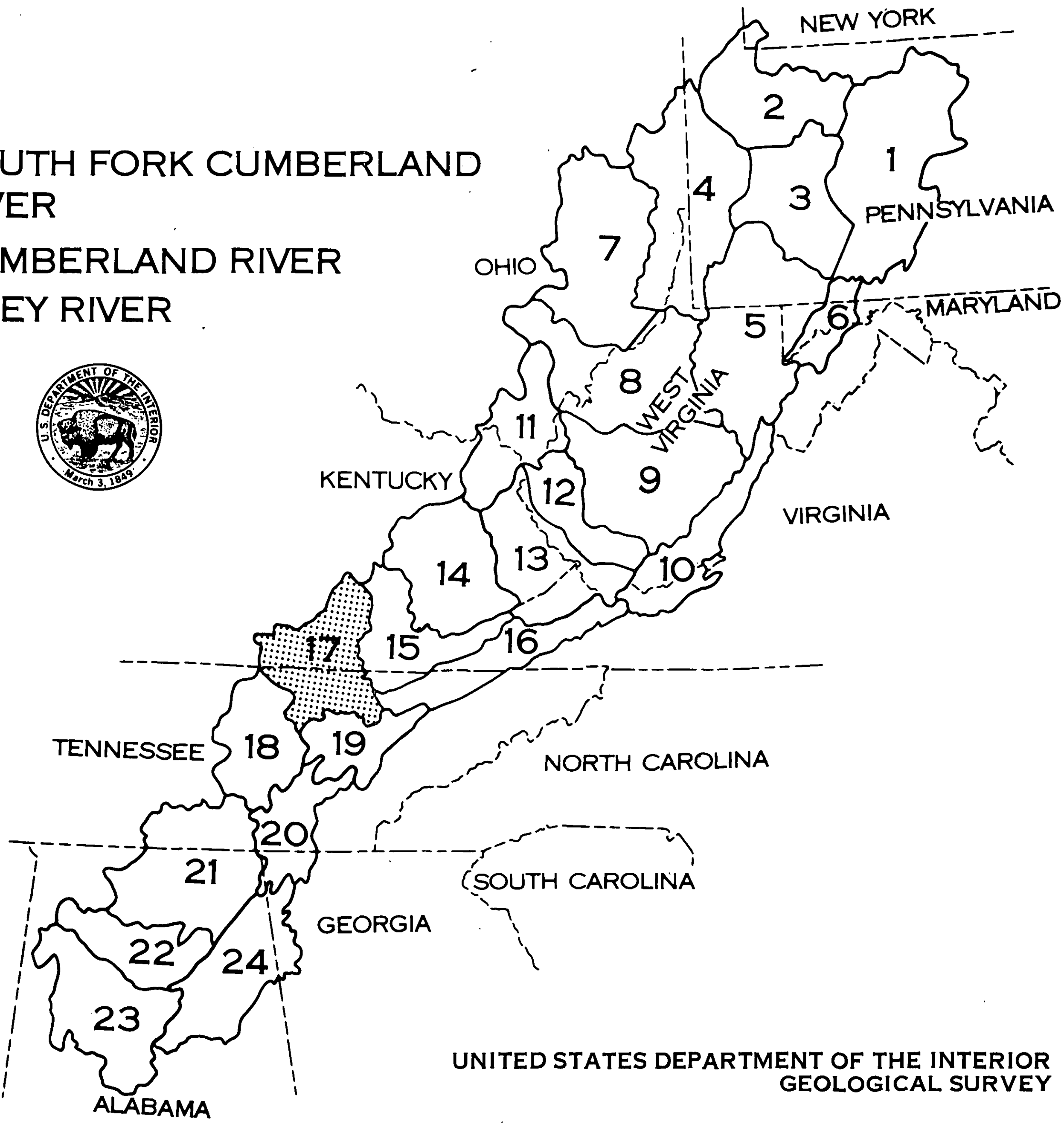
HYDROLOGY OF AREA 17, EASTERN COAL PROVINCE, TENNESSEE AND KENTUCKY

- SOUTH FORK CUMBERLAND RIVER
- CUMBERLAND RIVER
- OBEY RIVER



UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

WATER-RESOURCES INVESTIGATIONS
OPEN-FILE REPORT 81-1118

HYDROLOGY OF AREA 17, EASTERN COAL PROVINCE, TENNESSEE AND KENTUCKY

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MICHAEL W. GAYDOS AND OTHERS

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NASHVILLE, TENNESSEE
JANUARY 1982

UNITED STATES DEPARTMENT OF THE INTERIOR

JAMES G. WATT, *SECRETARY*

GEOLOGICAL SURVEY

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

CONTENTS

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

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

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

HYDROLOGY OF AREA 17, EASTERN COAL PROVINCE, TENNESSEE AND KENTUCKY

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ABSTRACT

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

This report describes the physical and hydrologic features of Area 17, 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 17, consisting of approximately 4,200 square miles, is in two physiographic sections, the Cumberland Plateau and the Highland Rim. Numerous surface mines, about 3 percent of the land use, are in the Cumberland Plateau. Some deep mines also are operated in the Cumberland Plateau. No mines are operated in the Highland Rim. No significant trends in streamflow related to physiography can be detected, although the average annual flow ranges from approximately 1.2 to 2.1 cubic feet per second per square mile in much of Area 17. Ground water availability varies widely; well yields in parts of the Highland Rim in Tennessee range from about 5 to more than 600 gallons per minute, but reported well yields in 93 percent of the Highland Rim in Kentucky were less than 5 gallons per minute. Wells penetrating the fractured Pennsylvanian rocks yield from less than 5 to more than 300 gallons per minute.

Increased sedimentation and acidic and (or) highly mineralized effluents from mine sites are the most severe surface-water problems in coal-mine areas. Low pH values and concentrations of iron and manganese exceeding limits for mine effluents have been determined at several sites. High sulfate concentrations have also been determined. Suspended-sediment loads and total recoverable iron concentrations are related and can be estimated at several sites.

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

1.0 INTRODUCTION

Hydrologic Environment Can Be Adversely Affected by Surface Mining

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

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

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

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

Recognizing the potentially adverse impact that coal mining could have on the environment, the Surface Mining Control and Reclamation Act of 1977 was enacted as Public Law 95-87, August 3, 1977. The Act requires (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.

Objective

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

Scope

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

Area 17, which is in the southern part of the Eastern Coal province, is located in Tennessee and Kentucky and includes parts of 22 counties (fig. 1.0-3). This report describes the physical and hydrologic features of the area with emphasis on the quality of the surface and ground water. It also identifies the network of hydrologic stations for which data are available. Much of the data used in this report was collected prior to enactment of 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. However, data were collected throughout Area 17 at sites both upstream and downstream from existing effluents and mine seepages. These data should provide hydrologic information for the general area, but not for specific mine sites. Few ground-water data have been acquired in the area since 1979.

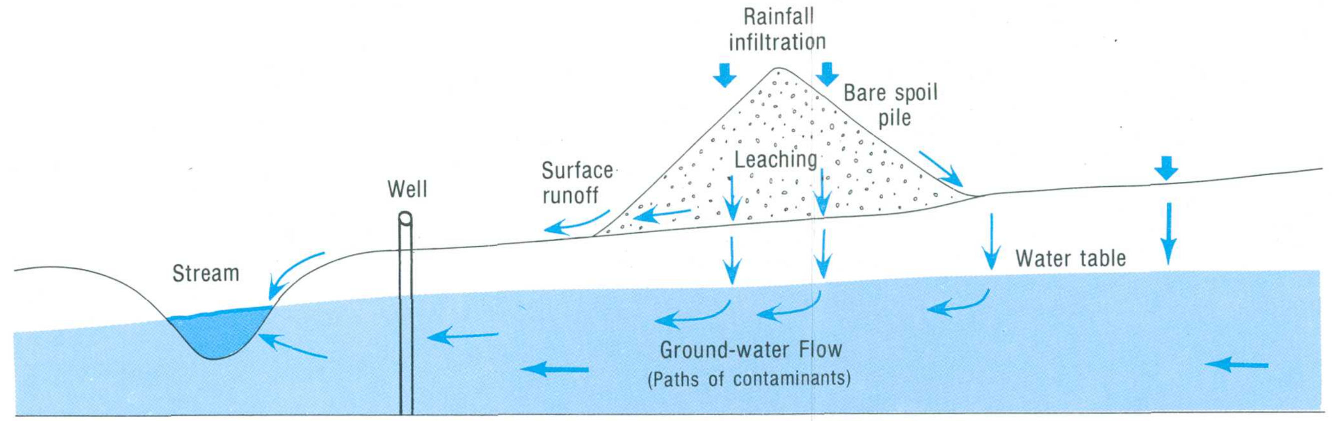


Figure 1.0-1 Leaching from spoil material

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

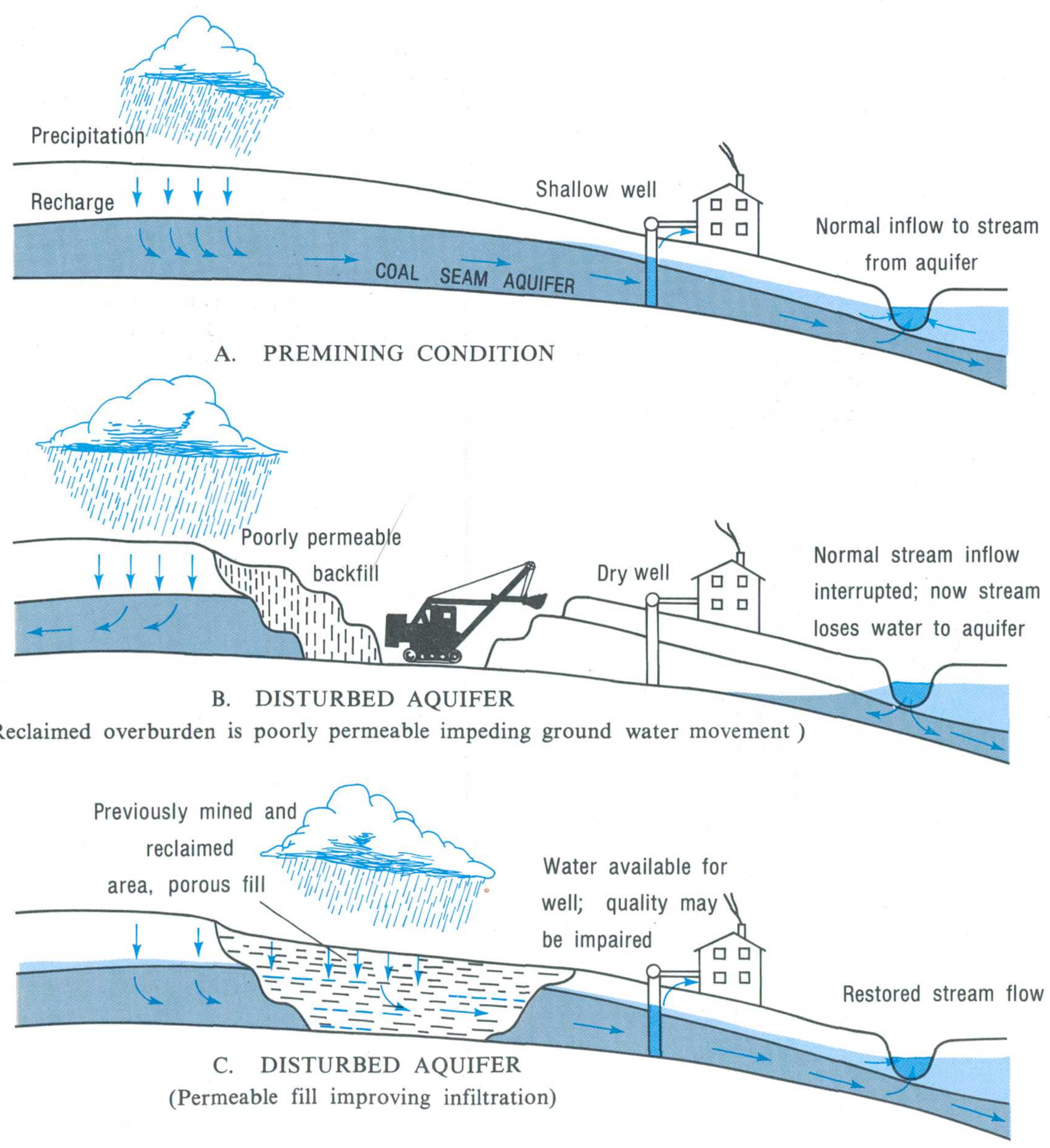


Figure 1.0-2 Potential impact of mining on aquifers

Figure 1.0-3 Location of Area 17 in Tennessee and Kentucky.

Parts of Two Physiographic Sections Are in Area 17

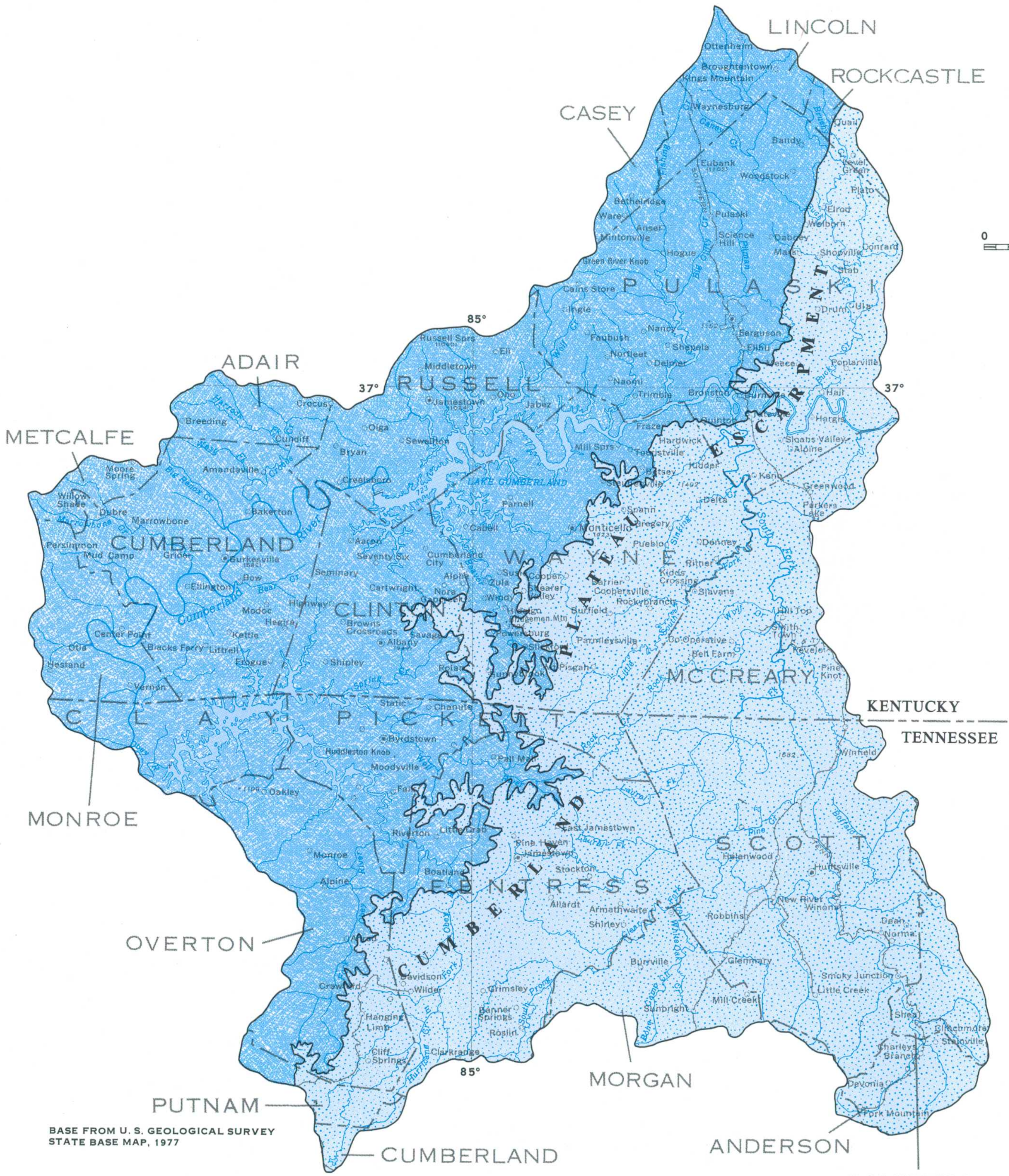
Two physiographic sections are represented in Area 17. The Cumberland Plateau (a section of the Appalachian Plateaus province) is an upland area and the Highland Rim (a section of the Interior Low Plateau province) is a lower-level plain.

The Cumberland Plateau (a section of the Appalachian Plateaus province) comprises the eastern half of Area 17 (fig. 2.1-1). The Cumberland Mountains in the southeastern corner rise in altitude from 2,000 to 3,500 feet and have a generally steep terrain with slopes averaging 20 to 60 percent (fig. 2.1-2). To the north and west, the general level of the Plateau ranges from 1,200 to 1,800 feet, and the terrain is undulating with an average slope of 20 percent. It is drained to the north by the South Fork Cumberland River and New River. These streams flow into the Cumberland River and Lake Cumberland.

Separating the Cumberland Plateau from the Highland Rim is a highly dissected escarpment with 600 to 900 feet of relief. This escarpment is called the Cumberland Plateau escarpment and its topography is dominated by cliffs and steep slopes which average 60 to 90 percent.

The Highland Rim (a section of the Interior Low Plateau province) comprises the western half of Area 17. The altitude is approximately 1,000 feet and the average relief is about 200 feet. The terrain is from near level to gentle slopes which average 5 to 25 percent. The Highland Rim is drained to the northwest by the Obey River and to the southwest by the Cumberland River.

In Kentucky, the Highland Rim is commonly referred to as the Pennyroyal Plain of the Mississippian Plateaus. However, for convenience in this report, Highland Rim will be used.



Physiography modified from Fenneman, 1938

SCALE 1:750,000

0 10 20 30 MILES

0 10 20 30 KILOMETERS

EXPLANATION

Cumberland Plateau section of the Appalachian Plateaus Province

Highland Rim section of the Interior Low Plateau Province

Figure 2.1-1 Physiography of Area 17

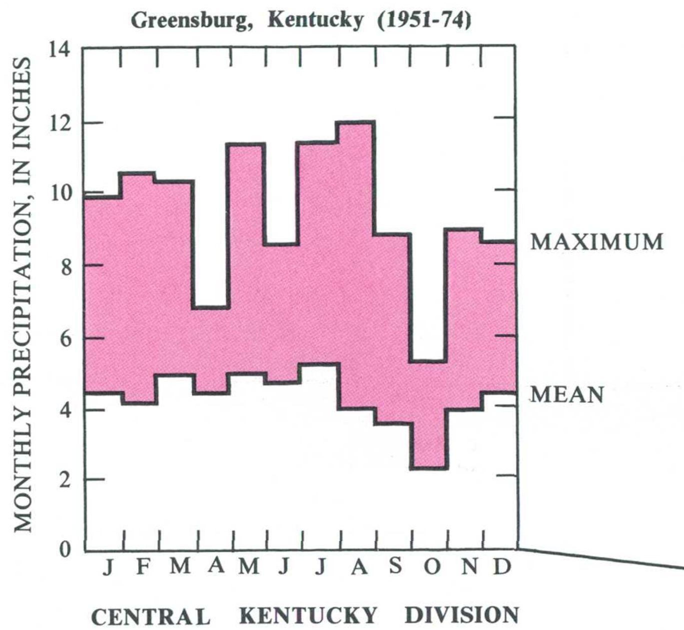
Figure 2.1-2 Shaded-relief map

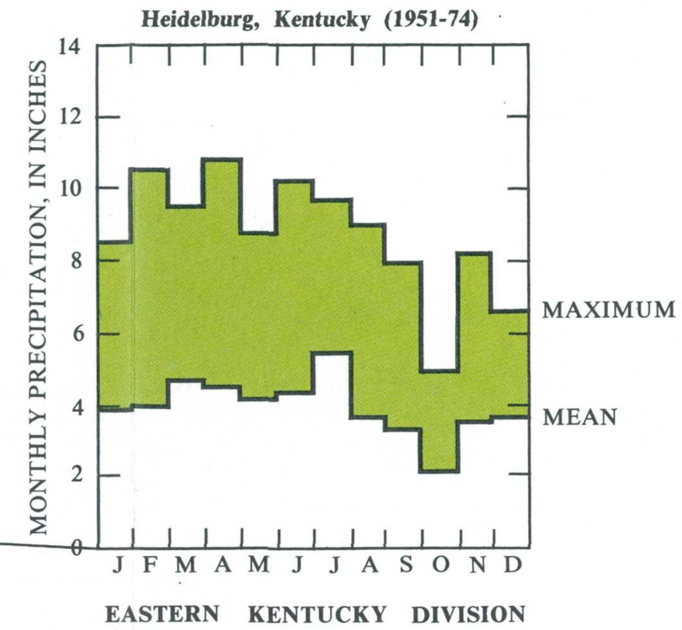
Area 17 Has Moderate Climate

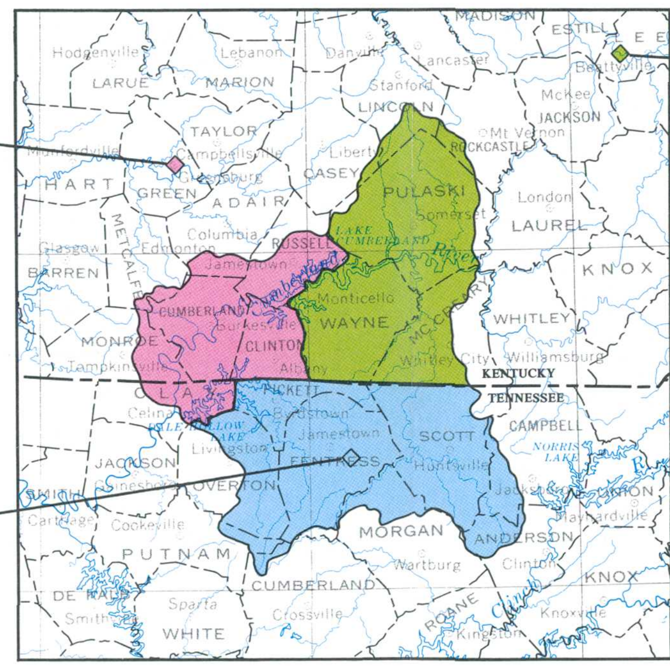
Mean annual precipitation is about 50 inches with extremes of about 35 and 70 inches. Average annual temperature is about 56°F.

Area 17 is in parts of three climatological divisions, two in Kentucky and one in Tennessee (fig. 2.2-1). The average annual precipitation for the area is about 50 inches, but ranges from about 35 inches in dry years to about 70 inches in wet years (National Oceanic and Atmospheric Administration, 1977). Thunderstorms which often produce locally heavy rainfall occur about 45 days per year and are sometimes accompanied by damaging winds and extreme changes in temperature. The 10-year 24-hour rainfall (fig. 2.2-1) is about 4.5 inches (U.S. Department of Commerce, 1961). Although only one rainfall station for which maximum and mean monthly precipitation data are available is located within Area 17, data at a representative location in each of the other two climatological divisions are also shown.

The average annual temperature for Area 17 is about 56°F with extremes seldom above 100°F or below -5°F. Temperatures are above 90°F about 40 days per year. There is a frost-free season of about 160 days from late April to early October. Minimum temperatures of zero or below occur in December, January, and February, but the number of days with such values is generally less than 4 in any year.



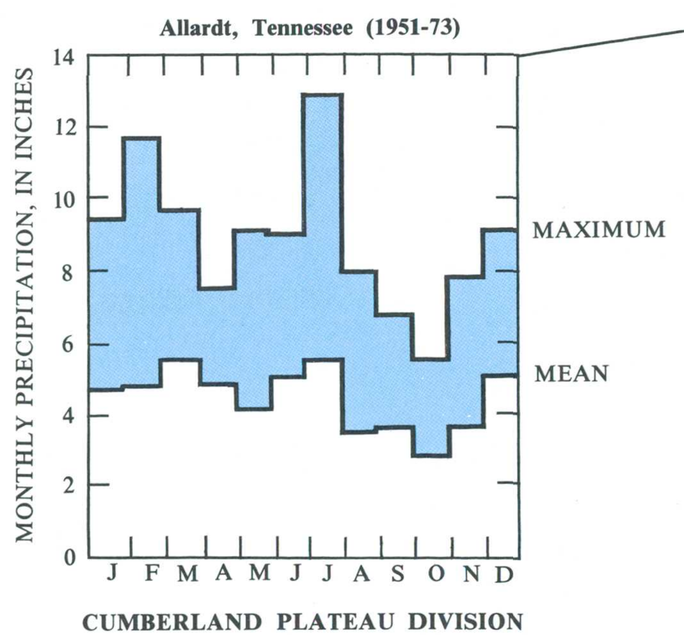




EXPLANATION

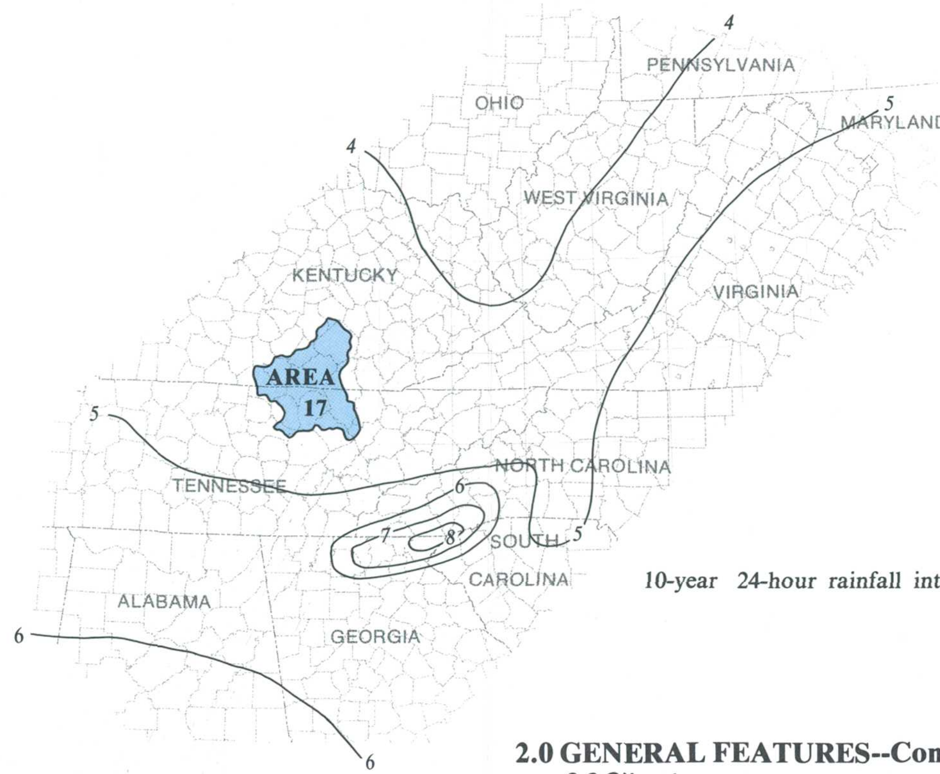
◇ Long-term precipitation station

〜 Climatological boundary



Climatological data from National Oceanic and Atmospheric Administration, 1977 and U.S. Department of Commerce, 1961

Figure 2.2-1 Precipitation data for the three climatological divisions



10-year 24-hour rainfall intensity in inches

Different Types of Rock Underlie Area 17

The Cumberland Plateau is underlain by Pennsylvanian sandstone and shale, and the Highland Rim is underlain by Mississippian carbonate rocks.

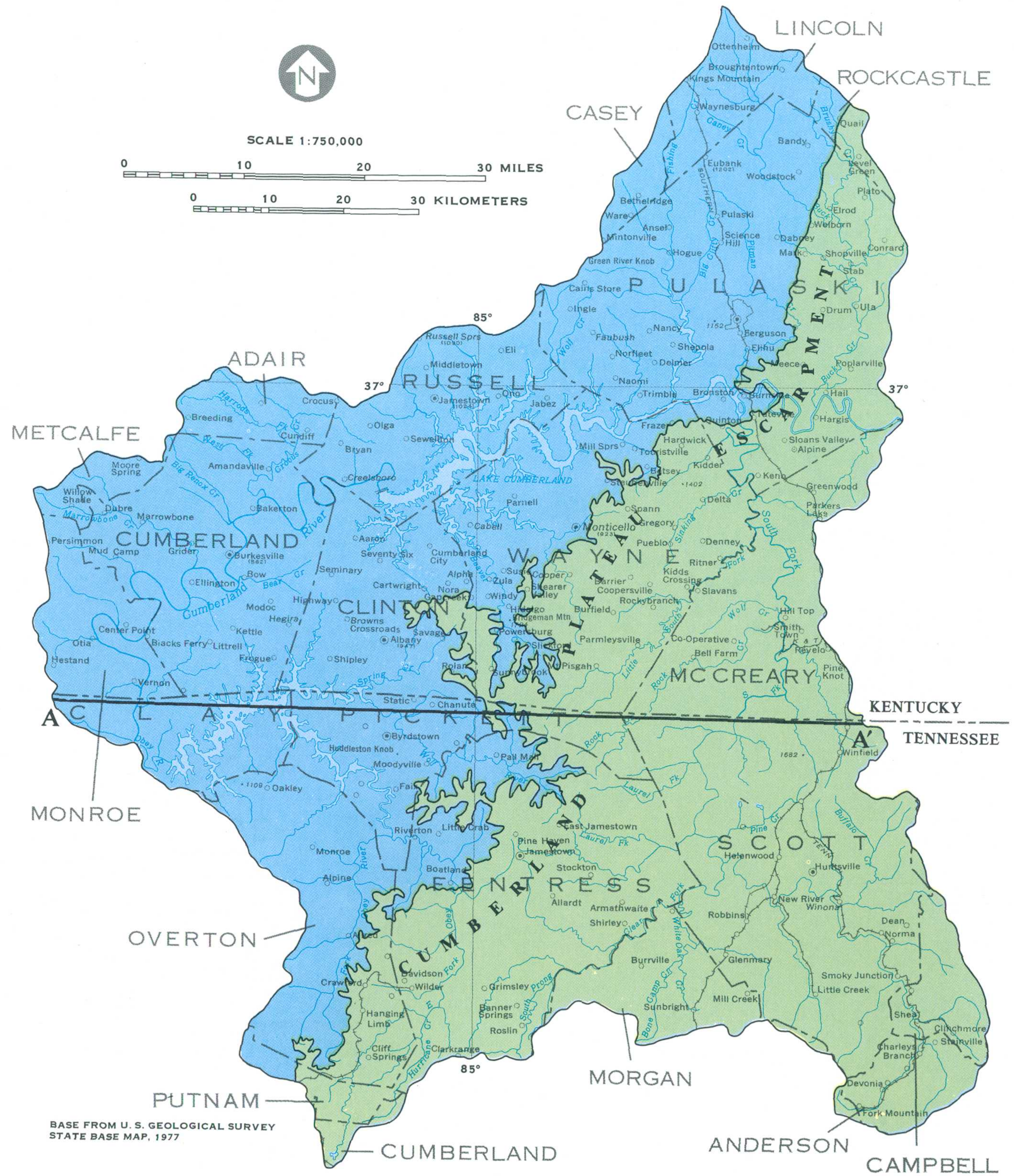
The Cumberland Plateau is underlain by Pennsylvanian rocks which include all of the coal beds in Area 17 (fig. 2.3-1). These rocks have a maximum thickness of approximately 600 feet in the western half of the area and approximately 3,000 feet in the eastern half. The formations that crop out in the western half of the Plateau consist mostly of shale and conglomeratic sandstone with lesser amounts of siltstone and coal (essentially the equivalent of the Lee Formation in Kentucky). The eastern half of the Plateau in Area 17 is underlain by younger Pennsylvanian rocks which are essentially the Breathitt Formation in Kentucky. This unit consists of shale, sandstone, siltstone, and coal. There are approximately 30 major coal beds in Kentucky. The important coal beds in Tennessee are the Jellico, Sewanee, Pewee, Coal Creek, and Big Mary.

The regolith of the Cumberland Plateau has an average thickness of 2 to 3 feet. Anomalous thicknesses of up to 30 feet occur in some fractures and joints.

The Pennington Formation of Late Mississippian age separates the Pennsylvanian rocks above from the Mississippian carbonate rocks below. It ranges in thickness from 100 to 500 feet and is composed of shale, limestone, dolomite, and conglomeratic and fine-grained sandstones. The Pennington underlies most of the Cumberland Plateau and crops out along the western escarpment.

The Highland Rim is underlain by Mississippian carbonate rocks which average 600 to 700 feet in thickness. The dominant lithologies of this region are calcareous shale, siltstone, and cherty limestone with lesser amounts of dolomite and sandstone. Mississippian rocks are exposed throughout the Highland Rim and underlie the Cumberland Plateau with a maximum thickness of 1,100 feet. The regolith is composed of cherty and clayey soils derived from shale and limestone and is generally 15 to 20 feet thick.

Underlying the Mississippian carbonate rocks and separating them from the Ordovician limestone below is the Chattanooga Shale of Devonian age. It crops out along the Highland Rim escarpment and the Cumberland River south of Lake Cumberland. Ordovician rocks underlie all of Area 17 at depth and minor exposures occur along the Cumberland River downstream of Lake Cumberland.



