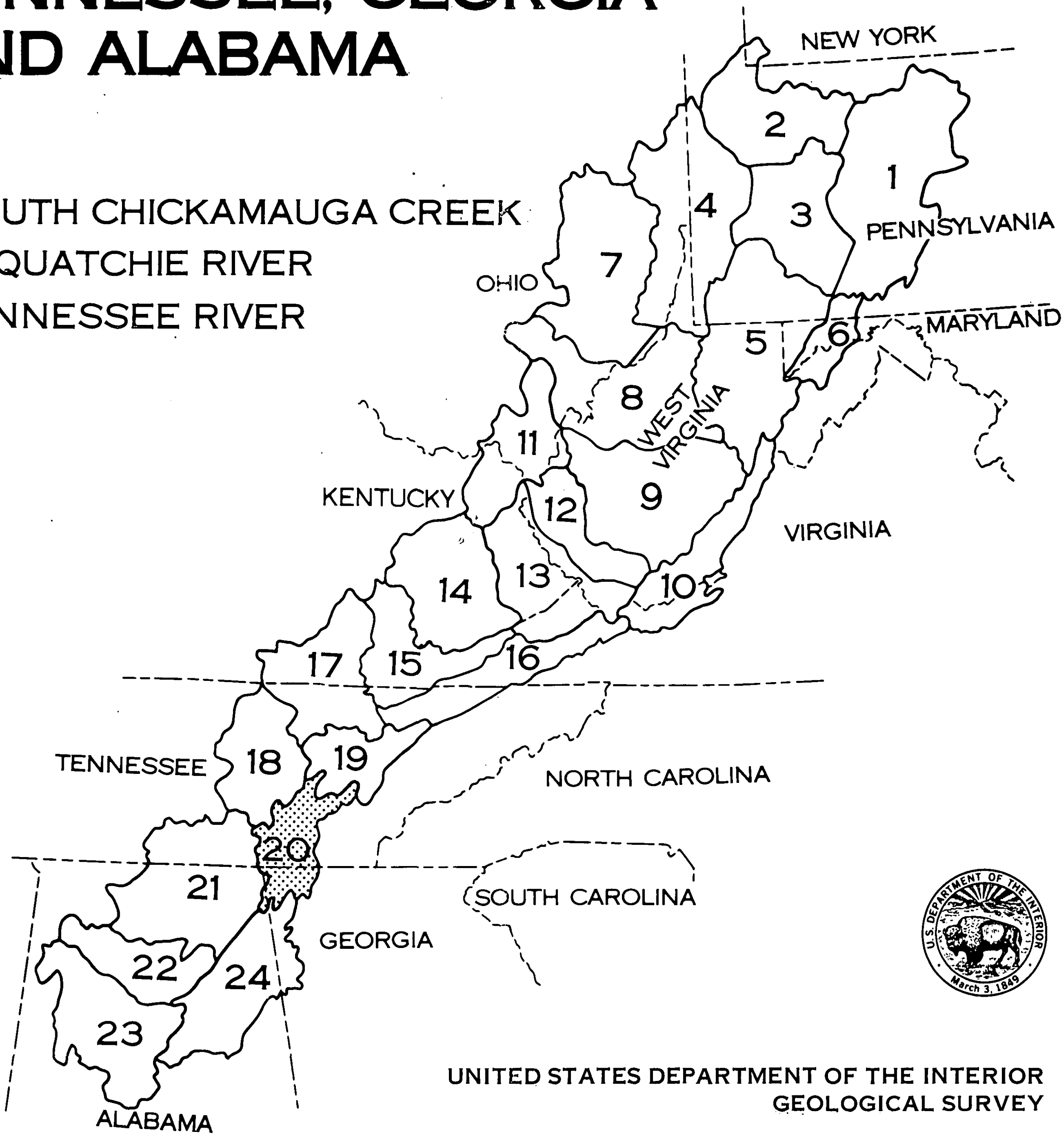
HYDROLOGY OF AREA 20, EASTERN COAL PROVINCE, TENNESSEE, GEORGIA AND ALABAMA

- SOUTH CHICKAMAUGA CREEK
- SEQUATCHIE RIVER
- TENNESSEE RIVER



UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

WATER-RESOURCES INVESTIGATIONS
OPEN-FILE REPORT 82-440

HYDROLOGY OF AREA 20, EASTERN COAL PROVINCE, TENNESSEE, GEORGIA AND ALABAMA

BY
E.F. HOLLYDAY AND OTHERS

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NASHVILLE, TENNESSEE
JANUARY 1983

UNITED STATES DEPARTMENT OF THE INTERIOR

JAMES G. WATT, *SECRETARY*

GEOLOGICAL SURVEY

Dallas L. Peck, *Director*

For additional information write to:

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

CONTENTS

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

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

Multiply	By	To obtain
inches (in)	25.40	millimeters (mm)
inches per hour (in/h)	25.4	millimeters per hour (mm/h)
	2.54	centimeters per hour (cm/h)
feet (ft)	0.3048	meters (m)
feet per mile (ft/mi)	0.1894	meters per kilometer (m/km)
miles (mi)	1.609	kilometers (km)
square miles (mi^2)	2.590	square kilometers (km^2)
gallons per minute (gal/min)	0.06309	liters per second (L/s)
million gallons per day (mgal/d)	0.04381	cubic meters per second (m^3/s)
	3785.	cubic meters per day (m^3/d)
cubic feet per second (ft^3/s)	0.02832	cubic meters per second (m^3/s)
cubic feet per second per square mile [$(ft^3/s)/mi^2$]	0.01093	cubic meters per second per square kilometer [$(m^3/s)/km^2$]
tons per square mile per year [$(ton/mi^2)/yr$]	0.3503	metric tons per square kilometer per year [$(t/km^2)/a$]
micromhos per centimeter at 25° Celsius (μmhos/cm)	100	microsiemens per meter at 25° Celsius (μS/m)
degrees Fahrenheit (°F)	0.556, after subtracting 32.0	degrees Celsius (°C)
square feet per day (ft^2/d)	0.0929	square meters per day (m^2/d)

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

HYDROLOGY OF AREA 20, EASTERN COAL PROVINCE, TENNESSEE, GEORGIA AND ALABAMA

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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. This information is needed prior to mining coal in order to evaluate the potential effects of mining on the hydrologic environment. The Surface Mining Control and Reclamation Act of 1977 establishes specific limits for selected chemical constituents and physical properties of mine effluents. This report describes the physical and hydrologic features of Area 20, one of the 24 hydrologic reporting areas in the Eastern Coal Province which includes parts of 10 states. The report provides a background for the more detailed, site-specific studies required by the Act.

Area 20 encompasses about 2,450 square miles in two physiographic sections, the Cumberland Plateau and the Ridge and Valley. Numerous surface mines, about 1 percent of the land area, are exclusively in the uplands of the Cumberland Plateau. During dry periods, streams on the Plateau are not as well sustained as are those in the Ridge and Valley. Although low flows are smaller on the Cumberland Plateau, average annual flows are about 2 cubic feet per second per square mile throughout Area 20. Ground-water availability varies widely; yields from wells in the Pennsylvanian rocks on the Cumberland Plateau range from less than 5 to about 300 gallons per minute, whereas yields from carbonate rocks in the Ridge and Valley range from about 5 to more than 3,000 gallons per minute.

Acidic, highly mineralized drainage and increased sediment are usually the most severe water problems in coal-mine areas, but no widespread water-quality problems have been identified in Area 20. Several low pH values and a few concentrations of iron or trace constituents exceeded the mandatory or recommended criteria at several sites. Specific conductance was highest in streams draining mining, rural-agricultural, and urban areas; the highest concentration of dissolved sulfate, however, occurred in Rock Creek that drains an abandoned coal-mine site. Benthic invertebrates at one site appeared to be affected by mining. Concentrations of suspended sediment exceeded the limits at several sites, but appeared to be related generally to a variety of land use and particularly to sampling during storms.

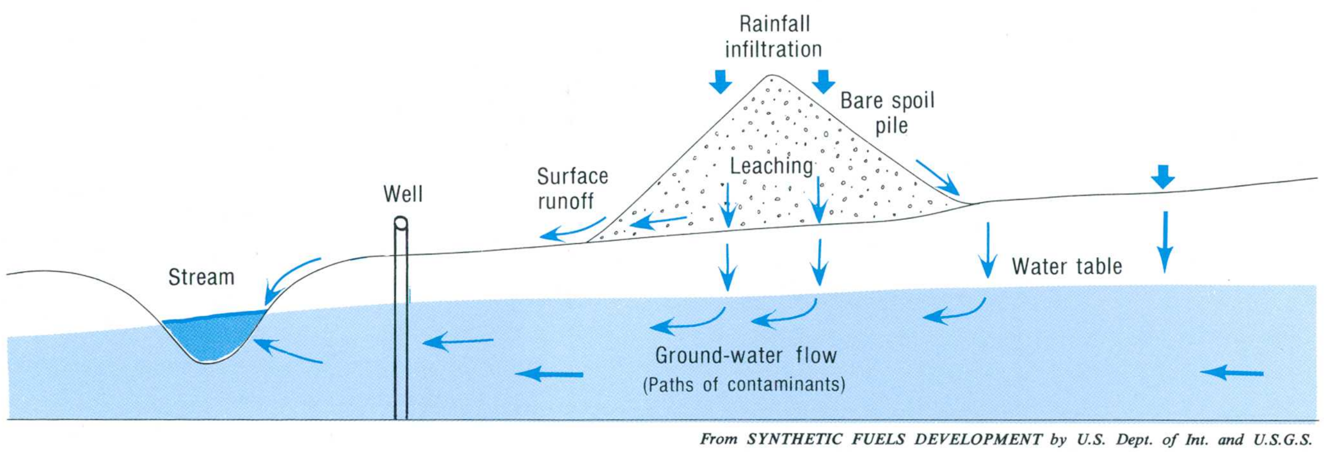
Hydrologic Environment can be Adversely Affected by Surface Mining

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.

Efficient development of coal resources 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. 1.1-1).

Increased sediment and dissolved minerals can cause severe water-quality problems, limiting the domestic, municipal, industrial, and recreational use of water. 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. 1.1-2). The quality of ground water can also be affected at points remote from mining activities, although the effects may take much longer to determine 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. These include mining and reclamation methods, land slopes, type of rocks, rainfall, quality of ground and surface waters, and rates 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 and other land-use activities can have a cumulative impact downstream.



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

Figure 1.1-1 Leaching from spoil material.

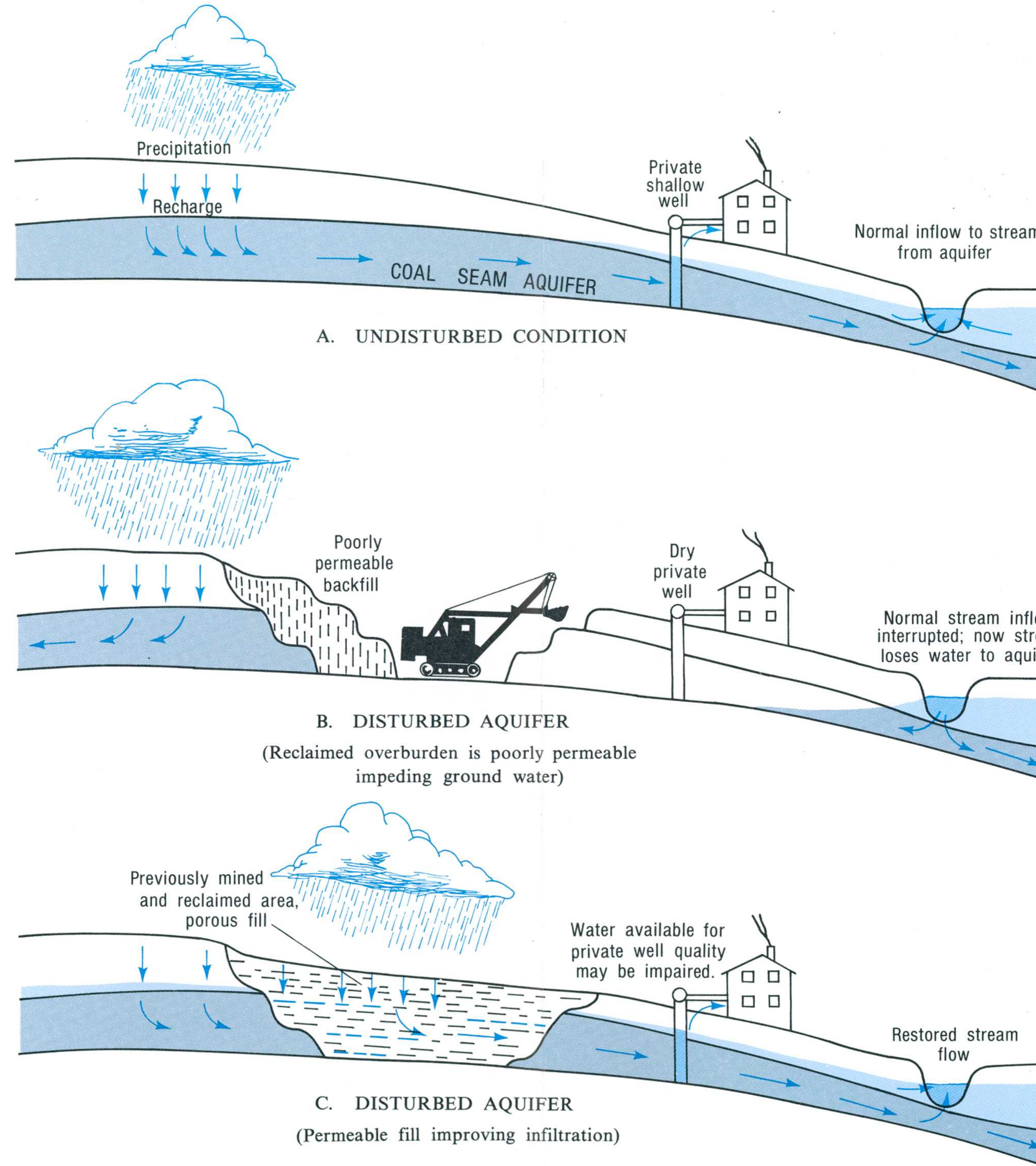


Figure 1.1-2 Possible impacts of mining

Area 20 Report to Aid in Coal Mine Permitting

This report describes the physical and hydrologic features of an 18-county, multi-state area and identifies sites where hydrologic data are available to assist in the preparation and review of applications.

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 (1) that each mining-permit applicant make an analysis of the potential effects of the proposed mine on the hydrology of the mine site and adjacent area, (2) that "an appropriate Federal or State agency" provide to each mining-permit applicant "hydrologic information on the general area prior to mining," and (3) that measures be taken by mining permittees 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 background 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 extending from New York to Alabama, includes parts of 10 states, and is divided into 24 hydrologic reporting areas. Drainage basins or parts of basins are combined to form each reporting area with additional factors considered being location, size, and mining activity.

Area 20, which is in the southern part of the Eastern Coal Province, is located in southeastern Tennessee, northwestern Georgia, and northeastern Alabama and includes all or parts of 18 counties (fig. 1.2-1). This report describes the physical and hydrologic features of Area 20 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 the Act, 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, no mine effluent data were collected as part of an effort to establish trends. However, data were collected throughout Area 20 at sites both upstream and downstream from existing effluents and mine seepages. These data should provide general hydrologic information for the area, but not for specific mine sites. Few ground-water data have been acquired in the area since 1979.

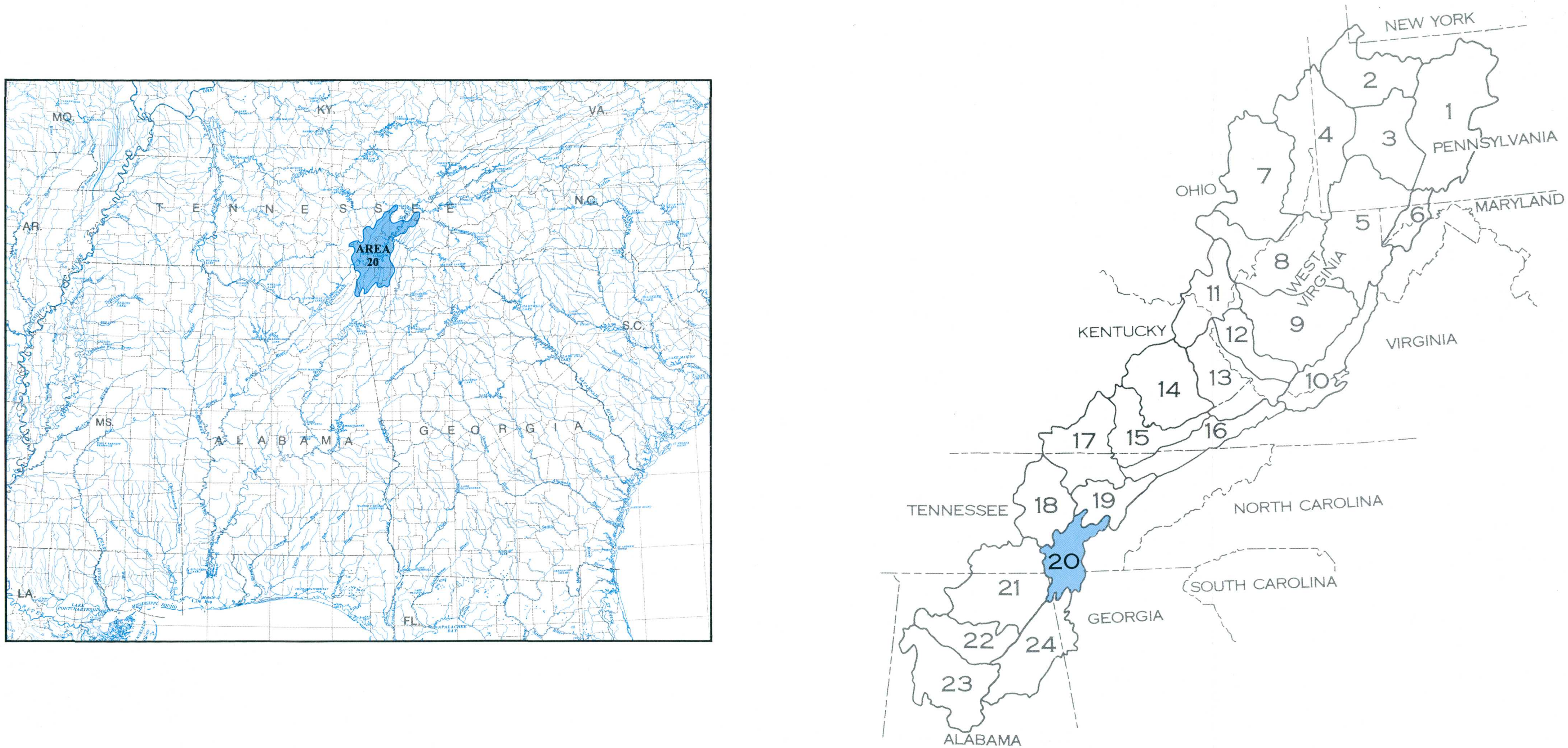


Figure 1.2-1 Location of Area 20 in the Eastern Coal Province and in parts of Tennessee, Georgia, and Alabama.

Two Physiographic Sections Represented in Area 20

The two physiographic sections of Area 20 are the Cumberland Plateau Section of the Appalachian Plateau province and the Southern Section of the Ridge and Valley province.

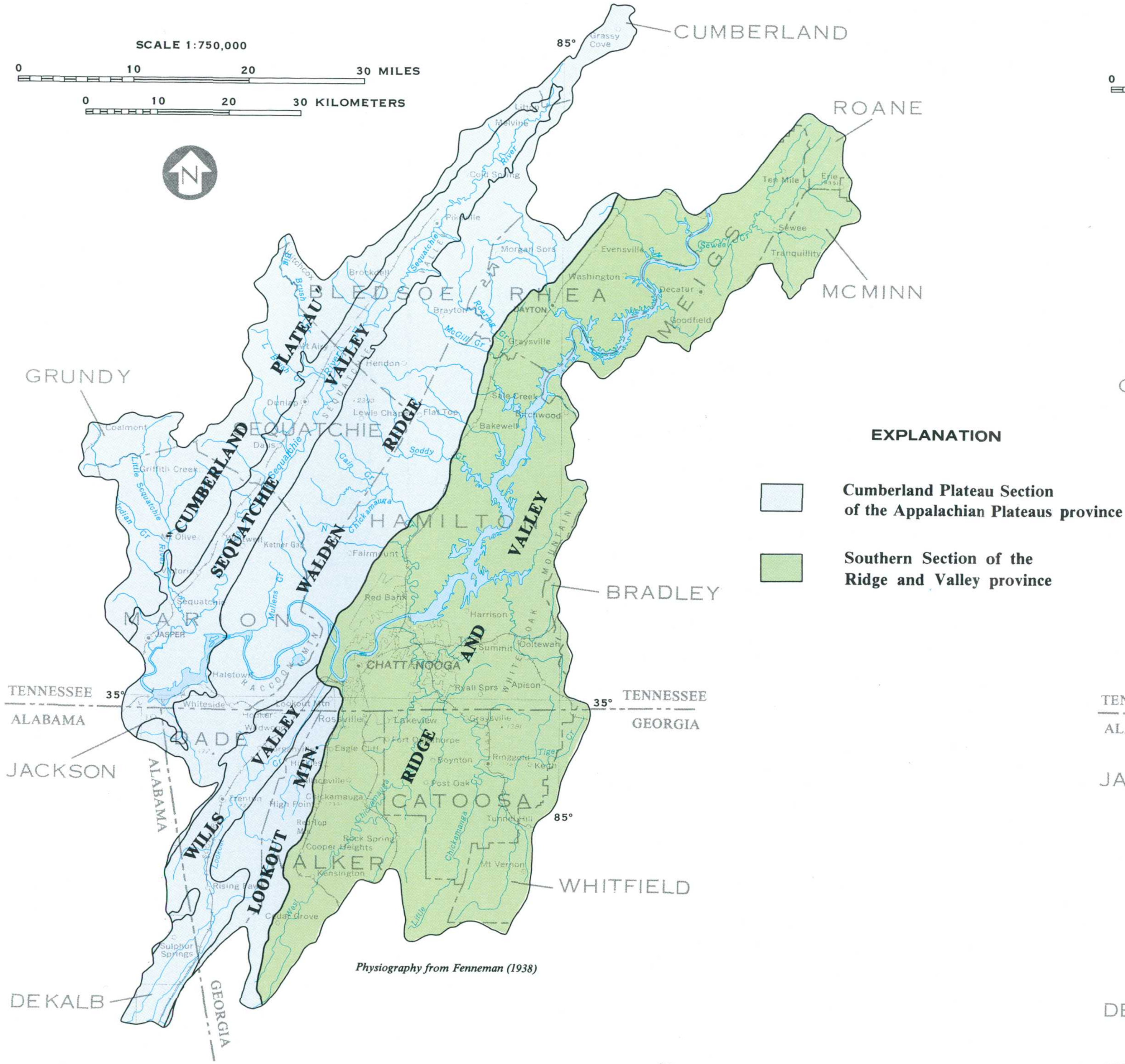
The Cumberland Plateau comprises the western 57 percent (1,396 mi^2) of Area 20. Two anticlinal valleys, the Sequatchie and Wills (Fenneman, 1938) divide the Plateau into three gently rolling upland parts containing the coal resources in Area 20. Locally, the westernmost upland part is known as the "Cumberland Plateau", the part between the two valleys is Walden Ridge, and the easternmost upland part is Lookout Mountain (fig. 2.1-1). Across the plateau surface, altitudes average 1,800 feet and the relief averages 200 feet. The terrain is undulating, with slopes from 5 to 25 percent. The upper parts of the slopes between the plateau surface and valley floors are nearly vertical.

Steep escarpments bound both valleys and in some parts rock cliffs at the top of the escarpments tower as much as 1,000 feet above the valley floors (fig. 2.1-2). The altitude of the Sequatchie Valley ranges from 900 feet at its most northern extent to 600 feet at the Tennessee-Alabama border. The altitude of the Wills Valley ranges from 600 to 800 feet. Topographic relief is usually less than 100 feet in both valleys and slopes range from 0 to 10 percent.

The Cumberland Plateau is drained by Lookout Creek, and Little Sequatchie, Sequatchie, and Tennessee Rivers. All of Wills Valley in Area 20 is drained by Lookout Creek.

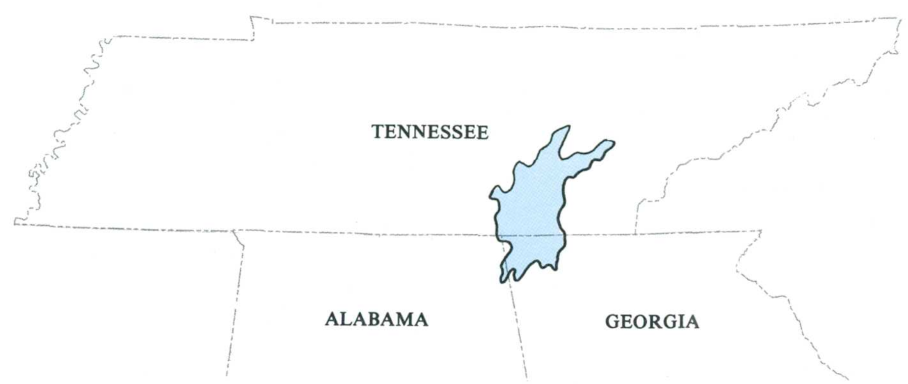
The Ridge and Valley comprises the eastern 43 percent (1,054 mi^2) of Area 20 with elongate ridges and intervening valleys trending northeast-southwest. Ridges range in altitude from 800 to 1,000 feet, whereas the altitude of the valleys averages 750 feet. The resulting relief averages 100 to 200 feet. The ridges are steep, with slopes greater than 25 percent whereas the terrain of the valleys is nearly level, with slopes of generally less than 5 percent.

The Ridge and Valley is drained by West Chickamauga, Little Chickamauga, and South Chickamauga Creeks and by the Tennessee River.



BASE FROM U.S. GEOLOGICAL SURVEY STATE BASE MAPS;
TENNESSEE 1973, ALABAMA AND GEORGIA, 1966

Figure 2.1-1 Physiography of Area 20.



Location of Area 20.

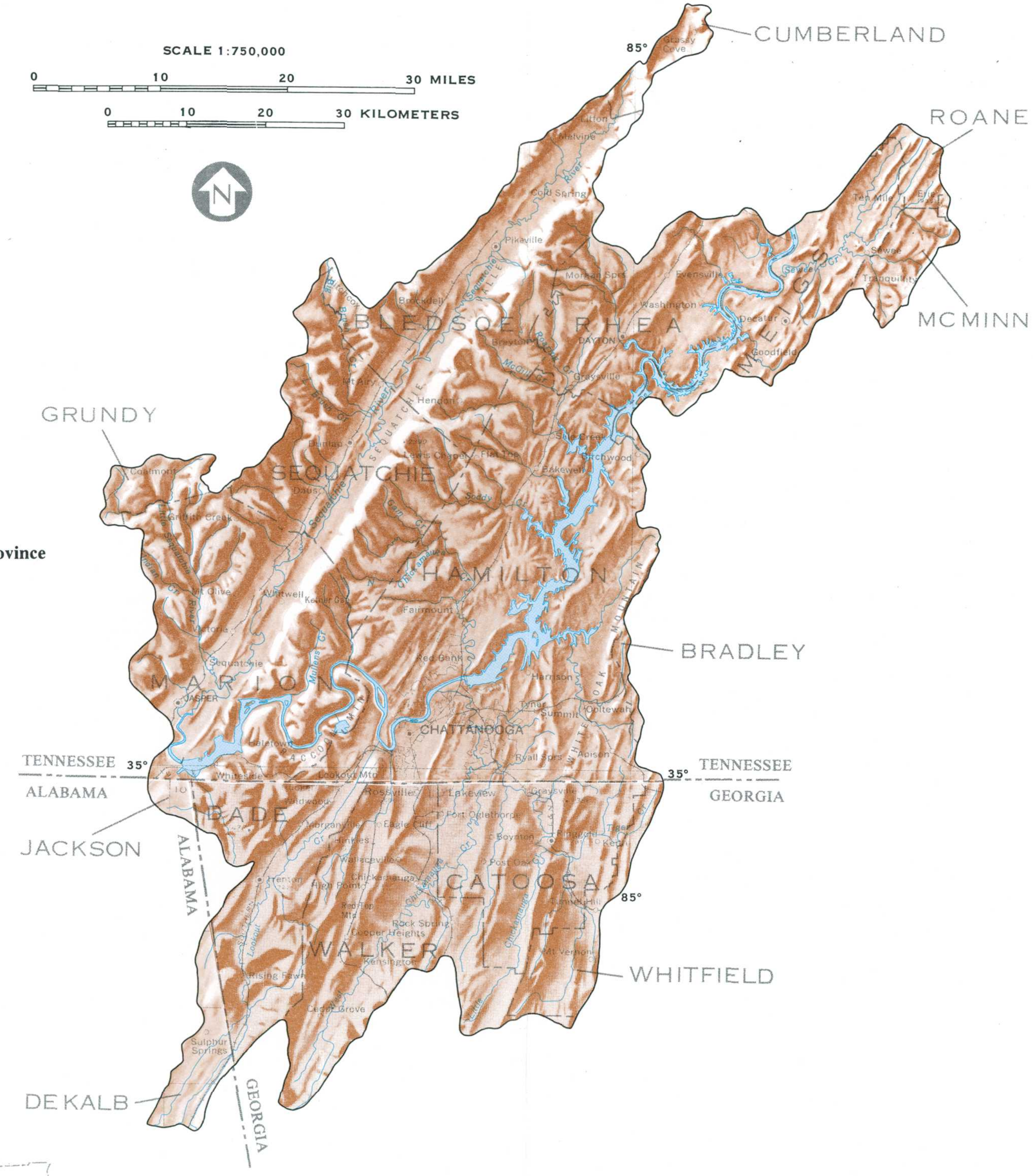


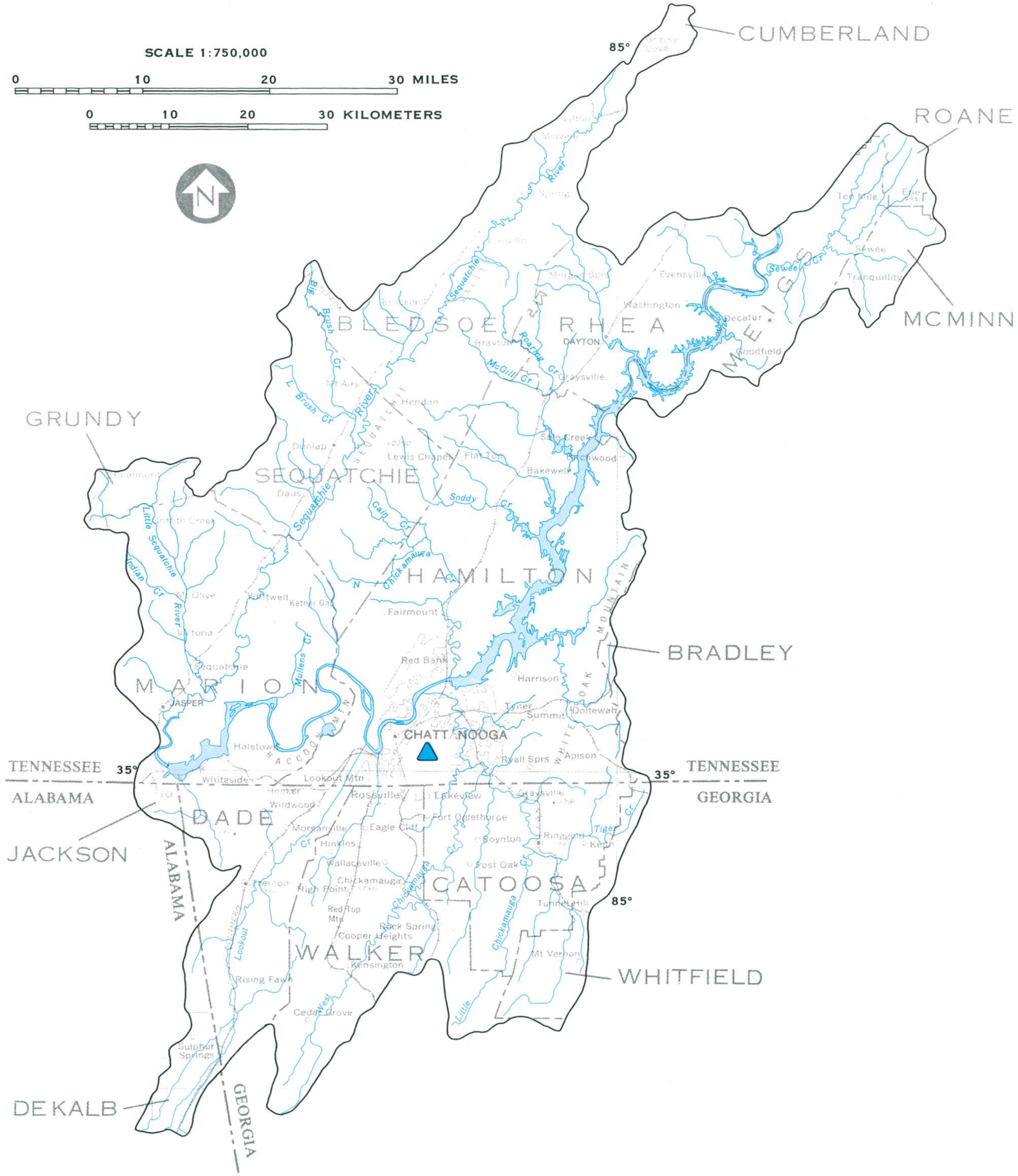
Figure 2.1-2 Shaded relief.

Climate of Area 20 is Moist Temperate

Average annual precipitation is about 54 inches, and average annual temperature is about 58°F.

The average annual precipitation for the area is about 54 inches, but ranges from about 35 inches in dry years to about 70 inches in wet years (National Oceanic and Atmospheric Administration, 1976, 1977, and 1978). Thunderstorms which often produce locally heavy rainfall occur about 55 days per year and are sometimes accompanied by damaging winds and extreme changes in temperature. The 25-year 24-hour rainfall (fig. 2.2-1) is about 6 inches (U.S. Department of Commerce, 1961). Maximum, minimum, and normal monthly precipitation at Chattanooga, Tennessee is considered to be representative of the area (fig. 2.2-2).

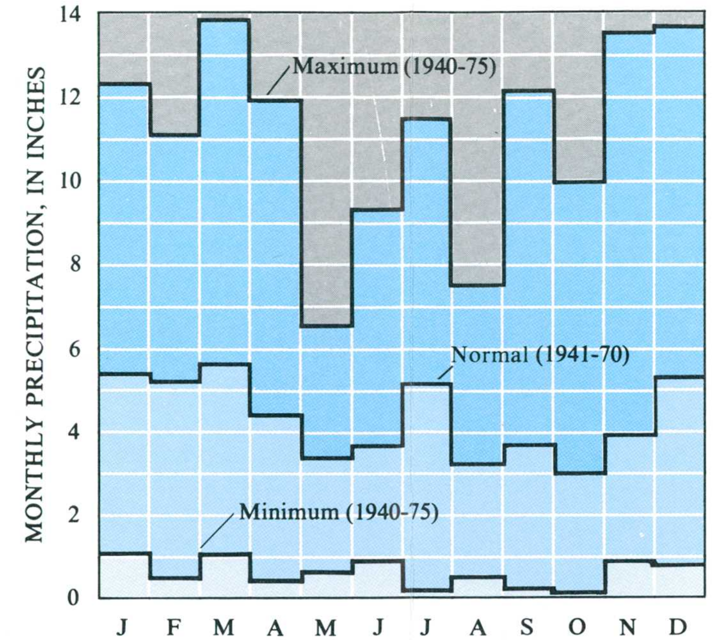
The average annual temperature for Area 20 is about 58°F with extremes seldom above 100°F or below 0°F. Daily maximum temperatures are above 90°F about 50 days per year. There is a frost-free season of about 180 days from early April to late October. Minimum temperatures near zero can occur in December, January, and February, but the number of days with such values is generally less than 2 in any year.



BASE FROM U.S. GEOLOGICAL SURVEY STATE BASE MAPS;
TENNESSEE 1973, ALABAMA AND GEORGIA, 1966

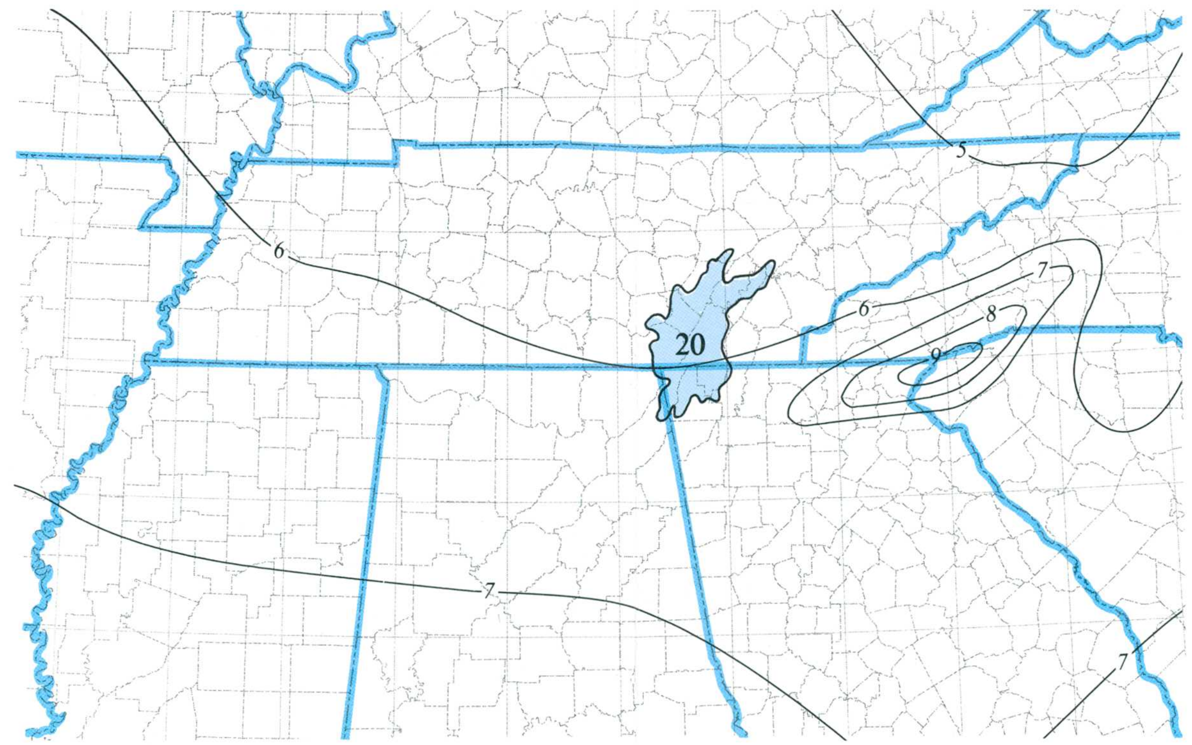
EXPLANATION

▲ **Long-term precipitation station at Chattanooga, Tennessee**



Climatological data from National Oceanic and Atmospheric Administration (1977)

Figure 2.2-2 Precipitation data for Chattanooga, Tennessee.



Climatology from U.S. Department of Commerce (1961)

Figure 2.2-1 25-year 24-hour rainfall intensity, in inches.

The Two Physiographic Sections of Area 20 Vary in Rock Compostion and Structure

The Cumberland Plateau is capped by sandstone and has slightly dipping beds with minimal structural deformation except in the area of the Sequatchie and Wills (anticlinal) Valleys. In contrast, the Ridge and Valley province has mostly carbonate rocks that have been strongly folded and faulted.

