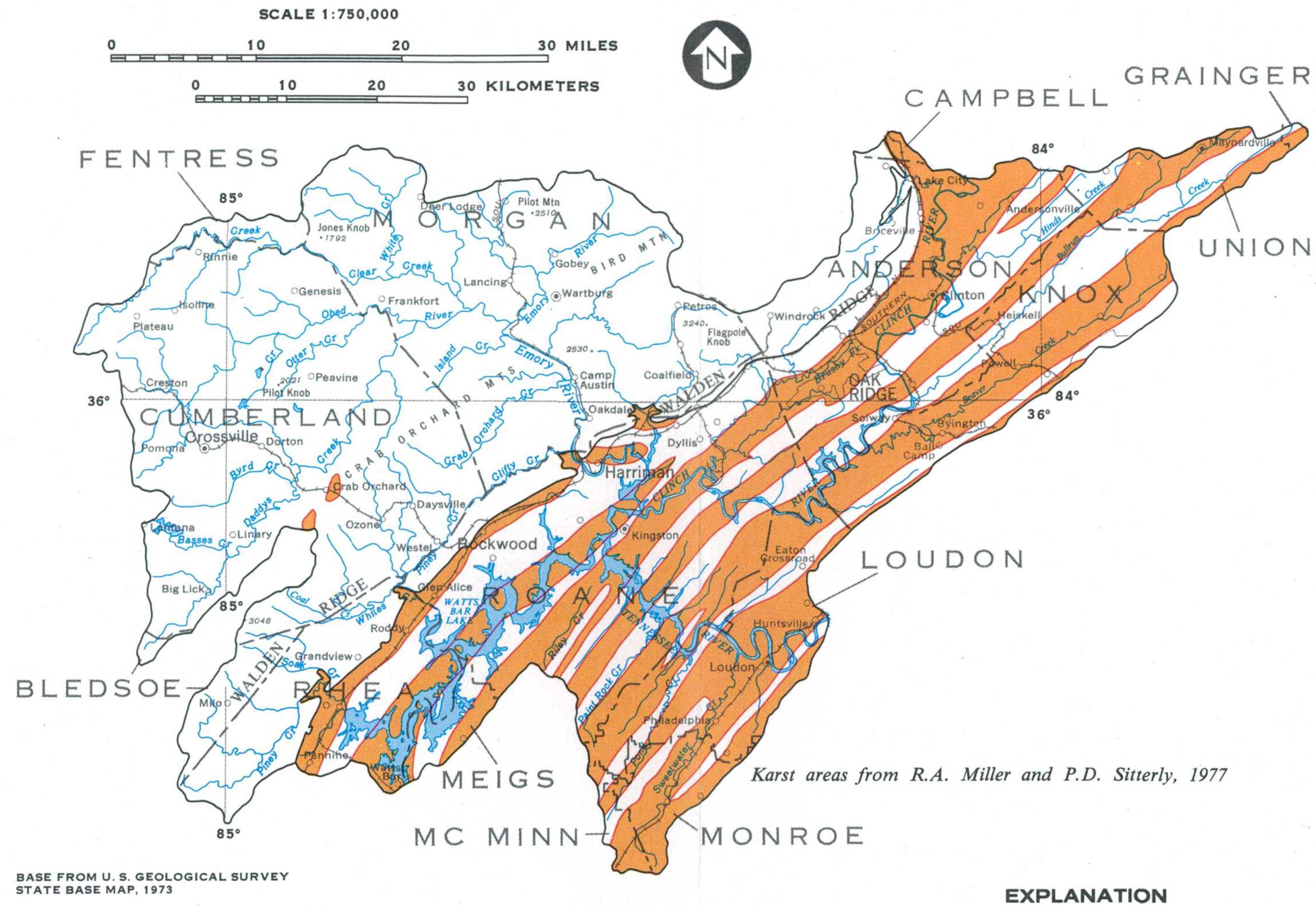


Figure 2.3-1 Generalized geologic map and cross section.



EXPLANATION

Karst areas

Contain sinkholes, caves, and disappearing streams

Figure 2.3-2 Karst areas.

Soils Reflect Geologic Origin

Soils of the Cumberland Plateau are derived from sandstone, shale, and siltstone. The Ridge and Valley province soils are derived from dolomite, limestone, and shale. Soil characteristics are highly variable in both physiographic provinces.

The Cumberland Plateau soils are derived from sandstone, and some shale and siltstone. These are predominantly loamy, well-drained soils with low natural fertility. Soil depth ranges from less than 1 to 5 feet over most of the plateau. The potential for erosion is slight to moderate. Along the steep slopes of the mountains and the escarpment formed by Walden Ridge, soil depths range from 1 to 2 feet near the top and up to 7 feet on the slopes. The erosion potential on the slopes is great and erosion can become severe if the vegetation cover is removed.

The soils of the Ridge and Valley are derived from dolomite, limestone, and shale. These are generally well-drained to excessively-drained clayey and loamy soils with low to moderate natural fertility. Soil depth ranges from 4 to more than 8 feet over most of the Ridge and Valley. These soils generally have a slight to moderate potential for erosion.

The soils in Area 19 are generally acidic with a pH range of 3.6 to 6.0 units. Permeability rates are moderate to rapid at 0.6 to 20.0 in/h (table 2.4-1). The soils also have very low to high available water capacity ranging from 1.07 to 8.96 in/40-inch profile. Infiltration rates range from moderate to very slow. The hydrologic soils group classification shown in table 2.4-2 indicates this variability. Class B soils have moderate infiltration rates, class C soils have slow infiltration rates, and class D soils have very slow infiltration rates which cause high runoff. These features can vary greatly even within soil associations, which are groups of soil series ordinarily found together on a landscape (fig. 2.4-1).

Additional soil information is available from the county offices of the Soil Conservation Service, U.S. Department of Agriculture.

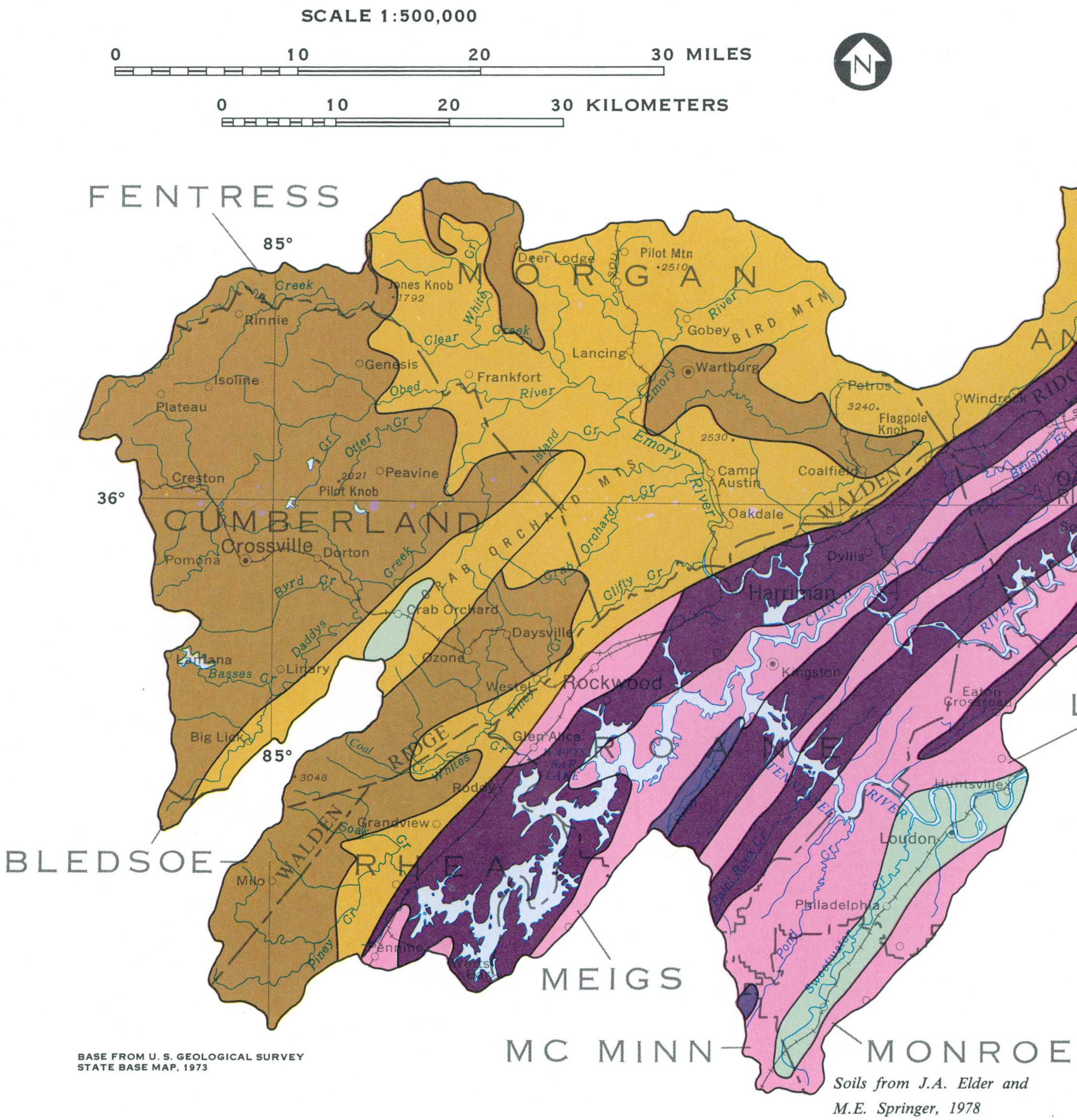


Figure 2.4-1 Soil associations.

Table 2.4-2 Hydrologic soils group.

Cumberland Plateau: Soil series	Cumberland Plateau: Hydrologic soils group	Ridge and Valley: Soil series	Ridge and Valley: Hydrologic soils group
Bouldin	B	Allen	B
Gilpin	C	Bodine	B
Grimsley	B	Decatur	B
Hartsells	B	Dewey	B
Jefferson	B	Etowah	B
Lonewood	B	Fullerton	B
Muskingum	C	Montevallo	D
Ramsey	D	Sequatchie	B
		Talbott	C
		Wallen	C
		Waynesboro	B

Note: Hydrologic soils groups based on the minimum rate of infiltration obtained for bare soil

Table 2.4-1 Soil associations.

Soil association	Depth to Bedrock (in)	pH	Permeability (in/h)	Available water capacity (in/40" profile*)	Description
Soil Associations of the Cumberland Plateau					
Hartsells-Lonewood-Ramsey-Gilpin	10-40 Lonewood 40-72	3.6-5.5	0.6-2.0 Ramsey 6.0-20.0	2.80-6.48 Ramsey 1.62-2.16 Lonewood 6.50-7.35	Moderately deep, well drained, loamy soils from sandstone and shale
Hartsells-Ramsey-Gilpin	10-40	3.6-5.5	0.6-2.0 Ramsey 6.0-20.0	2.80-6.48 Ramsey 1.62-2.16	Moderately deep to shallow, well drained, loamy soils from sandstone and shale
Bouldin-Ramsey	Ramsey 10-20 Bouldin 60-120	4.5-5.5	Ramsey 6.0-20.0 Bouldin 2.0-6.0	1.40-4.00	Well drained, stony and loamy soils with rock outcrops from colluvium, sandstone and shale
Ramsey-Hartsells-Grimsley-Gilpin	10-60	3.6-5.5	0.6-6.0 Ramsey 6.0-20.0	2.16-6.48 Ramsey 1.62-2.16	Well drained, stony and loamy soils from sandstone and shale
Muskingum-Gilpin-Jefferson	20-40 Jefferson 60	3.6-6.0	0.6-6.0	2.80-5.40 Jefferson 4.30-6.88	Well drained, loamy soils from shale and sandstone
Soil Associations of the Ridge and Valley					
Fullerton-Dewey	60-100	3.6-5.5	0.6-2.0	4.00-7.32	Deep, well drained, cherty and clayey soils from dolomite and limestone
Fullerton-Bodine	60-100	3.6-5.3	0.6-6.0	2.08-5.79	Deep, well drained, cherty and clayey soils from dolomite and limestone
Decatur-Dewey-Waynesboro	60-80	4.5-5.5	0.6-2.0	4.60-7.32	Deep, well drained, clayey soils from alluvium and limestone
Waynesboro-Etowah-Sequatchie-Allen	60-80	4.5-5.5	0.6-2.0	Waynesboro-Allen 4.62-7.04 Sequatchie-Etowah 6.00-8.96	Deep, well drained, clayey and loamy soils from alluvium and colluvium
Talbott-Etowah	Talbott 20-40 Etowah 72	4.5-6.0	0.6-2.0	Talbot 3.70-5.92 Etowah 6.00-8.00	Shallow to deep, well drained, clayey and loamy soils with rock outcrops, from shale and limestone
Wallen-Talbott-Montevallo	10-40	4.5-6.0	0.6-6.0	1.07-2.70 Talbot 3.70-5.45	Shallow to moderately deep, excessively to well drained, stony and clayey soils from sandstone, shale and limestone

*or profile to a limiting layer, such as bedrock or a hardpan

Forests Cover Most of the Cumberland Plateau

The Cumberland Plateau in Area 19 is covered largely by forests. Agriculture is the second largest land-use category, followed by urbanization and mining. No land-use maps are available for the Ridge and Valley.

Changes in the land use may alter infiltration and runoff rates as well as the amount of sediment being transported. Urban development reduces the amount of infiltration and increases runoff rates. Removing the vegetation cover for row crops, urban development, or surface mining directly affects the runoff and infiltration rates and increases the potentional for erosion.

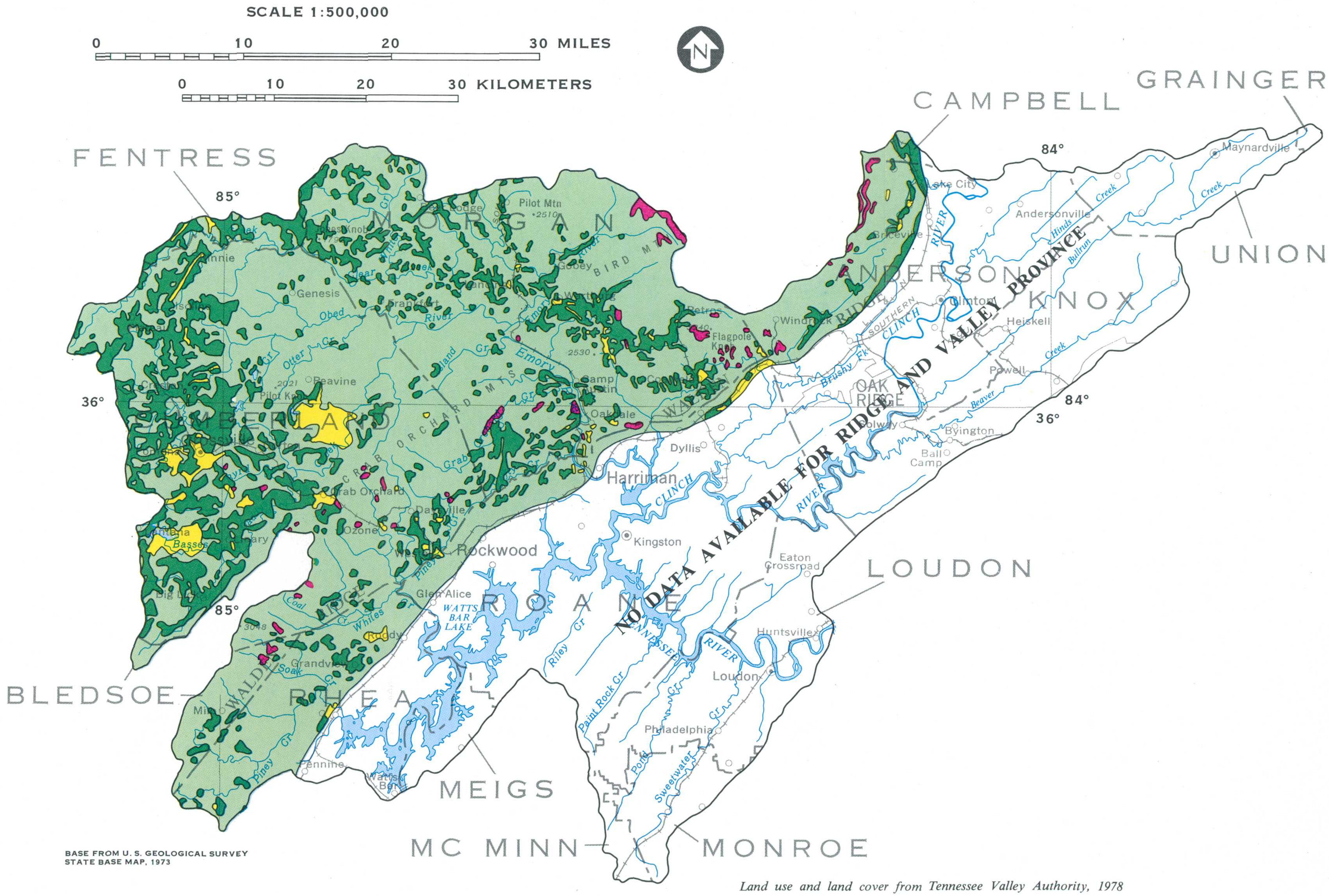
Land use and land cover is shown for the Cumberland Plateau of Area 19 (fig. 2.5-1). Land-use and land-cover maps which include the Ridge and Valley in Area 19 are not available as of 1981. About 90 percent of the Cumberland Plateau is covered by deciduous and evergreen forests. Approximately 5 percent of the land is used for agriculture; about 1 percent is used for mining.

Land-use and land-cover maps for the Cumberland Plateau are available from:

Mapping Services Branch
Tennessee Valley Authority
216 Haney Building
Chattanooga, TN 37401

Information on the Land Use Series is available from:

U.S. Geological Survey
National Cartographic Information Center
507 National Center
12201 Sunrise Valley Drive
Reston, VA 22082.



EXPLANATION

- Forest land
- Agriculture and other open land
- Urban or Developed areas
- Mining (including quarries)
- Water

Fig. 2.5-1 Land use and land cover

Tennessee and Clinch Rivers are the Principal Streams

All surface drainage in Area 19 flows into the Tennessee River.

Area 19 has a total surface drainage of 2,201 mi^2. All surface drainage is to the Tennessee River which flows west, then southwesterly across the southeast part of the area. Clinch River and its tributaries drain 1,501 mi^2, 68 percent of the surface area. The drainage basins for all the streams in Area 19 except the Tennessee and Clinch Rivers are contained within the area. The principal sub-basins of the area are listed below and are shown in figure 2.6-1.

Sub-basin	Drainage Area (mi^2)
Clinch River above Bullrun Creek	180
Bullrun Creek	104
Poplar Creek	136
Daddys Creek	175
Clear Creek	173
Obed River	172
Emory River	345
Clinch River	216
Whites Creek	138
Piney River	137
Tennessee River	425
Total Area 19	2,201

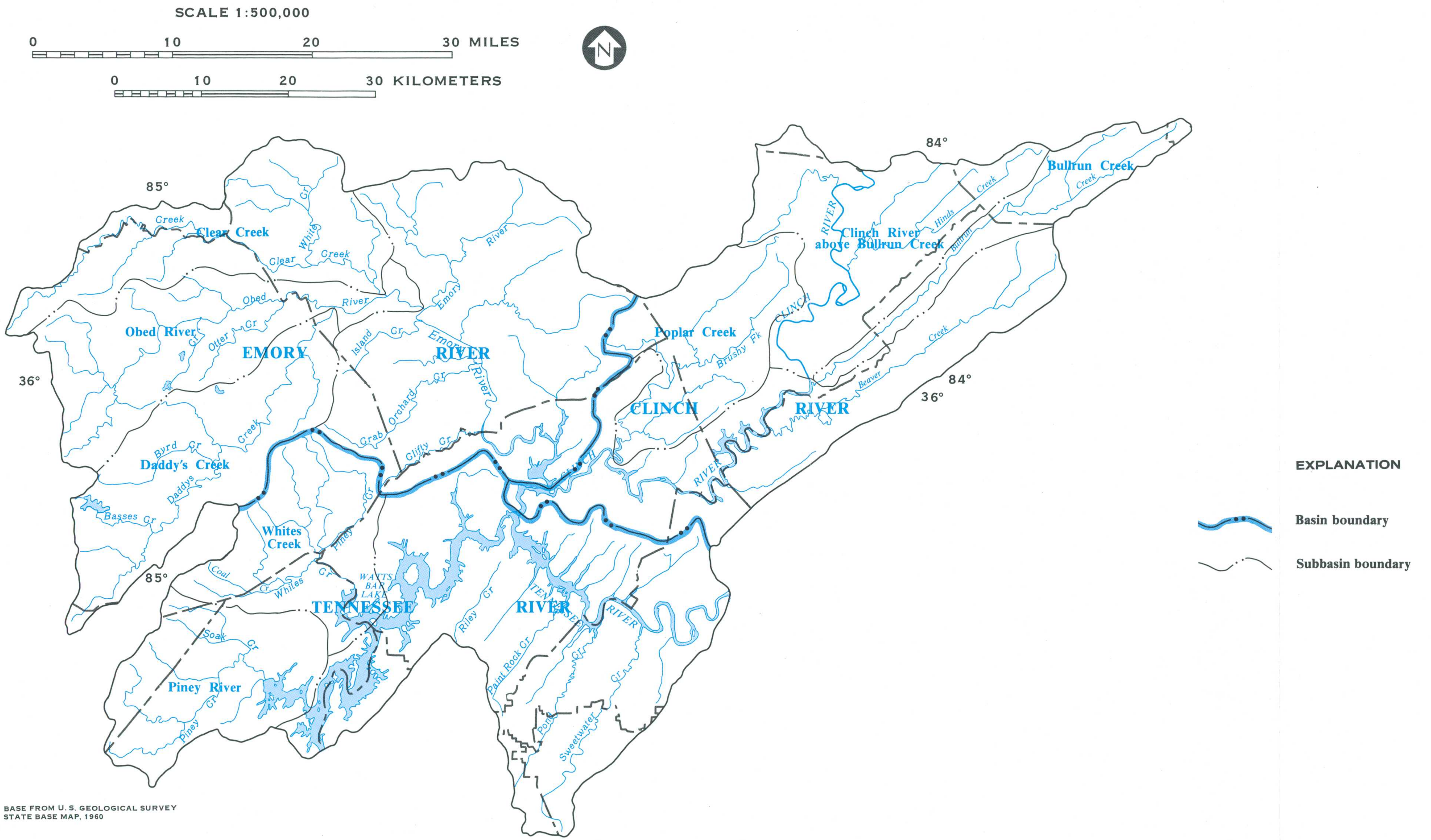


Fig. 2.6-1 Drainage basins.

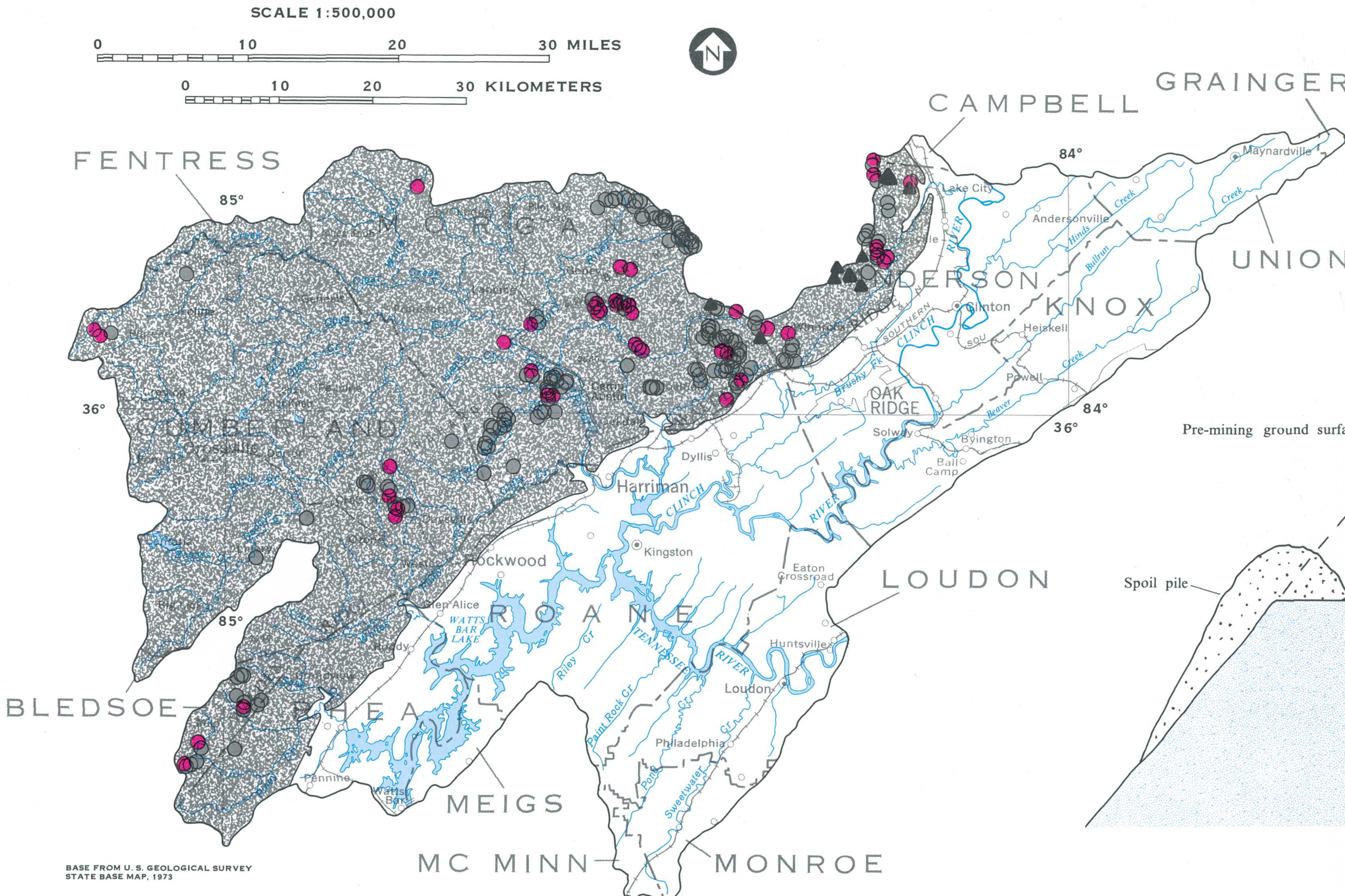
Coal-Mining Activities Occur Throughout Cumberland Plateau

Surface mines are numerous on the Cumberland Plateau. Fourteen deep mines are operated in Anderson and Morgan counties.

Location of State mining permits issued by the Tennessee Department of Conservation since 1972 are shown in figure 2.7-1. Permits labeled as active were issued in 1979 or 1980. Fourteen deep mines were active in Anderson and Morgan Counties. State mining permits are required to be renewed annually. Hence, those issued prior to 1979 were considered inactive.

Coal is usually mined by stripping away overlying material in order to remove, load, and haul the coal. Commonly, coal is mined in the area by stripping along the contours (contour mining) of hills. The coal seams are mined as far back into the mountain as is economically feasible (fig. 2.7-2). In some mining operations, additional coal is extracted by augering the coal seam after the stripping operation is completed.

Contour mining leaves bare earth and rocks, high walls, benches, and spoil banks. High walls are vertical to near vertical bare earth and rock walls created by slicing a strip off the side of a mountain. Benches are level to near level floors of the stripped area used for access and hauling. Spoil banks are unstable, loose earth and rocks pushed or dumped on the bench or down the mountainside. Deep mining usually disturbs less surface area than surface mining.



BASE FROM U. S. GEOLOGICAL SURVEY
STATE BASE MAP, 1973

Coal permits data from Tennessee Department of Conservation, written communication 1980

EXPLANATION

	Coal resources area	**Coal mine permits:**	
		●	Active surface mine
		●	Inactive surface mine
		▲	Deep mines (thru 1978) Active plus Inactive

Fig. 2.7-1 Coal-mining activities.

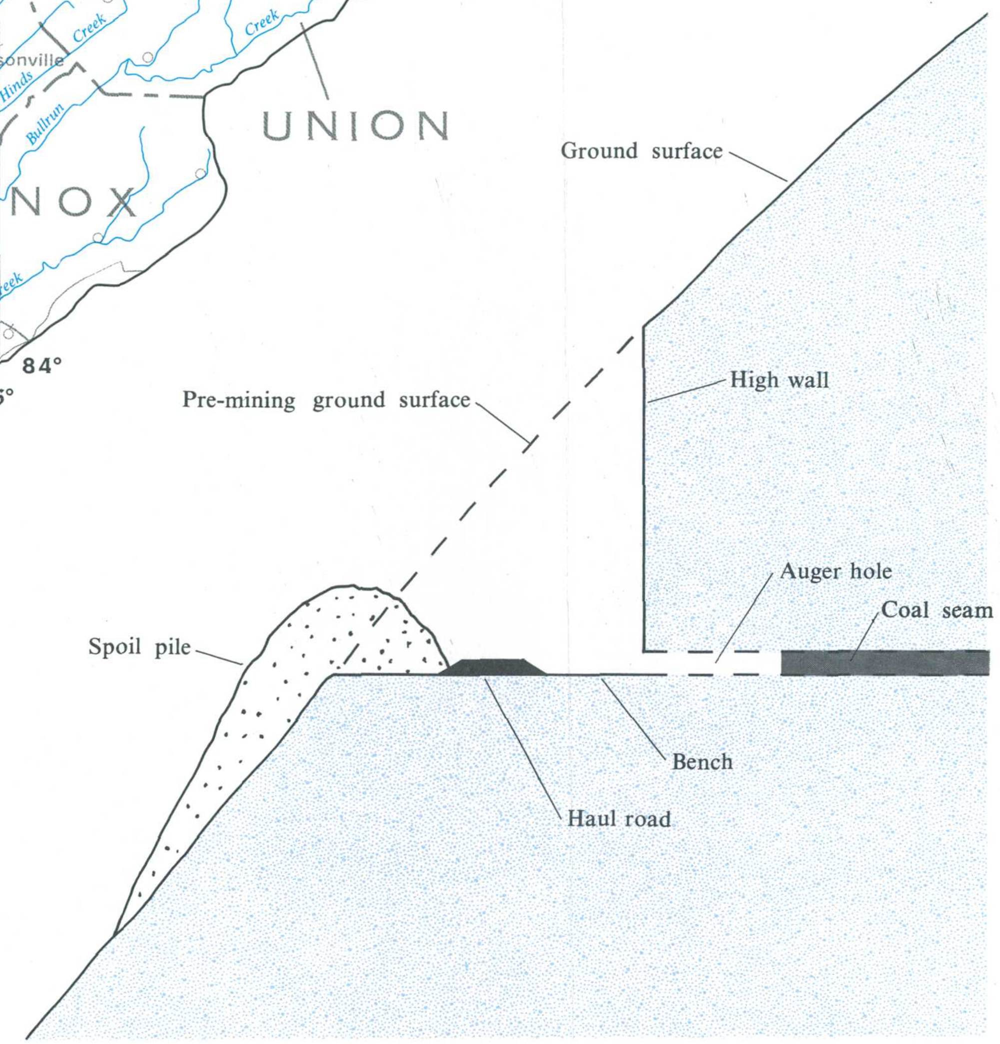


Fig. 2.7-2 Typical contour (strip) mining site.