EXPLANATION

Pennsylvanian

Mississippian and older

Highland Rim

Cumberland Plateau

Geology from H.B. Renfro and D.E. Feray, 1970

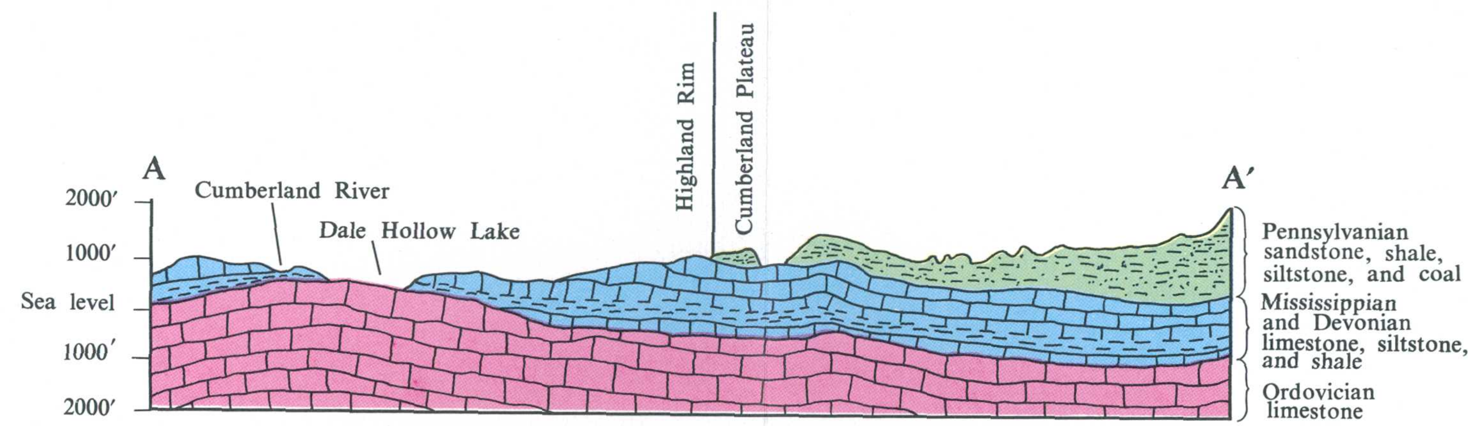


Figure 2.3-1 Geology and cross section

Area 17 Soils Have Moderate to High Erosion Potentials

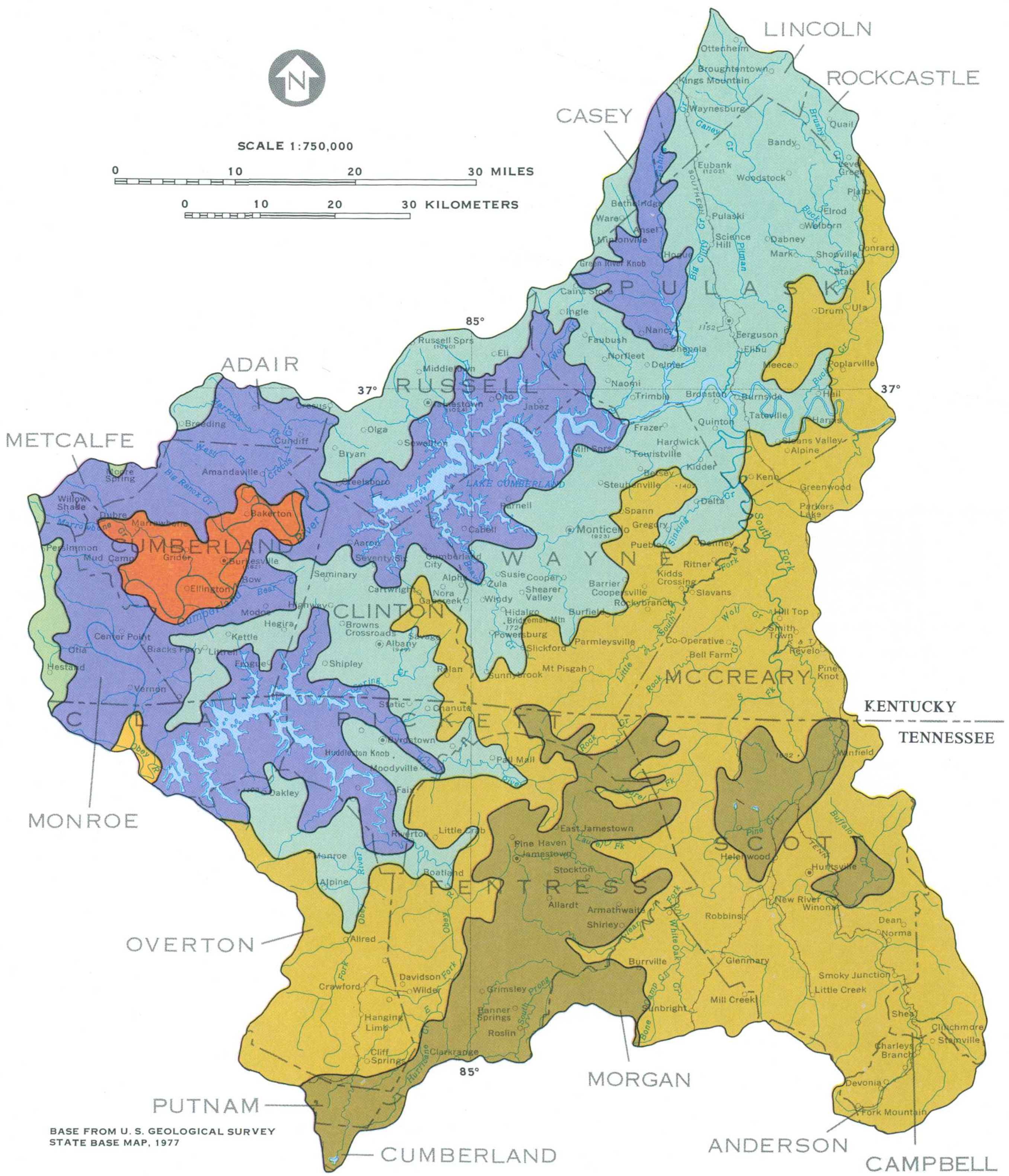
Soils of the Cumberland Plateau are derived from sandstone and shale and are generally loamy and stony. The soils of the Highland Rim are derived from limestone, shale, and a minor amount of loess. The soils are generally cherty, clayey, and shaly.

The soils of the Cumberland Plateau are derived from sandstone and shale and soil depth ranges from shallow to deep (figure 2.4-1 and table 2.4-1). These are well drained and are generally low in natural fertility. The terrain is moderately steep to steep with slopes of 20 to 60 percent giving the soils a moderate to high potential for erosion.

The escarpment separating the Cumberland Plateau from the Highland Rim has generally stony soils derived from the sandstone cliffs above. The soils are shallow to moderately deep and, because of the steepness of the slopes, have a high potential for erosion.

The soils of the Highland Rim are primarily derived from limestone and shale and soil depth ranges from moderately deep to very deep. Highland Rim soils are well drained and are generally low to moderately fertile. The gently rolling terrain has a slope of 5 to 40 percent with a moderate potential for erosion.

Infiltration rates for soils in the area range from moderate to very slow. The hydrologic soils group classification shown in table 2.4-2 indicates this variability. Class B soils have moderate infiltration rates, class C soils have slow infiltration rates, and class D soils have very slow infiltration rates.



Soils modified from Soil Conservation Service in cooperation with Kentucky and Tennessee Agricultural Experiment Stations

Figure 2.4-1 Soil associations in Area 17

Table 2.4-1 Soil associations in Area 17

Soil association	Soil depth (in)	Depth to bedrock (in)	Soil reaction pH	Permeability (in/h)	Available water capacity (in/in)	Slope (%)	Description
SOILS OF THE CUMBERLAND PLATEAU							
Hartsells-Lonewood-Ramsey-Gilpin	10-36 Lonewood 40-65	10-40 40-72	3.6-6.5	0.6-6.0 Ramsey 6.0-20.0	0.04-0.18	0-70	Well-drained, moderately deep, loamy soils from sandstone and shale
Hartsells-Ramsey-Gilpin	10-36	10-40	3.6-5.5	0.6-2.0 Ramsey 6.0-20.0	0.06-0.18	0-70	Well-drained, moderately deep to shallow, loamy soils from sandstone and shale
Bouldin-Ramsey	Ramsey 10-20 Bouldin 60-100	10-20 10-120	4.5-5.5	6.0-20.0 2.0-6.0	0.04-0.12	8-75	Well-drained, stony and loamy soils with rock outcrops from colluvium, sandstone, shale, and limestone
Ramsey-Hartsells-Grimsley-Gilpin	10-36	10-60	3.6-5.5	0.6-6.0 Ramsey 6.0-20.0	0.05-0.18	0-70	Well-drained, stony and loamy soils from sandstone and shale
Muskingum-Gilpin-Jefferson	0-65	20-40 Jefferson 60	3.6-6.0	0.6-6.0	0.02-0.18	2-70	Well-drained, loamy soils from shale and sandstone
SOILS OF THE HIGHLAND RIM							
Waynesboro-Decatur-Bewleyville-Curtistown	60-72	60-80	4.5-6.0	0.6-2.0	0.10-0.22	0-30	Well-drained, clayey and loamy soils from alluvium and thin loess
Baxter-Bewleyville-Pembroke	72-100	72-100	4.5-6.0	0.6-2.0	0.08-0.23	0-60	Well-drained, cherty, clayey, and silty soils from limestone, thin loess, and alluvium
Sulphura-Christian-Mountview	40-96 Sulphura 20	60-100 Sulphura 10-30	3.6-6.5	0.6-6.0	0.09-0.22	2-50	Well-drained, shaly, cherty and clayey soils from shale and limestone; silty soils from thin loess and residuum
Dellrose-Mimosa-Bodine	40-72	40-80	3.6-6.0	0.2-6.0	0.06-0.20	2-60	Well-drained, deep to moderately deep, cherty and clayey soils from colluvium, phosphatic limestone, cherty limestone, and shale
Fairmont-Faywood	Fairmont 10-20 Faywood 20-40	10-15 20-35	5.1-8.4	0.06-0.6	0.12-0.2	6-50	Well-drained, shallow to moderately deep, clayey soils from limestone residuum

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

CORRELATION OF SOIL ASSOCIATIONS

TENNESSEE	KENTUCKY
CUMBERLAND PLATEAU	
Hartsells-Lonewood-Ramsey-Gilpin	———
Hartsells-Ramsey-Gilpin	———
Bouldin-Ramsey	Shelocta-Gilpin
Ramsey-Hartsells-Grimsley-Gilpin	Jefferson-Shelocta
Muskingum-Gilpin-Jefferson	Latham-Shelocta
HIGHLAND RIM	
Waynesboro-Decatur-Bewleyville-Curtistown	Frederick-Mountview
Baxter-Bewleyville-Pembroke	Trimble-Baxter
Sulphura-Christian-Mountview	Garmon-Frederick
Dellrose-Mimosa-Bodine	———
———	Fairmont-Faywood

Table 2.4-2 Hydrologic soils group

Cumberland Plateau

Soil series	Hydrologic soils group
Bouldin	B
Gilpin	C
Grimsley	B
Hartsells	B
Jefferson	B
Lonewood	B
Muskingum	C
Ramsey	D

Highland Rim

Soil series	Hydrologic soils group
Baxter	B
Bewleyville	B
Bodine	B
Christian	C
Curtistown	B
Decatur	B
Dellrose	B
Fairmont	D
Faywood	C
Mimosa	C
Mountview	B
Pembroke	B
Sulphura	D
Waynesboro	B

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

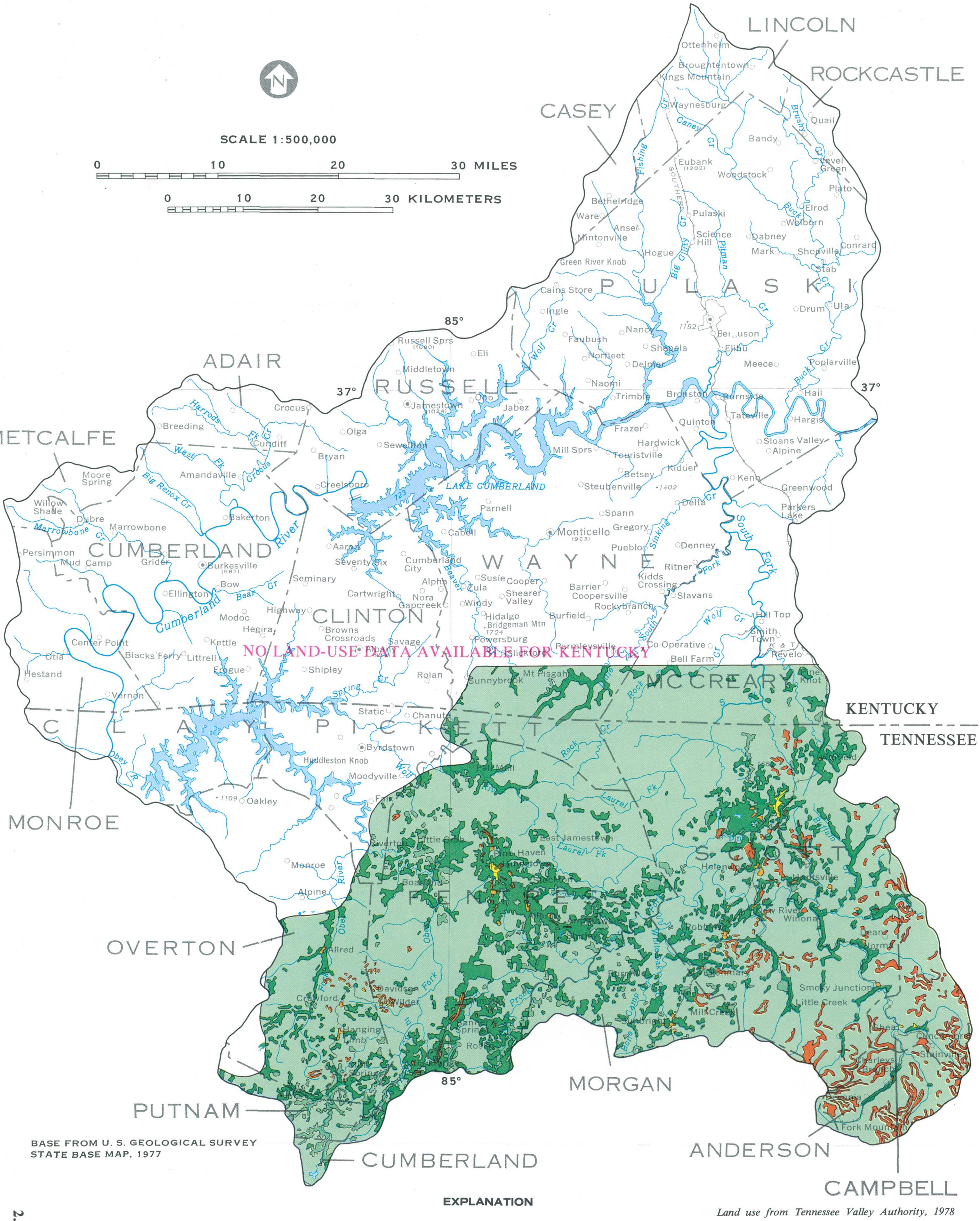
Forest Cover Predominant in Coal Resource Area

Land-use data are available for only about 35 percent of the area. Of the mapped areas, forest accounts for approximately 75 percent of the land cover of the Cumberland Plateau. No land-use data are available for the Highland Rim.

The Cumberland Plateau in Tennessee is approximately 75 percent forest, 20 percent agriculture and open land, 3 percent mining, and 2 percent urban or rural residential (fig. 2.5-1). These percentages were based upon analysis of high-altitude aerial photography collected between 1974 and 1976. The primary coal resources are located in the Cumberland Mountains in the southeast one-fifth of the area. In this area, forest accounts for nearly 90 percent of the land use; mining, approximately 5 percent; agriculture and open land, 4 percent; and urban or rural residential, 1 percent. The Cumberland Plateau escarpment is completely forested.

Land-use maps for the area shown by inset (fig. 2.5-1) are available from:

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



EXPLANATION

Land Use

- Urban
- Agriculture and open land
- Water
- Mining
- Rural residential
- Deciduous
- Evergreen

Figure 2.5-1 Land use in the southeastern part of Area 17

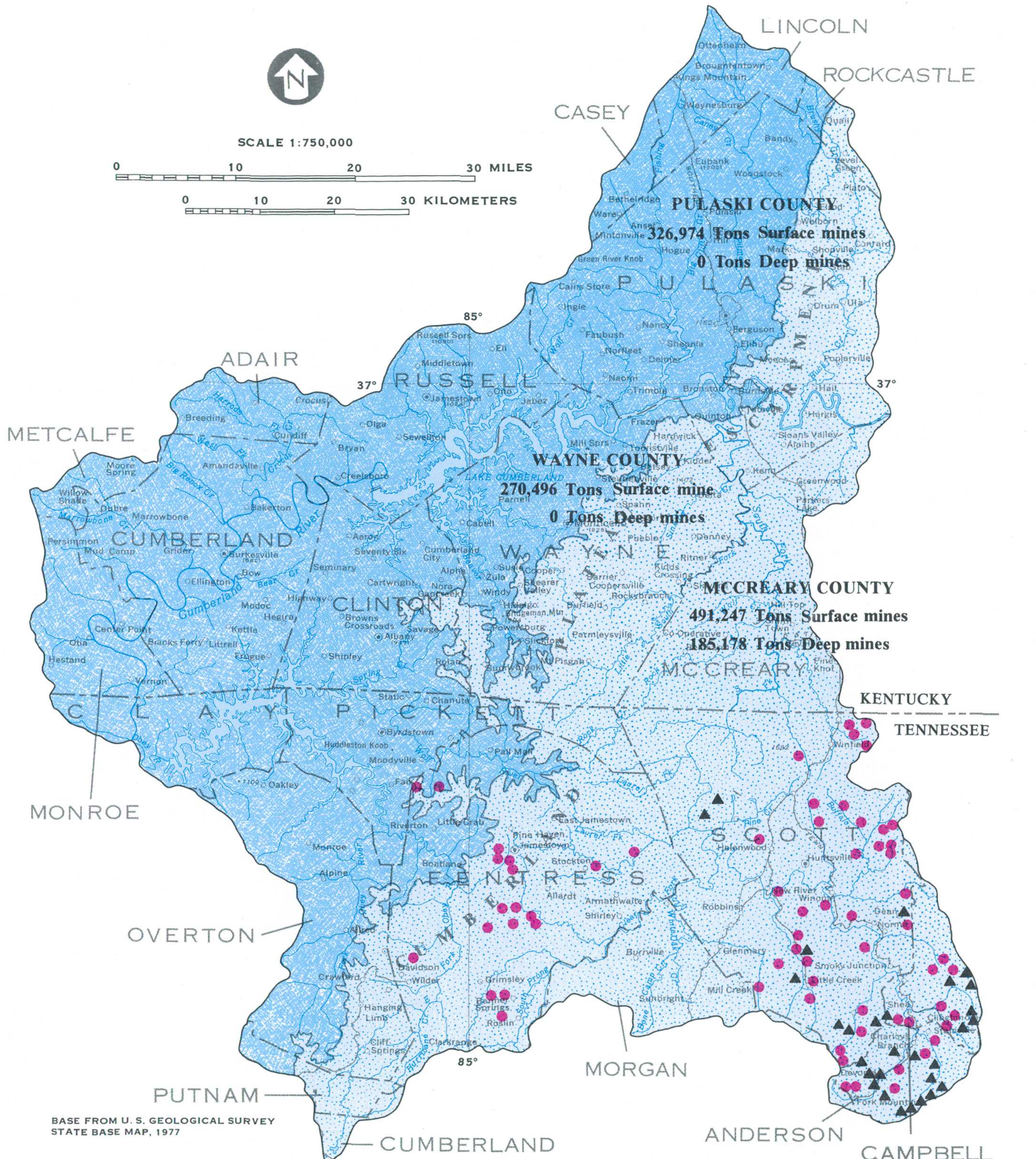
Coal-Mining Activities in Area 17 Occur in the Cumberland Plateau

Surface coal mining is widespread throughout the Cumberland Plateau. Both surface mines and deep mines are operated in Tennessee and Kentucky.

The locations of active mines in Tennessee (Tennessee Department of Public Health, 1978) are shown in figure 2.6-1. Sixty-seven surface mines and twenty-nine deep mines were approved for operation in Tennessee as of 1978. Similar data are not available for Kentucky; however, coal production from both deep and surface mines in 1979 is shown for McCreary, Pulaski, and Wayne Counties. The production given is for the entire county, although parts of two counties are outside Area 17.

In many parts of Area 17, surface mining is the commonly used method. Surface mining in these areas is done by stripping along the contours (contour mining) of hills and mountains where the edges of coal seams are mined as far back into the mountain as is economically feasible (fig. 2.6-2). In some mining operations, additional coal is extracted by augering the coal seam after the stripping operation is completed.

Contour mining leaves bare earth and rocks, high-walls (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 banks (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.



EXPLANATION

Coal mine permits

● **Surface mine**

▲ **Deep mine**

Coal permits data from Tennessee Department of Public Health, 1978

Tonnage from Kentucky Department of Mines and Minerals, 1979

Highland Rim **Cumberland Plateau**

Figure 2.6-1 Coal-mining activities

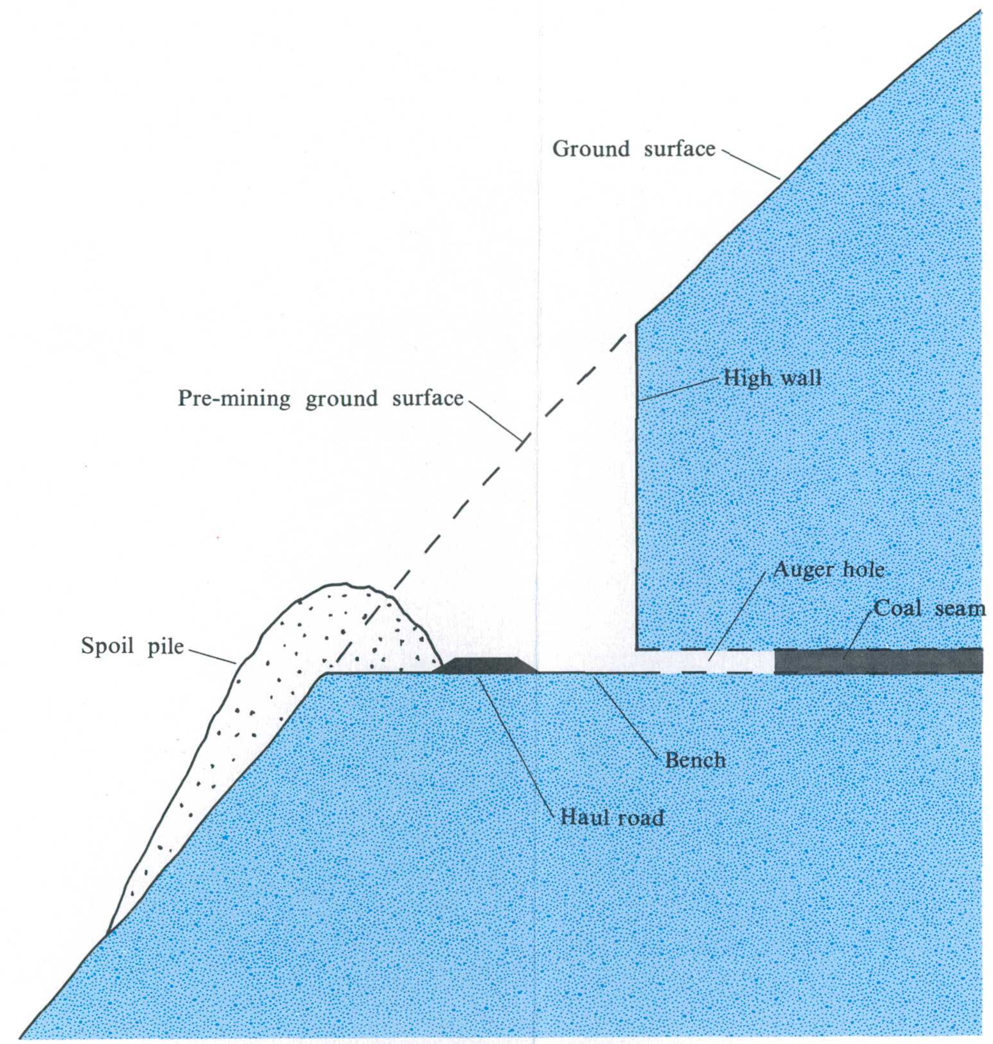


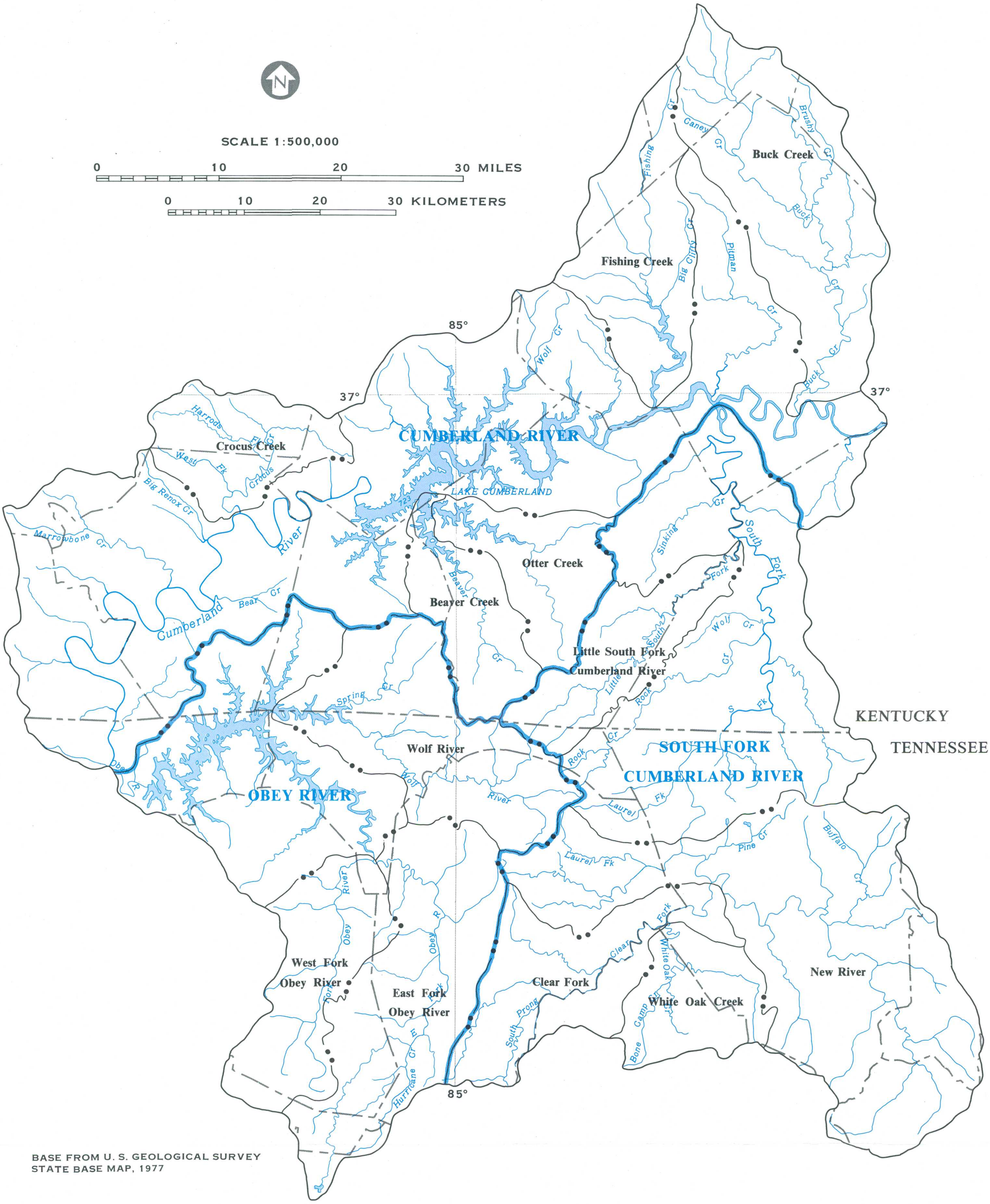
Figure 2.6-2 Typical contour (strip) mining site

All Surface Drainage in Area 17 Flows into the Cumberland River

The Cumberland, South Fork Cumberland, and Obey Rivers are the largest streams.

Area 17 has a total surface drainage of 4,203 mi^2. All surface drainage is to the Cumberland River which flows southwesterly across the area. South Fork Cumberland River and its tributaries drain 1,382 mi^2, about 33 percent of the area. Obey River and its tributaries drain 947 mi^2, about 23 percent of the area. The entire drainage basins for all the streams in Area 17, except the Cumberland River basin, are contained within the area (fig. 2.7-1). The principal subbasins of the area are as follows:

Sub-basin	Drainage Area (square miles)
Buck Creek	294
New River	396
White Oak Creek	103
Clear Fork	180
Little South Fork Cumberland River	122
South Fork Cumberland River	581
Fishing Creek	179
Otter Creek	105
Beaver Creek	129
Crocus Creek	113
East Fork Obey River	263
West Fork Obey River	150
Wolf River	134
Obey River	400
Cumberland River (within Area 17)	1,054
Total Area 17	4,203



BASE FROM U. S. GEOLOGICAL SURVEY
STATE BASE MAP, 1977

EXPLANATION

Major basin boundary

Subbasin boundary

Figure 2.7-1 Drainage basins

Information on Surface Water Available at 101 Locations

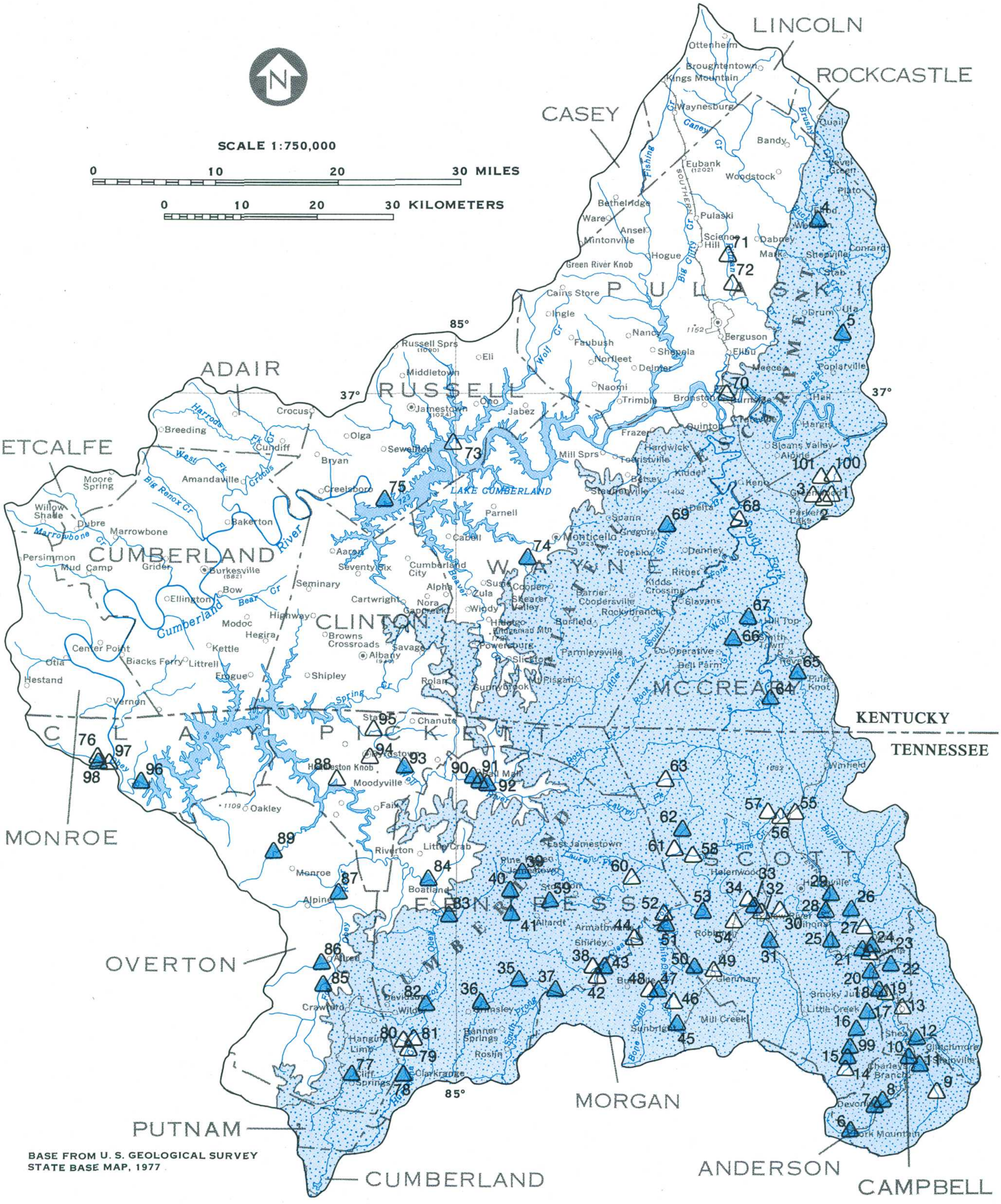
Streamflow data for many sites in Area 17 have been collected for more than 30 years. Most of the water-quality and suspended-sediment data were collected within the last 6 years. Beginning in 1979, data collection was increased in response to the Surface Mining Control and Reclamation Act.

Streamflow, water-quality or sediment data are available for 101 sites in Area 17 (fig. 3.1-1). Many streamflow sites have been operated for more than 30 years. Most water-quality and 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 network was expanded by 21 additional sites; in 1980, the Kentucky network was expanded by 6 sites.

Water-quality information is available for 57 locations in Area 17. Water-quality information includes field and laboratory analyses. Parameters include: water temperature; specific conductance; pH; dissolved major chemical constituents; dissolved and total recoverable trace constituents; and trace constituents in bottom material from streams. Suspended-sediment data are available for 47 sites, 39 of which were active in 1980.

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

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



EXPLANATION

▲86 Active site and number

△54 Inactive site and number

☐ Highland Rim ☐ Cumberland Plateau

See section 10.1 for detailed site description

Figure 3.1-1 Surface-water network

Limited Ground-Water Data Available in Area 17

Ground-water quality information is available for 60 wells and 17 springs. Continuous water-level data are available for two wells.

Detailed ground-water information in the Cumberland Plateau is scarce; few data have been collected in the area since 1979. Water-quality data are available for 60 wells and 17 springs and continuous water-level data have been recorded for two wells. Each of these sites is listed in section 10.2, and the locations are shown in figure 3.2-1.

Additional water-quality data have been collected at more than 100 sites in Kentucky not listed in section 10.2 nor shown on figure 3.2-1. Much of these data, however, were obtained during oil-exploration and are not considered representative of the potential ground-water resources in the area. Site information and data can be obtained from the U.S. Geological Survey computer files through the National Water Data Exchange (NAWDEX, see section 9.2) or from Faust, Banfield, and Willinger (1980).