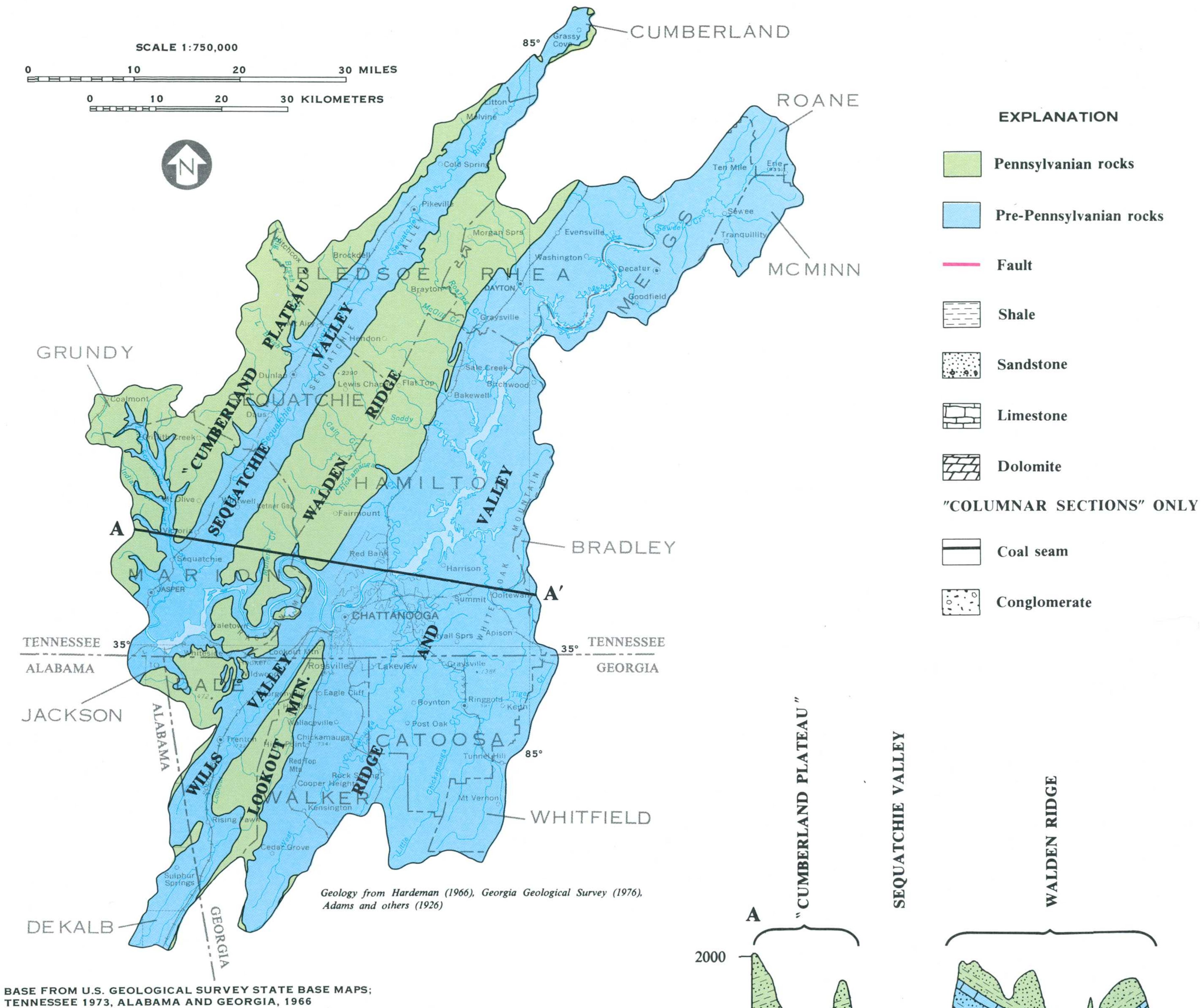
The "Cumberland Plateau", Walden Ridge, and Lookout Mountain parts of the Cumberland Plateau are capped by slightly dipping beds of Pennsylvanian rocks which range from 800 to 1,000 feet in thickness (fig. 2.3-1). Their lithology is dominated by widespread, conglomeratic sandstones interbedded with shale. The Pennsylvanian rocks contain the coal resources in Area 20. In ascending order, the major coal seams are the Bon Air, Richland, Sewanee, Lantana, and Morgan Springs (fig. 2.3-2). Because the rocks capping this area are strongly resistant, the regolith is generally thin, averaging 2 to 3 feet in thickness and composed chiefly of stony and loamy soils.

Underlying the Pennsylvanian rocks is the Pennington Formation of Late Mississippian age. The Pennington ranges in thickness from 200 to 400 feet and is composed of shale, limestone, dolomite, and conglomeratic and fine-grained sandstones (Milici and others, 1979). Directly underlying the Pennington are the Mississippian carbonate rocks, which have a maximum thickness of 1,100 feet and are chiefly limestone with some cherty limestone, sandstone, dolomite, and calcareous shale. The Chattanooga Shale of Devonian age underlies the Mississippian carbonate rocks. It has an average thickness of 25 feet and is composed of carbonaceous shale. About 100 feet of Silurian limestone separates the Chattanooga Shale from the underlying Ordovician limestone and dolomite. This entire sequence can be observed in the escarpments.

The streams of the Sequatchie and Wills Valleys cut through the Pennsylvanian rocks and expose the underlying formations. The floor of the Sequatchie Valley is underlain by Ordovician rocks with a maximum exposed thickness of 600 feet. The dominant lithology is cherty dolomite and limestone. Carbonate rocks underlying Wills Valley range from Mississippian to Ordovician in age.

Sequatchie and Wills Valleys are oriented along axes of gentle anticlines which are the result of the same compressive forces which folded the Ridge and Valley province. Both valleys were formed initially when the Pennsylvanian sandstone was breached. They lengthened both by headward erosion of their streams and by the collapse of large sinkholes formed in the carbonate rocks underlying the sandstone cap rock.

The Ridge and Valley is highly folded and faulted. The thick sequence of rocks underlying this area is of Ordovician and Cambrian age and is predominantly carbonate rocks, shale, and siltstone. The more resistant dolomite and sandstone cap the ridges but the valleys are underlain by the less resistant shale and limestone. The Ridge and Valley has no known coal seams. The regolith of the ridges is a residual clay which is deep and commonly accumulates to 100 feet and more. The regolith of the valleys is silty and averages about 40 feet in thickness but may be considerably thicker in alluvial deposits along the major streams.



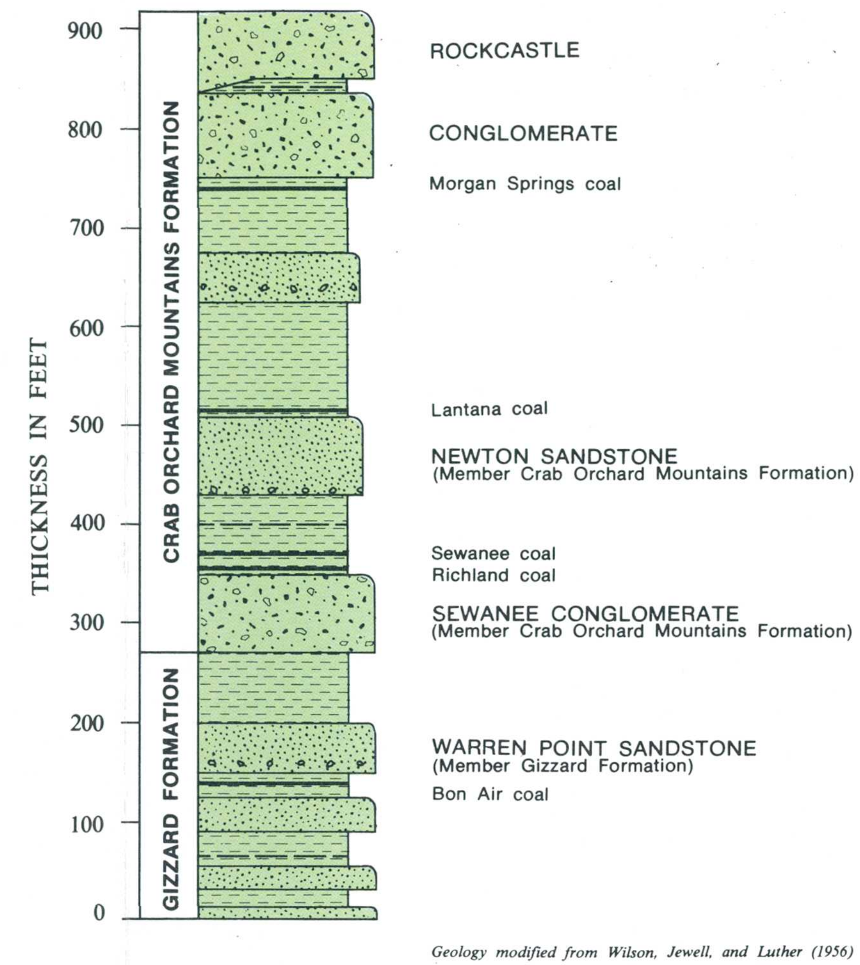


Figure 2.3-2 Stratigraphic column showing distribution of coal seams in Pennsylvanian rocks.

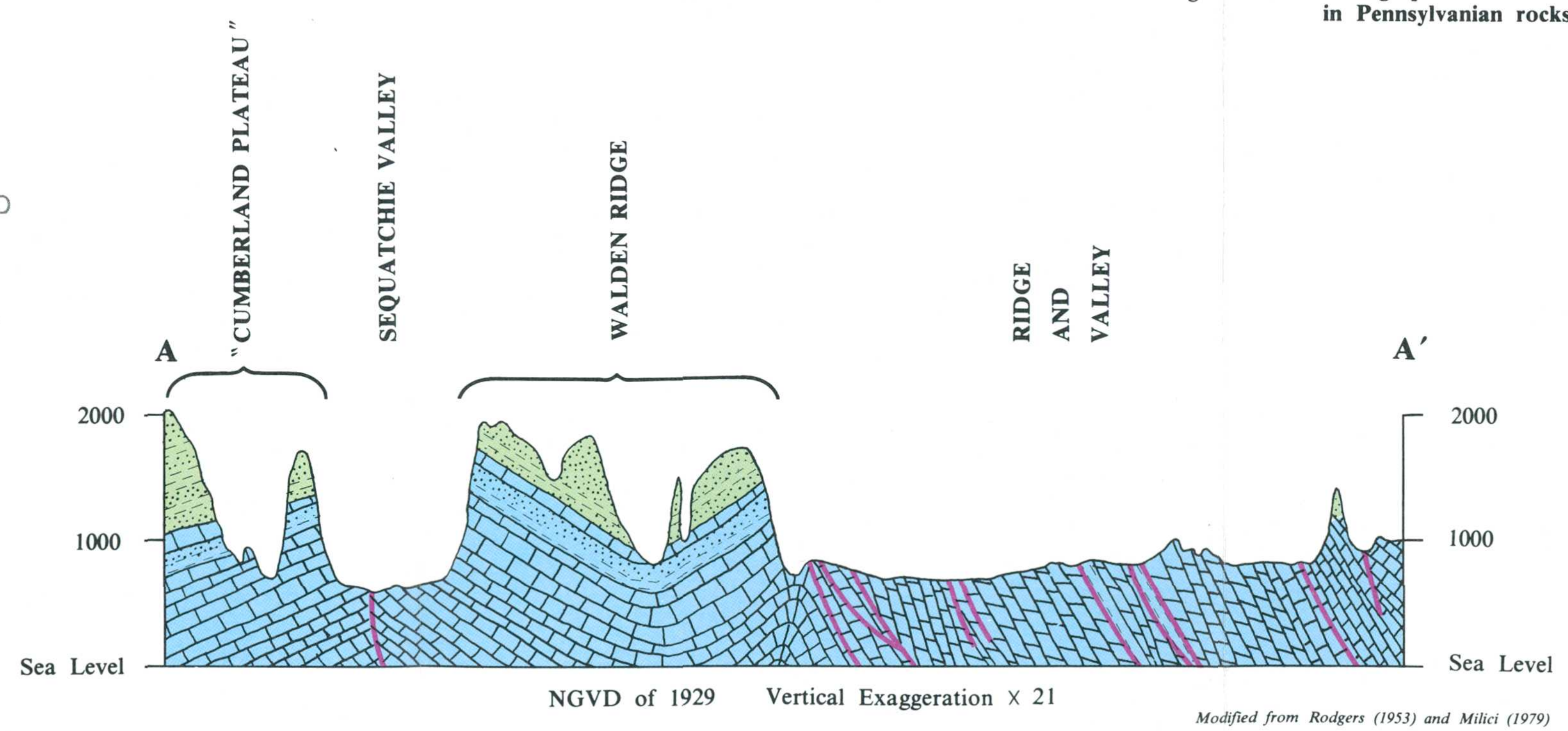


Figure 2.3-1 Geologic map and cross section.

Soils Reflect Geologic Origin

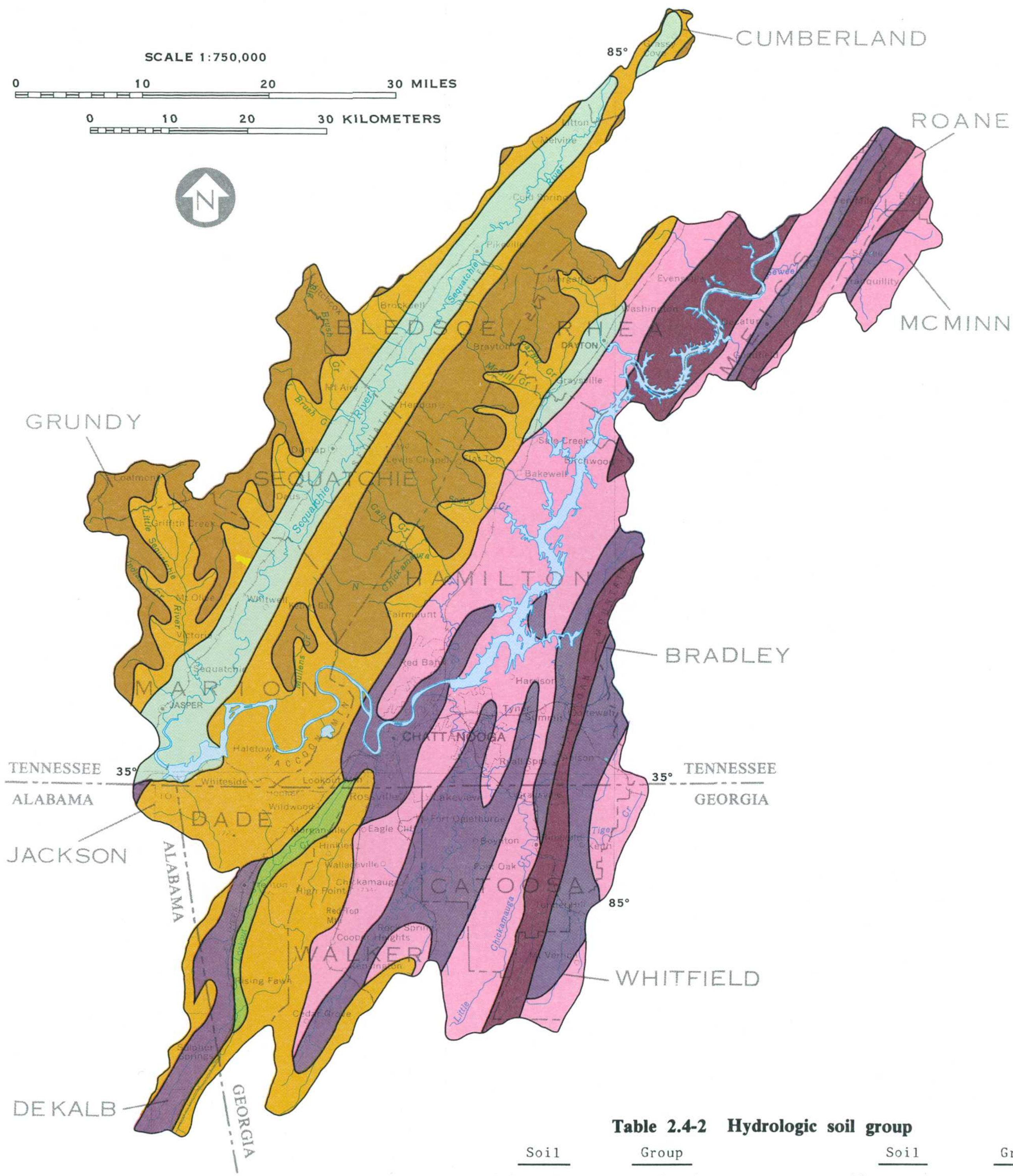
Soils of the Cumberland Plateau are formed primarily from sandstone and shale; soils of the Ridge and Valley are formed from limestone, dolomite, sandstone, and shale. Soil characteristics vary greatly throughout Area 20.

The soils of the Cumberland Plateau uplands (fig. 2.4-1) are derived primarily from sandstone and shale; the soils in Sequatchie and Wills Valleys, like some soils in the Ridge and Valley province, are derived from limestone, alluvium, and colluvium. The soils are generally loamy, but some cherty, sandy, or clayey soils are also present. Soil depths range from shallow to deep, but for the most part are moderately deep to deep (20 to greater than 40 inches). The soils are generally poorly to moderately well drained in the major valleys. Examples of such soils are Minvale, Fullerton, and associated soils. The upland soils, such as Hartsells, Albertville, Hector, Townley, and associated soils, are moderately well to somewhat excessively drained. The erosion hazard is generally slight to moderate for most soils of the Plateau, but can be severe for some soils. Some soil associations occur both on the Cumberland Plateau and in the Ridge and Valley.

Soils of the Ridge and Valley (table 2.4-1) are formed from limestone, dolomite, sandstone and shale. The soils are dominantly loamy with some cherty and clayey soils present. Most soil depths range from moderately deep to deep (20 to greater than 40 inches). The upland soils of the ridges, such as Sequoia, Shack, Jefferson, and associated soils, are moderately well to well drained. Soils on slopes and sharply dissected uplands, Wallen and Bodine, are well to excessively drained. The erosion hazard is generally slight to moderate for most soils, but can be severe for some soils.

Other characteristics of the soils throughout Area 20 vary greatly. The soils are acid with pH values ranging from 3.6 to 6.5 units. However, the Talbott series can have a pH of 7.8 units. The permeability is very slow to rapid, ranging from 0.06 to greater than 6.0 inches/hour. Available water capacities range from 0.02 to 0.24 inches/inch (table 2.4-1). The hydrologic soil groups (table 2.4-2) are based on the infiltration rate for a bare soil after prolonged wetting (Mockus, 1964). Group B soils have moderate infiltration rates. Group C soils have slow infiltration rates. Group D indicates very slow infiltration, causing high runoff.

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



BASE FROM U.S. GEOLOGICAL SURVEY STATE BASE MAPS; TENNESSEE 1973, ALABAMA AND GEORGIA, 1966

Soils from Elder and Springer (1978), Perkins and Shaffer (1977), and Hajek, Gilbert, and Steers (1975); modified by Beatty and Bradley, 1981

Figure 2.4-1 Soil associations.

Table 2.4-2 Hydrologic soil group

Soil	Group	Soil	Group
Albertville	C	Litz	C
Allen	B	Lonewood	B
Bodine	B	Lyerly	D
Bouldin	B	Minvale	B
Cartecay	C	Montevallo	D
Colbert	D	Nella	B
Conasauga	C	Ramsey	D
Cunningham	C	Sequatchie	B
Dewey	B	Sequoia	C
Etowah	B	Shack	B
Firestone	C	Talbott	C
Fullerton	B	Toccoa	B
Gilpin	C	Townley	C
Hartsells	B	Wallen	C
Hector	D	Waynesboro	B
Jefferson	B	Wehadkee	D
Linker	B	Wolftever	C

B, Moderate infiltration rate; C, slow infiltration rate; D, very slow infiltration rate (Mockus, 1964)

Table 2.4-1 Soil associations

Soil association	Depth to Bedrock (in)	pH units	Permeability (in/h)	Available water capacity (in/in)	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	.05-.20	Loam soils over sandstone and shale
Hartsells-Ramsey-Gilpin	10-40	3.6-5.5	0.6-2.0 Ramsey 6.0-20.0	.06-.18	Loam soils over 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	.06-.12	Loam and stony soils underlain by sandstone, shale and alluvium. Also occurs in the Ridge and Valley of Georgia.
Nella-Townley-Hector	10-40 Nella > 60	3.6-6.5	.06-6.0	.05-.18	Loam soils from colluvium underlain by sandstone. Also present in Ridge and Valley of Georgia.
Hartsells-Linker-Albertville	20-40 Albertville 40-60	3.6-5.5	0.2-6.0	.08-.24	Clay loam soils underlain by sandstone and shale
Hartsells-Hector	10-40	3.6-6.5	0.6-6.0	.05-.18	Sandy loam soils over sandstone with limestone outcrops
Hector-Allen	10-20 Allen > 60	4.5-6.5	0.6-6.0	.05-.19	Loam soils over sandstone with limestone outcrops
Waynesboro-Etowah-Sequatchie-Allen	60-80	4.5-5.5	0.6-.20	.09-.20	Loam and clay from alluvium and colluvium. It also occurs in the Ridge and Valley of Tennessee.
Cartecay-Toccoa-Wehadkee	> 60	4.5-6.5	0.6-6.0 Cartecay 2.0-20.0	.06-.20	Loam and sandy loam soils formed in thick alluvial sediments
Soil Associations of the Ridge and Valley					
Colbert-Conasauga-Firestone	20-60	3.6-6.5 Colbert 5.1-7.3	.06-2.0	.08-.24	Silty clay and loam soils over limestone and shale. Also occurs along Wills Valley in the Cumberland Plateau in Alabama.
Minvale-Fullerton	> 60	4.5-5.5	0.6-6.0	.08-.20	Cherty loam soils over limestone and dolomite. Also occurs along Wills and Sequatchie Valleys in the Cumberland Plateau in Alabama.
Talbott-Etowah	Talbott 20-40 Etowah 72	5.1-7.8 4.5-5.5	0.6-2.0	.10-.20	Clay and loam soils from limestone and shale with limestone outcrops
Litz-Sequoia-Talbott	20-40	4.5-5.5 Talbott 5.1-7.8	0.2-2.0	.04-.20	Silt and clay loam soils over limestone and shale.
Conasauga-Lyerly-Wolftever	20-40 Wolftever > 60	3.6-6.5 Lyerly 4.5-7.3	< .06-2.0	.08-.24	Silt loam soils over limestone and shale Also present in Wills Valley in the Cumberland Plateau of Georgia.
Townley-Montevallo-Cunningham	10-40 Cunningham 40-60	3.6-6.0	.06-2.0	.02-.22	Loam soils underlain by shale and siltstone
Fullerton-Bodine	60-100	3.6-5.3	0.6-6.0	.05-.16	Chert and clay soils over dolomite and limestone
Fullerton-Dewey	60-100	3.6-5.5	0.6-2.0	.10-.20	Chert and clay soils over dolomite and limestone
Shack-Fullerton-Bodine	> 60	3.6-6.0	0.6-6.0	.05-.18	Cherty silt and clay loam soils over limestone and dolomite
Wallen-Talbott-Montevallo	10-40	4.5-6.0	0.6-6.0	.02-.18	Excessively well drained, stony and clay soils over limestone, shale, and sandstone
Ramsey-Wallen-Jefferson	10-40 Jefferson > 60	4.5-5.4	2.0-6.0 Ramsey 6.0-20.0	.05-.16	Gravelly loam soils from colluvium over sandstone
Nella-Townley-Hector	10-40 Nella > 60	3.6-6.5	.06-6.0	.05-.18	Loam soils from colluvium underlain by sandstone. Also present in Cumberland Plateau of Georgia.

(unpublished)

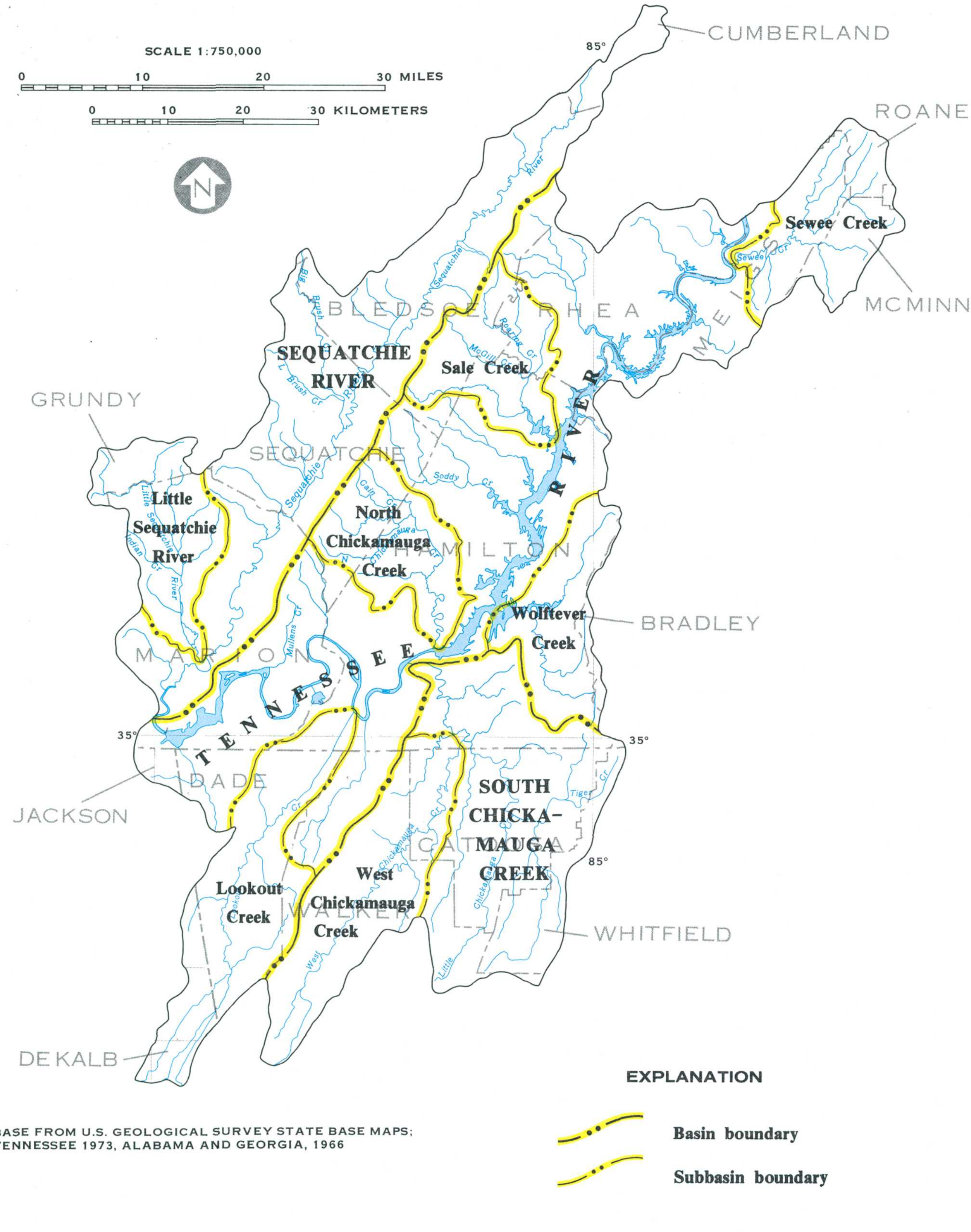
Data from Soil Conservation Service Soil Interpretation Records (SCS-SOILS-5)

All Surface Drainage in Area 20 Flows into the Tennessee River

The Tennessee and Sequatchie Rivers and South Chickamauga Creek are the largest streams.

Area 20 has a total surface drainage of 2,450 mi^2. All surface drainage is to the Tennessee River which enters the northeast edge of Area 20 and flows southwesterly through the area. South Chickamauga Creek and its tributaries drain 464 mi^2, 19 percent of the area. Sequatchie River and its tributaries drain 605 mi^2, 25 percent of the area. The Tennessee River receives flow from 17,310 mi^2 before entering Area 20. Some of this upstream area is affected by coal mining. In addition, the Hiwassee River enters Area 20 at Tennessee River mile 499.4 near the town of Sale Creek and contributes flow from 2,700 mi^2 not affected by coal mining. The entire drainage basins for all the streams in Area 20, except the Tennessee River basin are contained within the area. The principal sub-basins of the area are listed below and are shown in figure 2.5-1.

Sub-basin	Drainage Area (mi^2)
Cumberland Plateau	
Sale Creek	116
North Chickamauga Creek	121
Lookout Creek	187
Little Sequatchie River	132
Sequatchie River	473
Ridge and Valley	
Sewee Creek	123
Wolftever Creek	101
West Chickamauga Creek	175
South Chickamauga Creek	289
Tennessee River (within Area 20)	733
Total Area 20	2,450



BASE FROM U.S. GEOLOGICAL SURVEY STATE BASE MAPS; TENNESSEE 1973, ALABAMA AND GEORGIA, 1966

Figure 2.5-1 Drainage basins.

Forest Covers Most of the Cumberland Plateau

Land-use maps are available for most of the Cumberland Plateau in Area 20. Of this mapped area, forest accounts for approximately 75 percent of the land cover.

The Cumberland Plateau west of Wills Valley is approximately 75 percent forest and 20 percent agriculture and open land (fig. 2.6-1). Hales Bar Lake occupies 2 percent, urban and rural residential 2 percent, and mining 1 percent. Native forest is predominantly hardwoods, whereas evergreen forest is mostly in tree farms on Walden Ridge. Agriculture is dominant in the Sequatchie Valley. Urban areas occur in small towns in the Sequatchie Valley and in suburbs of Chattanooga, north of Hales Bar Lake, and along the east edge of Walden Ridge. Mining is evenly distributed throughout the uplands. This information is based upon an analysis of high-altitude aerial photography collected between 1974 and 1976. The land-use maps resulting from this analysis are available from:

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

A map index showing the availability of maps in the U.S. Geological Survey land use and land cover series is available from:

Branch of Distribution
U.S. Geological Survey
1200 South Eads Street
Arlington, VA 22202

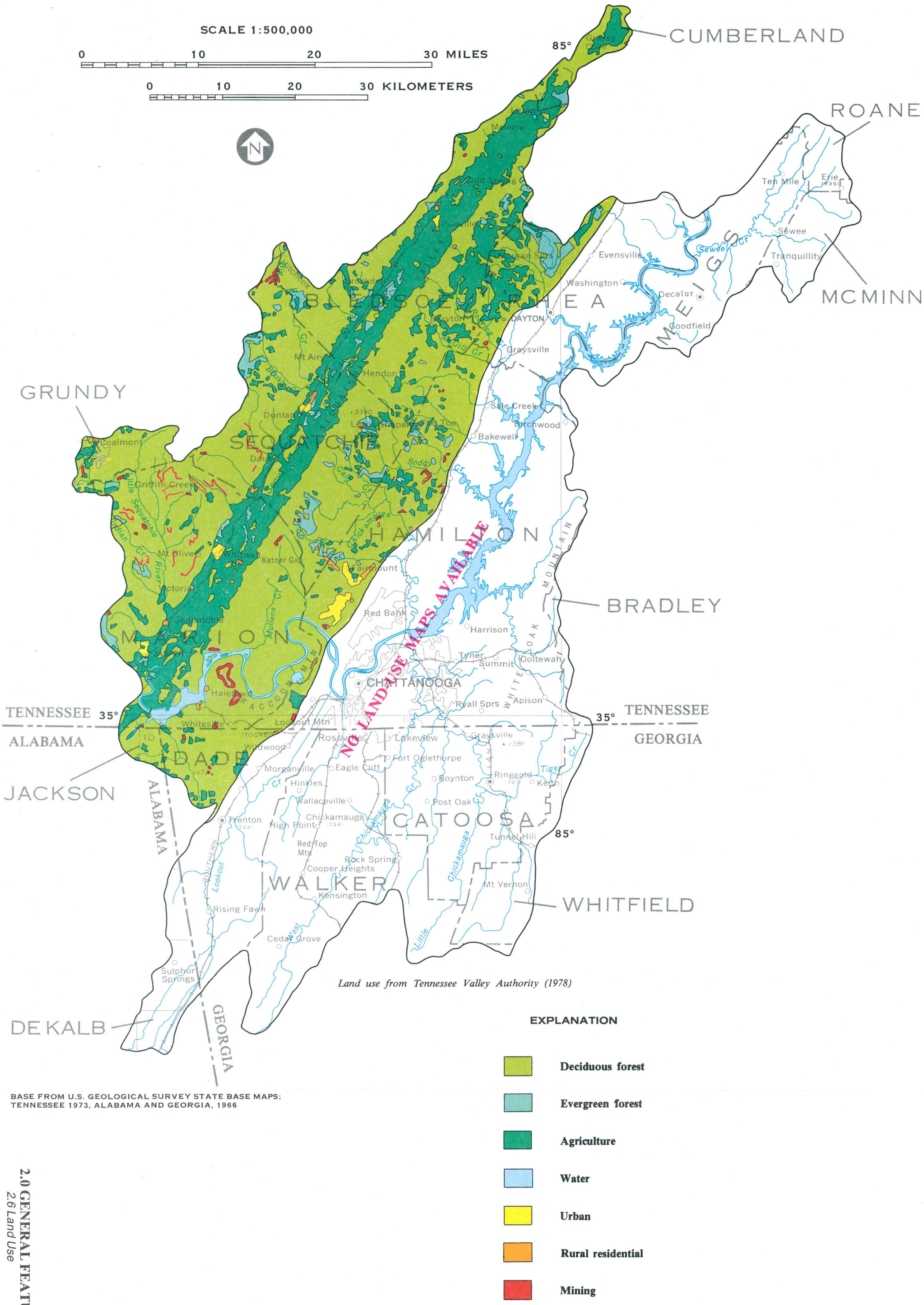


Figure 2.6-1 Land use in the western half of Area 20.

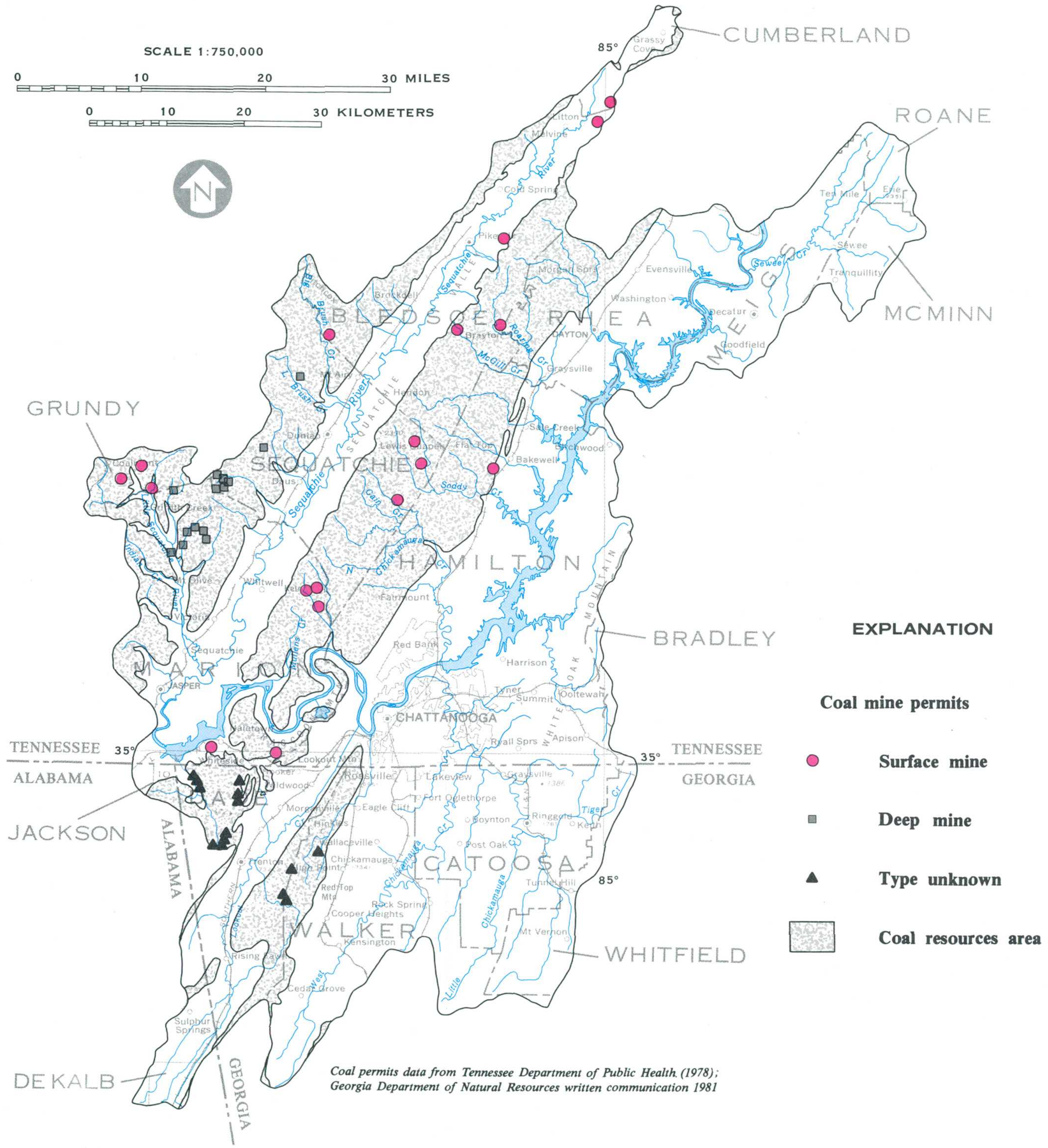
Coal-Mining Activities Occur Throughout Cumberland Plateau

Both surface and underground mines are operated in Tennessee; no mines are operated in Alabama in Area 20; permits have been issued in Georgia but data are not available as to type or activity.

Locations of active mines in Tennessee (Tennessee Department of Public Health, 1978) and locations of mines for which permits have been issued by the Georgia Department of Natural Resources (written commun., 1981) since 1969 are shown in figure 2.7-1. Eighteen surface mines and 14 deep mines were approved for operation in Tennessee as of 1978. Fourteen permits have been issued in Georgia since 1969 but data are not available as to type, or as to activity. There is no mining activity in Area 20 in Alabama.

The commonly used mining method in many parts of Area 20 is surface mining which is done by stripping along the sides of hills and mountains (contour mining) where the coal seams are mined as far back into the mountain as it 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, highwalls (vertical to near vertical bare earth and rock walls created by slicing a strip off the side of a mountain), benches (level to near level floor of the stripped area used for access and hauling), and spoil piles (unstable, loose earth and rocks pushed or dumped on the bench or down the mountainside). Alteration to the environment can be lessened by reclaiming the mined area during or after mining.



BASE FROM U.S. GEOLOGICAL SURVEY STATE BASE MAPS; TENNESSEE 1973, ALABAMA AND GEORGIA, 1966

Figure 2.7-1 Coal-mining activities.