Information on Surface Water Available at 159 Locations

Streamflow data for most sites in Area 19 have been collected for more than 20 years. Most of the miscellaneous water-quality and suspended-sediment data were collected within the last 15 years. Beginning in 1979, data collection was extended in response to the Surface Mining Control and Reclamation Act.

Streamflow, water-quality, and (or) sediment data are available for 159 surface hydrologic sites in Area 19 (fig. 3.1-1). Most streamflow sites have been operated for more than 20 years. Most water-quality and sediment information has been collected in the last 15 years. The location of each data-collection site, period of operation, type of record, and other pertinent information are included in section 10.1.

Beginning in 1979, in response to the Surface Mining Control and Reclamation Act, the network was expanded by the addition of 16 water-quality sites. Two sites were upgraded, making water-quality information available for 70 locations. Water-quality information includes field and laboratory analyses. Parameters include: water temperature; specific conductance; pH; dissolved major chemical constituents; dissolved and total recoverable trace constituents; and trace constituents in bottom material from streams. Suspended-sediment information is also collected at sites which were activated or upgraded in 1979. Information includes suspended-sediment concentrations and computations of suspended-sediment loads.

Streamflow data include (1) continuous records of stages and discharges, (2) records of flood stages and flood discharges, and (3) measurements of discharge at various stages.

Station information in addition to that given in section 10.1, as well as surface water quantity and quality data, can be obtained from U.S. Geological Survey computer files through the National Water Data Exchange (NAWDEX, see section 9.2) or from the annual publication "Water Resources Data for Tennessee."

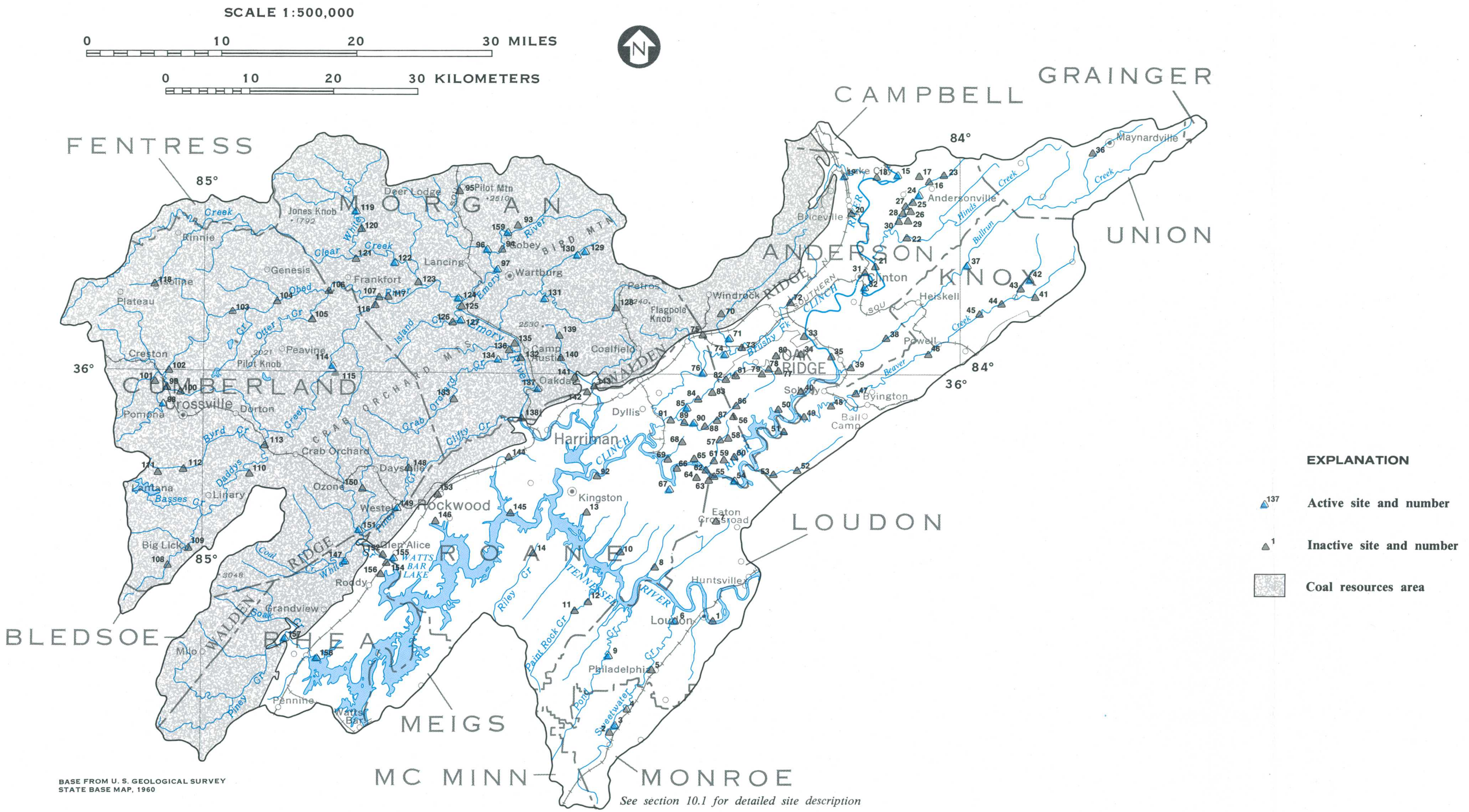


Fig. 3.1-1 Surface-water network.

Ground Water Data Available at 27 Locations

Information on ground water has been collected at 13 wells and 14 springs. Types of information include water-level measurements, water-quality analyses, and discharge measurements of springs.

Water-level, discharge, and (or) water-quality data are available for 13 wells and 14 springs in Area 19 (fig. 3.2-1). However, data are available for only four wells in coal-bearing rocks. The location, period, and type of record available for each site are listed in section 10.2.

Types of information available for wells may include (1) periodic water-level measurements, (2) continuous records of water levels, and (3) water-quality analyses. Discharge information is available for 14 springs. Site information and data can be obtained from U.S. Geological Survey computer files through the National Water Data Exchange (NAWDEX, see section 9.2) or from the annual data publication "Water Resources Data for Tennessee."

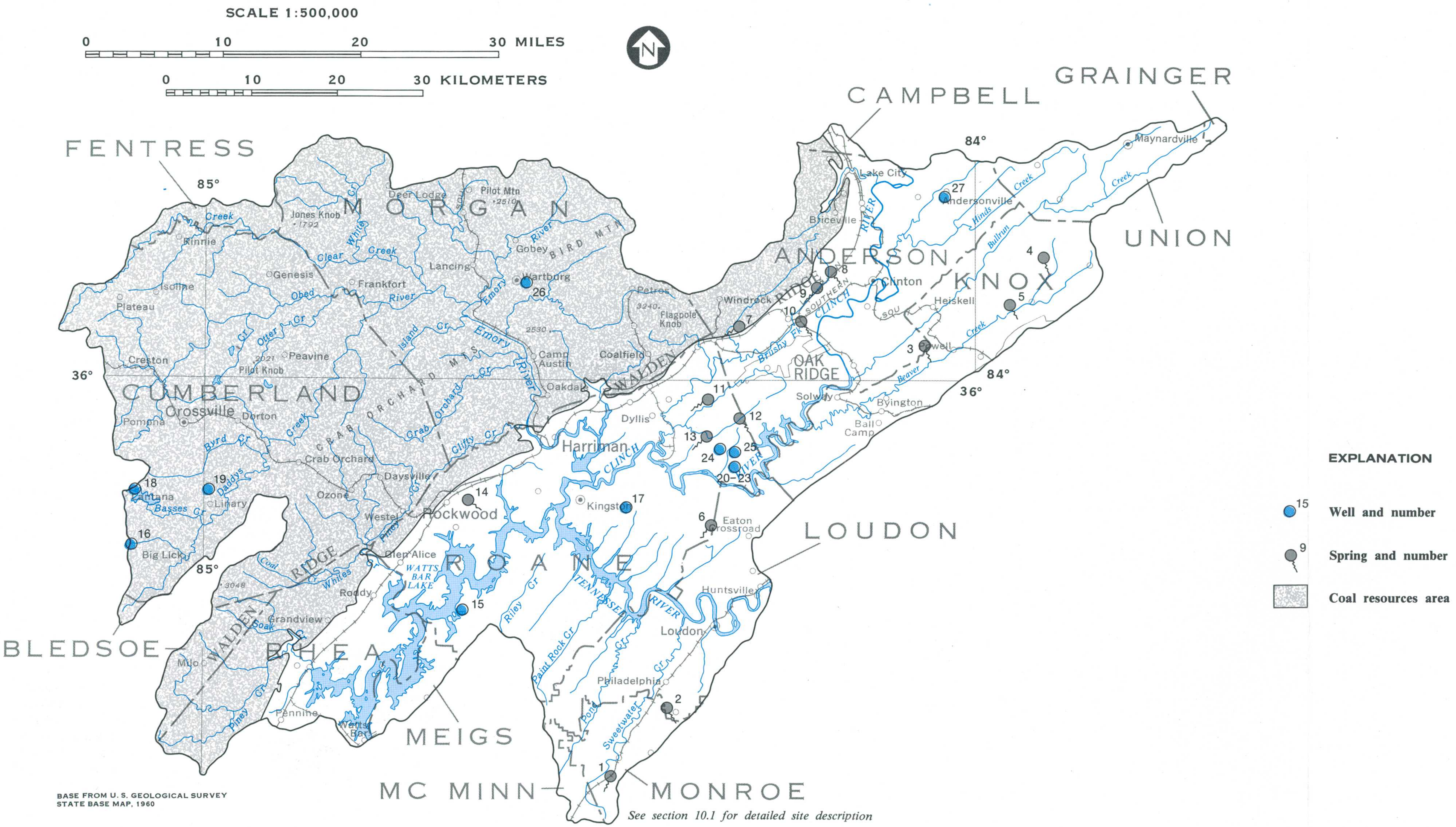


Fig. 3.2-1 Ground-water network.

Streamflow Varies with Time and Place

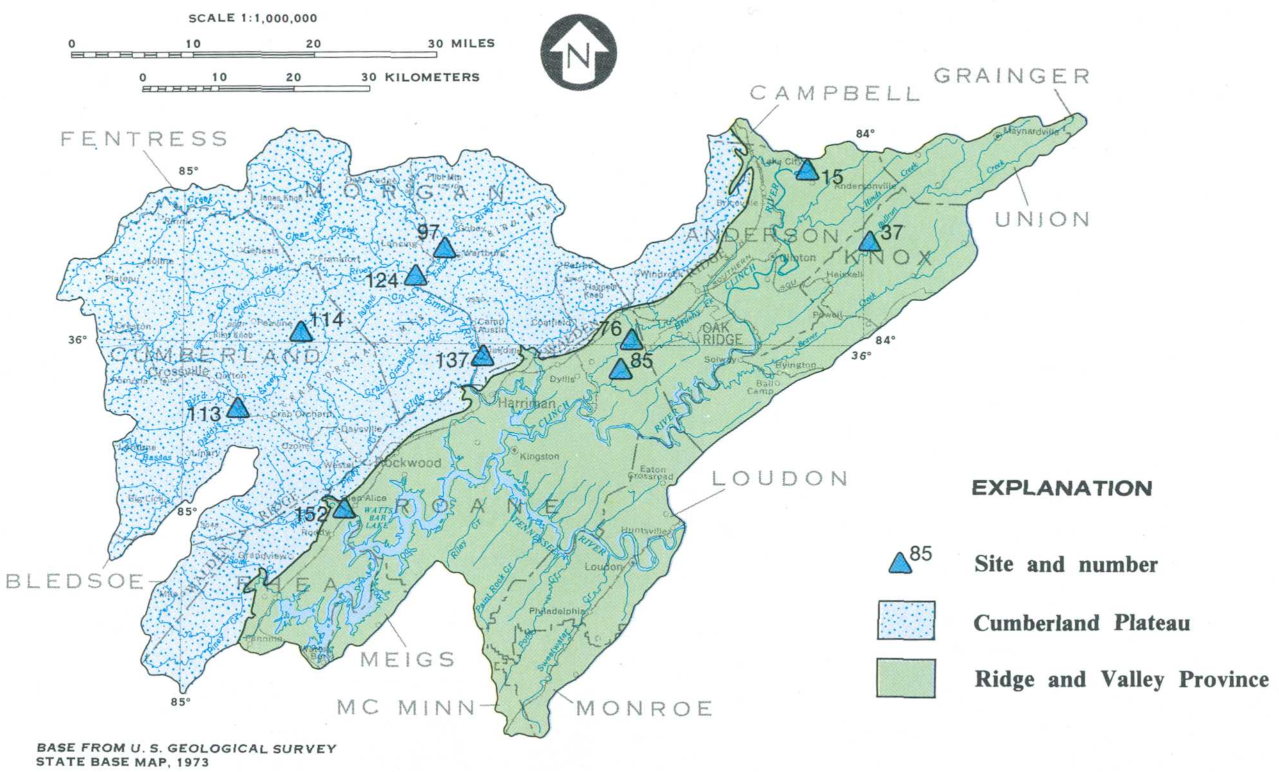
Streamflow varies in a pattern similar to the seasonal variation in rainfall and varies between streams because of differences in drainage basin size and other physical characteristics.

Surface water is the water stored in lakes, ponds, and reservoirs and the water flowing in streams. The volume of stored water is relatively stable although there is some seasonal fluctuation. Streamflow, the largest component of surface water, is highly variable with time and place. It is made up of two components; direct runoff that supplies most of the volume of streamflow during flood periods and runoff from ground-water storage that feeds the streams during the periods of no direct runoff. The average annual runoff from any area in Tennessee can be approximated as the mean annual precipitation for the area minus approximately 30 inches of evapotranspiration. From this approximation, the average annual runoff for Area 19 is about 22 inches.

Area 19 is in parts of two physiographic provinces (fig. 4.1-1) which have significant differences in topography, slope, soils, and geology (section 2.0). These factors, along with differences in drainage basin size, contribute to the variability of flow from stream to stream, especially during the 250 days per year on the average when no rainfall occurs. Streamflow varies in a pattern similar to the seasonal variation in rainfall (fig. 2.2-1).

The streams in Area 19 can be classified and related to physiography by: (1) those draining areas totally within one physiographic province whose flow characteristics are determined by that province; and (2) those draining areas from more than one physiographic province whose streamflow is an integration of the characteristics of the provinces which it drains. Although some streams in Area 19 drain both provinces, few systematic streamflow records on these streams are available. Monthly mean discharge as a percentage of the annual mean at selected sites in the area is shown in figure 4.1-1. Although no significant physiographic trends can be detected, this table illustrates the seasonal variability of individual streams. For site 85, the values are artificially high because the natural flow is supplemented by effluent from the Department of Energy's Y-12 plant at Oak Ridge and the city of Oak Ridge's west end sewage treatment plant.

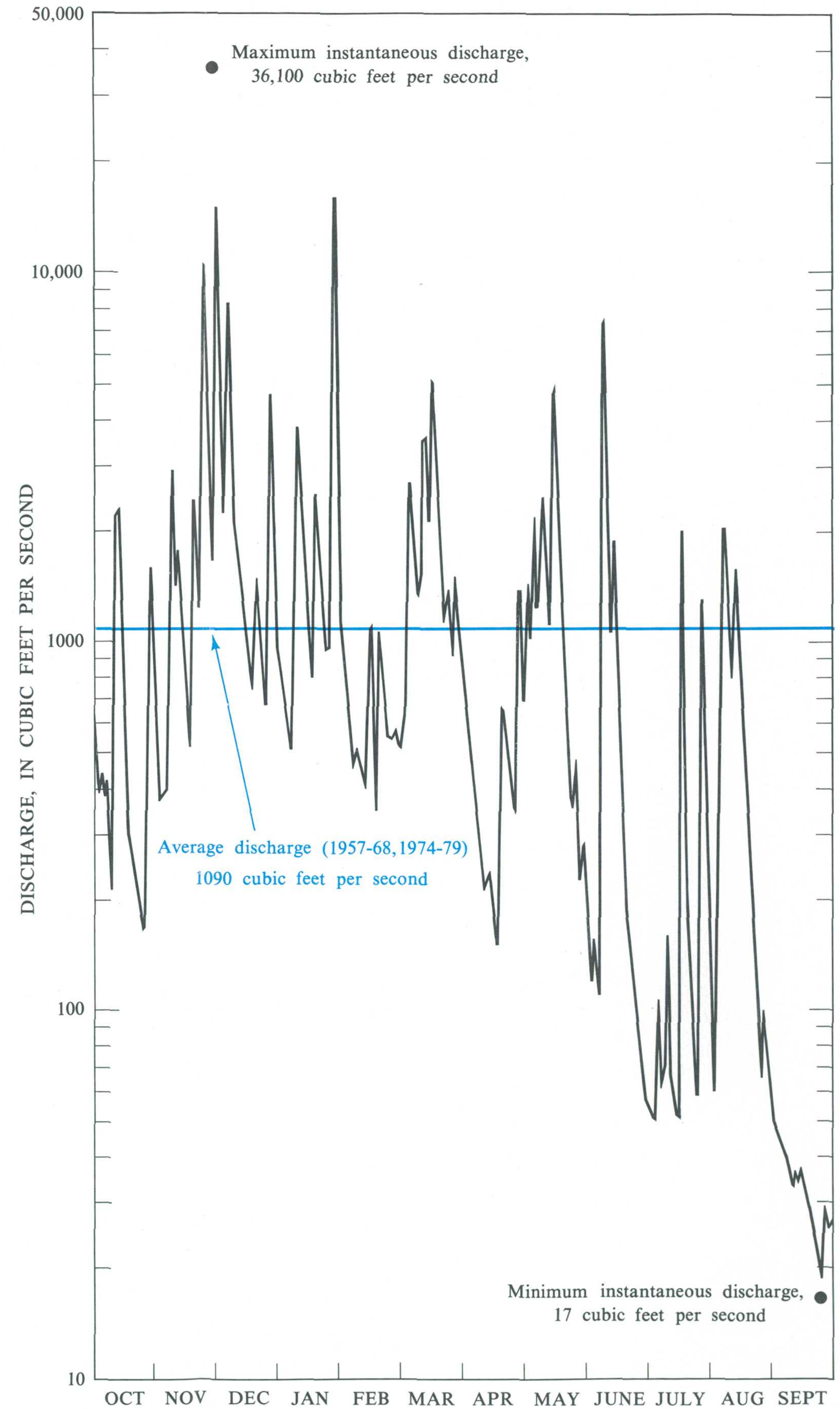
The flow variability in the Obed River near Lancing (site 124) during the 1978 water year (October 1977 to September 1978) which is typical for the area is shown by the hydrograph in figure 4.1-2. The maximum and minimum instantaneous discharge for the year and the average discharge for the period of record also are shown. Another way of illustrating this flow variability for one year is shown in figure 4.1-3 which includes monthly mean flow and the maximum and minimum daily flow for each month of 1978. The long-term seasonal variability of Obed River near Lancing is illustrated in figure 4.1-4.



Site number	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
15	2.55	4.46	9.05	14.3	14.8	17.0	11.9	8.91	5.83	4.66	4.03	2.53
37	2.27	6.02	11.4	14.0	13.1	18.6	13.3	8.07	5.10	4.20	2.42	1.51
76	2.52	6.49	12.8	14.4	12.7	18.5	10.8	7.09	4.26	5.98	2.81	1.57
85	4.84	7.41	10.5	11.9	10.9	14.6	9.71	7.56	6.22	6.90	4.99	4.52
97	.75	3.68	12.7	18.5	19.8	18.0	11.5	6.37	2.66	3.08	1.71	1.28
113	1.04	4.78	13.1	17.7	20.6	17.1	12.2	6.82	2.22	1.87	1.58	.92
114	2.01	8.23	12.8	12.7	14.4	20.5	13.4	7.27	2.70	3.00	1.62	1.37
124	2.44	8.10	11.8	14.9	12.6	21.2	11.9	7.92	3.16	3.45	1.11	1.39
137	1.51	5.75	12.0	16.2	17.3	18.7	12.3	7.34	3.26	2.77	1.62	1.26
152	.77	3.99	12.3	19.4	19.7	18.3	11.6	6.37	1.85	2.50	1.87	1.38

Note: Percentages will not add up to 100 due to rounding — *See section 10.1 for detailed site description*

Fig. 4.1-1 Percent of annual mean discharge occurring in indicated month at selected sites.



Note: Obed River near Lancing (site 124) drainage area is 518 square miles

Figure 4.1-2 Daily mean discharge for Obed River near Lancing (site 124) for the 1978 water year.

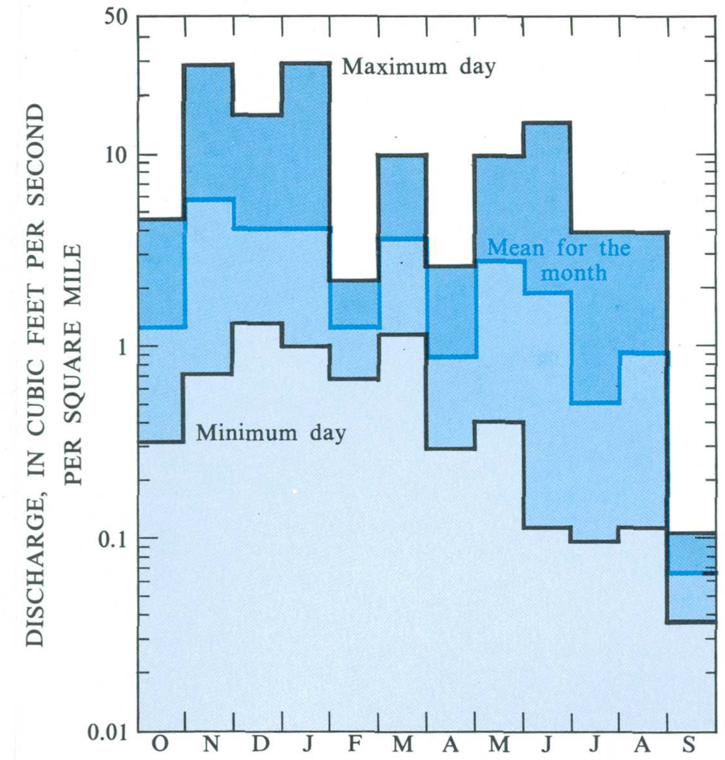


Figure 4.1-3 Monthly range in daily flows for the 1978 water year, Obed River near Lancing (site 124).

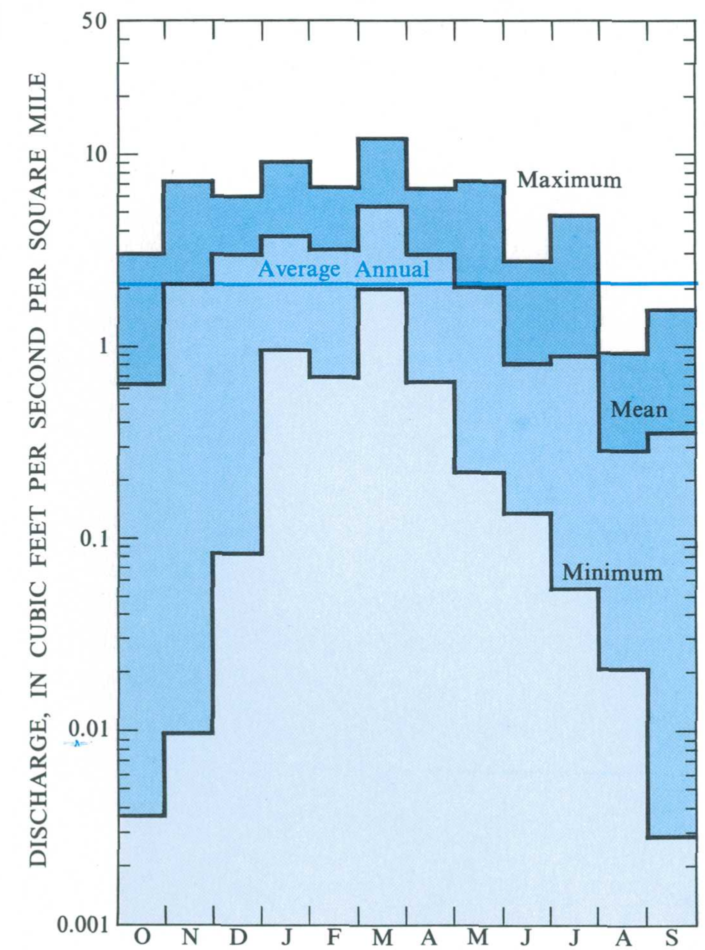


Figure 4.1-4 Range in monthly flows for the periods 1958-68, 1973-80, Obed River near Lancing (site 124).

Average Annual Flow per Square Mile Is about Two Cubic Feet per Second

The seasonal variability of the mean and maximum monthly flows per square mile is similar throughout Area 19; however, the minimum monthly flow per square mile is lower for the Cumberland Plateau.

Assuming the same annual precipitation, the principal factor affecting the average annual flow of streams in Area 19 is the size of the drainage basin. The average annual flow in cubic feet per second per square mile is shown for several streams of various sizes in figure 4.2-1. This unit of flow eliminates the variation due to the size of the drainage basin so that a more direct comparison between streams can be made. The average annual flow per square mile is approximately the same for all sites, about 2 $(ft^3/s)/mi^2$.

The average annual flow of streams may be useful in some hydrologic studies, but for most purposes mean monthly flow is more useful. In addition to drainage basin size, seasonal variations in rainfall affect monthly flows. For streams in Area 19, the seasonal variability of the mean and maximum monthly flows per square mile is similar even with the varying lengths of available record (fig. 4.2-1). However, minimum monthly flows indicate variations due to other factors, the most important one being that the underlying geology affects the minimum monthly flow especially during the dry months. The minimum monthly flows per square mile for the dry months are much lower for streams on the Cumberland Plateau than for streams in the Ridge and Valley. The flow of streams on the Cumberland Plateau is not well sustained during periods of no rainfall. This is a result of either poor infiltration rvoirs to store and release water.

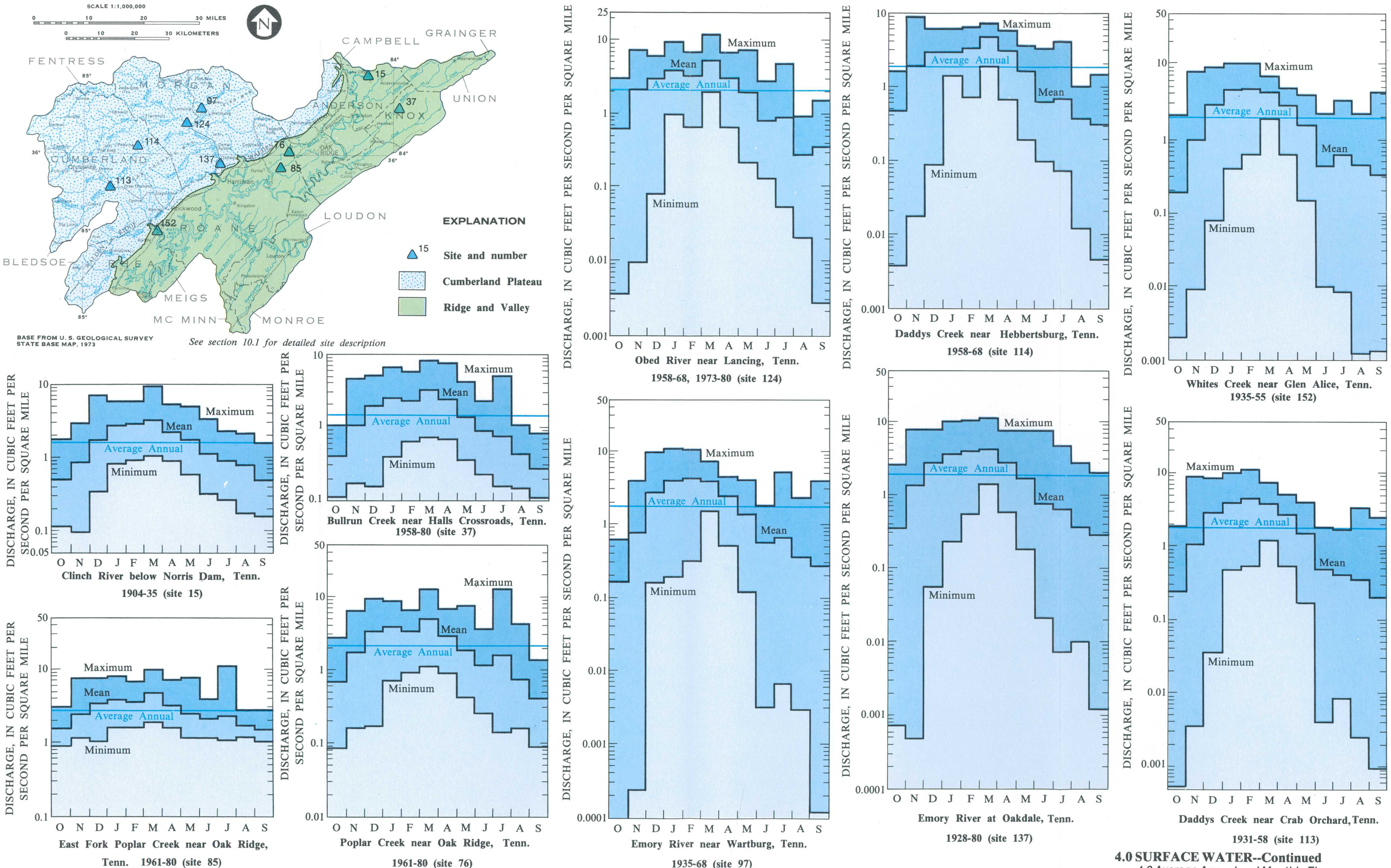


Figure 4.2-1 Average annual and range in monthly flow per square mile at ten sites.

Cumberland Plateau Streams have Lower Yields Than Streams Elsewhere during Low Flow

The 3-day 20-year and the 7-day 10-year recurrence interval low flows are lower for Cumberland Plateau streams than for Ridge and Valley streams.

The low-flow characteristics of streams in Area 19 are difficult to define because they are not readily susceptible to regionalization. This is because the low flow is affected by several factors which are difficult to measure quantitatively, such as the storage and transmission capacity of the rocks of the area, the perviousness of the soil, and the type and density of vegetation.

Low-flow frequency curves can be derived from streamflow data. Low-flow frequency is expressed as the lowest average flow for a given number of consecutive days for a given recurrence interval. A generalized view of a common index of low flow used in Tennessee, the 3-day 20-year recurrence interval flow, is shown for selected streams in Area 19 as a discharge range that is applicable to a reach of stream (fig. 4.3-1). The low flows of streams on the Cumberland Plateau are generally lower than for streams in the Ridge and Valley.