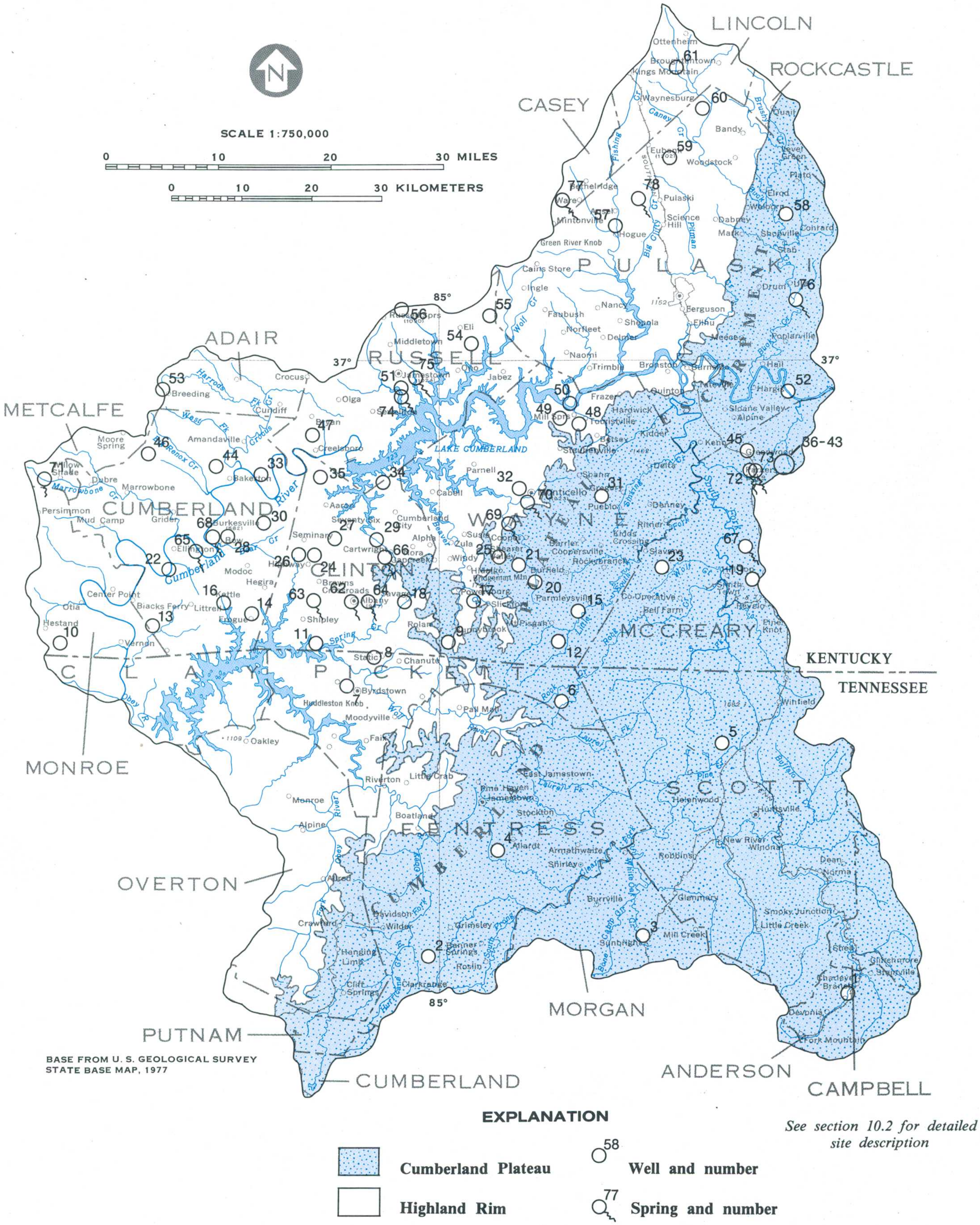


Figure 3.2-1 Ground-water network

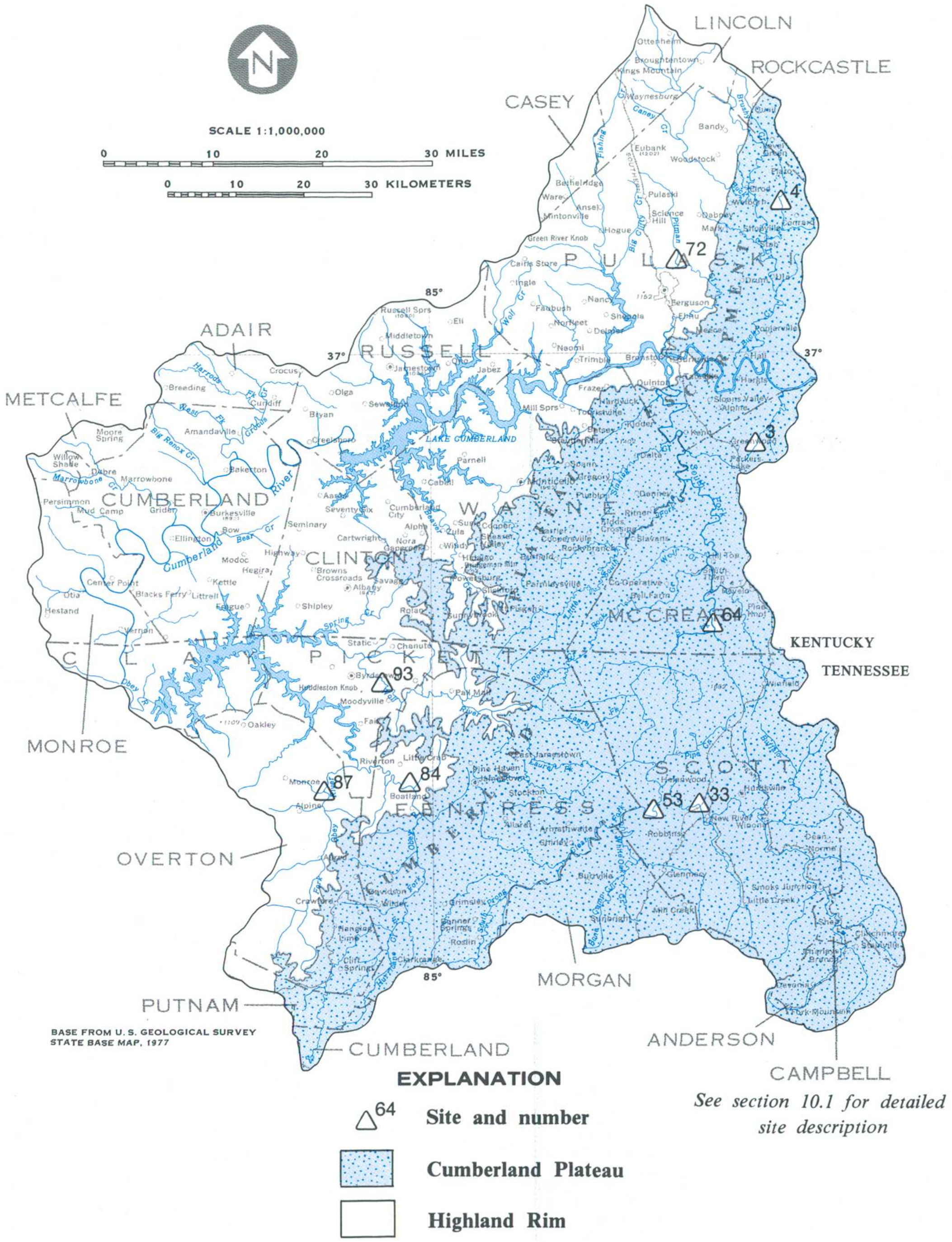
Streamflow Varies with Time and Place

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

Surface water includes the water stored in lakes, ponds, and reservoirs and that flowing in streams. The volume of stored water is relatively stable although there is some seasonal fluctuation. Streamflow, the largest component of surface water, is highly variable with time and place. It is made up of two components; direct runoff that supplies most of the volume of streamflow during flood periods, and base flow from ground-water storage that feeds the streams during the periods of no direct runoff. The average annual runoff from Area 17 can be approximated as the mean annual precipitation for the area, about 50 inches, minus approximately 30 inches of evapotranspiration.

Significant differences in topography, slope, soils, and geology between the two physiographic sections in Area 17 (section 2.0) along with differences in drainage basin size, contribute to the variability of flow from stream to stream, especially during the 250 days per year on the average when no rainfall occurs. Streamflow varies in a pattern similar to the seasonal variation in rainfall (section 2.7). Monthly mean discharge as a percentage of the annual mean is shown in figure 4.1-1. Although no significant trends related to physiography can be detected, this table illustrates the seasonal variability of individual streams.

The flow variability in the Wolf River near Byrdstown, Tenn. (site 93), during the 1977 water year is typical for the area (fig. 4.1-2). The average discharge for the period of record also is shown in this figure. Another way of illustrating flow variability is shown in figure 4.1-3 which compares mean daily flow with the maximum and minimum daily flow for each month of the 1977 water year. The long-term monthly variability of Wolf River is illustrated in figure 4.1-4.



Site number	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
3	1.89	4.95	10.9	14.1	17.1	17.7	14.2	7.76	4.00	3.44	2.06	1.96
4	2.21	4.35	12.7	14.3	16.1	16.8	12.8	7.16	4.56	3.72	1.99	3.38
33	1.43	5.20	12.0	16.6	17.1	18.3	12.5	7.30	3.44	3.18	1.76	1.18
53	.87	3.71	11.0	16.3	19.5	19.1	13.2	7.32	3.21	2.88	1.86	1.15
64	1.77	5.44	12.2	16.3	16.9	17.9	12.2	7.48	3.62	3.04	1.84	1.36
72	1.10	3.24	10.6	13.2	20.0	19.1	14.3	7.17	4.00	3.62	2.13	1.49
84	1.69	5.26	12.0	16.0	17.1	18.4	12.7	7.83	3.45	2.71	1.33	1.50
87	.99	4.17	10.9	15.8	19.8	19.4	13.2	6.62	3.67	2.61	1.53	1.24
93	1.42	4.77	11.6	15.8	17.2	18.8	12.9	6.94	4.25	2.91	2.02	1.56

Figure 4.1-1 Percentage of annual mean discharge occurring in indicated month at selected sites

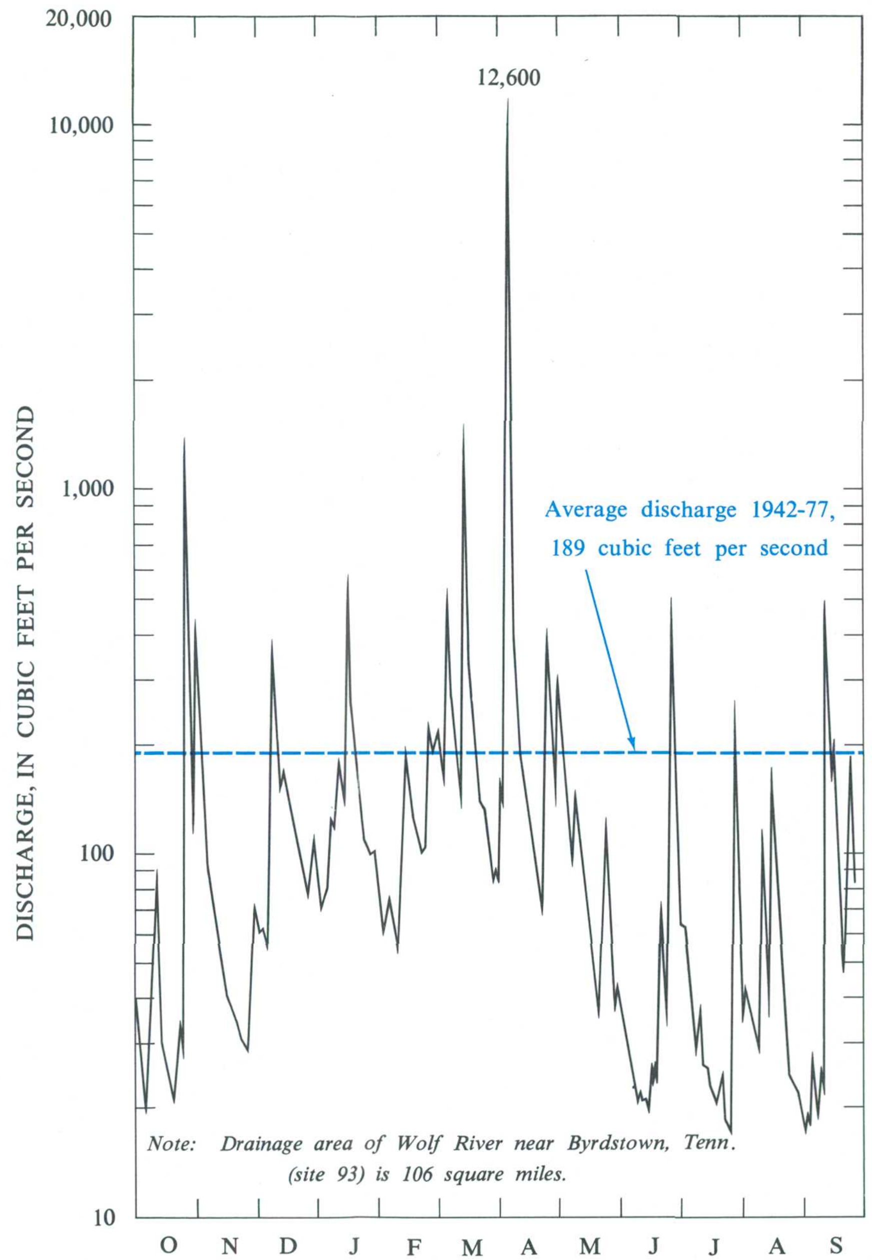


Figure 4.1-2 Discharge hydrograph for Wolf River near Byrdstown, Tenn., for the 1977 water year

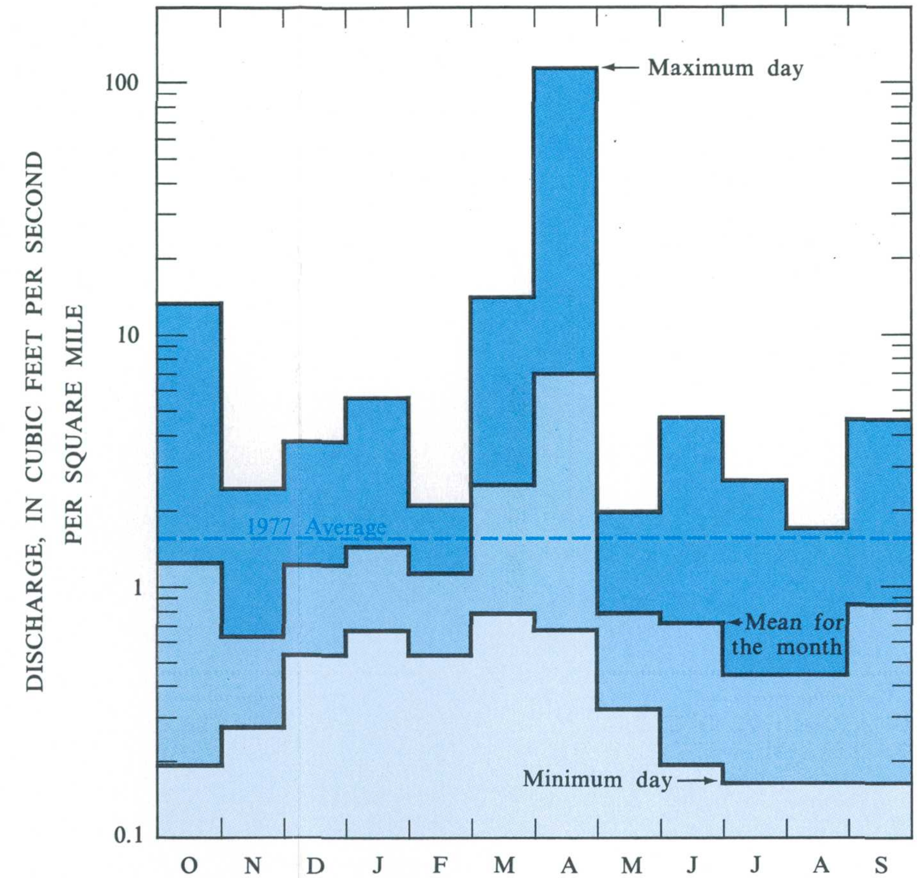


Figure 4.1-3 Monthly range in daily flows for the 1977 water year, Wolf River near Byrdstown, Tenn.

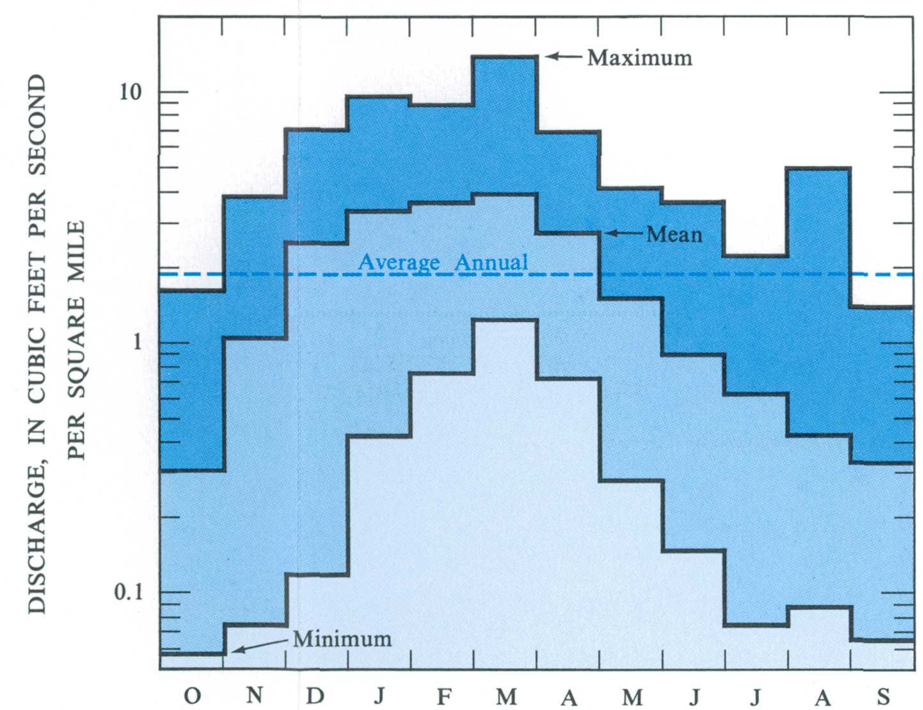


Figure 4.1-4 Range in monthly flows for the period 1943-79, Wolf River near Byrdstown, Tenn.

The Principal Factor Affecting the Average Annual Flow of Streams Is the Size of the Drainage Basin

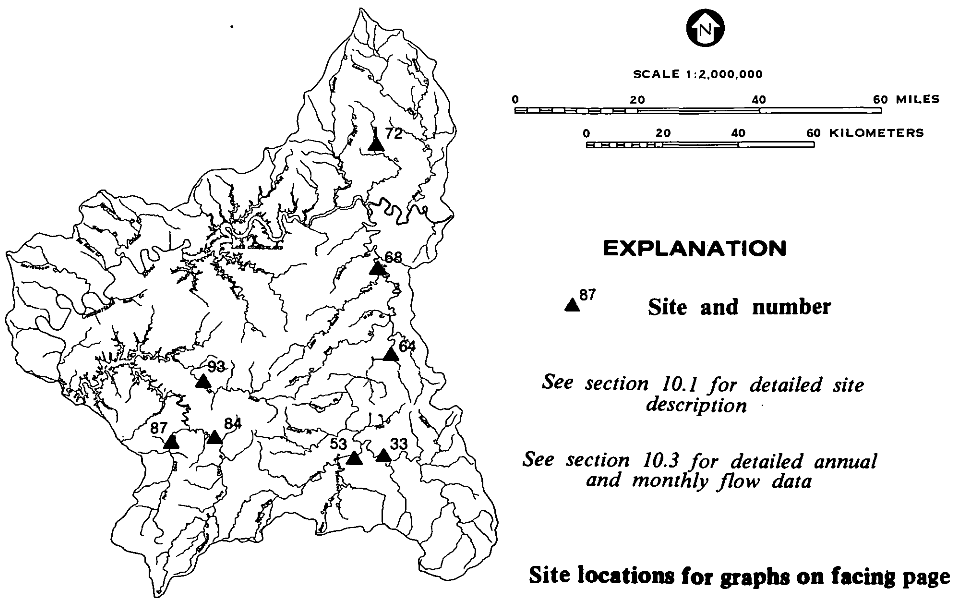
Average annual flow ranges from approximately 1.2 to 2.1 cubic feet per second per square mile in Area 17. The seasonal variability of the mean and maximum monthly flows per square mile is similar throughout Area 17.

The average annual flow in cubic feet per second per square mile is shown for several streams of various sizes in figure 4.2-1 and in section 10.3. This unit of flow eliminates the variation due to the size of the drainage basin so that a more direct comparison between streams can be made. Assuming that differences were not caused by use of varying periods of record, the average annual flow ranges from approximately 1.2 to 2.1 $(ft^3/s)/mi^2$ for the sites shown in section 10.3. Using a base period of 1954-71, the average flow of seven sites ranged from about 1.3 to 1.9 $(ft^3/s)/mi^2$ (table 4.2-1). Comparison of data in the two tables shows only small differences in average flows, although the period of record is variable.

In addition to drainage basin size, seasonal variations in rainfall affect monthly flows. For streams in Area 17, the seasonal variability of the mean and maximum monthly flows per square mile is similar even with the varying lengths of available record (see fig. 4.2-1 and section 10.3). However, minimum monthly flows indicate variations due to other factors. The most important one is that the geology affects the minimum monthly flow, especially during periods of no rainfall when the flow of some streams is not well sustained. This is a result of either the poor infiltration qualities of the land surface or the poor ability of the underground reservoirs to store and release water.

Table 4.2-1 Average annual flow at 8 sites for the period 1954-71

Site number	Average annual flow $(ft^3/s)/mi^2$
3	1.28
4	1.44
33	1.86
64	1.75
72	1.37
84	1.90
87	1.30
93	1.68



Site locations for graphs on facing page

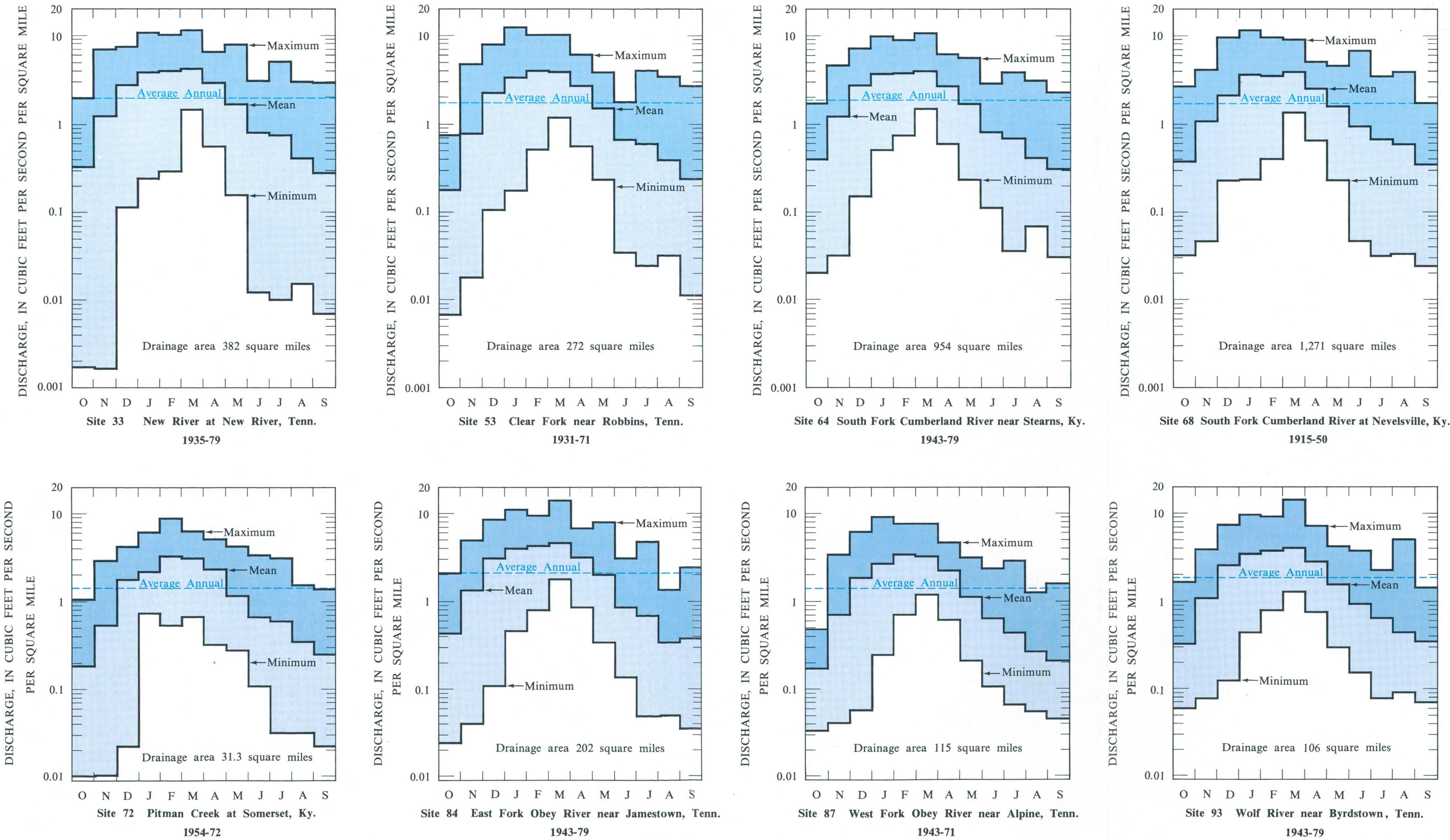


Figure 4.2-1 Average annual and range in monthly flow per square mile at selected sites

Some Streams in Area 17 Go Dry

The 3-day 20-year and the 7-day 10-year recurrence interval low flows are zero for some streams in Area 17.

The low-flow of streams is generally defined in terms of frequency. Low-flow frequency is expressed as the lowest average flow for a given number of consecutive days for a given recurrence interval. Common indices of low flow used in Kentucky are the 7-day 2-year and the 7-day 10-year flows, and those used in Tennessee are the 7-day 10-year and the 3-day 20-year. In general the 7-day 10-year flow is larger than the 3-day 20-year flow. Low-flow frequencies have been computed for nine sites in Area 17. The locations are shown in fig. 4.3-1 and the indices are given in table 4.3-1. These data are taken from Gold (1980) and from Sullavan (1980). The low flow of streams in Area 17 cannot be regionalized at this time due to the lack of data.

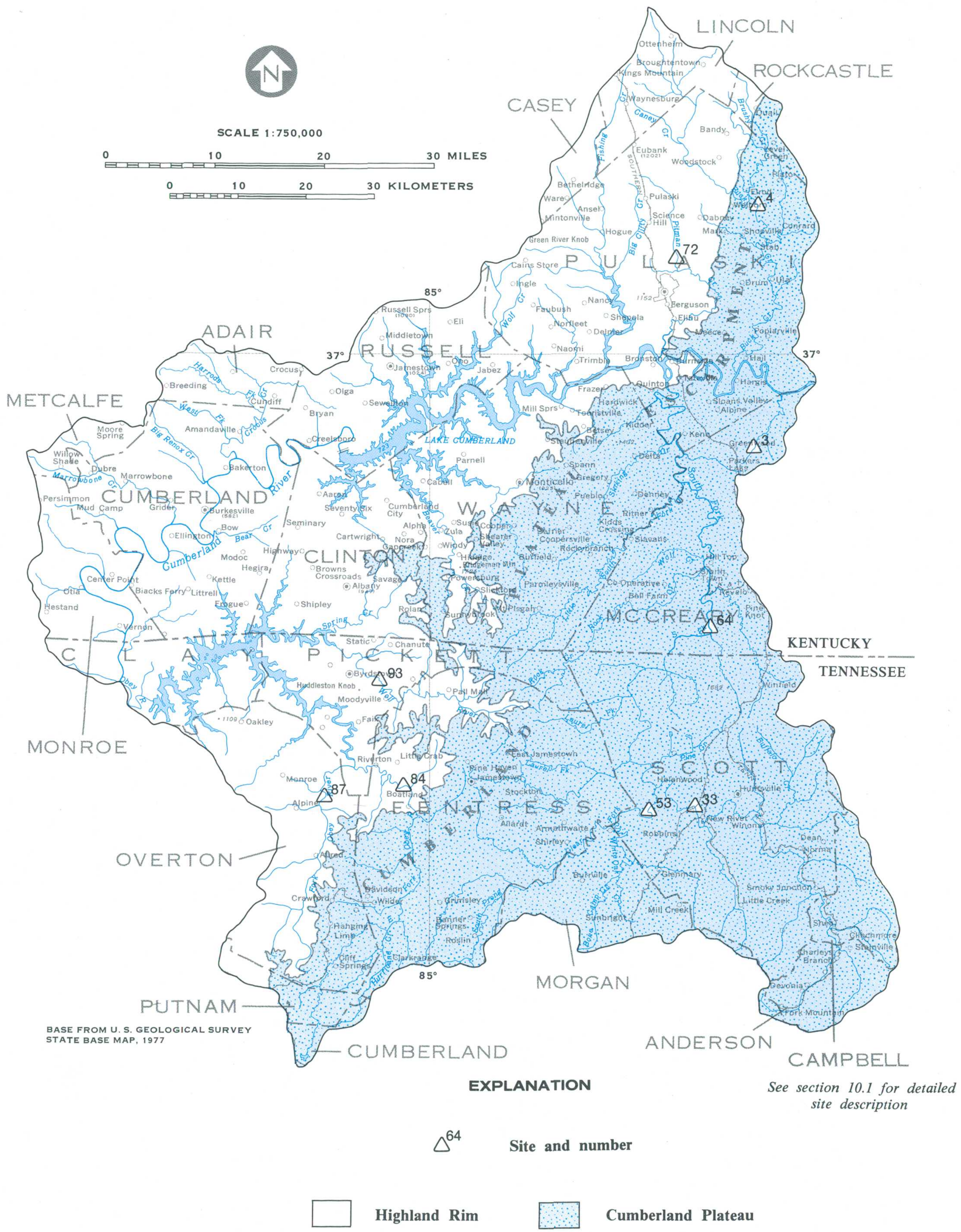


Figure 4.3-1 Location of sites for which low-flow information is tabulated

Table 4.3-1.--Low flows at selected sites

Site number	Drainage area (mi²)	Station name	7-day 2-year recurrence interval flow (ft³/s)	7-day 10-year recurrence interval flow (ft³/s)	3-day 20-year recurrence interval flow (ft³/s)
3	0.85	Helton Branch at Greenwood, Ky.	0.1	0.1	0.1
4	165	Buck Creek near Shopville, Ky.	.1	.0	.0
33	382	New River at New River, Tenn.	4.25	.42	.18
53	272	Clear Fork near Robbins, Tenn.	4.74	1.40	.76
64	954	South Fork Cumberland River nr. Stearns, Ky.	43	20	15
72	31.3	Pitman Creek at Somerset, Ky.	.3	.3	.0
84	202	East Fork Obey River near Jamestown, Tenn.	8.99	4.80	3.89
87	115	West Fork Obey River near Alpine, Tenn.	4.53	3.08	2.73
93	106	Wolf River near Byrdstown, Tenn.	7.92	5.07	3.45

Most Floods Occur During the Period December Through April

Most floods occur in the winter and spring. About 84 percent occur from December through April. Techniques have been developed for estimating flood magnitude and frequency.

The range in maximum known floods experienced in Area 17 for a given drainage basin size is about one order of magnitude for basins under 10 mi^2 and less than that for larger basins (fig. 4.4.1-1). For example, at 8 square miles the range is from about 1,100 to about 12,000 ft^3/s and at 500 square miles the range is from about 35,000 to about 80,000 ft^3/s. In general, large basins produce large maximum floods and smaller basins produce smaller maximum floods. The occurrence of floods is a natural, random phenomenon, and greater floods than those observed can occur at any time.

Floods occur in Area 17 in any month of the year. However, about 65 percent of the annual peaks occur during the period January through March and about 84 percent occur during the longer period December through April (fig. 4.4.1-2). About 25 percent of the annual peaks occur in March. Only about 2 percent of the annual peaks occur during the period August through October.

The flood-frequency of natural streams have been defined in Tennessee by Randolph and Gamble (1976) and in Kentucky by Hannum (1976). All gaging station records of 10 or more years in length and not significantly affected by man-made changes were analyzed. Each state was divided into hydrologic areas which have distinct flood-frequency characteristics. Area 17 is in part of hydrologic area 2 in Tennessee and parts of areas 6, 8, and 9 in Kentucky (fig. 4.4.1-3).

Equations for computing discharges at ungaged sites for various recurrence intervals for each hydrologic area are given in these reports. For Tennessee and Kentucky, the equations take the general form:

Tennessee

$$Q = CA^x,$$

where:
Q is discharge in cubic feet per second;
C is a regression constant;
A is the contributing drainage area in square miles;
x is a regression coefficient

Kentucky

$$Q = CA^xR^y$$

where:
Q is discharge in cubic feet per second;
C is a regression constant;
A is the contributing drainage area in square miles;
R is a geographical factor;
x and y are regression coefficients

The computed relation between the 50-year flood and size of the drainage basin is shown in fig. 4.4.1-1. Limitations and applications of these equations are given in the reports. Recurrence interval is defined as the average interval of time, in years, within which the given flood magnitude will be equaled or exceeded. For example, a 50-year flood could be expected, on the average, once in 50 years or, stated another way, has a 2 percent chance of occurring in any given year.

In addition to the equations for ungaged sites, recommended methods for computing flood frequency at sites which are relatively near gaging stations (where the drainage area is within 50 percent of the area at the gage site) are given by Randolph and Gamble (1976) and Hannum (1976).