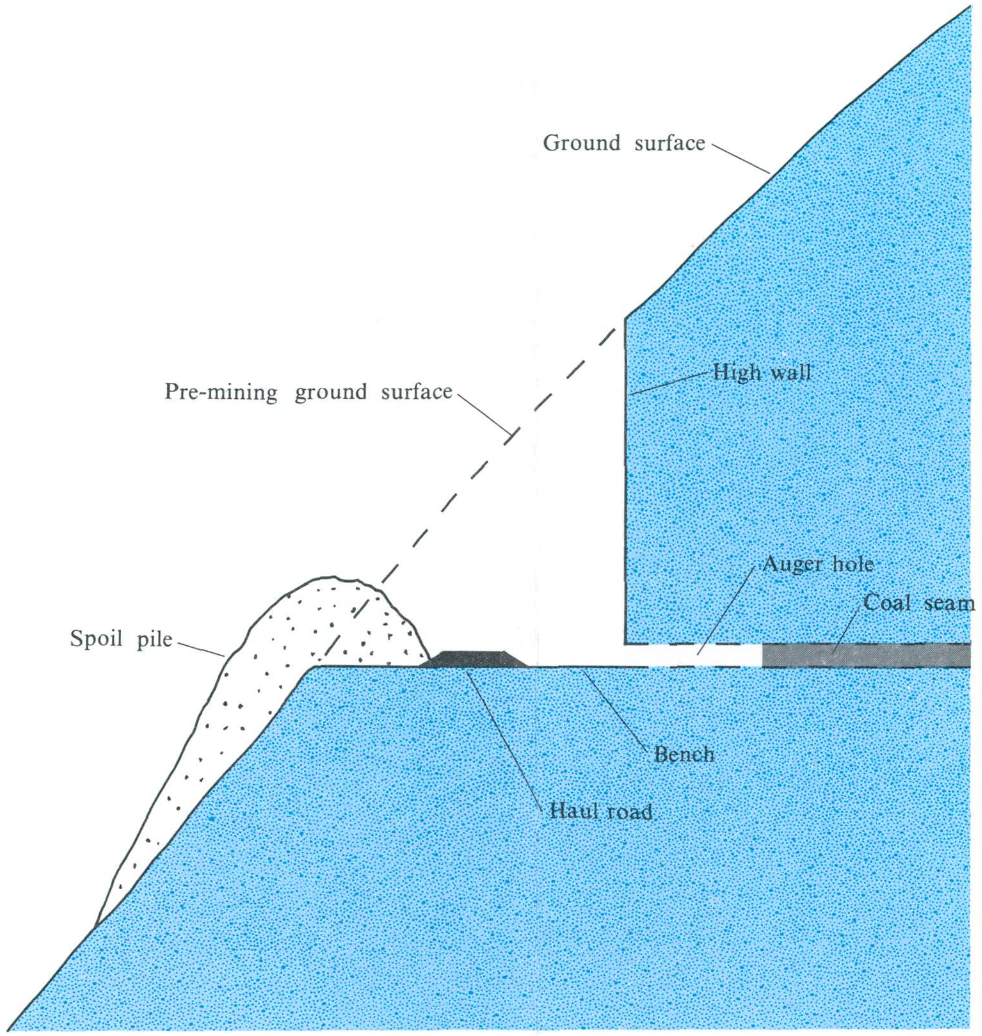


Fig. 2.7-2 Typical contour (strip) mining site.

Information on Streams Available for 142 Locations

Streamflow data for many sites in Area 20 have been collected for more than 30 years with most of the water-quality and suspended-sediment data collected within the last 6 years.

Streamflow, water-quality or suspended-sediment data are available for 142 sites in Tennessee and Georgia in Area 20 (fig. 3.1-1). No data are available for the Alabama part of Area 20. Many streamflow sites have been operated for more than 30 years. Most water-quality and suspended-sediment information has been collected in the last 6 years. The location of each data-collection site, period of operation, type of record, and other pertinent information are included in section 10.1. In 1979, in response to the Act, the Tennessee and Georgia networks were expanded by 14 and 15 additional sites, respectively.

Streamflow data may include:

- continuous records of stages and discharges,
- records of flood stages and flood discharges, and
- measurements of discharge at various stages.

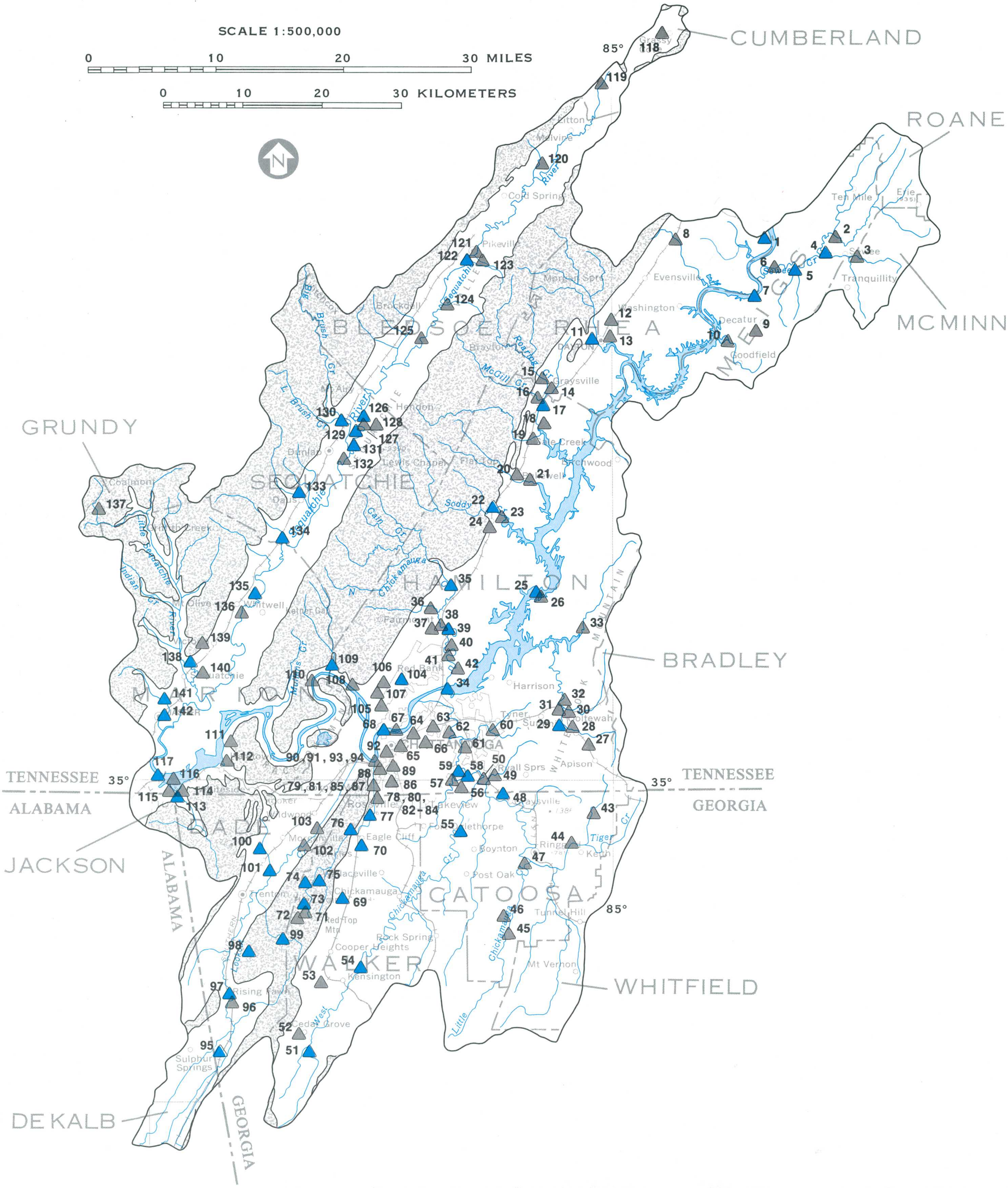
Water-quality information is available for 59 sites in Area 20. Water-quality information includes water temperature, specific conductance, pH, dissolved major chemical constituents, dissolved and total recoverable trace constituents, and trace constituents in bottom material from streams. Suspended-sediment data are available for 31 sites active in 1980.

Information in addition to that given in section 10.1 can be obtained from U.S. Geological Survey computer files through the National Water Data Exchange (NAWDEX, see section 8.2) or from the annual data publications "Water Resources Data for Tennessee" or "Water Resources Data for Georgia", available from:

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

or

U.S. Geological Survey
Water Resources Division
6481 Peachtree Industrial Blvd.
Suite B
Doraville, GA 30360



BASE FROM U.S. GEOLOGICAL SURVEY STATE BASE MAPS;
TENNESSEE 1973, ALABAMA AND GEORGIA, 1966

EXPLANATION

Site and number

55 **Active**

47 **Inactive**

Coal resources area

See section 10.1 for detailed site description.

Figure 3.1-1 Surface-water network.

Ground-Water Data Available for 35 Wells and 12 Springs

Ground-water data may include geologic source, water-level measurements, water-quality analyses, and discharge measurements of springs.

Water-level, discharge, and (or) water-quality data are available for 35 wells and 12 springs in Area 20 (fig. 3.2-1). No data are currently being collected from wells or springs in the coal resources area. However, data have been collected from 19 wells and 5 springs throughout the Cumberland Plateau, and for 16 wells and 7 springs in the Ridge and Valley. Water-level data are currently being collected from two wells in the Ridge and Valley.

Types of information available for wells may include:

- geologic source,
- periodic or continuous water-level measurements, and
- water-quality analyses.

Discharge data are available for 12 springs. Site information and data can be obtained from the U.S. Geological Survey computer files through the National Water Data Exchange (NAWDEX) or from the annual data publication "Water Resources Data for Tennessee", "Water Resources Data for Georgia", and "Water Resources Data for Alabama" available from:

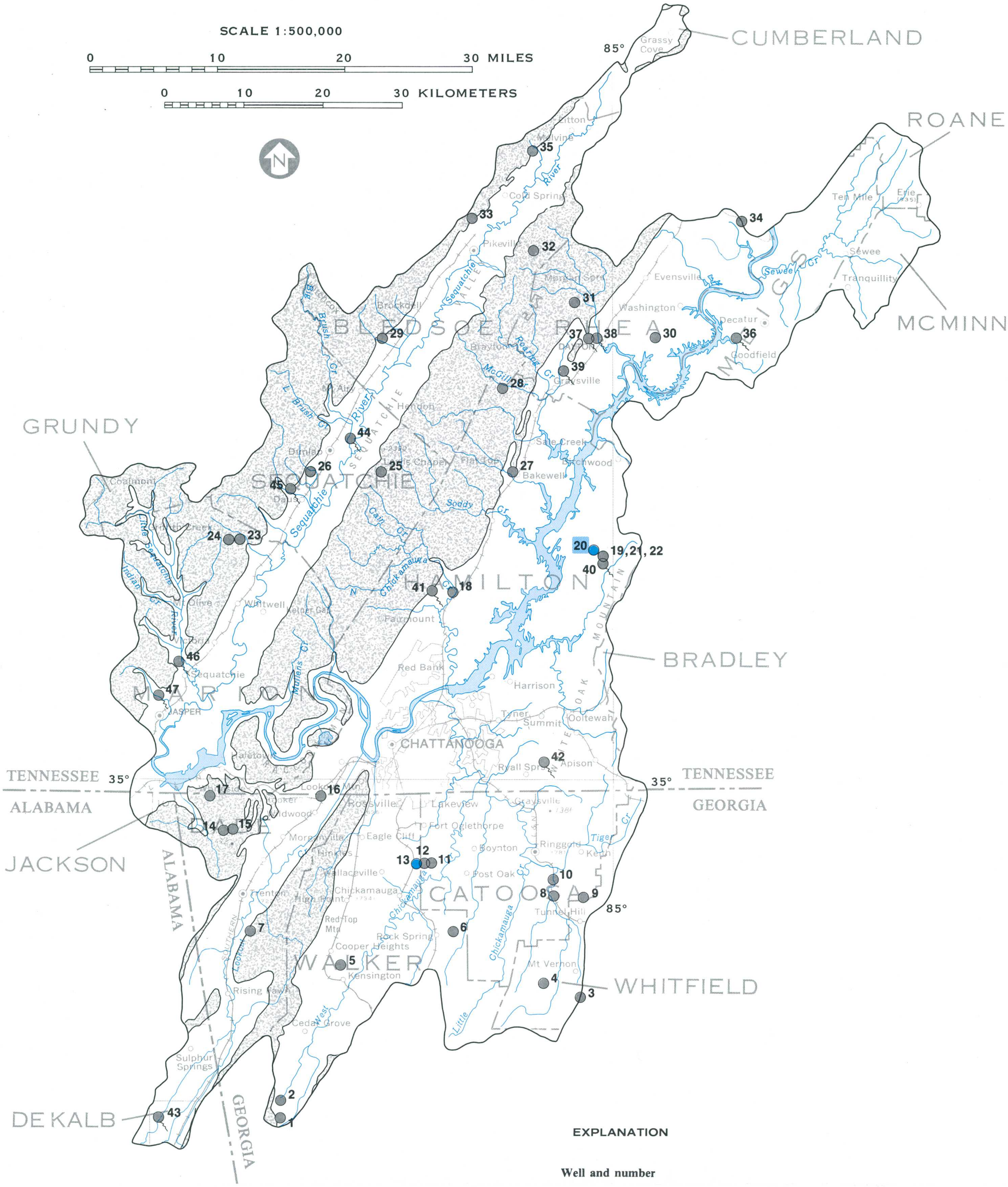
U.S. Geological Survey
Water Resources Division
A-413 Federal Building
U.S. Courthouse
Nashville, TN 37203

or

U.S. Geological Survey
Water Resources Division
6481 Peachtree Industrial Blvd.
Suite B
Doraville, GA 30360

or

U.S. Geological Survey
Water Resources Division
520 19th Avenue
Tuscaloosa, AL 35401



BASE FROM U.S. GEOLOGICAL SURVEY STATE BASE MAPS;
TENNESSEE 1973, ALABAMA AND GEORGIA, 1966

EXPLANATION

Well and number

- 13 **Active**
- 12 **Inactive**
- 20 **Recording**

Spring and number

- 42 **Inactive**
- **Coal resources area**

See section 10.2 for detailed site description.

Figure 3.2-1 Ground-water network.

Streamflow Varies with Season and Basin

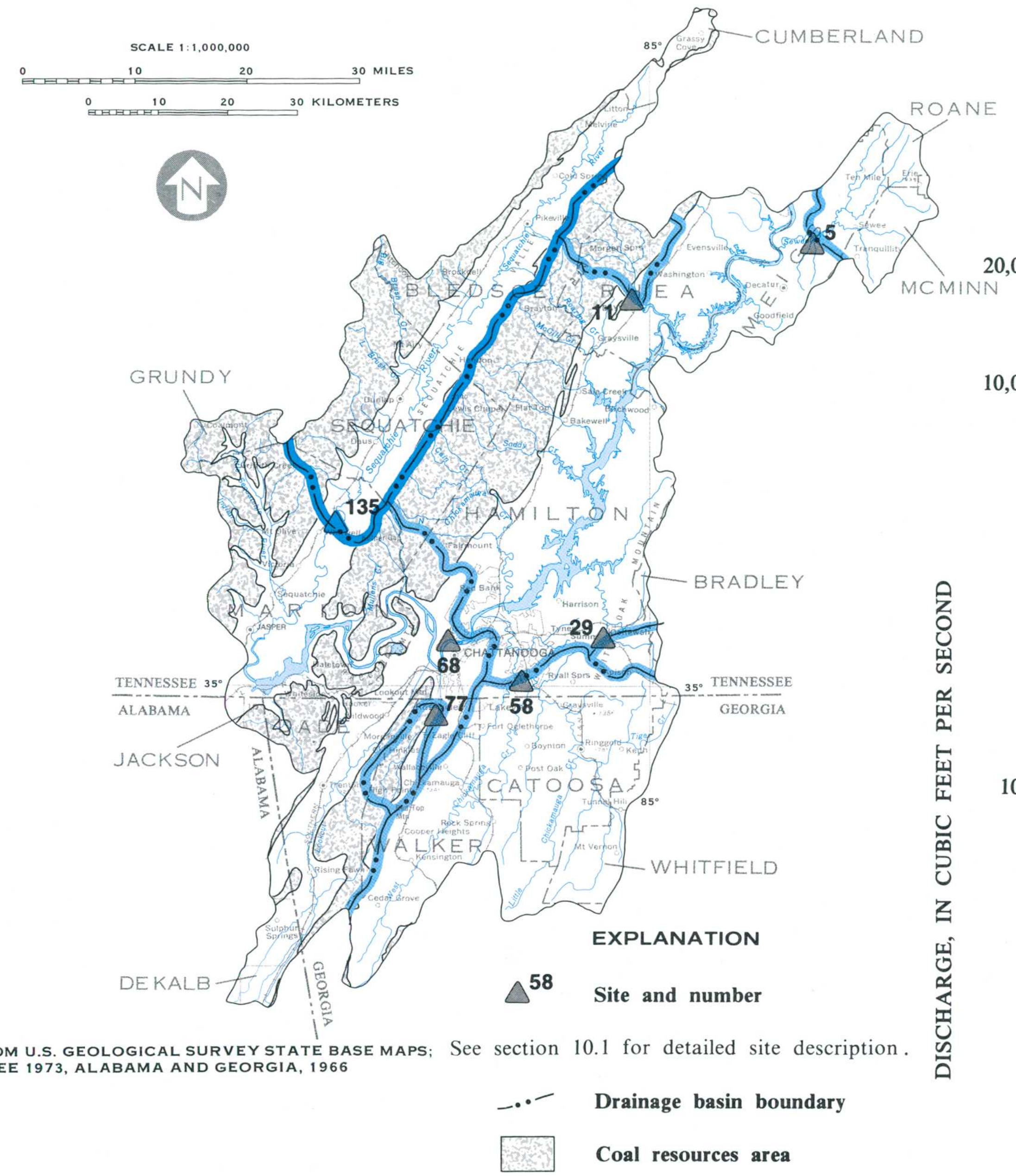
Streamflow varies seasonally in a pattern similar to the variation in rainfall and evapotranspiration and because of differences in drainage basin size, geology, and other physical characteristics.

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 discharge 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 (Tennessee Division of Water Resources, 1961). Thus the average annual runoff for Area 20 is about 24 inches.

Area 20 is in two physiographic sections (fig. 4.1-1) which have significant differences in topography, slope, soils, and geology. These factors, along with differences in drainage basin size, contribute to the variability of flow from stream to stream, especially during extended periods of no rainfall. Streamflow varies seasonally in a pattern similar to the variation in rainfall.

Mean monthly discharge expressed as a percentage of the annual mean, the annual mean, and the drainage area are shown in table 4.1-1 for selected sites in the area. No significant physiographic trends can be detected in this table except that the mean flow for the fall months, which are usually dry, seem to be small for Richland Creek near Dayton (site 11) whose drainage basin lies mostly in the coal resources area. This table also illustrates the seasonal flow variability of individual streams.

The flow variability in the Sequatchie River near Whitwell (site 135) during the 1977 water year (October 1976 to September 1977), shown by the hydrograph in figure 4.1-2, is typical for the area. The maximum and minimum instantaneous discharge, and the average discharge for the year as well as for the period of record 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 1977. The long-term seasonal flow variability of Sequatchie River near Whitwell is illustrated in figure 4.1-4.



BASE FROM U.S. GEOLOGICAL SURVEY STATE BASE MAPS; TENNESSEE 1973, ALABAMA AND GEORGIA, 1966

Figure 4.1-1 Location of selected sites and drainage basins.

Table 4.1-1 Percent of annual mean discharge occurring in indicated month

Site number	Drainage area (mi²)	Annual mean discharge (ft³/s)	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
5	117	196	2.34	5.30	10.3	15.5	17.1	18.0	12.1	6.65	3.73	4.09	2.42	2.41
11	50.2	105	1.21	4.91	12.0	18.8	19.0	17.3	11.6	6.19	2.70	3.44	1.79	1.12
29	18.8	34.7	3.43	6.37	10.4	14.7	13.5	20.0	11.2	6.66	3.26	4.19	1.97	4.37
58	428	703	3.16	5.83	9.32	15.0	16.8	17.1	11.6	7.06	3.90	4.15	2.75	3.39
68	21,400	38,420	3.41	4.72	7.88	12.2	14.1	15.5	12.8	8.51	6.51	5.61	4.90	3.80
77	50.6	86.6	1.89	4.72	10.4	14.9	19.4	18.6	14.2	7.48	2.83	2.68	1.42	1.48
135	402	751	1.92	5.15	10.6	15.3	16.9	18.5	13.3	7.44	3.84	2.91	2.25	1.85

See section 10.1 for detailed site description.

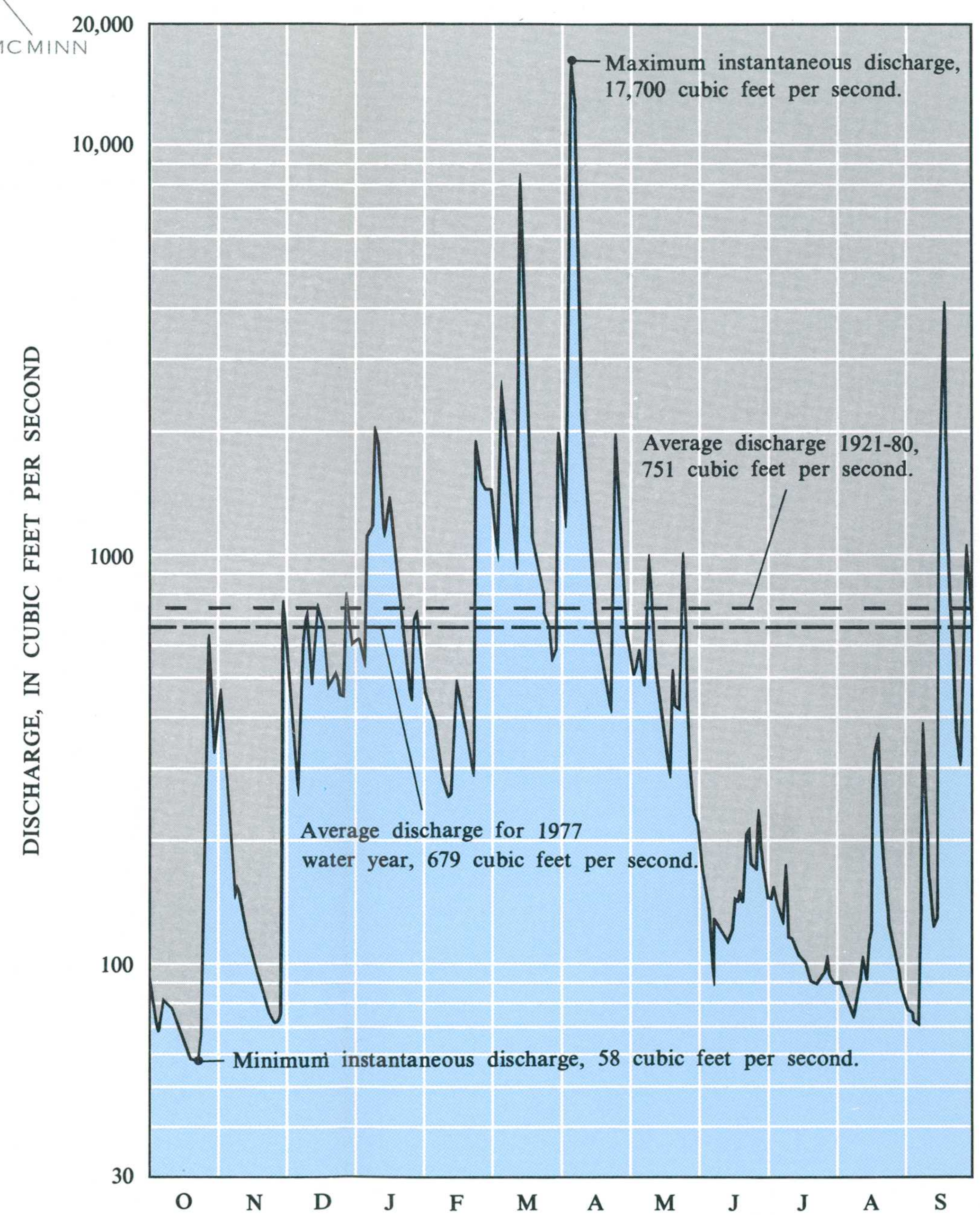


Figure 4.1-2 Discharge hydrograph for Sequatchie River near Whitwell, Tenn. (site 135), for 1977 water year.

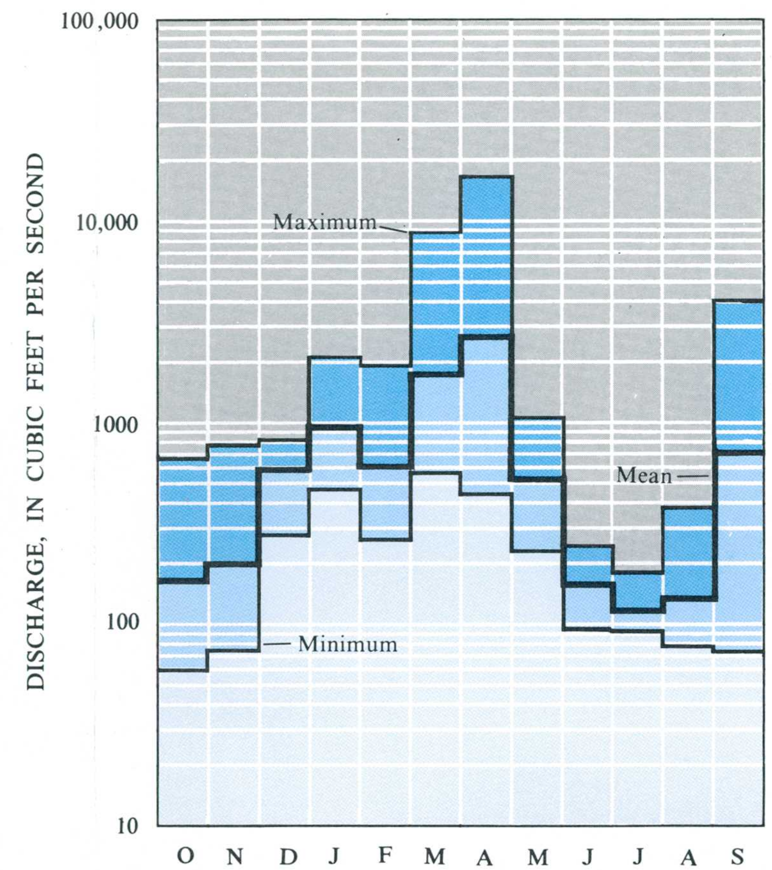


Figure 4.1-3 Monthly range in daily flow for the 1977 water year, Sequatchie River near Whitwell, Tenn. (site 135).

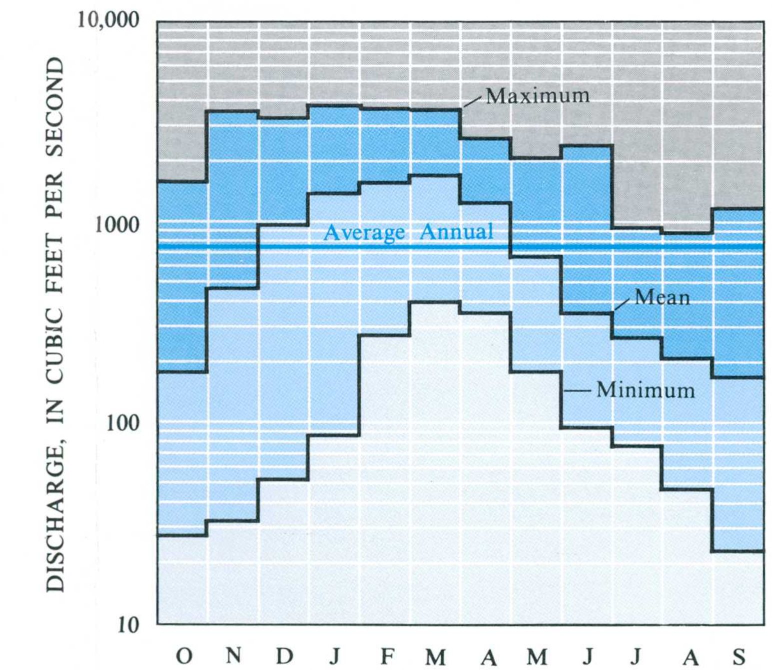


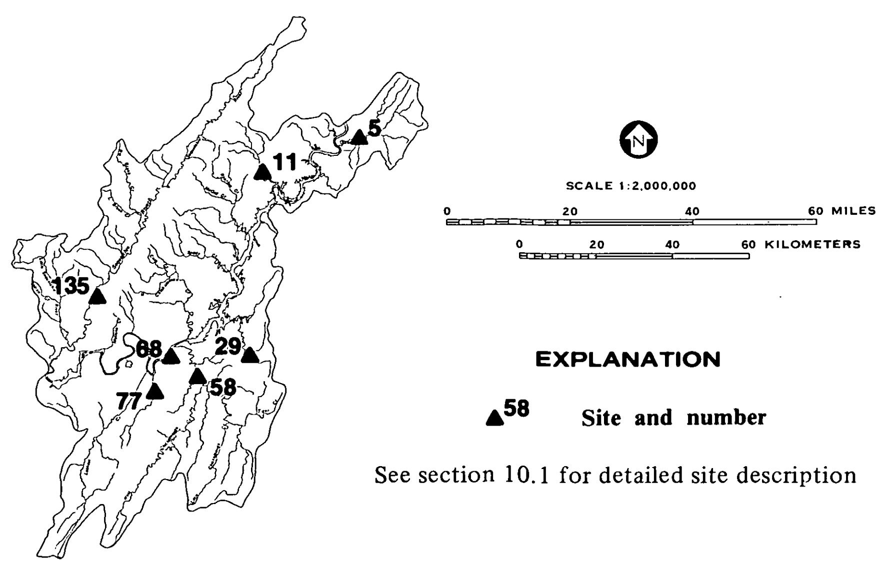
Figure 4.1-4 Range in monthly flows for the period 1921-80, Sequatchie River near Whitwell, Tenn. (site 135).

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 20; however, the minimum monthly flow per square mile is smaller for streams in the coal area.

The average annual flow in cubic feet per second per square mile has been computed for several streams having various size drainage basins (fig. 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 may be made. The average annual flow is about 2 $(ft^3/s)/mi^2$ for all sites.

The average annual flow of streams may be useful but for most purposes monthly flows are more useful. In addition to drainage basin size, seasonal variations in rainfall affect monthly flows. For streams in Area 20, the seasonal variability of the mean and maximum monthly flows per square mile is similar (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 flows especially during the dry months. The minimum monthly flows per square mile for the dry months are much smaller for streams in the coal resources area than for streams elsewhere as evidenced by Richland Creek near Dayton (site 11), whose drainage basin lies on Walden Ridge, an upland of the Cumberland Plateau Section. The flow of streams in the coal resources area is not well sustained during periods of no rainfall. This is a result of a variable combination of infiltration qualities of the land surface and the ability of the underground reservoirs to store and release water.



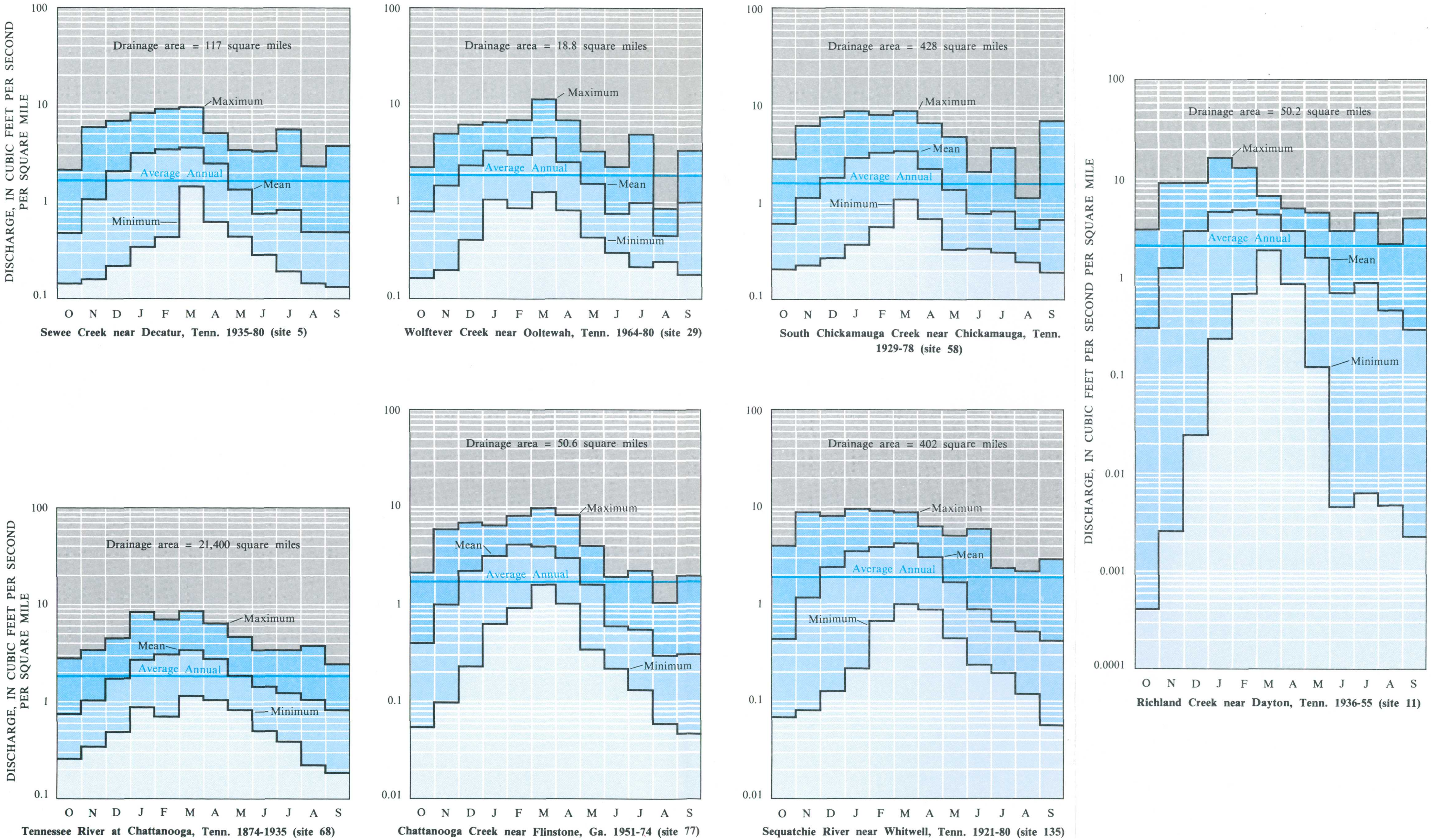


Figure 4.2-1 Average annual and range in monthly flow per square mile at selected sites.

Streams in the Coal Resources Area Have Smaller Yields than Streams Elsewhere During Low Flow

The 3-day 20-year and the 7-day 10-year recurrence interval low flows are smaller for streams in the coal resources area than elsewhere.

The low-flow characteristics of ungaged streams in Area 20 are difficult to define because they are not readily susceptible to regionalization. This is because low flows are 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 continuous-record streamflow data. Low-flow frequency is expressed as the lowest average flow for a given number of consecutive days for a given recurrence interval. The 3-day 20-year low flow, a commonly used index in Tennessee, is shown in figure 4.3-1 for selected stream reaches in Area 20. There are many small streams in Area 20 for which the 3-day 20-year low flow is less than one cubic foot per second, but no actual data are available. The low flows of streams in the coal resources area are generally less than for streams in the Ridge and Valley.

Another common index of low flow is the 7-day 10-year recurrence interval flow. There is no exact relationship between the two indices but the 7-day 10-year recurrence interval flow is larger than the 3-day 20-year recurrence interval flow. The two low-flow indices are shown for several sites in Area 20 in table 4.3-1. The locations of these sites are shown on figure 4.3-1.

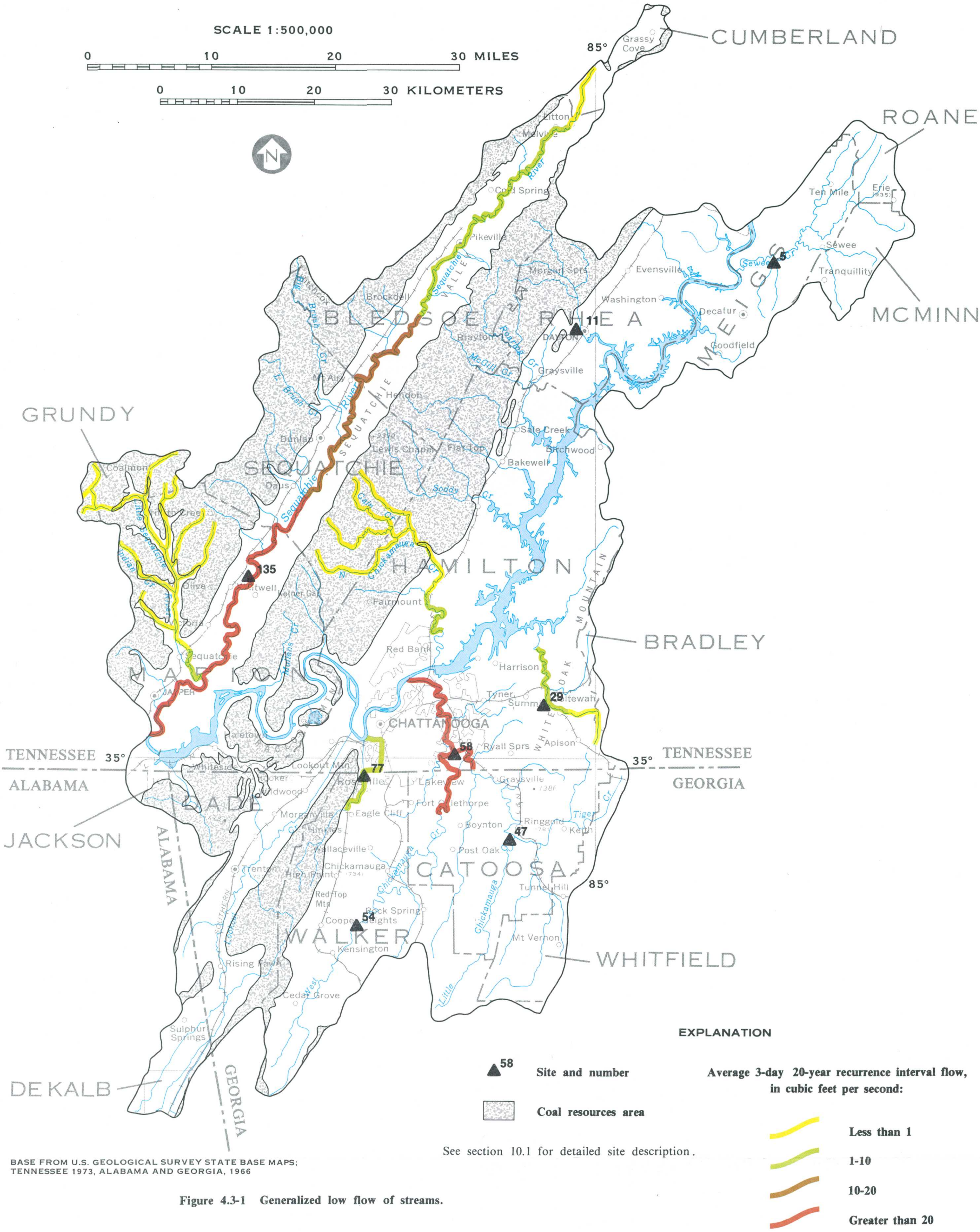


Figure 4.3-1 Generalized low flow of streams.