Another common index of low flow is the 7-day 10-year recurrence interval flow. In the Ridge and Valley, the 7-day 10-year recurrence interval flow is generally about 20 percent larger than the 3-day 20-year recurrence interval flow (Gold, 1980). However, for the Cumberland Plateau streams the difference is greater and more variable (fig. 4.3-1 and table 4.3-1).

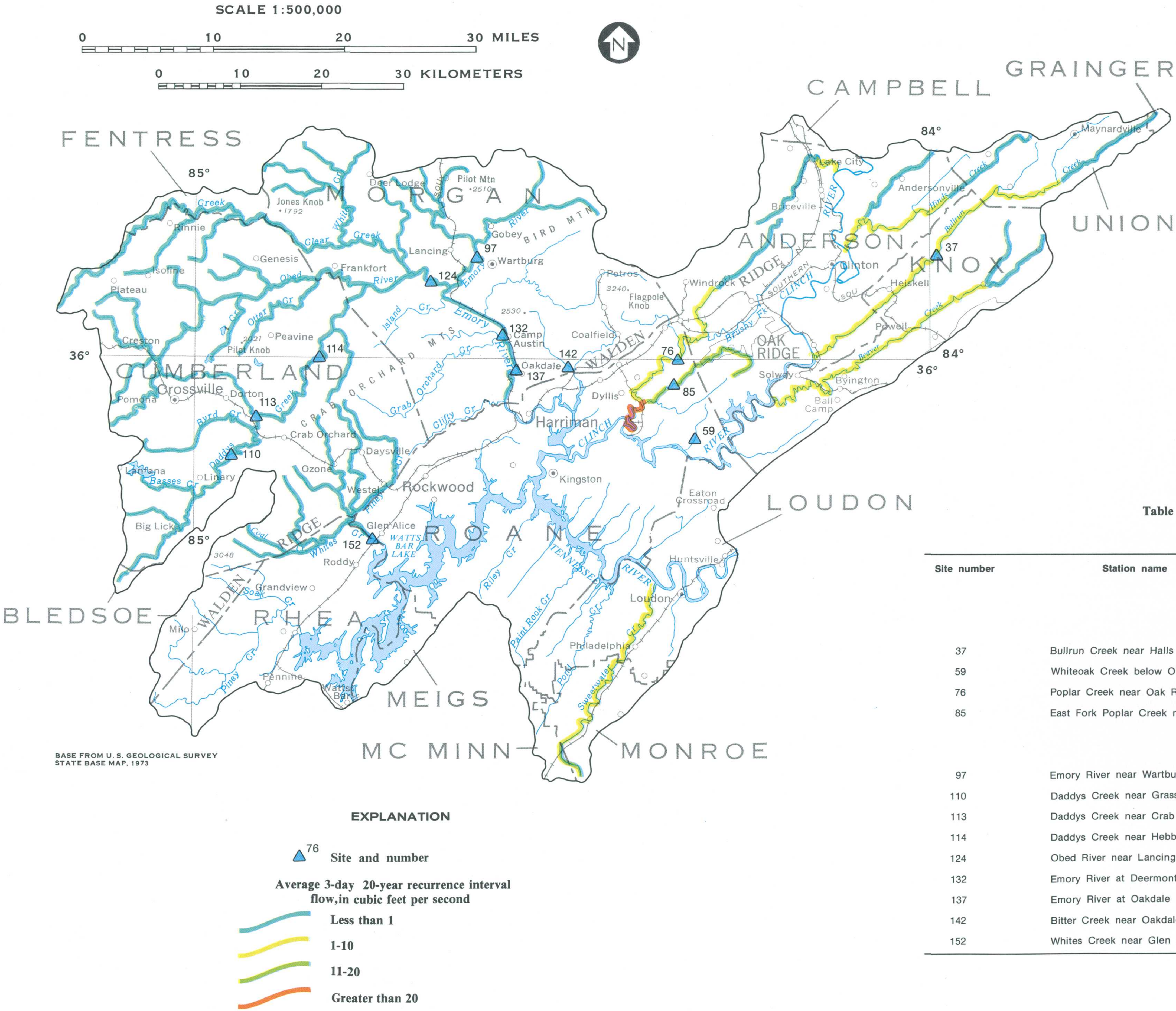


Figure 4.3-1 Generalized low flow of streams in Area 19.

Table 4.3-1 Low flows at selected sites.

Site number	Station name	Drainage area (mi²)	3-day 20-year recurrence interval flow (ft³/s)	7-day 10-year recurrence interval flow (ft³/s)
	Ridge and Valley			
37	Bullrun Creek near Halls Crossroads	68.5	4.14	4.86
59	Whiteoak Creek below ORNL, near Oak Ridge	3.62	2.64	3.07
76	Poplar Creek near Oak Ridge	82.5	4.92	5.80
85	East Fork Poplar Creek near Oak Ridge	19.5	16.6	17.7
	Cumberland Plateau			
97	Emory River near Wartburg	83.2	0.0	0.0
110	Daddys Creek near Grassy Cove	51.2	0.0	.05
113	Daddys Creek near Crab Orchard	93.5	0.0	.03
114	Daddys Creek near Hebbertsburg	139	.29	.49
124	Obed River near Lancing	518	.75	1.54
132	Emory River at Deermont	704	--	4.0
137	Emory River at Oakdale	764	.07	.44
142	Bitter Creek near Oakdale	12.6	.02	.03
152	Whites Creek near Glen Alice	108	.07	.12

Floods Vary Seasonally and with Basin Size

In Area 19, the range in maximum known floods for a given basin size is about one order of magnitude. Most floods occur in the winter and spring. Techniques have been developed for estimating flood frequencies.

The range in maximum known floods experienced in Area 19 for a given drainage basin size is about one order of magnitude (fig. 4.4.1-1). For example, at 20 mi^2 the range is from about 3,000 ft^3/s to almost 30,000 ft^3/s. In general, large basins produce large maximum floods and smaller basins produce smaller maximum floods. The occurrence of floods is a natural, random phenomenon, and higher floods than those observed can occur at any time.

Floods occur in Area 19 in any month of the year. However, about 67 percent of the annual peaks occur during the period December through March and about 79 percent occur during the longer period December through April (fig. 4.4.1-2). About 25 percent of the annual peaks occur in March. Only about 2 percent of the annual peaks occur during the period August through October.

The flood-frequency characteristics of unregulated streams in Tennessee have been defined (Randolph and Gamble, 1976) using all gaging station records of 10 or more years in length and not significantly affected by manmade changes. The State was divided into four flood-frequency hydrologic areas which have distinct flood-frequency characteristics; Area 19 lies entirely within hydrologic area 1 (fig. 4.4.1-3). The equations for computing flood discharges for various recurrence intervals for hydrologic area 1 are:

Magnitude of floods (ft^3/s)	Standard error of estimate (percent)
$Q_2 = 127 A^{.752}$	45
$Q_5 = 211 A^{.735}$	45
$Q_{10} = 276 A^{.727}$	46
$Q_{25} = 366 A^{.719}$	47
$Q_{50} = 442 A^{.714}$	49
$Q_{100} = 524 A^{.709}$	50

where: Q_n equals the discharge for the recurrence interval n years;

A is the drainage area in mi^2. The range in drainage basin for which these equations are applicable is from 0.36 mi^2 to 3,035 mi^2.

The computed relationship between the 50-year flood and the size of the drainage basin is also shown on figure 4.4.1-1 for comparison. Recurrence interval is defined as the average interval of time, in years, within which the given flood magnitude will be equaled or exceeded. For example, a 50-year flood could be expected, on the average, once in 50 years or, stated another way, has a 2-percent chance of occurring in any given year. A 5-year flood is one that has a 20-percent chance of occurring in any given year. Methods for computing flood frequency at sites which are relatively near gaging stations (where the drainage area is within 50 percent of the area at the gage site) also have been presented by Randolph and Gamble (1976).

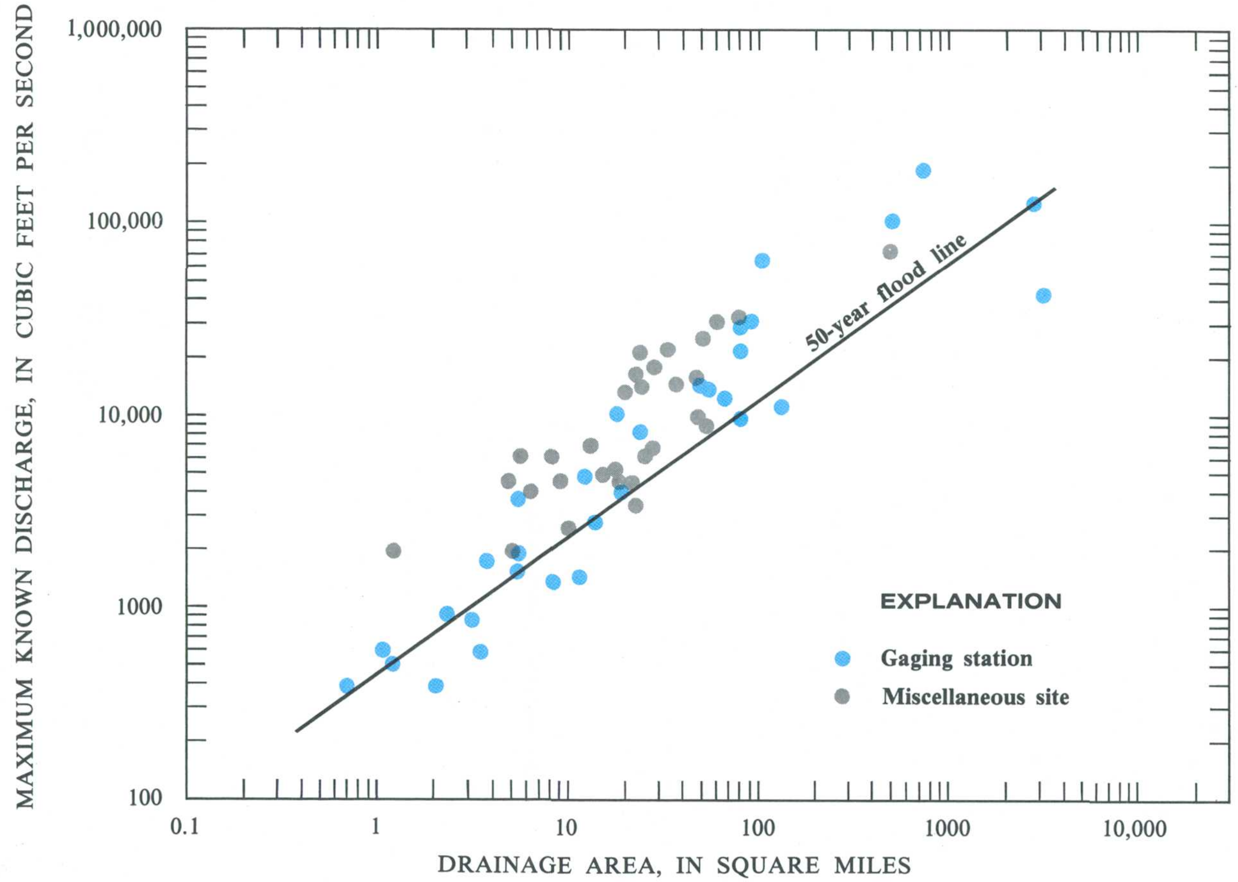


Figure 4.4.1-1 Relation of maximum known floods and 50-year flood to drainage area.

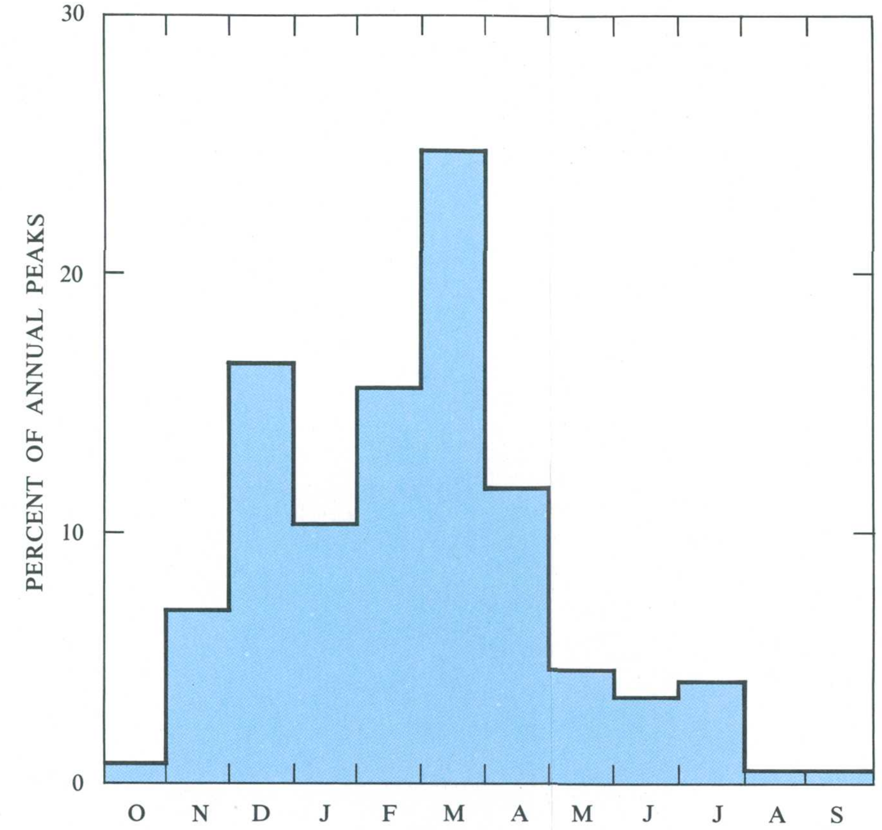


Figure 4.4.1-2 Seasonal distribution of floods.

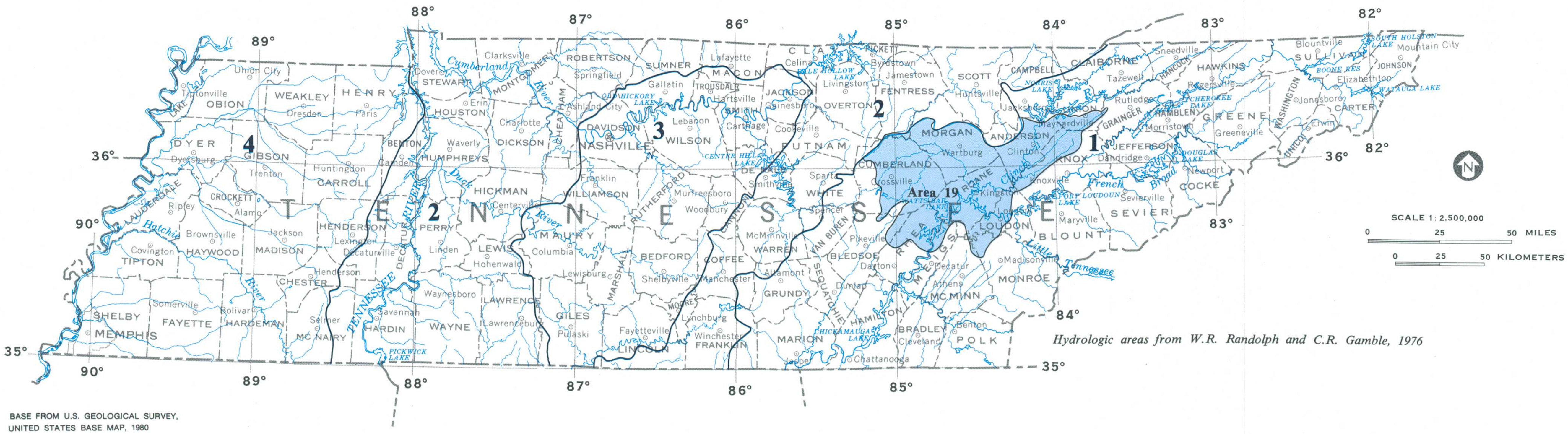


Figure 4.4.1-3 Flood-frequency hydrologic areas.

Flood-Prone Area Maps Available

Flood-prone area maps are available for about one-half of Area 19. Depths for the 100-year flood are predictable.

The National Flood Insurance Act of 1968 and the Flood Disaster Protection Act of 1973 established programs for identifying towns and streams subject to flooding and for outlining approximate flood-prone areas on topographic maps using existing information. In 1968, the U.S. Geological Survey began delineating flood-prone areas of the maximum known flood on 7½-minute (1:24,000) topographic quadrangle maps. After two years it was decided that uniformity of the delineated flood would be desirable, so the 100-year flood was selected for mapping in 1970. All maps in Area 19 were done in 1973 and, therefore, show the flood-prone area of the 100-year flood. A method was developed for estimating the depth (feet) of the 100-year flood on small streams by relating depth to drainage basin size in each of four flood-depth hydrologic areas (fig. 4.4.2-1) in Tennessee (Gamble and Lewis, 1977). Area 19 is in parts of two of these areas (fig. 4.4.2-2). The equation for computing flood depth for each area is shown with the drainage area limits of application.

The relation between flood depth and drainage area was used in the flood-prone area mapping program to determine 100-year flood depths. It can be used to estimate the depth of the 100-year flood for any purpose where extreme accuracy is not necessary. Flood-prone area maps within or partially within Area 19, are indicated by shading in figure 4.4.2-2. The names and locations of all 7½-minute topographic quadrangle maps in the area are also shown.

In addition to maps prepared by the U.S. Geological Survey, the Tennessee Valley Authority also mapped flood-prone areas in 1973. Copies of these maps may be obtained from:

Chief, Flood Hazard Analysis Branch
Tennessee Valley Authority
100 Liberty Building
Knoxville, TN 37901

Copies of flood-prone area maps prepared by the U.S. Geological Survey may be obtained from:

U.S. Geological Survey
Water Resources Division
A413 Federal Building - U.S. Courthouse
Nashville, Tennessee 37203

Copies of 7½-minute topographic maps may be purchased from:

Tennessee Department of Conservation
Division of Geology
G-5 State Office Building
Nashville, TN 37219.

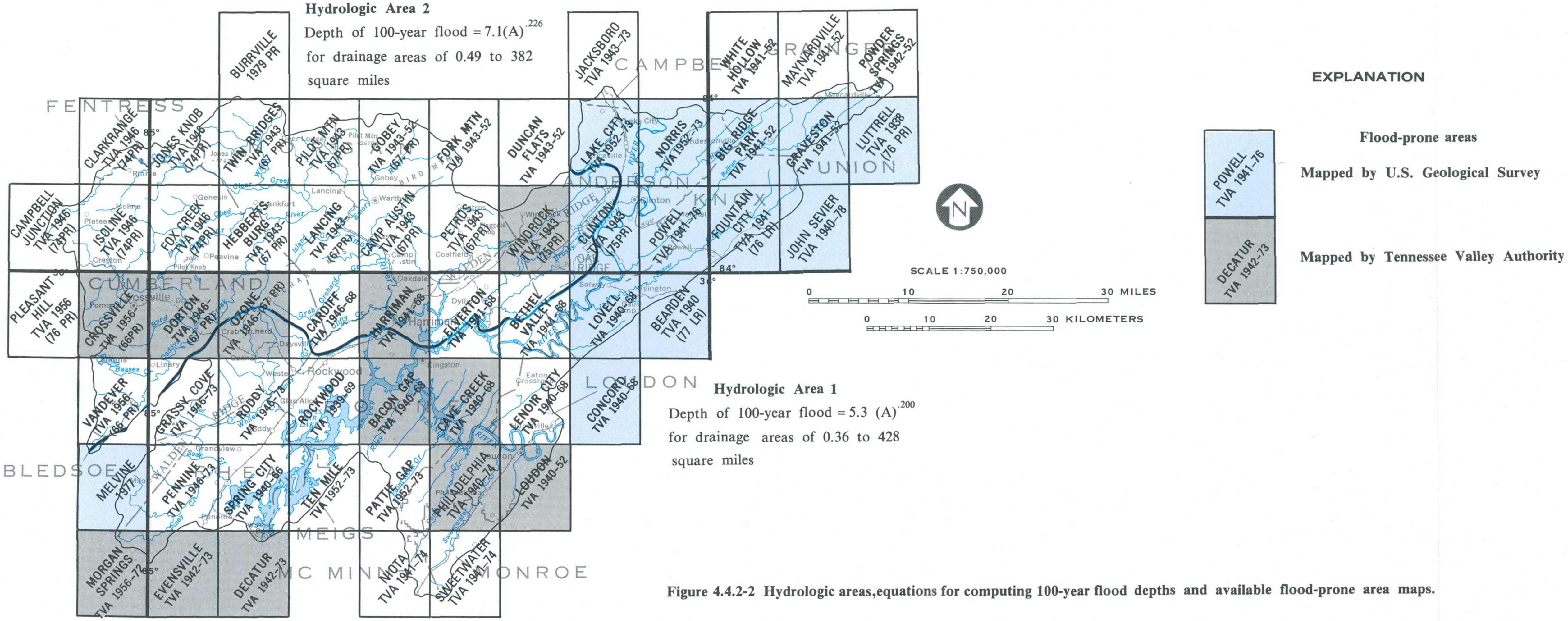
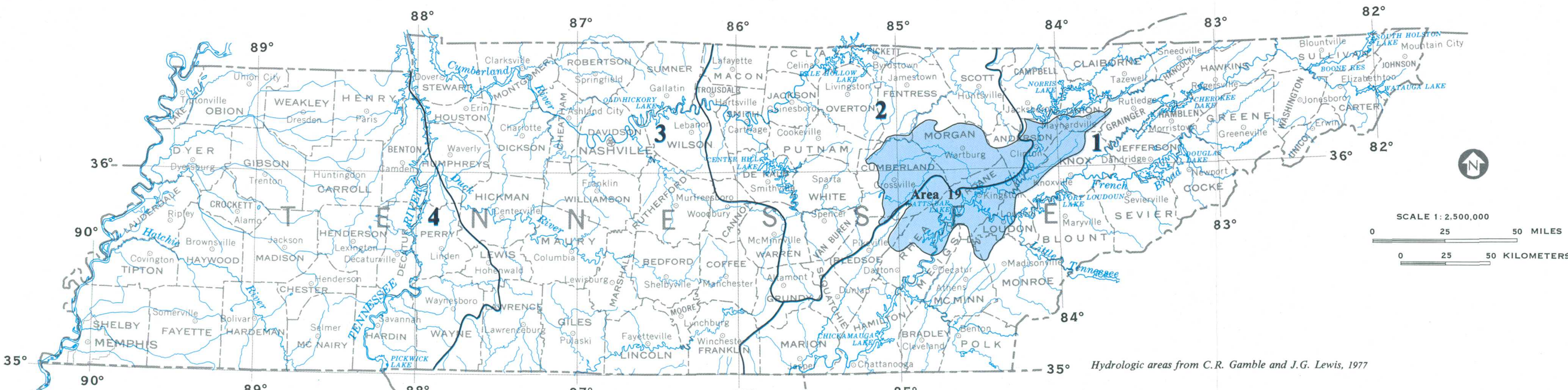


Figure 4.4.2-2 Hydrologic areas, equations for computing 100-year flood depths and available flood-prone area maps.

BASE FROM U. S. GEOLOGICAL SURVEY
STATE BASE MAP, 1973



Hydrologic areas from C.R. Gamble and J.G. Lewis, 1977

BASE FROM U.S. GEOLOGICAL SURVEY,
UNITED STATES BASE MAP, 1980

Figure 4.4.2-1 Hydrologic areas for 100-year flood depths.

Flow of Streams Draining the Cumberland Plateau is Poorly Sustained

The low flow of streams in the Cumberland Plateau is not as well sustained as in the Ridge and Valley.

The streamflow at a given point represents the surface outflow of the drainage basin upstream. It is an integration of the effects of climate, topography, and geology, and gives a distribution of runoff both in time and in magnitude. Flows can be arranged according to frequency of occurrence and plotted as a flow-duration curve. The resulting curve shows the integrated effect of the various factors that affect streamflow. Flow-duration curves provide a convenient means of comparing the flow of streams or basins.

The slope of the flow-duration curve for a stream is a measure of that stream's variability of flow. A steep slope indicates highly variable flow whereas a flat slope indicates a more uniform flow.

Flow-duration curves for two sites (fig. 4.5-1) in Area 19 are shown in figure 4.5-2. These curves are based on different periods of record but are plotted in unit discharge (cubic feet per second per square mile) so that more direct comparison can be made. The streams selected are representative of the two physiographic provinces of the area. Flow duration data for other streams in Area 19 are published in Gold (1980).

The curve for Emory River at Oakdale (site 137) is typical of streams of the Cumberland Plateau. It is rather steep at discharges greater than 1.0 $(ft^3/s)/mi^2$, indicating poor recharge to and subsequent discharge from the ground water system. The curve is even steeper at discharges less than 1.0 $(ft^3/s)/mi^2$ which is related to the poor storage qualities of the ground-water system. The result is poor yields to streams during dry periods. The curve for Bullrun Creek near Halls Crossroads (site 37) represents the Ridge and Valley and has a flatter slope on the lower end indicating better yields from the ground-water system of that province.

The slope of the upper end of the curves is essentially the same. The curves are fairly close together indicating that the high-flow runoff per square mile is similar.

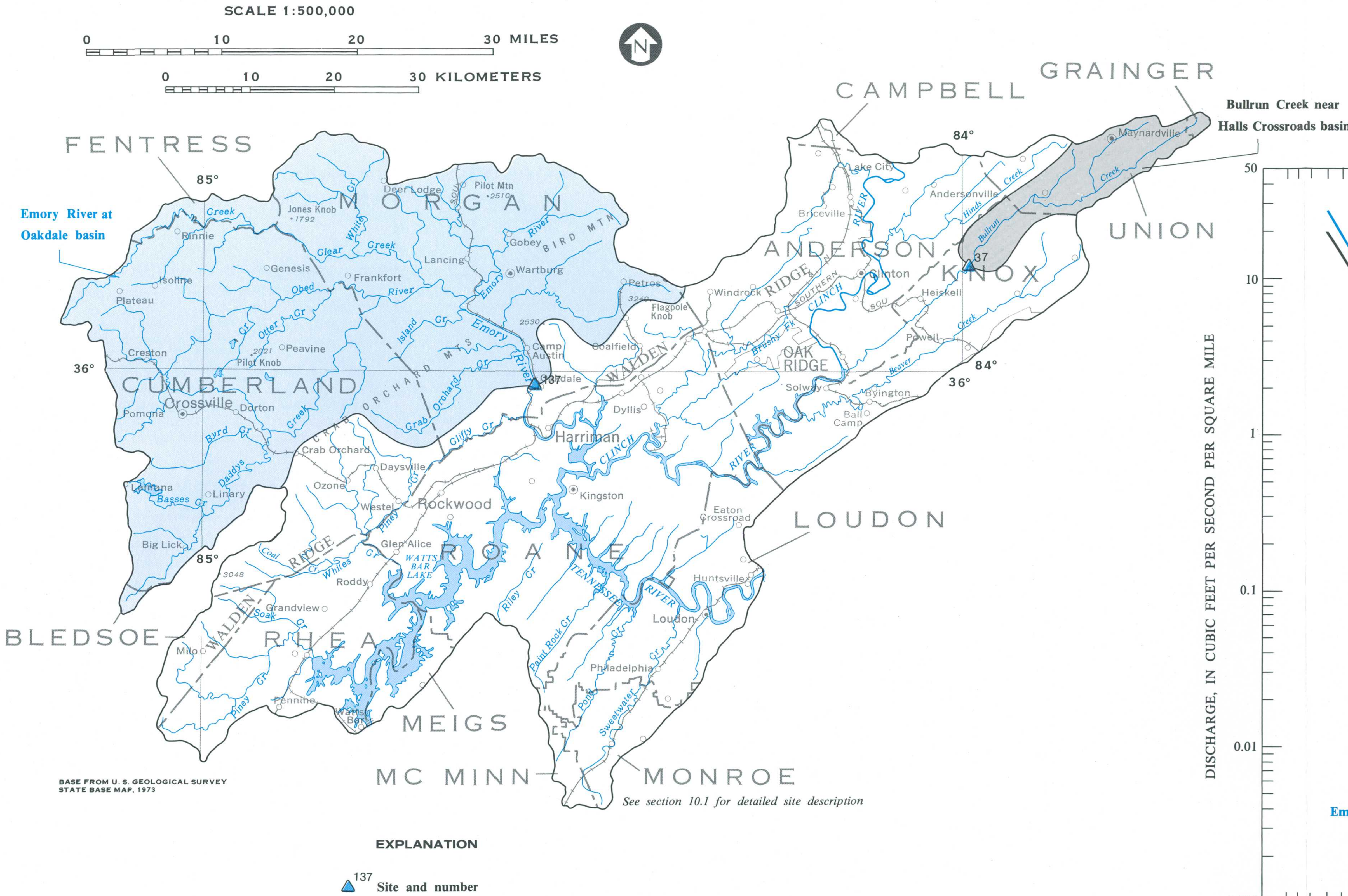


Figure 4.5-1 Location of basins for which flow-duration curves are shown.

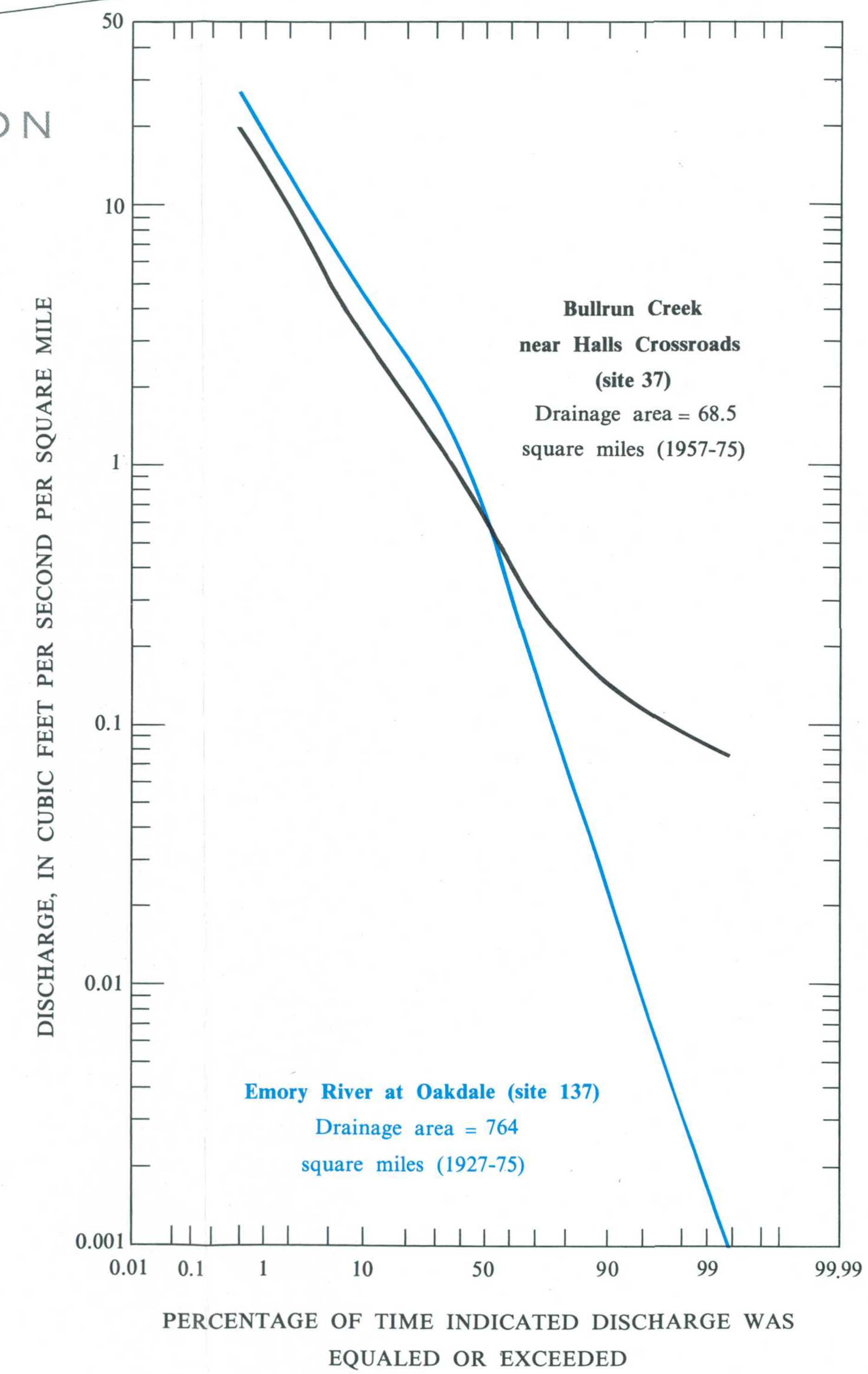


Figure 4.5-2 Selected flow-duration curves.