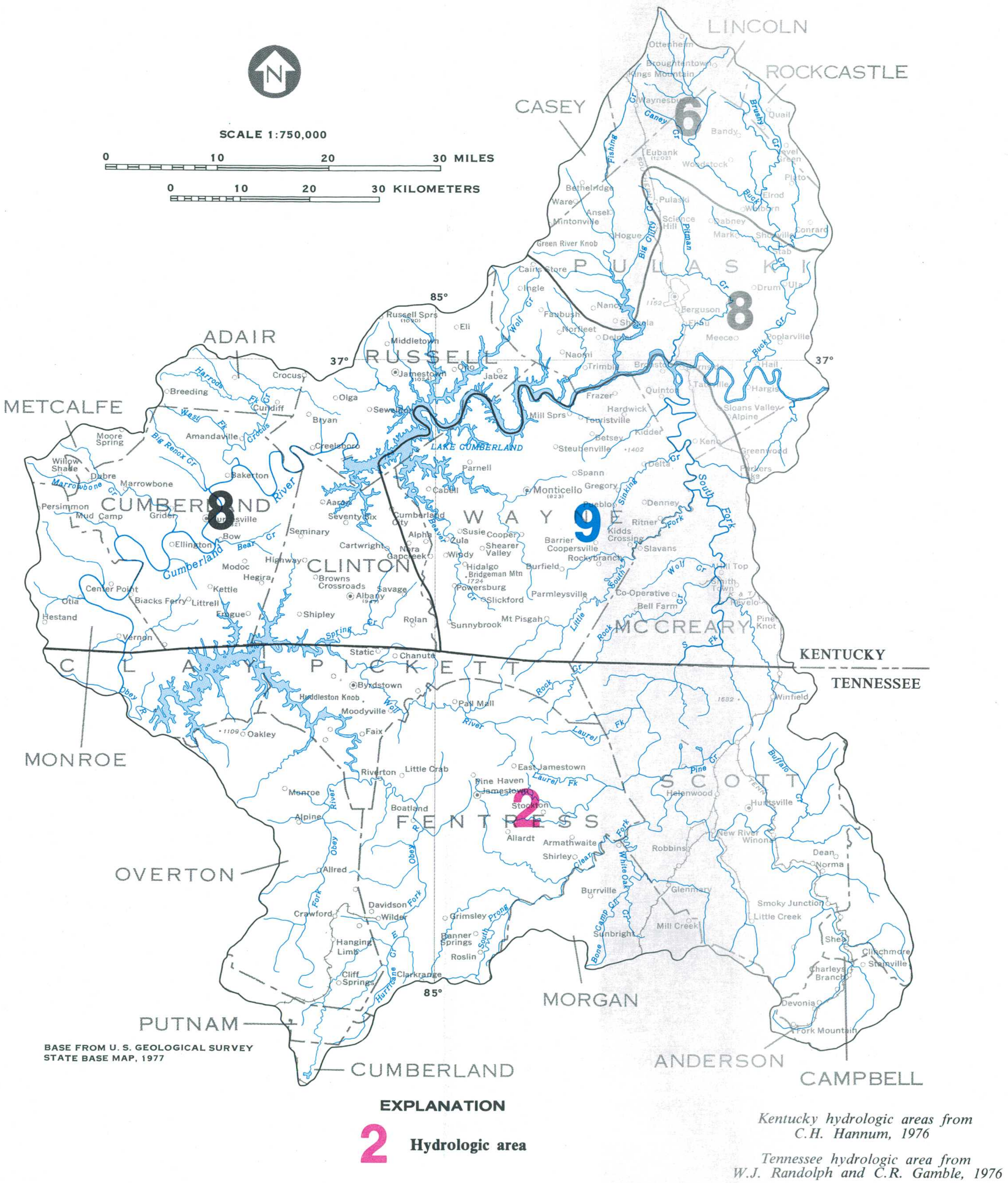


Figure 4.4.1-3 Flood-frequency hydrologic areas

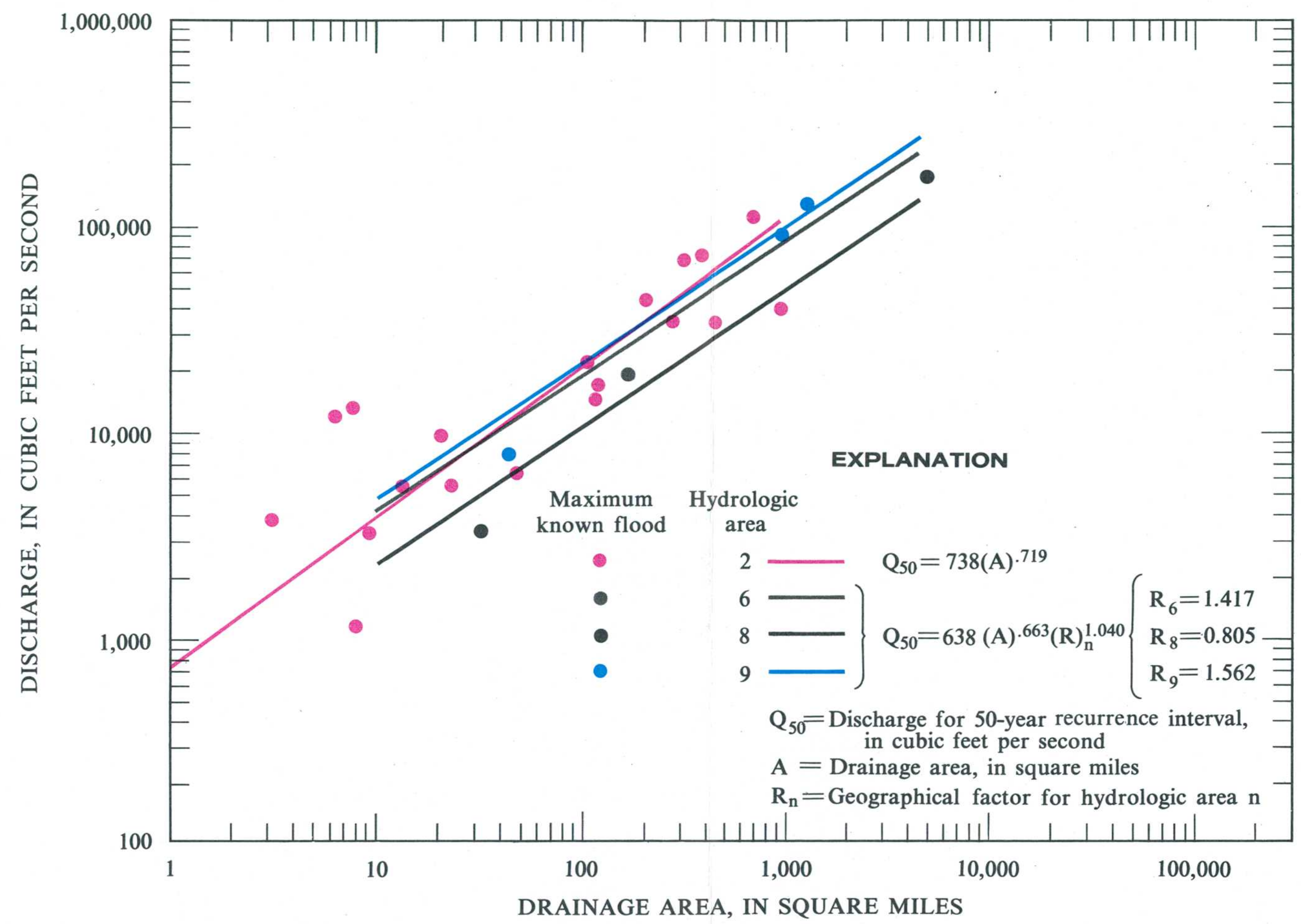


Figure 4.4.1-1 Relation of maximum known floods and 50-year flood to drainage area

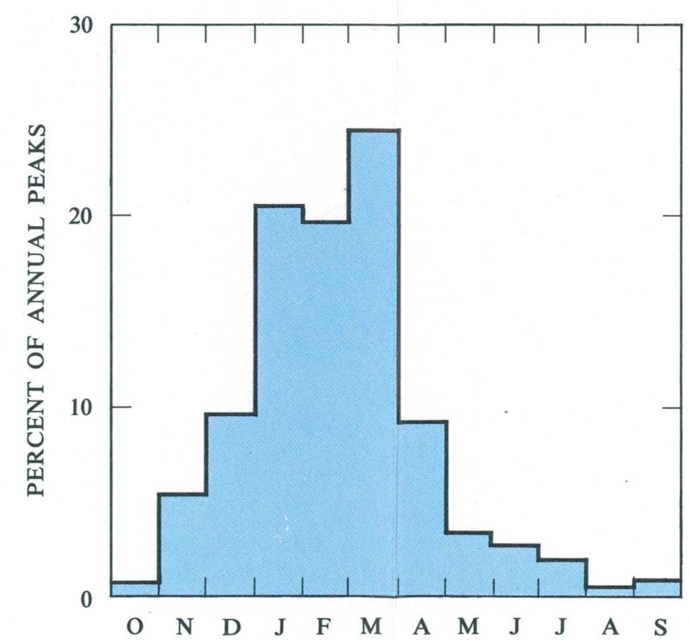


Figure 4.4.1-2 Seasonal distribution of floods in Area 17

Method of Predicting 100-Year Flood Depths Available For Some Locations

Depths for the 100-year flood are predictable.
Four flood-prone area maps are available.

The 100-year flood is one which could be expected, on the average, once in 100 years. Stated another way, such a flood has a 1 percent chance of occurring in any given year. In Tennessee, a method was developed for estimating the depth (feet) of the 100-year flood on small streams by relating depth to drainage basin size in each of four hydrologic areas (Gamble and Lewis, 1977). Area 17 is in hydrologic area 2 (fig. 4.4.2-1). The equation for computing flood depth is:

$$\text{Depth of 100-year flood} = 7.1\,(A)^{0.226}$$

where: A is the drainage area in square miles. The range in drainage basin size for which this equation is applicable is from 0.49 to 382 mi^2.

The relation between flood depth and drainage area was used in the flood-prone area mapping program to determine 100-year flood depths. It can be used to estimate the depth of the 100-year flood for any purpose where extreme accuracy is not necessary. This method has not been verified for use in Kentucky. However, there is some indication that the relation may apply to streams with basins ranging in size from 100 to 380 mi^2.

The four available flood-prone area maps within or partially within Area 17 are indicated by shading in figure 4.4.2-2. The names and locations of all 7½-minute topographic quadrangle maps in the area are also shown.

Flood-prone area maps may be obtained from:

(KENTUCKY MAPS)
U.S. Geological Survey
Room 572 Federal Building
600 Federal Place
Louisville, KY 40202

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

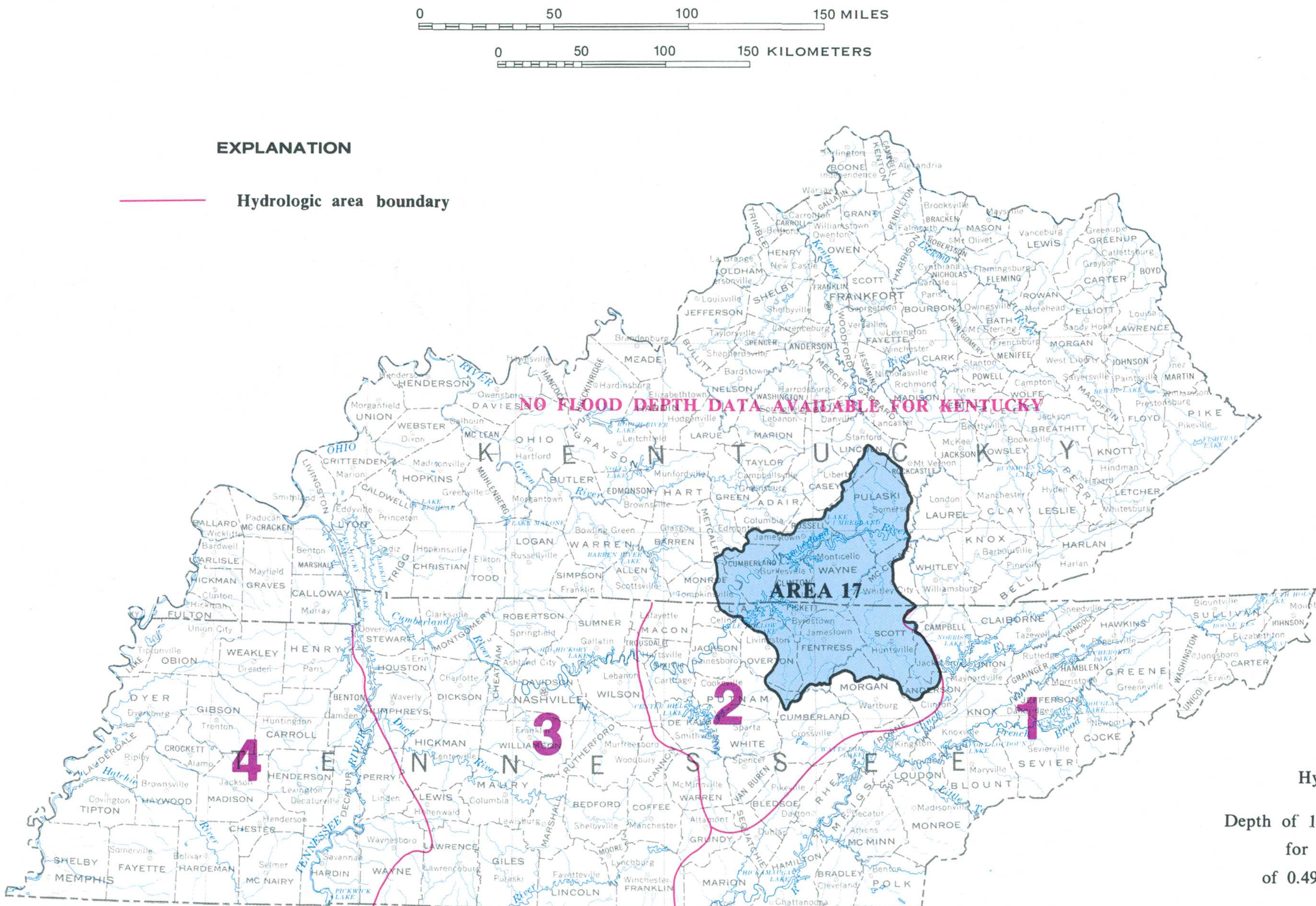
Copies of 7½-minute topographic maps may be purchased from:

(KENTUCKY MAPS)
Kentucky Geological Survey
University of Kentucky
311 Breckenridge Hall
Lexington, KY 40506

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

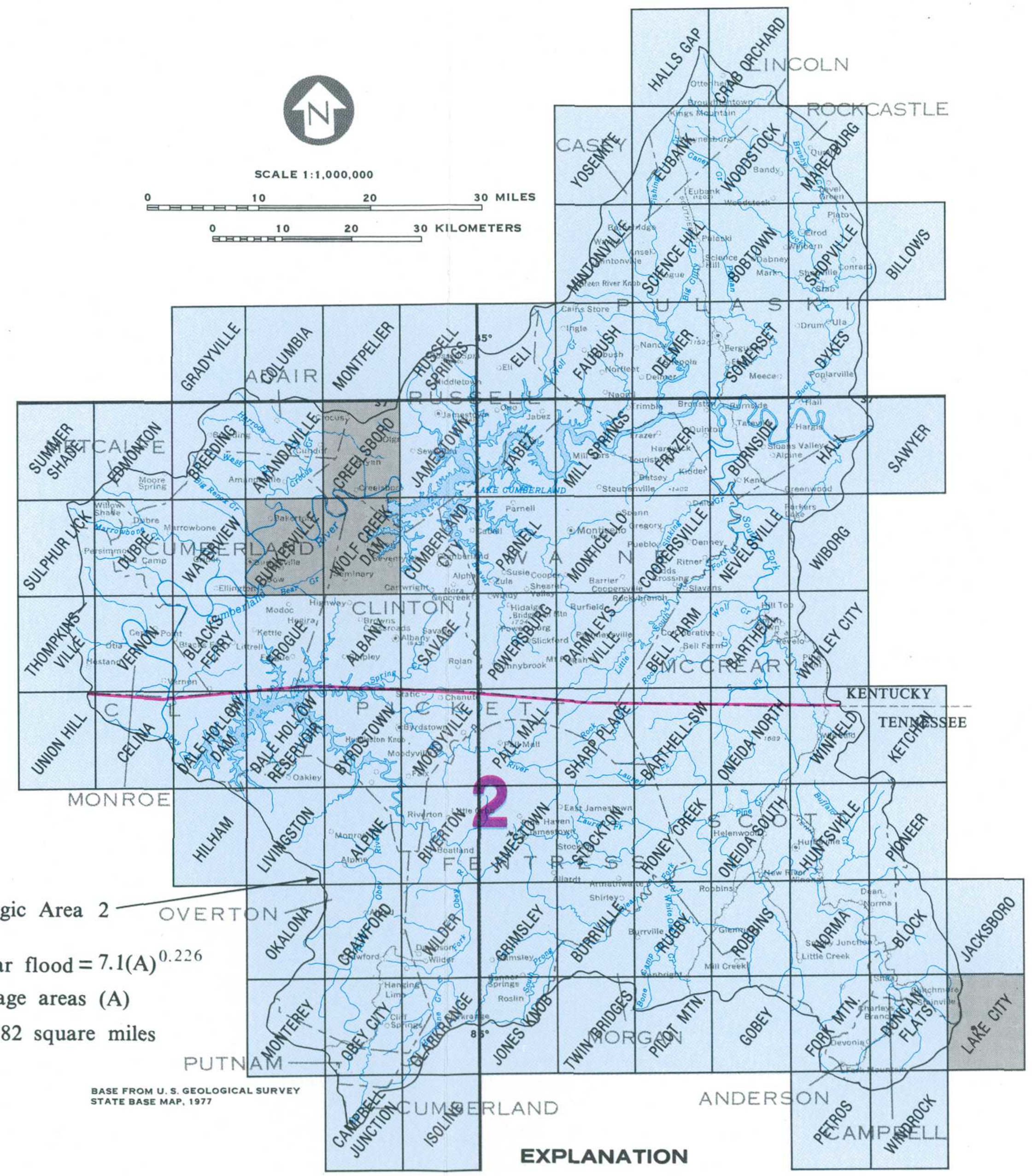
EXPLANATION

Hydrologic area boundary



Flood depth data from C.R. Gamble and J.G. Lewis, 1977

Figure 4.4.2-1 Hydrologic areas for 100-year flood depths in Tennessee



Hydrologic Area 2

Depth of 100-year flood $= 7.1(A)^{0.226}$ for drainage areas (A) of 0.49 to 382 square miles

EXPLANATION

Flood-prone-area map

7½″ topographic map

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

Flow of Some Streams is Poorly Sustained

The low flow of streams in Area 17 varies with the differing water-bearing characteristics of the geologic formations underlying the basins.

The streamflow at a given point represents the surface outflow of the drainage basin upstream. Thus, the streamflow record is an integration of the effects of climate, topography, and geology, and gives a distribution of runoff both in time and in magnitude. Flows can be arranged according to frequency of occurrence and plotted as a flow-duration curve. The resulting curve shows the effect of the various factors affecting streamflow from that basin and provides a convenient means of comparing the flow 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 more uniform flow.

Differences in streamflow at two sites in Area 17 are illustrated by flow-duration curves (fig. 4.5-1). These curves are based on the same period of record and are plotted in unit discharge so that more direct comparison may be made. The streams shown represent basins of differing geologic characteristics (fig. 4.5-2). Flow duration data for Tennessee streams may be found in Gold (1980) and for Kentucky streams may be found in Quinones, Kiesler, and Macy (1980).

The low discharge of Pitman Creek at Somerset, Ky. (site 72) during dry periods is shown by the steep slope of curve. The curve for Wolf River near Byrdstown, Tenn., has a flatter slope on the lower end indicating better yields from the ground-water system of that basin. The upper ends of both curves have similar slopes and are close together indicating that the high-flow runoff per square mile from the two basins is nearly the same.

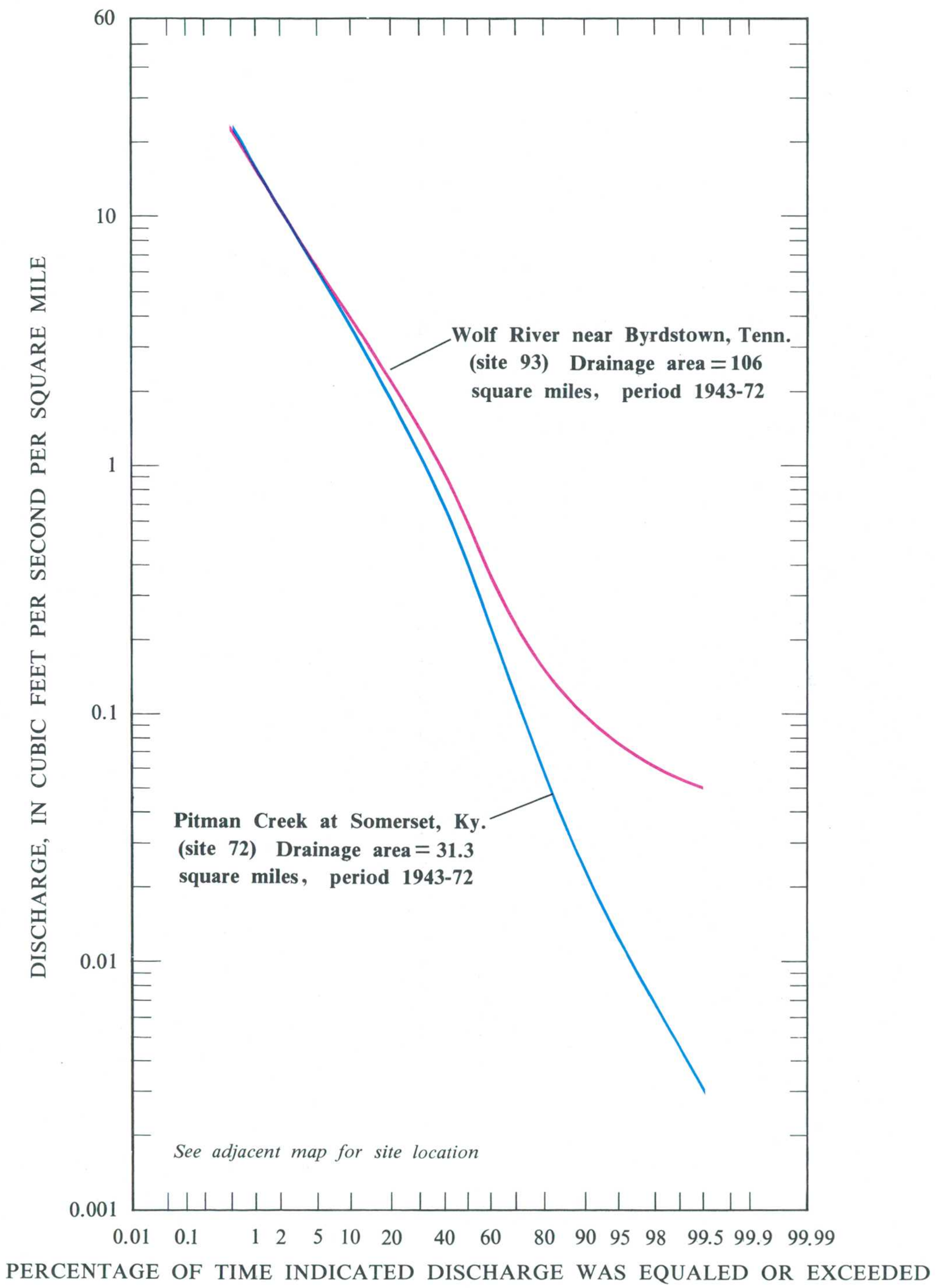


Figure 4.5-1 Selected flow-duration curves

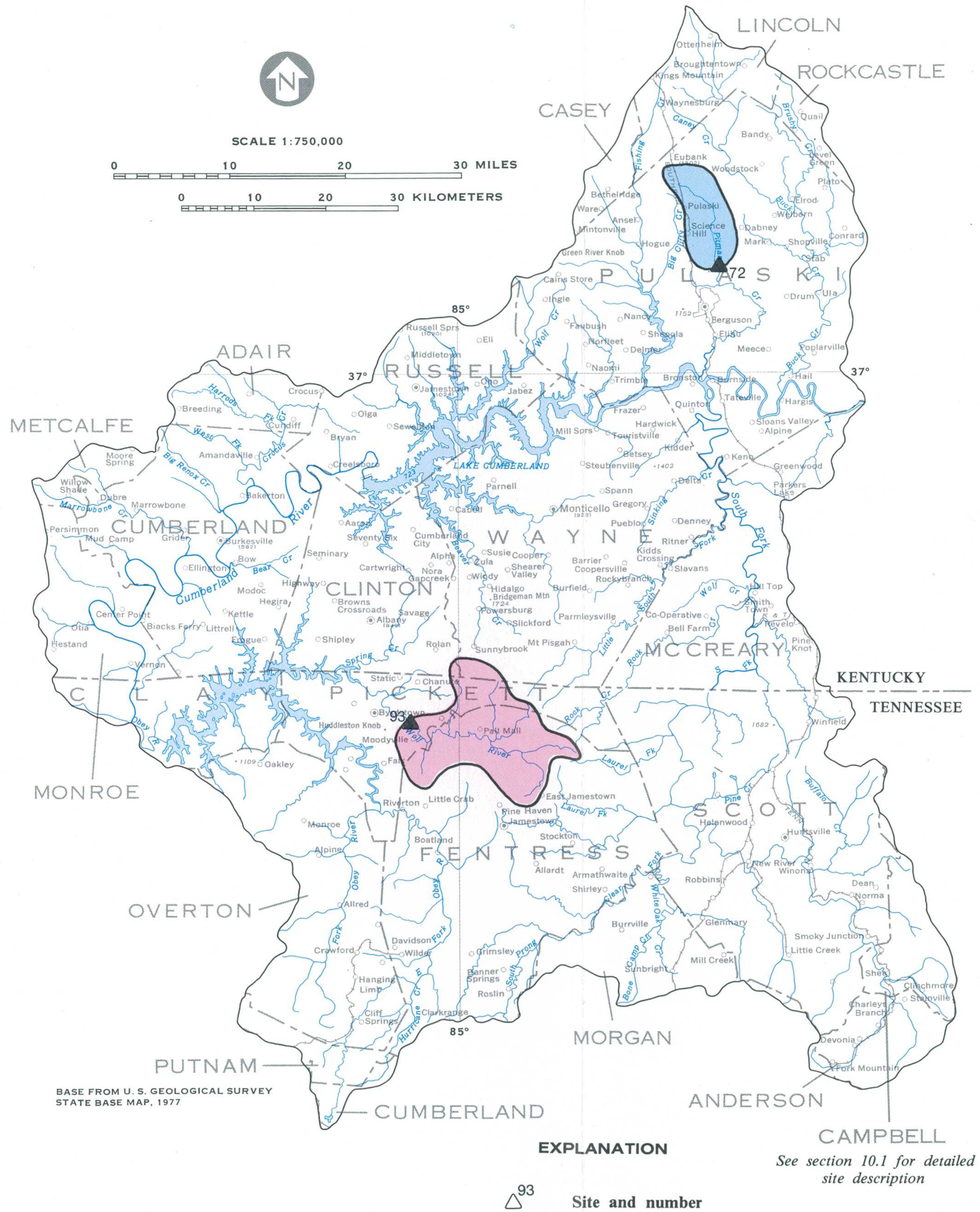


Figure 4.5-2 Basins represented by flow-duration curves

4.0 SURFACE WATER--Continued
4.5 Flow Duration

Hydrologic Effects of Mining Activities Reflected in Water-Quality Data

The hydrologic effects of surface coal-mining activities on the hydrologic environment often can be evaluated by using water-quality data.

Beginning in 1979 in response to the Act, the U.S. Geological Survey established a network of 27 data-collection sites in Area 17. Fourteen other sites for which water-quality data are available were active prior to 1979. The water-quality data collected at the 41 sites (fig. 5.1-1), as well as data previously collected through other programs, are presented in this report. However, the following important points regarding those data must be considered:

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

• Locally severe water-quality problems may exist and not be detected. No mine drainage or seepage was sampled and no sampling of such effluents is planned.

• The water-quality data collected at the 27 sites established in 1979-80 include those parameters specified in the Act. Allowable ranges or maximums in mine effluents are as follows:

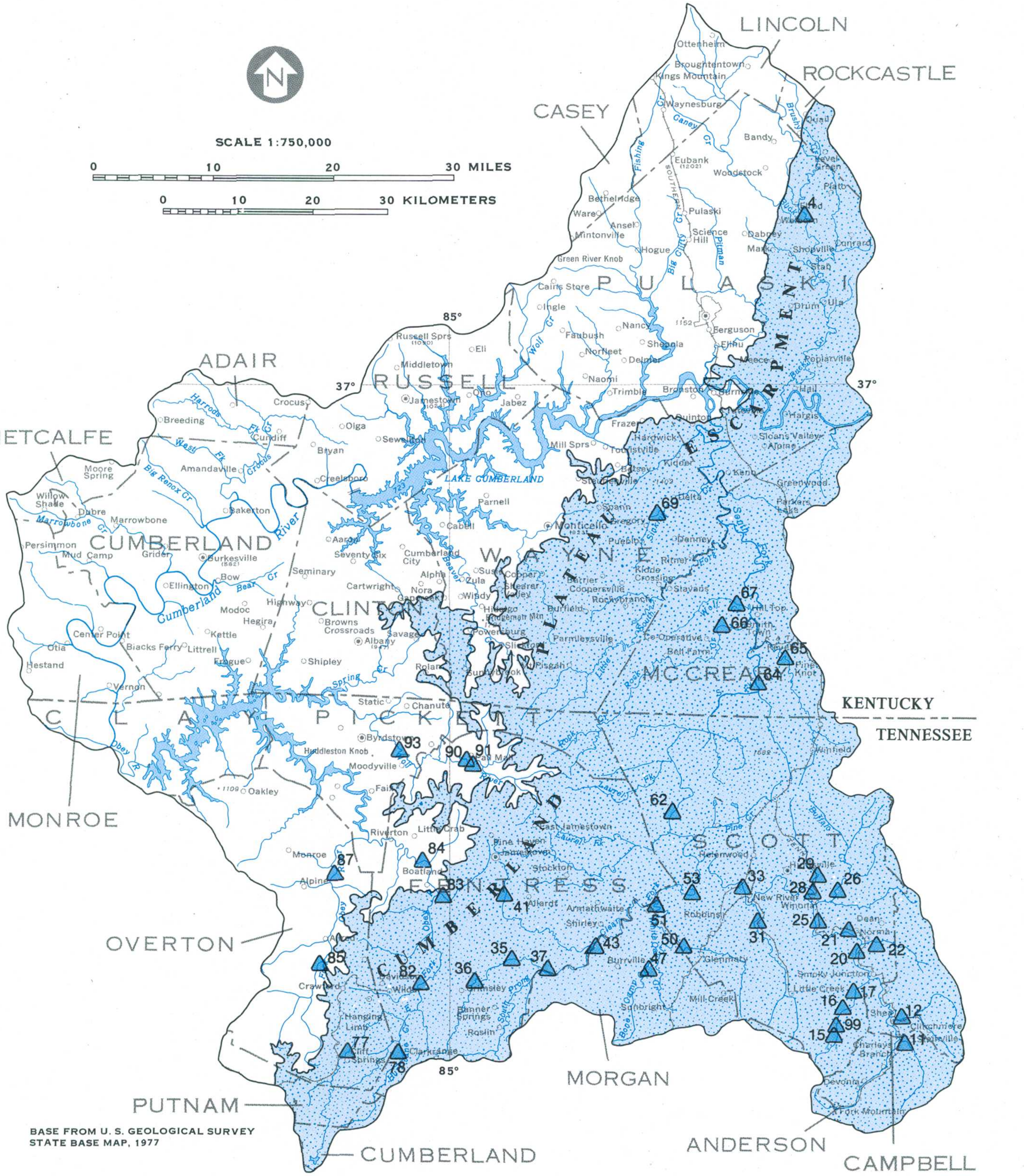
(a) pH range from 6.0 to 9.0 units

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

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

(d) 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 to sample during several streamflow conditions (low, medium, and high flow) was made. Concentrations of selected trace constituents in bottom material from stream channels were determined only at low flow.



EXPLANATION

See section 10.1 for detailed site description

▲64 Site and number

☐ Highland Rim ☐ Cumberland Plateau

Figure 5.1-1 Active sites for which water-quality data are available

Stream Uses Classified by State Agency

Most streams in the Tennessee part of Area 17 have been classified by the Tennessee Water Quality Control Division for use for fish, recreation, irrigation, and livestock and wildlife purposes. Other use classifications pertaining to streams in Tennessee include domestic water supply, industrial water supply, and navigation. Similar information is not available for Kentucky.

Criteria for developing and implementing area-wide water-quality management plans are defined in Section 208 of the Federal Water Pollution Control Act Amendments of 1972 (Public Law 92-500). In compliance with that Act and Amendments, the Tennessee Department of Public Health, Division of Water Quality Control, developed and published a water-quality management plan for Tennessee (1978). The use classifications for most major streams in the State are included in that plan. Also included are the water-quality criteria for each use classification (table 5.2-1). Stream reaches and use classifications are shown in figure 5.2-1. Some of the water-quality criteria probably will be reviewed when the State regulatory agencies develop plans to implement the guidelines in the Surface Mining Control and Reclamation Act. Similar information is not yet available for Kentucky.

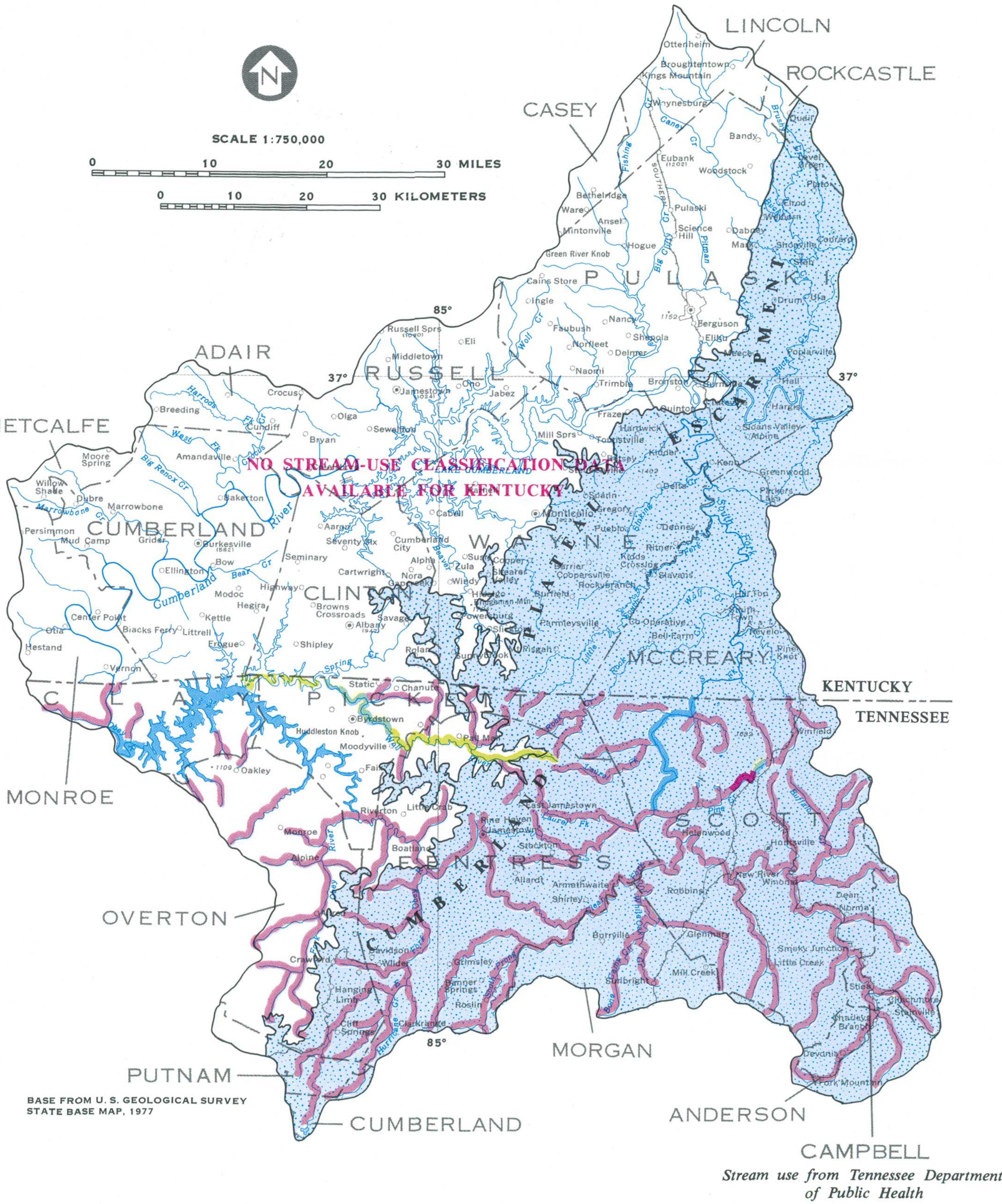
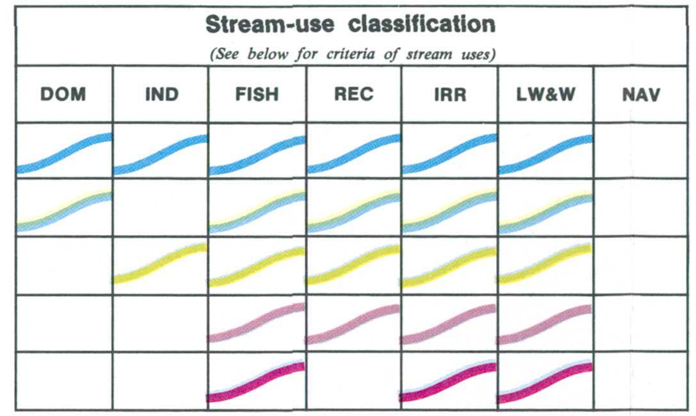


Figure 5.2-1 Stream-use classification.