Table 4.3-1 Low flows for selected streams

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)
5	Sewee Creek near Decatur, Tenn.	117	12.9	14.5
11	Richland Creek near Dayton, Tenn.	50.2	.019	.039
29	Wolftever Creek near Ooltewah, Tenn.	18.8	2.34	2.63
47	South Chickamauga Creek at Ringgold, Ga.	169	--	3.8
54	West Chickamauga Creek near Kensington, Ga.	73.0	--	5.6
58	South Chickamauga Creek near Chickamauga, Tenn.	428	85.9	88.3
77	Chattanooga Creek near Flintstone, Ga.	50.6	2.92	2.99
135	Sequatchie River near Whitwell, Tenn.	402	26.7	32.2

Floods Occur Seasonally and Magnitude Varies with Basin Size

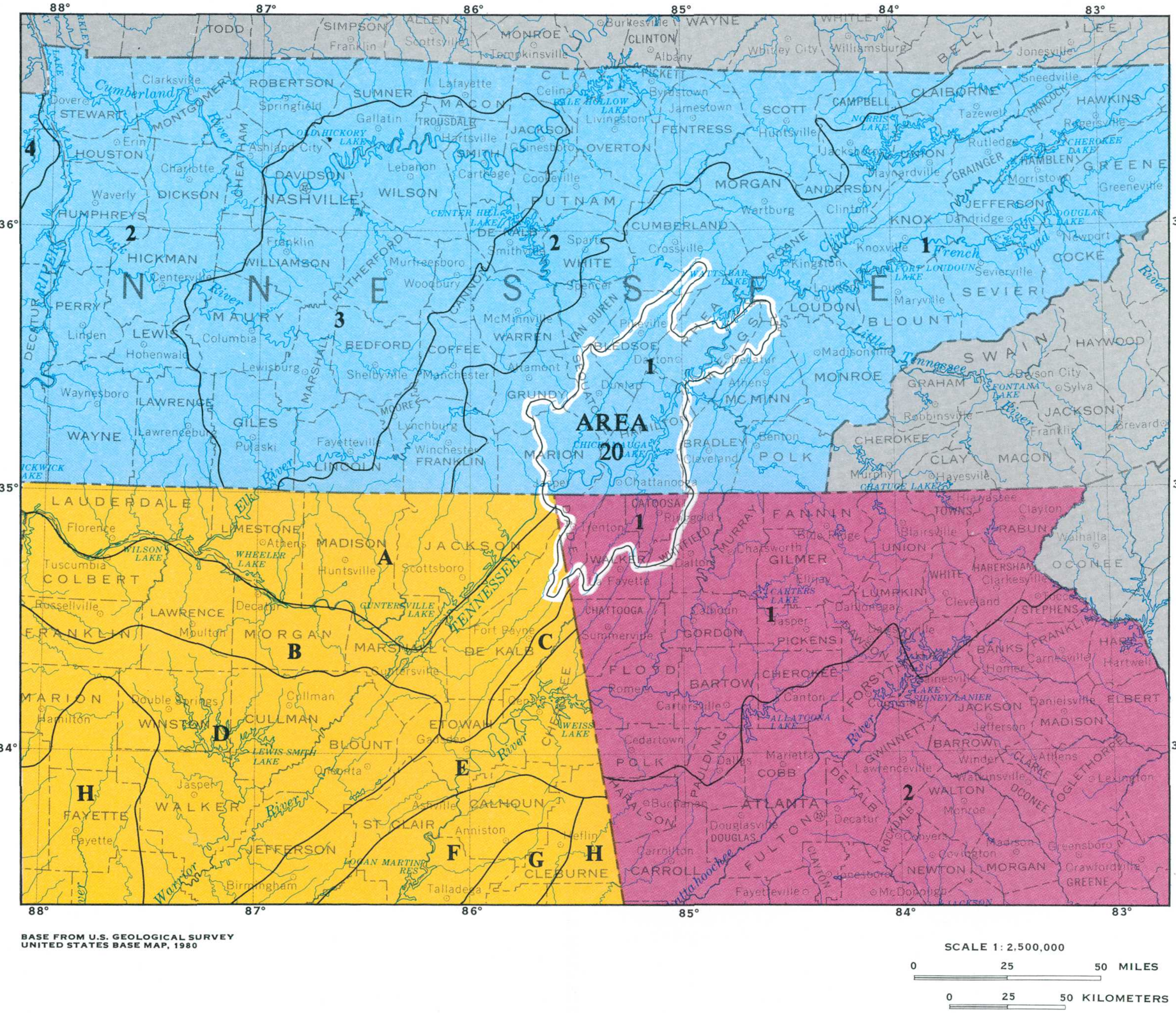
Most floods occur in the winter and spring. Techniques have been developed for estimating flood frequencies.

The range in maximum known floods observed in Area 20 for a given drainage basin size is about one-half of an order of magnitude (fig. 4.4.1-1). For example, at 100 square miles the approximate range in discharge is from 10,000 ft^3/s to 30,000 ft^3/s. The occurrence of floods is a natural, random phenomenon, and larger floods than those observed can occur at any time.

Floods occur in Area 20 in any month of the year. However, about 50 percent of the annual peaks occur during the period February and March and about 80 percent occur during the longer period December through April (fig. 4.4.1-2). Twenty-eight percent of the annual peaks occur in March. Only about 3 percent of the annual peaks occur during the period August through October.

Methods for estimating the flood-frequency characteristics of natural streams in Area 20 are contained in reports for Alabama by Hains (1973), and Olin and Bingham (1977); for Georgia by Price (1979); and for Tennessee by Randolph and Gamble (1976). Methods and results vary somewhat between states but in general all gaging station records of 10 or more years in length and not significantly affected by manmade changes were analyzed. Each state was divided into hydrologic areas having distinct flood-frequency characteristics. Area 20 is composed of parts of three of these areas (fig. 4.4.1-3). The results of the analysis generally take the form of equations relating discharge for a given recurrence interval to significant basin characteristics. The computed relationship between the 50-year flood and size of the drainage basin for Georgia and Tennessee streams is also shown in figure 4.4.1-1 for comparison. The discharge-frequency relation for Alabama involves additional variables other than drainage area and can not readily be shown graphically. Recurrence interval is defined as the average interval of time, in years, within which the given flood magnitude will be equaled or exceeded once. 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.

The discharge-frequency relation for ungaged sites where parts of the basin are in different states can be estimated by computing the desired discharge as if the total drainage area lies in each state and weighting the discharge on the percentage of drainage area in each state. Various other refinements and adjustments are given in the individual reports.



EXPLANATION

TENNESSEE Hydrologic areas, from Randolph and Gamble, 1976

GEORGIA Hydrologic areas, from Price, 1977

ALABAMA Hydrologic areas, from Hains, 1973

Figure 4.4.1-3 Flood-frequency hydrologic areas.

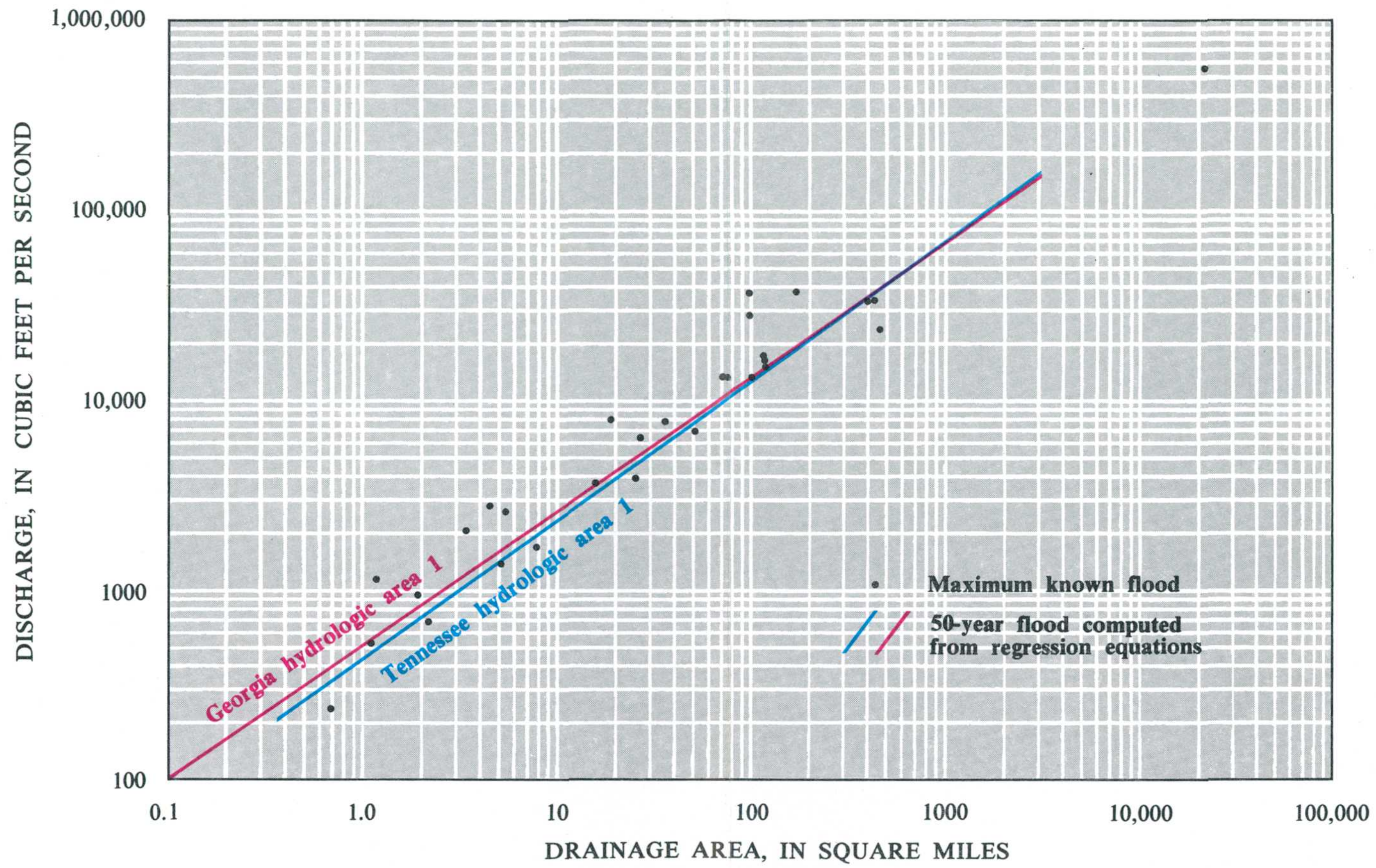


Figure 4.4.1-1 Relation of maximum known floods and 50-year flood to drainage area.

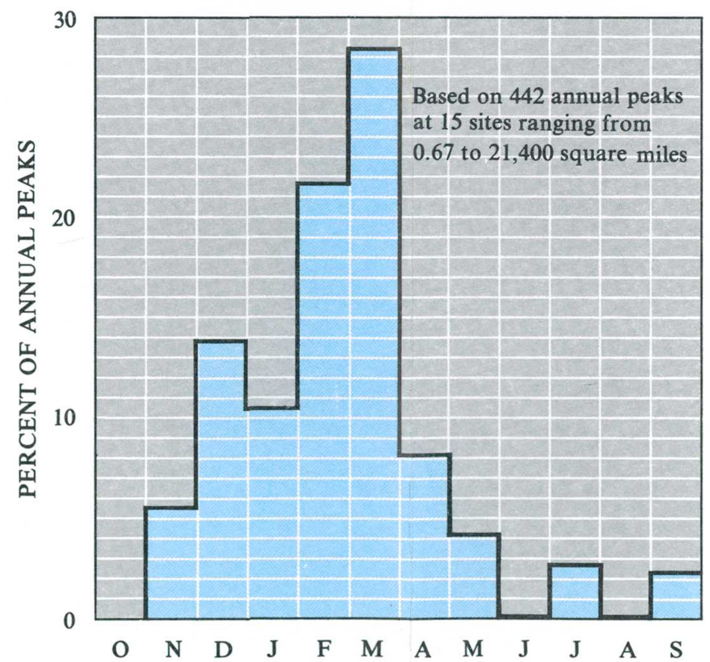


Figure 4.4.1-2 Seasonal distribution of floods.

100-Year Flood Depths Predictable

Methods for predicting 100-year flood depths are available. Flood-prone area maps are available for selected areas.

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

A method was developed by Gamble and Lewis (1977) for Tennessee, by Price (1977) for Georgia, and by Hains (1976) for Alabama to estimate depth (feet) of the 100-year flood on natural streams unaffected by works of man. Equations were developed which relate 100-year flood depth to drainage basin size. Each state was divided into several hydrologic areas. Area 20 is in parts of five of these areas (fig. 4.4.2-1). The equation for computing flood depth for each hydrologic area is shown along with the basin size 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, where no other data were available. It can be used to estimate the depth of the 100-year flood for any purpose where extreme accuracy is not necessary. The location of maps within Area 20 depicting the flood-prone area of the maximum known flood or the 100-year flood is indicated by shading in figure 4.4.2-2.

The Tennessee Valley Authority also mapped some flood-prone areas in 1973 (fig. 4.4.2-2) using the 100-year flood. 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 Geological Survey may be obtained from:

(Alabama maps)
U.S. Geological Survey
Water Resources Division
520 19th Avenue
Tuscaloosa, AL 35401

(Georgia maps)
Georgia Department of Natural Resources
Georgia Geologic Survey
19 Martin Luther King Jr. Drive S.W.
Atlanta, GA 30334

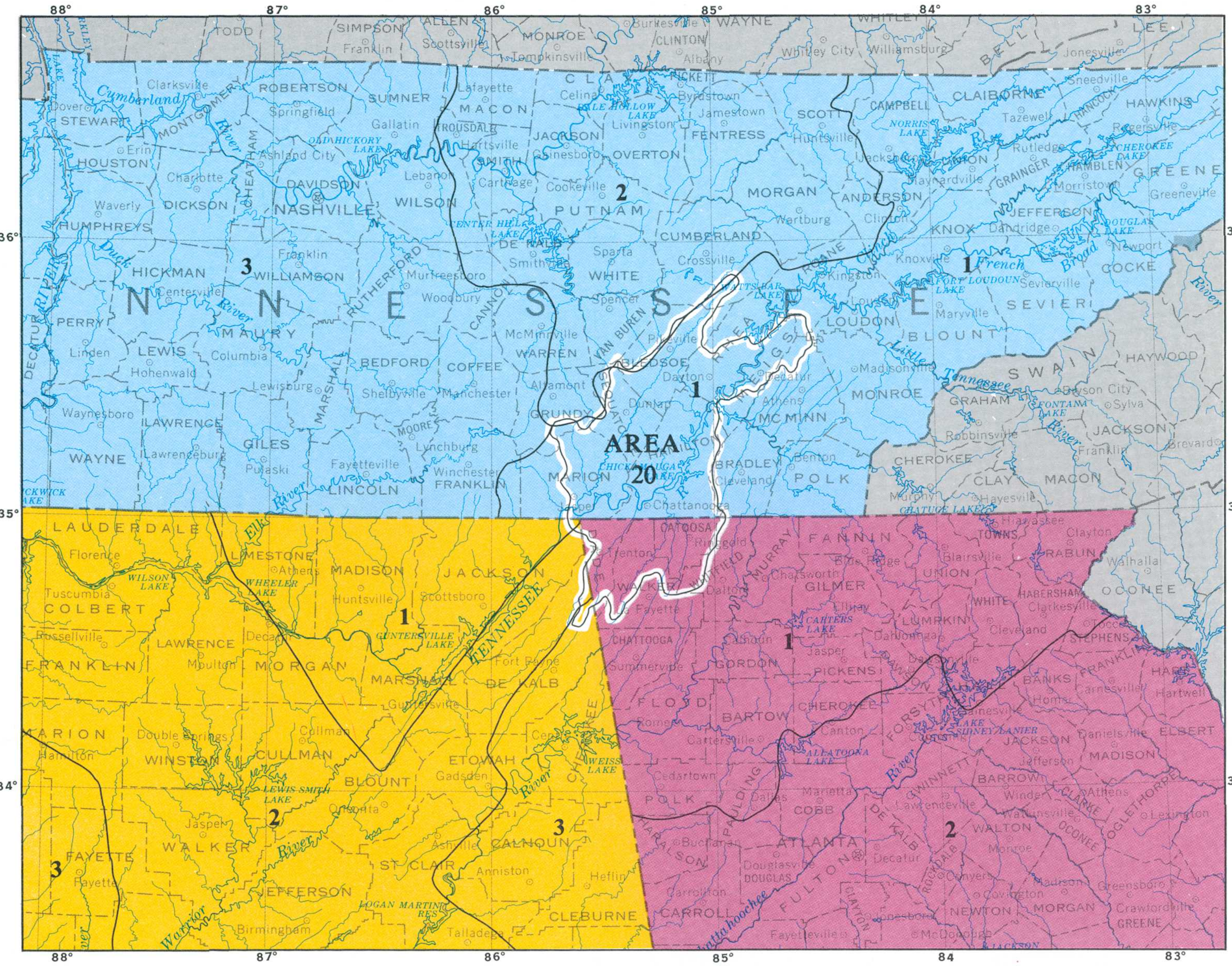
(Tennessee maps)
U.S. Geological Survey
Water Resources Division
A413 Federal Building - U.S. Courthouse
Nashville, TN 37203

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

(Alabama maps)
Geological Survey of Alabama
P.O. Drawer O
University, AL 35486

(Georgia maps)
Georgia Department of Natural Resources
Georgia Geologic Survey
19 Martin Luther King Jr. Drive S.W.
Atlanta, GA 30334

(Tennessee maps)
Tennessee Department of Conservation
Division of Geology
701 Broadway
Nashville, TN 37203



EXPLANATION

DEPTH OF 100-YEAR FLOOD

TENNESSEE Hydrologic areas, from Randolph and Gamble, 1976

1 $5.3(A)^{0.20}$ for drainage areas of 0.36 to 428 square miles

2 $7.1(A)^{0.23}$ for drainage areas of 0.49 to 382 square miles

3 $6.1(A)^{0.23}$ for drainage areas of 0.17 to 666 square miles

ALABAMA Hydrologic areas, from Price, 1977

1, 3 $6.3(A)^{0.20}$ for drainage areas of 1 to 800 square miles

2 $9.6(A)^{0.20}$ for drainage areas of 1 to 800 square miles

GEORGIA Hydrologic areas, from Hains, 1973

1 $3.79(A)^{0.32}$ for drainage areas of 1 to 740 square miles

2 $6.38(A)^{0.22}$ for drainage areas of 0.39 to 990 square miles

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

EXPLANATION

MCDONALD TVA 1940 (76PR) — Name of 7½ minute quadrangle

Mapped by USGS

Mapped by TVA

Mapped by both USGS and TVA

Figure 4.4.2-2 Location of quadrangles for which flood-prone area maps are available.

Flow of Streams Draining the Coal Resources Area is Poorly Sustained

The low flow of streams in the coal resources area 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 and is an integration of the effects of climate, topography, and geology, which 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 characteristics of streams.

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 which may be caused by surface- or ground-water contributions.

Flow-duration curves for two sites in Area 20 are shown in figure 4.5-1. These curves are based on the base period 1936-55 and are plotted in unit discharge (cubic feet per second per square mile) so that more direct comparison may be made. The streams selected are representative of the coal area and the Ridge and Valley. Flow-duration data for Tennessee streams in Area 20 are given by Gold (1980); data for Alabama streams, by Hayes (1978); and data for Georgia streams, by Inman (1971).

Richland Creek near Dayton (site 11) is typical of streams draining uplands of the Cumberland Plateau. Its flow-duration curve is steep at discharges less than one $(ft^3/s)/mi^2$ due to the small ground-water contribution to the stream. South Chickamauga Creek near Chickamauga (site 58) is typical of the Ridge and Valley and its flow-duration curve has a flatter slope on the lower end indicating larger yields from the ground-water system.

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

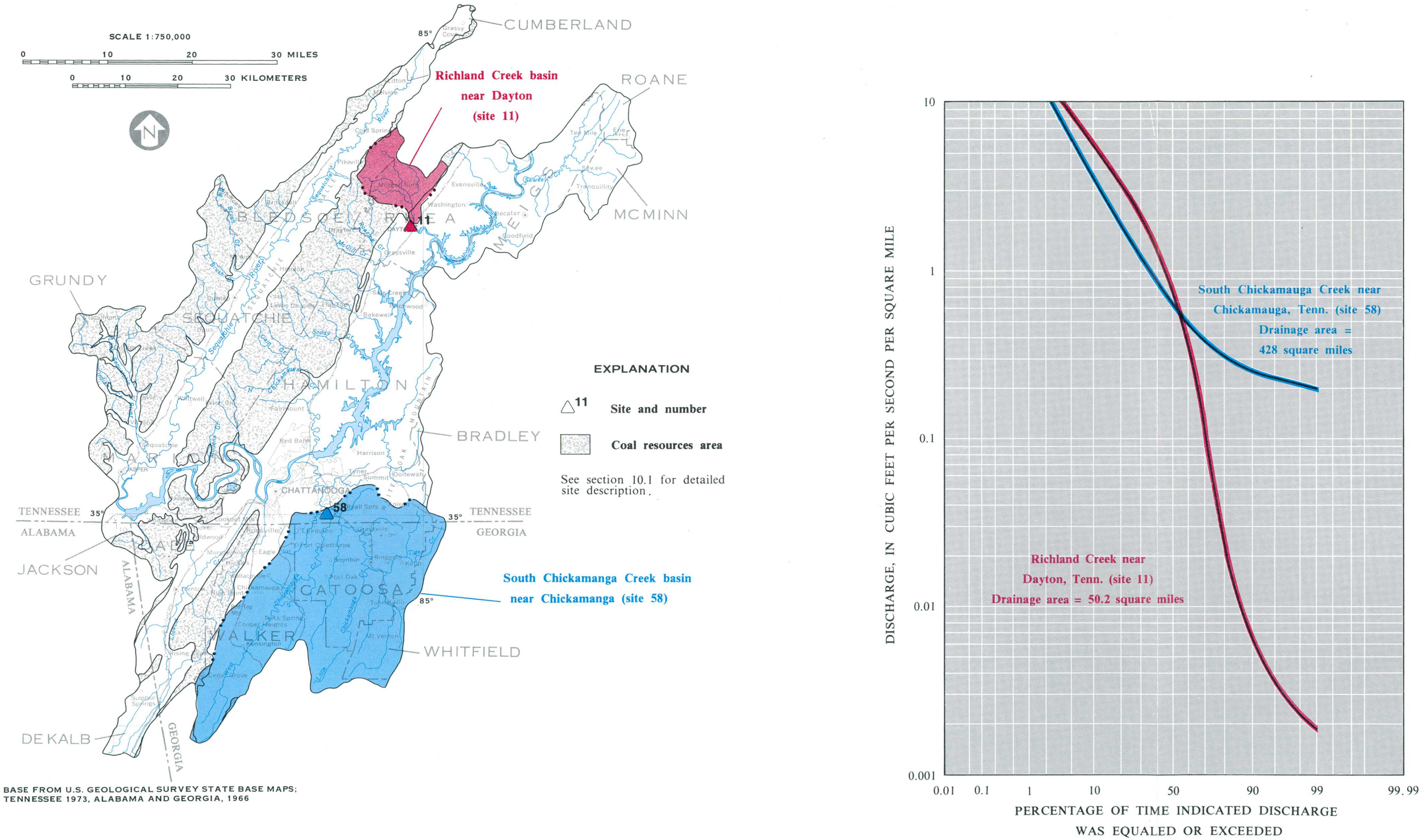


Figure 4.5-1 Flow-duration curves for sites 11 and 58 (base period 1936-55).

Water-Quality Information Useful for Evaluating Effects of Mining Activities

Beginning in 1979, water-quality data were collected to measure baseline water-quality conditions and to evaluate water-quality trends in the coal area.

Water-quality data can be used to evaluate the effects of surface coal-mining activities and other land-use activities on the hydrologic environment. Beginning in 1979 in response to the Act, the U.S. Geological Survey established a network of 29 data-collection sites in Area 20. Eleven other sites for which water-quality data are available were active prior to 1979. The water-quality data collected at these 40 sites (fig. 5.1-1), as well as data previously collected at 19 sites through other programs, are presented in this report and should be useful in evaluating water quality in the coal area. The following important points regarding those data should be considered:

• The term "quality" is not precise. The quality of water from any source cannot be defined unless the intended use is considered. For example, water unsuitable for drinking may be adequate for use in mining operations.

• Locally severe water-quality problems may exist and not be detected. No mine drainage or seepage was sampled.

• The water-quality data collected since 1979 emphasized those constituents and properties specified in the "Surface Mining Control and Reclamation Act of 1977 (Public Law 95-87)." The specified range or maximum limits are:

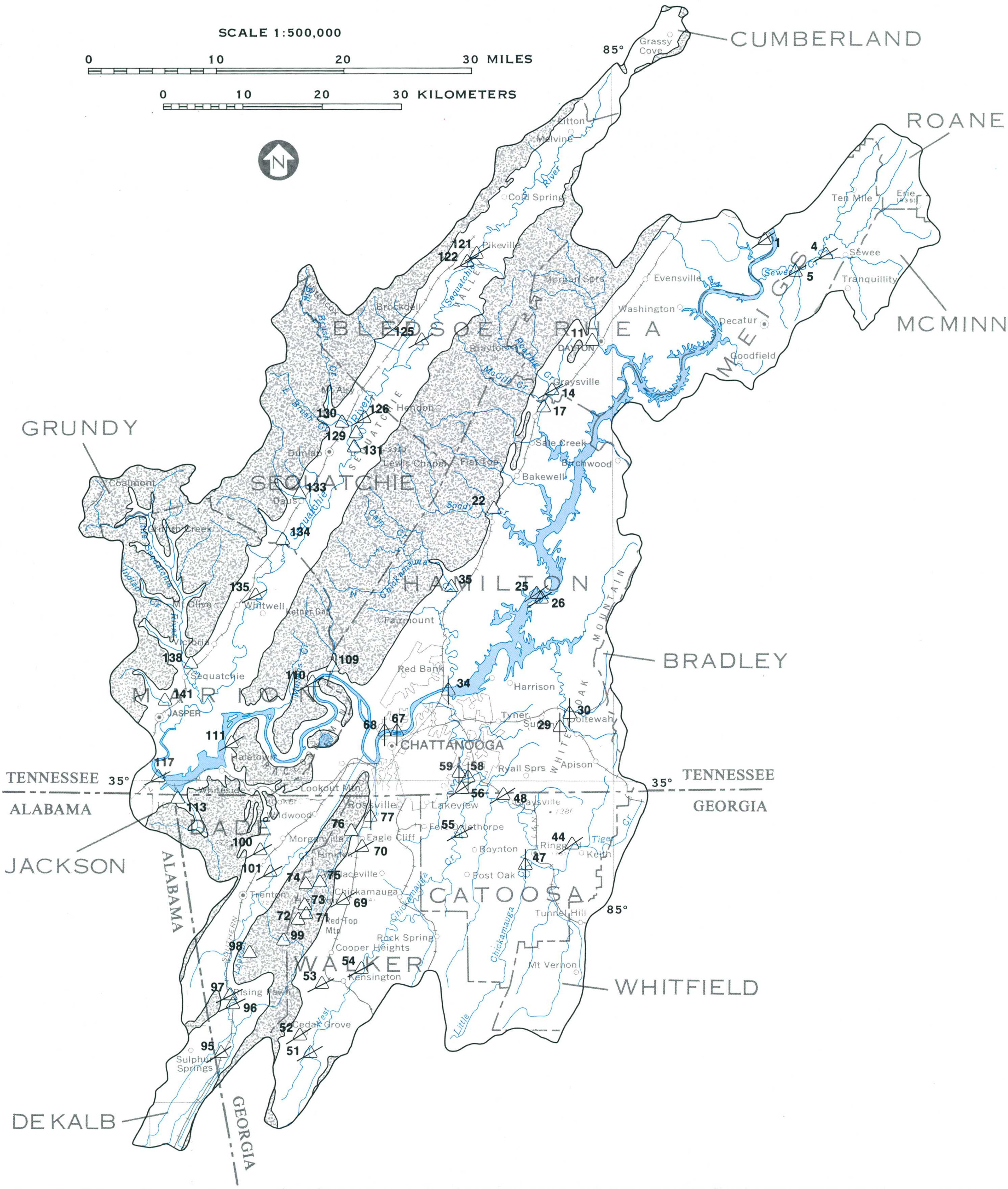
• pH range from 6.0 to 9.0 units;

• total manganese concentration, 4,000 μg/L;

• total iron concentration, 7,000 μg/L; and

• total suspended-solids concentration, 70 mg/L.

Sufficient data to define seasonal water-quality variations 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). Samples were collected during low flow to determine the concentrations of selected trace constituents in bottom material from stream channels.



BASE FROM U.S. GEOLOGICAL SURVEY STATE BASE MAPS; TENNESSEE 1973, ALABAMA AND GEORGIA, 1966

EXPLANATION

△11 **Coal-area site and number**

1 **Rural-area site and number**

30 **Urban-area site and number**

See section 10.1 for detailed site description.

Coal resources area

Figure 5.1-1 Sites for which water-quality data are available.

Specific Conductance and Dissolved Solids are High in Areas Extensively Disturbed by Man

Dissolved-solids concentrations (estimated from specific conductance values) were generally less than 250 milligrams per liter. Dissolved solids concentrations were higher in streams in areas disturbed by man.

Dissolved solids expressed in milligrams per liter (mg/L), is a direct measure of the total concentration of dissolved material in the water. Specific conductance, expressed in micromhos per centimeter at 25°C (μmhos/cm), is a measure of the ability of water to conduct an electrical current. The presence of dissolved constituents causes the water to conduct electricity and as the concentration of these constituents increases, the conductance of the solution increases.

Because the specific conductance is related to the quantity and type of material dissolved in water, it can be used as a general indication of the dissolved-solids concentration. Commonly, the factor relating specific conductance to dissolved solids is between 0.55 and 0.75. However, this factor can range from 0.54 to 0.96 (Hem, 1970), and thus must be used with care when estimating dissolved-solids concentration from specific-conductance values. It is important to limit such estimates to areas where previous work has been conducted, and for which the empirical relationship between specific conductance and dissolved solids has been defined.

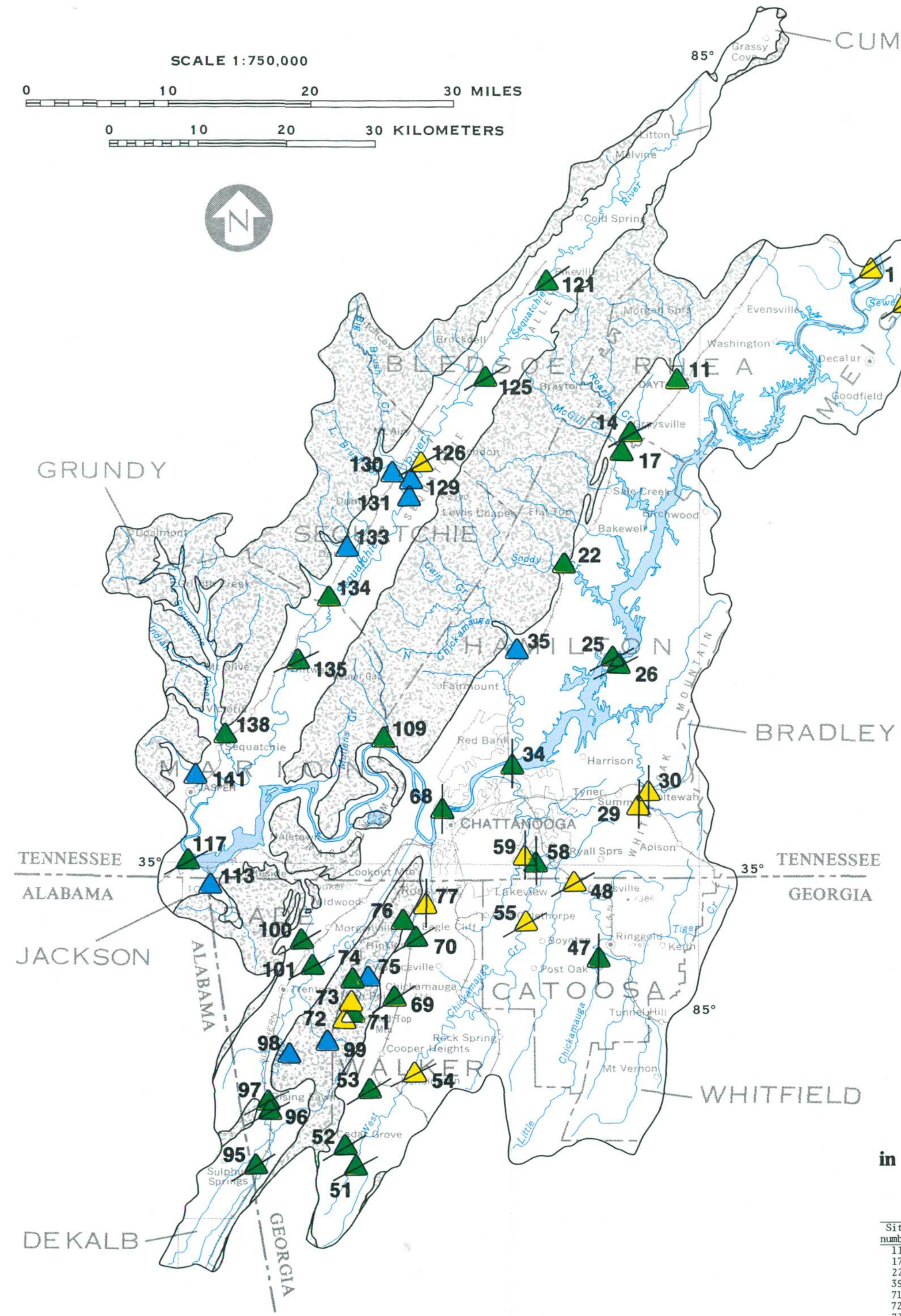
An estimate of the dissolved-solids concentration in water in most streams in Area 20 can be made by multiplying the specific-conductance value by 0.76 (all coal area sites), by 0.52 (rural sites), or by 0.55 (urban sites). These factors were determined by a comparison of measured dissolved-solids and specific-conductance data of water from streams in Area 20 (fig. 5.2-1). Based on currently available data, dissolved-solids concentrations generally are less than 250 mg/L.

Specific conductance of surface water in Area 20 was generally low (table 5.2-1 and fig. 5.2-2), but was higher in areas extensively disturbed by man. Streams in mining, rural-agricultural, and urbanized areas had the highest specific-conductance values. Lowland stream sites within Area 20 generally had higher specific conductance than upland stream sites. This probably is a result either of lowland areas being more suitable for human activities or of differences in geologic parent material. For example, one of the lowest specific-conductance values occurred in an upland stream basin (site 99) draining a relatively undisturbed area. On the other hand, streams in and near urban (site 30), rural-agricultural (site 54), and mining (site 71) areas had higher specific conductances (fig. 5.2-3).

In the entire coal area, most specific-conductance values in streams draining relatively undisturbed basins were less than 100 μmhos/cm. In contrast, specific-conductance values in streams draining areas with coal-mining activities within the coal area were more variable and all were less than 600 μmhos/cm. Consistently high specific-conductance values occurred in the upper Rock Creek basin (sites 71, 72, 73, and 74), a stream draining an area with abandoned coal mines.

Not all streams draining areas having coal mines have been affected noticeably by coal-mine drainage. In general, specific conductance of water draining from a mine can be highly variable and depends on such factors as: (1) the presence of pyrite and other minerals in spoil material, (2) the length of time of exposure of these minerals to weathering by air and water, and (3) the quantity of water leaving the mine. In addition, if water draining from a mine has high specific conductance, this conductance may be decreased by dilution downstream. In the future, sites currently lacking any noticeable effects will be particularly important in the assessment of the impact of mining activities upon water quality.

Specific conductance is generally higher during low flow because the water in streams at this time is coming from ground-water storage where it has had prolonged contact with soluble minerals in soils and rocks. During high flow, specific conductance is generally lower because the water in streams at this time is predominantly surface runoff that has had shorter contact time with soluble minerals.



BASE FROM U.S. GEOLOGICAL SURVEY STATE BASE MAPS;
TENNESSEE 1973, ALABAMA AND GEORGIA, 1966

Figure 5.2-2 Sites for which specific conductance data are available.

EXPLANATION

△11 Coal-area site and number

△1 Rural-area site and number

△30 Urban-area site and number

Coal resources area

Maximum specific conductance

▲ Less than 100 micromhos per centimeter

▲ 100-300 micromhos per centimeter

▲ Greater than 300 micromhos per centimeter

See section 10.1 for detailed site description.

Table 5.2-1 Specific conductance, in micromhos per centimeter at 25°C of water in streams

Sites in the coal area

Site number	Minimum	Median	Maximum	Number of determinations
11	27	40	168	26
17	45	70	102	15
22	26	34	145	9
35	25	31	54	4
71	267	272	300	3
72	--	--	554	1
73	258	282	358	8
74	86	176	295	10
75	14	24	63	8
76	48	103	273	10
98	21	30	50	10
99	18	25	33	10
109	55	90	135	5
113	47	57	66	4
129	--	--	31	1
130	38	58	83	4
131	32	48	62	4
133	38	50	73	9
134	30	65	150	6
138	70	151	195	7
141	--	--	32	1

Sites in rural areas

Site number	Minimum	Median	Maximum	Number of determinations
1	97	160	319	119
4	165	285	295	5
5	130	250	310	37
14	109	148	260	4
25	100	170	250	192
26	112	172	240	51
48	103	215	580	51
51	138	183	230	8
52	140	--	220	2
53	213	--	229	2
54	146	217	460	26
55	95	256	435	68
69	184	218	268	8
70	170	209	255	10
95	146	196	228	8
96	204	--	250	2
97	129	178	238	8
100	157	166	224	6
101	140	191	267	25
117	24	150	190	34
121	--	--	158	1
125	101	200	250	18
126	120	165	758	16
135	95	175	267	65

Sites in urban areas

Site number	Minimum	Median	Maximum	Number of determinations
29	37	260	500	61
30	140	280	420	13
34	109	150	190	44
47	210	223	270	3
58	70	200	300	37
59	120	240	380	13
68	160	167	220	4
77	26	147	310	33

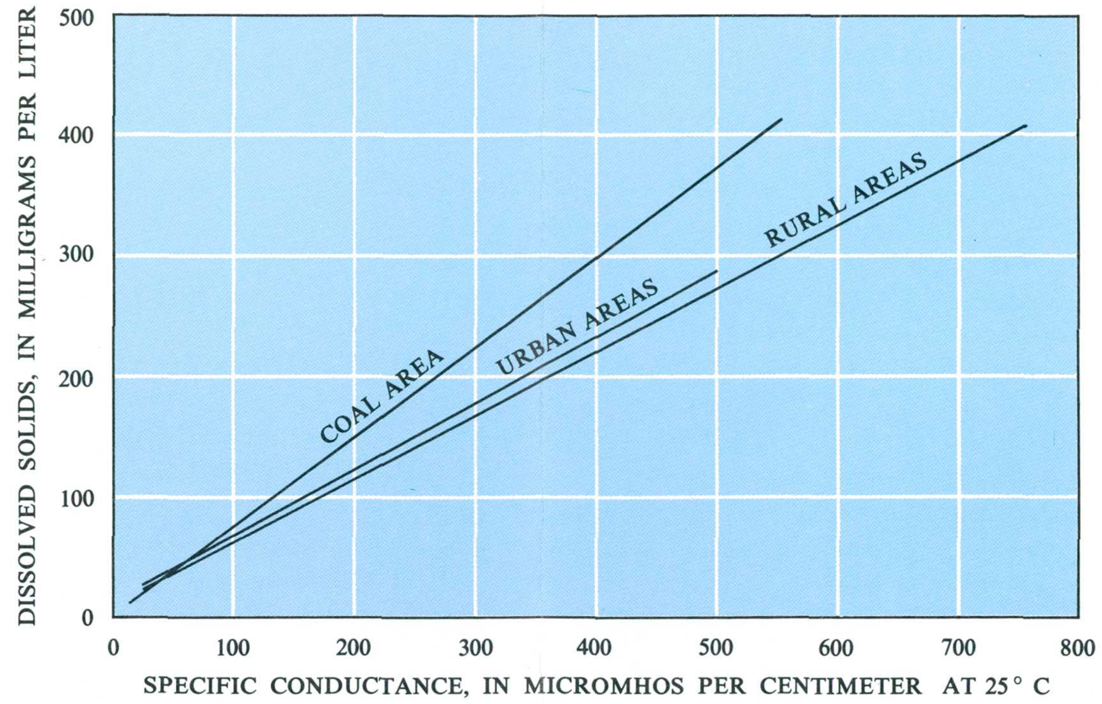


Figure 5.2-1 Relationship between dissolved solids and specific conductance for the various resources areas.