Water-Quality Information Needed to Evaluate Effects of Mining Activities

A network of 16 sites, in addition to the upgrading of two sites, was established in 1979 to measure water-quality conditions and to evaluate water-quality trends in coal-resources areas.

The effects of surface coal-mining activities on the hydrologic environment often can be evaluated by using water-quality data. In 1979, the U.S. Geological Survey established a network of 16 data-collection sites in Area 19 (fig. 5.1-1). Two existing data-collection sites were upgraded. One site operated by the Tennessee Valley Authority is also active. The water-quality data collected at those sites, as well as data collected through other programs, are presented in this report. However, the following important points regarding those data must be considered:

- The term "quality" is not precise. The quality of water from any source cannot be defined unless the intended use is considered. The use itself, in fact, probably has the greatest effect on suitability. For example, water unsuitable for drinking may be adequate for use in mining operations.

- Locally severe water-quality problems may exist at unsampled or unmeasured sites near any of the network sites and not be detected. No mine drainage or seepage was sampled; no sampling of such effluents is planned.

- The water-quality data collected at the sites established or upgraded in 1979 emphasized those parameters specified in the "Surface Mining Control and Reclamation Act of 1977". Because the Act specifies limits for certain water-quality parameters in mine effluents, most of these were determined at each of the 18 sites. Specified ranges or maximums are as follows:

  (a) pH range from 6.0 to 9.0 units;

  (b) total manganese concentration, 4,000 μg/L;

  (c) total iron concentration, 7,000 μg/L; and

  (d) total suspended-solids concentration, 70 mg/L.

Sufficient data to define seasonal water-quality variations also are required by various sections of the Act. Therefore, additional chemical, physical, and biological data were collected at selected sites. An effort was made to sample during several streamflow conditions (low, medium, and high flow). Concentrations of selected trace constituents in bottom material from stream channels were also determined. These data plus the data collected prior to 1979 are summarized in the following sections of this report.

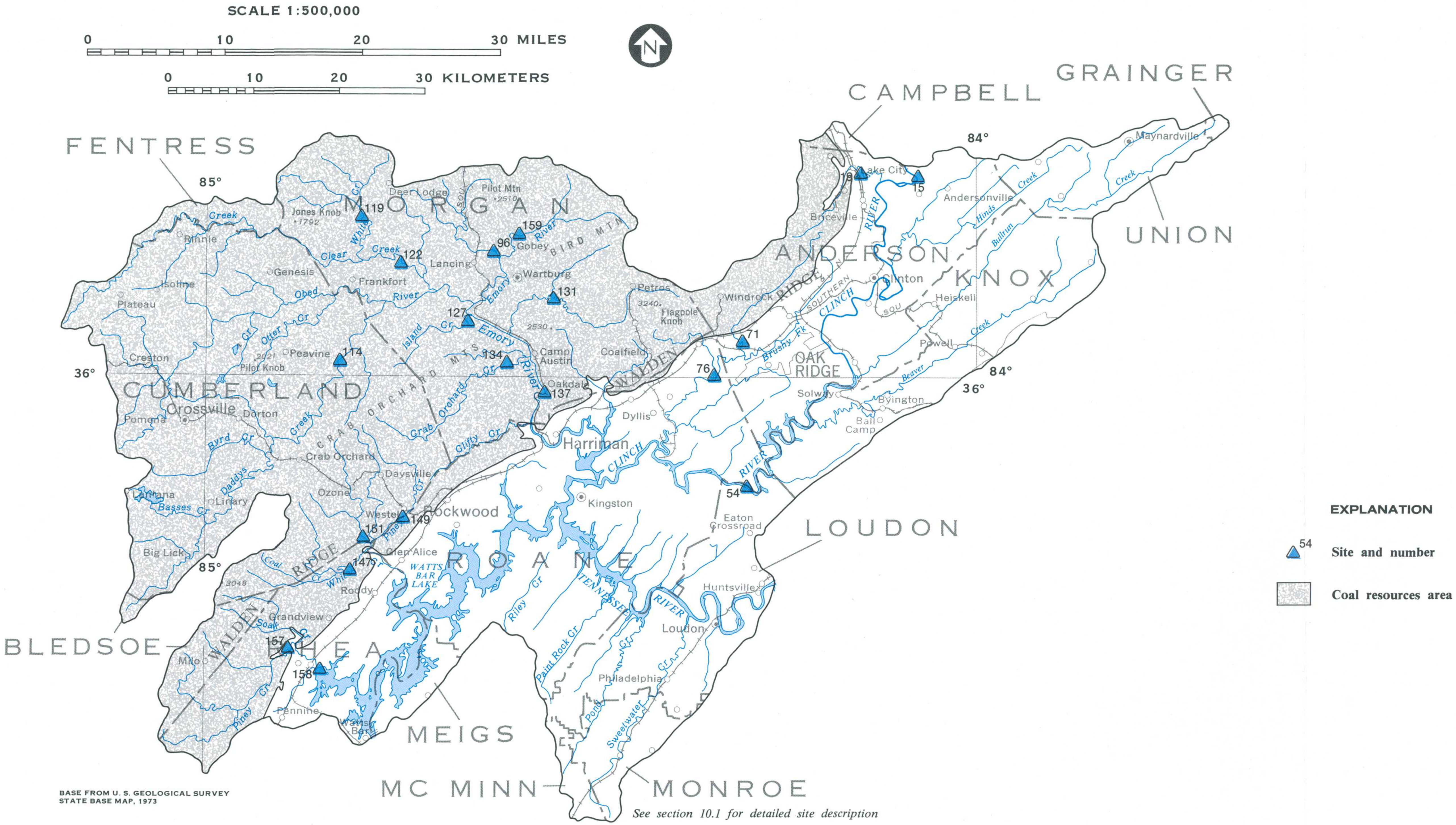
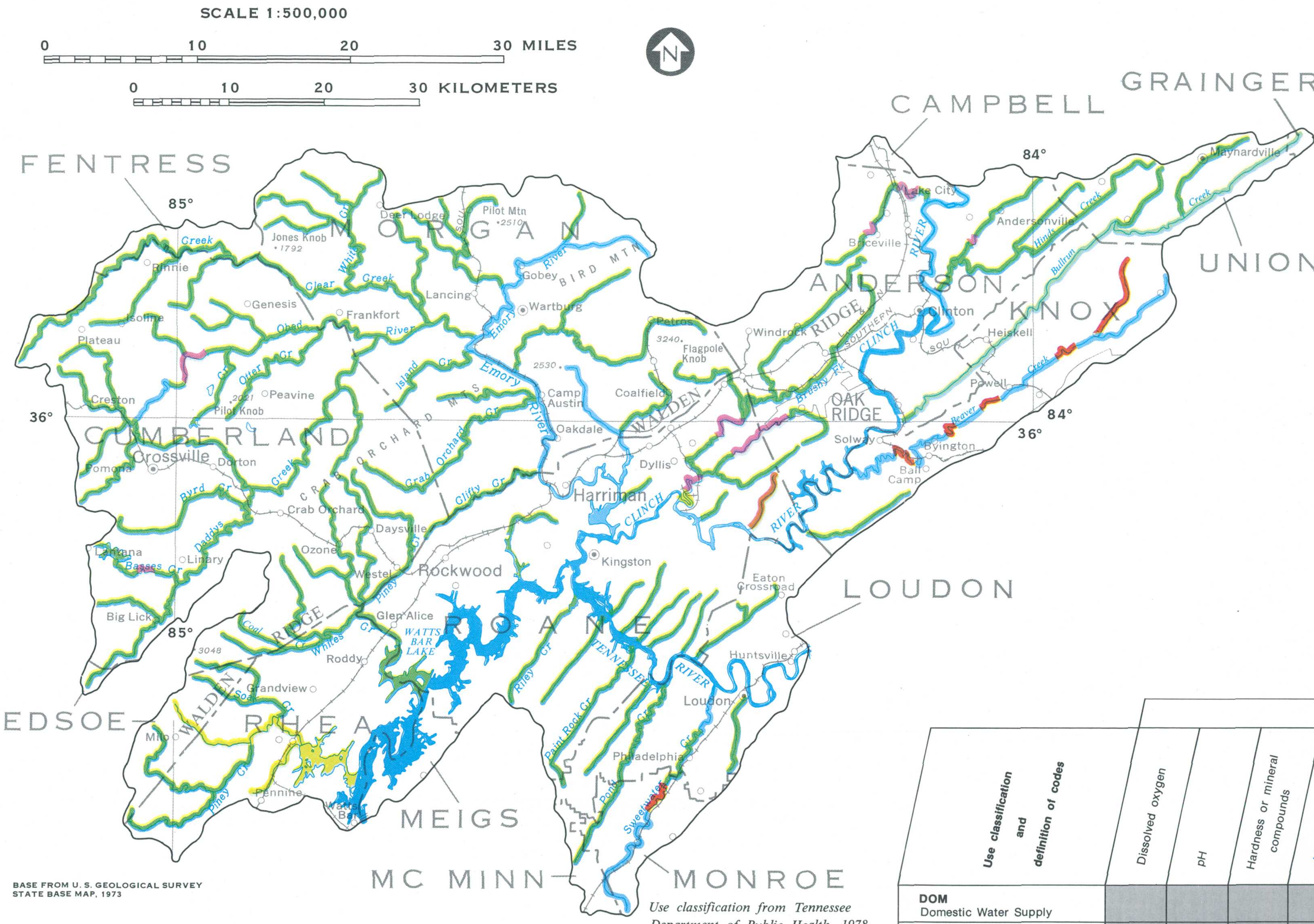


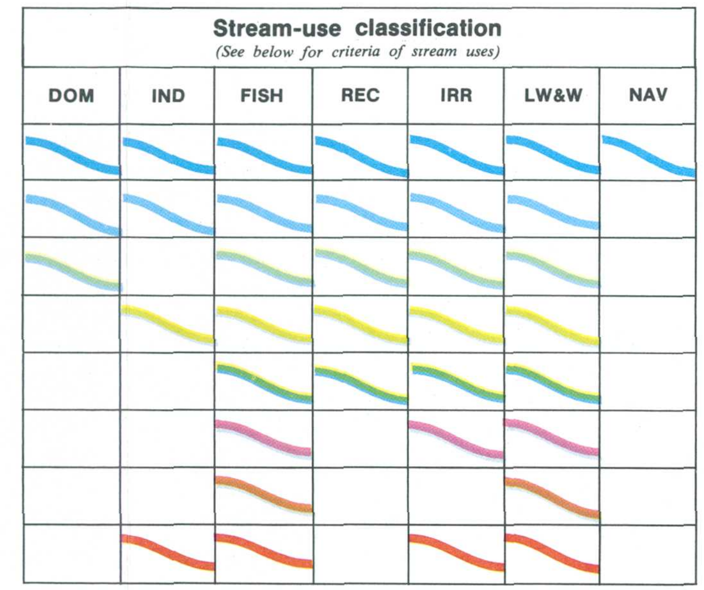
Figure 5.1-1 Location of active sites for which water-quality data are available.

Stream Uses Classified by State Agency

Most streams in Area 19 are classified for use for recreation, fishing, irrigation, and livestock and wildlife purposes. Other stream classifications include domestic and industrial water supply and navigation.

Section 208 of the Federal Water Pollution Control Act Amendments of 1972 (Public Law 92-500) defined criteria for developing and implementing areawide water-quality management plans. In compliance with that Act and Amendments, the Tennessee Department of Public Health, Division of Water Quality Control developed and published a water-quality management plan for Tennessee (1978). The use classifications for most major streams in the State are included in that plan. Also included are the water-quality criteria for each use classification (table 5.2-1). Stream reaches and use classifications are shown in figure 5.2-1. Some of the water-quality criteria probably will be reviewed when the State regulatory agencies develop plans to implement the guidelines in the Surface Mining Control and Reclamation Act.





Use classification and definition of codes	Dissolved oxygen	pH	Hardness or mineral compounds	Total dissolved solids	Solids, floating materials and deposits	Turbidity or color	Temperature	Coliform	Taste or odor	Toxic substances	Other pollutants
	Parameters for which criteria are defined										
DOM Domestic Water Supply	■	■	■	■	■	■	■	■	■	■	■
IND Industrial Water Supply	■	■	■	■	■	■	■		■	■	■
FISH Fish and Aquatic Life	■	■			■	■	■	■	■	■	■
REC Recreation	■	■			■	■	■	■	■	■	■
IRR Irrigation	■	■	■		■		■			■	■
LW&W Livestock Watering and Wildlife	■	■	■		■		■			■	■
NAV Navigation	■		■		■		■			■	■

Figure 5.2-1 Stream use classification.

Specific Conductance and Dissolved Solids are Low Except in Coal Mine and Urban Areas

Specific conductance values ranged from 20 to 1,110 micromhos in the area. Dissolved-solids concentrations (estimated from specific conductance) were generally low.

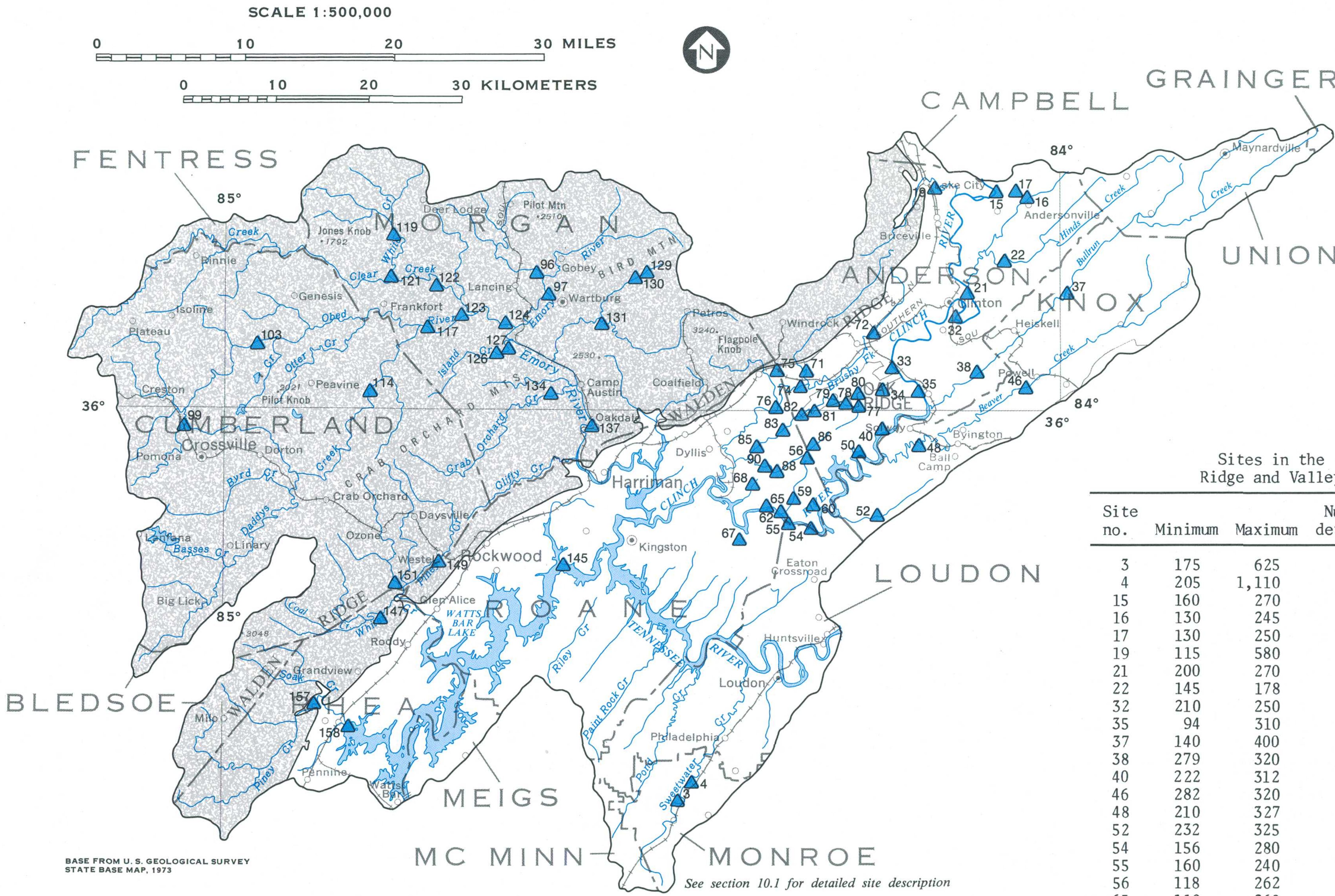
Specific conductance values are not included in any of the commonly-used water-quality criteria, but can be used to estimate dissolved solids and individual constituents in water which have specific limits (Hem, 1970). An estimate of the dissolved-solids concentration in water in most streams in Area 19 can be made by multiplying the specific conductance value by 0.6. This factor was determined by a comparison of dissolved-solids and specific conductance data of water from streams in the area. It is also typical of calcium or sodium bicarbonate type waters found elsewhere (Hem, 1970). Thus, based on currently available surface-water quality data, dissolved-solids concentrations are generally less than 250 milligrams per liter (mg/L), low by most criteria.

The specific conductance of water of streams in the Cumberland Plateau differed with that in streams in the Ridge and Valley or urban areas. In the Cumberland Plateau streams, specific conductance ranged from 20 to 695 micromhos per centimeter (μmhos/cm) (table 5.3-1). The maximum specific conductance in the Cumberland Plateau occurred in Crooked Fork near Wartburg (site 131), a stream severely affected by mine drainage (fig. 5.3-1). Not all streams draining areas with coal mines have been affected by coal-mine drainage. In the future, these sites will be particularly important in the assessment of the potential impact of mining activities upon water quality.

In the Ridge and Valley specific conductance ranged from 28 to 1,110 μmhos/cm (table 5.3-1). The maximum specific conductance occurred in Sweetwater Creek (site 4) in 1969 shortly before data collection at the site was discontinued. The water at this site was a sodium chloride type, a type more likely found in ground water at depth that in surface water under natural conditions. High specific conductances in water at several sites (19, 71, 75, and 76) in the Ridge and Valley having drainage predominantly in the Cumberland Plateau reflect mine drainage from the Plateau part of these basins.

In streams draining urban areas, in or near Oak Ridge, Tenn., the specific conductance ranged from 149 to 838 μmhos/cm. The somewhat higher minimum specific conductance at these sites probably reflects the addition of municipal or industrial waste to the streams.

The specific conductance of most streams did not have a statistically significant relation to streamflow. In the Clinch River, one of the largest rivers in Area 19, specific conductance ranged from 160 to 270 μmhos/cm at the most upstream site (site 15) and from 156 to 280 μmhos/cm at the farthest downstream site for which a large number of determinations is available (site 54). The total range in the Clinch River (sites 15, 21, 32, 35, 54, 55) was 94 to 310 μmhos/cm.



See section 10.1 for detailed site description

EXPLANATION

▲79 Site and number

Coal resources area

Figure 5.3-1 Sites for which specific conductance data are available.

Table 5.3-1 Range of specific conductance, in micromhos per centimeter at 25°C.

Sites in the Ridge and Valley

Site no.	Minimum	Maximum	Number of determinations
3	175	625	14
4	205	1,110	11
15	160	270	61
16	130	245	7
17	130	250	8
19	115	580	6
21	200	270	38
22	145	178	2
32	210	250	11
35	94	310	105
37	140	400	51
38	279	320	4
40	222	312	7
46	282	320	3
48	210	327	7
52	232	325	8
54	156	280	63
55	160	240	3
56	118	262	8
65	110	268	7
67	185	338	8
68	123	250	7
71	80	350	13
72	176	294	8
74	141	272	6
75	199	450	7
76	98	360	61
83	110	260	8
145	130	270	12
158	28	120	7

Sites in the Cumberland Plateau

Site no.	Minimum	Maximum	Number of determinations
96	32	200	5
97	35	140	31
99	42	340	13
103	36	130	12
114	33	120	10
117	50	--	1
119	22	27	3
121	27	--	1
122	21	55	8
123	30	46	2
124	25	90	38
126	30	--	1
127	20	39	5
129	34	--	1
130	30	40	2
131	51	695	25
134	35	310	23
137	35	175	107
147	26	78	5
149	28	85	5
151	29	195	5
157	26	73	5

Sites in urban areas

Site no.	Minimum	Maximum	Number of determinations
33	350	493	7
34	335	380	8
50	300	--	1
59	275	457	7
60	239	315	7
62	250	369	7
77	265	809	8
78	343	828	6
79	352	838	7
80	226	464	7
81	275	727	7
82	149	365	8
85	160	620	45
86	341	736	7
88	214	390	7
90	193	382	7

Dissolved Sulfate Concentrations Generally Low

Dissolved sulfate concentrations generally were low in Area 19, ranging from 1.0 to 300 mg/L.

Dissolved sulfate concentrations ranged from 1.0 to 26 milligrams per liter (mg/L) in water in streams draining relatively undisturbed or non-urban areas of both the Cumberland Plateau and the Ridge and Valley. Concentrations above these baseline levels often occur in streams adversely affected by acid-mine drainage due to the weathering of sulfur minerals in coal-mine spoil piles and in streams draining urban areas. Only three sites draining areas unaffected by coal-mine drainage or urbanization had concentrations greater than 20 mg/L. The source of the sulfate is unknown, but the sites are some distance from any known mining activities. Generally, in streams draining undisturbed areas, dissolved sulfate concentrations were lower.

Dissolved sulfate concentrations ranged from 1.0 to 130 mg/L in water in streams in the Ridge and Valley, with most concentrations less than 25 mg/L (fig. 5.4-1 and table 5.4-1). Concentrations exceeding 25 mg/L were usually at sites (19, 71, 75, and 76) whose drainage basins are mostly in the Cumberland Plateau.

Dissolved sulfate concentrations in the water at the Clinch River sites (15, 21, 32, 35, 54, and 55) varied somewhat, in part reflecting the inflow from tributary streams draining coal-mining areas. At the upper-most site (site 15), the concentrations ranged from 7.0 to 25 mg/L. Downstream at site 21 concentrations ranged from 14 to 32 mg/L, the increase possibly due to inflow from streams such as Coal Creek (site 19) draining coal-mining areas. At the site farthest downstream for which a large number of determinations is available (site 54), concentrations ranged from 7.0 to 24 mg/L. Higher concentrations occurred in water between the upstream and downstream sites, resulting in an overall range from 7.0 to 40 mg/L in the Clinch River.

Higher concentrations of dissolved sulfate are evident in streams draining urbanized areas. The dissolved sulfate concentrations in water at these sites ranged from 4.8 to 300 mg/L, with the highest concentration occurring in East Fork Poplar Creek at East Vanderbilt Drive at Oak Ridge (site 79) in February 1962. Nearly all of the highest concentrations of dissolved sulfate among the urban sites occurred that month. Because these extremes determined nearly twenty years ago cannot be explained, conclusions based on the data should be qualified; no data have been collected recently.

Dissolved sulfate concentrations were higher during low flow in both the Cumberland Plateau and the Ridge and Valley. However, differences caused by flow were generally small and not statistically significant. At the urban sites, differences caused by flow were greater but still not statistically significant. An estimate of dissolved sulfate concentrations frequently can be obtained using specific conductance data; but no statistically significant relation between sulfate and conductance has yet been established for surface water in Area 19.

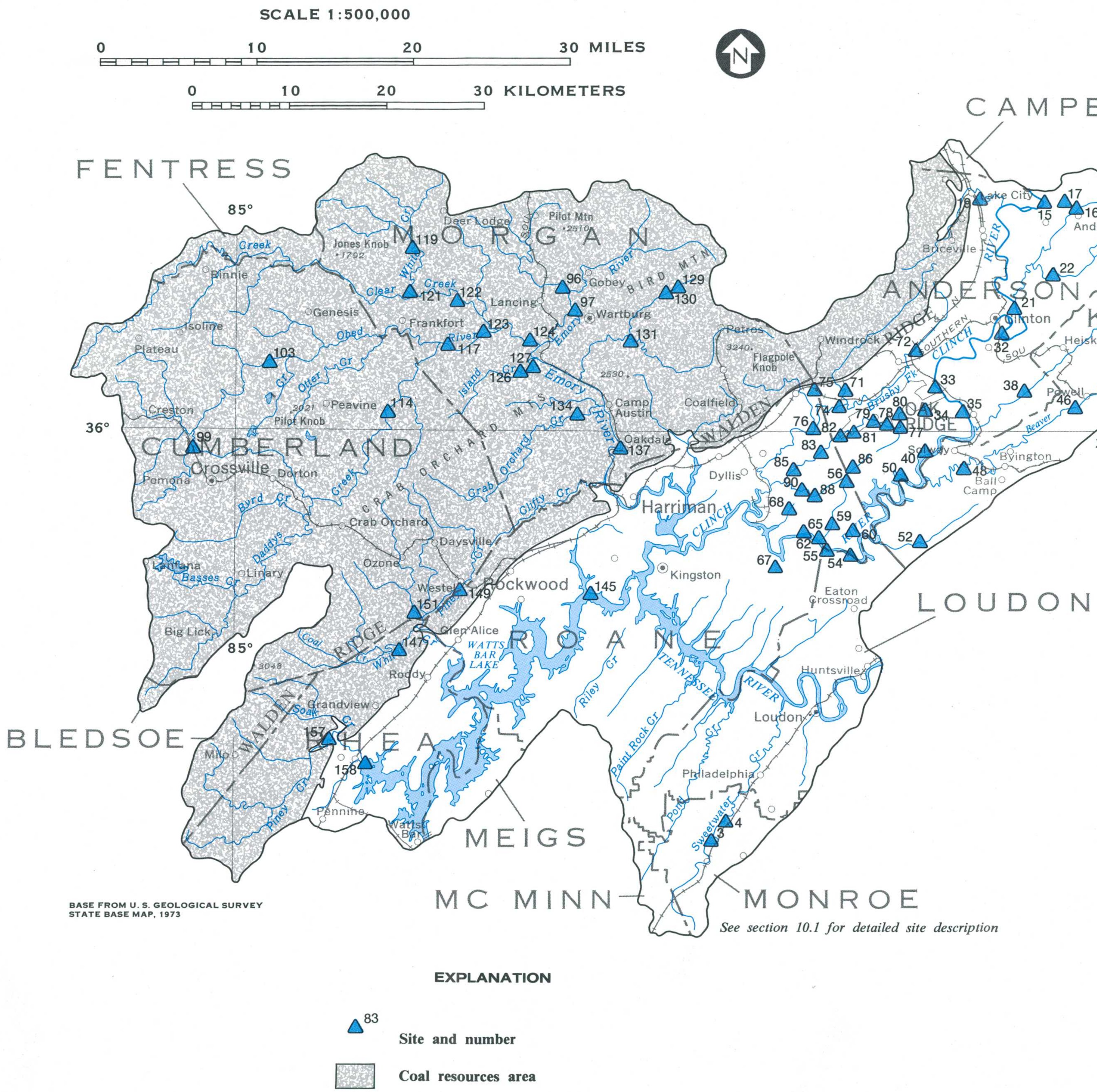


Figure 5.4-1 Sites for which dissolved sulfate data are available.

Table 5.4-1 Range of dissolved sulfate concentrations, in milligrams per liter.

Sites in the Ridge and Valley

Site no.	Minimum	Maximum	Number of determinations
3	2.7	16	14
4	5.0	26	11
15	7.0	25	56
16	2.0	3.5	7
17	2.0	4.5	8
19	32	130	6
21	14	32	33
22	11	13	2
32	11	22	11
35	11	40	95
37	1.0	16	13
38	4.8	8.4	4
40	1.2	5.6	7
46	7.0	21	3
48	3.6	14	7
52	7.2	13	8
54	7.0	24	57
55	14	20	3
56	1.4	4.2	8
65	1.8	4.4	7
67	1.8	7.8	8
68	4.2	8.8	7
71	24	67	13
72	5.4	9.4	8
74	12	31	6
75	66	112	7
76	16	72	22
83	9.8	15	7
145	14	24	12
158	3.4	13	7

Sites in the Cumberland Plateau

Site no.	Minimum	Maximum	Number of determinations
96	4.8	8.7	5
97	7.2	50	31
99	5.0	15	13
103	5.0	12	11
114	3.2	6.7	10
117	7.0	--	1
119	3.7	5.7	3
121	1.8	--	1
122	2.6	8.0	8
123	5.6	12	2
124	1.4	8.6	20
126	11	--	1
127	5.4	9.8	5
129	7.6	--	1
130	11	11	2
131	19	262	25
134	7.6	110	23
137	3.0	86	71
147	4.1	5.2	5
149	5.2	6.7	5
151	5.6	13	5
157	4.8	13	5

Sites in urban areas

Site no.	Minimum	Maximum	Number of determinations
33	18	30	7
34	5.4	14	8
50	36	--	1
59	18	34	7
60	14	21	7
62	21	35	7
77	21	44	8
78	21	263	6
79	17	300	7
80	4.8	7.6	7
81	22	36	7
82	9.2	23	8
85	19	45	13
86	24	66	7
88	9.2	20	7
90	14	38	7

pH Differs Between Unaffect and Coal-Mined Areas

Acid-mine drainage is not a widespread problem in Area 19. The pH is usually in the near-neutral range (6.0-8.0 units).