EXPLANATION



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

Table 5.2-1 Criteria for water conditions

Specific Conductance and Dissolved Solids Are Low Except in Heavily-Mined Areas

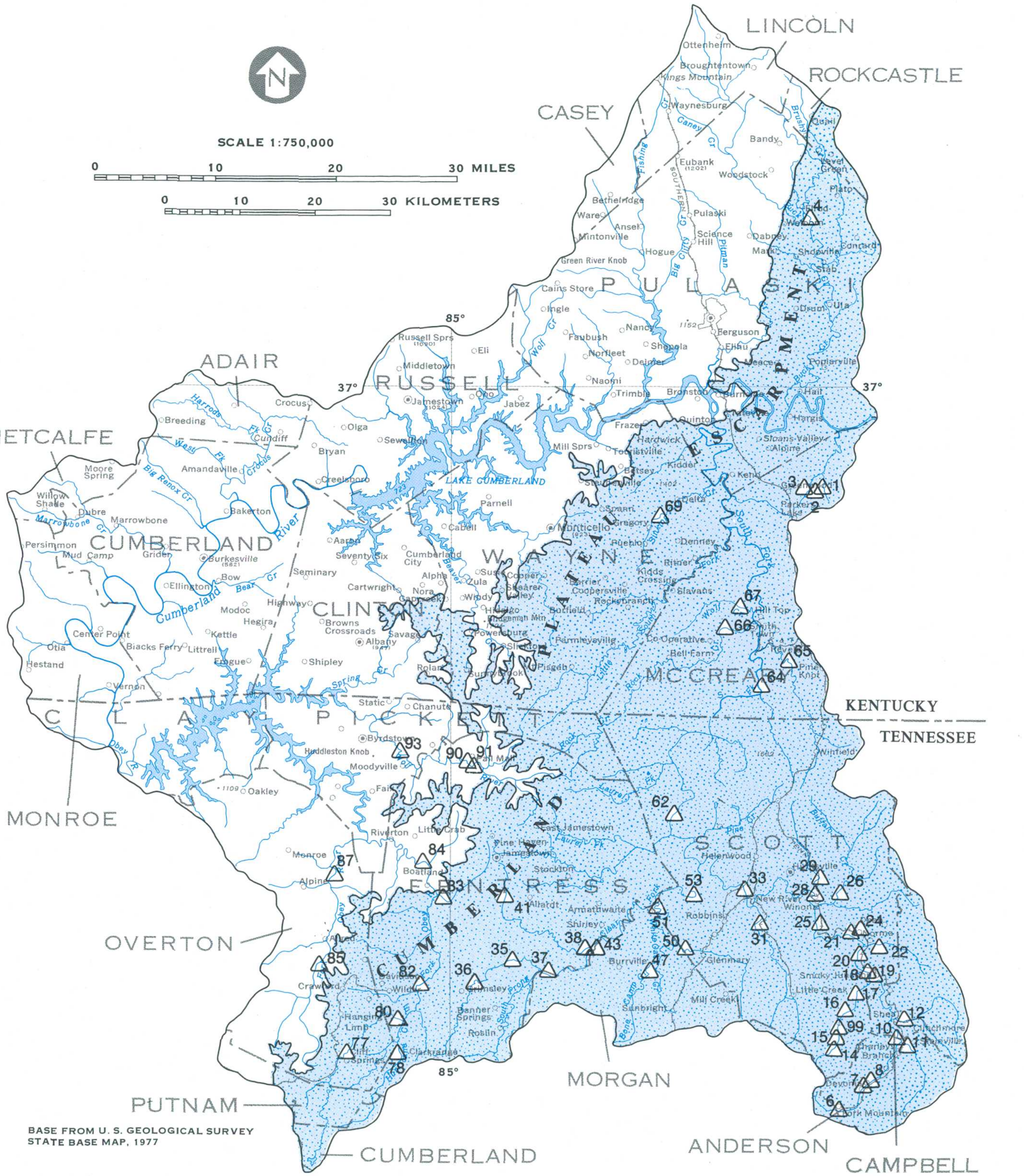
Specific conductance ranged from 10 to 2,400 micromhos in Area 17. Dissolved-solids concentrations (estimated from specific conductance) were generally low.

Specific conductance values are not included in any of the commonly-used water quality criteria, but can be used to estimate dissolved solids and individual constituent concentrations which have specific limits (Hem, 1970). An estimate of the dissolved-solids concentration in water in most streams in Area 17 can be made by multiplying the specific conductance value by 0.6. This factor was determined by a comparison of dissolved-solids and specific conductance data of water from streams in the area. It is typical of calcium or sodium bicarbonate type waters (Hem, 1970). Thus, based on currently available surface-water data, dissolved-solids concentrations are generally less than 250 milligrams per liter (mg/L), low by most criteria. Specific conductance ranged from 10 to 2,400 micromhos per centimeter (μmhos/cm). The maximum specific conductance occurred in East Fork Obey River near Wilder, Tenn. (site 82), a stream severely affected by mine drainage (fig. 5.3-1 and table 5.3-1).

Obviously, not all streams draining areas with coal mines have been affected adversely by mining activities. For example, in Clear Fork specific conductance ranged from 38 to 270 μmhos/cm at the most upstream site (site 35) and 30 to 130 μmhos/cm at the site farthest downstream (site 53) indicating the effect of dilution. The Clear Fork sites will be particularly important in the assessment of the potential impact of mining activities.

In contrast to Clear Fork, water in the Obey River appears to be affected adversely by coal-mine drainage, particularly in the East Fork Obey River. Specific conductance ranged from 53 to 650 μmhos/cm at the most upstream site (site 77) and from 27 to 523 μmhos/cm at the most downstream site on the East Fork (site 87). In the West Fork Obey River, specific conductance ranged from 130 to 450 μmhos/cm.

At sites in the New River, draining a heavily-mined area, specific conductance ranged from 115 to 345 μmhos/cm at the most upstream site (site 6) and from 80 to 530 μmhos/cm at the farthest downstream site (site 33). At intermediate sites, specific conductance ranged from 100 to 860 μmhos/cm showing the impact of mineralized water entering the stream between sites 6 and 11, but also indicating some dilution downstream from site 11. In both the Clear Fork and New River basins, and in most other basins in the area, low specific conductances generally occurred during high flows. However, no statistically significant areawide relation between streamflow and specific conductance has been established.



EXPLANATION

△64 Site and number

Highland Rim

Cumberland Plateau

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

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

Site number	Minimum	Maximum	Number of determinations	Site number	Minimum	Maximum	Number of determinations
New River sites							
6	115	345	15	24	240	260	2
11	215	860	19	25	100	615	58
19	253	270	2	33	80	530	79
Clear Fork sites							
35	38	270	4	43	37	55	4
37	37	155	4	53	30	130	43
38	24	-	1				
East Fork Obey River sites				West Fork Obey River sites			
77	53	650	10	85	130	280	14
80	130	-	1	87	130	450	19
82	90	2,400	5				
84	27	523	35				
Other sites							
1	84	1,580	432	31	90	285	7
2	18	34	26	36	10	126	28
3	18	239	130	41	60	385	33
4	105	200	8	47	20	48	5
7	490	885	2	50	96	240	4
8	340	420	2	51	44	580	16
10	300	320	2	62	95	195	4
12	150	300	6	64	75	280	14
14	260	315	2	65	75	195	4
15	80	215	26	66	110	770	4
16	105	350	54	67	60	150	2
17	16	95	14	69	280	-	1
18	80	245	18	78	20	53	5
20	38	360	11	83	96	214	4
21	15	65	13	90	68	200	5
22	205	324	5	91	95	250	5
26	59	180	5	93	142	375	49
28	125	375	2	99	75	135	2
29	85	250	8				

Dissolved Sulfate Concentrations Generally High

Water at more than half of the sites in Area 17 had maximum dissolved sulfate concentrations of at least 50 milligrams per liter.

Dissolved sulfate concentrations ranged from 0.2 to 1,250 mg/L in water from streams in Area 17 (table 5.4-1). High concentrations often occur in streams adversely affected by acid-mine drainage due to the weathering of sulfur minerals in coal-mine spoil piles. To some extent, the chemical composition of the spoil piles determines the magnitude of the effect. Concentrations of 1,200 mg/L (site 82) and 1,250 mg/L (site 7) were determined in two streams in heavily-mined areas. Water at more than 50 percent of the sites in Area 17 had maximum dissolved sulfate concentrations of at least 50 mg/L.

An example of the effect of mining activity is illustrated by comparing data from two sites. Anderson Branch near Montgomery, Tenn. (site 20), in an area mined since 1976, is geographically close to Lowe Branch near Montgomery, Tenn. (site 21), in an area only recently mined. Anderson Branch drains 0.69 mi^2 and Lowe Branch drains 0.92 mi^2. Since coal-mining activity upstream from Anderson Branch (site 20) was begun, the range in dissolved sulfate concentrations has increased (fig. 5.4-1). Prior to the mining activity, Lowe Branch water had higher dissolved sulfate concentrations than Anderson Branch. But since the mining activity began in 1976, dissolved sulfate concentrations in water in Anderson Branch have increased significantly.

Dissolved sulfate concentrations in water at the New River sites varied somewhat (table 5.4-1). At the upstream site (site 6), the concentrations ranged from 25 to 77 mg/L, while at the site farthest downstream (site 33), concentrations ranged from 23 to 208 mg/L,indicating a general increase in dissolved sulfate concentrations caused by mining activities. A few higher concentrations occurred in water at sites 11 and 25.

Although coal mines are in the drainage basin of North Prong Clear Fork, dissolved sulfate concentrations in the water at the different Clear Fork sites were generally lower than in other streams draining heavily-mined areas. At the uppermost site (site 35), concentrations ranged from 5.4 to 18 mg/L, and at the site farthest downstream (site 53) concentrations ranged from 5.4 to 26 mg/L.

Considerably higher dissolved sulfate concentrations have occurred in the water at the Obey River sites. In general, the East Fork Obey River sites had higher concentrations than the West Fork Obey River sites. At the site farthest upstream (site 77), concentrations ranged from 13 to 190 mg/L, but at the site farthest downstream (site 84), concentrations ranged from 20 to 267 mg/L. This indicates the effects of mining activities. Dissolved sulfate concentrations in the West Fork Obey River ranged from 8.0 to 130 mg/L. The highest concentration occurring in any of the Obey River sites was 1,200 mg/L in water in East Fork Obey River near Wilder, Tenn. (site 82).

Dissolved sulfate concentrations in most Area 17 streams were higher during low flow. However, except in heavily-mined areas, differences caused by flow were generally small. An estimate of dissolved sulfate concentrations frequently can be obtained using specific conductance data. In Area 17, a statistically significant relation between sulfate and conductance has been established (fig. 5.4-2).

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

Site number	Minimum	Maximum	Number of determinations
New River sites			
6	25	77	15
11	76	360	19
19	88	94	2
24	88	90	2
25	30	230	31
33	23	208	49
Clear Fork sites			
35	5.4	18	4
37	5.2	11	4
38	4.4	-	1
43	4.1	9.6	4
53	5.4	26	25
East Fork Obey River sites			
77	13	190	7
80	14	-	1
82	31	1,200	5
84	20	267	20
West Fork Obey River sites			
85	8.0	38	6
87	14	130	20

Site number	Minimum	Maximum	Number of determinations
Other sites			
1	21	696	405
2	4.0	13	26
3	.2	60	131
7	88	1,250	140
8	140	230	2
10	90	120	2
12	46	81	6
14	45	285	137
15	5.0	84	138
16	47	120	10
17	2.0	37	125
18	24	85	15
20	2.0	33	121
21	2.0	22	125
22	83	120	5
26	13	43	5
28	190	-	1
29	17	54	8
31	27	82	7
36	4.6	28	8
41	16	170	8
47	3.3	6.2	5
50	26	54	4
51	6.2	35	16
62	27	58	4
64	22	91	14
65	18	41	4
66	38	340	4
67	16	43	2
69	26	-	1
78	3.6	18	5
83	12	33	4
90	5.8	9.5	5
91	5.5	10	5
93	11	50	20
99	29	41	2

See section 3.1 for site locations

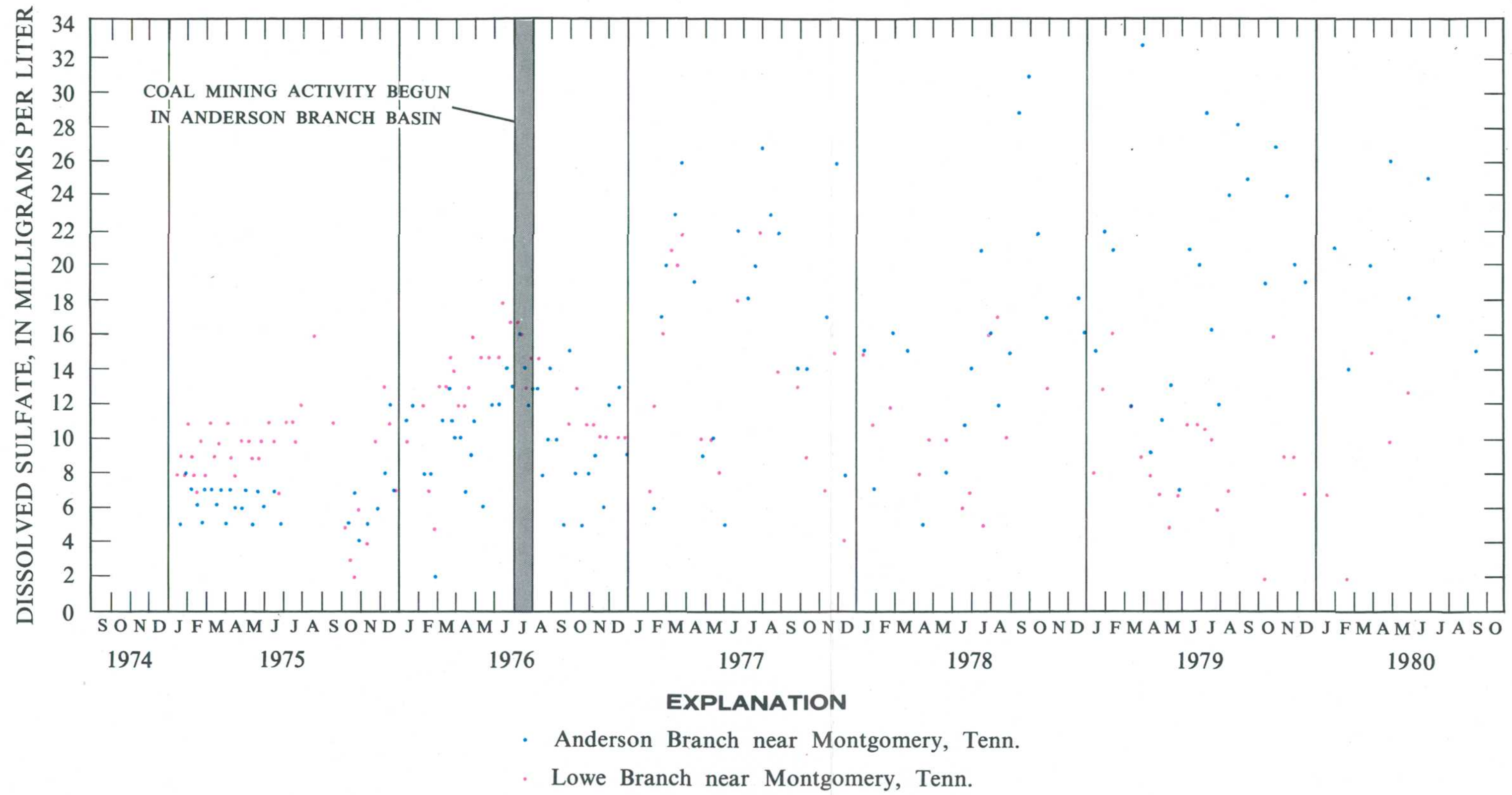


Figure 5.4-1 Range of dissolved sulfate concentration in Anderson Branch and Lowe Branch near Montgomery, Tenn.

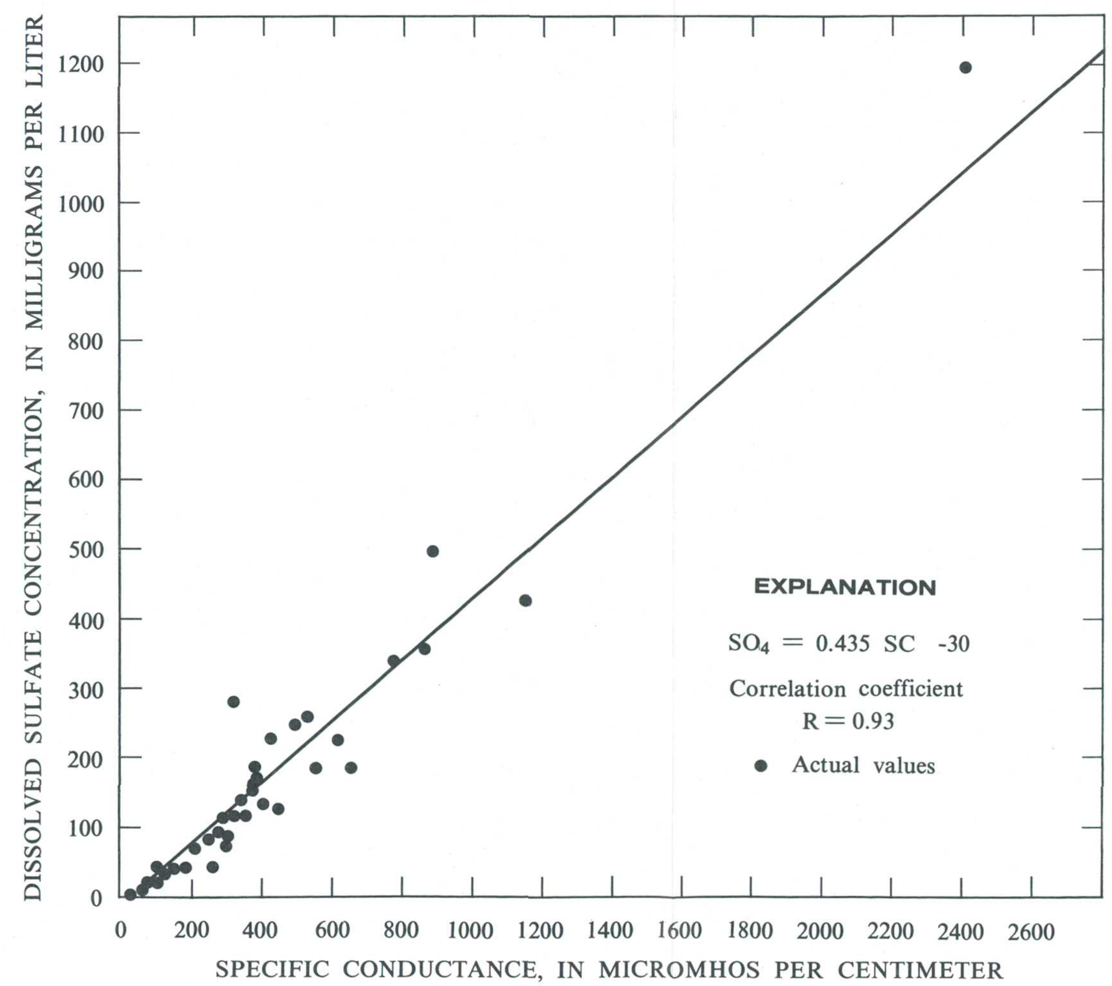


Figure 5.4-2 Relation between dissolved sulfate concentration and specific conductance in water in streams

pH of Streamflow Usually in Near-Neutral Range

Acid-mine drainage is not a widespread problem in Area 17. The pH is usually in the near-neutral range (6.0-8.0 units).

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

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

Although the pH of water in Area 17 streams ranged from 2.7 to 8.6 units, the pH in most streams was between 6.0 and 8.0 units (fig. 5.5-1 and table 5.5-1). The lowest pH (2.7 units) occurred in water in the East Fork Obey River near Wilder, Tenn. (site 82) and Cane Branch near Parkers Lake, Ky. (site 1). These streams drain heavily mined areas. Water at some sites throughout Area 17 near coal mines is unaffected by acid-mine drainage. These sites are important in the assessment of the potential impact of mining activities.

Although New River and Clear Fork drain heavily-mined areas, most pH values at the various sites were in the near-neutral range (6.0 to 8.0 units) indicating that acid-mine drainage generally was neutralized. The pH of the water in New River varied little, ranging from 5.4 to 8.2 units at the site farthest upstream (site 6) and from 5.6 to 7.9 units at the site farthest downstream (site 33). Only one value at a New River site, 8.5 units at site 11, exceeded these ranges. The pH of the water in Clear Fork also varied little. The pH of the water ranged from 6.2 to 7.0 units at the uppermost site on Clear Fork (site 35) and ranged from 5.2 to 7.6 units at the site farthest downstream (site 53).

The pH of the water in the East Fork Obey River is indicative of acid-mine drainage. The pH ranged from 3.1 to 4.4 units at site 77 and ranged from 4.9 to 8.3 units at site 84. The site 84 values show the effects of neutralization of the acid-mine drainage entering the upstream part of the basin. In the West Fork Obey River, pH ranged from 7.1 to 8.4.

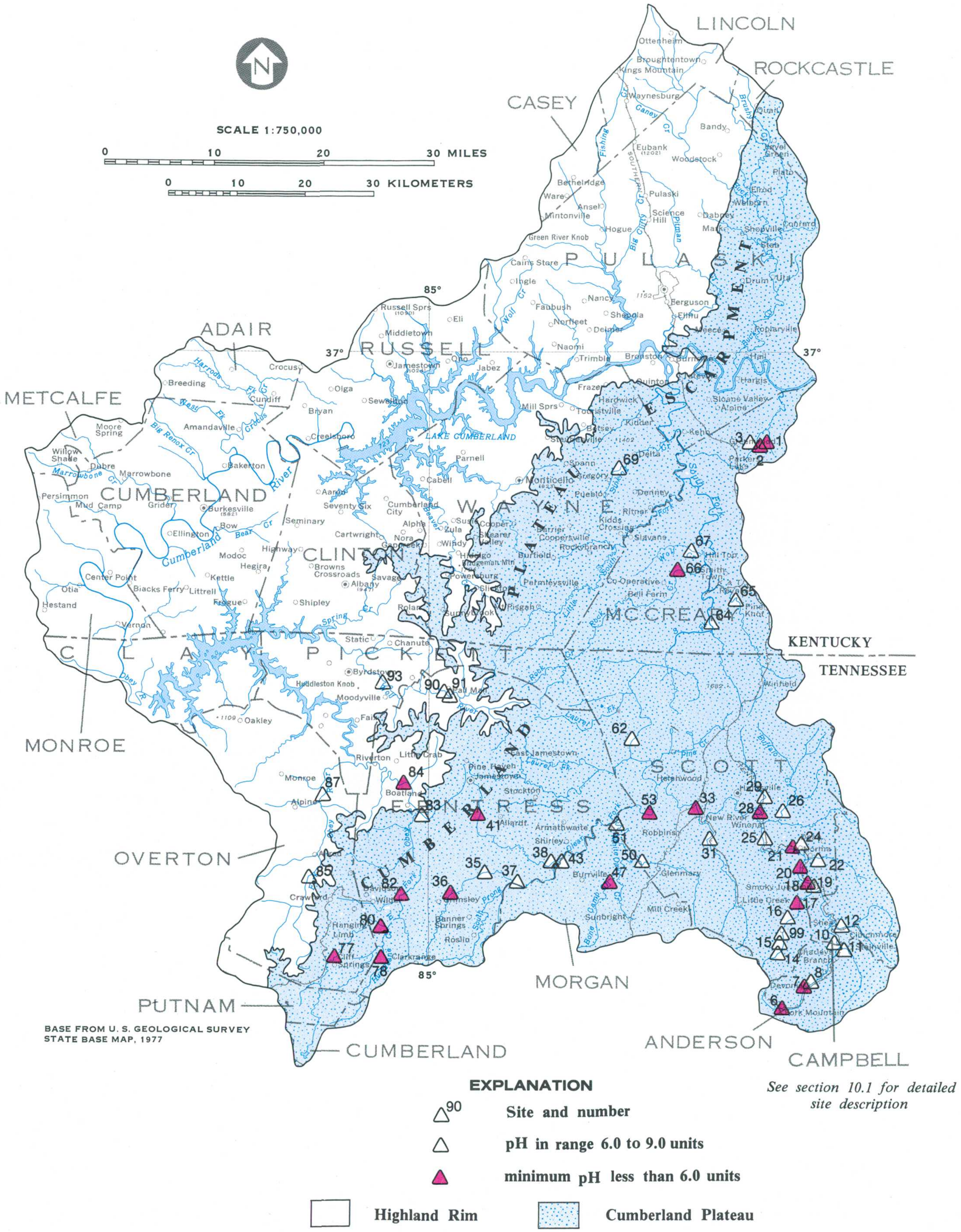


Figure 5.5-1 Sites for which pH data are available

Table 5.5-1 Range of pH, in standard units

Site number	Minimum	Maximum	Number of determinations	Site number	Minimum	Maximum	Number of determinations
		New River sites					
6	5.4	8.2	14	24	7.1	8.0	2
11	6.8	8.5	18	25	6.3	8.2	32
19	7.2	8.0	2	33	5.6	7.9	53
		Clear Fork sites					
35	6.2	7.0	4	43	6.2	7.3	4
37	6.5	7.2	4	53	5.2	7.6	25
38	6.9	-	1				
East Fork Obey River sites				West Fork Obey River sites			
77	3.1	4.4	8	85	7.2	8.2	9
80	7.9	-	1	87	7.1	8.4	19
82	2.7	4.4	5				
84	4.9	8.3	20				
		Other sites					
1	2.7	4.4	400	31	6.8	7.7	7
2	5.2	7.6	26	36	4.5	6.5	8
3	6.0	8.5	123	41	5.1	7.9	8
7	5.2	8.0	137	47	5.7	7.5	4
8	6.8	7.7	2	50	6.4	7.3	4
10	7.5	8.4	2	51	6.3	7.7	16
12	6.9	8.0	6	62	6.7	7.7	4
14	6.4	8.0	135	64	6.7	7.6	14
15	6.0	7.6	135	65	7.0	7.6	4
16	6.7	7.8	11	66	3.4	6.6	4
17	4.8	7.6	122	67	6.7	6.8	2
18	5.3	8.4	14	69	8.0	-	1
20	4.7	8.0	121	78	5.5	7.8	5
21	5.1	7.6	113	83	7.4	7.8	4
22	6.6	7.8	5	90	7.6	8.6	5
26	6.8	7.4	5	91	7.7	8.4	5
28	4.8	6.5	2	93	7.6	8.6	23
29	7.2	8.2	8	99	6.8	7.1	2

Iron Concentrations Indicate Impacts of Mining

The maximum concentrations of total recoverable iron in some streams were higher than the mandatory limits specified for effluents from mining areas.

Iron in excessive concentrations can limit severely the use of water for public supply, domestic, and recreational purposes. Consequently, most water-supply criteria contain recommended maximum limits for dissolved iron; the recommended maximum concentration of iron in drinking water is 300 μg/L (U.S. Environmental Protection Agency, 1976). The Act specifies 7,000 μg/L as the maximum allowable concentrations of total iron in effluents from mining operations. Total recoverable (dissolved plus suspended) concentrations of iron in water have been determined at 50 sites in Area 17 (fig. 5.6-1).

Total recoverable iron concentrations in water in streams in the area ranged from 0 to 83,000 μg/L (table 5.6-1). The maximum concentration occurred in New River near New River, Tenn. (site 33) in an area severely affected by mining activities. At 14 other sites in Area 17, about 30 percent of the sites in the area, total recoverable iron concentrations exceeded 7,000 μg/L at least once. This is an example of the impact of mining on the quality of water in streams.

Dissolved iron is only a small part of the total recoverable iron transported by most streams in Area 17. Concentrations generally were less than 200 μg/L except in the most seriously affected streams. Although dissolved iron concentrations ranged from 0 to 77,000 μg/L, the maximum occuring at site 82, only 100 of approximately 1,100 determinations exceeded 300 μg/L. Forty of the one hundred values occurred at Indian Fork above Braytown, Tenn. (site 7), indicating another area seriously affected by mining activities. Sixteen of the values exceeding 300 μg/L occurred at Cane Branch near Parkers Lake, Ky. (site 1). Dissolved iron did not vary significantly with large changes in streamflow. Although pH is an important factor affecting iron solubility, no statistically significant relation between pH and dissolved iron has been established areawide.

The maximum total recoverable iron in water from most streams occurred during high flows because large amounts of suspended iron were transported with suspended sediment. The increase in iron load correlates significantly with increase in suspended-sediment concentrations (section 5.9). Because of this relation and because most of the suspended sediment in a particular stream is transported during storms, suspended-sediment and total recoverable iron yields can be defined only with data obtained by comprehensive sampling.

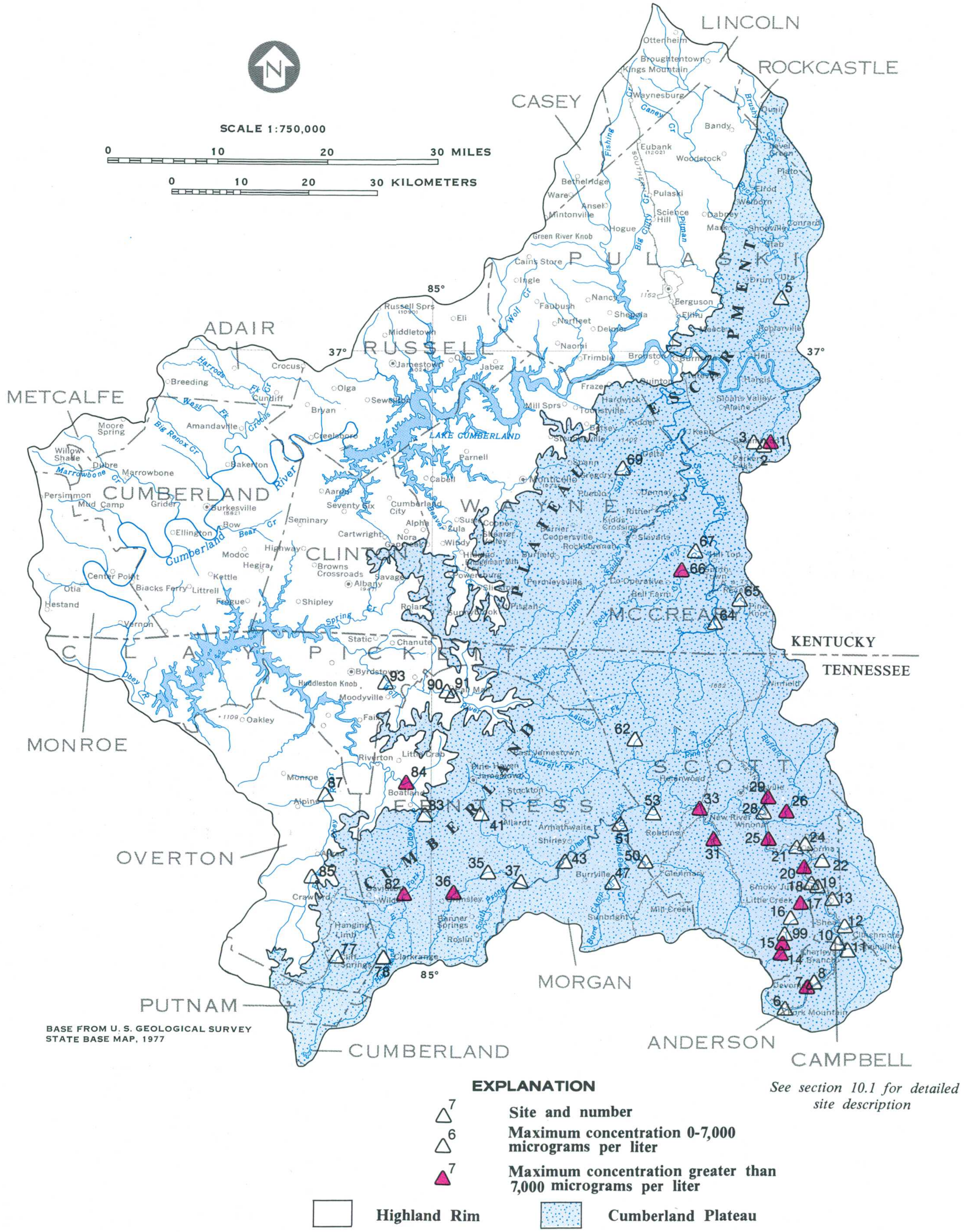


Figure 5.6-1 Sites for which total recoverable iron data are available

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

Site no.	Minimum	Maximum	Median	No. of determinations	Site no.	Minimum	Maximum	Median	No. of determinations
New River sites									
6	30	1,000	160	15	24	350	470	--	2
11	320	1,800	770	19	25	190	36,000	620	33
19	370	940	--	2	33	170	83,000	780	38
Clear Fork sites									
35	240	860	420	4	43	180	4,000	300	5
37	170	3,200	760	5	53	150	4,900	310	28
East Fork Obey River sites					**West Fork Obey River sites**				
77	740	3,700	3,500	8	85	150	3,900	360	7
82	3,400	28,000	7,600	5	87	60	5,600	310	21
84	110	8,600	730	21					
Other sites									
1	140	24,000	5,900	33	36	210	10,000	450	10
2	10	340	110	12	41	500	1,300	970	12
3	40	550	100	15	47	140	480	290	7
7	600	54,000	6,200	147	50	370	1,900	610	5
10	180	580	--	2	51	180	1,100	360	19
12	60	1,400	250	6	62	370	1,100	630	4
14	0	65,000	580	149	64	140	1,800	480	17
15	0	80,000	510	152	65	480	1,300	750	5
16	180	5,900	490	13	66	410	11,000	2,700	5
17	11	41,000	760	135	67	390	560	470	3
18	200	3,800	490	15	69	1,000	2,800	--	2
20	50	41,000	840	132	78	150	3,200	500	6
21	0	1,000	180	120	83	160	2,200	940	4
22	190	4,900	870	5	90	230	5,200	580	5
26	680	10,000	1,100	5	91	120	3,900	470	6
28	390	--	--	1	93	120	1,500	310	21
29	440	24,000	720	9	99	360	850	--	2
31	690	18,000	1,100	6					

Manganese Concentrations Higher in Mined Areas

The concentrations of total recoverable manganese in water in most streams were less than the mandatory limits specified for effluents from mining areas. However, concentrations were higher in streams draining mined areas.