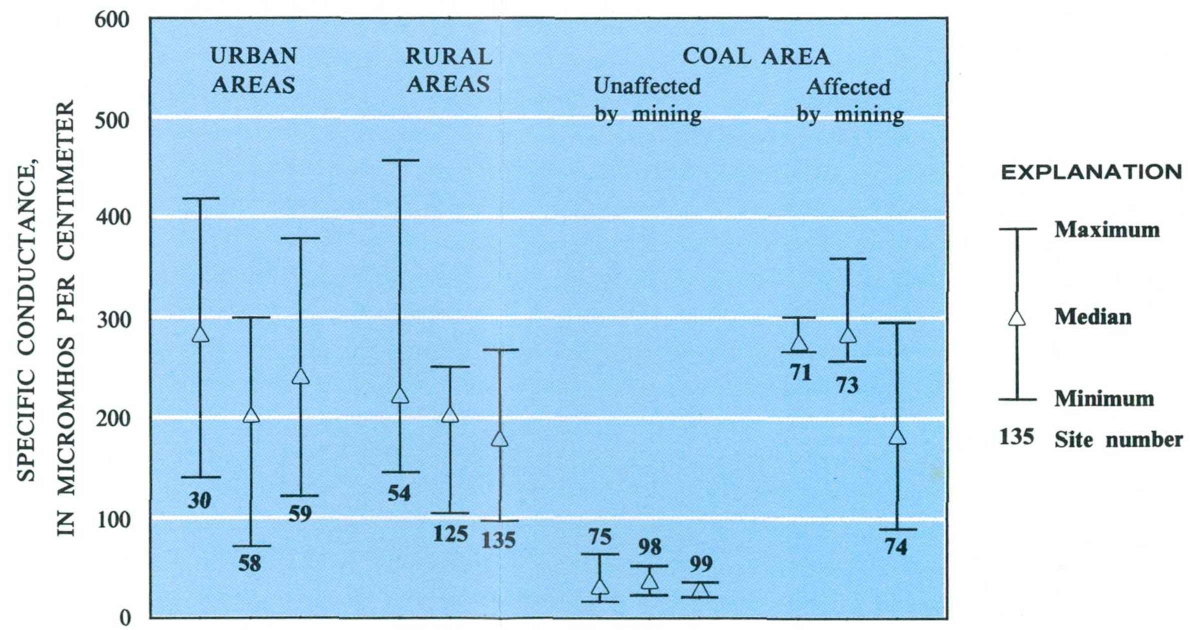


Figure 5.2-3 Median and range of specific conductance at selected sites.

Dissolved-Sulfate Concentrations Generally Low

Dissolved-sulfate concentrations were highest in streams draining areas with abandoned coal mines.

Most dissolved-sulfate concentrations in streams of Area 20 were low (table 5.3-1 and fig. 5.3-1), except in some areas extensively disturbed by man. Streams in mined and in urbanized areas had the highest dissolved-sulfate concentrations. Figure 5.3-2 illustrates the effects of mining and urban activities on dissolved-sulfate concentrations of streams draining such areas.

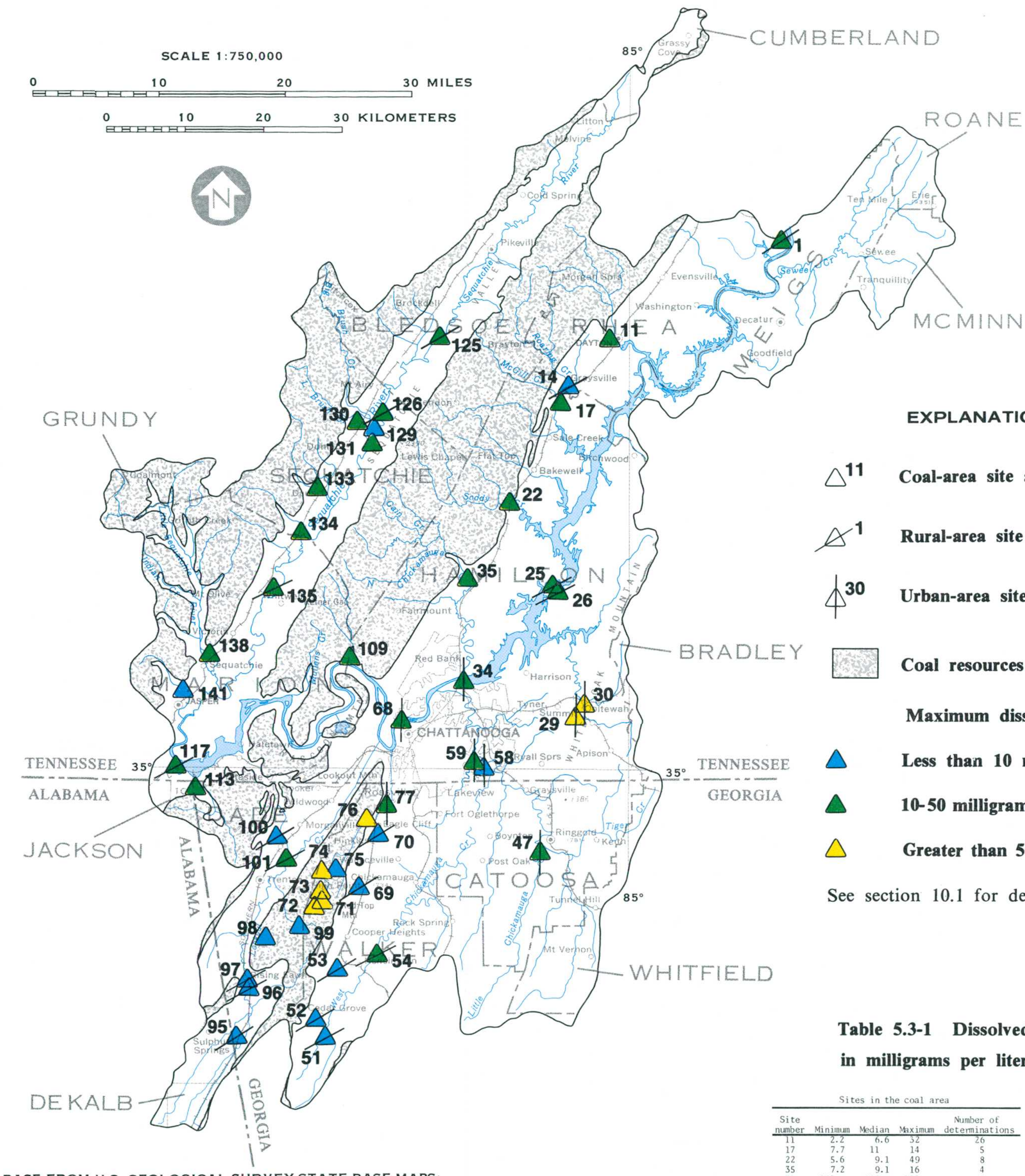
In streams in the coal area, dissolved-sulfate concentrations ranged from 2.2 to 300 mg/L (table 5.3-1). Most dissolved-sulfate concentrations in streams draining relatively undisturbed basins were less than 10 mg/L. In contrast, dissolved-sulfate concentrations in streams draining coal-mining areas were more variable, although all but one was less than 300 mg/L. Dissolved sulfate commonly is used as an indicator of mine drainage because in mine effluents it generally occurs in the highest concentration and is the most persistent dissolved constituent. The highest concentrations occurred in Rock Creek (sites 71, 72, 73, and 74), a stream draining an abandoned coal-mine site.

Not all streams draining areas having coal mines have been affected by coal-mine drainage. In general, the concentration of dissolved sulfate in water draining from a mine can be highly variable and depends on such factors as: (1) the presence of pyrite and other sulfur minerals in spoil material, (2) the length of time of exposure of these minerals to weathering by air and water, and (3) the quantity of water leaving the mine. In addition, if water draining from a mine has a high concentration of dissolved sulfate, this concentration may be decreased by dilution downstream. Water at some sites located in the coal area, as of now, is apparently unaffected by coal-mine drainage. In the future, data from these sites will be particularly important in the assessment of the impact of mining activities upon water quality.

Dissolved-sulfate concentrations ranged from 0.8 to 46 mg/L in streams in the rural areas, with most concentrations being less than 15 mg/L (table 5.3-1). Higher concentrations of dissolved sulfate (2.0 to 88 mg/L) occur at some stream sites draining urban areas; for example, Wolftever Creek (sites 29 and 30).

Dissolved-sulfate concentrations are generally higher during low flow because the water in streams at this time is coming from ground-water storage where it has had prolonged contact with soluble minerals in soils and rocks. During high flow, dissolved-sulfate concentrations are generally lower because the water in streams at this time is predominantly surface runoff that has had shorter contact time with soluble minerals.

Sulfate concentrations relate directly to specific conductance, an indicator of the degree of mineralization in water. Because of this relation, specific conductance may be used to estimate the concentration of sulfate. The accompanying graph (fig. 5.3-3) is useful for estimating sulfate concentrations in streams in the area.



BASE FROM U.S. GEOLOGICAL SURVEY STATE BASE MAPS;
TENNESSEE 1973, ALABAMA AND GEORGIA, 1966

Figure 5.3-1 Sites for which dissolved sulfate data are available.

Table 5.3-1 Dissolved-sulfate concentrations, in milligrams per liter, in water in streams

Sites in the coal area

Site number	Minimum	Median	Maximum	Number of determinations
11	2.2	6.6	32	26
17	7.7	11	14	5
22	5.6	9.1	49	8
35	7.2	9.1	16	4
71	100	110	120	3
72	--	--	300	1
73	100	110	160	8
74	30	68	130	10
75	4.7	5.4	9.7	8
76	12	35	100	10
98	2.2	4.6	5.8	10
99	2.8	4.9	7.5	10
109	16	31	46	5
113	8.0	9.5	11	4
129	--	--	3.6	1
130	6.6	8.5	10	4
131	5.6	7.8	10	4
133	11	13	19	3
134	5.5	12.5	35	6
138	12	21	37	7
141	--	--	6.8	1

Sites in rural areas

Site number	Minimum	Median	Maximum	Number of determinations
1	3.0	13	20	103
14	0.8	5.0	8.4	4
25	4.0	13	18	32
26	10	15	17	51
51	2.5	4.5	6.0	8
52	2.3	--	3.7	2
53	3.5	--	4.5	2
54	4.1	8.6	46	8
69	4.1	5.0	6.0	8
70	4.7	5.9	8.8	10
95	2.5	4.1	5.7	8
96	5.9	--	7.6	2
97	3.9	4.4	5.8	8
100	4.8	6.5	9.5	6
101	4.4	6.5	12	25
117	2.0	12	23	33
121	5.0	5.0	5.0	1
125	4.0	6.2	12	18
126	4.7	7.9	10	8
135	5.0	8.0	13	35

Sites in urban areas

Site number	Minimum	Median	Maximum	Number of determinations
29	4.8	29	65	15
30	13	28	88	13
34	6.0	15	36	121
47	14	16	30	3
58	5.5	6.5	9.4	5
59	2.0	8.0	18	13
68	12	15	20	3
77	3.6	16	25	33

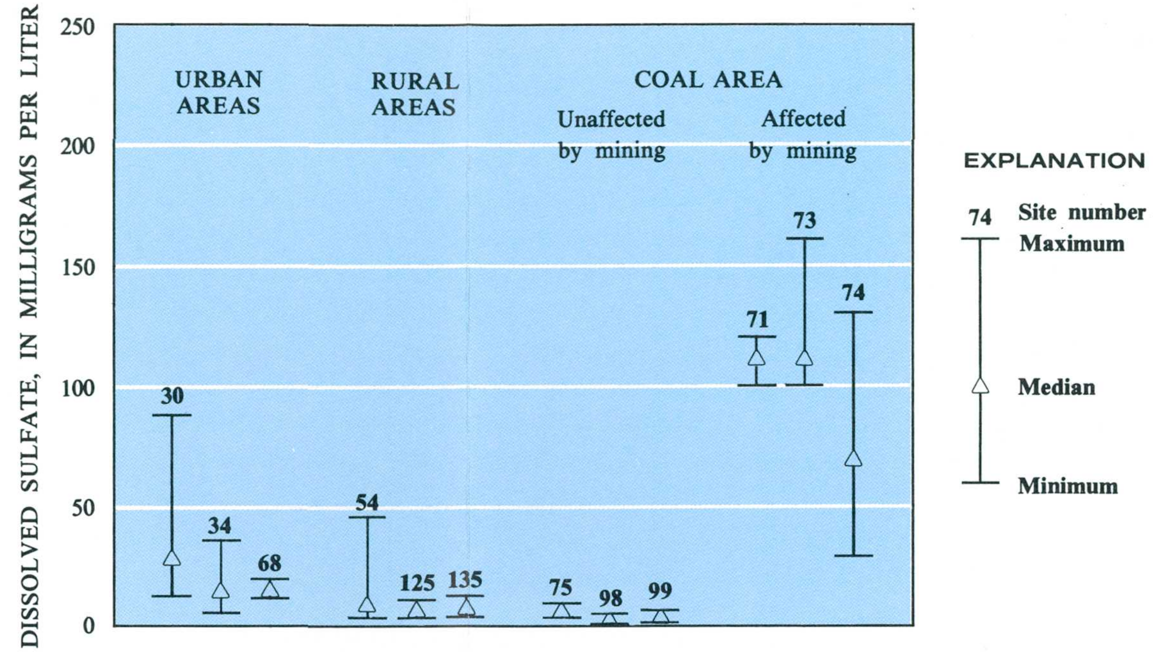


Figure 5.3-2 Median and range of dissolved sulfate at selected sites.

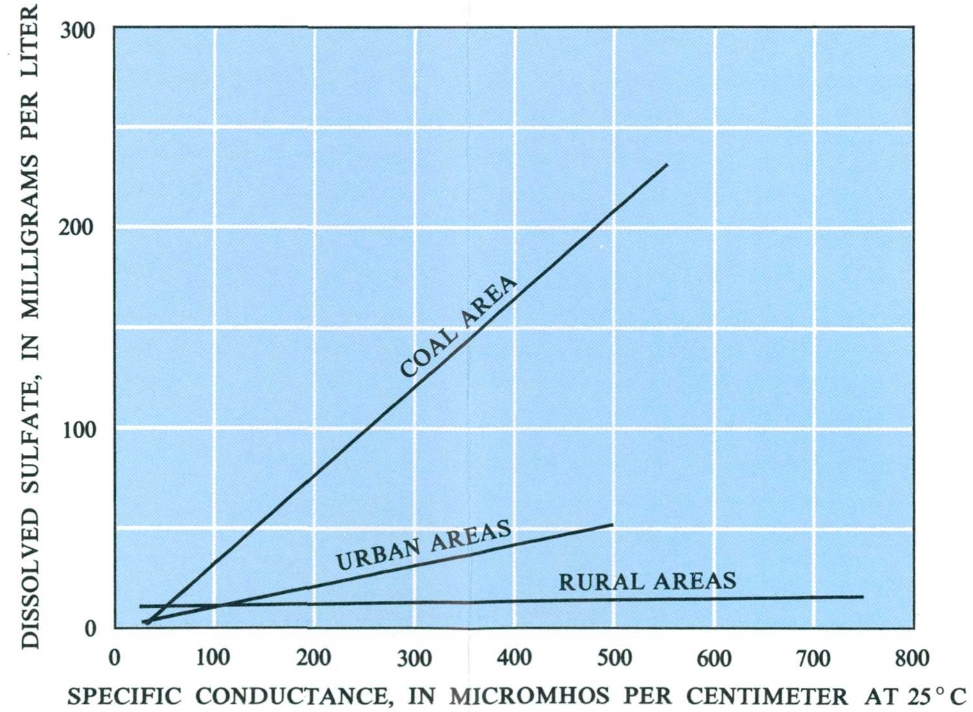


Figure 5.3-3 Relationship between dissolved sulfate and specific conductance for the various resources areas.

pH Differs Between Unmined and Mined Areas

Acid-mine drainage is not a widespread problem in Area 20. The pH is usually in the near-neutral range (6.0 to 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 affects the suitability of a water for many purposes. For example, it affects water treatment methods and may contribute to corrosion of waterworks structures, distribution lines, and household fixtures. Corrosion due to low pH can add some trace constituents to the water, such as copper, lead, zinc, and cadmium. In addition, in streams the toxicity of most pollutants increases or decreases as the pH increases or decreases from neutral (National Academy of Sciences and National Academy of Engineering, 1972). For most purposes, stream-use classification criteria specify an acceptable pH range as 6.0 to 9.0 units (Alabama, 1979; Georgia, 1980; and Tennessee, 1978). Additionally, the Surface Mining Control and Reclamation Act of 1977 (Public Law 95-87) specifies that the pH of mine effluents must range from 6.0 to 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 natural weathering of geologic strata. In coal mine areas the pH of mine effluent is determined by the chemical character of spoil. In some areas, weathering of pyrite and other sulfur-bearing minerals results in the production of sulfuric acid.

The pH values of water in most Area 20 streams were in the near-neutral range (6.0 to 8.0 units) (table 5.4-1 and fig. 5.4-1). The highest pH values generally occurred in streams primarily underlain by carbonate rock, such as pre-Pennsylvanian limestone and dolomite. Water in these streams was more alkaline than streams draining the coal resources area. The lowest pH values generally occurred in streams draining basins having coal-mining disturbance.

The pH values in streams in rural and urban areas ranged from 5.9 to 8.5 units. Water in streams in the coal area had pH values ranging from 4.0 to 8.4 units. The lowest occurred at site 72, a stream draining an abandoned coal-mine site. Water in some other streams (sites 22, 35, 109, and 133) located in coal-mining areas seems to be affected by acid-mine drainage. Additional sampling in the upstream parts of these basins would be needed to verify and quantify the impact of mining activities on water quality.

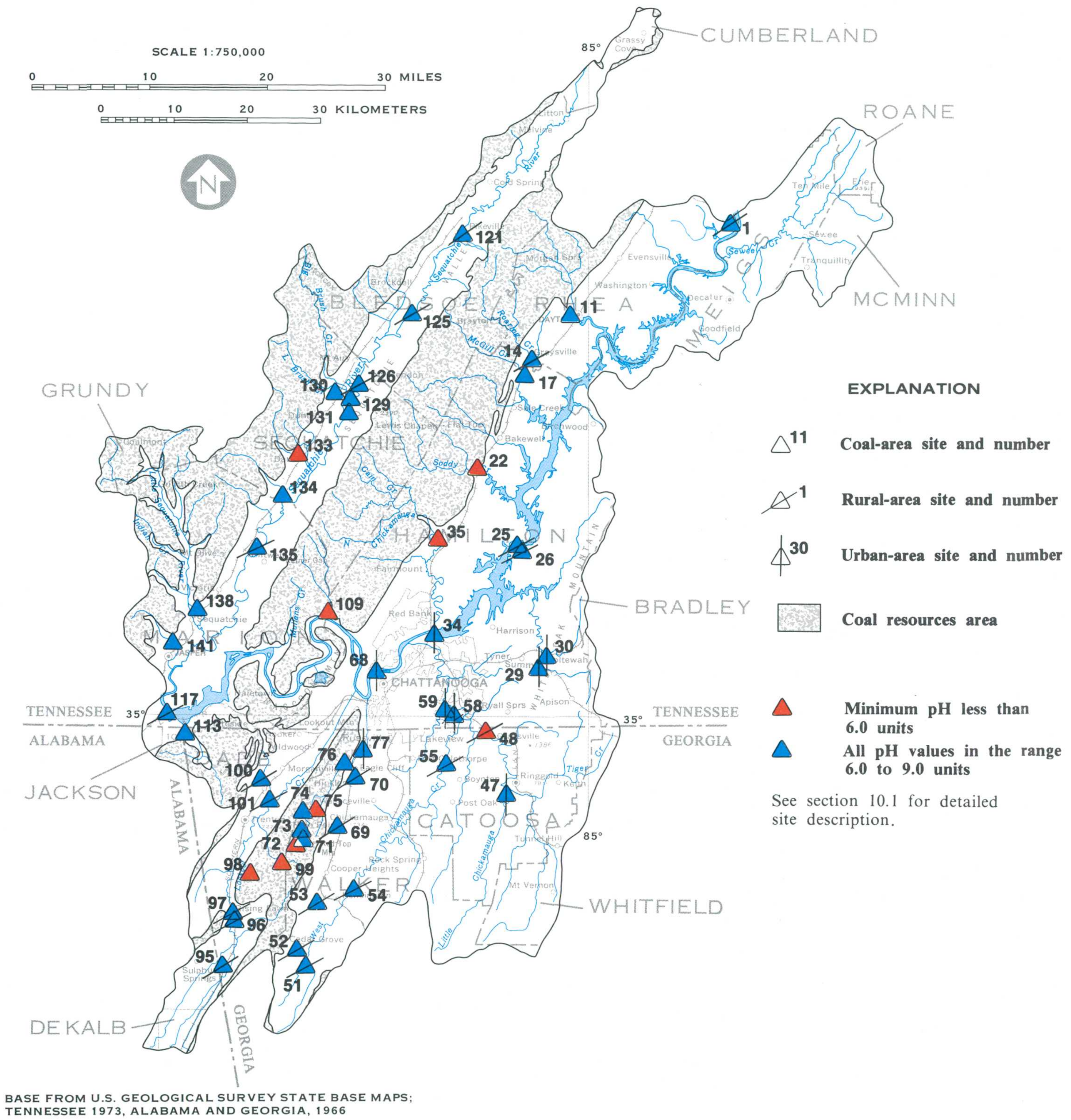


Figure 5.4-1 Sites for which pH data are available.

Table 5.4-1 pH, in standard units, of water in streams

Sites in the coal area

Site number	Minimum	Median	Maximum	Number of determinations
11	6.4	7.2	8.4	26
17	6.3	6.7	7.9	14
22	5.0	5.8	6.4	9
35	4.8	5.1	5.5	4
71	6.6	6.6	7.2	3
72	--	--	4.0	1
73	6.6	7.0	7.1	8
74	6.4	6.8	7.3	10
75	5.7	6.3	7.3	8
76	6.6	6.9	7.5	10
98	5.8	6.5	7.2	10
99	5.3	6.4	6.6	6
109	4.5	4.8	5.8	5
113	6.0	6.3	6.7	4
129	--	--	7.0	1
130	7.2	7.7	7.9	4
131	7.1	7.3	7.4	4
133	5.0	5.6	6.4	7
134	7.2	7.6	8.4	6
138	7.4	7.8	8.1	7
141	--	--	6.6	1

Sites in rural areas

Site number	Minimum	Median	Maximum	Number of determinations
1	6.0	7.4	8.5	116
14	7.2	7.4	7.8	4
25	6.0	7.3	7.9	193
26	6.8	7.1	7.7	51
48	5.9	7.7	8.2	56
51	7.4	7.8	8.1	8
52	7.2	--	8.0	2
53	7.8	--	7.8	2
54	7.4	7.6	8.3	27
55	6.6	7.6	8.0	76
69	7.7	7.9	8.1	8
70	7.5	7.8	7.9	10
95	7.7	8.0	8.1	8
96	6.9	--	7.6	2
97	7.4	7.8	8.0	8
100	7.5	7.6	7.9	6
101	7.3	7.7	8.3	25
117	6.5	7.3	8.1	37
121	--	--	7.6	1
125	6.8	7.6	7.8	18
126	6.9	7.9	8.2	11
135	6.8	7.7	8.3	36

Sites in urban areas

Site number	Minimum	Median	Maximum	Number of determinations
29	6.5	7.3	8.0	15
30	7.3	7.8	8.1	13
34	6.1	7.3	8.0	47
47	7.3	7.7	8.0	4
58	7.2	7.3	7.9	5
59	7.5	7.7	7.9	13
68	7.5	7.5	7.8	3
77	6.8	7.5	8.3	34

Iron Concentrations Vary with Streamflow and Location

Higher total recoverable iron concentrations were generally found in streams in areas of urban, rural-agricultural or coal-mining development.

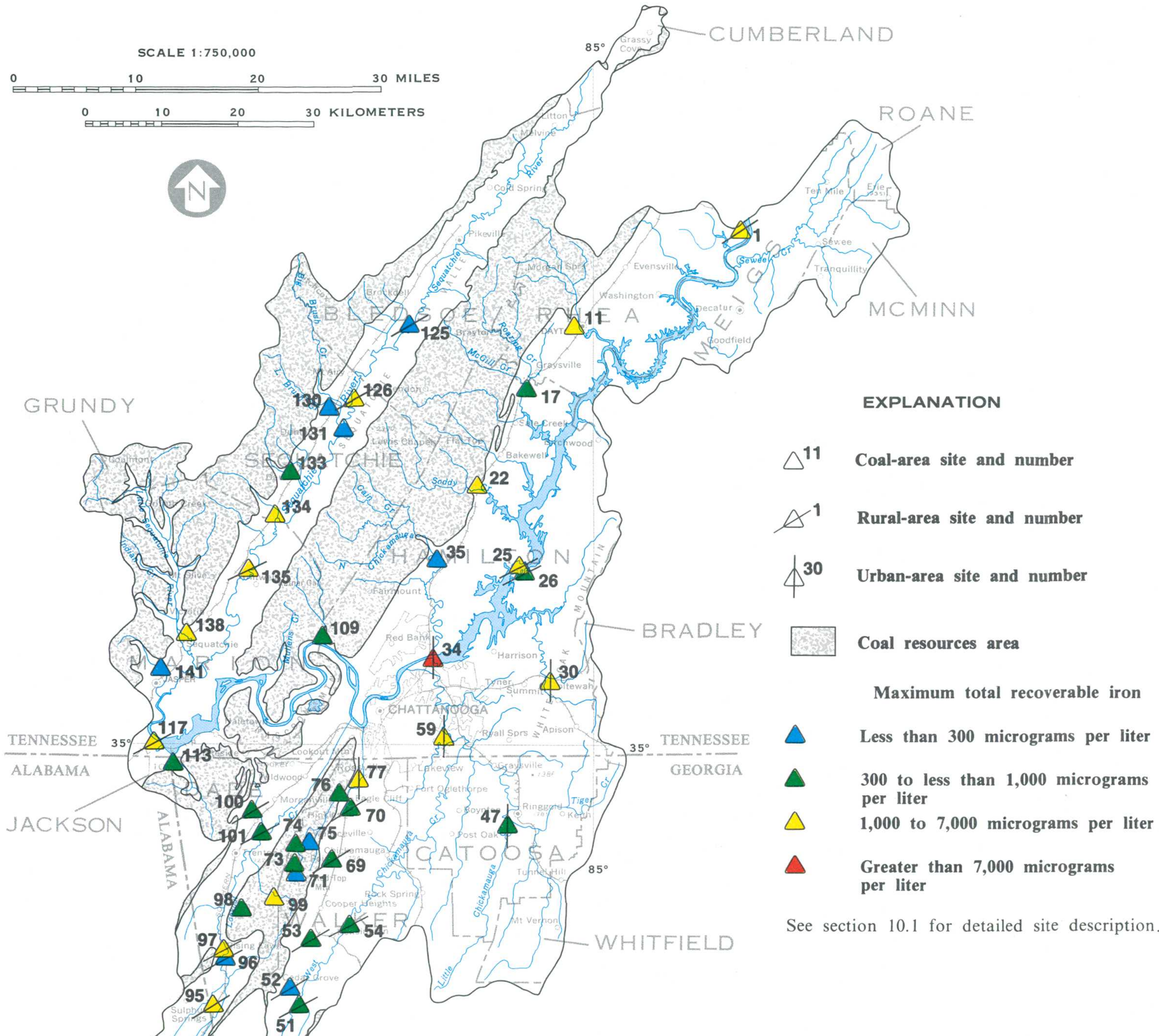
Iron in excessive concentrations can severely limit the use of water for public supply, domestic, and industrial purposes. Dissolved-iron concentrations exceeding 300 μg/L impart an objectionable taste to water, cause staining, and generally limit the water's use. Consequently, most water-supply criteria contain recommended maximum limits for iron; the recommended maximum concentration of iron in drinking water is 300 μg/L (U.S. Environmental Protection Agency, 1979). The Surface Mining Control and Reclamation Act of 1977 (Public Law 95-87) specifies 7,000 μg/L as the maximum allowable concentration of total iron (dissolved plus suspended) in effluents from mining operations.

Sources of iron in water generally include soils rich in organic material and iron-bearing minerals in geologic strata underlying the basins. In mining areas, large quantities of soluble iron salts can be contributed to streamflow from coal-mine spoils as a result of accelerated weathering of iron-bearing minerals. Although dissolved-iron concentrations can be high in mine effluent, aeration and dilution rapidly decrease the high dissolved-iron concentrations. Even though dissolved iron may decrease, the iron usually remains in the hydrologic environment adsorbed to sediment or as a precipitate.

In Area 20, median total-recoverable iron concentrations exceeding 300 μg/L are a result of disturbances associated with urban, rural-agricultural, or coal-mining land-use practices. Total-iron concentrations in water have been determined at 42 sites in Area 20 (fig. 5.5-1). At the urban sites, total-recoverable iron ranged from 20 to 7,800 μg/L (table 5.5-1). The maximum concentration occurred at site 34 in Chickamauga Reservoir on the Tennessee River. This maximum value was associated with high turbidities in the reservoir and, therefore, probably was a result of storm runoff having high suspended-sediment concentrations. The median total-recoverable iron concentration at this site was 400 μg/L. Total-recoverable iron in streams in the rural areas ranged from 20 to 4,400 μg/L with medians exceeding 300 μg/L at about one-half of the sites. Total-recoverable iron in streams in the coal area ranged from 30 to 3,500 μg/L, with medians exceeding 300 μg/L at only two sites. These two sites (109 and 138) are located in basins with mining activities.

The maximum total-iron concentrations in water from most streams occurred during high flows because large amounts of iron were transported with suspended sediment (section 5.9). High suspended-sediment concentrations generally occurred during high streamflow periods and low concentrations occurred during low flow. During low flow, total-iron concentrations were nearly the same as dissolved-iron concentrations.

Dissolved iron is only a small part of the total iron transported by streams in Area 20. Concentrations of dissolved iron were determined at 48 sites (fig. 5.5-2) and generally were less than 100 μg/L, ranging from 0 to 640 μg/L (table 5.5-2). Dissolved iron did not vary significantly with large changes in streamflow.



BASE FROM U.S. GEOLOGICAL SURVEY STATE BASE MAPS; TENNESSEE 1973, ALABAMA AND GEORGIA, 1966

Figure 5.5-1 Sites for which total recoverable iron data are available.

Table 5.5-1 Total-recoverable iron concentrations, in micrograms per liter, in water in streams

Sites in the coal area

Site number	Minimum	Median	Maximum	Number of determinations
11	60	140	1,900	21
17	180	300	700	5
22	100	230	3,500	4
35	30	100	150	4
71	90	110	130	3
73	80	130	600	8
74	70	160	440	10
75	60	100	260	8
76	60	125	880	10
98	80	220	380	10
99	90	270	1,000	9
109	100	360	490	5
113	60	115	310	4
130	80	140	180	4
131	110	190	270	4
133	80	100	600	3
134	60	135	1,700	6
138	210	330	1,600	5
141	--	--	40	1

Sites in rural areas

Site number	Minimum	Median	Maximum	Number of determinations
1	70	320	2,500	69
25	80	410	2,100	32
26	20	90	380	51
51	220	450	700	8
52	250	--	270	2
53	140	--	380	2
54	150	430	860	25
69	140	235	630	8
70	220	295	580	10
95	130	235	1,900	8
96	70	--	90	2
97	170	380	1,200	8
100	120	180	350	6
101	120	380	690	5
117	80	375	1,900	36
125	60	100	220	7
126	250	470	2,300	8
135	20	370	4,400	35

Sites in urban areas

Site number	Minimum	Median	Maximum	Number of determinations
30	110	320	2,000	13
34	50	400	7,800	116
47	--	--	400	1
59	330	1,000	3,000	13
77	20	400	1,300	31

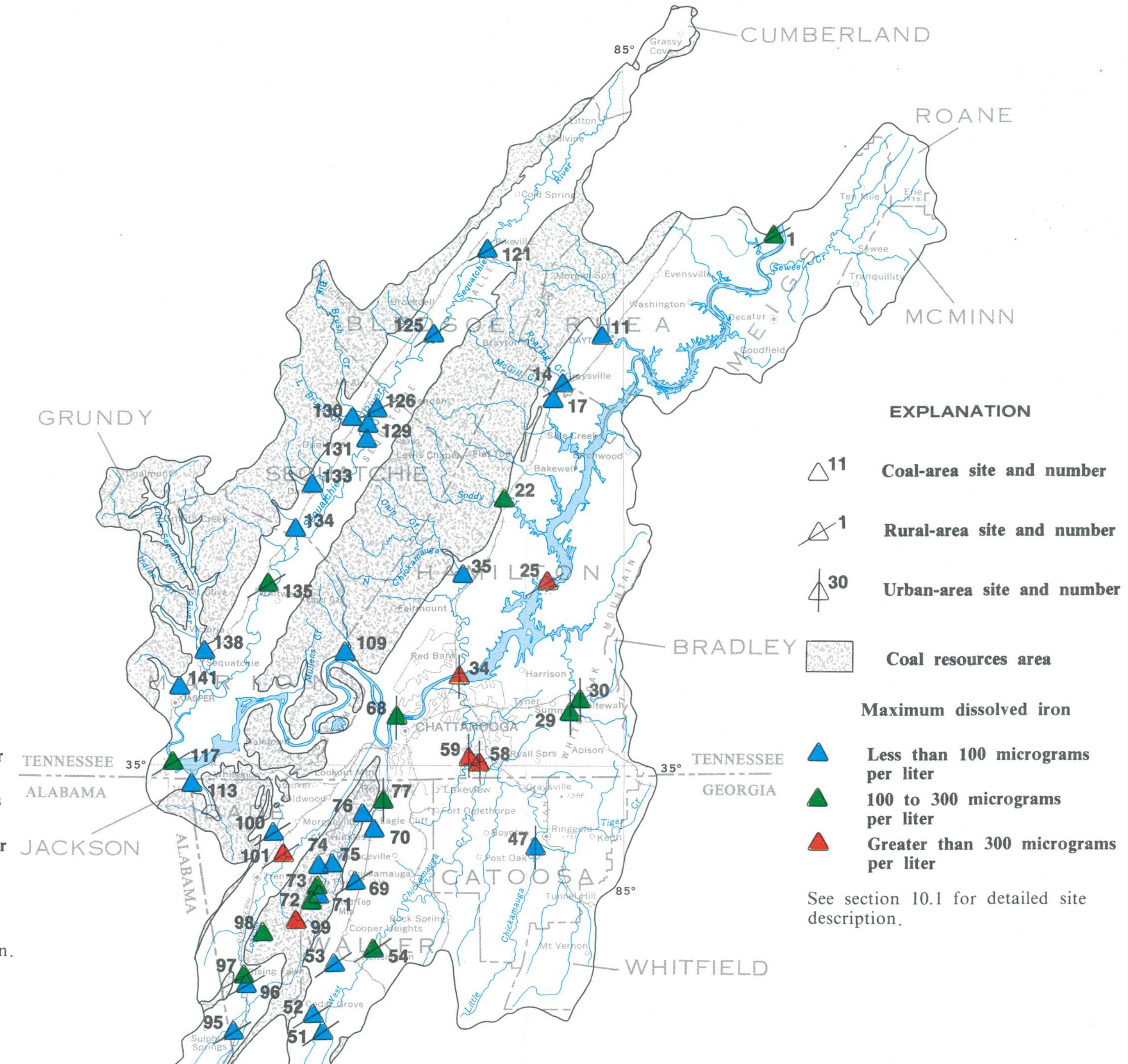


Figure 5.5-2 Sites for which dissolved iron data are available.

Table 5.5-2 Dissolved-iron concentrations, in micrograms per liter, in water in streams

Sites in the coal area

Site number	Minimum	Median	Maximum	Number of determinations
11	0	10	70	27
17	0	10	70	5
22	0	20	150	8
35	10	20	40	4
71	10	40	80	3
72	--	--	110	1
73	10	40	110	6
74	0	10	30	8
75	0	20	40	6
76	0	15	30	8
98	10	45	130	8
99	0	40	640	7
109	20	50	60	5
113	0	10	20	4
129	--	--	90	1
130	10	10	20	4
131	20	25	30	4
133	0	30	30	3
134	0	15	50	6
138	10	20	50	7
141	--	--	20	1

Sites in rural areas

Site number	Minimum	Median	Maximum	Number of determinations
1	0	50	150	50
14	20	55	60	4
25	10	50	330	31
51	10	35	50	6
52	50	--	80	2
53	10	--	10	2
54	10	50	150	23
69	0	15	30	6
70	10	45	80	8
95	0	20	50	6
96	20	--	60	2
97	0	40	240	6
100	0	10	10	4
101	0	30	360	22
117	20	50	100	14
121	--	--	20	1
125	0	0	20	11
126	0	30	60	8
135	0	20	200	27

Sites in urban areas

Site number	Minimum	Median	Maximum	Number of determinations
29	0	0	300	16
30	50	50	190	12
34	10	50	600	25
47	10	--	20	2
58	10	20	330	6
59	50	80	350	12
68	20	30	220	3
77	0	50	110	24

Maximum Manganese Concentrations Occur During High Flow

The concentrations of total-recoverable manganese in water in most streams are low, except in areas disturbed by coal-mining activities.

Manganese in excessive concentrations can severely limit the use of water for public, domestic, and industrial supplies. Dissolved-manganese concentrations exceeding 50 µg/L impart an objectionable taste to water, cause staining and generally limit the water's use. Consequently, most water-supply criteria contain recommended maximum limits for manganese; the recommended secondary maximum concentration of manganese in drinking water is 50 µg/L (U.S. Environmental Protection Agency, 1979). The Surface Mining Control and Reclamation Act of 1977 (Public Law 95-87) specifies 4,000 µg/L as the maximum allowable concentration of total manganese (dissolved plus suspended) in effluents from mining operations.

Manganese usually occurs in small quantities in water and generally is derived from soils rich in organic material and from the geologic strata underlying the basins. In mining areas, large quantities of soluble manganese salts can be contributed to streamflow from coal-mine spoil as a result of accelerated weathering of manganese minerals. Although dissolved-manganese concentrations can be high in mine effluent, aeration and dilution by alkaline stream water rapidly decrease the high dissolved-manganese concentrations. Even though dissolved manganese may decrease, the manganese usually remains in the hydrologic environment adsorbed to sediment or as a precipitate.

Total-manganese concentrations in water have been determined at 42 sites in Area 20 (fig. 5.6-1). At the urban sites, total-recoverable manganese ranged from 0 to 2,300 µg/L (table 5.6-1). The maximum concentration occurred at site 34 in Chickamauga Reservoir on the Tennessee River. This maximum value was associated with high turbidities in the reservoir and, therefore, probably was a result of storm runoff having high suspended-sediment concentrations. The median total-recoverable manganese concentration at this site was 60 µg/L. Total-recoverable manganese in streams in the rural areas ranged from 0 to 260 µg/L with medians exceeding 50 µg/L at 2 sites (25 and 117). Total-recoverable manganese in streams in the coal area ranged from 0 to 1,400 µg/L with medians exceeding 50 µg/L at 40 percent of the sites. All of these sites are located in basins with mining activities.