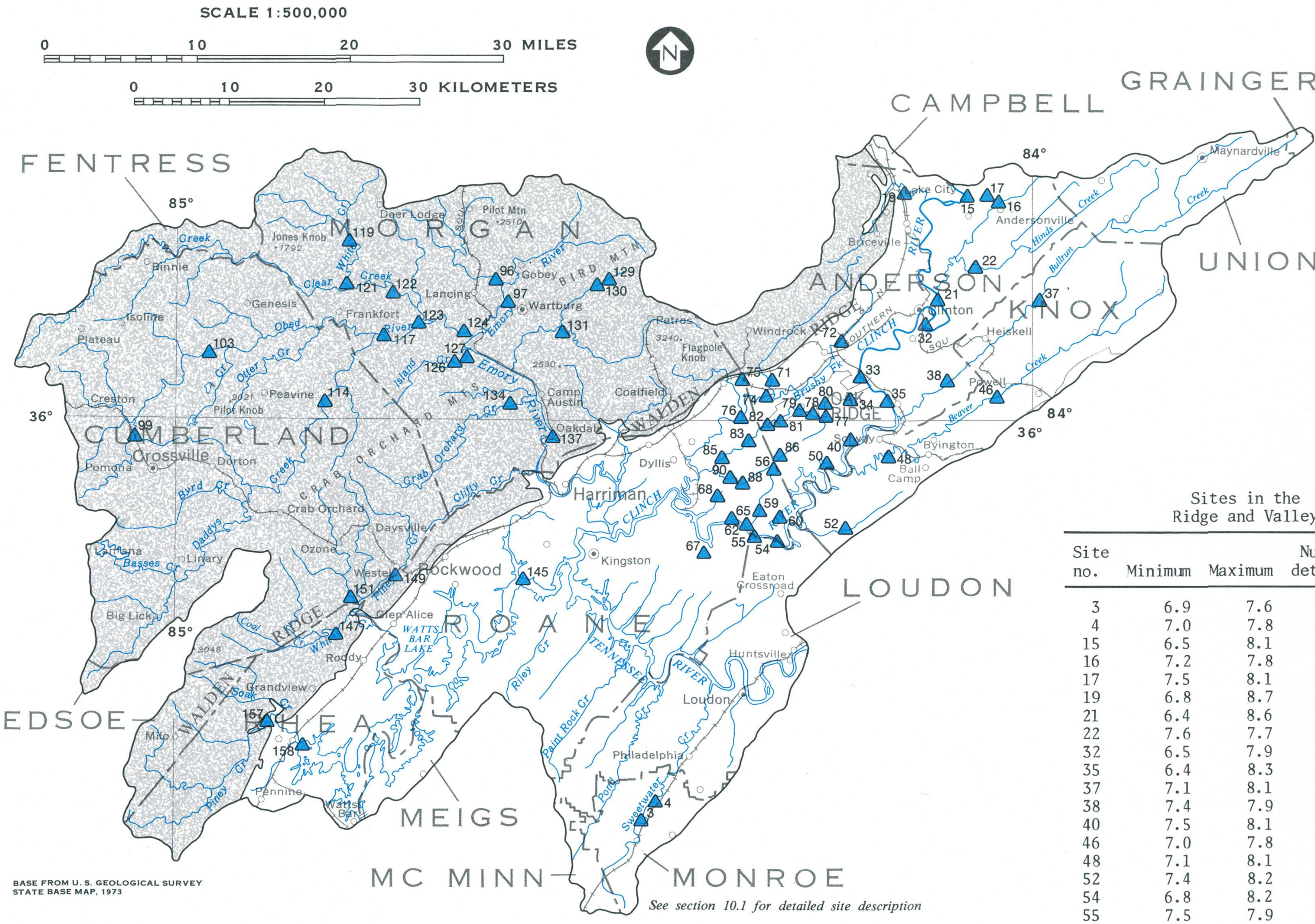
The pH scale, ranging from 0 to 14 units, is an indicator of the relative acidity or alkalinity of a solution. A pH of 7.0 indicates neutrality. Progressively lower pH values indicate increasingly acidic solutions. Similarly, progressively higher pH values indicate increasingly alkaline solutions.

The pH of water affects its suitability for industrial, municipal, and recreational purposes. Acidic water adversely affects most substances with which it comes in contact. For most purposes, criteria specify an acceptable pH range as 6.0 to 8.0 units. Additionally, the Act specifies that mine effluents must be between a pH of 6.0 and 9.0 units. Acidity in streams has several important sources other than mine drainage, including rainfall, reaction of rainfall with organic matter in soils, and weathering of geologic strata.

The pH of the water in the Clinch River (sites 15, 21, 32, 35, 54, 55) varied little, ranging from 6.5 to 8.1 units at the site farthest upstream (site 15). At the site farthest downstream for which a large number of determinations is available (site 54), pH ranged from 6.8 to 8.2 units.

The pH of water in most Area 19 streams ranged from 6.0 to 8.0 units (fig. 5.5-1). Overall, the range of pH values in streams in the Ridge and Valley was from 5.8 to 8.7 units. At most sites, the pH range was generally less than one unit. Water in streams in the Cumberland Plateau had pH values ranging from 4.5 to 8.5 units, the lowest occurring in Crooked Fork near Wartburg (site 131). Water at some sites located in the central part of the coal-mining areas is unaffected by acid-mine drainage. In the future, these sites will be particularly important in the assessment of the potential impact of mining activities on water quality.

The sites near Oak Ridge drain areas affected by urbanization. The range of pH values in these streams was from 6.9 to 10.7 units (table 5.5-1). However, many of these pH values were determined nearly twenty years ago; no data have been collected recently.



See section 10.1 for detailed site description

EXPLANATION

▲78 Site and number

Coal resources area

Figure 5.5-1 Sites for which pH data are available.

Table 5.5-1 Range of pH, in standard units.

Sites in the Ridge and Valley

Site no.	Minimum	Maximum	Number of determinations
3	6.9	7.6	13
4	7.0	7.8	11
15	6.5	8.1	60
16	7.2	7.8	7
17	7.5	8.1	8
19	6.8	8.7	6
21	6.4	8.6	38
22	7.6	7.7	2
32	6.5	7.9	11
35	6.4	8.3	93
37	7.1	8.1	13
38	7.4	7.9	4
40	7.5	8.1	7
46	7.0	7.8	3
48	7.1	8.1	6
52	7.4	8.2	8
54	6.8	8.2	63
55	7.5	7.9	3
56	7.5	8.1	9
65	7.6	8.0	7
67	7.3	8.2	8
68	7.4	8.0	7
71	5.8	8.1	13
72	7.3	8.1	8
74	7.1	8.0	6
75	6.1	7.6	7
76	6.7	8.1	23
83	7.4	8.1	7
145	6.9	7.5	12
158	6.4	8.1	7

Sites in the Cumberland Plateau

Site no.	Minimum	Maximum	Number of determinations
96	6.8	7.2	5
97	6.1	8.3	32
99	6.2	7.9	14
103	5.1	7.0	12
114	6.6	7.8	10
117	7.1	--	1
119	6.1	6.9	3
121	6.7	--	1
122	6.1	7.3	8
123	6.6	6.9	2
124	6.3	7.9	20
126	6.6	--	1
127	6.1	6.8	5
129	8.0	--	1
130	7.5	8.2	2
131	4.5	7.9	25
134	4.6	6.8	23
137	4.9	8.5	77
147	6.5	7.5	5
149	6.4	7.5	5
151	6.3	7.9	5
157	6.5	7.4	5

Sites in urban areas

Site no.	Minimum	Maximum	Number of determinations
33	7.3	8.0	7
34	7.1	8.2	8
50	7.8	--	1
59	7.2	9.2	7
60	7.3	8.1	7
62	7.1	8.1	7
77	7.2	10.7	8
78	7.2	9.5	6
79	7.0	9.7	7
80	7.3	8.2	7
81	7.2	10.0	7
82	7.4	7.9	8
85	6.9	7.7	13
86	7.0	8.1	7
88	7.5	8.0	7
90	7.5	8.1	7

Iron Concentrations Vary with Streamflow and Location

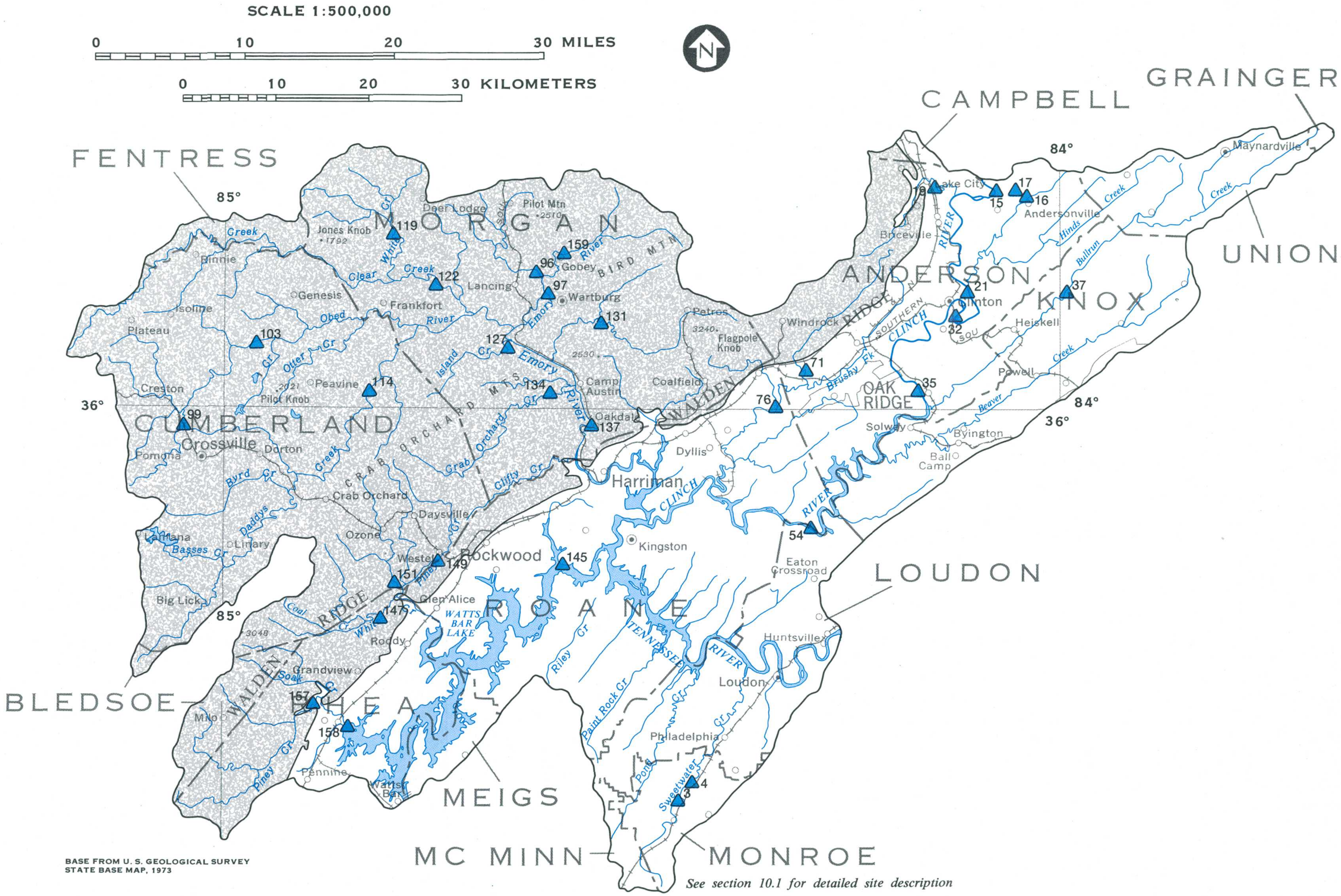
Although iron concentrations vary with streamflow and location, the concentrations of total recoverable iron in most streams were less that the mandatory limits specified for effluents from mining areas.

Iron in excessive concentrations can limit severely the use of water for public supply, domestic, and recreational purposes. Consequently, most water-supply criteria contain recommended maximum limits for dissolved iron; the recommended maximum concentration of iron in drinking water is 300 μg/L (U. S. Environmental Protection Agency, 1976). The Act specifies 7,000 μg/L as the maximum allowable concentration of total iron in effluents from mining operations. Total recoverable (dissolved plus suspended) and dissolved concentrations of iron in water have been determined at 31 sites in Area 19 (fig. 5.6-1).

Total recoverable iron concentrations in water in streams in the area ranged from 0 to 44,000 μg/L (table 5.6-1). The maximum concentration occurring in Coal Creek (site 19), which drains a basin mostly in the Cumberland Plateau, is equivalent to the transport of about 13 tons of iron per day (assuming the instantaneous concentrations and streamflow were sustained throughout the day). At four other sites in the Ridge and Valley (three with basins mostly in the Cumberland Plateau), total recoverable iron concentrations exceeded 7,000 μg/L at least once. Total recoverable iron at sites on streams in the Cumberland Plateau ranged from 0 to 10,000 μg/L with determined maximums exceeding 1,000 μg/L at about two-thirds of the sites. Concentrations exceeded the maximum for mine effluents at two sites.

Dissolved iron is only a small part of the total recoverable iron transported by streams in Area 19; concentrations generally were less than 200 μg/L. Although dissolved iron concentrations ranged from 0 to 1,300 μg/L, only eight of approximately 500 determinations exceeded 300 μg/L. Dissolved iron did not vary significantly with large changes in streamflow. Although pH is an important factor affecting metal solubilities, no statistically significant relation between pH and dissolved iron has been established areawide.

The maximum total recoverable iron in water from most streams occurred during high flows because large amounts of suspended iron were transported with suspended sediment. The increase in iron load correlates significantly with increasing suspended-sediment concentrations (section 5.9). Because of this relation and because most of the suspended sediment in a particular stream is transported during storms, neither suspended-sediment nor iron yields can be defined with data obtained by random sampling. These yields from a basin can be determined only by more comprehensive sampling.



EXPLANATION

▲54 Site and number

Coal resources area

Figure 5.6-1 Sites for which total recoverable iron data are available.

Table 5.6-1 Range of total recoverable iron concentrations, in micrograms per liter.

Sites in the Cumberland Plateau

Site number	Minimum	Maximum	Number of determinations
96	150	2,300	5
97	0	10,000	13
99	150	2,000	13
103	190	1,000	12
114	190	5,200	8
119	130	950	3
122	130	520	3
127	80	510	5
131	410	9,600	5
134	260	2,500	5
137	<50	3,700	56
147	80	3,400	5
149	110	550	5
151	110	920	5
157	100	3,800	5
159	300	6,400	4

Sites in the Ridge and Valley

Site number	Minimum	Maximum	Number of determinations
3	60	200	14
4	120	360	11
15	10	840	57
16	10	<50	7
17	10	<50	8
19	430	44,000	5
21	10	1,600	37
32	150	910	11
35	0	8,600	105
37	130	1,600	13
54	80	1,000	46
71	430	7,100	5
76	0	12,000	14
145	10	170	11
158	120	7,400	5

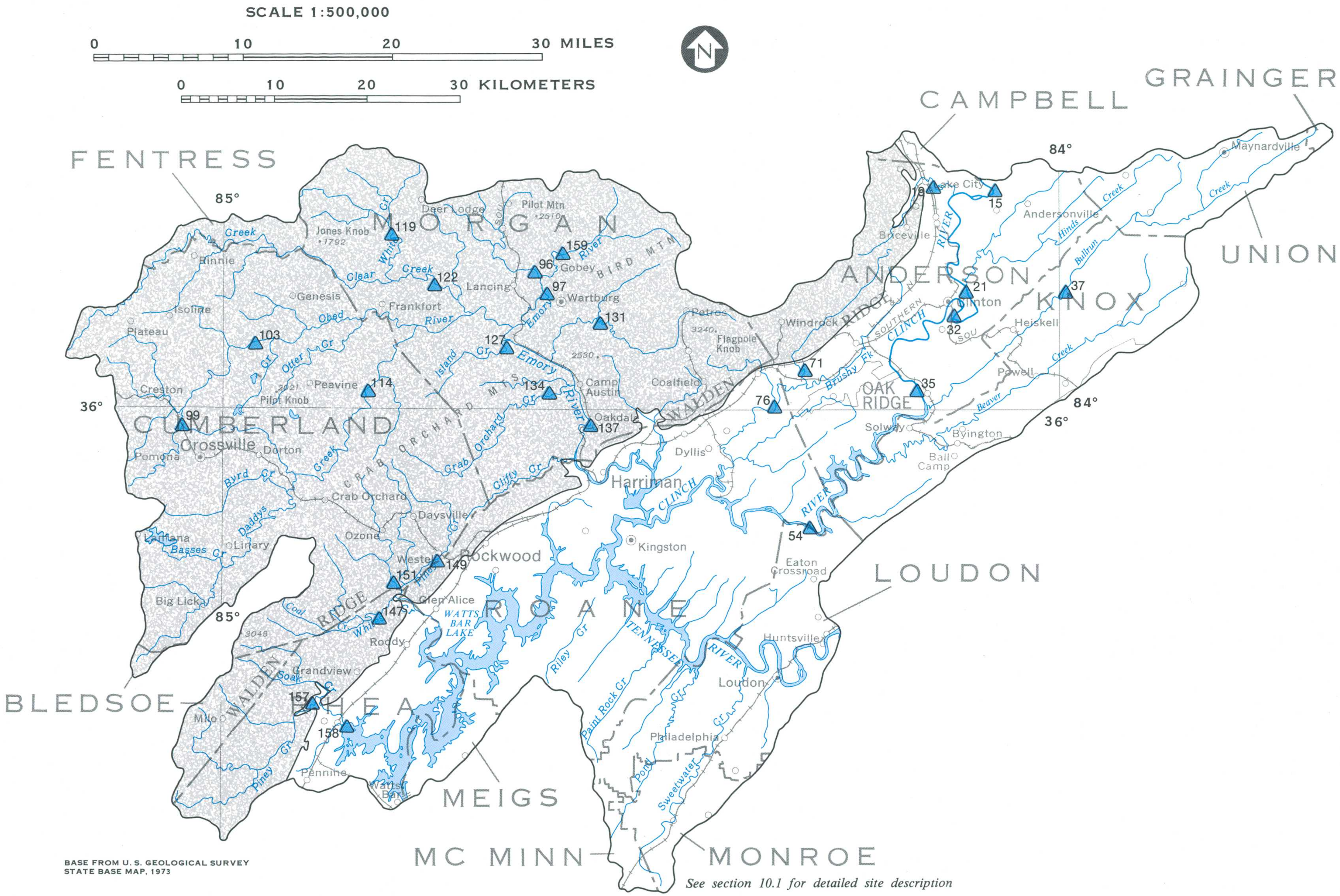
Manganese Concentrations Vary with Streamflow and Location in Area 19

The concentrations of total recoverable manganese in water in most streams were less than the mandatory limits specified for effluents from mining areas, but varied with streamflow and location.

Excessive concentrations of manganese can limit severely the use of water for public supply, domestic, and recreational purposes. As a result, most water-supply criteria contain recommended maximum limits for dissolved manganese; the recommended maximum limit for drinking water is 50 μg/L (U.S. Environmental Protection Agency, 1976). As specified in the Act, the maximum allowable concentration of total manganese in effluents from mined areas is 4,000 μg/L. Concentrations of total recoverable manganese (dissolved plus suspended) in water from 26 sites in Area 19 have been determined, most beginning in 1979 (fig. 5.7-1).

Generally, higher concentrations of total recoverable manganese were determined during high flows because large amounts of suspended manganese were transported with suspended sediment (section 5.9). The total recoverable manganese concentrations in water in streams in the area ranged from 0 to 3,300 μg/L, the maximum occurring in Crab Orchard Creek (site 134). No concentrations at sites either in the Cumberland Plateau or in the Ridge and Valley exceeded the limit established for mine effluents; most maximums determined were less than 500 μg/L (table 5.7-1).

Most dissolved manganese concentrations in Area 19 streams were less than 100 μg/L. Maximum concentrations were somewhat higher at sites in the Cumberland Plateau than at sites in the Ridge and Valley. Determined maximum concentrations at 9 of 15 sites in the Plateau exceeded 50 μg/L, whereas that concentration was exceeded at only 5 of 16 sites in the Ridge and Valley. Metal solubilities, including manganese, generally are affected significantly by pH. However, no statistically significant relation between pH and dissolved manganese has yet been determined areawide.



See section 10.1 for detailed site description

EXPLANATION

△35 Site and number

Coal resources area

Figure 5.7-1 Sites for which total recoverable manganese data are available.

Table 5.7-1 Range of total recoverable manganese concentrations, in micrograms per liter.

Sites in the Cumberland Plateau

Site number	Minimum	Maximum	Number of determinations
96	10	500	5
97	20	330	10
99	20	220	13
103	10	180	12
114	10	450	8
119	10	40	3
122	20	60	3
127	10	160	5
131	280	920	5
134	260	3,300	5
137	20	920	55
147	10	240	5
149	10	230	5
151	10	80	5
157	10	380	5
159	50	180	4

Sites in the Ridge and Valley

Site number	Minimum	Maximum	Number of determinations
15	<10	500	32
19	90	970	4
21	<10	370	20
32	10	1,000	11
35	<10	450	61
37	20	130	9
54	10	130	46
71	120	390	4
76	0	900	14
158	10	690	5

Low Concentrations of Trace Constituents Found in Water and Bottom Materials

Most concentrations of trace constituents found in water in streams or in bottom material in stream channels at 23 sites in Area 19 were low. No areawide potentially serious problems were detected.

Trace constituents are predominantly metals of low solubility, but also include inorganic and organic compounds. Trace constituents normally occur in low concentrations in water in most streams. Although high concentrations of some constituents can be toxic, low concentrations generally are essential for a balanced environment. Most high concentrations are a result of urban, industrial, and domestic effluents, not natural occurrence.

Selected trace constituents in water have been determined at 8 sites in Area 19 (table 5.8-1). In addition, concentrations of several constituents in bottom material from stream channels were determined at 16 sites in September 1979 (fig. 5.8-1 and table 5.8-2). No widespread occurrence of any of the constituents in potentially troublesome quantities was evident either in water or in bottom material.

Several important facts should be considered in any interpretation of concentrations of trace constituents in water or in bottom material in the area. These include the following:

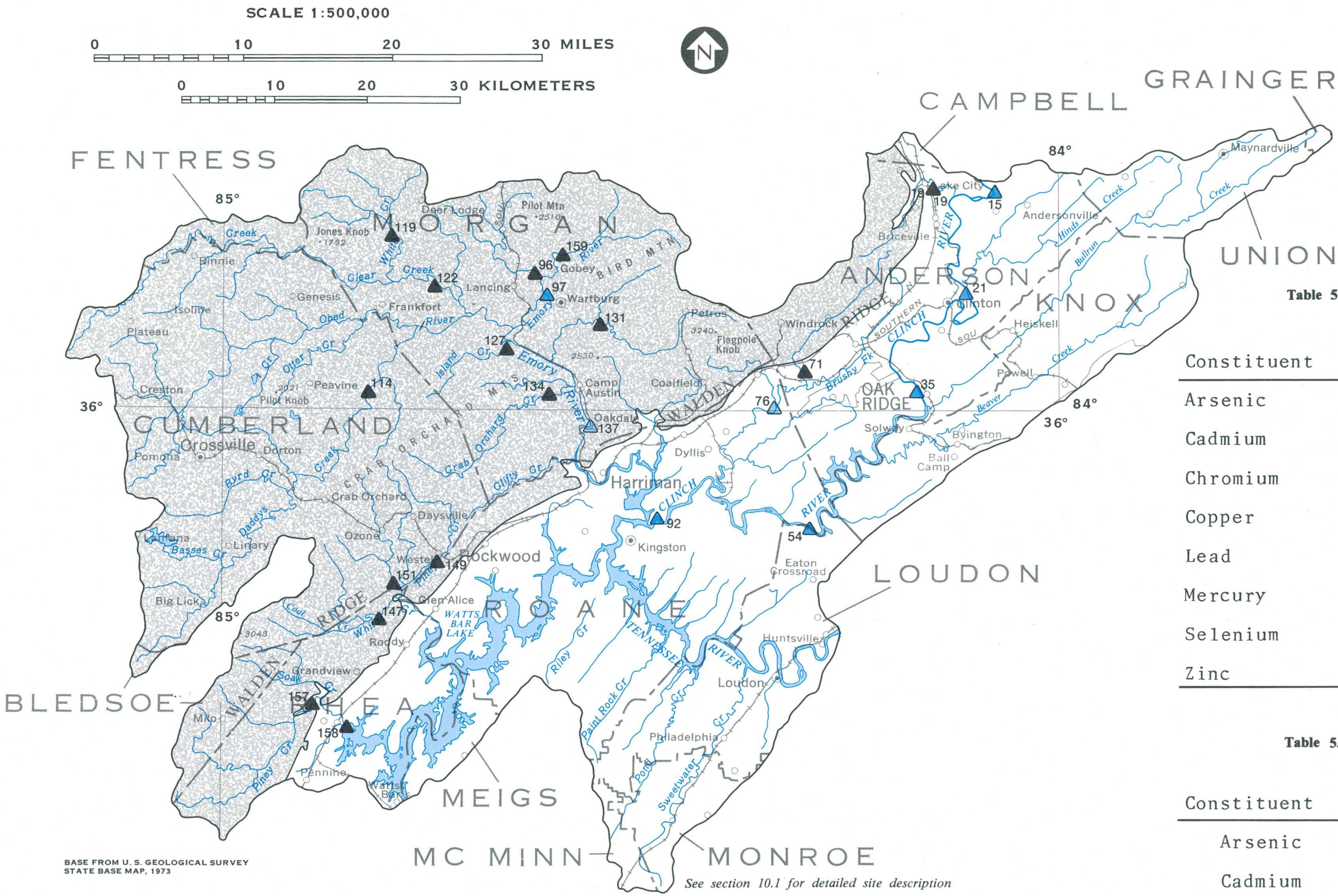
- Mandatory or recommended criteria for concentrations of several dissolved or total recoverable (dissolved plus suspended) trace constituents in water such as arsenic, lead, mercury, selenium, zinc, and others have been established. The State of Tennessee has adopted most of the drinking-water regulations issued by the U.S. Environmental Protection Agency, although State criteria are more stringent for physical properties such as turbidity.

- Limits for concentrations of trace constituents in bottom material have not been established.

- Concentrations of constituents exceeding recommended or mandatory limits in raw water in streams do not necessarily violate those standards because drinking-water regulations apply only to water delivered to a consumer.

- Although the maximum total recoverable chromium (site 35), mercury (site 54), and selenium (site 35) concentrations exceeded recommended criteria, each occurred only once, all prior to 1979. No recently collected total recoverable trace-constituent concentrations exceeded public-supply criteria.

- Large concentrations of constituents in bottom material are potentially troublesome because the constituents can be transported downstream or can be dissolved or suspensed by natural geochemical or biological processes. The presence of any constituent in bottom material at a particular site does not identify a source in the immediate area.



EXPLANATION

92 Site with dissolved trace-constituent data

19 Site with bottom material trace-constituent data

76 Site with both dissolved and bottom material data

Coal resources area

Figure 5.8-1 Sites for which trace-constituent data are available.

Table 5.8-1 Range of total recoverable trace-constituent concentrations in water, in micrograms per liter.

Constituent	Maximum	Median	Minimum	Number of determinations
Arsenic	9	5	0	81
Cadmium	3	1	0	122
Chromium	51	5	5	81
Copper	5,400	20	1	122
Lead	33	10	0	122
Mercury	2.3	.2	.10	119
Selenium	35	1	0	81
Zinc	200	20	10	122

Table 5.8-2 Range of total recoverable trace-constituent concentrations in bottom material, in micrograms per gram.

Constituent	Maximum	Minimum	Number of determinations
Arsenic	0	0	16
Cadmium	10	10	16
Chromium	30	10	16
Copper	20	10	16
Lead	80	10	16
Mercury	.0	.0	16
Selenium	0	0	16
Zinc	110	10	16

Suspended-Sediment Concentration Data are Significant in Determining Effects of Coal-Mine Drainage

Suspended-sediment loads and total recoverable iron concentrations are functionally related and can be estimated at several sites in Area 19.

The production and transport of suspended sediment depends on the interaction of sensitive and complex relations between basin characteristics such as land use and external factors such as climate. Any land-use activity that strips the surface of its natural vegetative cover may greatly increase erosion and sediment yields. Suspended sediment in sufficient quantities can have far-reaching effects on the aquatic environment as well as the whole morphologic pattern of the drainage network. The amount of sediment supplied to a stream reflects upstream activities. The ability of this sediment to transport adsorbed constituents is determined predominantly by its physical characteristics, such as particle-size distribution and percentage of organics.

Due to the dynamic nature of the sediment-water system, individual sediment-discharge measurements must be carefully considered prior to estimating sediment yields. Factors influencing suspended-sediment concentrations include type of bed and bank material, source area, precipitation characteristics (such as duration and intensity), and antecedent conditions. Seasonality and position on the hydrograph are also important in constructing the water discharge versus sediment discharge relationship, commonly known as a sediment rating curve.

Suspended-sediment data were collected at 18 sites in Area 19 (fig. 5.9-1). As a result, sufficient data to produce statistically significant correlations between stream discharge and suspended-sediment discharge were developed at three sites: Daddys Creek (site 114), Poplar Creek (site 76), and Emory River (site 137). These sites are representative of stream basins in which there is strip mining. At sites 76 and 137, severe sediment problems due to mining are evident (Tennessee Department of Public Health, Division of Water Quality Control, 1978).