Excessive concentrations of manganese can limit severely the use of water for public supply, domestic, and recreational purposes. As a result, most water-supply criteria contain recommended maximum limits for dissolved manganese; the recommended maximum limit for drinking water is 50 μg/L (U.S. Environmental Protection Agency, 1976). As specified in the Act, the maximum allowable concentrations of total manganese in effluents from mined areas is 4,000 μg/L. Total recoverable (dissolved plus suspended) concentrations of manganese in water from 49 sites in Area 17 have been determined, about half since 1979 (fig. 5.7-1).

Generally, higher concentrations of total recoverable manganese occurred during high flows because large amounts of suspended manganese were transported with suspended sediment (section 5.9). The total recoverable manganese concentrations in water in streams in the area ranged from 0 to 21,000 μg/L, the maximum occurring in Cane Branch near Parkers Lake, Ky. (site 1). The limit established for mine effluents was also exceeded at Buffalo Creek near Winona, Tenn. (site 26) and at Crooked Creek near Allardt, Tenn. (site 41). At most other sites, maximum concentrations were less than 500 μg/L, although maximum concentrations exceeded 1,000 μg/L at 12 sites (table 5.7-1).

Most total recoverable manganese concentrations at sites on New River and Clear Fork, streams draining heavily-mined areas, were less than 300 μg/L. The maximum concentration occurred at the most downstream New River site (site 33). The differences between site 35 and site 53 on Clear Fork are not significant (table 5.7-1). In contrast, the East Fork Obey River sites illustrate the impact of mining activities in that drainage area. Total recoverable manganese concentrations at those sites are significantly higher than at sites on the West Fork Obey River.

Most dissolved manganese concentrations in Area 17 streams were less than 300 μg/L. However, maximum concentrations at 75 percent of the sites exceeded 50 μg/L. Although pH is an important factor affecting manganese solubility, no statistically significant relation between pH and dissolved manganese has been established areawide.

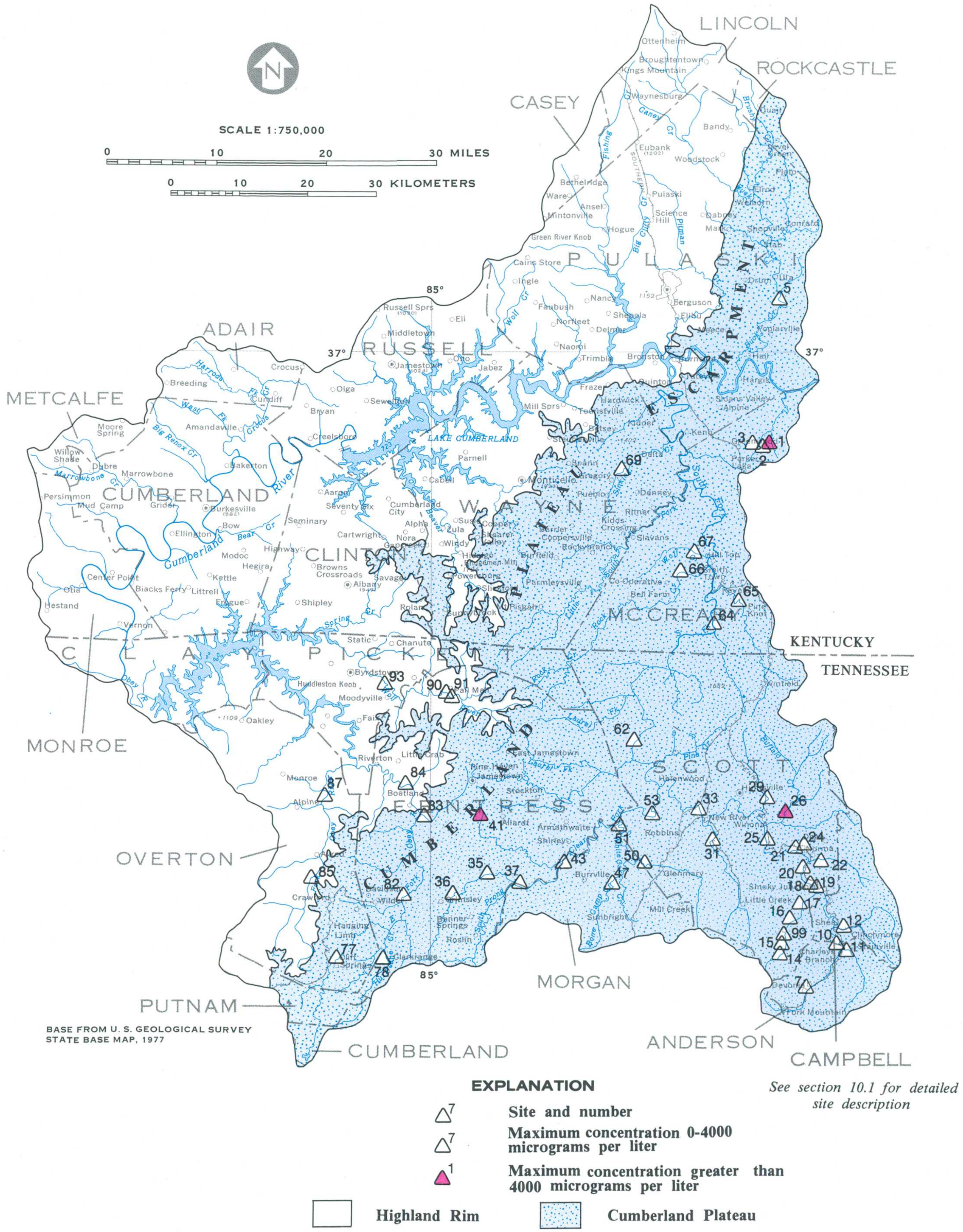


Figure 5.7-1 Sites for which total recoverable manganese data are available

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

Site no.	Minimum	Maximum	Median	No. of determinations	Site no.	Minimum	Maximum	Median	No. of determinations
New River sites									
5	0	70	10	15	24	150	160	--	2
11	30	260	200	17	25	50	610	150	32
19	110	120	--	2	33	30	1,600	260	36
Clear Fork sites									
35	20	130	60	4	43	20	360	30	5
37	20	390	110	5	53	10	220	40	28
East Fork Obey River sites					West Fork Obey River sites				
77	110	2,100	230	8	85	20	210	60	6
82	310	3,600	710	5	87	10	340	50	19
84	20	1,300	310	22					
Other sites									
1	1,000	21,000	7,500	86	36	60	3,600	110	9
2	0	140	70	12	41	220	6,500	520	11
3	0	960	30	25	47	10	40	20	7
7	50	3,700	800	151	50	120	410	250	5
10	30	50	--	2	51	30	190	80	19
12	20	50	40	6	62	70	120	80	4
14	0	2,500	250	149	64	80	250	130	16
15	0	1,800	50	151	65	110	260	180	5
16	20	120	30	13	66	140	2,600	840	5
17	0	1,000	20	111	67	60	340	70	3
18	40	200	60	15	69	110	170	--	2
20	0	780	60	127	78	20	260	50	6
21	0	150	0	106	83	10	190	80	4
22	370	1,000	520	4	90	20	340	40	5
26	680	10,000	1,100	5	91	20	240	40	6
29	60	730	160	9	93	0	110	40	20
31	170	860	350	7	99	80	180	--	2

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

Low concentrations of trace constituents were found in water in streams and in bottom material in stream channels in Area 17. No areawide potentially serious problems were detected.

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

Selected trace constituents in water have been determined at 34 sites in Area 17 (fig. 5.8-1 and table 5.8-1). In addition, concentrations of several constituents in bottom material from stream channels have been determined at 30 sites since 1979 (fig. 5.8-2 and table 5.8-2). No widespread occurrence of any of the constituents in potentially troublesome quantities was evident either in water or in bottom material.

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

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

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

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

- Although total selenium and total recoverable cadmium, chromium, and lead concentrations in water have exceeded recommended criteria at sites in Area 17, there is no indication of a chronic trace-constituent problem at any site.

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

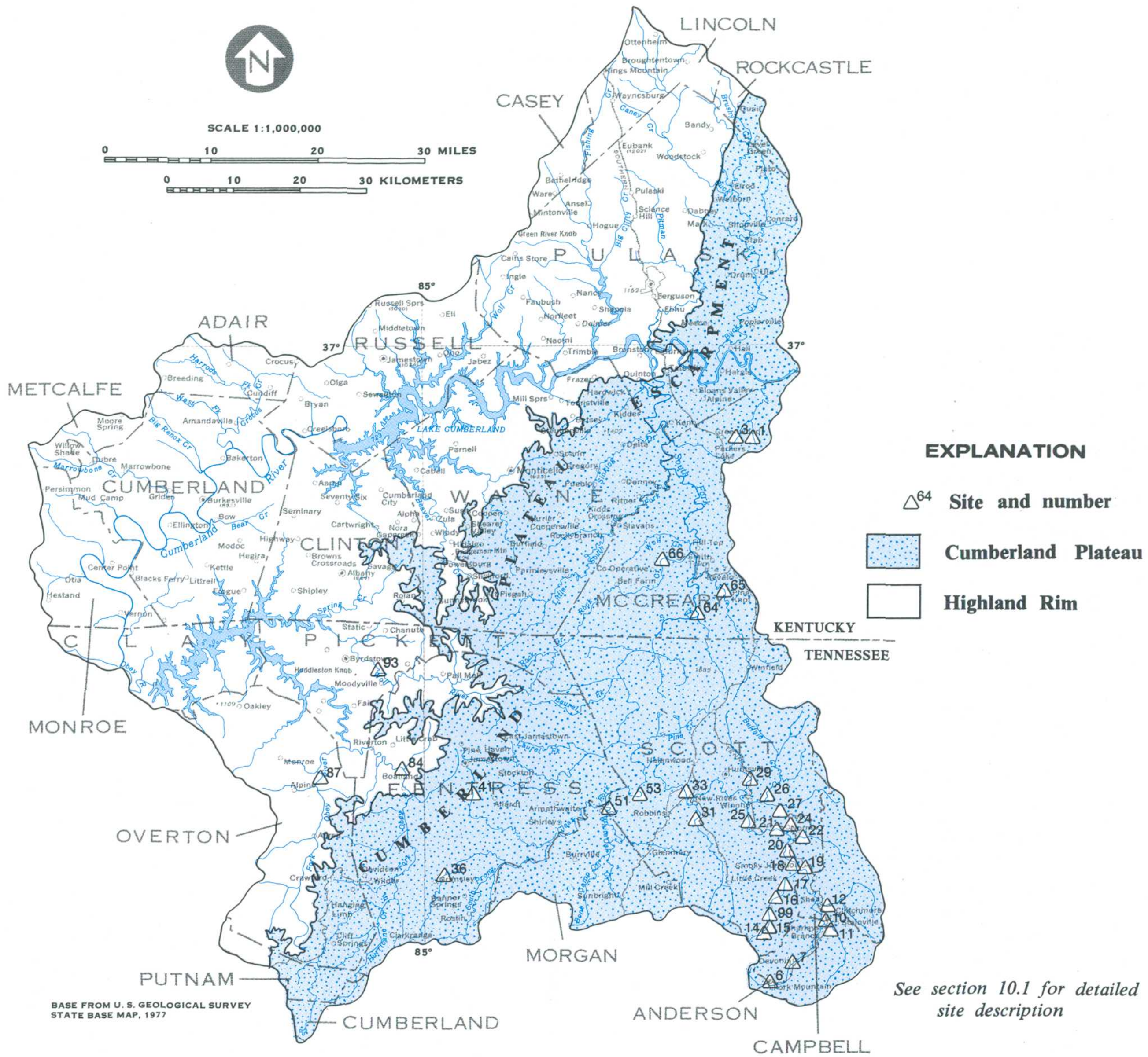
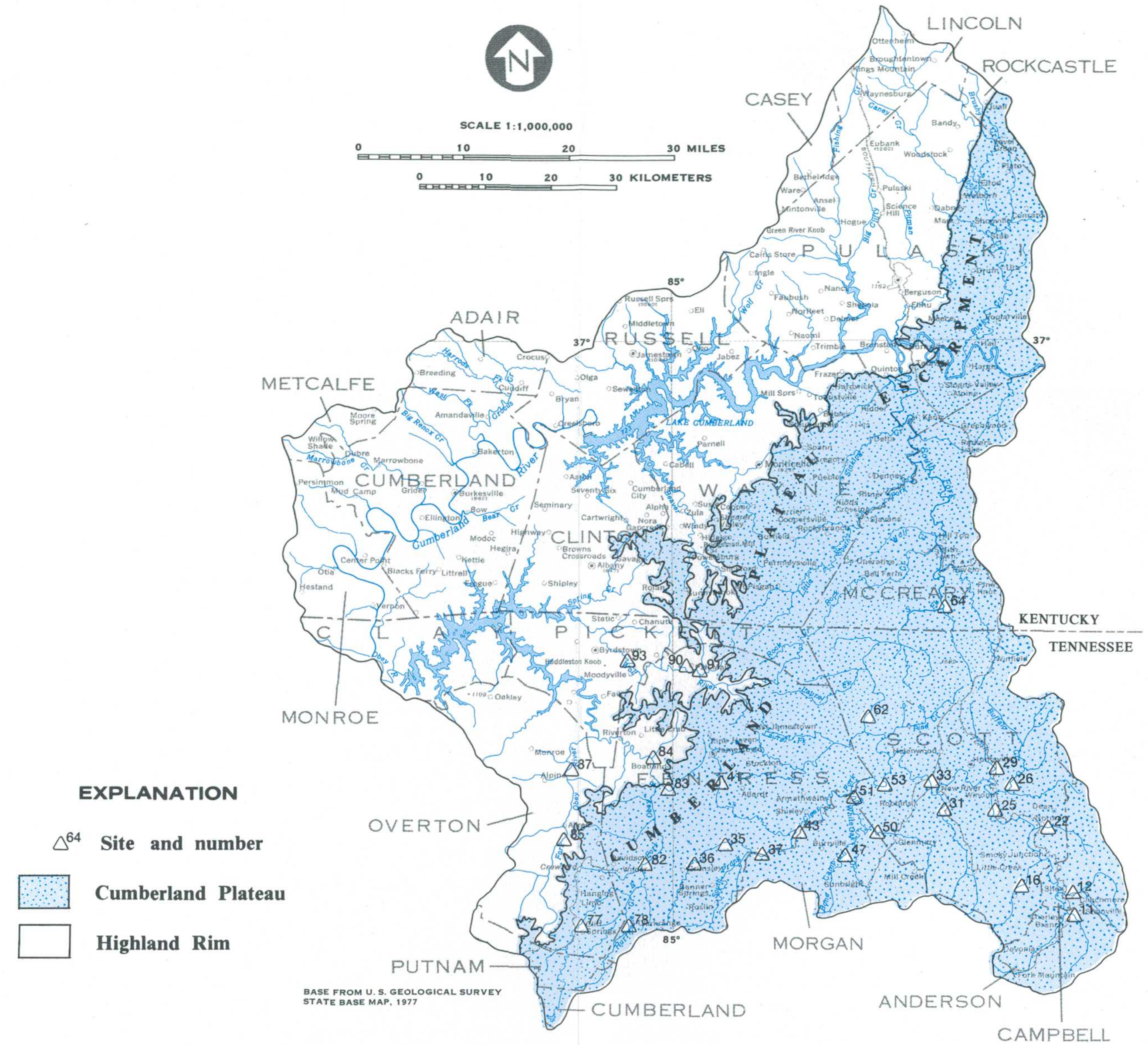


Figure 5.8-1 Sites for which dissolved trace constituent data are available

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

Constituent	Minimum	Maximum	Median	Number of determinations
Arsenic	0	25	0	444
Cadmium	0	50	0	820
Chromium	0	160	1	453
Copper	0	335	2	778
Lead	0	282	0	748
Mercury	0	.5	.1	64
Selenium	0	26	0	62
Zinc	0	900	1	726

Note: Arsenic and selenium values are total concentrations.



See section 10.1 for detailed site description

Figure 5.8-2 Sites for which data for trace constituents recoverable from bottom material are available

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

Constituent	Minimum	Maximum	Median	Number of determinations
Arsenic	0	2	0	56
Cadmium	10	10	10	56
Chromium	10	60	10	56
Copper	10	60	10	56
Lead	10	170	10	56
Mercury	0.0	.02	0.0	55
Selenium	0	0	0	55
Zinc	5	610	40	55

Note: Arsenic and selenium values are total concentrations.

Suspended-Sediment and Sediment-Associated Pollutant Yields High in Strip-Mined Basins in Area 17

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

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

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

Suspended-sediment data were collected at 48 sites in Area 17. As determined by representative land use, physiography, and amount of available data, several sites were selected for detailed analysis. The New River basin, located near the eastern boundary of the Cumberland Plateau, is highly dissected and extensively mined. Parameters from site 33 in this basin were compared to those from site 53 in the adjacent Clear Fork watershed which is characterized by gentle slopes and hardwood forests. The East Fork Obey River near Jamestown (site 84) drains some disturbed areas on the western edge of the Cumberland Plateau. The watershed of the West Fork Obey River near Alpine (site 87) drains the Highland Rim and Cumberland Plateau escarpment and is not affected seriously by mining activities. The headwaters of the Wolf River at Byrdstown (site 93) are located in the plateau escarpment where strip-mines are active.

Severe sediment problems are evident at all sites considered to be representative of actively-mined basins (Tennessee Department of Public Health, Division of Water Quality Control, 1978). These sites are compared with upstream sites within the same watershed and with sites in less-disrupted basins to depict the effects of mining on downstream water quality.

The relation between water discharge and suspended-sediment yield data for selected sites has been established (fig. 5.9-1 (a-e)). In order to minimize the effects of basin area on differences in suspended-sediment and water discharge values, and to facilitate basin comparisons, these data have been expressed in terms of tons per day per square mile and cubic feet per second per square mile. It can be argued that these regression lines will be displaced relative to one another according to their respective drainage areas, with the larger basins producing less sediment yield per square mile because of greater storage and dilution. This relation may occur where basin characteristics are consistent, but it may be reversed due to the affect of land use (see fig. 5.9-1a and fig. 5.9-1e).

The relation between suspended-sediment yield and total recoverable iron and manganese for New River at New River (site 33) is shown in figure 5.9-2. These relatively abundant constituents commonly are exposed during coal mining, are weathered quickly, and are transported in the stream system either in the dissolved or in the suspended phase. Because of the affinity for fine suspended sediment, concentrations of these constituents often can be correlated with suspended-sediment yield.

The exceptional difference in both suspended

Note: 5.9 Sediment text continued from tip-in at left

sediment and total recoverable iron between New River at New River and Clear Fork near Robbins is shown in figure 5.9-1a. The annual suspended-sediment load of the New River was 30 times that of Clear Fork, or 20 times as much suspended sediment per square mile during the 1977 water year (Parker and Carey, 1980). Calculated average annual suspended-sediment yields and total recoverable iron loads for these and three other sites are shown in table 5.9-1. The New River basin is the most extensively mined watershed in Area 17 and this is reflected by the large amounts of total recoverable iron transported. A large storm on April 3, 4, and 5, 1977, transported 76 percent of the total annual suspended-sediment load and almost 10,500 tons (62 percent of annual load) of suspended iron. In addition, the New River transported approximately 200 tons of total recoverable manganese during the storm, more than 70 percent of the total annual yield of this constituent. This illustrates the significance of low frequency, high magnitude events in the erosion and tranport of suspended-sediment and associated constituents.

Dilution, as related to basin area, does not occur on the mainstem of the New River as evidenced by comparing New River at Cordell (site 25) with New River at New River (site 33) (fig. 5.9-1b). Because mines are operated throughout the basin, there apparently is little chance for downstream dilution of suspended sediment and chemical constituent concentrations in this reach. In contrast, some dilution occurs within the Wolf River basin downstream of the mined and steeper headwater areas of the plateau escarpment. The Wolf River transports less suspended sediment in tons per day per square mile per unit of water discharge near Byrdstown (site 93) than in the upstream reaches at sites 90 and 91 (fig. 5.9-1c). At site 93, on the average, less total recoverable iron is transported annually (1.5 tons per square mile) than at any of the other selected sites, notwithstanding the upstream disturbances.

The increased erosion and sediment yields due to mining in the larger basin of the East Fork Obey River near Jamestown (site 84) is shown in figure 5.9-1d. An average of 14 tons per square mile of total recoverable iron is transported at site 84 compared to 1.7 tons per square mile for the West Fork Obey River near Alpine (site 87). This occurs because iron is made available for fluvial transport in the East Fork Obey River when mining activities expose iron-bearing minerals. Average annual suspended-sediment yields for the West Fork Obey River are approximately one-third that of the East Fork Obey River (36 per tons per square mile and 100 tons per square mile, respectively) despite its smaller drainage area (table 5.9-1).

Similar suspended-sediment yields at high flows at both upstream (site 77) and downstream (site 84) sites along the East Fork Obey River are indicated in figure 5.9-1e. The large discrepancy in the iron transported at these sites is a function of in-stream chemical equilibria. At site 77, the East Fork Obey River transports larger quantities of dissolved iron (43 percent, as compared to 5 percent at site 84). The higher background levels at relatively low suspended-sediment transport rates reflect this difference. Therefore, the East Fork Obey River near Jamestown (site 84) transports suspended-associated iron originally entering the stream in the dissolved phase in the Obey City area (site 77), 27 miles upstream.

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

The range of suspended-sediment yield for selected sites in Area 17 is given in section 10.4. The corresponding discharge and total recoverable iron data are also given.

Table 5.9-1 Average annual suspended-sediment yields and total-recoverable iron loads for selected sites

Site	Suspended-sediment yield		Total recoverable iron	
No.	(Tons)	(Tons/mi^2)	(Tons)	(Tons/mi^2)
33*	590,000	1,540	16,800+	44+
53	20,400	75	570	2.1
84	20,200	100	2,850	14
87	4,170	36	199	1.7
93	4,550	43	159	1.5

* measured yields from continuous data, 1977 water year (from Parker and Carey, 1980)
\+ suspended-iron data

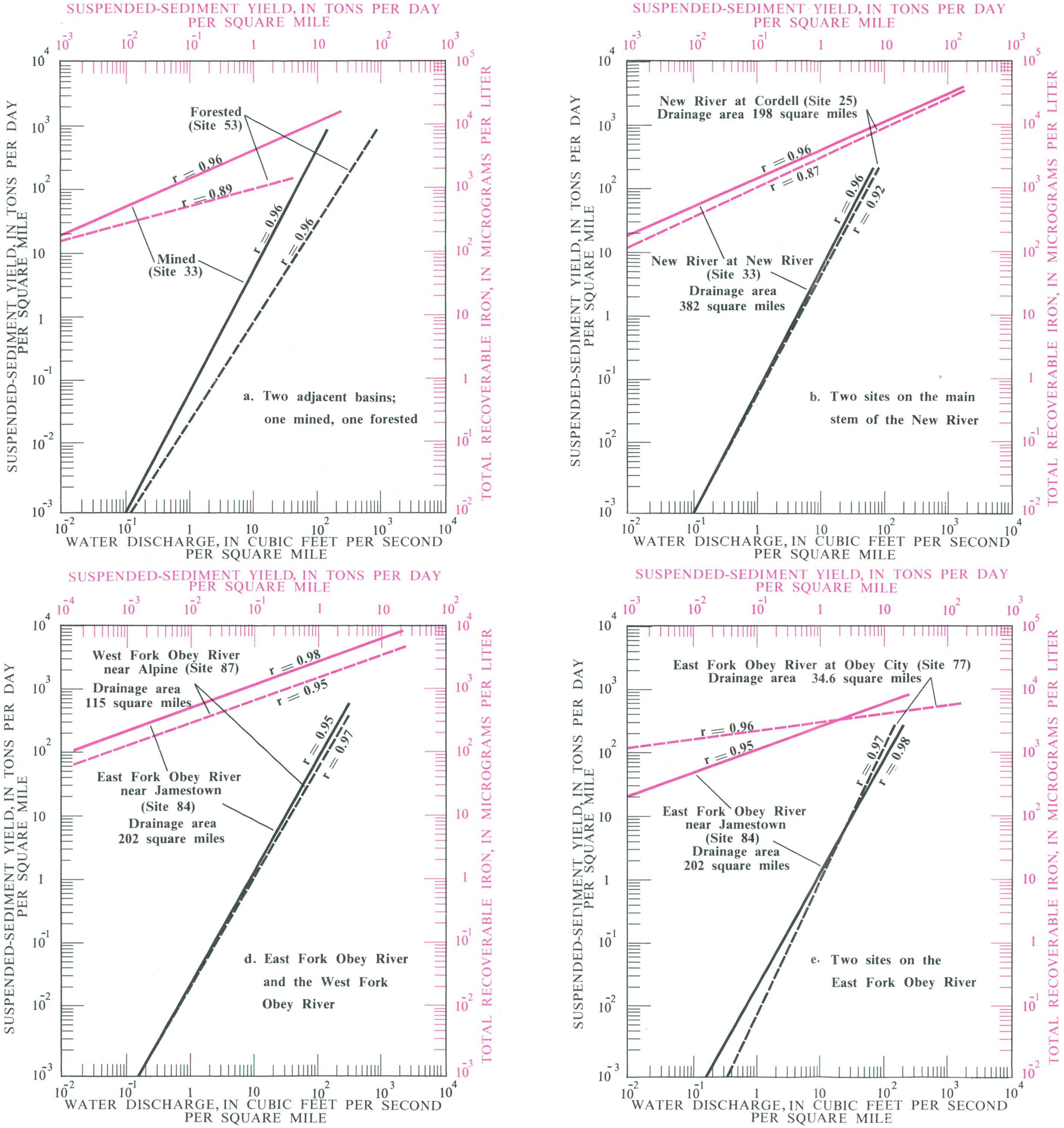


Figure 5.9-1 Relation between suspended sediment and total recoverable iron for selected sites

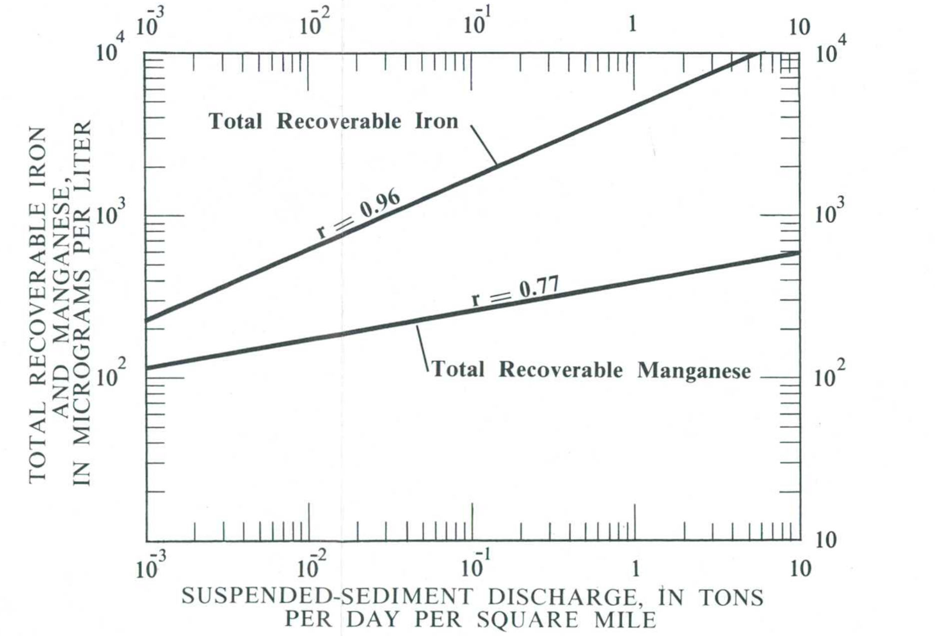


Figure 5.9-2 Relation between suspended sediment and total recoverable iron and manganese for the New River at New River (Site 33)

See fig. 3.1-1 for site locations

See section 10.1 for detailed site description

See section 10.4 for detailed suspended-sediment and total recoverable iron data

Benthic Invertebrate Populations Indicate a Wide Range of Water Quality

An index computed for 14 sites in Area 17 showed some streams free of pollution, but effects of pollution were found at some sites.

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

Benthic invertebrates were collected at 14 sites in Area 17 during May and June of 1980 (fig. 5.10-1). Sampling methods included artificial substrates, square-foot bottom samplers, and kick sampling with dip nets. Identification of individual organisms was usually to genus level.

A biotic index (J. Gore, Tennessee Technological University, written comm., 1980, modified from Hilsenhoff, 1977) was computed for each site within Area 17 using the formula:

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

where:

n_i is the number of individuals of a given taxon;

N is the total number of organisms collected;

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

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

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

Values for Area 17 streams ranged from good (1.81) at New River at Cordell, Tenn. (site 25) to poor (3.33) at East Fork Obey River near Obey City, Tenn. (site 77). The remaining sites were in the good and fair categories. Additional information concerning benthic invertebrate populations in streams draining coal-resource areas must be collected before the impact of mining practices can be defined.

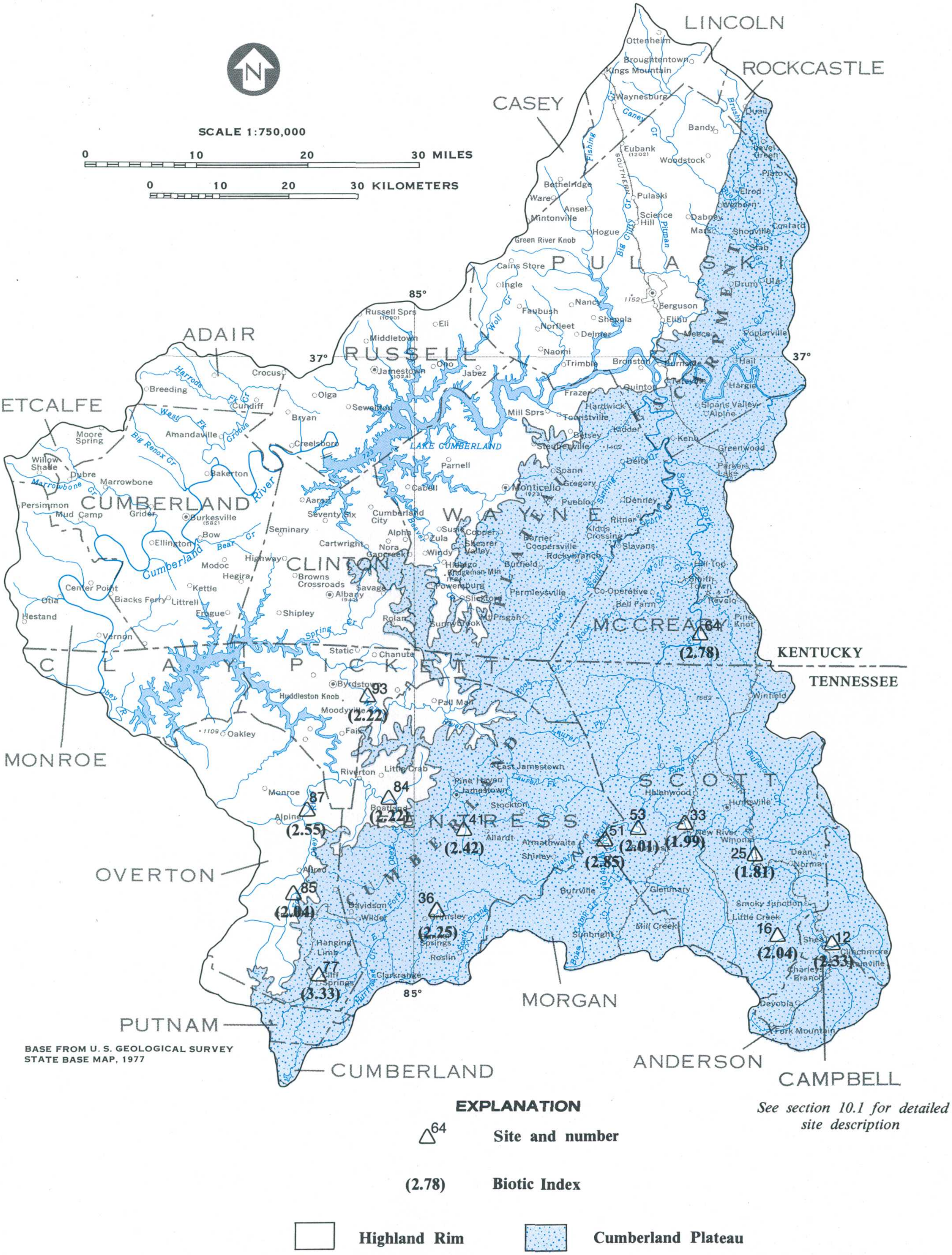


Figure 5.10-1 Sites for which benthic invertebrate data are available

Ground Water Occurs in Three Types of Aquifers

In the Cumberland Plateau, ground water occurs primarily in the fractured Pennsylvanian sandstone. The soluble Mississipian carbonate rocks are the main aquifer in the Highland Rim. Unconsolidated Quaternary alluvium is an aquifer along the Cumberland River and some of its major tributaries.