The maximum total-manganese concentrations in water from most streams occurred during high flows, because large amounts of manganese were transported with suspended sediment. High suspended-sediment concentrations generally occurred during high streamflow periods and low concentrations occurred during low flow. During low flow, total-manganese concentrations were nearly the same as dissolved-manganese concentrations.

Concentrations of dissolved manganese were determined at 44 sites (fig. 5.6-2), and generally were less than 50 µg/L ranging from 0 to 1,500 µg/L (table 5.6-2). In Area 20, those sites having medians of dissolved-manganese concentrations exceeding 50 µg/L are located in basins with coal mining (fig. 5.6-3). Dissolved manganese did not vary significantly with large changes in streamflow.

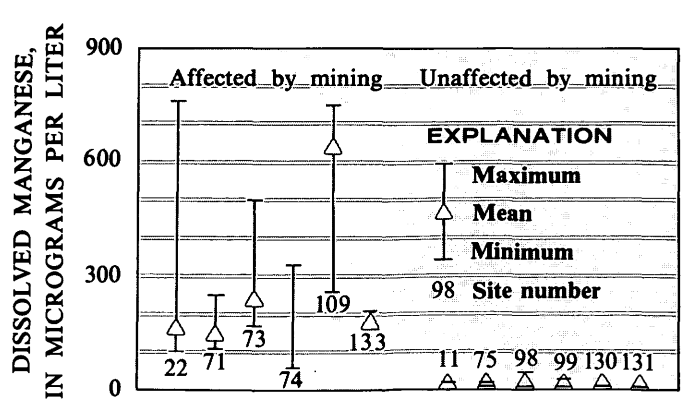
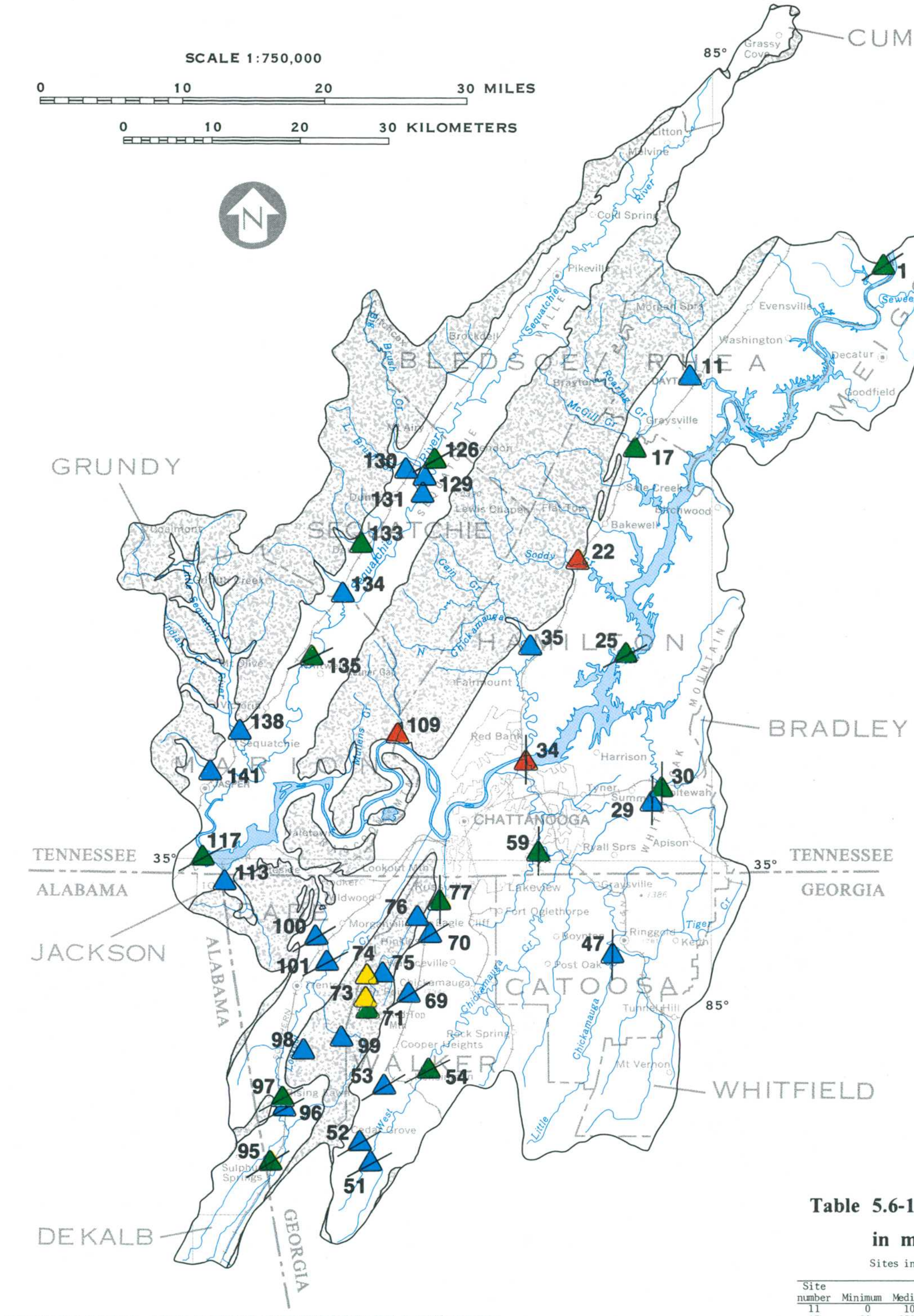


Figure 5.6-3 Median and range of dissolved manganese at selected sites.



BASE FROM U.S. GEOLOGICAL SURVEY STATE BASE MAPS:
TENNESSEE 1973, ALABAMA AND GEORGIA, 1966

EXPLANATION

△11 Coal-area site and number

△1 Rural-area site and number

△30 Urban-area site and number

Coal resources area

Maximum total recoverable manganese

- Less than 100 micrograms per liter
- 100 to less than 300 micrograms per liter
- 300 to 1,000 micrograms per liter
- Greater than 1,000 micrograms per liter

See section 10.1 for detailed site description.

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

Table 5.6-1 Total-recoverable manganese concentrations, in micrograms per liter, in water in streams

Sites in the coal area

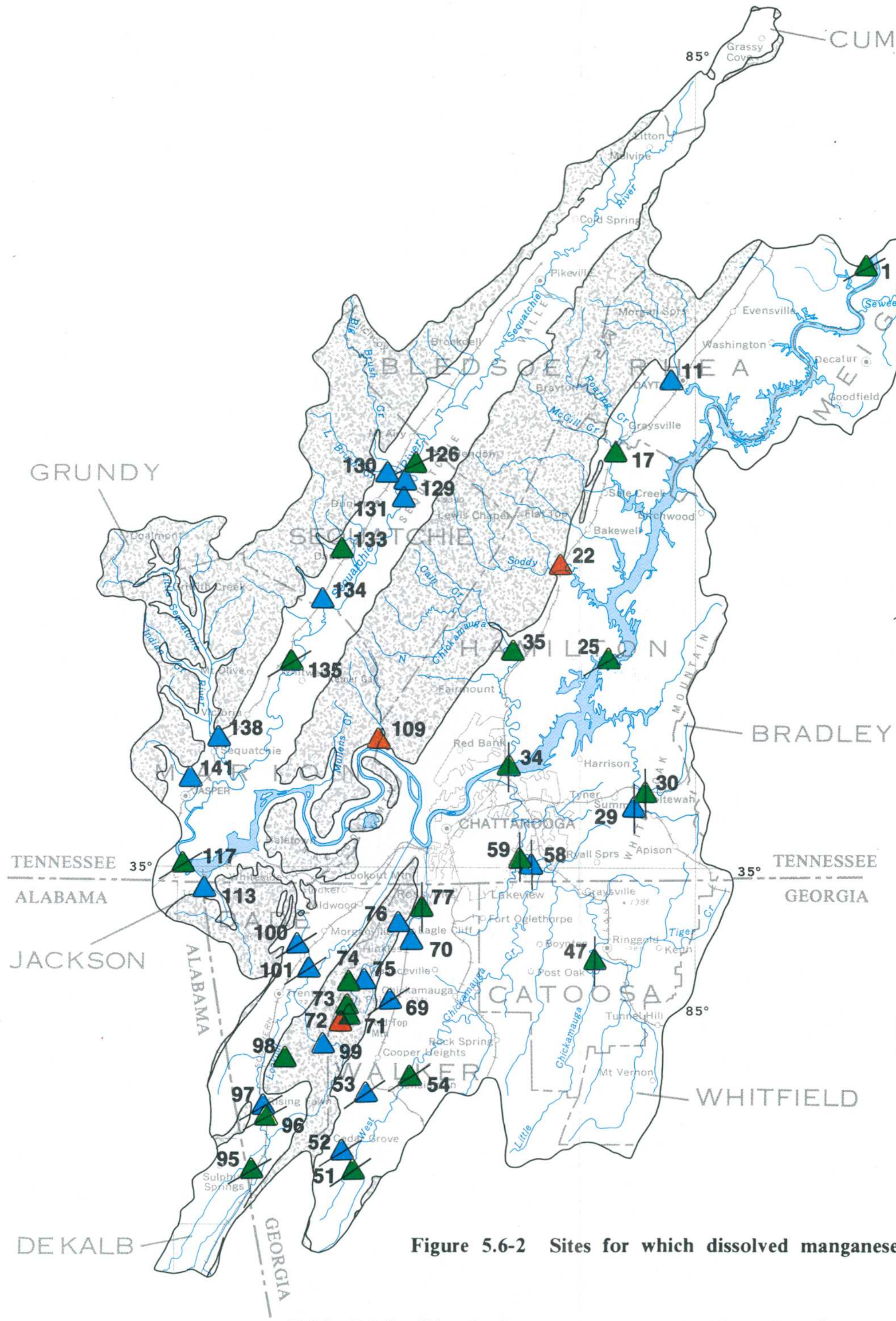
Site number	Minimum	Median	Maximum	Number of determinations
11	0	10	40	21
17	80	130	160	5
22	110	195	1,400	4
35	50	60	60	3
71	110	130	240	3
73	170	230	500	8
74	60	80	320	10
75	10	10	20	8
76	10	15	40	10
98	10	30	50	9
99	10	20	60	9
109	260	650	1,100	4
113	10	10	20	4
129	--	--	20	1
130	10	10	20	4
131	10	10	20	4
133	180	200	210	3
134	10	15	60	6
138	10	30	80	7
141	--	--	40	1

Sites in rural areas

Site number	Minimum	Median	Maximum	Number of determinations
1	20	50	160	69
25	30	60	180	32
51	20	40	80	8
52	30	--	40	2
53	50	--	60	2
54	30	50	110	25
69	20	25	40	8
70	20	40	60	10
95	10	20	150	8
96	40	--	70	2
97	20	40	100	8
100	10	10	10	6
101	20	40	90	24
117	30	60	120	36
126	40	50	240	8
135	0	50	260	31

Sites in urban areas

Site number	Minimum	Median	Maximum	Number of determinations
29	--	--	0	1
30	20	60	120	13
34	20	60	2,300	116
47	--	--	50	1
59	30	70	120	13
77	40	60	150	26



EXPLANATION

△11 Coal-area site and number

△1 Rural-area site and number

△30 Urban-area site and number

Coal resources area

Maximum dissolved manganese

- Less than 50 micrograms per liter
- 50 to 500 micrograms per liter
- Greater than 500 micrograms per liter

See section 10.1 for detailed site description.

Figure 5.6-2 Sites for which dissolved manganese data are available.

Table 5.6-2 Dissolved-manganese concentrations, in micrograms per liter, in water in streams

Sites in the coal area

Site number	Minimum	Median	Maximum	Number of determinations
11	0	10	20	21
17	60	110	160	5
22	100	160	760	5
35	40	65	110	4
71	110	140	250	3
72	--	--	1,500	1
73	170	230	500	6
74	60	80	330	8
75	10	10	20	6
76	10	10	30	8
98	10	20	50	8
99	10	10	30	7
109	260	630	750	5
113	10	10	20	4
129	--	--	20	1
130	10	10	10	4
131	10	10	10	4
133	160	170	210	3
134	10	10	20	6
138	10	10	20	5
141	--	--	20	1

Sites in rural areas

Site number	Minimum	Median	Maximum	Number of determinations
1	1	10	90	50
25	10	20	60	31
51	20	25	50	6
52	30	--	40	2
53	30	--	40	2
54	20	30	67	23
69	20	20	20	6
70	20	30	40	7
95	30	50	120	24
96	40	--	50	2
97	20	25	30	6
100	10	10	10	4
101	10	30	40	22
117	10	30	60	14
126	10	20	90	8
135	0	30	110	27

Sites in urban areas

Site number	Minimum	Median	Maximum	Number of determinations
29	0	0	0	5
30	20	45	80	12
34	10	20	110	25
47	--	--	50	1
58	--	--	10	1
59	10	30	60	12
77	30	50	120	24

Most Concentrations of Trace Constituents in Bottom Materials and in Water Were Low

Trace constituents generally occur in low concentrations and generally are not a water-quality problem in the area.

Trace constituents generally occur in small quantities in most streams. Major sources of these substances generally include soils, geologic strata underlying the basin, and atmospheric fallout. In low concentrations, trace constituents are essential to life; in higher concentrations, some can be toxic to plants and animals. High concentrations in streams can occur naturally; however, most high concentrations generally are associated with municipal- and industrial-waste discharges, or storm runoff from urban areas. In coal-mine areas, accelerated weathering of sulfide minerals present in coal-mine spoil produces acidic-mine drainage that is contributed to streamflow. The acid water reacts with other minerals and can produce adverse concentrations of trace constituents in mine drainage.

Selected trace constituents in water have been determined at 23 sites in Area 20 (table 5.7-1 and fig. 5.7-1). In addition, concentrations of trace constituents in bottom material from stream channels have been determined at 24 sites since 1979 (table 5.7-2 and fig. 5.7-1). Even though a few maximum trace-constituent concentrations listed were not within the maximum limits recommended by the U.S. Environmental Protection Agency (1977 and 1979), no widespread occurrence of any of the consitutents in potentially troublesome concentrations was evident, either in water or in bottom material. Two reservoir sites accounted for most of the trace-constituent concentrations listed in table 5.7-1 which exceeded maximum recommended levels. Maximum recommended levels of cadmium, copper, lead, and mercury were exceeded at site 34. The maximum cadmium and lead concentrations in rural areas occurred at site 1.

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:

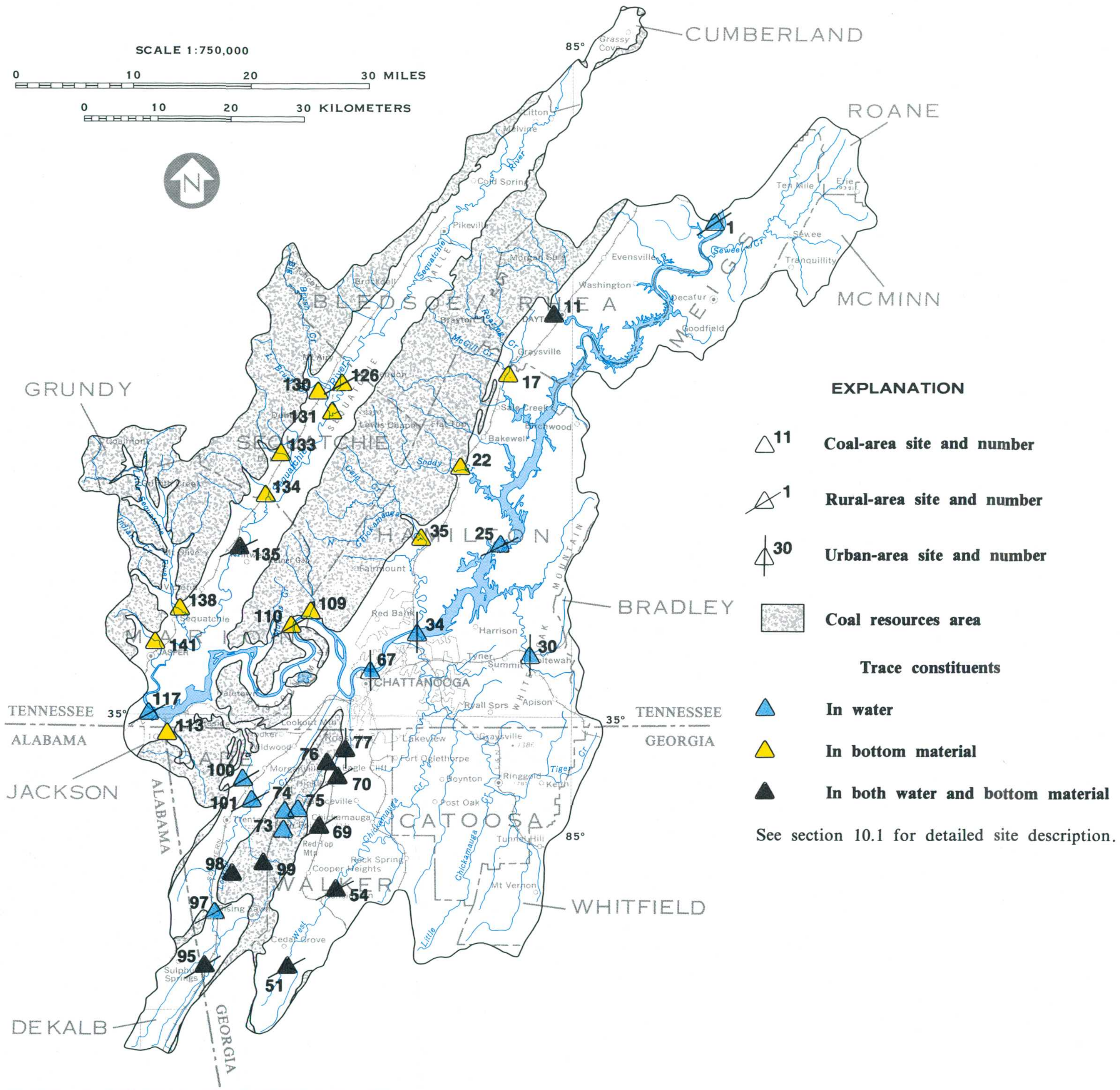
- Mandatory or recommended criteria for drinking water have been established for concentrations in water of several dissolved or total (dissolved plus suspended) trace constituents such as arsenic, cadmium, chromium, copper, lead, mercury, selenium, and zinc. The States of Tennessee, Georgia, and Alabama have adopted most of the drinking-water regulations issued by the U.S. Environmental Protection Agency (1977 and 1979), although state criteria in Tennessee are more stringent for physical properties such as turbidity.

- Concentrations of constituents exceeding recommended or mandatory limits (U.S. Environmental Protection Agency, 1977 and 1979) in streams do not necessarily violate those standards because drinking-water regulations apply only to water delivered to a consumer.

- Although total recoverable cadmium, copper, lead, and mercury concentrations have exceeded recommended criteria for drinking water (U.S. Environmental Protection Agency, 1977 and 1979) in streams in Area 20, there is no indication of a chronic trace-constituent problem at any site.

- Limits for concentrations of trace constituents in bottom material have not been established. High concentrations of constituents in bottom material, however, are potentially troublesome because the constituents can be transported downstream and can be redissolved or suspended by natural geochemical, biological, or physical processes. Because of downstream transport, the presence of any constituent in bottom material at a particular site does not identify a source in the immediate area.

- In general, dissolved trace constituent concentrations exceeding U.S. Environmental Protection Agency recommended limits (1977) in and near surface mines, usually decrease rapidly downstream. The decrease generally results from chemical reactions caused by mixing of mine drainage with near-neutral pH (6.0 to 8.0 units) water, from dilution, and from the strong sorption of trace constituents on suspended sediments.



BASE FROM U.S. GEOLOGICAL SURVEY STATE BASE MAPS; TENNESSEE 1973, ALABAMA AND GEORGIA, 1966

Figure 5.7-1 Sites for which trace constituent data are available.

Table 5.7-1 Total trace-constituent concentrations, in micrograms per liter, in water in streams

Data from 7 sites in the coal area

Constituent	Minimum	Median	Maximum	Number of determinations	Maximum contaminant level
Arsenic	0	1	3	14	50
Cadmium	0	0	2	14	10
Chromium	3	15	20	14	50
Copper	0	2.5	8	14	1,000
Lead	0	3.5	5	14	50
Mercury	.1	.35	.5	14	2
Selenium	0	1	1	14	10
Zinc	0	20	100	14	5,000

Data from 12 sites in rural areas

Constituent	Minimum	Median	Maximum	Number of determinations	Maximum contaminant level
Arsenic	0	2	10	109	50
Cadmium	0	2	15	116	10
Chromium	2	5	40	109	50
Copper	0	20	470	118	1,000
Lead	0	10	130	117	50
Mercury	.1	.2	.6	117	2
Selenium	0	1	4	106	10
Zinc	10	20	170	118	5,000

Data from 4 sites in urban areas

Constituent	Minimum	Median	Maximum	Number of determinations	Maximum contaminant level
Arsenic	0	5	10	12	50
Cadmium	0	2	11	104	10
Chromium	4	5	20	12	50
Copper	2	20	2,300	104	1,000
Lead	6	10	52	104	50
Mercury	.2	.2	2.9	106	2
Selenium	0	2	2	11	10
Zinc	10	20	320	104	5,000

Table 5.7-2 Total trace-constituent concentrations, in micrograms per gram, in bottom material from streams

Data from 15 sites in the coal area

Constituent	Minimum	Median	Maximum	Number of determinations
Arsenic	0	0	0	27
Cadmium	10	10	10	27
Chromium	10	10	40	27
Copper	10	10	20	27
Lead	10	10	30	27
Mercury	0	0	.01	27
Selenium	0	0	0	25
Zinc	10	22	70	27

Data from 7 sites in rural areas

Constituent	Minimum	Median	Maximum	Number of determinations
Arsenic	0	0	0	15
Cadmium	10	10	10	14
Chromium	10	10	40	15
Copper	10	10	10	15
Lead	10	10	20	15
Mercury	0	0	.01	15
Selenium	0	0	0	10
Zinc	6	20	60	15

Data from 2 sites in an urban area

Constituent	Minimum	Median	Maximum	Number of determinations
Arsenic	0	--	1	2
Cadmium	10	--	10	2
Chromium	20	--	40	2
Copper	10	--	20	2
Lead	10	--	70	2
Mercury	0	0	.5	3
Selenium	--	--	0	1
Zinc	30	--	360	2

Suspended-Sediment Yields Higher from Mined Areas

Suspended-sediment concentrations are highly variable; highest concentrations are associated with high flows.

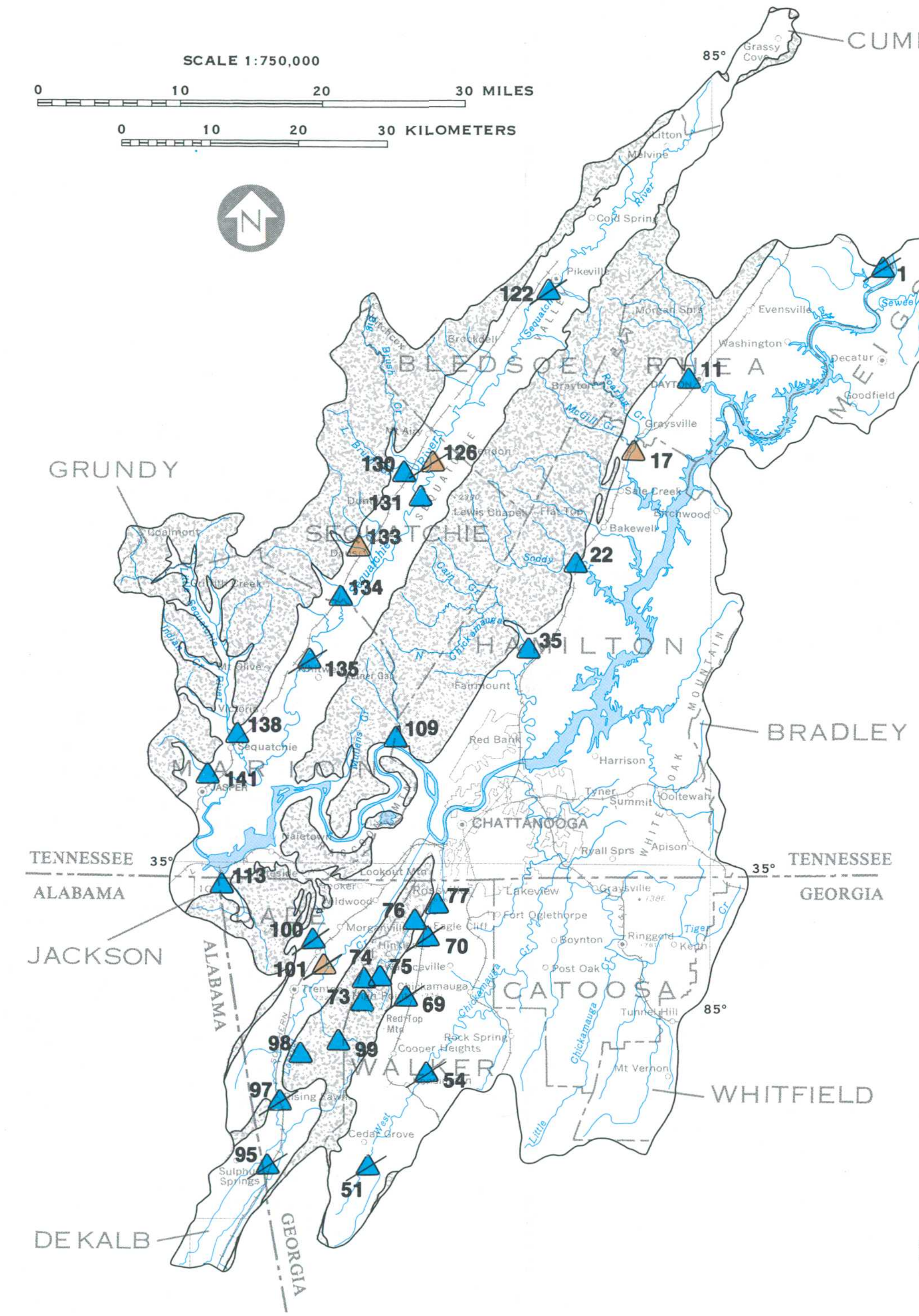
Any land-use activity that strips the surface of its vegetative cover may greatly increase erosion and sediment yields. Suspended sediment in sufficient quantities can have far-reaching effects on the aquatic environment as well as channel capacity and channel morphology. The amount of sediment supplied to a stream reflects upstream activities. The effect of the sediment load may be felt far from the source because the fine fraction may travel large distances downstream.

Suspended-sediment data were collected at 31 sites in Area 20 (fig. 5.8-1). Table 5.8-1 lists the minimum, mean, and maximum suspended-sediment concentrations for all sites. The number of samples collected, drainage area, and the availability of storm runoff sampling is also included in the table. The consistently higher values for means and maximums when sampling took place through high-flow events should be noted. Four out of five of the highest mean concentrations occurred at sites where samples were collected during storms. It is at these times that significant quantities of material are transported, making timely data collection most difficult but most important in accurately assessing trends in suspended-sediment transport. Depending on the availability of sufficient data, several sites were selected to determine the differences in suspended-sediment transport as a function of land use.

One of the difficulties in constructing the water discharge versus suspended-sediment discharge relationship (known as a suspended-sediment rating curve) is illustrated by fig. 5.8-2. This figure shows the variability of suspended-sediment concentration with water discharge during a storm at site 17. Suspended-sediment concentration peaked approximately 10 hours prior to the peak in water discharge. The substantial differences in concentration relative to the sample's position on the hydrograph at a given discharge are apparent. For example, at a discharge of 600 ft^3/s, the concentration was both 260 mg/L and 25 mg/L.

The variability in suspended-sediment concentrations described above along with other factors such as basin area, source area, precipitation duration and intensity, type of bed and bank material, season of the year, and antecedent conditions must be considered in estimating sediment yields.

The suspended-sediment rating curves in figure 5.8-3 illustrate the effect of land use on suspended-sediment transport in Area 20. Significantly more material per unit of water discharge was transported at site 17 (Sale Creek near Sale Creek, Tenn.) than at site 54 (West Chickamauga Creek near Kensington, Ga.). This is because the drainage basin of site 17 has been disrupted by surface-mining activities, making more material available for transport. In order to minimize the effects of basin area on differences in suspended-sediment and water discharge values, and to facilitate basin comparisons, the data used to derive the above rating curves have been expressed in terms of tons per day per square mile and cubic feet per second per square mile, respectively.



BASE FROM U.S. GEOLOGICAL SURVEY STATE BASE MAPS:
TENNESSEE 1973, ALABAMA AND GEORGIA, 1966

EXPLANATION

△11 Site and number

▲1 Suspended-sediment sampling site

▲17 Suspended-sediment sampling site for which storm-produced sediment data are available

Note: / indicates rural area sites, all others are coal area sites.

See section 10.1 for detailed site description.

▒ Coal resources area

Figure 5.8-1 Sites for which suspended-sediment data are available.

Table 5.8-1 Suspended-sediment concentrations, in milligrams per liter, in water in streams

Site no.	Station name	Drainage area (mi²)	Concentration Minimum	Concentration Mean	Concentration Maximum	Number of samples
1	Tennessee River at Watts Bar Dam (Tailwater), Tenn.	17,310	4	10.1	43	66
11	Richland Creek near Dayton, Tenn.	50.2	0	7.8	36	14
17	Sale Creek near Sale Creek, Tenn.*	57.2	1	164	590	13
22	Soddy Creek at Soddy, Tenn.	49.0	2	45.5	163	4
35	North Chickamauga Creek near Daisy, Tenn.	62.6	1	1.8	2	4
51	Mud Creek at Cedar Grove, Ga.	22.2	7	14.3	20	3
54	West Chickamauga Creek near Kensington, Ga.	73.0	2	20.6	93	11
69	Chattanooga Creek at High Point, Ga.	5.5	4	11.3	16	3
70	Chattanooga Creek at SR 341 near Flintstone, Ga.	18.9	4	13.3	24	3
73	Rock Creek below SR 170 near Durham, Ga.	0.80	1	9.5	30	4
74	Rock Creek at Nickajack Road near Hinkle, Ga.	7.40	1	8.7	18	3
75	Long Branch near Hinkle, Ga.	3.73	1	4.5	9	4
76	Rock Creek near Flintstone, Ga.	22.2	1	6.7	10	3
77	Chattanooga Creek near Flintstone, Ga.	50.6	3	15.7	35	10
95	Lookout Creek at Sulphur Springs, Ga.	16.3	5	36.7	99	3
97	Lookout Creek at Rising Fawn, Ga.	68.7	5	26.0	66	3
98	Daniel Creek at SR 143 near Trenton, Ga.	4.80	1	2.5	5	4
99	Bear Creek at SR 157 near Durham, Ga.	7.98	1	2.3	4	3
100	Squirrel Town Creek near New England, Ga.	3.80	2	--	4	2
101	Lookout Creek near New England, Ga.*	149	1	41.8	134	18
109	Suck Creek near Chattanooga, Tenn.	22.6	3	10.0	17	5
113	Cole City Creek near South Pittsburgh, Tenn.	25.6	1	3.3	6	3
122	Sequatchie River near Pikeville, Tenn.	106	13	25.8	66	5
126	Sequatchie River near Mount Airy, Tenn.*	202	7	294	1,370	19
130	Little Brush Creek near Dunlap, Tenn.	15.4	1	5.0	6	4
131	Big Brush Creek near Dunlap, Tenn.	66.1	1	4.0	7	4
133	Woodcock Creek southwest of Dunlap, Tenn.*	15.3	1	41.6	84	9
134	Hicks Creek at Cartwright, Tenn.	17.9	1	40.0	74	5
135	Sequatchie River near Whitwell, Tenn.	402	3	23.3	57	15
138	Little Sequatchie River at Sequatchie, Tenn.	116	3	18.0	34	5
141	Pryor Cove Branch near Jasper, Tenn.	12.9	--	--	4	1

* Includes storm-period sampling.

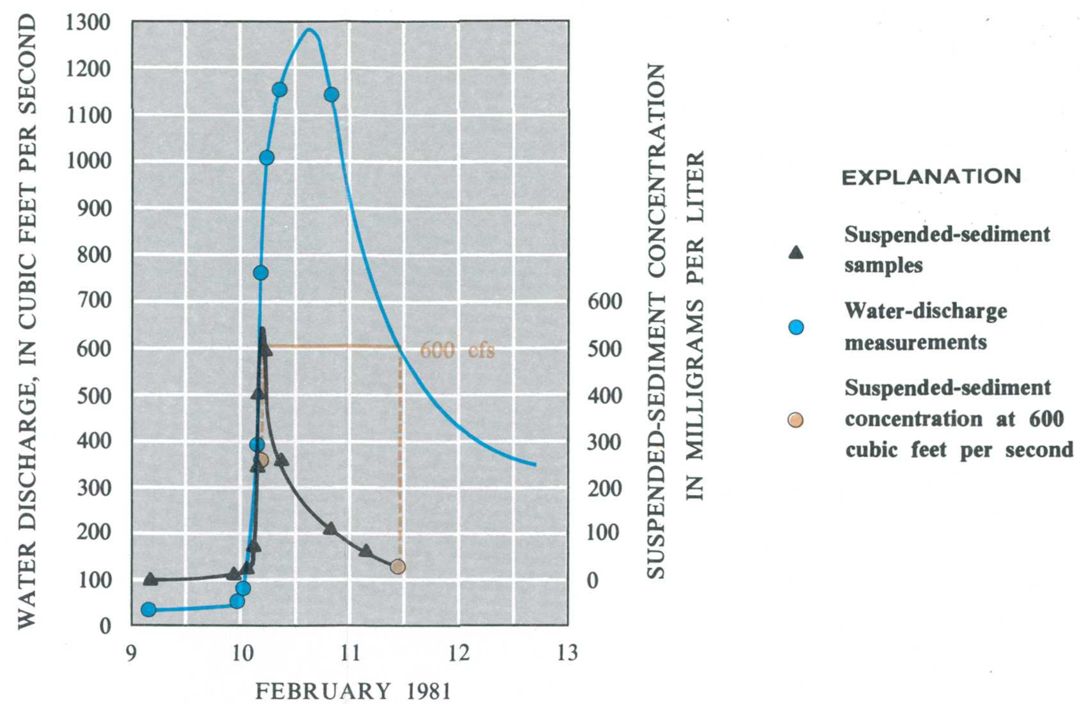
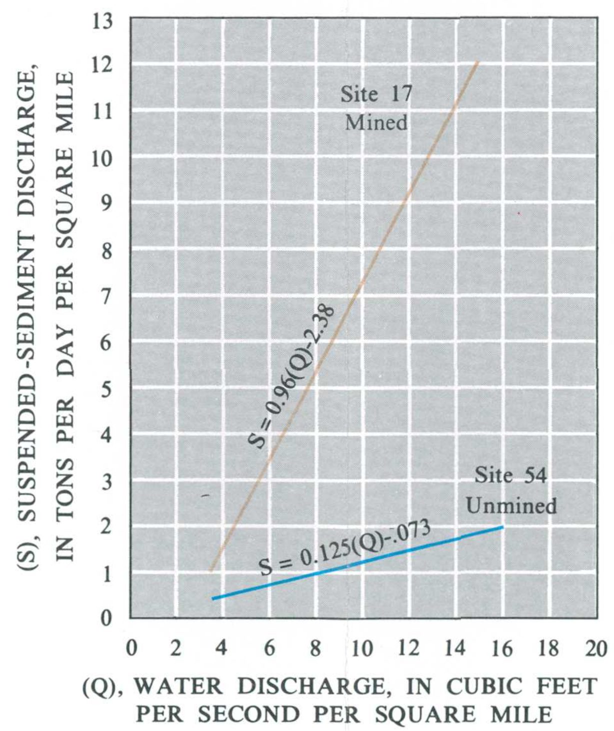


Figure 5.8-2 Relation between water discharge and suspended-sediment concentration during storm event of February 9-12, 1981 at Sale Creek near Sale Creek, Tenn. (site 17).



Site	Drainage Area (square miles)	Number of samples	Correlation Coefficient (r)	Resources area
17	57.2	13	.73	Coal area
54	73.0	11	.71	Rural area

Figure 5.8-3 Suspended-sediment rating curve for mine-affected and mine-unaffected sites.

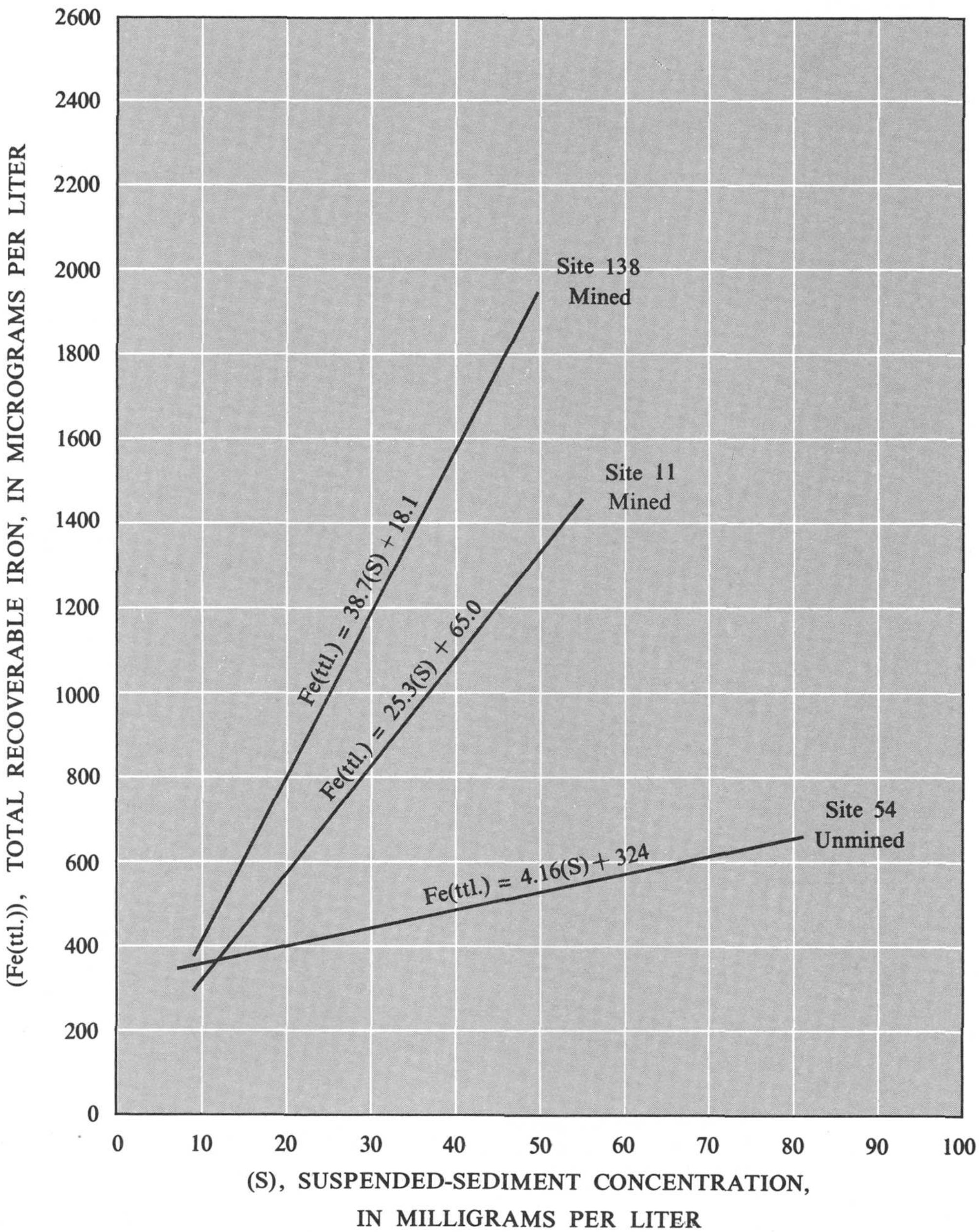
Sediment-Associated Iron Concentrations Higher in Mined Areas

The relation between suspended sediment and total recoverable iron can be calculated for several sites in the area.