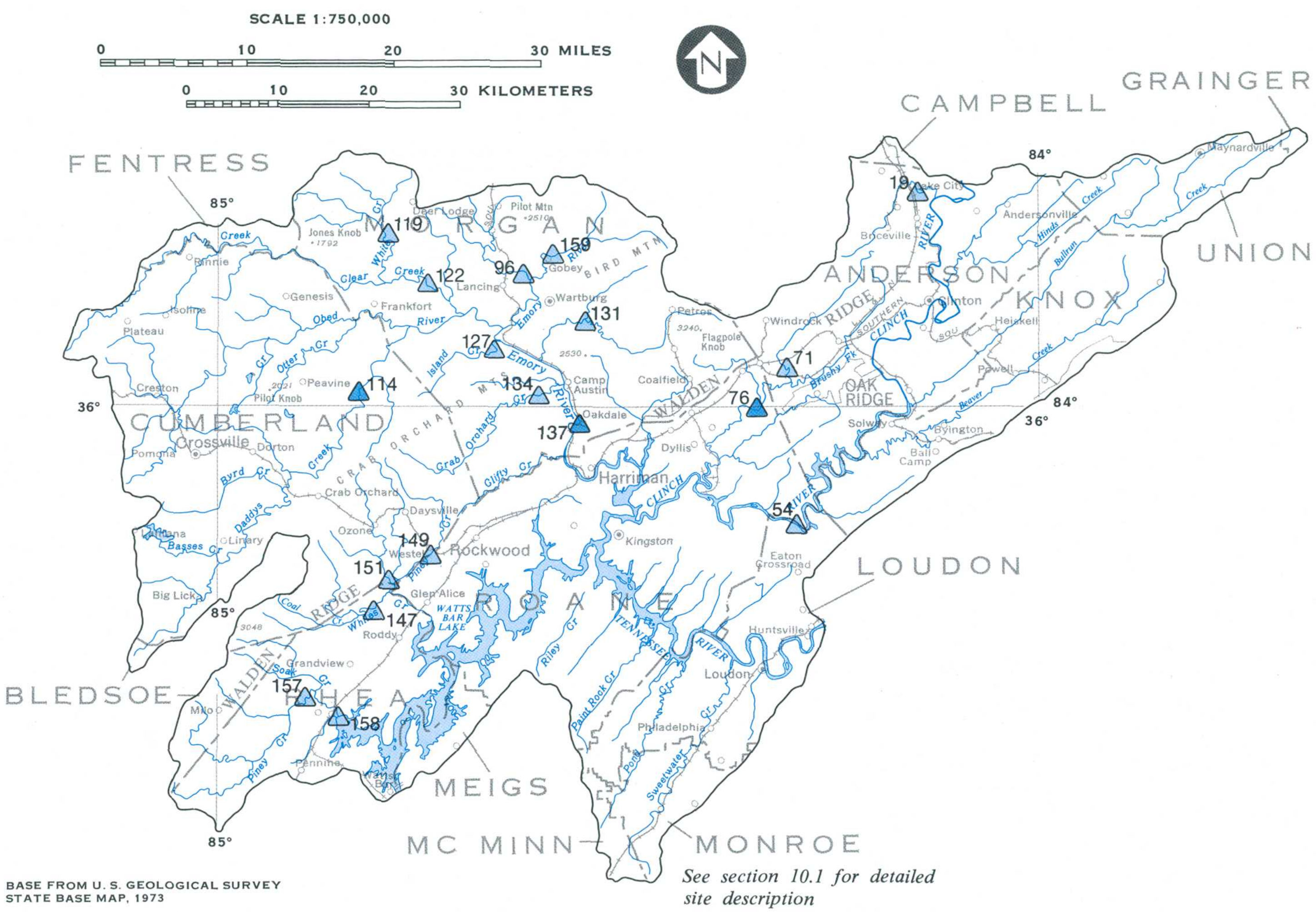
An analysis of the data for the three sites shows that while suspended-sediment concentrations increase with discharge, peak suspended-sediment discharge generally occurs prior to peak water discharge. This phenomenon is possibly a function of limited sediment availability. As a result, suspended-sediment concentrations are greater on the rising limb of the hydrograph than for a corresponding discharge on the falling limb such as at site 76 (fig. 5.9-2). Suspended-sediment concentrations at this site show greater than a 600 percent difference for the same water discharge (1,200 ft^3/s) and emphasize the caution that must be used in determining sediment yields, particularly from random data.

The relation between water and suspended-sediment discharge at sites 76, 114, and 137 is shown in figure 5.9-3. In order to minimize the effects of basin area on differences in sediment and water discharge values and to facilitate basin comparisons, the data have been expressed in terms of tons per day per square mile and cubic feet per second per square mile. It can be argued that these regression lines are displaced relative to one another according to their respective drainage areas, with the larger basins producing less sediment yield per square mile because of greater storage and dilution. Without additional data, the argument cannot be denied. Regression equations for the 13 remaining sites are not statistically significant due to the small number of samples.

Particle-size data were collected at least once per site and indicate a predominance of silt- and clay-sized material during high flows. The average percentages of silt-clay at sites 114, 76, and 137 at high flows were 65, 76, and 79 percent, respectively.

Instantaneous values for suspended sediment in Area 19 ranged from a minimum of zero (tons/d)/mi^2 during the low flows of the summer months to a maximum of 108 (tons/day)/mi^2 during the heavy spring rains of March 1980. Maximum and minimum instantaneous values for sediment discharge for all 18 sites are listed in table 5.9-1 along with their corresponding discharge data.

The detrimental effects of increased sediment yield and adsorbed constituents are not restricted to stream segments adjacent to disturbed slopes but extend downstream. The fine, constituent-transporting fraction of the sediment load may travel relatively large distances from its source area. Thus, materials may be delivered to areas where no mining occurs and, consequently, have an adverse effect on water quality.



EXPLANATION

137 Site with sufficient data to establish relation between water discharge and suspended-sediment discharge

122 Site with limited suspended-sediment data

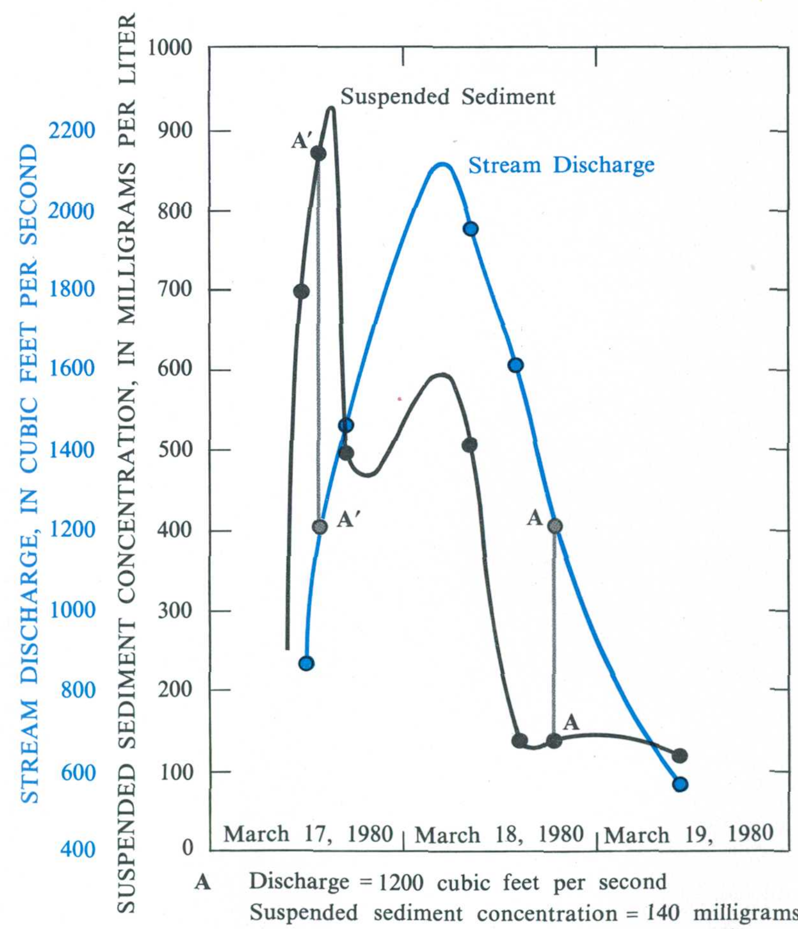
Figure 5.9-1 Sites for which suspended-sediment data are available.

Table 5.9-1 Maximum and minimum instantaneous suspended-sediment yield.

Site No.	Maximum sediment yield (tons/d)/mi²	Corresponding discharge (ft³/s)/mi²	Minimum sediment yield (tons/d)/mi²	Corresponding discharge (ft³/s)/mi²
19	25.6	4.37	0.0004	0.090
54	.233	5.38	.0002	.015
71	32.1	27.9	.0010	.018
76	34.5	14.7	.0025	.073
96	6.25	22.7	.0009	.005
114	106	55.6	.0002	.014
119	.078	14.3	.0005	.223
122	.346	7.52	.0001	.007
127	2.59	37.1	.0000	.082
131	38.6	25.0	.0010	.034
134	13.4	26.4	.0001	.006
137	5.93	11.3	.0002	.013
147	19.3	38.2	.0000	.004
149	3.58	41.5	.0010	.212
151	4.03	25.8	.0005	.026
157	37.1	40.9	.0003	.072-.008
158	108	56.5	.0001	.007
159	11.9	19.7	.0000	.004

Stream	Drainage area in square miles	Equation*	Correlation coefficient	Number of samples
Emory River	764	$Y = 2.73 \times 10^{-2} \cdot X^{1.40}$	0.94	13
Poplar Creek	82.5	$Y = 6.86 \times 10^{-2} \cdot X^{1.74}$	0.93	17
Daddys Creek	139	$Y = 5.19 \times 10^{-2} \cdot X^{1.62}$	0.98	11

*where *Y = suspended-sediment load* *X = stream discharge*



A Discharge = 1200 cubic feet per second
Suspended sediment concentration = 140 milligrams per liter

A′ Discharge = 1210 cubic feet per second
Suspended sediment concentration = 872 milligrams per liter

Figure 5.9-2 Relation between suspended-sediment concentration and stream discharge for the event of March 17-19, 1980 at Poplar Creek near Oak Ridge (site 76).

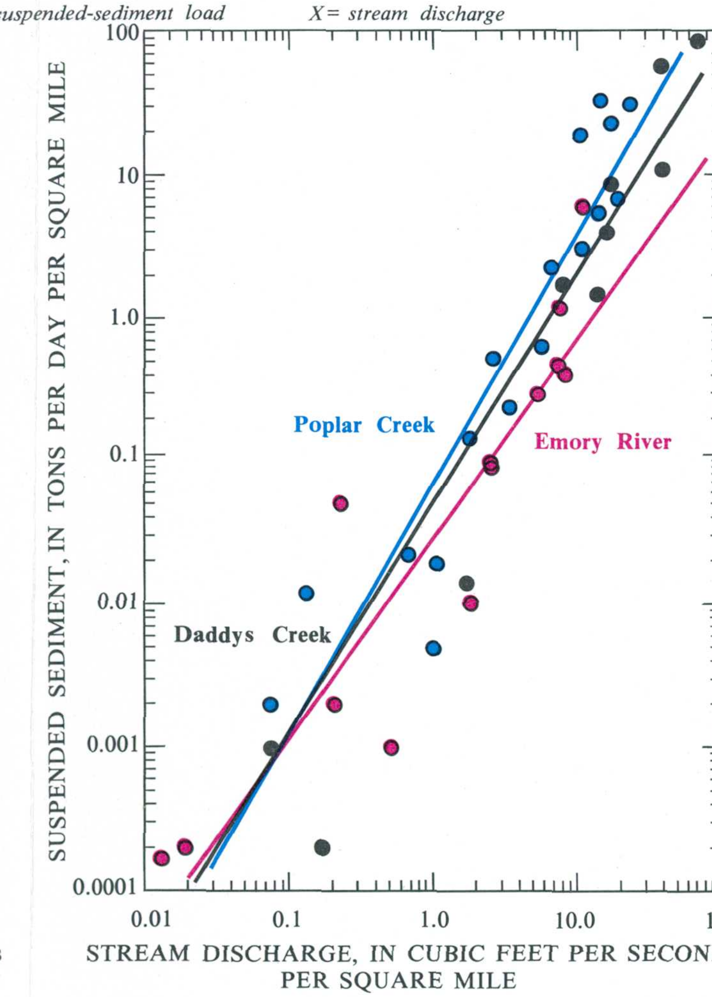


Figure 5.9-3 Relation between stream discharge and suspended sediment.

Benthic Invertebrate Populations Indicate a Wide Range of Water Quality

An index computed for four sites in Area 19 showed that the quality of water varied from excellent to poor.

Benthic invertebrates are useful indicators of water quality. Like all organisms, invertebrates have ranges of tolerance to environmental changes. When water quality is altered by increases in sediment and other pollutants, the population structure of benthic organisms responds with changes in species number and diversity. As sensitive species are eliminated, competition for food and shelter is reduced allowing those organisms more tolerant of pollution to flourish. Clean water is usually associated with a high community diversity while varying degrees of pollution produce lower diversities associated with lower or higher numbers in the total population.

Benthic invertebrates were collected at four sites in Area 19 during May and June of 1980 (fig. 5.10-1). Sampling methods included artificial substrates, square-foot bottom samplers, and kick sampling with dip nets. Individual organisms were identified to the lowest practical taxonomic level, usually to genus level.

A biotic index (Gore, Tennessee Technological University, written comm., 1980, modified from Hilsenhoff, 1977) computed for each site indicated a wide range of water quality within the area.

$$\text{Biotic Index} = \frac{\Sigma n_i a_i}{N}$$

where:

n_i is the number of individuals of a given taxon;

N is the total number of organisms collected;

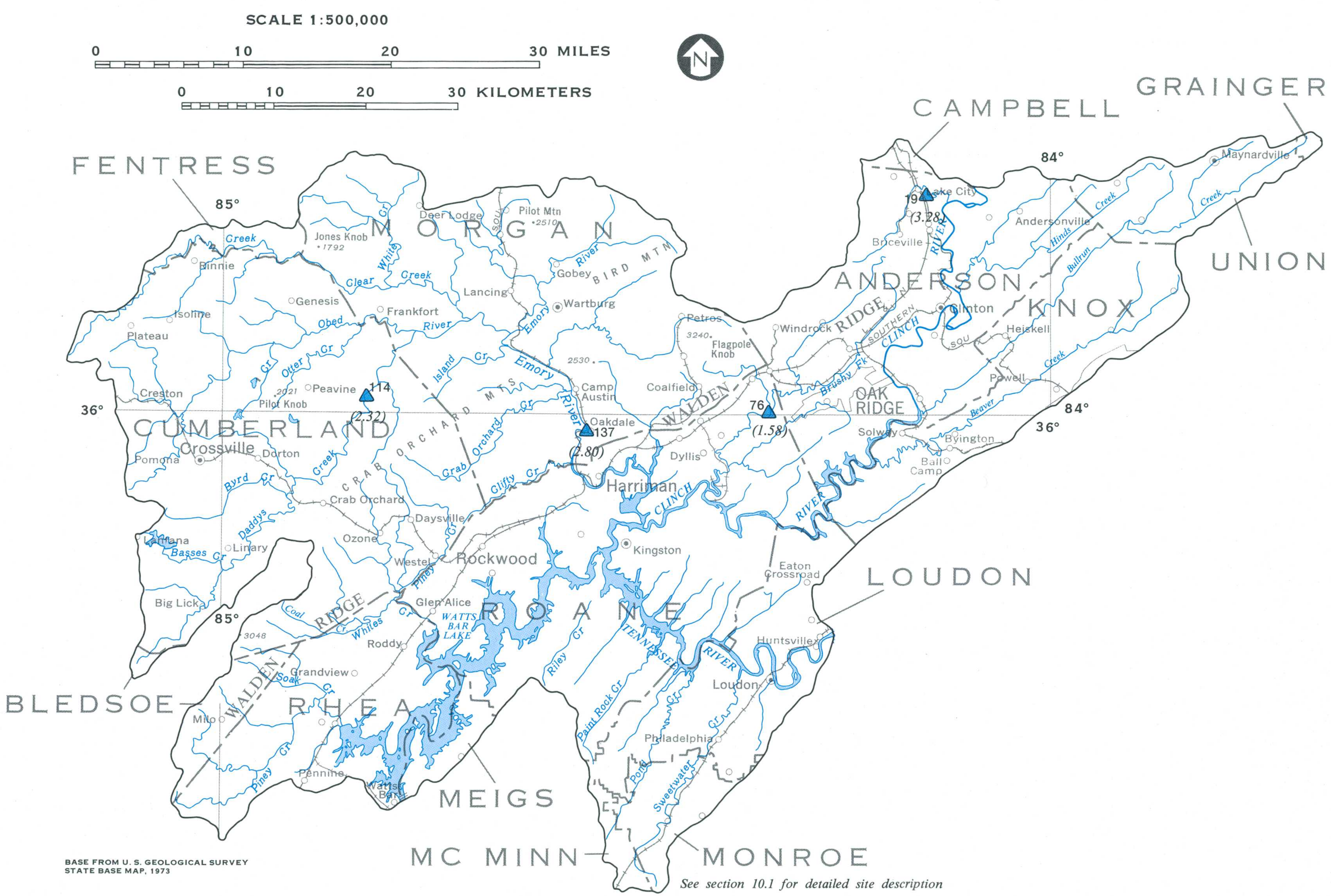
a_i is computed by assigning a value of zero to organisms known to be found only in the cleanest streams and a value of five to organisms found in extremely polluted waters. Intermediate values are assigned as appropriate.

In the Biotic Index, water quality is rated on a scale of zero to five with lower values indicating better water quality. The categories defined are:

Biotic index	Water-quality rating
<1.75	excellent
1.75-2.25	good
2.25-3.00	fair
3.00-3.75	poor
>3.75	very poor

This index is presently based on data from streams known to be polluted by organic materials. Additional information concerning benthic invertebrate populations in streams draining coal-bearing rocks must be collected before the impact of mining practices can be defined.

Water quality for the sites in Area 19 as rated by the Biotic Index ranged from excellent (1.58) at Poplar Creek near Oak Ridge, Tenn., to poor (3.28) at Coal Creek at Lake City, Tenn. Water quality at the other sites in the area was rated fair.



EXPLANATION

76 (1.58) — Site and number / Biotic index

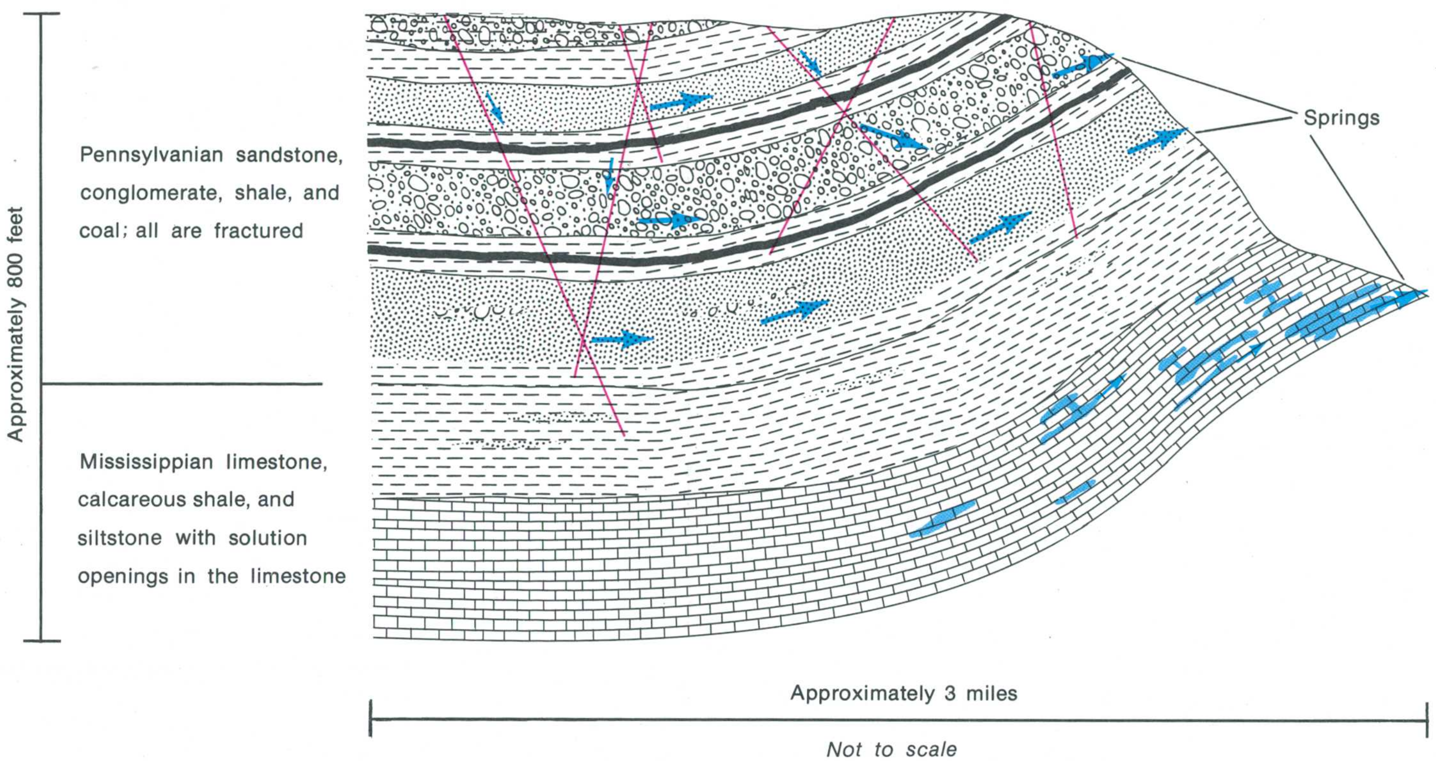
Figure 5.10-1 Sites for which benthic invertebrate data are available.

Ground-Water Occurrence Varies with Geologic Conditions

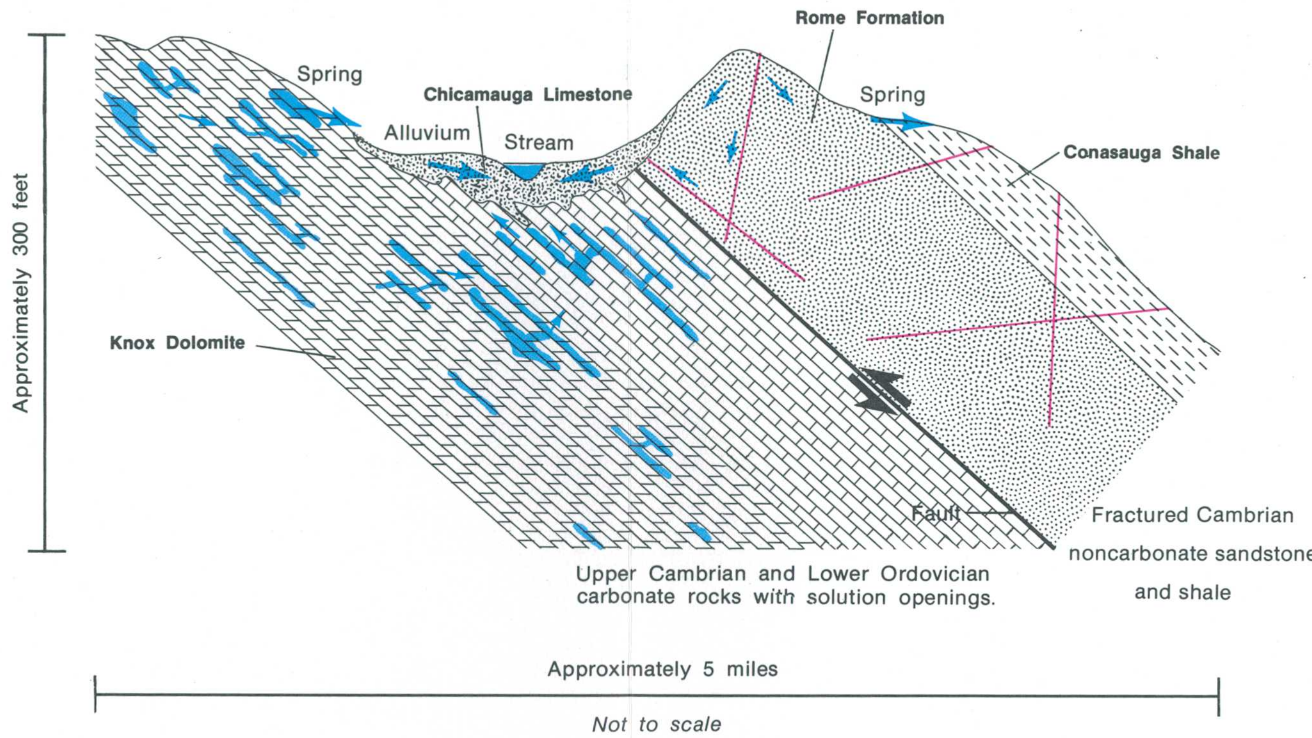
In the Cumberland Plateau, ground water occurs in fractured sandstones and shales. Ground water in the Ridge and Valley occurs primarily in soluble carbonate rock and, to a lesser extent, in fractured noncarbonate rocks and in thick alluvium in some of the major stream valleys.

The Cumberland Plateau is underlain by a sequence of generally horizontal Pennsylvanian sandstone, conglomerate, shale, and coal (fig. 6.1-1). The sandstone and conglomerate forms the major aquifer; the shale and coal beds act as confining layers. Most of the sandstone and conglomerate have low intergranular porosity, but fractures provide a secondary porosity and permeability which store and transmit most of the ground water. Nearly all of the wells penetrate water-bearing zones at depths less than 400 feet. Most of these zones are under artesian conditions. Due to the irregularity of the fracturing, aquifer yields and properties are highly variable. The regolith (rock weathered in place) is generally thin and provides little ground-water storage. Springs flow from the lower sandstone in the Pennsylvanian and from the Mississippian carbonate rocks along the edge of the escarpment.

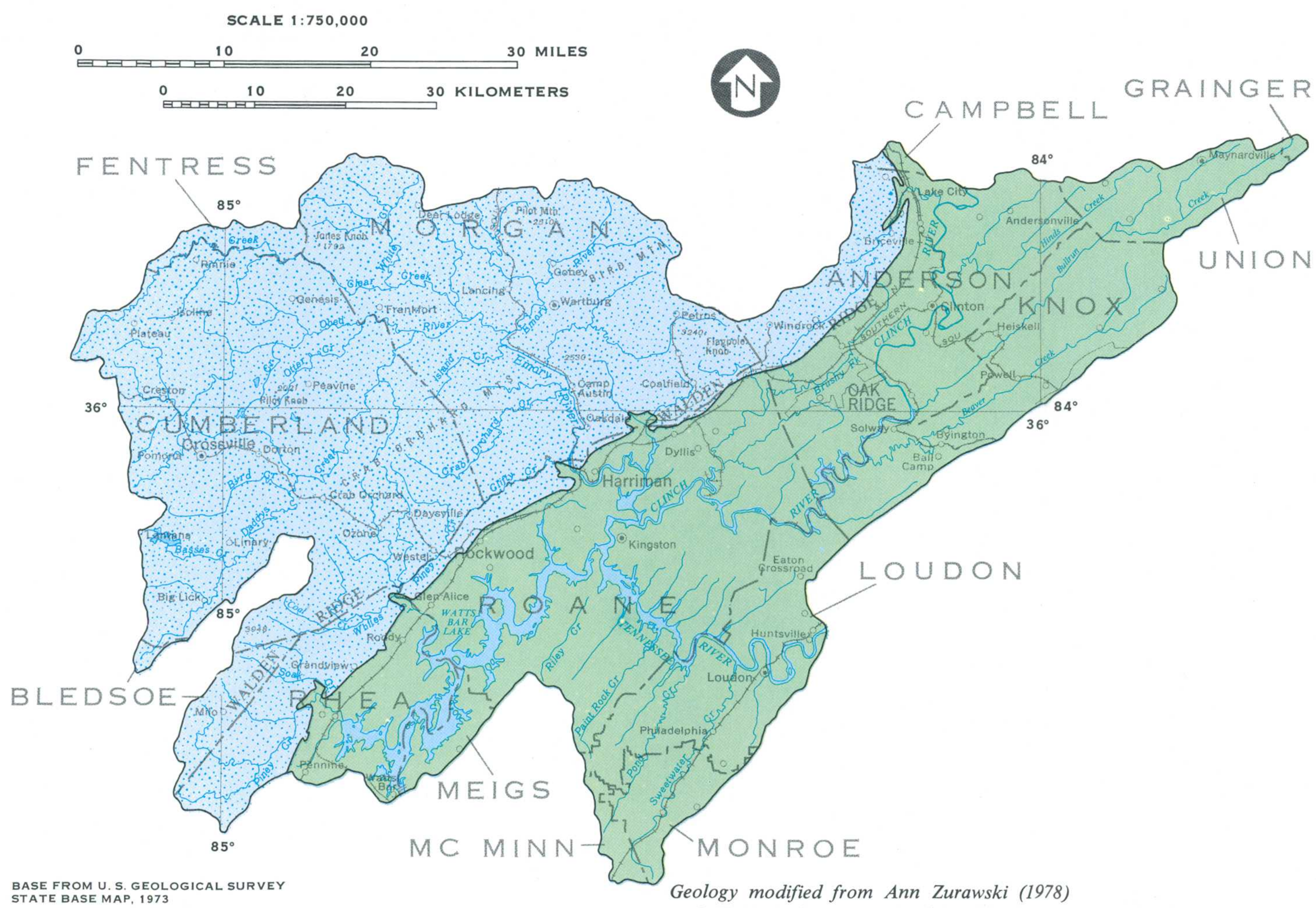
The Ridge and Valley is underlain by a series of resistant sandstone and cherty limestone and weaker limestone and shale, forming the parallel ridges and valleys of the province (fig. 6.1-1). Ground water occurs in the soluble limestone, dolomite, and calcareous shale where the dissolving action of ground water has enlarged the fractures, joints, and bedding planes. Karst terrain has developed in some areas underlain by soluble carbonate rocks. Ground water also occurs in noncarbonate sandstone and shale where the secondary openings have not been significantly enlarged by solvent action. These noncarbonate rocks are considered to be a poorer aquifer than the carbonate rocks. Ground water in the noncarbonate aquifers occurs primarily under artesian conditions. Depth to some water-bearing zones can be more than 400 feet in limestone and sandstone. In shale, the depth to water-bearing zones is generally less than 200 feet. Both the fractured noncarbonate rocks and the soluble carbonate rocks have highly variable aquifer properties because of the irregularity of the fracture and solution opening networks. Over most of the Ridge and Valley, the regolith stores water but is too fine-grained to transmit significant amounts of ground water. However, thick alluvium along the major streams and rivers has some potential as an aquifer. Springs flow from solution openings in limestone and dolomite as well as from fractured zones and bedding plane contacts.

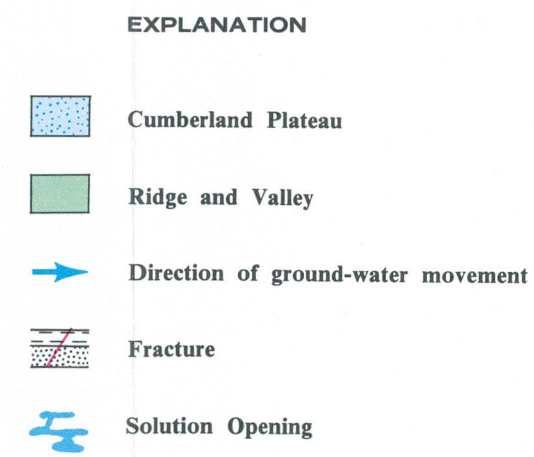


CUMBERLAND PLATEAU



RIDGE AND VALLEY





Geology modified from Ann Zurawski (1978) and H.A. Tiedemann and others (1965)

Figure 6.1-1 Ground-water occurrence in Area 19.

Aquifer Yields and Characteristics are Highly Variable

Yields to wells range from about 5 to more than 600 gallons per minute. Variations in yield and transmissivity are related to size of solution openings and fractures.

Fractured sandstones and conglomerates supply most of the ground water to wells in the Cumberland Plateau. Recorded yields for more than 500 wells reported to the Tennessee Division of Water Resources range from about 5 to about 150 gal/min. Transmissivities estimated from specific capacity data for 16 wells range from 20 to 2,000 ft^2/d (table 6.2-1). Sixty-eight percent of these estimated values range between 30 and 500 ft^2/d. This wide range is due to the wide variation in size and extent of the fractures in the Pennsylvanian rocks of the Cumberland Plateau.