In the Cumberland Plateau in Area 17, beds of sandstone and conglomerate are the main sources of water supplied to wells. Because these rocks contain very little primary porosity (intergranular voids), ground water occurs mostly in secondary openings such as fractures and joints (fig. 6.1-1). Locally, the ground water exists under artesian pressure causing water levels to rise above the top of the aquifer. Perched aquifers (saturated zones above the main water table) are also common. In general, wells are less than 400 feet deep and most domestic wells are less than 200 feet deep. The regolith (rock weathered in place) over most of the plateau is too thin to be of any significance. Springs act as natural discharge points and flow from joints and bedding planes.

Ground water in the Highland Rim occurs primarily in solution openings in the Mississippian carbonate rocks (fig. 6.1-1). These openings have been formed by the solvent action of ground water along the fractures and bedding planes of the formations. This is especially true in the karst terrains of Clay and Pickett Counties, Tenn., and Clinton, Wayne, and Pulaski Counties, Ky. Most wells penetrate water-bearing zones at depths of less than 300 feet and practically all of the ground water occurs under artesian conditions. Where less soluble siltstone, sandstone, and shale sequences are present, ground water occurs in fractures and bedding plane openings. Perched aquifers commonly occur above the shale layers. The regolith of the Highland Rim is thicker than that of the Cumberland Plateau. The regolith stores ground water generally under water table conditions and supplies it to the underlying bedrock. In areas with significant amounts of chert gravel, the regolith can supply ground water to wells.

Along the Cumberland River in Clay County, Tenn., and Cumberland and Russell Counties, Ky., there are thick deposits of Quaternary alluvium which are composed of silt, clay, sand, and some gravel. Ground water is stored in and primarily transmitted through the spaces between the sand grains and gravels in the unconsolidated alluvium. This ground water occurs primarily under water-table conditions. Locally, ground water below clay beds occurs under artesian conditions.

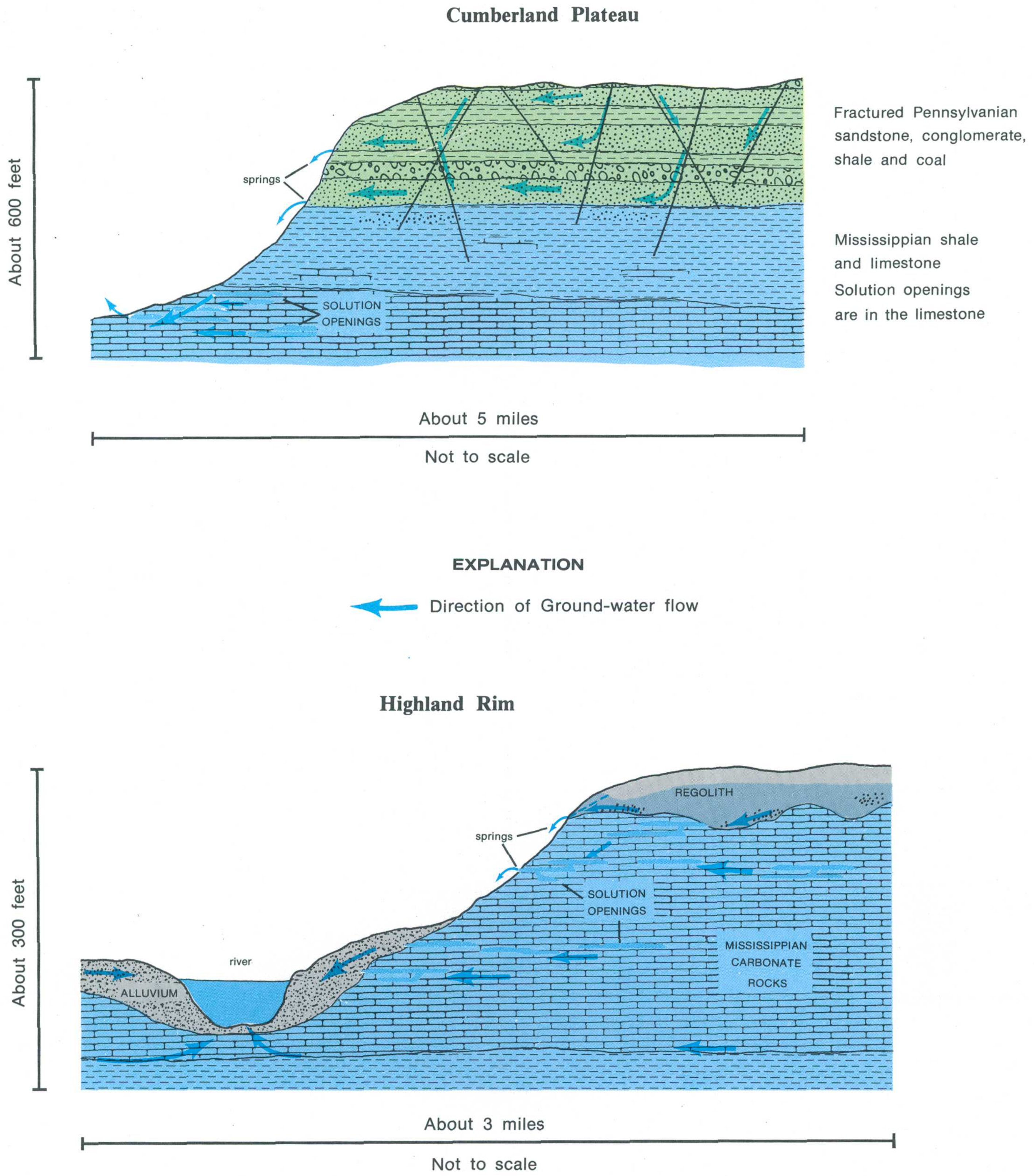


Figure 6.1-1 Ground-water occurrence and flow

Aquifer Yields and Transmissivities Vary

The variation in yields and transmissivities is due to the difference in the size and the irregular nature of the fracture system in the Pennsylvanian rocks and the solution openings within Mississippian carbonate rocks.

Wells penetrating the fractured Pennsylvanian rocks yield less than 5 to more than 300 gal/min. Sixty-two percent of the yields from the 376 wells reported to the Tennessee Division of Water Resources and in published reports on ground water in Kentucky range from 10 to 25 gal/min (Kilburn and others, 1962; Lambert and Brown, 1963). Specific capacity data from 23 wells were used to estimate transmissivity. For these wells, transmissivity ranged from 5 to 13,000 ft^2/day. Sixty-eight percent of the values are between 11 and 240 ft^2/day (table 6.2-1).

Wells in the carbonate rocks of the Highland Rim have yields ranging from less than 5 to more than 600 gal/min. In Tennessee, 57 percent of the wells reported to the Tennessee Division of Water Resources have yields between 10 and 25 gal/min. Data from published reports on ground water in the Highland Rim in Kentucky show that only 6 percent of the wells in this area yield from 5 to 50 gal/min. Yields of less than 5 gal/min occur in 93 percent of the reported wells. Many of the lower yields, however, may be a measure of the pump capacity, not the aquifer. For drilled wells equipped with a power pump, yields of 5 to 50 gal/min are reported for 30 percent of the wells (Kilburn and others, 1962; Lambert and Brown, 1963).

Transmissivities of aquifers in the Highland Rim were also estimated from specific capacity data from 17 wells in Kentucky and Tennessee. Transmissivity ranged from 35 to 7,000 ft^2/day. Within this range, 68 percent of the values fall between 51 and 2,000 ft^2/day (table 6.2-1). The wide range of these values is due to the heterogeneous and localized nature of the solution openings.

Yield of wells in the alluvium along the Cumberland River and other large streams is dependent on the grain size of the deposit. Wells in beds of fine-grained silt and clay have very low yields, less than 5 gal/min. Where there are beds of sand and gravel, the yield to wells can be more than 400 gal/min. Specific capacity data were not available for wells in the Quaternary alluvium in this area.

Table 6.2-1 Ranges of specific capacity and estimated transmissivity

	Cumberland Plateau		Highland Rim	
	Specific capacity (gal/min)/ft	Trans-missivity (ft^2/day)	Specific capacity (gal/min)/ft	Trans-missivity (ft^2/day)
Maximum	48	13,000	25	7,000
84 percentile	0.89	240	8.0	2,000
16 percentile	0.04	11	0.19	51
Minimum	0.02	5	0.13	35
Number of wells	43		17	

Ground-Water Levels Fluctuate From Season to Season

Ground-water levels rise in winter and decline in summer indicating a seasonal change in ground-water storage as a result of relative differences in rates of recharge to and discharge from the subsurface reservoirs.

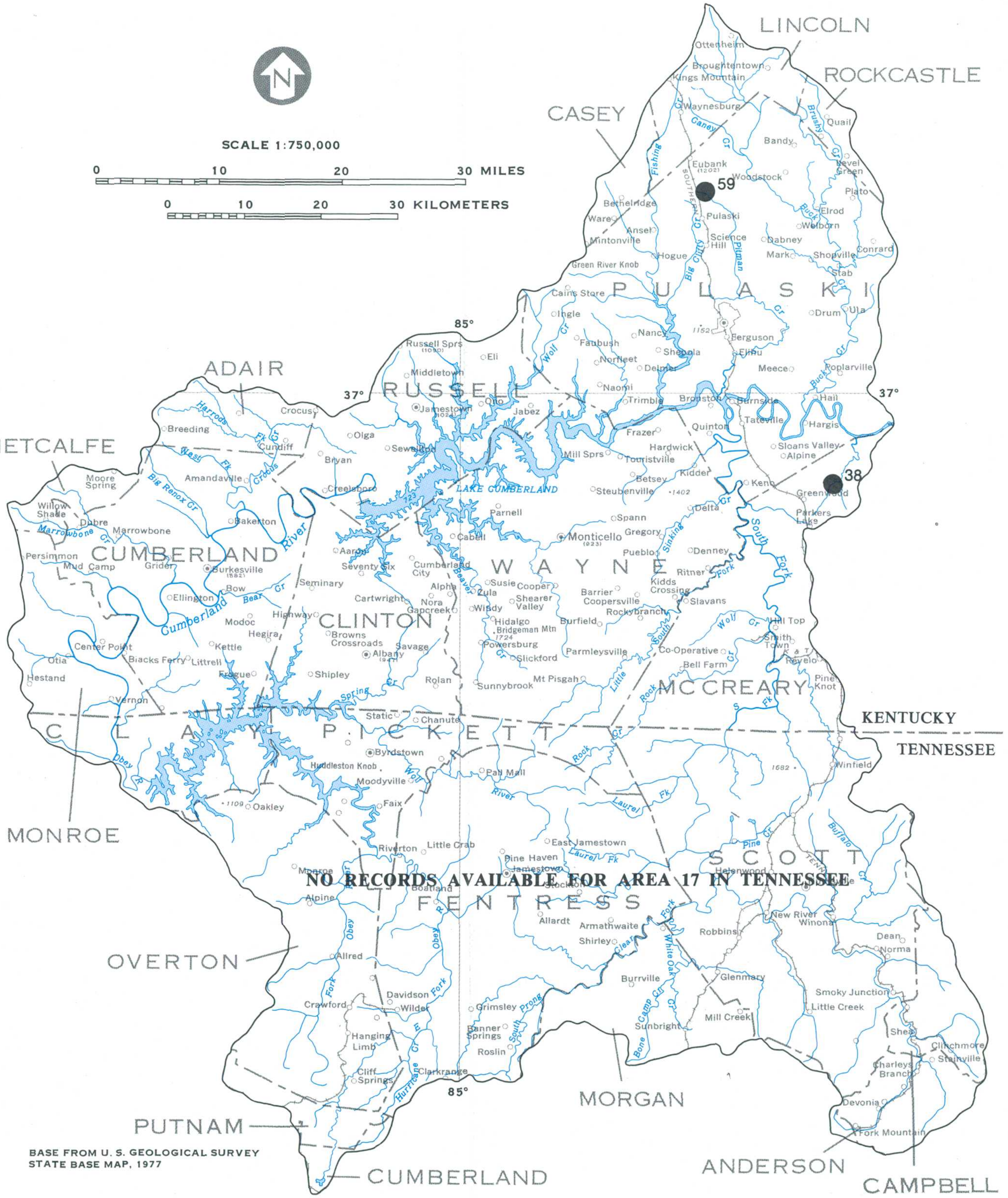
Throughout Area 17, water levels in wells tend to follow a seasonal cycle with highest levels occurring in the spring before the onset of the growing season and lowest levels occurring in the fall just prior to the first killing frost. During the non-growing season, water levels rise because the rate of recharge exceeds the rate of discharge causing an increase in ground-water storage. During the growing season, water levels decline when the rate of discharge exceeds the rate of recharge. These seasonal differences in the relative rates of recharge and discharge are due to evapotranspiration which is greatest in the warm summer months and least in the cold winter months.

Fluctuations of water levels assumed to be characteristic of aquifers in Area 17 are shown in observation well hydrographs (fig. 6.3-1). The monthly median and extremes of the instantaneous water levels measured at noon on the last day of each month for the period of record are also shown.

Long-term water-level records such as the ones in figure 6.3-1 can be used as an index to interpret hydrologic conditions in the general vicinity of the observation well. For example, current conditions can be inferred from a plot of current water level measurements in these observation wells, and by comparison of the relative position of the plotted points with respect to the previously recorded median and extremes.

The actual depths to water as measured in other wells in Area 17 may be more or less than those measured in the index wells, but the trend of fluctuations will be similar. Differences in the depth to water in this area primarily are due to differences in the topographic settings of the wells. For example, wells located on hilltops have the greatest depth to water, whereas wells in a valley near a perennial stream have the least depth to water. In general, depth to water in this area ranges from 10 to 100 feet (Rima and Mull, 1980).

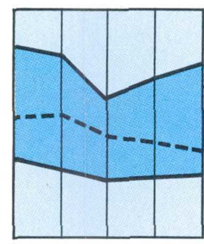
Water-level measurements for these index wells shown in figure 6.3-1 are published annually by the U.S. Geological Survey, Louisville, in "Water Resources Data for Kentucky." This report can be obtained from the District Chief, U.S. Geological Survey, Room 572 Federal Building, 600 Federal Place, Louisville, KY 40202. No continuous ground-water level data are available for Tennessee.

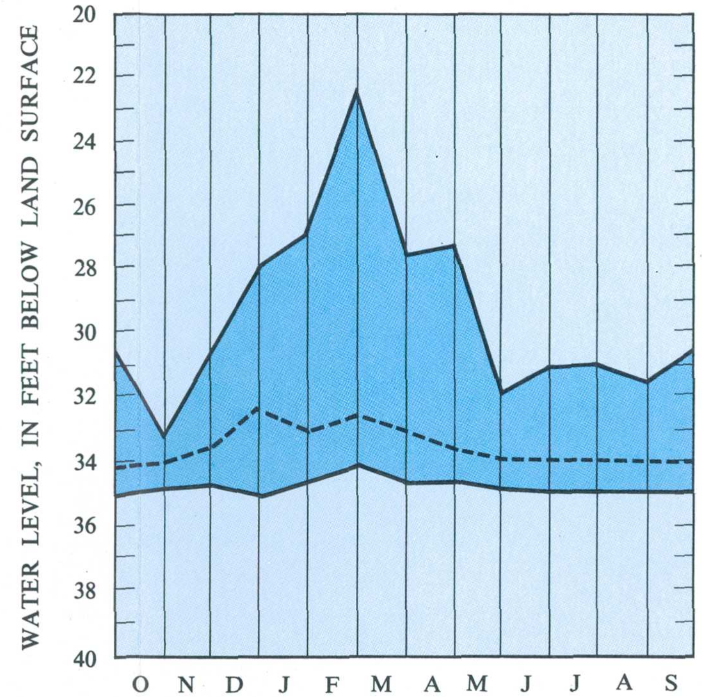


See section 10.2 for detailed site description

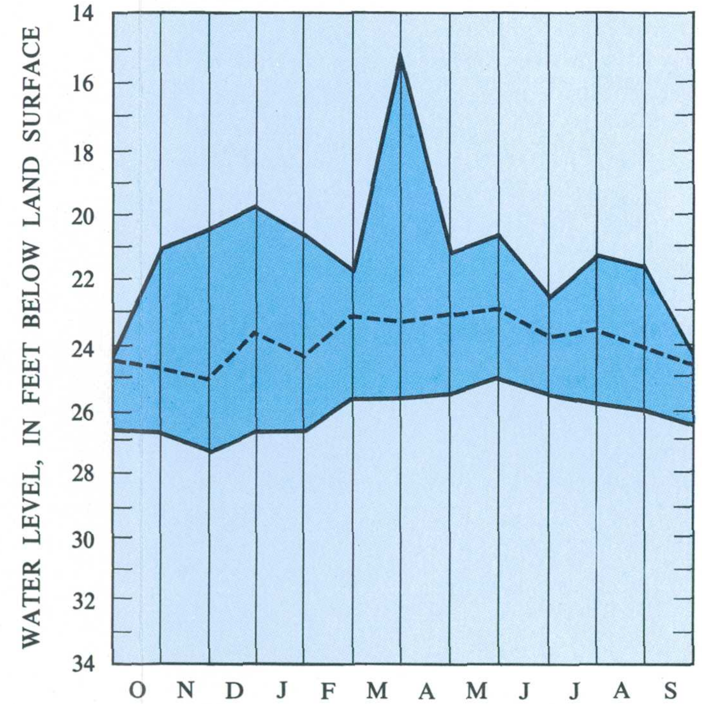
HYDROGRAPH EXPLANATION

● 38 Site and number





SITE: 59 WELL DEPTH: 67 feet
CASING DEPTH: 17 feet
AQUIFER: Borden Formation of Mississippian age
PERIOD OF RECORD: April 1954 to October 1980



SITE: 38 WELL DEPTH: 45 feet
CASING DEPTH: Unknown
AQUIFER: Sandstone and shale of Late Mississippian and Early Pennsylvanian age
PERIOD OF RECORD: April 1962 to October 1980

Figure 6.3-1 Hydrographs of index wells showing seasonal fluctuations in water levels

Quality of Ground Water in Area 17 Generally Good

Iron and chloride are the two most objectionable constituents of ground water in Area 17. Hardness can be a problem in some areas.

The water-quality program begun in the coal-producing region in 1979 does not include quality of ground-water data. Some data have been collected previously, although not all parameters specified in the Act have been determined at all sites. Average quality by aquifer systems is shown in figure 7.0-1. An analysis of data from other studies suggests the following:

- Iron and chloride are the two most objectionable constituents in Area 17. High iron concentrations are most likely to occur where water drains through beds of black shale or coal. Iron concentrations in excess of 300 μg/L is usually undesirable and requires treatment for most uses (U.S. Environmental Protection Agency, 1976). Chloride concentrations generally increase with depth where ground-water circulation and discharge are minimized; however, high chloride concentrations are known to occur at depths of less than 300 feet in Area 17.

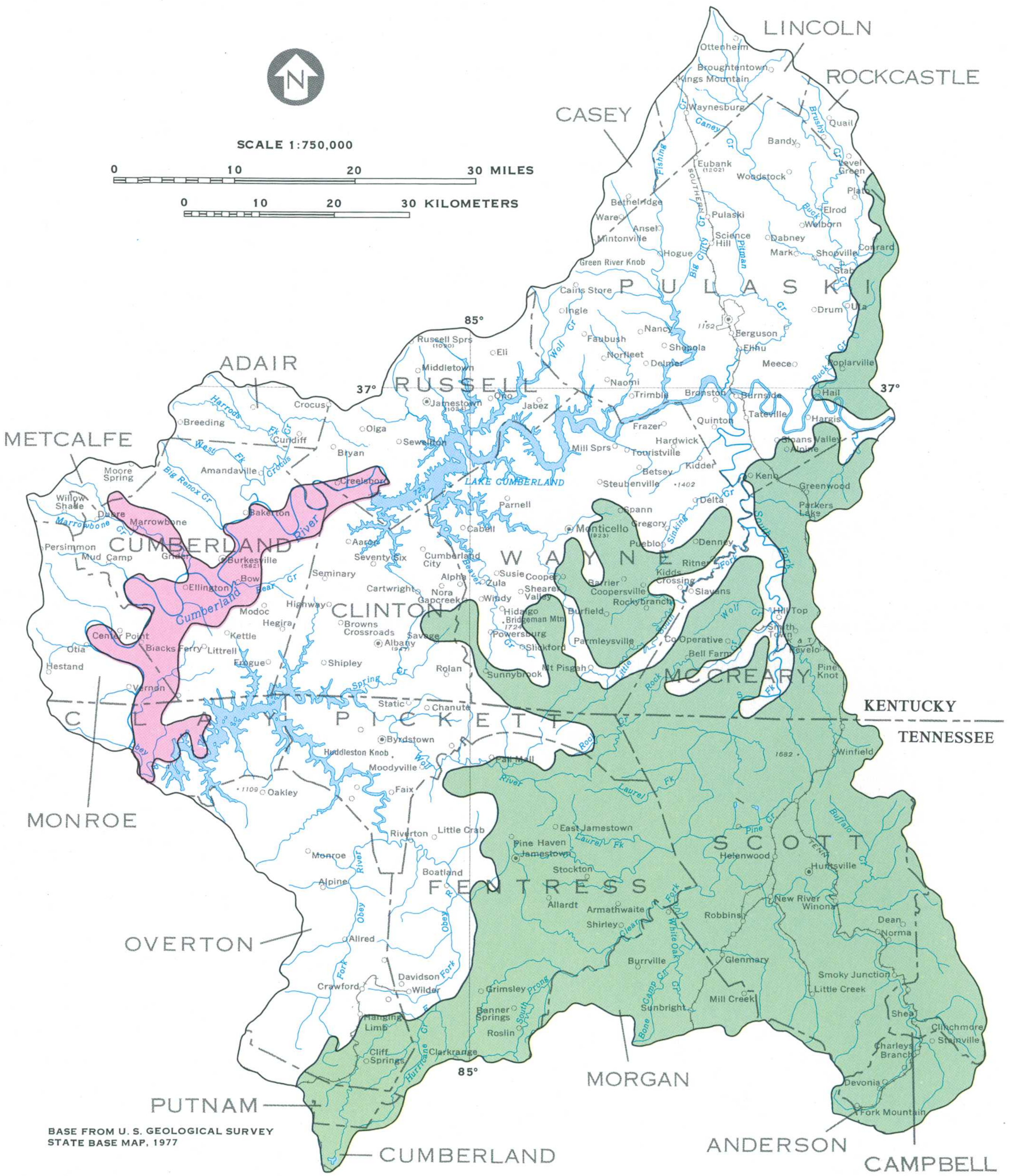
- Water from wells drilled into the water table is usually softer and less mineralized than water from greater depths in the bedrock aquifers (Rima and Mull, 1980).

The quality of ground water depends on several variables such as, composition of the aquifer, distance from recharge areas, length of time water has been in contact with the aquifer, and the pattern of ground-water circulation.

The quality of ground water from the Pennsylvanian rock aquifers varies within relatively wide limits, but the water is generally satisfactory for most uses or can be made so with minor treatment. Typically the water is moderately mineralized, slightly acidic, and soft to moderately hard. Most wells and springs in this area have iron concentrations in excess of the recommended limit.

The quality of water from the Mississippian rock aquifers is generally good. Characteristically, the water is a calcium bicarbonate type and slightly alkaline. Most of the reported values for dissolved solids are less than 500 mg/L. In some areas, hardness may be a problem and iron and chloride concentrations may exceed recommended limits. There are reports of hydrogen sulfide gas in the water from some wells in the area.

Water from the Ordovician rock aquifers is characteristically very hard, moderately mineralized, and moderately alkaline. Most of the supplies are free of objectionable constituents, but there are some exceptions. Hydrogen sulfide gas in small but detectable quantities has been reported in the water from some wells in the area, and locally, iron and chloride concentrations may exceed recommended limits (Rima and Mull, 1980).



Geology from D.R. Rima and D.S. Mull, 1980

WATER QUALITY BY AQUIFER OF THE GROUND WATER IN AREA 17

AQUIFER	Aquifer type	Hardness (milligrams per liter)	Iron (micrograms per liter)	Sulfate (milligrams per liter)	Chloride (milligrams per liter)	Dissolved solids (milligrams per liter)	pH (units)
Pennsylvanian rocks (undifferentiated)	Fractured sandstone and conglomerate	40-120	400-6,000	5-60	5-50	250-400	6.4-7.2
Mississippian rocks (undifferentiated)	Carbonate rocks	100-300	100-1,000	1-100	1-20	150-400	6.8-7.8
Ordovician rocks (undifferentiated)	Limestone	200-400	100-2,000	5-50	2-50	250-500	6.8-8.0

(Numerical ranges represent typical values and do not include unusually high or low values)

Figure 7.0-1 Chemical composition of ground water

8.0 SUMMARY

General Hydrology of Area 17 Summarized

Data collected since 1979 in Area 17, combined with previously collected data, should provide a background for site-specific studies required by the Surface Mining Control and Reclamation Act of 1977.

The Eastern Coal province 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 17, located in Tennessee and Kentucky in the southern part of the Eastern Coal province, includes parts of 22 counties. The area is in two physiographic sections, the Cumberland Plateau and the Highland Rim. Each comprises about one-half of the 4,203 square mile area. Numerous coal mines, about 3 percent of the land use, are in the Cumberland Plateau; but no mines are operated in the Highland Rim.

The Cumberland Plateau is capped by Pennsylvanian rocks, some conglomerate, and coal. The Pennsylvanian rocks have a maximum thickness of approximately 600 feet in the western half and approximately 3,000 feet in the eastern half. Soils on the Plateau reflect this geology. Most soils are derived from sandstone, limestone, and shale. Soils are shallow to deep, well drained, and low in natural fertility. The potential for erosion on the Cumberland Plateau is moderate to high. On the steep slopes, the erosion potential is great and can become severe if the vegetation cover is removed.

The climate of the area is moderate. The average annual temperature is about 56°F. Temperature extremes generally range from -5° to 100°F. Average annual precipitation is about 50 inches with extremes of about 35 and 70 inches.

Streamflow varies in a pattern similar to the seasonal variation in rainfall and varies from stream to stream because of differences in drainage basin size and other physical characteristics. The average annual streamflow in much of Area 17 is approximately 1.2 to 2.1 cubic feet per second per square mile. Most peak flows occur during the winter and spring months. About 65 percent of the annual peaks occur during the period January through March.

Water-quality data have been collected at 57 surface-water sites in Area 17; all but 6 of these are located in the Cumberland Plateau. Some of the remaining sites, located in the Highland Rim, are on streams draining areas of the Plateau. Water-quality problems caused by surface-mining activities are apparent at several sites in the area. Water at several sites is seriously affected by high sediment concentrations, low pH values, and high concentrations of dissolved sulfate, total recoverable iron, and (or) total recoverable manganese. In addition, severe water-quality problems may exist at sites near any of the sampled sites and not be detected. Water at some sites located in the central part of the coal-mining areas has not been affectd by mine drainage. In the future, data collected at these sites will be particularly important in the assessment of the potential impact of mining activities on water quality.

In the Cumberland Plateau, ground water occurs in the fractured Pennsylvanian sandstone. Ground water in the Highland Rim occurs primarily in soluble Mississippian carbonate rocks. Unconsolidated Quaternary alluvium along some of the major streams also is a source of ground water. Well yields in the area are highly variable, ranging from 5 to 600 gallons per minute in some parts of the Highland Rim in Tennessee to less than 5 gallons per minute in parts of the Highland Rim in Kentucky.

Iron and chloride are the two most objectionable constituents in ground water in the area. Water from wells drilled into the water table is usually softer and less mineralized than water from the bedrock aquifers. Hydrogen sulfide is reported in the water from some area wells.

NAWDEX, WATSTORE, and OWDC Water Information

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

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

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

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

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

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

NAWDEX Simplifies Access to Water Data

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

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

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

NAWDEX can assist organizations or individuals to identify and locate needed water data. The requester is referred to the organization that retains the needed data. To accomplish this service, NAWDEX maintains a computerized Master Water Data Index (MWDI) (fig. 9.2-2). The MWDI identifies sites for which water data are available, lists the type of data available for each site, and identifies the organization retaining the data. A Water Data Sources Directory (fig. 9.2-3) also is maintained that identifies the sources of water data and the locations from which data may be obtained. In addition, NAWDEX has direct access to some large water-data bases of its members and has reciprocal agreements for the exchange of services with non-member organizations.

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

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

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

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

Hours: 7:45 - 4:15 Eastern Time

or

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

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

Hours: 7:45 - 4:30 Central Time

or

Kentucky
U.S. Geological Survey
Room 572, Federal Building
600 Federal Place
Louisville, KY 40202

Telephone: (502) 582-5241
FTS 352-5241

Hours: 8:00 - 4:45 Eastern Time

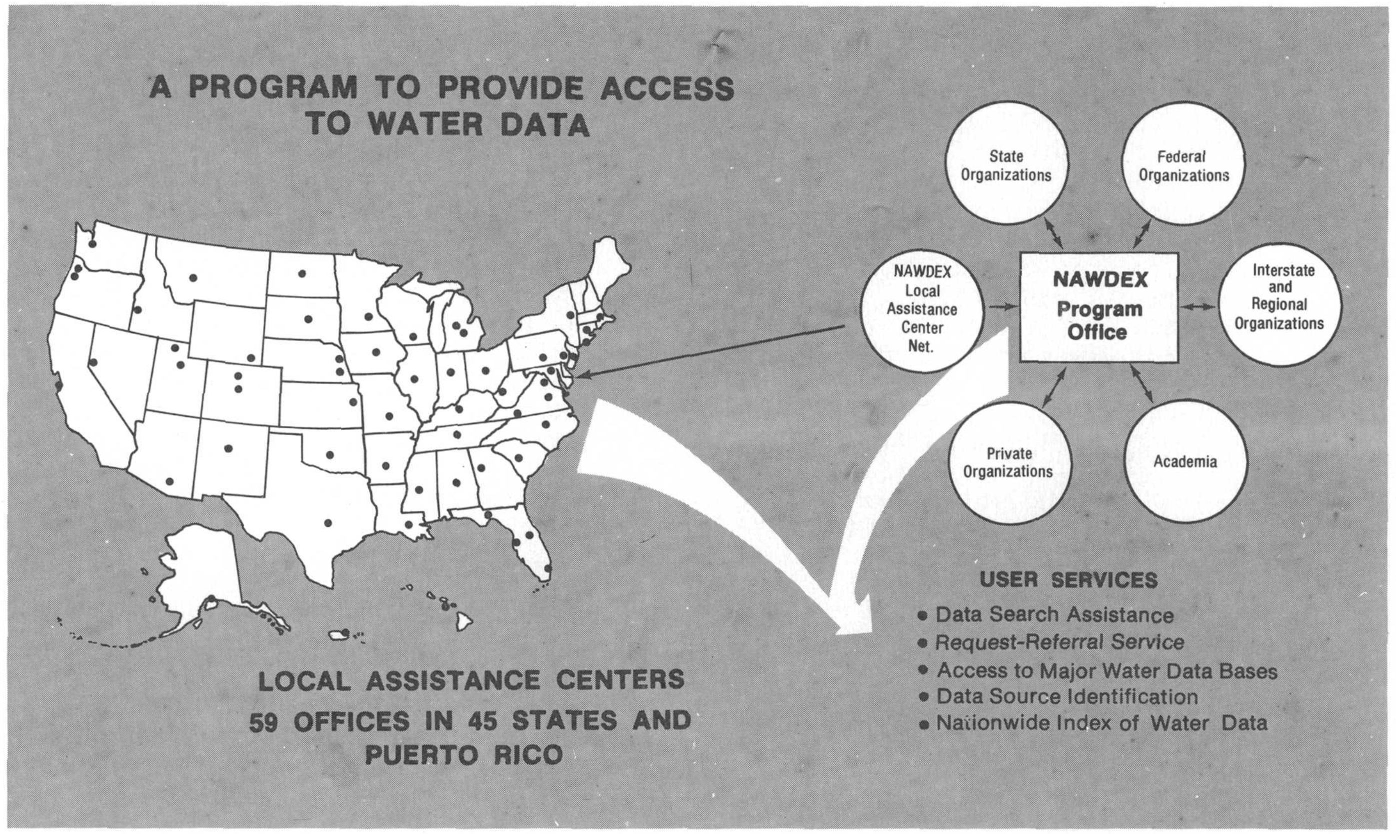


Figure 9.2-1 Access to water data

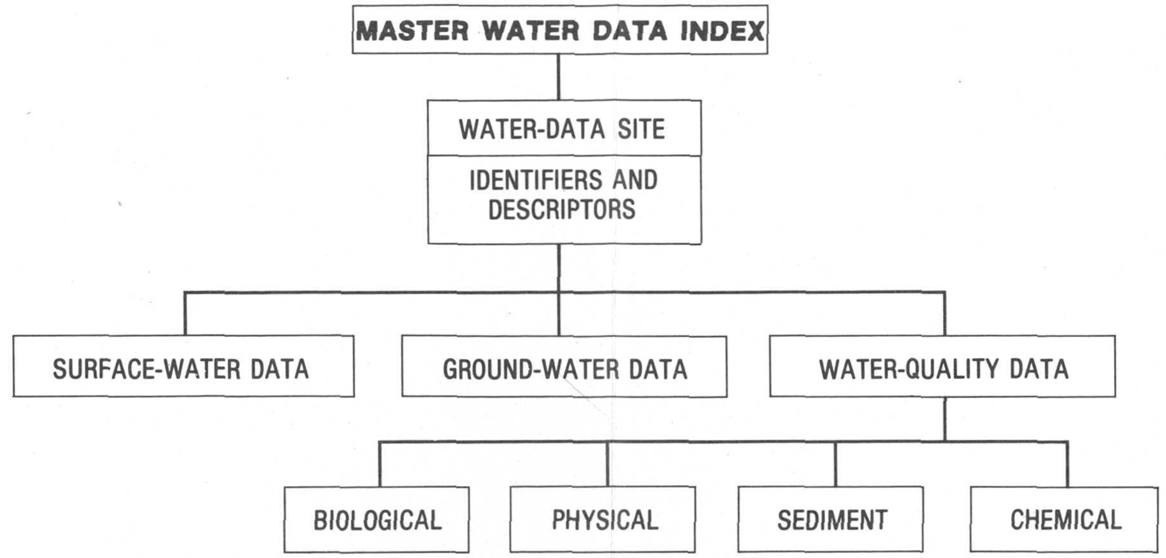


Figure 9.2-2 Master water-data index

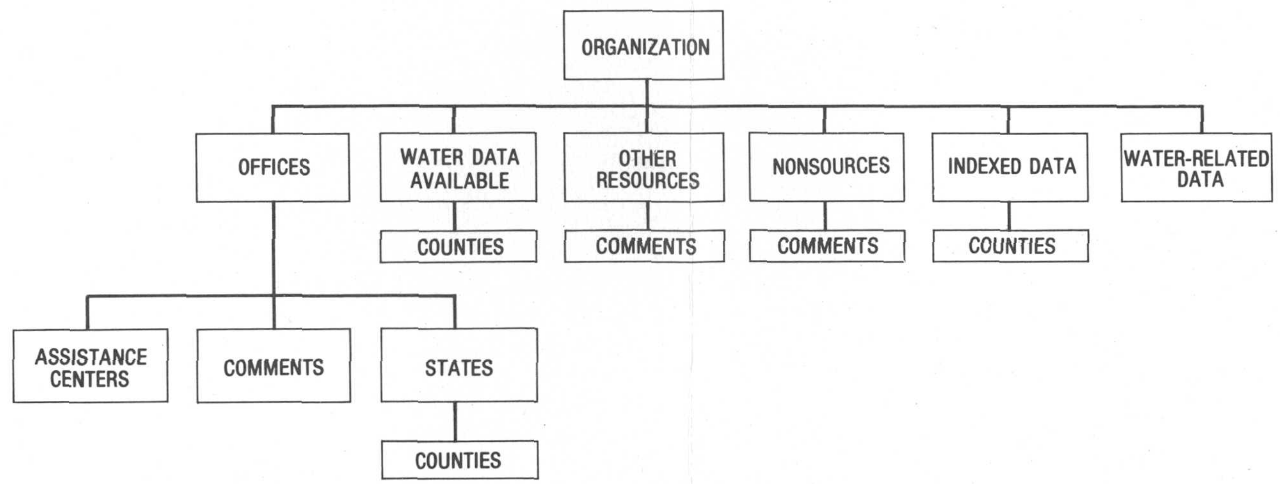


Figure 9.2-3 Water-data sources directory

WATSTORE Automated Data System

The National Water Data Storage and Retrieval System (WATSTORE) of 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, Va. 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
Room 572, Federal Building
600 Federal Place
Louisville, KY 40202

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

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

Station Header File: All sites for which data are stored in the Daily Values, Peak Flow, Water-Quality, or Unit Values files of WATSTORE are indexed in this file. It contains information pertinent to the identification, location, and physical description of nearly 220,000 sites.