Fine silt and clay in suspended sediment has the ability to adsorb chemical constituents and transport them downstream. Iron is a relatively abundant constituent that is commonly exposed during coal mining, is weathered quickly, and is transported in the stream system either in the dissolved or in the suspended phase. The mode of transport of iron and other constituents (either dissolved or adsorbed on sediment) is a function of many factors that determine chemical equilibrium in a stream and is beyond the scope of this report. Because of iron's affinity for fine suspended sediment, it is correlated with suspended-sediment concentration to establish the relation between constituent transport and suspended sediment. This implies that the transport of other constituents occurs by the same mechanism, though not necessarily at the same magnitude.

Figure 5.9-1 illustrates the difference in the transport of total-recoverable iron between mined and unmined basins. It is apparent that the mined sites (138, Little Sequatchie River at Sequatchie, Tenn.; and 11, Richland Creek near Dayton, Tenn.), transport greater amounts of total-recoverable iron per unit of suspended sediment than the unmined basin (site 54, West Chickamauga Creek near Kensington, Ga.). The heightened iron concentrations indicate that surface-mining activities do increase constituent delivery to surface waters draining these areas.

The detrimental effects of increased sediment yield and associated chemical constituents are not restricted to stream segments adjacent to disturbed slopes but extend far 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 still have an adverse effect on water quality.



Site	Drainage Area (square miles)	Number of samples	Correlation Coefficient (r)	Resources area
11	50.2	14	.92	Coal area
54	73.0	11	.72	Rural area
138	116	5	.91	Coal area

Figure 5.9-1 Transport of total recoverable iron as a function of suspended-sediment concentration at mine-affected and mine-unaffected sites.

Benthic Invertebrate Populations Indicative of Water Quality

Benthic data collected at four stream sites in Area 20 showed three relatively free of pollution.

Benthic invertebrates, organisms found in the substrate of aquatic environments, are useful indicators of water quality. Like all living creatures, invertebrates have ranges of tolerance to environmental changes. When water quality is altered by increases in sediment and other pollutants, there is a response by the population of these bottom dwellers. Clean water is usually associated with a high community diversity whereas varying degrees of pollution produce lower diversity with a larger or smaller number of individuals. It has been demonstrated that when pollution is heavy the effects on most invertebrates is so marked that whole taxonomic groups may be reduced or eliminated while more tolerant organisms may flourish (Hynes, 1963).

Because the type and number of invertebrates present depends upon a variety of physical factors as well as water quality, interpretation of biological data must be done carefully. Biological data is particularly useful when samples are collected along with chemical data over a period of time to monitor changes in environmental conditions. A combination of biological and chemical surveys is superior to either method used alone.

Benthic invertebrate samples were collected at four sites in Area 20 during May and June of 1980. Two sites are on streams draining areas almost entirely in the coal area and two are on streams draining larger watersheds, approximately half in the coal area (fig. 5.10-1). The kick sampling method was used to collect organisms. In this method the stream bottom is disturbed and dislodged organisms are collected in a dip net held downstream. After collection, organisms were separated from the debris and identified to genus.

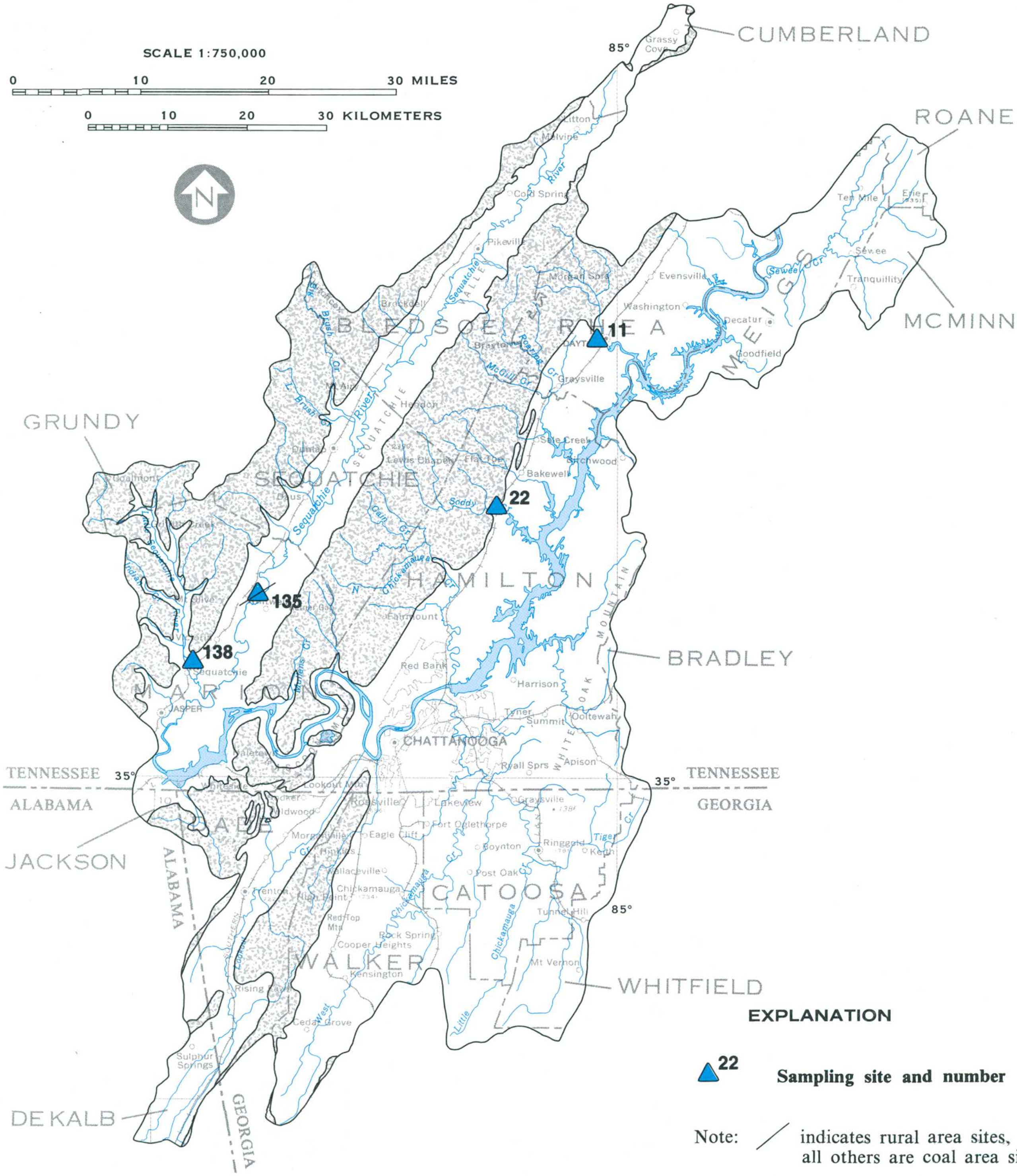
A biotic index (J. Gore, Tennessee Technological University, written comm., 1980) modified from Hilsenhoff (1977) and a diversity index (Shannon and Weaver, 1963) were computed for each site. Each index has its own limitations so it is often useful to evaluate samples by more than one method. The biotic index considers the pollution tolerance of the organisms in a sample. However, it is subjective since each genus is given a water quality "rating" and there is some variation in tolerance among species of the same genus. The biotic index used here is based on experience with organic pollutants.

The Shannon-Weaver equation takes into account the distribution of individuals among the various taxa but it does so without regard to the pollution tolerance of the organisms or sample size. Samples containing less than 100 individuals should be evaluated carefully, if at all. The sample at Soddy Creek contained only seven individuals so a diversity index was not computed. The scales for each index are different and are shown below. The results for each site are given in table 5.10-1.

Biotic index	Diversity index	Water quality rating
<1.75	>4	excellent
1.75-2.25	3-4	good
2.25-3.00	2-3	fair
3.00-3.75	1-2	poor
>3.75	<1	very poor

Disturbance at the sites on the Sequatchie and Little Sequatchie Rivers and on Richland Creek appears to be moderate as might be expected with present population densities and land use practices. Two of these sites have large drainage areas and the effects of mining may be minimized by dilution. Further sampling would be necessary for a definitive statement concerning mining impacts and water quality trends at these sites.

Site 22 on Soddy Creek was the only station sampled for aquatic organisms that apparently was affected by mining as indicated by the small number of invertebrates collected and the dominance of chironomids (*Diptera*). This is substantiated by the higher than background values for sulfate and suspended-sediment concentrations and by the lower than normal pH.



EXPLANATION

▲22 **Sampling site and number**

Note: ⁄ indicates rural area sites, all others are coal area sites.

See section 10.1 for detailed site description.

Coal resources area

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

Table 5.10-1 Results of kick samples for benthic invertebrates at sites in Area 20

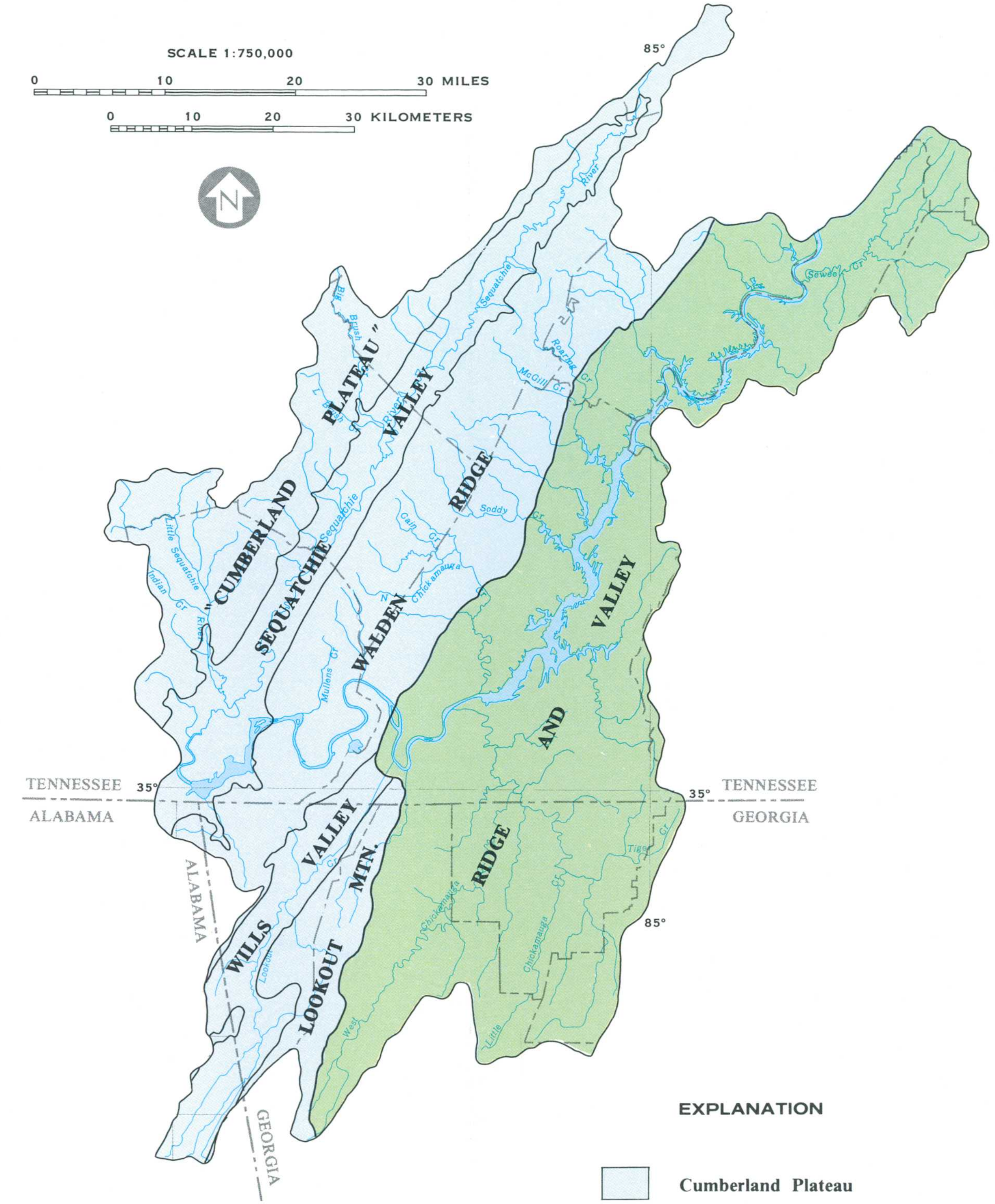
Site no.	Station name	Drainage area (mi^2)	Indices Biotic	Indices Diversity	Sample count	Dominant order	Composition (percent)
11	Richland Creek	50	2.23	3.62	2,197	Ephemeroptera	42
22	Soddy Creek	50	2.97	-	7	Diptera	96
135	Sequatchie River	402	1.58	2.52	2,054	Ephemeroptera	44
138	Little Sequatchie River	116	2.81	2.33	1,847	Tricoptera	39

Ground Water Occurs in Fractures and Solution Openings

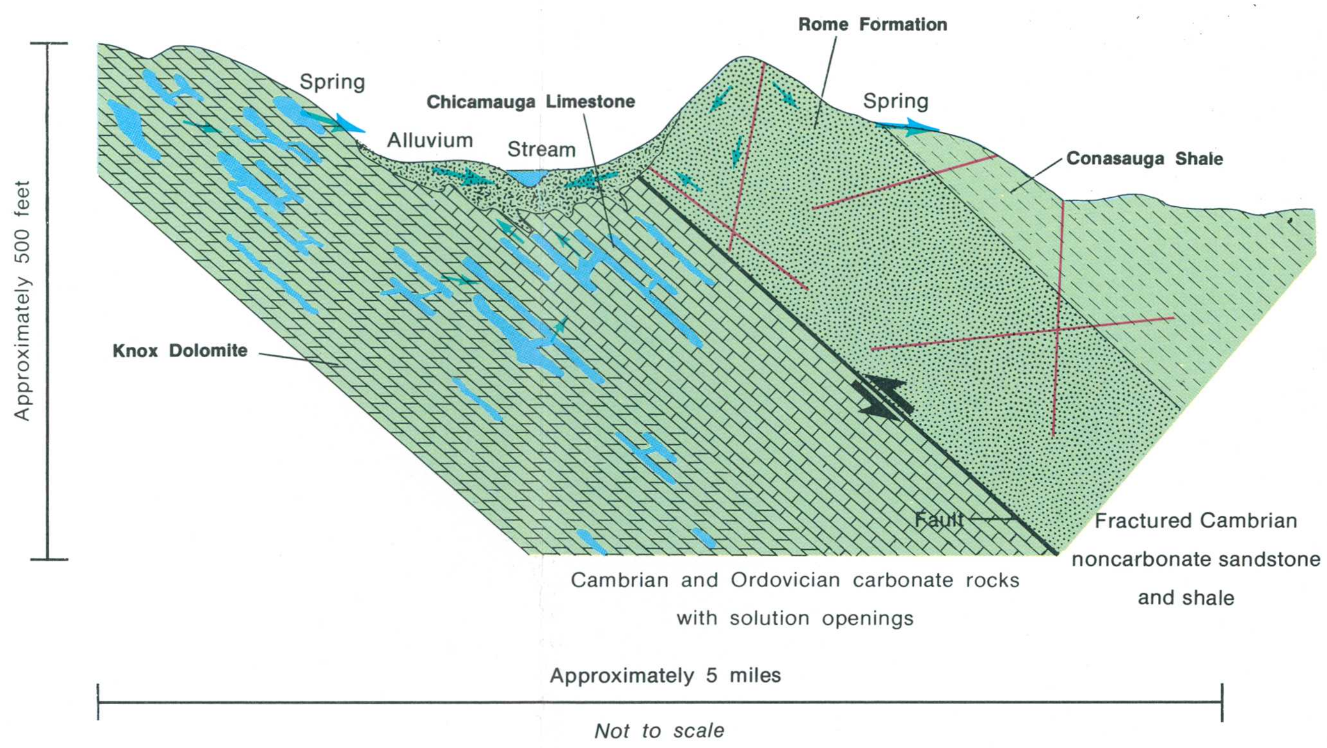
Ground water in the coal area primarily occurs in fractures in sandstone and shale; ground water in the major valleys in the Cumberland Plateau and in the Ridge and Valley occurs most abundantly in soluble carbonate rocks.

Ground water in the coal area of the Cumberland Plateau occurs primarily in fractures in sandstones and shales which have a low intergranular permeability (fig. 6.1-1). Fractures provide a secondary permeability, storing and transmitting most of the ground water. Water-bearing openings generally are encountered within 100 feet of land surface and appear to be evenly distributed throughout the Plateau. Although water-bearing openings are widespread, the yields are generally low. Large springs are commonly found issuing from carbonate rocks at the base of the steep escarpments bordering the Sequatchie and Wills Valleys.

Ground water in the two major valleys in the Cumberland Plateau and in the Ridge and Valley province occurs mostly in soluble limestone, dolomite, and calcareous shale. Enlargement of fractures, joints, and bedding planes by solvent action enables the rocks to store and transmit large amounts of water. The Knox Dolomite is a very important aquifer because in places it may contain either very soluble beds or karst features rejuvenated today after they were formed during a previous erosion cycle. Wells in the Knox range from 150 to 200 feet in depth, and some are capable of providing as much as 3,000 gal/min. Several springs issue from the Knox with flows exceeding 5,000 gal/min. In contrast, the noncarbonate rocks of this province produce only moderate yields from fractures in the bedrock and from pores in the overlying regolith. These moderate yields can be obtained almost anywhere in the noncarbonate rocks.

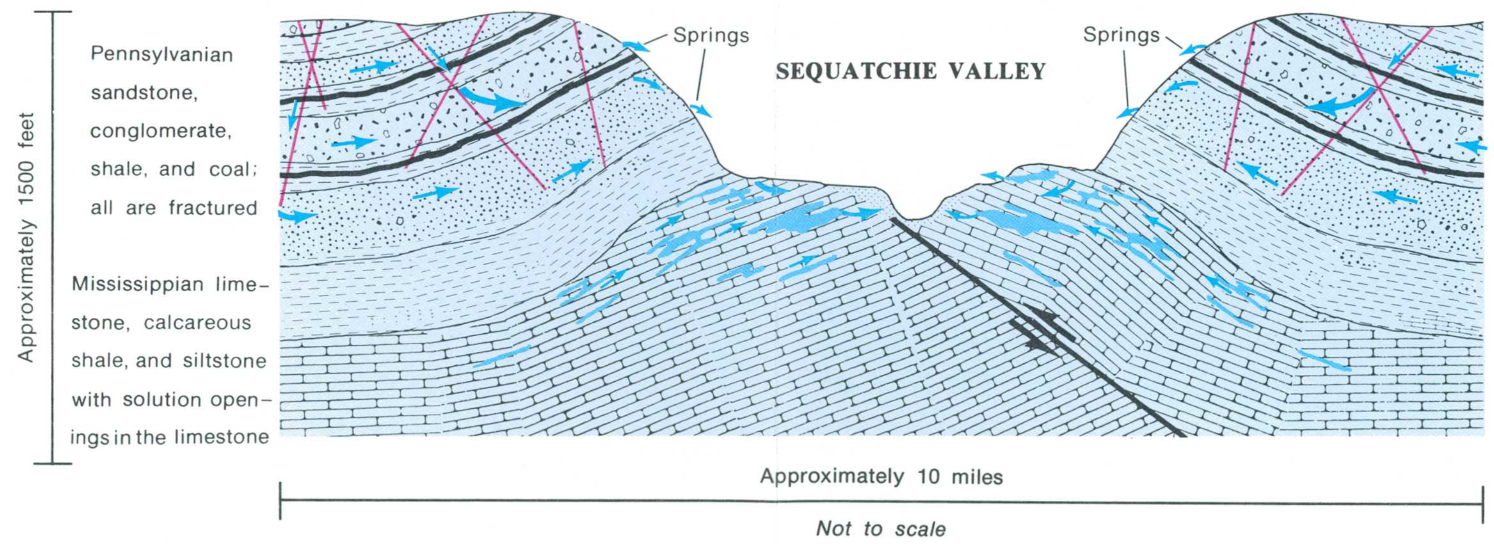


BASE FROM U.S. GEOLOGICAL SURVEY STATE BASE MAPS; TENNESSEE 1973, ALABAMA AND GEORGIA, 1966



RIDGE AND VALLEY

Geology modified from Zurawski (1978) and Milici (1979)



CUMBERLAND PLATEAU

Geology modified from Zurawski (1978) and Milici (1979)

EXPLANATION

- Cumberland Plateau
- Ridge and Valley
- Direction of ground-water flow
- Fracture
- Solution opening

Figure 6.1-1 Ground-water occurrence and flow.

Aquifer Yields and Transmissivities are Highly Variable

Yields to wells range from about 5 to more than 3,000 gallons per minute with variations in yield and transmissivity related to the size of fractures and solution openings.

Fractured Pennsylvanian sandstones and shales supply most of the ground water to wells in the coal resources area of the Cumberland Plateau. Reported yields to more than 400 wells in the Pennsylvanian rocks range from less than 5 gal/min to about 300 gal/min with 68 percent less than 20 gal/min. Specific capacity, the yield per foot of drawdown in a well, can be used to estimate transmissivity, the capacity of an aquifer to transmit water (Walton, 1962). Estimated transmissivities for six wells range from 20 to 750 ft^2/d (table 6.2-1) with 68 percent between 30 and 700 ft^2/d. The wide range in transmissivities is due to the variation in size and extent of water-bearing fractures in the rocks.

Carbonate rocks yield ground water to wells in the Sequatchie and Wills Valleys of the Cumberland Plateau. The reported yields range from about 5 to more than 1,000 gal/min, but most are between 10 and 50 gal/min. Data were insufficient to establish a valid range for transmissivities. However, it should be similar to that for the carbonate rocks of the Ridge and Valley.

Reported yields for more than 300 wells in the Ridge and Valley range from about 5 to more than 3,000 gal/min, but most are between 10 and 30 gal/min. Based on specific capacity data from 17 wells, estimated transmissivities range from 30 to 900 ft^2/d (table 6.2-1) with 68 percent between 50 and 300 ft^2/d. The wide range is due to differences in size of solution openings in the carbonate rocks.

Springs are positive indicators of a ground-water reservoir. The network springs in the Ridge and Valley had mean yields ranging from 49 to 3,600 gal/min. The mean yields of the network springs in the coal resources area ranged from 1,600 to 3,400 gal/min.

Table 6.2-1 Specific capacity and estimated transmissivity of rocks

	Cumberland Plateau		Ridge and Valley	
	Specific capacity (gal/min)/ft	Trans-missivity (ft^2/d)	Specific capacity (gal/min)/ft	Trans-missivity (ft^2/d)
Maximum	2.7	750	3.3	900
16 percent of data equal to or greater than this value	2.6	700	1.3	300
16 percent of data less than this value	0.1	30	0.2	50
Minimum	0.09	20	0.1	30

Ground-Water Levels Fluctuate Seasonally

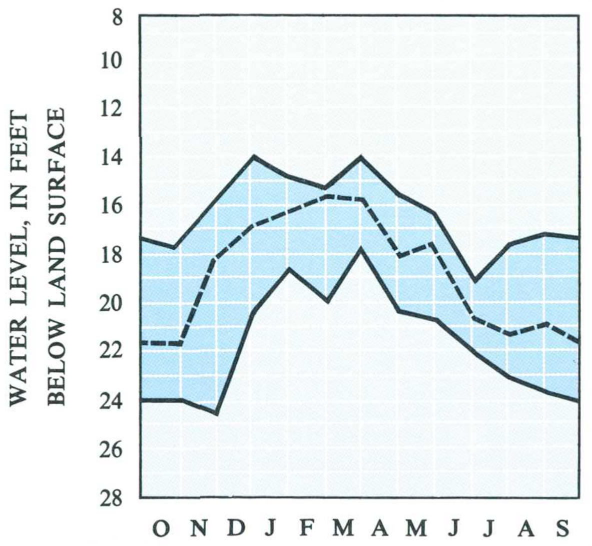
Water-level records from observation wells can be used to interpret hydrologic conditions.

The water-level hydrographs for two wells in the area are shown in figure 6.3-1. The levels are the monthly median and extremes of the lowest water levels measured near the end of each month for the period of record. Water levels are highest in the winter and spring and lowest in the summer and fall.

Current hydrologic conditions can be inferred from a plot of current water-level measurements from these observation wells, by comparing these measurements with the previously recorded median and extremes. If a current measurement is above or below the median for the month, it may be inferred that water levels are generally higher or lower, respectively, than normal. This inference can be applied to water-level measurements made in other wells with similar geology in the general vicinity of an observation well. In this way, the significance of infrequent measurements made at or near a site, with the same geologic setting, can be determined in terms of prevailing hydrologic conditions.

The actual depths to water as measured in other wells in Area 20 may be more or less than those measured at the observation wells primarily due to differences in the hydrogeology at the site. For example, wells located on hilltops usually have the greatest depth to water, whereas, wells located in a valley have the least depth to water. In some valleys in the Ridge and Valley part of Area 20, it is likely that the water levels in wells will rise above land surface.

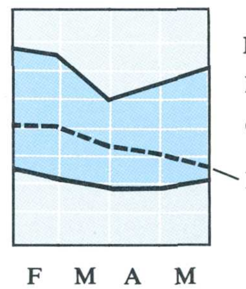
Water-level measurements for the observation wells in Tennessee, listed in section 10.2, are published annually by the U.S. Geological Survey, Nashville, in "Water Resources Data for Tennessee" and monthly in "Water Resources Conditions in Tennessee." These reports can be obtained from the District Chief, U.S. Geological Survey, Water Resources Division, Room A-413 Federal Building, U.S. Courthouse, Nashville, TN 37203. Water-level measurements for the observation wells in Georgia, listed in section 10.2, are published annually by the U.S. Geological Survey, Doraville. This report can be obtained from the District Chief, U.S. Geological Survey, Water Resources Division, Suite B-6481 Peachtree Industrial Blvd., Doraville, GA 30360.



LOCAL 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 discharge.
AQUIFER: Pennsylvanian sandstone.
PERIOD OF RECORD: Sept. 1964 to Sept. 1974

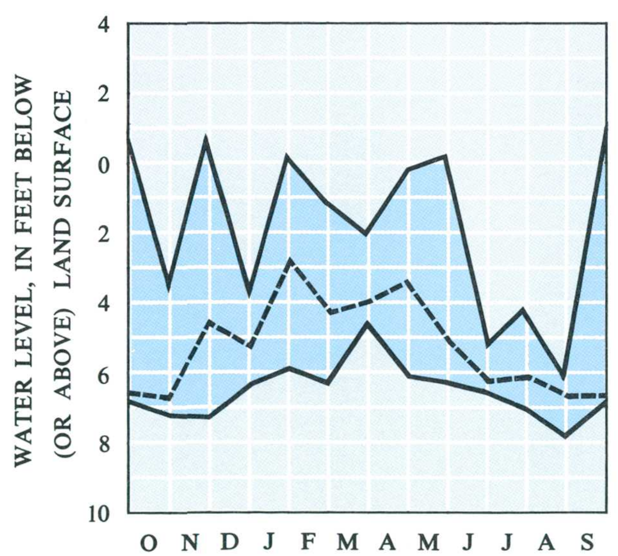
See section 10.2 in Hydrology of Area 19, Eastern Coal Province, Tennessee, Michael W. Gaydos and others for detailed site description of well Cu:C-1 (site 16)

EXPLANATION



Dark tones designate extremes for lowest water level on 25th or near end of month for period of record.

Median low of record



LOCAL WELL NO.: Hm:0-15 WELL DEPTH: 262 feet CASING DEPTH: 50 feet
AQUIFER: Knox Dolomite of Cambrian and Ordivician Age
PERIOD OF RECORD: May 1975 to Oct. 1980

See section 10.2 for detailed site description concerning well Hm: 0-15 (site 20)

Figure 6.3-1 Hydrographs of observation wells showing seasonal water-level fluctuations.

7.0 QUALITY OF GROUND WATER

Quality of Ground Water is Generally Suitable for Drinking

Locally, quality of ground water is variable.

Water-quality data have been collected from wells prior to the Act (fig. 7.0-1). An analysis of this data (table 7.0-1) suggests that ground-water quality in Area 20 is generally suited for most uses with minimum treatment. Water from a typical well in the coal area (fig. 7.0-1) is soft to moderately hard, of a calcium bicarbonate, sodium bicarbonate, or calcium sulfate type (Rima and Mull, 1980). Dissolved solids concentrations are low. Locally, concentrations of manganese or iron may exceed the recommended limits (U.S. Environmental Protection Agency, 1977). The quality of water from wells in the Ridge and Valley is generally suitable for drinking. Dissolved solids concentrations are generally less than the 500 mg/L maximum recommended by EPA for drinking water. Locally, iron concentrations and hardness may be a problem.

Some water-quality problems are apparent within the Ridge and Valley area of northwestern Georgia. In West Chickamauga Creek valley where the beds of limestone form a syncline, water from several wells is known to have a salty taste or to have a laxative effect making the water unfit for human or animal consumption (Cressler, 1963). Ground water in this area can have dissolved solids greater than 5,000 mg/L (table 7.0-1).

Contamination of ground water is a potentially serious problem throughout those areas of the Ridge and Valley that are underlain by carbonate rocks (Brahana and Macy, written commun., 1980). These carbonate rocks, primarily limestones and dolomites, are subject to dissolution along fractures, joints, and bedding planes. The formations with karst features are characterized by high permeability and rapid velocities which can facilitate the movement of contaminants through the system.

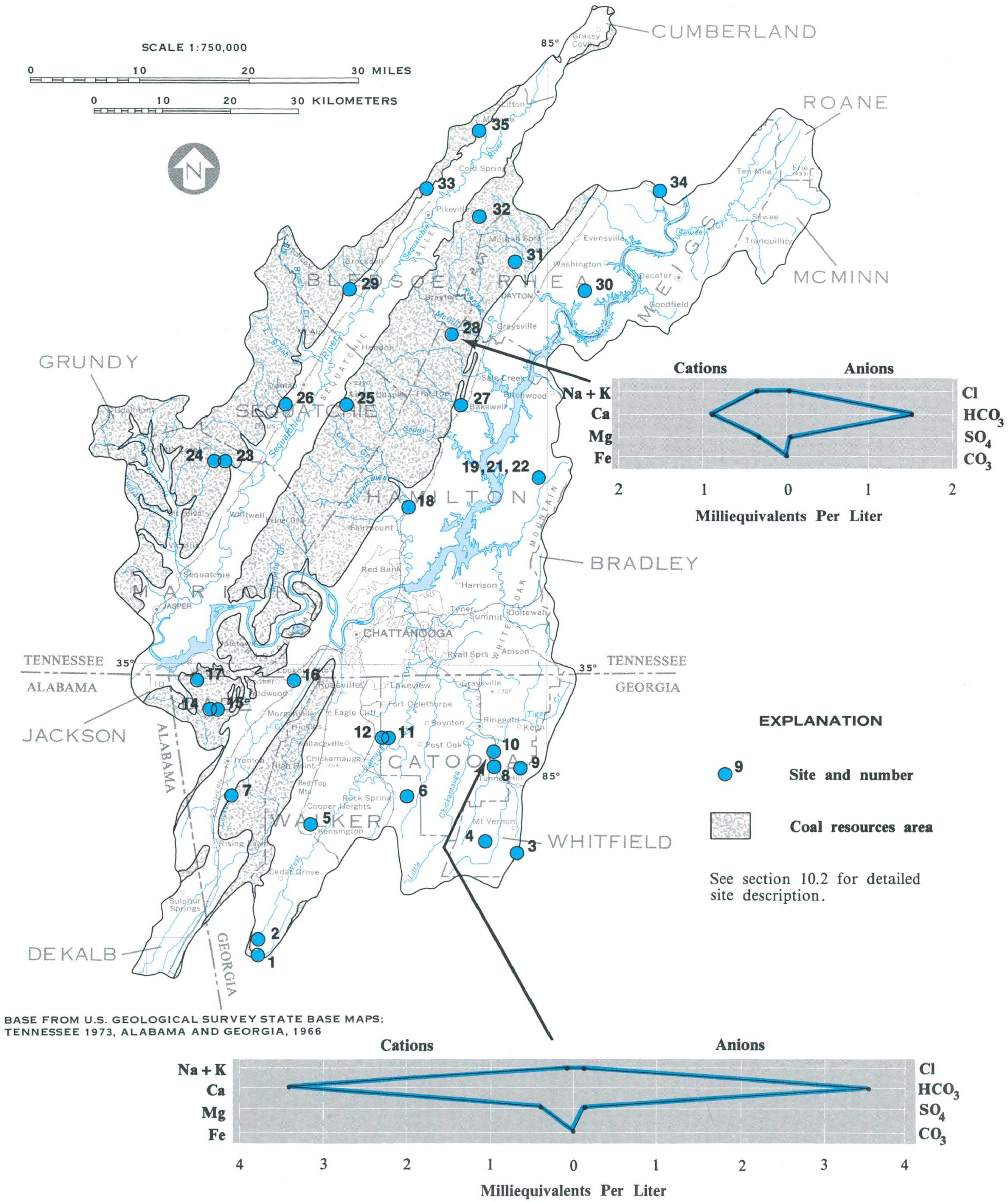


Figure 7.0-1 Wells for which water-quality data are available and typical water quality.

Table 7.0-1 Quality of water from wells.

Site number	Year sampled	Specific conductance (µmho/cm)	Dissolved solids, residue at 180°C (mg/L)	pH (units)	Dissolved iron (µg/L)	Dissolved manganese (µg/L)	Dissolved sulfate (mg/L)	Hardness as $CaCO_3$ (mg/L)
1	1960	128	106	6.7	-	-	4.0	-
2	1960	668	517	7.4	30	-	215.	370
3	1965	262	-	7.9	-	-	.4	140
4	1963	41	40	6.5	-	-	.0	8
5	1970	227	156	7.6	-	10	.0	-
6	1960	166	117	7.2	10	-	.4	84
7	1958	55	39	6.0	1,300	-	3.4	16
8	1958	275	160	7.4	490	-	18	140
9	1963	300	212	7.6	-	-	4.4	150
10	1958	365	213	7.6	20	-	6.2	190
11	1946	-	124	-	-	-	5.8	-
12	1946	-	7,280	-	-	-	206	-
14	1976	30	43	5.2	2,400	270	1.5	6
15	1976	138	128	6.4	960	1,200	.8	75
16	1958	289	163	7.7	120	-	4.8	150
17	1958	78	60	6.7	11,000	1,000	1.7	12
18	1977	200	126	7.4	10	0	10	91
19	1975	205	-	7.2	-	-	1.5	100
21	1974	140	-	7.4	-	-	-	68
22	1974	189	-	7.4	-	-	1.9	-
23	1954	135	77	6.8	-	-	14	54
24	1954	201	110	7.2	-	-	10	98
25	1954	180	102	6.9	-	-	3.0	90
26	1977	290	144	7.5	10	10	2.3	130
27	1977	180	118	7.9	40	0	3.0	97
28	1977	180	97	7.1	290	90	1.7	61
29	1954	-	62	6.6	-	0	3.0	34
30	1977	580	-	7.5	50	10	22	250
31	1977	250	144	7.5	30	310	5.2	84
32	1954	202	124	6.8	-	-	17	68
33	1977	225	115	7.4	0	0	7.3	100
34	1977	250	-	7.6	10	10	3.5	120
35	1977	280	160	7.8	0	10	3.1	120
Range		30-668	39-7,280	5.2-7.9	0-11,000	0-1,200	.0-215	6-370
Median		202	124	7.4	35	10	3.5	98
No. of Samples		30	27	31	18	14	32	28

Information from National Water Data Exchange, National Water Data Storage and Retrieval System, and Office of Water Data Coordination

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 available to the public.

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

NAWDEX Simplifies Access to Water Data

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

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

Services are available through a Program Office located at the U.S. Geological Survey 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. 8.2-1). A directory containing the names, addresses, telephone numbers, and office hours for each of the Assistance Centers can be obtained from the Program Office. It is entitled "Directory of Assistance Centers of the National Water Data Exchange (NAWDEX)", U.S. Geological Survey Open-File Report 80-1193.

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. 8.2-2). 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. 8.2-3) 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

or

GEORGIA
U.S. Geological Survey
Water Resources Division
6481 Peachtree Industrial Blvd.
Suite B
Doraville, GA 30360

Telephone: (404) 221-4858

FTS 242-4858

Hours: 7:45 to 4:30 Eastern Time

or

ALABAMA
U.S. Geological Survey
Water Resources Division

520 19th Avenue
Tuscaloosa, AL 35401

Telephone: (205) 752-8104
FTS 229-2957

Hours: 7:30 to 4:00 Central Time

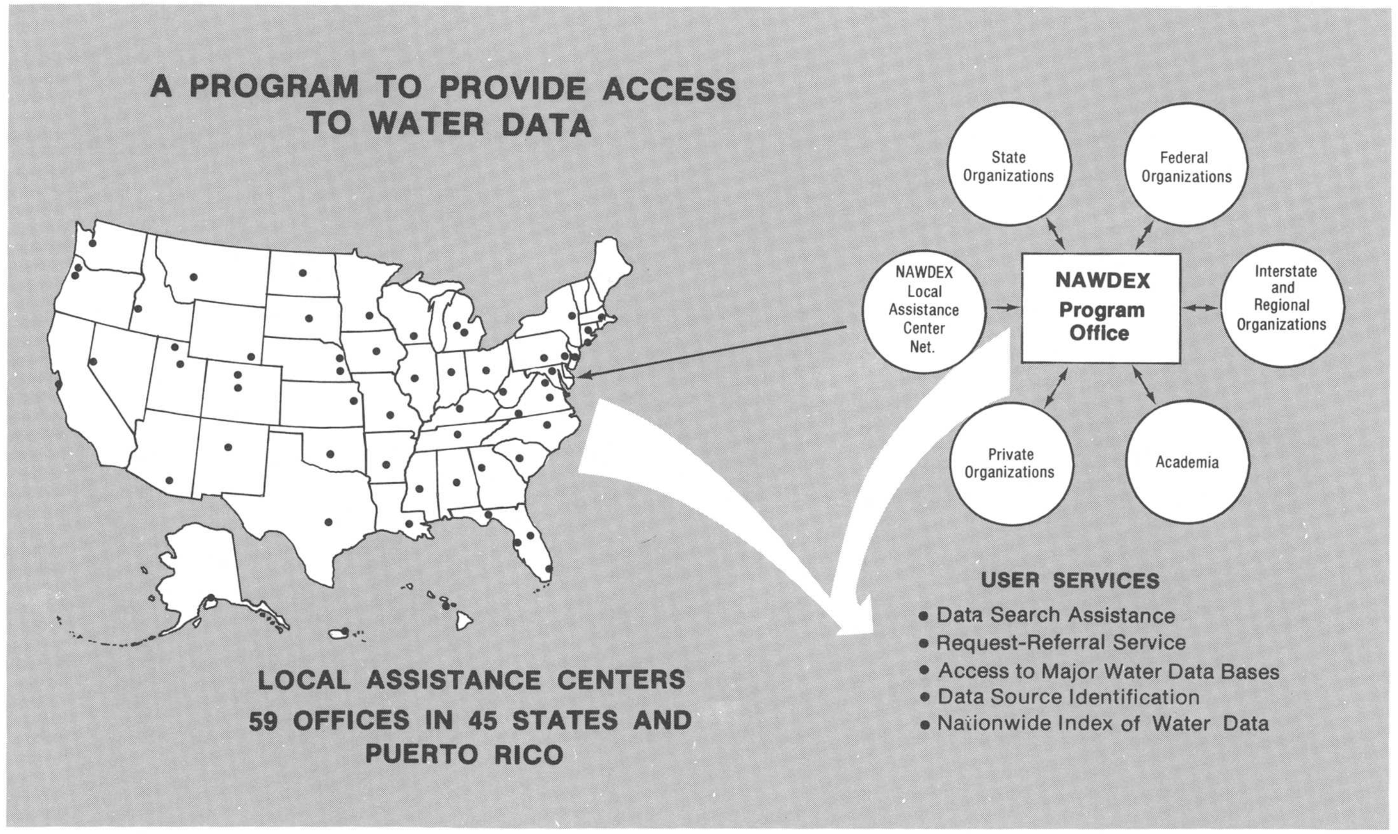


Figure 8.2-1 Access to water data.