Reported yields to wells in the Ridge and Valley range from about 5 to more than 600 gal/min, but most are between 10 and 25 gal/min. Based on specific capacity data from 38 wells, transmissivities are estimated to range from 7 to 8,000 ft^2/day (table 6.2-1). Sixty-eight percent are between 20 and 500 ft^2/day. The wide range is due to differences in size between solution openings in the carbonate rocks and the fractures in the noncarbonate rocks.

Table 6.2-1 Ranges of specific capacity and estimated transmissivity

	Cumberland Plateau		Ridge and Valley	
	Specific capacity (gallons/minute)/foot	Transmissivity ($feet^2$/day)	Specific capacity (gallons/minute)/foot	Transmissivity ($feet^2$/day)
Maximum	7.2	2,000	30.	8,000
84 percent	2.4	500	2.2	500
16 percent	0.2	30	0.1	20
Minimum	0.1	20	0.03	7

Ground-Water Levels Fluctuate Seasonally

Ground-water levels rise in winter and decline in summer indicating a seasonal change in ground-water storage as a result of relative differences in rates of recharge to and discharge from the subsurface reservoirs. Long-term water-level data are available for only one well in Area 19.

Water levels in wells tend to follow a seasonal cycle with highest levels occurring in the spring before the onset of the growing season and lowest levels occurring in the fall just prior to the first killing frost. During the non-growing season, water levels rise because the rate of recharge exceeds the rate of discharge causing an increase in ground-water storage. During the growing season, water levels decline when the rate of discharge exceeds the rate of recharge. These seasonal differences in the relative rates of recharge and discharge are due to the impact of evapotranspiration losses which are greatest in the warm summer months and least in the cold winter months.

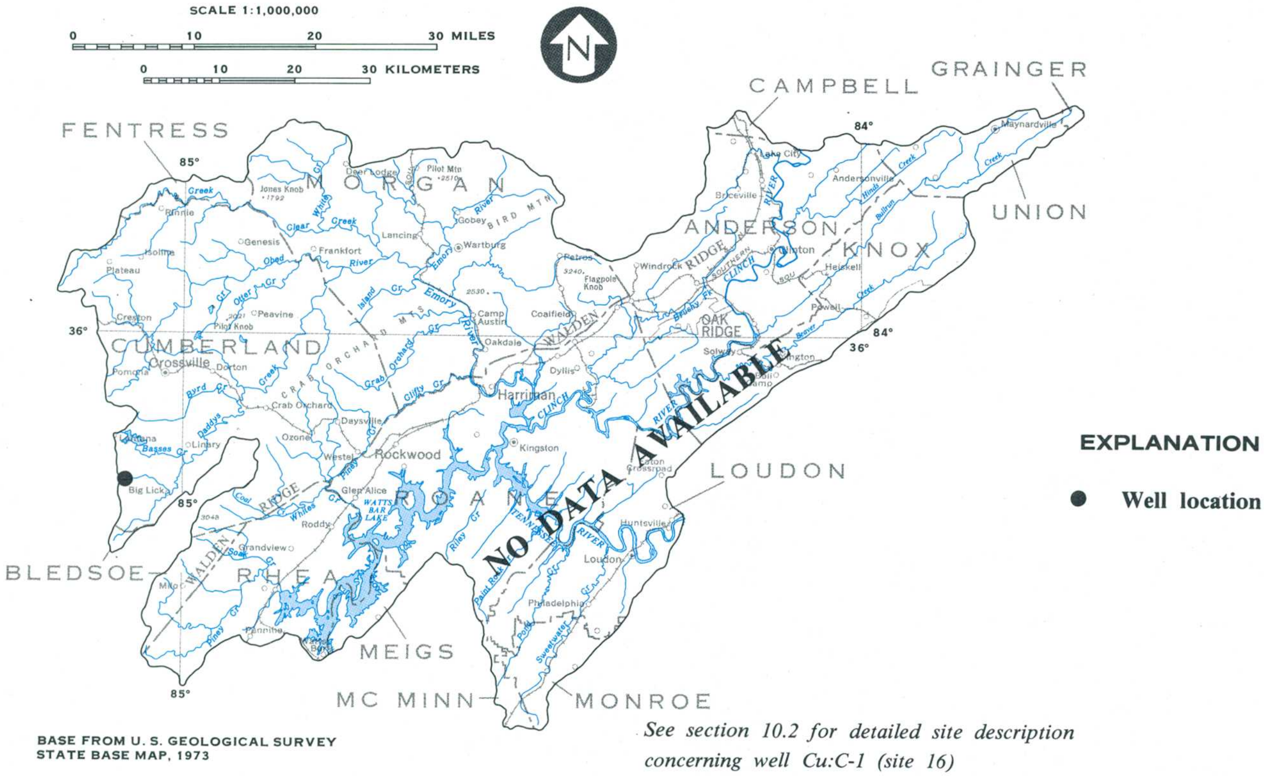
Fluctuations of water levels, assumed to be characteristic of wells in the Cumberland Plateau, are reflected in the hydrograph in figure 6.3-1. The monthly median and extremes of the lowest water levels measured near the end of each month for the period of record in well Cu:C-1 (site 16) are shown.

Such long-term water-level records can be used as an index to interpret hydrologic conditions in the general vicinity of the observation well. For example, current conditions can be inferred from a plot of current water-level measurements in this observation well and by comparison of the relative position of the plotted points with respect to the previously recorded median and extremes. If a measurement is above the median for the month in which it was made, it indicates that water levels are generally higher than normal in wells in the area represented by the index well. In contrast, if a measurement is below the median, the water levels are generally lower than normal. If any measurement exceeds the previously recorded extremes, water levels probably have reached new record highs or lows in the area represented by the index well. Whatever the inference, it can be applied to water-level measurements made in other wells in the general vicinity of the index well. In this way, the significance of infrequent measurements made at or near proposed mine sites can be determined in terms of prevailing hydrologic conditions.

The actual depths to water as measured in other wells in the Cumberland Plateau part of Area 19 may be more or less than those measured in well Cu:C-1 primarily due to differences in the topographic settings of the wells. For example, wells located on hilltops usually have the greatest depth to water, whereas wells located in a valley near a perennial stream have the least depth to water. In some valleys in the Cumberland Plateau part of Area 19, it is likely that the water level in deep wells will rise much above land surface.

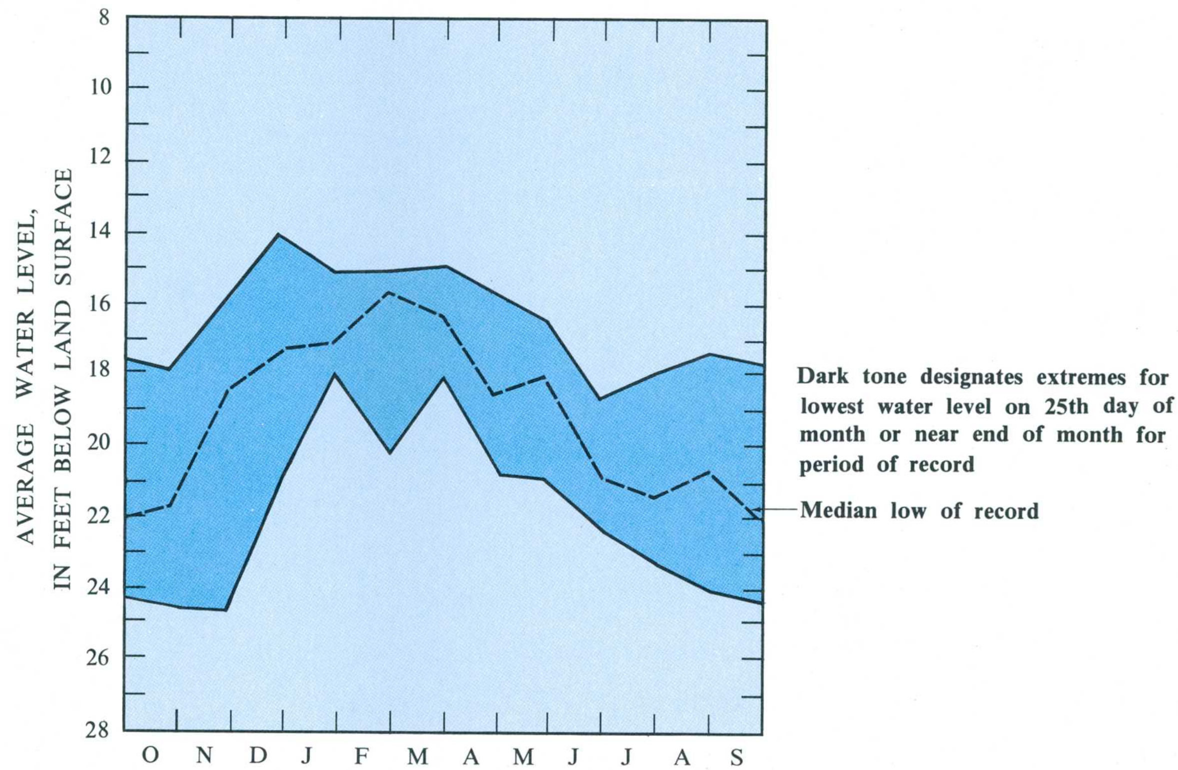
Water-level measurements for the index well shown in figure 6.3-1 are published annually by the U.S. Geological Survey, Nashville, in "Water Resources Data for Tennessee." This report can be obtained from:

U.S. Geological Survey
Water Resources Division
A-413 Federal Building - U.S. Courthouse
Nashville, TN 37203.



BASE FROM U. S. GEOLOGICAL SURVEY
STATE BASE MAP, 1973

See section 10.2 for detailed site description concerning well Cu:C-1 (site 16)



WELL NO.: Cu:C-1 WELL DEPTH: 69 feet CASING DEPTH: 69 feet TOPOGRAPHIC SETTING: On flat drainage divide, 1000 feet west of nearest point of natural divide AQUIFER: Pennsylvanian Sandstone PERIOD OF RECORD: Sept. 1964 to Dec. 1974

Figure 6.3-1 Hydrograph of index well showing seasonal fluctuations in water level.

7.0 QUALITY OF GROUND WATER

Quality of Ground Water Varies in Area 19

Ground-water quality has not been defined extensively in the area, but no widespread problems are evident. Ground water developed in the sandstone and conglomerate aquifers is suitable for most uses with minimum treatment. Low to moderate dissolved-solids concentrations generally occur in the ground water.

The water-quality program begun in the coal-producing region in 1979 does not include quality of ground-water data. Some data were collected prior to 1979, although not all parameters specified in the Act were determined at all sites (fig. 7.0-1). An analysis of data from other studies suggests the following:

- Although ground-water quality in Area 19 varies widely, the water is generally suited for most uses with minimum treatment, usually chlorination.

- Water from most wells in the Cumberland Plateau is a soft to moderately hard, mixed type (calcium bicarbonate, sodium bicarbonate, or calcium sulfate type). Dissolved-solids concentrations are relatively low (table 7.0-1). Locally, acidic water could be troublesome and some high concentrations of manganese are reported. In Cumberland County, excessive iron concentrations pose the major water-quality problem (Wilson, 1965).

- The quality of water from wells in the Ridge and Valley is generally good. Dissolved-solids concentrations are generally less than 250 mg/L; locally, hardness can be troublesome. No areawide water-quality problems are apparent. However, waste disposal, possibly causing contamination of drinking-water supplies, is a potentially serious problem throughout those areas of the Ridge and Valley that are underlain by carbonate rocks. These carbonate rocks, primarily limestone and dolomite, are subject to dissolution along fractures, joints and bedding planes. The resulting karst features are characterized by high permeability and rapid velocities which can facilitate the movement of pollutants through the system. Little is known about the water quality below a depth of about 500 feet in this system.

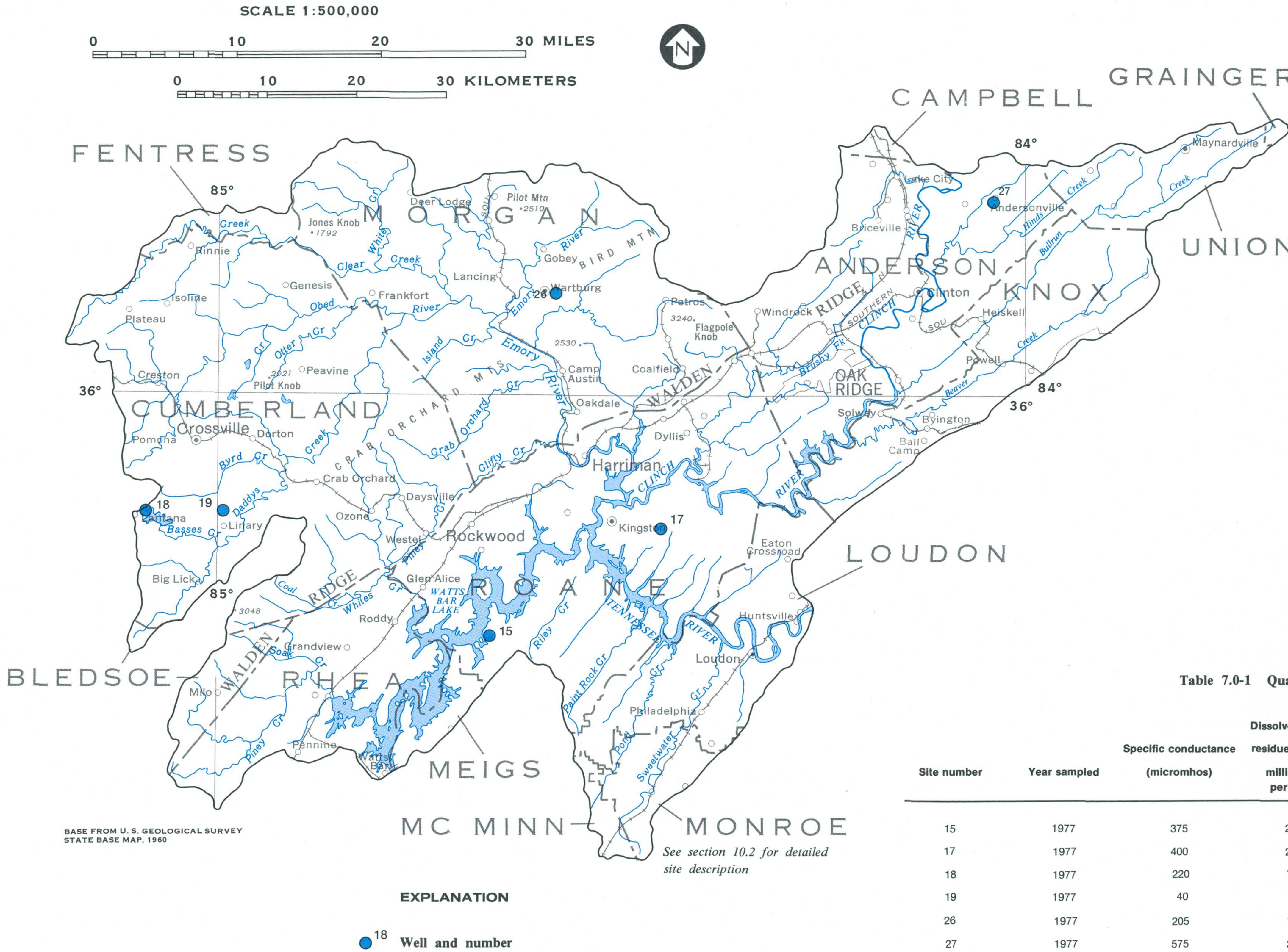


Figure 7.0-1 Wells for which water-quality data are available.

Table 7.0-1 Quality of water from wells in Area 19.

Site number	Year sampled	Specific conductance (micromhos)	Dissolved solids, residue at 180°C milligrams per liter	pH (units)	Dissolved iron (micrograms per liter)	Dissolved manganese (micrograms per liter)	Dissolved sulfate milligrams per liter
15	1977	375	208	7.5	10	0	5.0
17	1977	400	211	7.8	10	10	6.3
18	1977	220	131	7.7	60	60	2.9
19	1977	40	28	5.6	10	30	1.9
26	1977	205	114	6.4	14,000	50	28
27	1977	575	334	7.2	2,400	860	0.4

8.0 SUMMARY

General Hydrology of Area 19 Summarized

Data collected since 1979 in Area 19, combined with previously collected data, should provide a background for site-specific studies required by the Surface Mining Control and Reclamation Act of 1977.

The Eastern Coal province extends from New York to Alabama, includes parts of 10 states, and is divided into 24 hydrologic reporting areas. The division was based primarily on surface hydrologic basins, but factors such as location, size, and mining activity within the area also were considered. The hydrologic network in the area was expanded in 1979. These data combined with previously collected information should provide a background for the more-detailed, site-specific studies required of mining-permit applicants by the Surface Mining Control and Reclamation Act of 1977.

Area 19, located in eastern Tennessee in the southern part of the Eastern Coal province, includes parts of 15 counties. The area is in two physiographic provinces, the Cumberland Plateau and the Ridge and Valley. Each province comprises about one-half of the 2,200 square mile area. Numerous coal mines, comprising about 1 percent of the land use, are in the Cumberland Plateau; but no mines are operated in the Ridge and Valley.

The Cumberland Plateau is underlain by gently dipping Pennsylvanian sandstone and shale, some conglomerate, and coal. The main coal seams in the Pennsylvanian rocks are the Big Mary, Rock Spring, and Coal Creek. Soils on the Plateau reflect this geology. Most soils are derived from sandstone, some shale, and siltstone. Soil depth ranges from 1 to 5 feet over most of the Plateau; the potential for erosion is slight to moderate. However, on the steep slopes, the erosion potential is great and can become severe if the vegetation cover is removed.

The climate of the area is moderate. The average annual temperature is about 58°F. Temperature extremes generally range from -5° to 100°F. The average annual temperature is slightly lower on the Cumberland Plateau because of higher elevations. Average annual precipitation is about 52 inches with annual extremes ranging from 35 to 70 inches.

Streamflow varies in a pattern similar to the seasonal variation in rainfall and varies from stream to stream because of differences in drainage basin size and other physical characteristics. The flow of streams on the Cumberland Plateau is not well sustained during periods of no rainfall. The minimum flows per square mile for the dry months are much lower for streams on the Plateau than for streams in the Ridge and Valley. However, the average annual streamflow throughout Area 19 is approximately 2 $(ft^3/s)/mi^2$. Most peak flows occur during the winter and spring months. About 67 percent of the annual peaks occur during the period December through March.

Water-quality data have been collected at 70 surface-water sites in Area 19; 22 of these are located in the Cumberland Plateau. Other sites, located in the Ridge and Valley, are on streams draining areas of the Plateau. Available water-quality data do not indicate widespread problems caused by surface-mining activities in the area, although water at several sites is seriously affected by high sediment concentrations, low pH values, and high concentrations of dissolved sulfate, total recoverable iron, and (or) total recoverable manganese. In addition, severe water-quality problems may exist and not be detected. Water at some sites located in the central part of the coal-mining areas has not been affectd by mine drainage. In the future, data collected at these sites will be particularly important in the assessment of the potential impact of mining activities on water quality.

In the Cumberland Plateau, ground water occurs in the fractured sandstone and shale. Ground water in the Ridge and Valley occurs primarily in soluble carbonate rock and, to a lesser extent, in the fractured noncarbonate rocks and in the thick alluvium in some of the major stream valleys. Well yields in the Cumberland Plateau range from about 5 to 150 gal/min, whereas yields in the Ridge and Valley range from about 5 to 600 gal/min.

9.0 WATER-DATA SOURCES

9.1 Introduction

NAWDEX, WATSTORE, and OWDC Water Information

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

Three activities within the U.S. Geological Survey help to identify and to improve access to the vast amount of existing water data. These activities are:

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

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

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

A more detailed explanation of these three activities is given in sections 9.2, 9.3, and 9.4.

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 National Center in Reston, Va., and a nationwide network of Assistance Centers located in 45 states and Puerto Rico. These centers provide convenient access to NAWDEX (fig. 9.2-1). A directory containing the names, addresses, telephone numbers, and office hours for each of the Assistance Centers can be obtained from the Program Office [Directory of Assistance Centers of the National Water Data Exchange (NAWDEX), U.S. Geological Survey Open-File Report 79-423 (revised)].

NAWDEX can assist organizations or individuals to identify and locate needed water data. The requester is referred to the organization that retains the needed data. To accomplish this service, NAWDEX maintains a computerized Master Water Data Index (MWDI) (fig. 9.2-2). The MWDI identifies sites for which water data are available, lists the type of data available for each site, and identifies the organization retaining the data. A Water Data Sources Directory (fig. 9.2-3) also is maintained that identifies the sources of water data and the locations 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 non-member organizations.

Charges for NAWDEX services are assessed at the option of the organization providing the requested data or service. Most search assistance services are provided free by NAWDEX. Charges are assessed, however, for those requests involving computer costs, extensive personnel time, duplicating services, or other costs encountered by NAWDEX in the course of providing services. In no case, will charges assessed by NAWDEX Assistance Centers exceed the direct costs incurred in responding to the data request. Estimates of cost are provided by NAWDEX upon request and in those cases where substantial costs are anticipated.

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
TENNESSEE
U.S. Geological Survey
Water Resources Division
A413 Federal Building - U.S. Courthouse
Nashville, TN 37203

Telephone: (615) 251-5424
FTS 852-5424

Hours: 7:45 - 4:30 Central Time

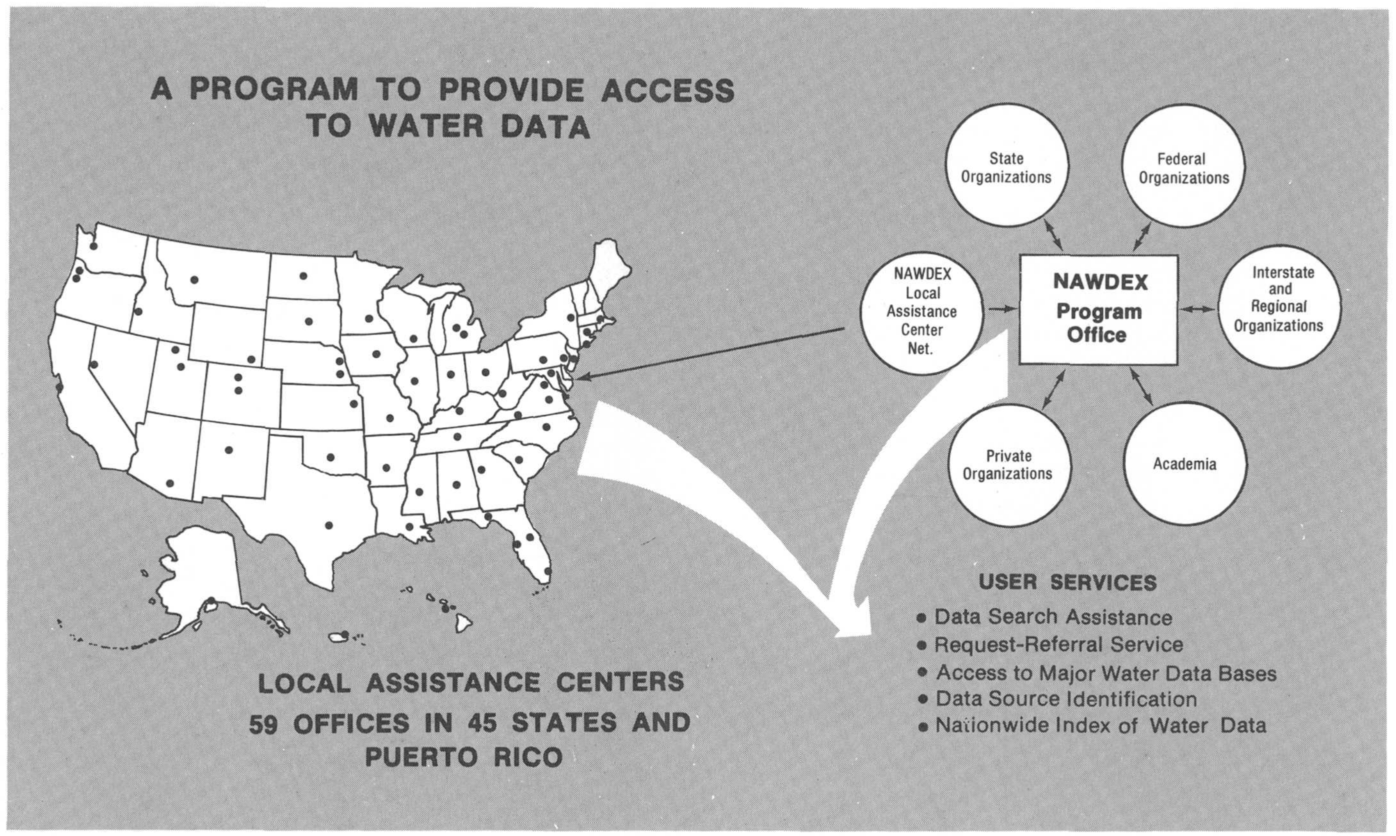


Figure 9.2-1 Access to water data.

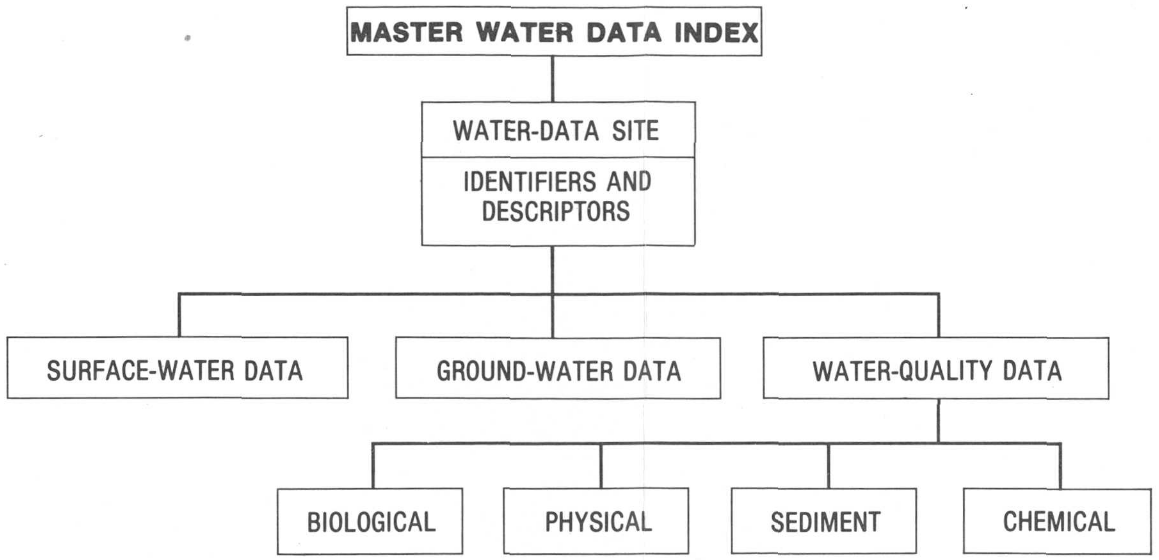


Figure 9.2-2 Master water-data index.

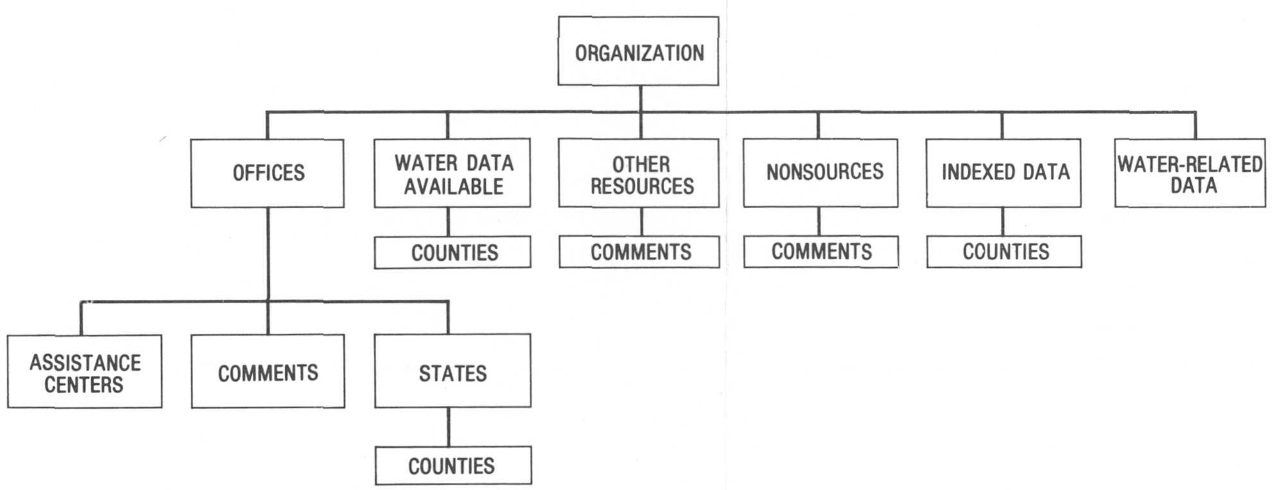


Figure 9.2-3 Water-data sources directory.

WATSTORE Automated Data System

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

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

or

U.S. Geological Survey
Water Resources Division
A413 Federal Building - U.S. Courthouse
Nashville, TN 37203

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

The WATSTORE system consists of several files in which data are grouped and stored by common characteristics and data-collection frequencies. The system is also designed to allow for the inclusion of additional data files as needed. Currently, files are maintained for the storage of: (1) surface-water, quality-of-water, and ground-water data measured on a daily or continuous basis; (2) annual peak values for streamflow stations; (3) chemical analyses for surface- and ground-water sites; (4) water parameters measured more frequently than daily; (5) geologic and inventory data for ground-water sites; and (6) aggregated water-use data. In addition, an index file of sites for which data are stored in the system is also maintained (fig. 9.3-1). 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, or 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, dissolved oxygen concentrations, pH, 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.

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. The file contains inventory data about wells, springs, and other sources of ground water. Site location and identification, geohydrologic characteristics, and well-construction history are some of the data included. The file is designed to accommodate 255 data elements and currently contains data for nearly 790,000 sites.

Water-Use File: This file is being developed to store and disseminate summary data about the withdrawal, return, and use of water throughout the Nation. The storage and retrieval system is needed to handle the vast amount of aggregated water-use data that will be submitted by the States.

Although all WATSTORE data files are maintained and managed at the National Center, data may be entered into or retrieved from WATSTORE at locations that are part of a nationwide telecommunication network.

Remote Job Entry Sites: Almost all of the district offices of the Water Resources Division are equipped with remote computer terminals for access to the WATSTORE system. These terminals permit rapid data entry and retrieval in response to data needs and requests.

Digital Transmission Sites: Digital recorders are used at many field locations to record values for parameters such as river stage, specific conductance, water temperature, turbidity, and dissolved oxygen. Data from these sites, recorded on 16-channel paper tape, are transmitted by telephone to the computer center at Reston, Va. In addition to this type of site, about 200 satellite-data collection platforms are being operated currently (1980) throughout the country. Battery operated radios are used as the communication link between the recorder and the satellite. Extensive testing indicates that the platforms are feasible for use in collecting real-time hydrologic data on a national scale.