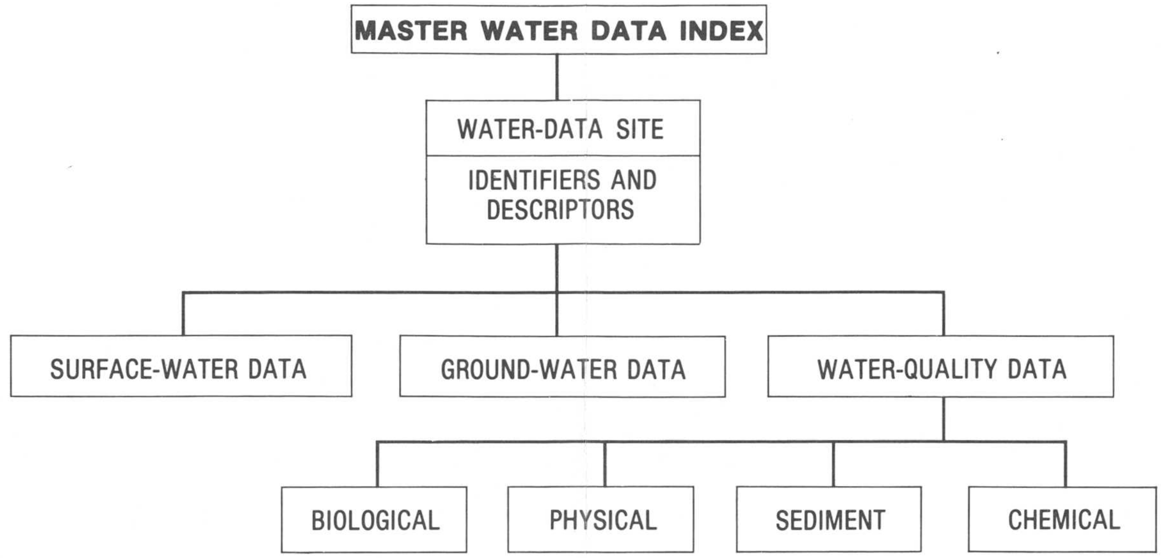


Figure 8.2-2 Master water-data index.

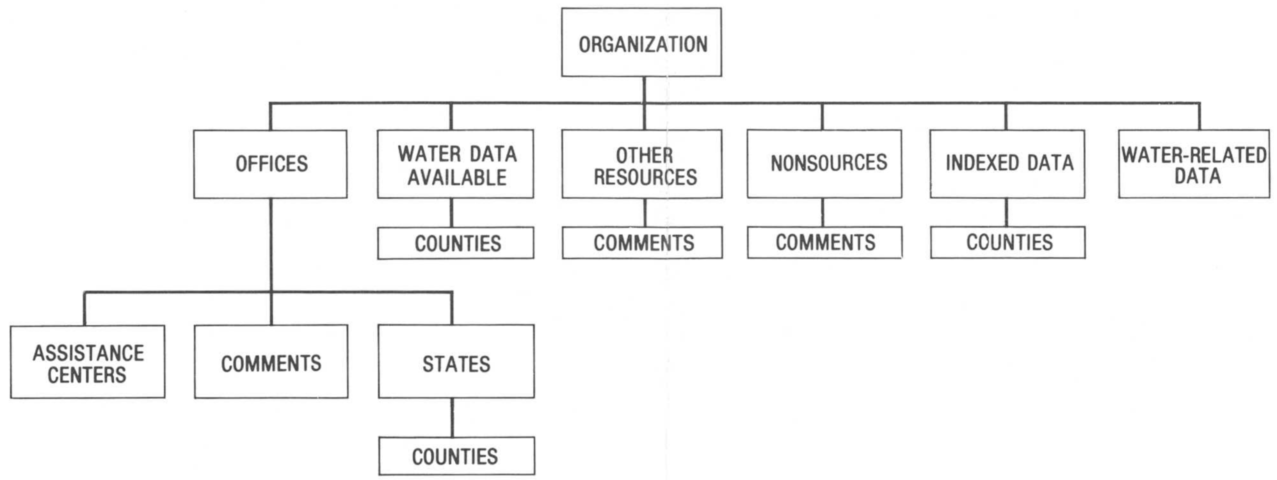


Figure 8.2-3 Water-data sources directory.

WATSTORE Automated Data System

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

The National Water Data Storage and Retrieval System (WATSTORE) was established in November 1971 to computerize the 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

or

U.S. Geological Survey
Water Resources Division
6481 Peachtree Industrial Blvd.
Suite B
Doraville, GA 30360

or

U.S. Geological Survey
Water Resources Division
520 19th Avenue
Tuscaloosa, AL 35401

The Geological Survey currently (1982) collects data across the Nation 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) water-use data. In addition, an index file of sites for which data are stored in the system is also maintained (fig. 8.3-1). A brief description of each file is as follows:

Station Header File: All sites for which data are stored in the Daily Values, Peak Flow, Water-Quality, 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, nationally.

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 nationally.

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 70,000 sites nationally.

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 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. The principal inputs to this network are:

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. Examples of these products are:

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.

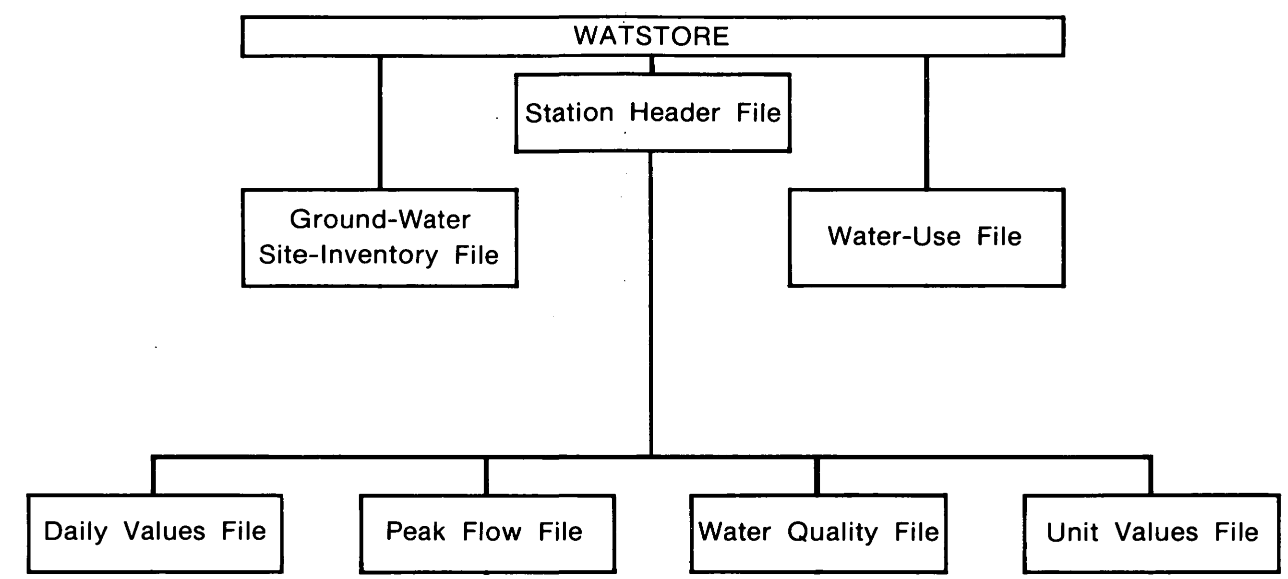


Figure 8.3-1 Files of stored data.

Water Data Indexed for Coal Provinces

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

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

This special index consists of five volumes (fig. 8.4-1): volume I, Eastern Coal Province; volume II, Interior Coal Province; volume III, Northern Great Plains and Rocky Mountain Coal Provinces; volume IV, Gulf Coast Coal Province; and volume V, Pacific Coast and Alaska Coal Provinces. The information presented will aid the user in obtaining data for evaluating the effects of coal mining on water resources and in developing plans for meeting additional water-data needs. The report does not contain the actual data; rather, it provides information that will enable the user to determine if needed data are available.

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

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

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

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

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

or

U.S. Geological Survey
Water Resources Division
6481 Peachtree Industrial Blvd.
Suite B
Doraville, GA 30360

Telephone: (404) 221-4858
FTS 242-4858

or

U.S. Geological Survey
Water Resources Division
520 19th Avenue
Tuscaloosa, AL 35401

Telephone: (205) 752-8104
FTS 229-2957

or

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

Telephone: (615) 637-8060
FTS 852-0060

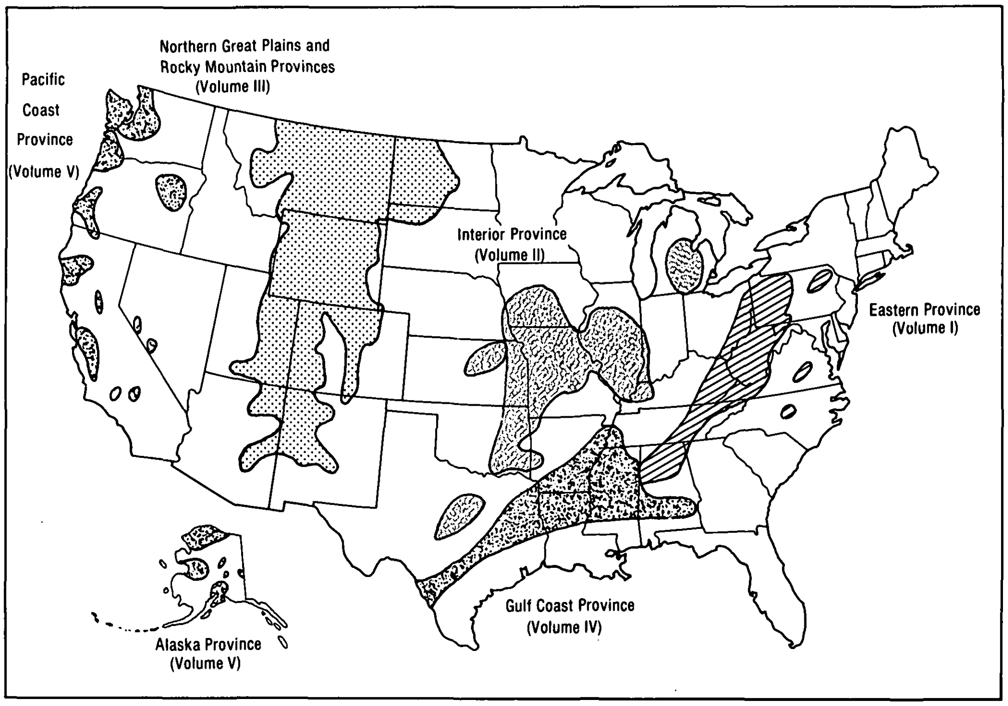


Figure 8.4-1 Index volumes and related provinces.

Background Hydrologic Information is Available

Streamflow and water-quality data collected since 1979 in Area 20, combined with previously collected hydrologic data, should provide a background for site-specific studies required by the Surface Mining Control and Reclamation Act of 1977.

The Eastern Coal Province which extends from New York to Alabama, and includes parts of 10 states 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 province 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 20, located in southeastern Tennessee, northwestern Georgia, and northeastern Alabama in the southern part of the Eastern Coal Province, includes parts of 18 counties. The area is in two physiographic sections, the Cumberland Plateau and the Ridge and Valley. The Cumberland Plateau contains three uplands separated by two major valleys. Each section comprises about one-half of the 2,450 square mile area. The average annual temperature is about 58°F; however, it is slightly lower in the uplands of the Cumberland Plateau because of higher elevations. Mean annual precipitation is about 54 inches with annual extremes ranging from 35 to 70 inches.

The uplands of the Cumberland Plateau are underlain by gently dipping Pennsylvanian conglomeratic sandstone interbedded with shales. These rocks contain the coal resources in Area 20. The main coal seams are the Bon Air, Richland, Sewanee, Lantana, and Morgan Springs. The soils are derived from the sandstones and shales. Soils are mostly moderately deep to deep and moderately well to excessively drained on the Plateau. The erosion potential is slight to moderate; however, on the steep slopes, the erosion potential is great and can become severe if the vegetation is removed. Most soils are classed in hydrologic soil group B, none in group A. Numerous coal mines, comprising about 1 percent of the land use in the western half of Area 20, are in the uplands of the Cumberland Plateau; no mines are operated in the Ridge and Valley or in the two major valleys of the Plateau. Drainage from these mines eventually reaches Lookout or South Chickamauga Creeks, or the Sequatchie or Tennessee Rivers.

Information on streamflow and stream-water quality for 142 sites is available where, in many cases, streamflow data have been collected for more than 30 years and water quality and sediment data for more than 6 years. Information on wells or springs is available at 47 sites where data have been collected on water levels and water quality in wells, and on discharge of springs.

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 in uplands of the Cumberland Plateau is not well sustained during periods of no rainfall. The minimum flows per square mile for the dry months are much less for streams on the Plateau than for streams in the Ridge and Valley. However, the average annual streamflow throughout Area 20 is approximately 2 cubic feet per second per square mile. Most peak flows occur during the winter and spring months. About 80 percent of the annual peaks occur during the period December through April.

Water-quality data, including sediment concentrations and invertebrate populations, may be the most sensitive indicators of the effects of surface coal mining on the hydrologic environment. In using the data in this report, however, it should be remembered that the term "quality" must be referenced to a particular use, that because no mine seepage was sampled, locally severe water-quality problems may exist yet not appear in these data, and that data collected at sites established after 1979 were focused upon those parameters specified in the Act.

Water-quality data have been collected at 59 surface-water sites in Area 20; 24 of these are located in the Cumberland Plateau. Of these, less than a dozen sites may be considered upland sites draining basins primarily on the Plateau. Other sites, located in the Ridge and Valley or in the two major valleys of the Cumberland Plateau section, may be 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. Water at some sites in the Cumberland Plateau section has not been affected by mine drainage. In the future, data collected at these sites would be particularly important in the assessment of the impact of mining activities on water quality.

In uplands of the Cumberland Plateau, ground water occurs in fractures in sandstone and shale. Ground water in the Ridge and Valley occurs primarily in solution openings in carbonate rocks. Yields of wells on the Cumberland Plateau range from less than 5 to about 300 gallons per minute, whereas yields in the Ridge and Valley range from about 5 to 3,000 gallons per minute. Observation wells indicate that water levels in wells fluctuate seasonally. The quality of ground water throughout Area 20 in general is good. Water on the Plateau is soft to moderately hard with low dissolved solids; iron or manganese may be troublesome. At one location in the Ridge and Valley, water from several wells contained greater than 5,000 milligrams per liter of dissolved solids.

There are three U.S. Geological Survey national activities that utilize computers for the storage and retrieval both of indexes to water information and of files of hydrologic data (most of which for Area 20 is summarized in this report): NAWDEX, WATSTORE, and OWDC. The data searcher or user may gain access to these indexes and files at a nominal fee through any one of several U.S. Geological Survey offices throughout the nation.

Table 10.0-1 Surface-water network

Site number	Station number	Station name	Location: Latitude (° ' ")	Location: Longitude (° ' ")	Drainage area (mi²)	Type of record and period collected: Discharge	Water quality	Suspended sediment
1	03543005	Tennessee River at Watts Bar Dam (Tailwater), Tn.	35 37 13	84 47 00	17,310	1942-	1975-	1975-
2	03543200	Ten Mile Creek near Decatur, Tn.	35 37 05	84 41 30	26.4	1952-72,1959-66		
3	03543290	South Fork Little Sewee Creek at Sewee, Tn.	35 35 30	84 40 37	13.3	1961-65,1968-71		
4	03543300	Little Sewee Creek near Center Point, Tn.	35 35 54	84 42 13	32.3	1952-53,1958, 1975-	1977-	
5	03543500	Sewee Creek near Decatur, Tn.	35 34 53	84 44 53	117	1934-	1975-	
6	03543995	Sewee Creek near Decatur, Tn.	35 35 03	84 45 04	117	1931-32		
7	03544000	Tennessee River at Breedenton, Tn.	35 32 47	84 48 02	17,440	1934-		
8	03544005	Clear Creek near Evensville, Tn.	35 36 42	84 54 49	7.47	1951,1955		
9	03544220	Decatur Creek near Decatur, Tn.	35 30 12	84 48 15	6.48	1963		
10	03544235	Goodfield Creek near Goodfield, Tn.	35 29 34	84 49 55	22.2	1971-72,1975		
11	03544500	Richland Creek near Dayton, Tn.	35 30 17	85 01 20	50.2	1934-	1966-67,1979-	1979-
12	03544610	Little Richland Creek near Richland, Tn.	35 31 02	84 59 58	15.4	1951,1955		
13	03544612	Little Richland Creek at Dayton, Tn.	35 30 12	85 00 24	17.3	1932,1943, 1952-55		
14	03566290	Sale Creek at Graysville, Tn.	35 26 30	85 04 46	13.2	1963-71	1967-68	
15	035662905	Roaring Creek at Graysville, Tn.	35 26 42	85 05 19	29.0	1943,1951-54, 1963		
16	03566291	McGill Creek near Graysville, Tn.	35 25 50	85 06 00	13.0	1954,1961-67, 1970		
17	03566292	Sale Creek near Sale Creek, Tn.	35 25 35	85 05 24	57.2	1955,1963,1979-	1979-	1979-
18	03566297	Sale Creek at Sale Creek, Tn.	35 24 00	85 06 14	62.9	1932,1943, 1952-54		
19	03566300	Rock Creek at Sale Creek, Tn.	35 23 10	85 06 30	38.1	1932,1943,1952-54, 1958-63,1965-66		
20	03566319	Possum Creek at Bakewell, Tn.	35 20 16	85 07 46	17.6	1932,1943, 1952-54		
21	03566320	Possum Creek near Bakewell, Tn.	35 20 19	85 07 25	22.7	1955		
22	03566400	Soddy Creek at Soddy, Tn.	35 18 05	85 09 56	49.0	1932,1955, 1958-68,1979-	1967-68,1979-	1979-
23	035664005	Soddy Creek near Soddy, Tn.	35 18 00	85 09 50	49.8	1932,1943, 1952-54		
24	03566401	Little Soddy Creek above Street Bridge in Soddy, Tn.	35 17 18	85 09 50	2.41	1961-63,1965-67, 1970		
25	03566404	Tennessee River at Sequoyah Nuclear Plant, Tn.	35 13 15	85 05 12	20,630		1975-	
26	03566405	Tennessee River near Harrison Bay State Park, Tn.	35 12 43	85 05 18	20,650		1969-73	
27	03566408	Chestnut Creek near Apison, Tn.	35 02 47	85 02 13	5.40	1961-63,1965-67, 1970		
28	03566410	Wolftever Creek at Collegedale, Tn.	35 03 15	85 03 02	18.1	1960,1963-70, 1973		
29	03566420	Wolftever Creek near Ooltewah, Tn.	35 03 43	85 03 59	18.8	1964-	1964-67,1975-	
30	03566428	Wolftever Creek above Ooltewah, Tn.	35 04 44	85 04 06	24.5		1976	
31	03566430	Little Wolftever Creek at Ooltewah, Tn.	35 04 42	85 03 36	10.8	1963-71,1973		
32	03566441	Wolftever Creek above Lee Hwy. near Ooltewah, Tn.	35 05 04	85 04 21	36.3	1643,1960,1968-69		

Table 10.0-1 Surface water network--Continued

Site number	Station number	Station name	Location		Drainage area (mi^2)	Type of record and period collected		
			Latitude (° ' ")	Longitude (° ' ")		Discharge	Water quality	Suspended sediment
33	03566450	Long Savannah Creek near Snow Hill, Tn.	35 10 38	85 02 15	28.3	1939-44,1952-54, 1963-71,1973		
34	03566510	Tennessee River at Chickamauga Dam (TW), Tn.	35 06 11	85 13 47	20,790	1940-	1975-	
35	03566530	North Chickamauga Creek near Daisy, Tn.	35 13 20	85 13 16	62.6	1925,1932,1943, 1952-54,1963,1979-	1979-	1979-
36	03566543	Falling Water Creek at Hwy. 27 at Falling Water, Tn.	35 11 40	85 14 40	13.2	1943,1952-55, 1963		
37	03566550	Pitts Branch near Hixson, Tn.	35 11 02	85 14 48	6.59	1943,1952-54, 1963-72		
38	03566560	North Chickamauga Creek near Falling Water, Tn.	35 10 44	85 14 13	97.6	1963		
39	03566599	North Chickamauga Creek at Greens Mill near Hixson, Tn.	35 10 30	85 13 40	99.5	1925,1943, 1952-55,1979-		
40	03566625	North Chickamauga Creek above Hixson, Tn.	35 10 03	85 13 19	108	1963-68,1970-71, 1973		
41	03566630	North Chickamauga Creek near Hixson, Tn.	35 08 46	85 13 37	114	1973		
42	03566633	North Chickamauga Creek at Hamillville, Tn.	35 07 46	85 12 57	118	1964,1973		
43	03566660	Sugar Creek near Ringgold, Ga.	34 58 14	85 01 29	4.4	1937-51,1966-74		
44	03566670	Tiger Creek near Ringgold, Ga.	34 54 20	85 04 38	43.2		1958	
45	03566685	Little Chickamauga Creek near Ringgold, Ga.	34 50 32	85 08 28	35.5	1965-74		
46	03566687	Little Chickamauga Creek Tributary near Ringgold, Ga.	34 51 36	85 08 40	3.36	1965-74		
47	03566700	South Chickamauga Creek at Ringgold, Ga.	34 55 07	85 07 32	169	1949-65,1973	1958,1971,1974	
48	03566800	South Chickamauga Creek at Graysville, Ga.	34 58 39	85 08 42	198	1958-66,1974-	1974-	
49	03566996	Mackey Branch near Brainerd, Tn.	35 00 13	85 10 13	12.1	1943,1952-55		
50	03567000	South Chickamauga Creek below Ga.-Tn. State Line	34 59 52	85 10 36	249	1952-57,1973		
51	03567125	Mud Creek at Cedar Grove, Ga.	34 42 24	85 25 01	22.2	1979-	1979-	1979-
52	03567130	Mill Creek near Cedar Grove, Ga.	34 42 43	85 25 42		1976-77	1976-77	
53	03567177	Mill Creek at SR 193 at Cassandra, Ga.	34 47 03	85 23 53		1976-77	1976-77	
54	03567200	West Chickamauga Creek near Kensington, Ga.	34 48 10	85 20 52	73.0	1950-76,1979-	1979-	1979-
55	03567340	West Chickamauga Creek at Cold Springs Road near Lakeview, Ga.	34 57 26	85 12 20	148	1974-	1974-	
56	03567400	West Chickamauga Creek at East Ridge, Tn.	34 59 21	85 11 44	153	1943,1952-54	1975	
57	03567496	Spring Creek near Brainerd, Tn.	35 00 10	85 13 11	19.3	1952-54,1967		
58	03567500	South Chickamauga Creek near Chickamauga, Tn.	35 00 50	85 12 27	428	1928-	1957-58,1965	
59	03567510	South Chickamauga Creek at Chickamauga, Tn.	35 00 52	85 12 36	428		1976-	
60	03567590	Friar Branch at Stanifer Gap Road at Tyner, Tn.	35 03 31	85 10 14	12.1	1964,1967-68, 1971		
61	03567596	Friar Branch at Airport at Chattanooga, Tn.	35 02 17	85 12 04	21.5	1939,1941,1964, 1967-68,1971-72		
62	03567600	South Chickamauga Creek near McCarty, Tn. (TVA)	35 04 05	85 12 50	458	1937-45		
63	03567935	United Hosiery Co. Ditch at Chattanooga, Tn.	35 03 55	85 15 03	.38	1947		
64	03567940	Citico Creek at Southern RR Yard at Chattanooga, Tn.	35 03 35	85 16 19	3.00	1964,1967,1973		
65	03567943	Citico Creek near Bushtown, Tn.	35 03 09	85 16 30	1.96	1967,1973		
66	03567945	Citico Creek Tributary at South RR Yards at Chattanooga, Tn.	35 03 13	85 16 34	1.96	1964,1973		
67	03567950	Tennessee River below Citico Creek at Chattanooga, Tn.	35 03 14	85 17 26	21,379		1970	
68	03568000	Tennessee River at Chattanooga, Tn.	35 05 12	85 16 43	21,380	1874-	1967-68,1979-	
69	03568250	Chattanooga Creek at High Point, Ga.	34 51 51	85 21 54	5.5	1979-	1979-	1979-
70	03568300	Chattanooga Creek at SR 341 near Flintstone, Ga.	34 55 26	85 20 44	18.9	1976,1979-	1976-77,1979-	1979-
71	03568304	Rock Creek at SR 170 near Durham, Ga.	34 51 37	85 25 59		1976,1977	1976-77	
72	03568305	Rock Creek Tributary (Mine Seep) at SR 170 near Durham, Ga.	34 51 37	85 26 03			1976	
73	03568306	Rock Creek below SR 170 near Durham, Ga.	34 51 38	85 25 59	.80	1979-	1979-	1979-
74	03568310	Rock Creek at Nickajack Road near Hinkle, Ga.	34 53 29	85 24 41	7.40	1976-77,1979-	1976-77,1979-	1979-
75	03568320	Long Branch near Hinkle, Ga.	34 53 03	85 23 36	3.73	1979-	1979-	1979-
76	03568360	Rock Creek near Flintstone, Ga.	34 56 33	85 21 25	22.2	1976-77,1979-	1976-77,1979-	1979-
77	03568500	Chattanooga Creek near Flintstone, Ga.	34 58 20	85 19 40	50.6	1950-74,1979-	1966,1972-73, 1979-	1979-
78	03568520	Chattanooga Creek at Salem Road near Bowling Springs, Ga.	34 59 00	85 19 40	52.0	1959-71,1973		
79	03568550	Chattanooga Creek at Burnt Mill Road at Chattanooga, Tn.	34 59 11	85 19 38	54.5	1929,1937,1941, 1943		
80	03568570	Chattanooga Creek at Wilson Road at Chattanooga, Tn.	34 59 05	85 18 38	55.1	1959-71,1973		
81	03568595	McFarland Springs at State-line Road at Chattanooga, Tn.	34 59 04	85 17 58	1.22	1947,1967		
82	03568600	Chattanooga Creek at Hooker Road at Chattanooga, Tn.	34 59 24	85 18 05	62.8	1923,1932, 1959-71,1973		
83	03568620	Chattanooga Creek at Central of Ga. at Chattanooga, Tn.	34 59 34	85 18 06	63.9	1959-71,1973		
84	03568630	Chattanooga Creek at Hamill Road at Chattanooga, Tn.	34 59 40	85 18 10	63.9	1937,1947, 1959-71,1973		
85	03568632	Tar Ditch on Hamill Road at Chattanooga, Tn.	34 59 45	85 18 23	.28	1947		
86	03568640	Chattanooga Creek at 38th St. at Chattanooga, Tn.	35 00 14	85 18 26	65.2	1932,1939-54, 1959-71,1975		
87	03568656	Southern Chemical Drainage Ditch at Chattanooga, Tn.	34 59 17	85 19 01	.08	1947		
88	03568668	Dobbs Creek at State Burnett Street at Chattanooga, Tn.	35 01 16	85 17 57	4.25	1947		

Table 10.0-1 Surface water network --Continued

Site number	Station number	Station name	Location: Latitude (° ' ")	Location: Longitude (° ' ")	Drainage area (mi²)	Type of record and period collected: Discharge	Water quality	Suspended sediment
89	03568670	Chattanooga Creek at Southern Railway at Chattanooga, Tn.	35 01 21	85 18 16	70.7	1932,1934, 1959-71,1973		
90	03568680	Chattanooga Creek at Market Street at Chattanooga, Tn.	35 01 27	85 18 43	72.0	1947,1966-68		
91	03568690	Chattanooga Creek at Alton Park Boulevard at Chattanooga, Tn.	35 01 20	85 18 54	72.2	1932,1937, 1959-67		
92	03568695	Chattanooga Creek at Broad Street at Chattanooga, Tn.	35 01 23	85 19 10	72.4	1929,1947		
93	03568700	Chattanooga Creek at AL. Great Southern RR at Chattanooga, Tn.	35 01 16	85 19 22	72.4	1966-71,1973		
94	03568710	Chattanooga Creek at L&N RR. at Chattanooga, Tn.	35 01 08	85 19 32	72.5	1966-71,1973		
95	03568745	Lookout Creek at Sulphur Springs, Ga.	34 41 32	85 32 14	16.3	1979-	1979-	1979-
96	03568782	Hurricane Creek near Rising Fawn, Ga.	34 45 48	85 30 12		1976-77	1976-77	
97	03568785	Lookout Creek at Rising Fawn, Ga.	34 45 51	85 31 37	68.7	1979-	1979-	1979-
98	03568840	Daniel Creek at SR 143 near Trenton, Ga.	34 48 58	85 29 29	4.80	1976-77,1979-	1976-77,1979-	1979-
99	03568860	Bear Creek at SR 157 near Durham, Ga.	34 49 41	85 27 33	7.98	1976-77,1979-	1976-77,1979-	1979-
100	03568920	Squirrel Town Creek near New England, Ga.	34 55 51	85 29 15	3.80	1979-	1979-	1979-
101	03568933	Lookout Creek near New England, Ga.	34 53 51	85 27 47	149	1979-	1979-	1979-
102	03568990	Lookout Creek above Wildwood, Ga.	34 56 14	85 25 02	163	1964-68,1970		
103	03569000	Lookout Creek near Wildwood, Ga.	34 57 22	85 24 12	165	1945-46,1953		
104	03569168	Stringers Branch at Leawood Drive at Red Bank, Tn.	35 07 00	85 17 28	1.54	1979-		
105	03569172	Stringers Branch near Valdeau, Tn.	35 05 11	85 19 32	5.90	1967,1973		
106	03569190	Mountain Creek near Glendale, Tn.	35 06 33	85 19 15	5.07	1961-63,1965-67, 1970		
107	03569193	Mountain Creek at Glendale, Tn.	35 05 54	85 19 42	6.37	1943,1951-53, 1959,1973		
108	03569199	Shoal Creek near Signal Mountain, Tn.	35 06 32	85 21 47	2.51	1952-55		
109	03569245	Suck Creek near Chattanooga, Tn.	35 07 28	85 23 26	22.6	1979-	1979-	1979-
110	03569250	Tennessee River near Signal Mountain, Tn.	35 06 39	85 24 54	21,710		1970	
111	03570000	Tennessee River at Hales Bar near Chattanooga, Tn.	35 01 43	85 32 48	21,781	1930-66	1971-72	
112	03570480	Running Water Creek at Haletown, Tn.	35 01 08	85 32 17	20.6	1952-55		
113	03570504	Cole City Creek near South Pittsburg, Tn.	34 59 10	85 35 52	25.6	1979-	1979-	1979-
114	03570505	Cole City Creek near Shellmound Station, Tn.	34 59 38	85 36 01	27.1	1952-55,1961-67, 1970		
115	03570511	Nickajack Creek near Nickajack Cave, Tn.	34 59 23	85 36 38	.19	1964-66		
116	03570512	Nickajack Creek near Shellmound, Tn.	34 59 34	85 36 43	.75	1941,1951-52, 1964		
117	03570525	Tennessee River at Nickajack Dam (Tailwater), Tn.	35 00 09	85 37 16	21,849	1967-	1975-	
118	03570560	Mill Cave Tributary in Grassy Cove, Tn.	35 51 16	84 55 14	12.1	1962-70		
119	03570580	Sequatchie River near Melvine, Tn.	35 47 08	85 00 54	23.7	1962-70		

Table 10.0-1 Surface water network--Continued

Site number	Station number	Station name	Location: Latitude (° ' ")	Location: Longitude (° ' ")	Drainage area (mi^2)	Type of record and period collected: Discharge	Water quality	Suspended sediment
120	03570590	Little Creek near Lone Oak Church near Ninemile, Tn.	35 41 51	85 06 00	5.21	1961-69,1971		
121	03570600	Sequatchie River at Pikeville, Tn.	35 36 19	85 11 09	104	1932-33,1952, 1959-66	1965	
122	03570602	Sequatchie River near Pikeville, Tn.	35 35 48	85 11 27	106	1932,1943, 1951-54,1979-	1979-	1979-
123	03570605	Skillern Creek near Pikeville, Tn.	35 35 09	85 11 27	5.67	1952-55		
124	03570630	Crystal Creek near Pikeville, Tn.	35 32 13	85 14 01	9.23	1952-55		
125	03570650	Sequatchie River near College Station, Tn.	35 30 09	85 15 23	154	1967-68	1966-69	
126	03570695	Sequatchie River near Mount Airy, Tn.	35 24 41	85 20 47	202	1979-	1979-	1979-
127	03570700	McWilliams Creek near Dunlap, Tn.	35 24 22	85 19 46	6.64	1959-64		
128	03570703	McWilliams Creek near Dunlap, Tn.	35 23 58	85 20 30	10.9	1952-55		
129	03570750	Big Brush Creek near Dunlap, Tn.	35 24 25	85 22 05	47.7	1965,1979-	1965,1979-	
130	03570800	Little Brush Creek near Dunlap, Tn.	35 24 15	85 23 18	15.4	1959-	1979-	1979-
131	03570810	Big Brush Creek near Dunlap, Tn.	35 23 55	85 21 50	66.1	1943,1951-55, 1958,1965,1979-	1979-	1979-
132	03570835	Sequatchie River near Dunlap, Tn.	35 21 34	85 22 20	292			
133	03570855	Woodcock Creek Southwest of Dunlap, Tn.	35 19 19	85 26 01	15.3	1952-55,1979-	1979-	1979-
134	03570870	Hicks Creek at Cartwright, Tn.	35 16 40	85 27 14	17.9	1979-	1979-	1979-
135	03571000	Sequatchie River near Whitwell, Tn.	35 12 22	85 29 48	402	1920-	1961-71,1973-	1979-
136	03571200	Sequatchie River at Whitwell Waterworks near Whitwell, Tn.	35 11 53	85 30 31	410	1976		
137	03571320	Scott Creek near Flat Branch, Tn.	35 18 14	85 42 42	6.14	1961-67,1970		
138	03571500	Little Sequatchie River at Sequatchie, Tn.	35 07 47	85 35 10	116	1925,1930, 1951-54,1965, 1979-	1979-	1979-
139	03571600	Brown Spring Branch near Sequatchie, Tn.	35 08 55	85 33 28	.67	1955-77		
140	03571604	Hall Creek near Sequatchie, Tn.	35 07 10	85 34 06	7.33	1961-67,1970		
141	03571700	Pryor Cove Branch near Jasper, Tn.	35 05 25	85 37 22	12.9	1954-57,1979-	1979-	1979-
142	03571730	Standifer Branch at Jasper, Tn.	35 04 22	85 36 56	15.3	1979		

Table 10.0-2 Ground-water network.

Site number	Station number	Station name	Formation tapped	Type of record and period collected: Water level	Type of record and period collected: Water quality
	Wells				
1	343622085275401	Mountain Cove Farms	Pennsylvanian System		1960
2	343748085272201	Mountain Cove Farms	Red Mountain Formation		1960
3	344446085020201	Tullock, D.	Chickamauga Limestone		1965
4	344603085060301	Hayes, C.	Rome Formation		1963
5	344638085223001	Kensington Water Association	Knox Dolomite		1970
6	344853085130501	Glover, W.	Conasauga Formation		1960
7	344934085300601	Adams, L. C.	Sewanee Conglomerate		1958
8	345136085052601	Bandy, P.	Floyd Shale		1958
9	345141085025701	Middleton, A. L.	Rome Formation		1963
10	345208085045401	Greeson, S.	Chickamauga Limestone		1958
11	345325085144001	Ivey, J. L., Barn	Chickamauga Limestone		1946
12	345326085144101	Ivey, J. L., House	Chickamauga Limestone		1946
13	345403085160001	Nos, Ft. Oglethorpe	Rockmart Slate	1959-60, 1979-	
14	345546085320401	Gass, D., 3	Sewanee Conglomerate		1976
15	345556085313401	Christopher, W., 2	Sewanee Conglomerate		1976
16	345819085242301	Fuller, W. R.	Sequatchie Formation		1958
17	345834085335101	Rogers, R. L. 1	Sewanee Conglomerate		1976
18	351147085130800	Hixson Well at Hixson, Tn.			1977
19	351424085003900	Hm:O-16 Savannah Valley, Tn.	Knox Dolomite		1975
20	341428085003600	Hm:O-15 Savannah Valley, Tn. (SV-15)	Knox Dolomite	1974-	
21	351428085003900	Savannah Valley No. 8			1974
22	351428085003901	Savannah Valley No. 1			1974
23	351500085310001	Ma:M-11 (14)	Sewanee Conglomerate		1954
24	351600085320001	Ma:P-11 (29)	Newton Sandstone		1954
25	352000085190001	Sq:E-11 (11)	Newton Sandstone		1954
26	352005085245000	Birch Dairy Well near Dunlap, Tn.			1977
27	352038085081300	Bakewell Well at Bakewell, Tn.		1977	1977
28	352532085084800	Bowman Well near Sale Creek, Tn.			1977
29	352900085190001	Bl:C-11 (2)	St. Louis Limestone		1954
30	352919084564100	Frazier School Well near Dayton, Tn.			1977
31	353152085031200	Rema Skillern Well near Dayton, Tn.			1977
32	353500085070001	Bl:J-11 (22)	Newton Sandstone		1954
33	353727085112100	Pikeville Well near Pikeville, Tn.			1977
34	353739084492100	TVA Well near Watts Bár, Tn.			1977
35	354224085062000	London Grocery Well near Melvine, Tn.		1968	1977

Table 10.0-2 Ground-water network--Continued

Site number	Station number	Station name	Formation tapped	Type of record and period collected: Water level	Discharge	Water quality
	Springs					
36	03544218	Marler Spring near Goodfield, Tn.			1950-52	
37	03544605	Dayton Spring No. 1 at Dayton, Tn.	Rockwood Formation		1950-51	
38	03544606	Dayton Spring No. 2 at Dayton, Tn.	Rockwood Formation		1950-51	
39	03566288	Henson-Rogers Spring at Graysville, Tn.	Newman Limestone		1951-52	
40	03566440	Anderson Spring near Georgetown, Tn.	Knox Dolomite		1931,1950-54, 1964,1974-76	
41	03566540	Cave Spring near Hixson, Tn.	Knox Dolomite		1928-29,1931, 1951-53	
42	03566770	Stone Springs near Ryall Springs, Tn.	Chickamauga Limestone		1951-52	
43	03568715	Dixie Brown Spring near Valley Head, Al.	Ordovician-Cambrian Systems		1968-70	
44	03570830	Barker Spring near Dunlap, Tn.			1931,1952-54, 1959	
45	03570860	Boynton Spring at Daus, Tn.			1931	
46	03571510	Blowing Spring at Sequatchie, Tn.			1928-31,1938, 1952-54	
47	03571720	Blue Spring at Jasper, Tn.			1930-31,1952-54	

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