Central Laboratory System: The Water Resources Division's two water-quality laboratories, located in Denver, Colorado, and Atlanta, Georgia, analyze more than 150,000 water samples per year. These highly-automated laboratories are equipped to analyze chemical constituents ranging from simple inorganics, such as chloride, to complex organic compounds, such as pesticides. The analysis results are verified by laboratory personnel and transmitted 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 water resources. In addition to data processing, storage, and retrieval capabilities, WATSTORE can provide a variety of useful products ranging from simple data tables to complex statistical analyses. A minimal fee, plus the actual computer cost incurred in producing a desired product, is charged to the requester.

Computer-Printed Tables: Users generally request data from WATSTORE in the form of computer-generated tables. These tables may contain either actual data or condensed indexes that indicate the availability of data. A variety of display formats is available.

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

Statistical Analyses: WATSTORE interfaces with a proprietary statistical package, Statistical Analysis System (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 in user-provided software systems. 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.

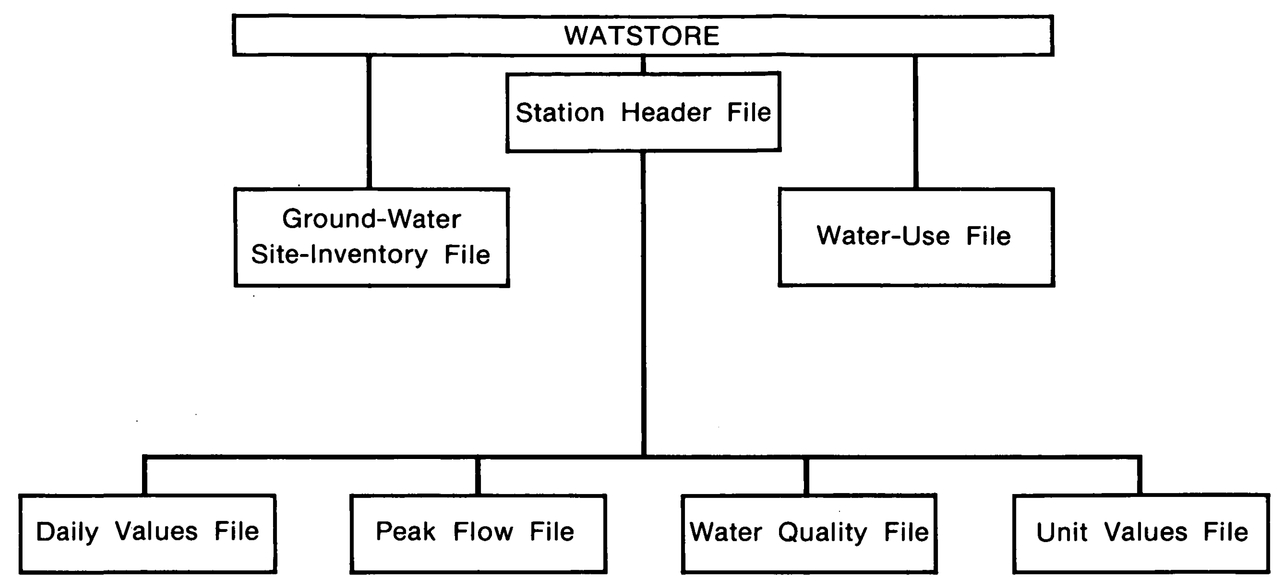


Figure 9.3-1 Index file stored data.

Water Data Indexed for Coal Provinces

A special index, "Index to Water-Data Activities in Coal Provinces of the United States," has been published by the U.S. Geological Survey's Office of Water Data Coordination (OWDC).

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

This special index consists of five volumes (fig. 9.4-1): volume I, Eastern Coal province; volume II, Interior Coal province; volume III, Northern Great Plains and Rocky Mountain Coal provinces; volume IV, Gulf Coast Coal province; and volume V, Pacific Coast and Alaska Coal provinces. The information presented will aid the user in obtaining data for evaluating the effects of coal mining on water resources and in developing plans for meeting additional water-data needs. The report does not contain the actual data; rather, it provides information that will enable the user to determine if needed data are available.

Each volume of this special index consists of four parts: Part A, Streamflow and Stage Stations; Part B, Quality of Surface-Water Stations; Part C, Quality of Ground-Water Stations; and Part D, Areal Investigations and Miscellaneous Activities. Information given for each activity in Parts A-C includes: (1) the identification and location of the station, (2) the major types of data collected, (3) the frequency of data collection, (4) the form in which the data are stored, and (5) the agency or organization reporting the activity. Part D summarizes areal hydrologic investigations and water-data activities not included in the other parts of the index. The agencies that submitted the information, agency codes, and the number of activities reported by type are shown in a table.

Those who need additional information from the Catalog file or who need assistance in obtaining water data should contact the National Water Data Exchange (NAWDEX, see section 9.2).

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

U.S. Geological Survey
Water Resources Division
A413 Federal Building - U.S. Courthouse
Nashville, TN 37203

Telephone: (615) 251-5424
FTS 852-5424

or

Office of Surface Mining
U.S. Department of the Interior
530 Gay St., Suite 500
Knoxville, TN 37902

Telephone: (615) 971-5100
FTS 852-0205

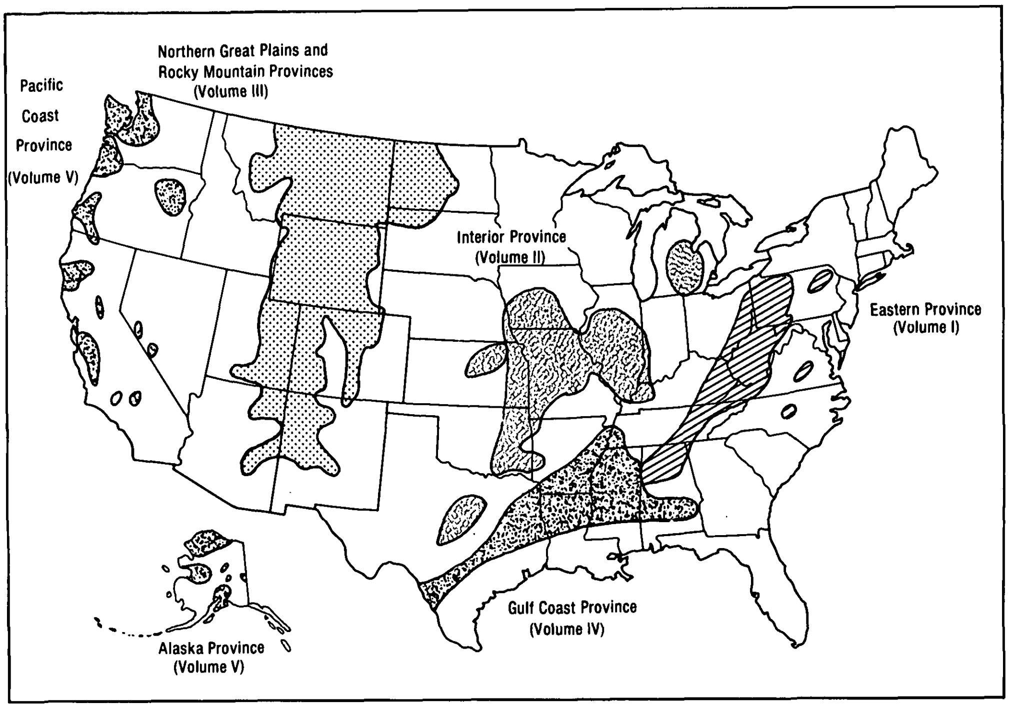


Figure 9.4-1 Index volumes and related provinces.

Surface-Water Network

Map number	Station number	Station name	Location: Latitude (° ' ")	Location: Longitude (° ' ")	Drainage area (mi^2)	Type of record and period collected: Discharge	Water quality	Sediment
1	03520000	Tennessee River at Loudon, Tn.	35 44 33	84 19 56	12,220	1922-55		
2	03520043	Sweetwater Creek at Sweetwater, Tn.	35 36 32	84 27 40	23.3	1932,1949-54 1956,1958,1964		
3	03520045	Sweetwater Creek below Sweetwater, Tn.	35 37 31	84 26 27	26.4	1970-	1970-72	
4	03520050	Sweetwater Creek near Sweetwater, Tn.	35 38 04	84 26 27	28.2	1964-70	1969-70	
5	03520065	Bacon Creek at Philadelphia, Tn.	35 40 36	84 24 23	6.36	1953,1961-65, 1968-71		
6	03520100	Sweetwater Creek near Loudon, Tn.	35 44 17	84 22 25	62.2	1954-		
7	03520150	Hines Creek Tributary near Eaton Forest, Tn.	35 50 15	84 19 08	2.58	1951,1953, 1956		
8	03520160	Cave Creek near Cave Creek, Tn.	35 47 11	84 24 17	4.58	1943,1952-55		
9	03520170	Pond Creek near Adolphus, Tn.	35 42 20	84 27 35	30.8	1954,1975-		
10	03520185	Greasy Run (Little Paint Rock Creek) near Dogwood, Tn.	35 48 11	84 26 55	4.45	1943,1952-53		
11	03520196	Paint Rock Creek at Paint Rock, Tn.	35 44 29	84 30 32	25.7	1951,1953, 1956,1958		
12	03520197	Paint Rock Creek near Paint Rock, Tn.	35 44 57	84 29 28	28.0	1943,1952-55		
13	03520220	Smith Creek near Kingston, Tn.	35 50 57	84 29 35	2.71	1943,1952-53, 1961		
14	03520225	Riley Creek near Bacon Gap, Tn.	35 48 03	84 33 49	9.58	1961-65, 1968-71		
15	03533000	Clinch River below Norris Dam, Tn.	36 12 56	84 04 56	2,913	1904-74	1969-70,1972-73,1975-	
16	03533098	Clear Creek near Andersonville, Tn.	36 12 58	84 03 00	2.51		1972-73	
17	03533102	Clear Creek at Norris, Tn.	36 12 48	84 03 38	3.08		1972-73	
18	03533500	Clinch River at Coal Creek, Tn.	36 12 22	84 06 29	2,921	1902,1925, 1927-37,1960		
19	03534000	Coal Creek at Lake City, Tn.	36 13 14	84 09 27	24.5	1932-34,1955-	1965,1979-	1979-
20	03534020	Cane Creek near Medford Station, Tn.	36 10 07	84 08 39	5.70	1961-63, 1969-72		
21	03534100	Clinch River near Clinton, Tn.	36 07 22	84 06 52	2,980		1972-74,1977	
22	03534200	Hinds Creek near Clinton, Tn.	36 08 45	84 04 34	39.3	1944,1953-54, 1964-70,1972	1968	
23	03534400	Buffalo Creek NE of Andersonville, Tn.	36 12 40	84 01 21	4.98	1950-1970		
24	03534500	Buffalo Creek at Norris, Tn.	36 11 05	84 03 34	9.92	1947-50,1954-		
25	03534501	Buffalo Creek 0.5 miles below Freeway, near Norris, Tn.	36 10 56	84 03 53	10.0	1947-49		
26	03534502	Buffalo Creek 0.86 miles below Freeway, near Norris, Tn.	36 10 50	84 03 48	10.1	1948		
27	03534503	Buffalo Creek 1.0 miles below Freeway, near Norris, Tn.	36 10 48	84 03 55	10.1	1947-48		
28	03534504	Buffalo Creek 1.3 miles below Freeway, near Bethel, Tn.	36 10 39	84 04 03	10.8	1947-48,1968		
29	03534507	Buffalo Creek 1.9 miles below Freeway, near Bethel, Tn.	36 10 21	84 04 06	10.8	1947-48		
30	03534510	Buffalo Creek near Norris, Tn.	36 09 38	84 04 49	13.8	1943,1952-55		
31	03534600	Clinch River at Clinton, Tn.	36 06 10	84 07 43	3,056	1883-1920,1936-37,1943,1947		
32	03534612	Clinch River at Clinton, Tn.	36 05 45	84 07 57	3,057	1965-	1974	
33	03534700	Clinch River Tributary at Clinch RM 51.1 at Oak Ridge, Tn.	36 02 21	84 12 34	2.53	1961-64	1961-64	

Map number	Station number	Station name	Location: Latitude (° ' ")	Location: Longitude (° ' ")	Drainage area (mi²)	Type of record and period collected: Discharge	Water quality	Sediment
34	03534800	Emory Valley Creek at Oak Ridge, Tn.	36 01 27	84 13 00	0.85	1961-64	1961-64	
35	03534900	Clinch River at Edgemoor, Tn.	36 01 32	84 10 03	3,089	1937-43	1969-78	
36	03534980	North Fork Bullrun Creek near Maynardville, Tn.	36 13 46	83 49 30	7.82	1966		
37	03535000	Bullrun Creek near Halls Crossroads, Tn.	36 06 52	83 59 16	68.5	1958-	1976	
38	03535050	Bullrun Creek near Powell, Tn.	36 01 56	84 05 50	93.3	1961-63	1961-63	
39	03535055	Bullrun Creek near Edgemoor, Tn.	36 00 17	84 08 32	103	1943,1952-53		
40	03535100	Scarboro Creek near Oak Ridge, Tn.	35 59 13	84 12 58	1.13	1961-64	1961-64	
41	03535160	Beaver Creek near Halls Crossroads, Tn.	36 04 59	83 54 26	14.1	1967-73		
42	03535180	Willow Fork near Halls Crossroads, Tn.	36 05 59	83 54 27	3.23	1925-		
43	03535183	Willow Fork near Halls Crossroads, Tn.	36 05 07	83 55 16	7.12	1961-63, 1969-73		
44	03535186	Beaver Creek below Hines Branch near Halls Crossroads, Tn.	36 04 16	83 56 49	32.1	1952-53		
45	03535187	Beaver Creek near Dante, Tn.	36 03 31	83 58 25	36.4	1972-73,1975		
46	03535200	Beaver Creek near Powell, Tn.	36 01 06	84 03 06	56.1	1953-55,1959-64,1967-68	1967-68	
47	03535375	Beaver Creek near Solway, Tn.	35 58 24	84 08 26	73.8	1968,1972		
48	03535400	Beaver Creek at Solway, Tn.	35 57 51	84 10 41	86.8	1961-64	1961-64	
49	03535405	Beaver Creek at Couch Ford, Tn.	35 57 04	84 12 23	90.3	1943,1948, 1952-54,1956		
50	03535600	Clinch River Tributary No. 3 near Oak Ridge, Tn.	35 58 02	84 14 54	0.59	1961	1961	
51	03535619	Conner creek near Solway Station, Tn.	35 56 01	84 13 43	6.40	1943,1952-54, 1956,1961-63, 1969-72		
52	03535800	Hickory Creek near Farragut, Tn.	35 53 28	84 13 23	4.36	1961-64	1961-64	
53	03535820	Hickory Creek at Buttermilk Rd. near Farragut, Tn.	35 53 20	84 14 44	6.92	1943,1952-53 1956		
54	03535912	Clinch River at Melton Hill Dam (Tailwater), Tn.	35 53 07	84 18 03	3,343	1961-	1975-	1979-
55	03535915	Clinch River near Eaton Crossroads, Tn.	35 53 14	84 19 28	3,346		1973	
56	03536200	Whiteoak Creek above Oak Ridge National Laboratory near Oak Ridge, Tn.	35 56 28	84 18 05	0.80	1961-64	1961-64	
57	03536400	Whiteoak Creek near Gaging Station at Oak Ridge National Laboratory, Tn.	35 55 25	84 19 00	2.20	1960-61		
58	03536500	Whiteoak Creek at Oak Ridge National Laboratory near Oak Ridge, Tn.	35 55 34	84 18 49	2.08	1950-55		
59	03537000	Whiteoak Creek below Oak Ridge National Laboratory near Oak Ridge, Tn.	35 54 44	84 18 59	3.62	1951-53, 1955-64	1961-64	
60	03537500	Melton Branch near Oak Ridge, Tn.	35 54 38	84 18 54	1.48	1955-64	1961-64	
61	03537550	Whiteoak Creek near Oak Ridge, Tn.	35 54 09	84 19 20	5.86	1960		
62	03538000	Whiteoak Creek at Whiteoak Dam near Oak Ridge, Tn.	35 53 17	84 19 15	6.01	1953-55, 1960-64	1961-64	
63	03538089	Grubb Creek near Pawpaw Plains, Tn.	35 52 45	84 20 00	2.52	1964-72		
64	03538090	Pawpaw Creek near Melton Hill Dam, Tn.	35 52 58	84 20 51	8.71	1961-1975		
65	03538110	Clinch River Tributary No. 2 near Oak Ridge, Tn.	35 54 16	84 21 29	0.94	1961-64	1961-64	
66	03538117	Clinch River near Wheat, Tn.	35 53 34	84 22 29	3,368	1936		
67	03538130	Caney Creek near Kingston, Tn.	35 51 53	84 23 07	3.32	1961-	1961-64	
68	03538140	Grassy Creek near Oak Ridge, Tn.	35 55 00	84 22 13	1.00	1961-64	1961-64	
69	03538150	Clinch River near Oak Ridge, Tn.	35 54 25	84 23 32	3,385	1967-68		
70	03538153	Cow Creek near Oliver Springs, Tn.	36 03 33	84 18 48	3.41	1961-65,1968, 1970-71		
71	03538160	Poplar Creek at Batley Road near Oliver Springs, Tn.	36 01 57	84 18 16	30.3	1961-64,1979-	1961-64, 1979-	1979-
72	03538180	Brushy Fork at Dossett, Tn.	36 04 11	84 13 40	10.2	1961-70	1961-64	
73	03538195	Brushy Fork near Oak Ridge, Tn.	36 01 33	84 17 16	23.2	1953,1955-56, 1958		
74	03538200	Poplar Creek near Oliver Springs, Tn.	36 01 20	84 18 37	55.9	1951-	1961-64	
75	03538215	Indian Creek at Oliver Springs, Tn.	36 02 45	84 20 48	18.4	1961-72	1961-64	
76	03538225	Poplar Creek near Oak Ridge, Tn.	35 59 55	84 20 23	82.5	1960-	1961-65,1979-	1979-
77	03538235	East Fork Poplar Creek at Bear Creek Valley Road at Oak Ridge, Tn.	35 59 48	84 14 25	1.69	1961-65	1961-64	
78	03538237	East Fork Poplar Creek at Tuskeegee Drive at Oak Ridge, Tn.	36 00 15	84 15 24	3.23	1961-70	1961-64	
79	03538239	East Fork Poplar Creek at East Vanderbilt Drive at Oak Ridge, Tn.	36 00 28	84 15 54	4.53	1961-70	1961-64	
80	03538240	East Fork Poplar Creek Tributary at Oak Ridge, Tn	36 00 47	84 15 50	1.14	1961-70	1961-64	
81	03538242	East Fork Poplar Creek at Wiltshire Drive at Oak Ridge, Tn.	35 59 55	84 18 00	8.72	1961-70	1961-64	
82	03538243	Mill Branch at Oak Ridge, Tn.	35 59 46	84 18 10	1.78	1961-66	1961-64	
83	03538247	Gum Hollow Branch at Oak Ridge, Tn.	35 58 31	84 20 08	2.40	1961-66	1962-64	
84	03538248	East Fork Poplar Creek at Turnpike near Oak Ridge, Tn.	35 58 11	84 20 48	18.1	1951,1953-54		
85	03538250	East Fork Poplar Creek near Oak Ridge, Tn.	35 57 58	84 21 30	19.5	1960-	1961-64	
86	03538260	Bear Creek at County Line near Oak Ridge, Tn.	35 57 26	84 18 03	1.57	1961-64	1961-64	
87	03538265	Bear Creek (Site 2) near Oak Ridge, Tn.	35 56 51	84 19 13	2.62	1959-61		
88	03538270	Bear Creek at State Hwy. 95 near Oak Ridge, Tn.	35 56 17	84 20 29	4.26	1961-64	1961-64	
89	03538274	Bear Creek at mile 0.5 near Oak Ridge, Tn.	35 56 41	84 21 46	7.15	1951,1953-56, 1958		
90	03538275	Bear Creek near Oak Ridge, Tn.	35 56 50	84 21 48	7.15	1960-	1961-64	
91	03538280	Poplar Creek at Blair Road near Oak Ridge, Tn.	35 56 31	84 23 26	132	1962-63		
92	03538290	Clinch River near Lawnville, Tn.	35 53 08	84 29 24	3,540	1970	1971	
93	03538296	Greasy Creek near Gobey, Tn.	36 09 17	84 35 04	13.8	1961-65,1967-68,1970-71		
94	03538297	Emory River above Wartburg, Tn.	36 07 40	84 37 00	49.2	1973		
95	03533300	Rock Creek near Sunbright, Tn.	36 11 54	84 39 39	5.54	1955-71		
96	03538398	Rock Creek near Gobey, Tn.	36 08 02	84 37 31	31.2	1979-	1979-	1979-
97	03538500	Emory River near Wartburg, Tn.	36 06 46	84 36 54	83.2	1935-	1965-68,1975-76	
98	03538600	Obed River at Crossville, Tn.	35 57 27	85 03 00	12.0	1955-		
99	03538618	Obed River near Crossville, Tn.	35 58 27	85 02 55	14.0	1950,1954 1967-68	1976	
100	03538700	Little Obed River near Crossville, Tn.	35 58 31	85 02 06	4.71	1955-70		
101	03538800	Obed River Tributary near Crossville, Tn.	35 58 59	85 03 31	0.72	1955-70		
102	03538820	Obed River below Crossville, Tn.	35 59 48	85 02 41	56.0	1968		
103	03538840	Obed River at Adams Bridge near Crossville, Tn.	36 03 42	84 57 42	92.4	1954-56	1974	
104	03538860	Obed River at Potter Ford near Crossville, Tn.	36 04 22	84 54 10	108	1955		
105	03538871	Otter Creek near Hebbertsburg, Tn.	36 03 16	84 51 21	11.4	1954-55		

Surface-Water Network - Continued

Map number	Station number	Station name	Location: Latitude (° ' ")	Location: Longitude (° ' ")	Drainage area (mi²)	Type of record and period collected: Discharge	Water quality	Sediment
106	03538875	Otter Creek below Hebbertsburg, Tn.	36 05 00	84 49 56	20.1	1954		
107	03538880	Obed River above Daddys Creek near Hebbertsburg, Tn.	36 04 49	84 46 04	156	1943,1953,1955		
108	03538900	Self Creek near Big Lick, Tn.	35 47 54	85 02 33	3.80	1967-75		
109	03538950	Lick Creek at Big Lick, Tn.	35 48 38	85 01 13	8.58	1967-74		
110	03539000	Daddys Creek near Grassy Cove, Tn.	35 53 26	84 53 16	51.2	1925-30		
111	03539100	Byrd Creek near Crossville, Tn.	35 53 40	85 03 38	1.10	1967-75		
112	03539120	Byrd Creek near Crossville, Tn.	35 53 36	85 01 32	5.38	1961-65,1968-69,1971		
113	03539500	Daddys Creek near Crab Orchard, Tn.	35 55 33	84 54 47	93.5	1930-58		
114	03539600	Daddys Creek near Hebbertsburg, Tn.	35 59 53	84 49 24	139	1957-68,1979-	1965,1979-	1979-
115	03539650	Crabapple Branch near Watson, Tn.	35 59 43	84 49 15	5.05	1961-65, 1968-69		
116	03539698	Daddys Creek near Hebbertsburg, Tn.	36 04 01	84 06 02	175	1954-56		
117	03539700	Obed River near Frankfort, Tn.	36 04 16	84 45 51	331	1965	1966	
118	03539715	No Business Creek at Isoline, Tn.	36 05 23	85 03 50	2.83	1961-65, 1968-69,1971		
119	03539719	White Creek at Twin Bridges, Tn.	36 10 40	84 48 01	38.4	1979-	1979-	1979-
120	03539720	White Creek near Twin Bridges, Tn.	36 09 31	84 47 20	45.0	1961-71		
121	03539730	White Creek near Frankfort, Tn.	36 07 29	84 47 58	50.5	1965	1965	
122	03539750	Clear Creek near Lancing, Tn.	36 07 18	84 44 46	153	1966-68,1979-	1966-67,1979-	1979-
123	03539780	Clear Creek at Howard Mill, Tn.	36 06 07	84 43 01	170	1965	1965-66	
124	03539800	Obed River near Lancing, Tn.	36 04 53	84 40 15	518	1956-68,1972-	1965-68	
125	03539820	Emory River near Nemo, Tn.	36 04 09	84 39 46	612	1955		
126	03539830	Island Creek at Catoosa, Tn.	36 03 10	84 40 02	17.0	1965	1965	
127	03539831	Island Creek near Catoosa, Tn.	36 03 10	84 40 01	18.4	1979-	1979-	1979-
128	03539840	Crooked Fork at Petros, Tn.	36 04 04	84 27 13	11.7	1952-53,1967		
129	03539848	Flat Fork near Petros, Tn.	36 07 35	84 30 11	4.16	1975-	1975	
130	03539850	Judge Branch near Petros, Tn.	36 07 34	84 30 11	2.69	1975-	1975	
131	03539860	Crooked Fork near Wartburg, Tn.	36 05 05	84 33 18	50.3	1966-68,1979-	1965-68,1979-	1979-
132	03540000	Emory River at Deermont, Tn.	36 01 39	84 34 47	704	1920-27		
133	03540090	Crab Orchard Creek at Pine Orchard, Tn.	35 58 09	84 40 13	18.9	1955		
134	03540100	Crab Orchard Creek near Deermont, Tn.	36 00 40	84 36 44	33.7	1966-68,1979-	1966-68,1979-	1979-
135	03540103	Mill Creek near Deermont, Tn.	36 01 34	84 35 19	7.52	1961-65,1968, 1970-71		
136	03540105	Crab Orchard Creek at Deermont, Tn.	36 01 18	84 34 53	47.2	1955		
137	03540500	Emory River at Oakdale, Tn.	35 58 59	84 33 29	764	1927-	1965-67,1974-	1979-
138	03540793	Clifty Creek near Harriman, Tn.	35 57 03	84 34 44	19.5	1943,1952-53		
139	03541000	Bitter Creek near Wartburg, Tn.	36 01 57	84 31 25	2.01	1967-71		
140	03541100	Bitter Creek near Camp Austin, Tn.	36 00 53	84 31 33	5.53	1967-75		
141	03541200	Forked Creek near Oakdale, Tn.	36 00 12	84 30 45	2.44	1967-75		
142	03541300	Bitter Creek near Oakdale, Tn.	35 59 22	84 29 16	12.6	1967-75		
143	03541303	Little Emory River near Harriman, Tn.	35 58 53	84 28 56	34.3	1943,1952-53, 1955-56,1958		
144	03541439	Caney Creek near Cardiff, Tn.	35 54 28	84 35 31	7.43	1943,1952-55		
145	03541450	Caney Creek near Rockwood, Tn.	35 51 19	84 35 55	26.1		1970-71	
146	03541459	Unnamed Branch of King Creek at Parkview, Tn.	35 50 13	84 41 31	1.36	1943,1952-53		
147	03541485	Whites Creek at Bakers Bridge near Glen Alice, Tn.	35 47 50	84 48 43	33.8	1979-	1979-	1979-
148	035414865	Piney Creek near Rockwood, Tn.	35 53 53	84 43 37	11.2	1961-65		

Surface-Water Network - Continued

Map number	Station number	Station name	Location		Drainage area (mi^2)	Type of record and period collected		
			Latitude (° ' ")	Longitude (° ' ")		Discharge	Water quality	Sediment
149	03541487	Piney Creek near Westel, Tn.	35 51 14	84 44 17	19.0	1943,1952-53, 1955,1979-	1979-	1979-
150	03541490	Mammys Creek near Ozone, Tn.	35 52 29	84 47 19	9.54	1955,1957		
151	03541496	Fall Creek near Ozone, Tn.	35 50 16	84 47 56	21.1	1979-	1979-	1979-
152	03541500	Whites Creek near Glen Alice, Tn.	35 47 49	84 45 37	108	1934-78		
153	03541990	Black Creek at Rockwood, Tn.	35 51 51	84 41 20	3.48	1950		
154	03541995	Black Creek near Glen Alice, Tn.	35 47 44	84 45 25	11.8	1943,1952-55, 1957		
155	03542000	Whites Creek at Glen Alice, Tn.	35 47 40	84 44 51	120	1930-34,1979-		
156	03542005	Camp Creek near Roddy, Tn.	35 46 55	84 45 48	6.25	1955,1957		
157	03542495	Piney River above Spring City, Tn.	35 43 02	84 53 08	62.3	1979-	1979-	1979-
158	03542500	Piney River at Spring City, Tn.	35 41 59	84 51 17	95.9	1927-31,1955-	1979-	1979-
159	360858084355000	Emory River at Gobey, Tn.	36 08 58	84 35 50	43.3	1979-	1979-	1979-

Ground-Water Network

Site number	Station number	Station name	Formation tapped	Type of record and period collected: Discharges	Water Levels	Water Quality
	Springs					
1	03520040	Kilpatrick Spring near Sweetwater, Tn.		1931-32, 1950-52		
2	03520060	Reed Spring near Philadelphia, Tn.		1931-32, 1950-52		
3	03535040	Fowler Spring near Powell, Tn.		1950-51		
4	03535182	Hobbs Spring near Halls Crossroads, Tn.		1950-51		
5	03535185	Big Blue Spring near Fountain City, Tn.		1931-32, 1952-54		
6	03538080	Blue Spring near Oral, Tn.		1950-52		
7	03538155	Blue Spring near Oliver Springs, Tn.		1950-52, 1966-68		
8	03538170	Burress Spring near Clinton, Tn.		1950-51		
9	03538175	Shetterly Spring near Clinton, Tn.		1950-51		
10	03538190	Bacon Spring at Dossett, Tn.		1931-51		
11	03538245	Crystal Spring near Oak Ridge, Tn.		1931-32, 1951-54, 1962		
12	03538261	Bear Creek Spring no. 1 near Oak Ridge, Tn.		1959-62		
13	03538269	Bear Creek Spring no. 2 near Oak Ridge, Tn.		1959-62		
14	03541440	Factory Spring near Rockwood, Tn.		1931-32, 1950-53		
	Wells					
15	354452084394500	Bayside Marina well near Rockwood, Tn.				1977
16	354922085053500	Cu:C-1 Lantana, Tn.	Rockcastle Conglomerate		1964-80	
17	355225084263000	I-40 Amoco well near Kingston			1967	1977
18	355228085044800	Lake Tansi Development well near Vandever, Tn.				1977
19	355334084584800	H. York well near Cumberland State Park, Tn.				1977
20	355444084184501	Rn:ORNL 5-436	Conasauga Group		1977-80	
21	355444084184502	Rn:ORNL 5-T60-1	Conasauga Group		1977-80	
22	355444084184603	Rn:ORNL 5-T105-6	Conasauga Group		1977-80	
23	355447084184200	Rn:ORNL 5-T64-1	Conasauga Group		1977-80	
24	355451084184801	Rn:ORNL 5-176	Conasauga Group		1977-80	
25	355457084183701	Rn:BG5-174	Conasauga Group		1978-80	
26	360538084343100	Wartburg well at Wartburg, Tn.				1977
27	361155084021600	Andersonville well at Andersonville, Tn.				1977

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