Daily Values File: All water-data parameters measured or observed either on a daily or on a continuous basis and numerically reduced to daily values are stored in this file. Instantaneous measurements at fixed-time intervals, daily mean values, and statistics such as daily maximum and minimum values also may be stored. This file currently contains over 200 million daily values including data on streamflow, river stages, reservoir contents, water temperatures, specific conductance, dissolved oxygen concentrations, pH, sediment concentrations, sediment discharges, and ground-water levels.

Peak Flow File: Annual maximum (peak) streamflow (discharge) and gage height (stage) values at surface-water sites comprise this file, which currently contains over 400,000 peak observations.

Water-Quality File: Results of over 1.4 million analyses of water samples that describe the chemical, physical, biological, and radiochemical characteristics of both surface and ground waters are contained in this file.

Unit Values File: Water parameters measured on a schedule more frequent than daily are stored in this file. Rainfall, stream discharge, and temperature data are examples of the types of data stored in the Unit Values File.

Ground-Water Site-Inventory File: This file is maintained within WATSTORE independent of the files discussed above, but it is cross-referenced to the Water-Quality File and the Daily Values File. The file contains inventory data about wells, springs, and other sources of ground water. Site location and identification, geohydrologic characteristics, and well-construction history are some of the data included. The file is designed to accommodate 255 data elements and currently contains data for nearly 70,000 sites.

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

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

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

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

Central Laboratory System: The Water Resources Division's two water-quality laboratories, located in Denver, Colorado, and Atlanta, Georgia, analyze more than 150,000 water samples per year. These highly-automated laboratories are equipped to analyze chemical constituents ranging from simple inorganics, such as chloride, to complex organic compounds, such as pesticides. The analysis results are verified by laboratory personnel and transmitted to the central computer facilities to be stored in the Water-Quality File of WATSTORE.

Water data are used in many ways by decision-makers for the management, development, and monitoring of water resources. In addition to data processing, storage, and retrieval capabilities, WATSTORE can provide a variety of useful products ranging from simple data tables to complex statistical analyses. A minimal fee, plus the actual computer cost incurred in producing a desired product, is charged to the requester.

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

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

Statistical Analyses: WATSTORE interfaces with a proprietary statistical package, Statistical Analysis System (SAS), to provide extensive analyses of data such as regression analyses, the analysis of variance, transformations, and correlations.

Digital Plotting: WATSTORE also makes use of software systems that prepare data for digital plotting on peripheral offline plotters available at the central computer site. Plots that can be obtained include hydrographs, frequency distribution curves, X-Y point plots, contour plots, and three-dimensional plots.

Data in Machine-Readable Form: Data stored in WATSTORE can be obtained in machine-readable form for use on other computers or for use in user-provided software systems. These data are available in the standard storage format of the WATSTORE system or in the form of punched cards or card images on magnetic tape.

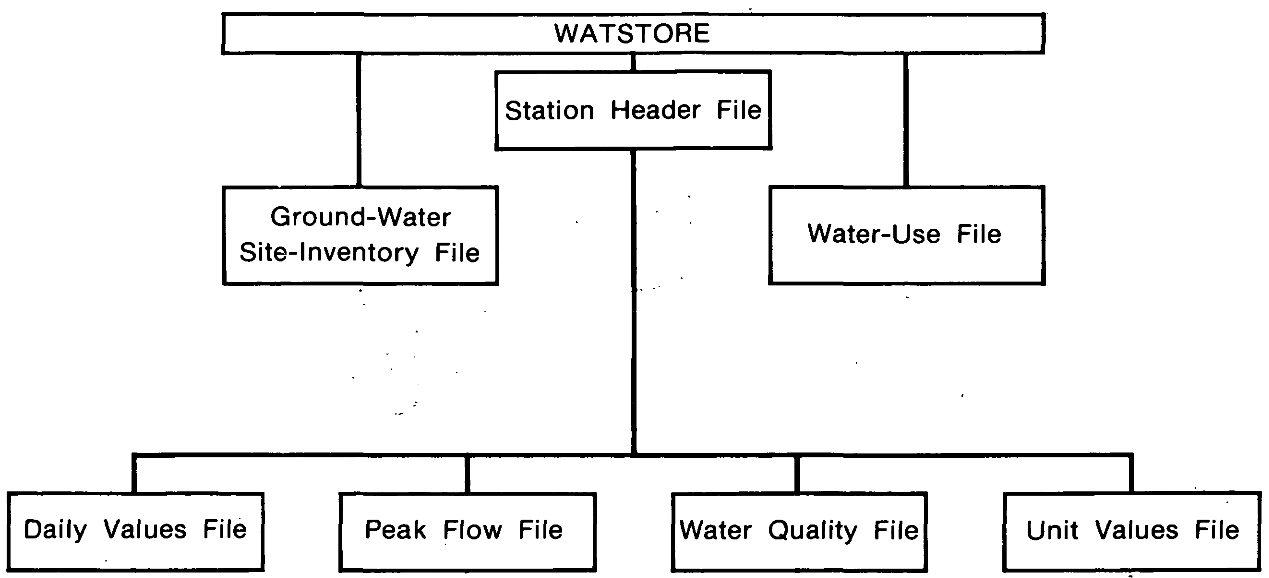


Figure 9.3-1 Index file for stored data

Water Data Indexed for Coal Provinces

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

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

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

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

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

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

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

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

or

U.S. Geological Survey
Water Resources Division
Room 572, Federal Building
600 Federal Place
Louisville, KY 40202

Telephone: (502) 582-5241
FTS 352-5241

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

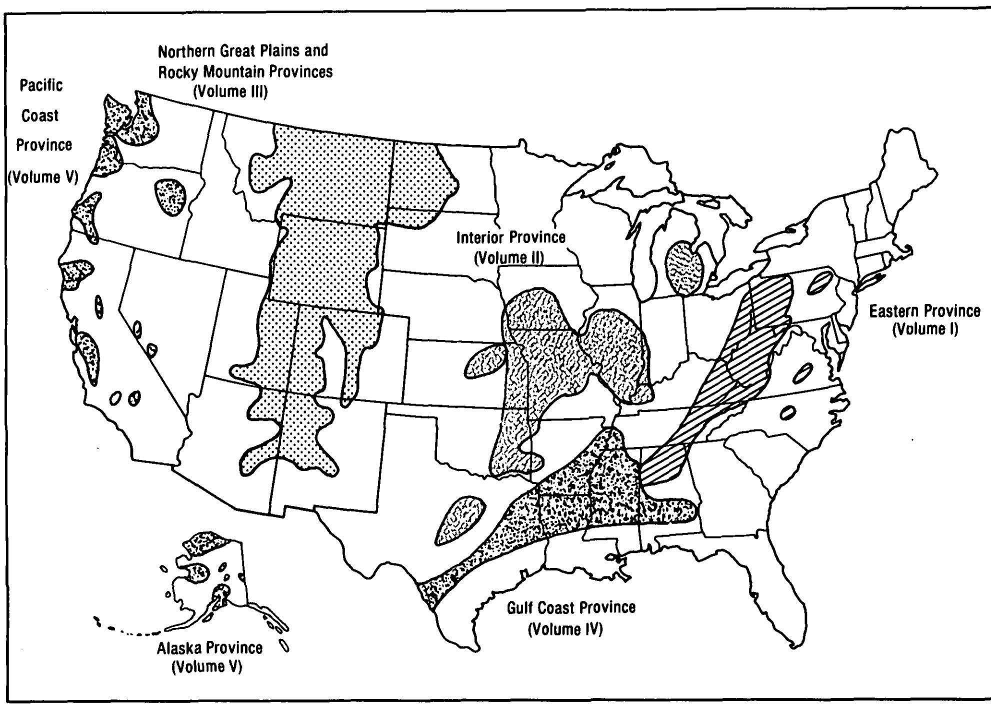


Figure 9.4-1 Index volumes and related provinces

Surface-Water Sites

Site number	Station number	Station name	Location: Latitude (° ' ")	Location: Longitude (° ' ")	Drainage area (mi^2)	Period of record: Discharge	Period of record: Water quality	Period of record: Sediment
1	03407100	Cane Branch near Parkers Lake, Ky.	36 52 05	84 26 57	.67	1956-66, 1973-74	1957-58,1960-75	1957,1961, 1964-66
2	03407200	West Fork Cane Branch near Parkers Lake, Ky.	36 51 49	84 27 08	.26	1956-74	1958,1960-62, 1974	1960
3	03407300	Helton Branch at Greenwood, Ky.	36 53 07	84 28 55	.85	1956-74	1958-67,1973-75	1966*
4	03407500	Buck Creek near Shopville, Ky.	37 12 38	84 27 52	165	1952-	1980-	1980-
5	03407640	Buck Creek at Dykes, Ky.	37 03 36	84 25 35	253	1972-		
6	03407790	New River at Fork Mountain, Tenn.	36 07 28	84 25 32	3.37	1975-	1975-77	1975-77
7	03407804	Indian Fork above Braytown, Tenn.	36 09 37	84 23 15	4.32	1975-	1975-79	
8	03407805	Indian Fork at Braytown, Tenn.	36 09 19	84 22 39	4.83	1975-	1975	
9	03407820	Ligias Fork near Stainville, Tenn.	36 10 14	84 17 13	8.99	1962		
10	03407840	Ligias Fork at Stainville, Tenn.	36 12 22	84 19 12	20.4	1962, 1975-	1975-76	
11	03407850	New River at Stainville, Tenn.	36 12 34	84 19 18	66.0	1962, 1975-	1975-	1979-
12	03407873	Beech Fork at Shea, Tenn.	36 14 17	84 19 49	27.9	1975-	1975-	1979-
13	034078735	Nicks Creek near Smoky Junction, Tenn.	36 16 13	84 20 39	5.03	1975		
14	03407874	Green Branch near Hembree, Tenn.	36 12 09	84 24 59	1.38	1975-79	1975-79	1976
15	03407875	Bills Branch near Hembree, Tenn.	36 12 39	84 24 19	.67	1975-	1975-	1979-*
16	03407876	Smoky Creek at Hembree, Tenn.	36 14 23	84 24 48	17.2	1976-	1978-	1978-*
17	03407877	Bowling Branch above Smoky Junction, Tenn.	36 16 14	84 24 17	2.19	1975-	1975-	1978-79
18	03407879	Smoky Creek at Smoky Junction, Tenn.	36 16 38	84 22 27	32.8	1975-	1975-76	1975-76
19	03407880	New River at Smoky Junction, Tenn.	36 17 13	84 22 01	146	1975-76	1975-76	1975
20	03407881	Anderson Branch near Montgomery, Tenn.	36 18 34	84 23 14	.69	1975-	1975-	1979-
21	03407882	Lowe Branch near Montgomery, Tenn.	36 19 04	84 23 07	.92	1979-	1975-	1979-
22	03407890	Montgomery Fork at Montgomery, Tenn.	36 19 43	84 22 01	22.1	1950, 1979-	1975, 1979-	1979-
23	03407900	New River above Norma, Tenn.	36 19 42	84 22 31	177	1970		
24	03407905	New River at Norma, Tenn.	36 20 09	84 23 29	179	1975-	1975-76	
25	03407908	New River at Cordell, Tenn.	36 20 10	84 27 06	198	1976-	1975-	1975-76, 1979-
26	03407920	Buffalo Creek near Winona, Tenn.	36 23 16	84 25 13	42.5	1975-	1975-	1979-
27	03407930	Straight Fork near Norma, Tenn.	36 22 14	84 23 39	17.1	1950		
28	03407940	Buffalo Creek at Winona, Tenn.	36 22 18	84 26 55	64.9	1950-51,1975-	1975-	
29	03407960	Paint Rock Creek near Huntsville, Tenn.	36 24 14	84 26 59	21.5	1975-	1975-	1979-
30	03408000	New River near New River, Tenn.	36 23 03	84 31 43	314	1922-34		
31	03408200	Brimstone Creek near Robbins, Tenn.	36 20 43	84 32 22	48.7	1955-71,1975-	1965,1979-	1979-
32	03408450	Phillips Creek at New River, Tenn.	36 23 10	84 32 59	11.0	1950		
33	03408500	New River at New River, Tenn.	36 23 08	84 33 17	382	1934-	1964-67,1975-	1976-*
34	03408502	New River below New River, Tenn.	36 23 45	84 33 29	383	1933		
35	03408550	North Prong Clear Fork near Grimsley, Tenn.	36 18 25	84 54 35	27.1	1979	1979-	1979-
36	03408600	Long Branch near Grimsley, Tenn.	36 15 32	84 57 40	1.11	1976,1979-	1979-	1979-
37	03408700	Clear Fork at Gatewood, Tenn.	36 17 13	84 50 33	70.2	1979-	1979-	1979-
38	03408800	Clear Fork above Crooked Creek near Burrville, Tenn.	36 19 24	84 47 10	87.9	1965,1970	1965	
39	03408805	Crooked Creek near Jamestown, Tenn.	36 24 42	84 54 41	.68			
40	03408810	Crooked Creek Tributary near Allardt, Tenn.	36 23 30	84 54 43	.25	1976-		
41	03408815	Crooked Creek near Allardt, Tenn.	36 22 59	84 54 50	3.62	1976-	1979-	1979-
42	03408850	Crooked Creek near Burrville, Tenn.	36 19 28	84 47 10	32.0	1970		
43	03408860	Clear Fork near Burrville, Tenn.	36 19 28	84 47 13	120	1929,1979-	1979-	1979-
44	03408900	Clear Fork near Rugby, Tenn.	36 21 02	84 43 46	142	1926,1929		
45	03409000	White Oak Creek at Sunbright, Tenn.	36 14 38	84 40 14	13.5	1929,1932-33, 1955-		
46	03409100	White Oak Creek near Sunbright, Tenn.	36 16 52	84 40 58	21.4	1932		

Site number	Station number	Station name	Location: Latitude (° ' ")	Location: Longitude (° ' ")	Drainage area (mi²)	Period of record: Discharge	Period of record: Water quality	Period of record: Sediment
47	03409350	Bone Camp Creek near Burrville, Tenn.	36 17 12	84 42 15	23.0	1979-	1979-	1979-
48	03409370	Bone Camp Creek near Rugby, Tenn.	36 18 10	84 41 55	26.2	1951		
49	03409380	Black Wolf Creek at Glenmary, Tenn.	36 19 01	84 37 29	21.5	1932		
50	03409395	Black Wolf Creek near Glenmary, Tenn.	36 19 16	84 39 13	31.4	1979-	1979-	1979-
51	03409400	White Oak Creek at Rugby, Tenn.	36 21 12	84 41 26	98.0	1954,1970	1979-	1979-
52	03409410	White Oak Creek near Rugby, Tenn.	36 22 30	84 41 02	103	1951		
53	03409500	Clear Fork near Robbins, Tenn.	36 23 18	84 37 49	272	1930-71,1975-	1964-65,1975-	1976-
54	03409600	Black Creek Tributary near Robbins, Tenn.	36 21 53	84 35 21	.25	1955-62		
55	03410000	Pine Creek Tributary at Oneida, Tenn.	36 30 18	84 30 32	1.21	1932-33, 1950-52,1954		
56	03410010	Pine Creek at U.S. Hwy. 27 at Oneida, Tenn.	36 29 49	84 31 08	5.27	1951-52		
57	03410020	Pine Creek above Sewer Outfall at West Oneida, Tenn.	36 29 58	84 31 54	7.80	1949		
58	03410050	South Fork Cumberland River near Helenwood, Tenn.	36 27 13	84 39 04	712	1925,1952-55		
59	03410070	Lynn Branch near Allardt, Tenn.	36 24 22	84 51 48	.38			
60	03410100	North White Oak Creek at Zenith, Tenn.	36 25 38	84 44 14	51.0	1970		
61	03410200	South Fork Cumberland River near Speck, Tenn.	36 27 36	84 39 58	801	1922		
62	03410210	South Fork Cumberland River at Leatherwood Ford near Oneida, Tenn.	36 28 38	84 40 09	806	1961,1979-	1979-	1979-
63	03410300	Station Camp Creek near Oneida, Tenn.	36 32 42	84 40 02	32.0	1970-71		
64	03410500	South Fork Cumberland River near Stearns, Ky.	36 37 37	84 32 00	954	1942-	1972,1980-	1980-*
65	03410530	Roaring Paunch Creek near Barthell, Ky.	36 40 09	84 29 39		1980	1980-	1980-
66	03410560	Rock Creek at White Oak Junction, Ky.	36 42 10	84 35 44		1980	1980-	1980-
67	03410700	Wolf Creek at Wolf Creek, Ky.	36 43 56	84 33 34		1980	1980-	1980-
68	03411000	South Fork Cumberland River at Nevelsville, Ky.	36 50 25	84 35 00	1271	1915-50		
69	03411100	Sinking Creek near Gregory, Ky.	36 50 21	84 41 25		1980	1980-	1980-
70	03411500	Cumberland River at Burnside, Ky.	36 59 21	84 36 35	4865	1914-50		
71	03412000	Pitman Creek near Somerset, Ky.	37 08 05	84 35 15	26.3	1950-53		
72	03412500	Pitman Creek at Somerset, Ky.	37 07 01	84 35 31	31.3	1953-72		
73	03413000	Cumberland River near Jamestown, Ky.	36 56 00	85 00 00	5331	1938-40		
74	03413200	Beaver Creek near Monticello, Ky.	36 47 51	84 53 46	43.4	1967-		
75	03414000	Cumberland River near Rowena, Ky.	36 53 02	85 06 22	5790	1939-		
76	03414310	Proctor Creek near Celina, Tenn.	36 33 48	85 31 19	9.78	1953		
77	03414340	East Fork Obey River at Obey City, Tenn.	36 11 02	85 09 53	34.6	1975-	1979-	1979-
78	03414346	Hurricane Creek at Camp Ground, Tenn.	36 11 42	85 04 06	15.8	1979-	1979-	1979-
79	03414350	Hurricane Creek near Clarkrange, Tenn.	36 14 30	85 04 05	33.7	1965		
80	03414400	East Fork Obey River near Clarkrange, Tenn.	36 14 03	85 04 06	90.4	1965	1965	
81	03414401	East Fork Obey River below Hurricane Creek near Clarkrange, Tenn.	36 14 16	85 03 51	90.6	1965	1965	
82	03414430	East Fork Obey River near Wilder, Tenn.	36 16 24	85 02 40	117	1979-	1979-	1979-
83	03414470	Buffalo Cove Creek near Boatland, Tenn.	36 23 06	85 00 34	23.4	1965,1979-	1965,1979-	1979-
84	03414500	East Fork Obey River near Jamestown, Tenn.	36 24 58	85 01 35	202	1932-33,1942-	1965,1979-	1979-
85	03414680	West Fork Obey River near Allred, Tenn.	36 18 52	85 10 53	70.8	1975-	1979-	1979-
86	03414700	Puncheon Camp Creek at Allred, Tenn.	36 19 35	85 11 10	15.5	1955-		
87	03415000	West Fork Obey River near Alpine, Tenn.	36 23 49	85 10 28	115	1942-71,1979-	1965,1979-	1979-
88	03415500	Obey River near Byrdstown, Tenn.	36 32 09	85 10 13	445	1938-43		
89	03415700	Big Eagle Creek near Livingston, Tenn.	36 26 57	85 16 27	7.98	1955-		
90	03415960	Wolf River at Wolf River, Tenn.	36 32 14	84 57 09	41.0	1979-	1979-	1979-
91	03415975	Rotten Fork Wolf River near Pall Mall, Tenn.	36 32 20	84 56 56	21.6	1979-	1979-	1979-
92	03415980	Wolf River near Pall Mall, Tenn.	36 32 28	84 57 45	63.5	1979-		
93	03416000	Wolf River near Byrdstown, Tenn.	36 33 37	85 04 23	106	1942-	1964-65,1979-	1979-
94	03416050	Town Branch at Byrdstown, Tenn.	36 34 06	85 07 24	2.21	1968		
95	03416100	Wolf River at State Hwy 42 near Byrdstown, Tenn.	36 36 04	85 07 12	138	1926,1932-33		
96	03417000	Obey River below Dale Hollow Dam, Tenn.	36 32 14	85 27 19	936	1943-		
97	03417490	Obey River at Celina, Tenn.	36 33 21	85 30 38	947	1922		
98	03417500	Cumberland River at Celina, Tenn.	36 33 15	85 30 52	7307	1922-		
99	361252084245300	Bills Branch at Mouth near Hembree, Tenn.	36 12 52	84 24 53	1.17	1975-	1975-	1975
100	365138084271601	Hughes Fork near McCreary, Ky.	36 51 38	84 27 16		1973	1973	
101	365325084280801	Hurricane Branch near McCreary, Ky.	36 53 25	84 28 08		1973	1973	

* Some continuous suspended-sediment data available.

Ground-Water Sites

Site number	Identification number	Well name or ownership	Depth to bottom of sample interval (ft)	Formation or series tapped	Period of water-quality record
	Wells				
1	361017084205600	Rosendale Elem. School at Rosendale, Tenn.			1977
2	361346085003000	Culligan Well near Clarkrange, Tenn.			1977
3	361504084395300	Sunbright Well at Sunbright, Tenn.			1977
4	362157084533000	Burnett Well near Allardt, Tenn.			1977
5	362938084322700	West Coal Well near Oneida, Tenn.			1977
6	363304084475600	Pickett State Park Well near Pall Mall, Tenn.			1977
7	363416085080500	Blan Pierce Well at Byrdstown, Tenn.			1977
8	363658085055700	Conner Rich Well near Static, Tenn.			1977
9	363818084590301	Roy D. Dishman	84	Chesterian Series	1955
10	363821085362201	Bessie Slaughter	93	Lexington Limestone	1952
11	363827085111401	Virgil R. Thacker	--	St. Louis Limestone	1955
12	363830084473301	J. B. Burnett	--		1961
13	363906085264401	Jack Kerr	--	Upper Ordovician Series	1955
14	363959085175801	C. E. Coop	35	St. Louis Limestone	1955
15	364055084454001	Agnes Burnett	62	Chesterian Series	1955
16	364111085200101	R. Parrish	1,655	Knox Dolomite	1968
17	364120084564201	Siesta Oil & Exploration Company	226	Newman Limestone	1966
18	364133085025601	Deller Savage	--	Ste. Genevieve Limestone	1955
19	364210084290901	Albert Hickman	66	Lee Formation	1955
20	364301084502201	Davenport No. 2	--		1961
21	364342084504801	Stanley O. Young	--	Meramerican Series	1955
22	364346085250401	Black Star Coal Corporation	--	Breathitt Formation	1953,1958
23	364413084384801	Sylvester Burke	--	Glen Dean Limestone	1954
24	364434085120601	Charlie Albertson	--		1955
25	364456084535301	Flonnie Denny	--	Meramerican Series	1955
26	364458085121701	R. S. Brown	1,200	Stones River Group	1965
27	364615085100701	Ada Butler	--		1961
28	364625085202301	Cominco American Co. Burkesville Well 235	--	Knox Dolomite	1975
29	364636085053301	Earl York	31	Warsaw Formation	1955
30	364749085165801	J. Radford	--	Warsaw Formation	1955
31	364944084441001	Lyle Morrow	--	St. Louis Limestone	1969
32	365002084505801	Monticello Munic. Water Co.	55	St. Louis Limestone	1951,1957
33	365036085165901	Seymour Oil Co.	105	Leipers Limestone	1967
34	365038085044201	Jessie Starmes	--	Osagean Series	1955
35	365057085104501	G. Loy and L. Frost	--	Lexington Limestone	1968

Site number	Identification number	Well name or ownership	Depth to bottom of sample interval (ft)	Formation or series tapped	Period of water-quality record
	Wells--Continued				
36	365137084271301	E. Taylor #20	--	Lee Formation	1958-60, 1966
37	365137084271401	E. Taylor #21	--	Lee Formation	1958-60, 1966
38	365138084264101	E. Taylor #12	--	Lee Formation	1958-67, 1968-
39	365139084271001	E. Taylor #19	--	Lee Formation	1958-60, 1966
40	365143084264801	E. Taylor #16	--	Lee Formation	1958-66
41	365143084270401	E. Taylor #18	--	Lee Formation	1958-60
42	365144084270201	E. Taylor #17	--	Lee Formation	1958-60, 1966
43	365144084271701	Unknown	--	Lee Formation	1958
44	365209085210601	T. Sprouls	25	Upper Ordovician Series	1955
45	365223084293501	L. Corder	--	Lee Formation	1958
46	365328085273801	B. Garmon	41	Sellersburg and Jeffersonville Limestones equivalents	1956
47	365422085114801	C. F. Mann	21	Lexington Limestone	1956
48	365530084454201	Flora Denny	59	St. Louis Limestone	1955
49	365542084473301	Robert West	210	Fort Payne Formation	1967
50	365603084463901	Commonwealth of Kentucky	--	St. Louis Limestone	1955
51	365736085025901	Ms. Floyd Cothem	--	Menard Limestone	1956
52	365749084263601	T. F. Thompson	236	Pennington Formation	1969
53	365752085260301	Sellie Reese	--	Menard Limestone	1956
54	370054084563801	C. O. Tucker	50	Salem Limestone	1956
55	370313084545801	H. C. Gosser	28	Menard Limestone	1956
56	370421085040301	City of Russel Springs	--		1952,1957
57	370947084423901	E. W. Jasper	31	New Albany Shale	1955
58	371051084262101	Melvin O. Taylor	91	Menard Limestone	1955
59	371620084370001	Harold Sanders		St. Louis Limestone	
60	371932084341201	C. Leslie Littrell	--		1955
61	372318084361501	J. Wilcop	29	Osagean Series	1953

Note: Records of continuous water-levels are available for the following wells:
Site 38 from 1959 to current year
site 59 from 1954 to current year

Site number	Identification number	Spring name	Depth to bottom of sample interval (ft)	Formation or series tapped	Period of water-quality record
	Springs				
62	364110085080101	Albany Munic. Water Co.			1951
63	364119085121001	Caney Branch Church			1955
64	364132085082801	George Hancock			1956-63
65	364437085232001	D. O. Stapp			1955
66	364524085051201	Garrett Spring			1956-63
67	364531084302801	Alvin Angle			1954
68	364607085211801	Ernest Garner			1959
69	364750084535201	Golie Sexton			1959-63
70	364942084505901	City of Monticello, Ky.			1955-
71	365046085375801	Emberton			1955
72	365217084292101	U. S. Park Service			1958
73	365226084293001	L. Corder			1958
74	365753084050701	O. Grissom			1960-62
75	365837085030501	Jamestown Public Water			1952
76	370409084261001	S. L. Dykes			1955
77	371227084490501	Dewitt Roy			1955
78	371417084412301	O. E. Blevins			1955

Average annual and range in monthly flow per square mile at selected sites

Site number	Drainage area (mi^2)	Period of record	Average annual flow [(ft^3/s)/mi^2]		Minimum, mean, and maximum monthly flow [(ft^3/s)/mi^2] OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP
3	0.85	1956-74	1.22	Min	.141	.176	.165	.247	.918	1.01	.435	.271	.176	.165	.153	.118
				Mean	.329	.859	1.89	2.45	2.99	3.08	2.47	1.35	.694	.600	.365	.341
				Max	.859	3.99	4.16	9.15	7.95	6.54	5.15	3.82	2.27	2.59	1.46	.988
4	165	1953-79	1.70	Min	0.00	0.00	.002	.842	.457	.848	.346	.235	.069	.016	.002	.001
				Mean	.454	.891	2.60	2.94	3.30	3.45	2.62	1.47	.933	.764	.409	.691
				Max	4.43	3.61	15.01	8.83	9.52	9.36	6.18	4.63	4.76	3.75	1.87	6.37
30	314	1923-35	2.01	Min	.010	.072	.631	1.60	1.66	1.54	1.12	3.69	.078	.046	.005	.007
				Mean	.338	1.38	2.98	3.62	3.96	4.23	2.84	2.05	1.14	.589	.529	.328
				Max	1.72	5.08	9.28	6.39	6.89	11.37	5.28	5.40	7.21	1.68	.258	1.39
33	382	1935-79	1.95	Min	.002	.006	.115	.246	.293	1.50	.565	.159	.012	.010	.015	.007
				Mean	.335	1.23	2.82	3.92	4.02	4.30	2.94	1.72	.809	.749	.416	.277
				Max	1.97	7.02	7.67	11.01	10.19	11.44	6.71	8.10	3.13	5.20	3.03	2.94
53	272	1931-71	1.71	Min	.007	.018	.105	.175	.518	1.22	.559	.236	.035	.024	.032	.011
				Mean	.180	.765	2.27	3.35	4.01	3.93	2.72	1.51	.662	.596	.382	.237
				Max	.732	4.79	8.04	12.57	10.27	10.14	6.15	3.85	1.79	4.12	3.46	2.70
64	954	1943-79	1.89	Min	.022	.032	.157	.523	.760	1.50	.603	.235	.112	.036	.069	.031
				Mean	.404	1.24	2.79	3.71	3.86	4.07	2.78	1.71	.826	.693	.421	.311
				Max	1.75	4.78	7.30	10.08	9.17	11.09	6.33	5.87	2.92	3.95	3.14	2.31
68	1,271	1915-50	1.73	Min	.031	.045	.225	.231	.392	1.32	.634	.223	.045	.030	.032	.023
				Mean	.364	1.07	2.09	3.65	3.41	3.78	2.49	1.54	.925	.652	.573	.334
				Max	2.63	4.15	9.54	11.50	9.39	8.78	4.94	4.42	6.70	3.38	3.85	1.69
70	4,865	1915-50	1.57	Min	.025	.030	.129	.214	.331	1.24	.619	.245	.045	.027	.031	.017
				Mean	.309	.835	1.84	3.36	3.18	3.40	2.27	1.44	.874	.682	.458	.252
				Max	1.74	3.09	8.28	10.13	8.09	8.22	4.44	4.13	3.72	2.99	1.77	.975
72	31.3	1954-72	1.39	Min	.010	.014	.022	.754	.537	.681	.329	.281	.108	.032	.032	.023
				Mean	.185	.546	1.78	2.22	3.35	3.23	2.41	1.20	.674	.610	.358	.251
				Max	1.07	2.88	4.25	6.10	8.98	6.29	5.18	4.34	3.35	3.18	1.51	1.34
74	43.4	1969-79	1.65	Min	.060	.080	.629	.908	.666	.993	.654	.431	.123	.082	.062	.082
				Mean	.400	.846	2.35	3.11	2.72	3.36	3.00	1.35	.986	.622	.643	.419
				Max	1.72	1.72	6.77	6.11	4.45	11.04	5.39	3.69	3.82	2.33	2.86	1.72
75	5,790	1940-49	1.33	Min	.029	.036	.135	.232	.353	1.24	.819	.286	.165	.031	.101	.045
				Mean	.146	.542	1.33	2.68	2.90	3.25	2.20	.974	.627	.807	.420	.160
				Max	.637	1.29	4.45	5.87	5.97	5.62	3.72	1.87	1.38	2.73	1.52	.504
84	202	1943-79	2.09	Min	.024	.040	.109	.460	.797	1.78	.866	.330	.138	.048	.050	.036
				Mean	.426	1.33	3.02	4.02	4.32	4.64	3.20	1.98	.871	.683	.336	.378
				Max	2.03	4.82	8.43	11.15	9.41	14.34	6.78	8.00	2.99	4.76	1.36	2.45
87	115	1943-71	1.38	Min	.033	.040	.055	.238	.690	1.18	.598	.204	.107	.064	.053	.044
				Mean	.165	.694	1.81	2.63	3.30	3.23	2.20	1.10	.610	.435	.254	.206
				Max	.476	3.34	6.01	8.90	7.58	7.47	4.59	3.10	2.31	2.84	1.23	1.59
88	445	1919-43	1.69	Min	.046	.054	.225	.217	.506	1.17	.845	.308	.083	.068	.042	.048
				Mean	.283	.973	2.06	2.93	3.36	3.91	2.78	1.48	.892	.578	.609	.380
				Max	1.88	4.42	9.79	10.40	8.16	9.19	5.08	3.73	6.63	2.82	2.98	2.51
93	106	1943-79	1.81	Min	.058	.074	.123	.429	.760	1.25	.728	.291	.153	.076	.090	.068
				Mean	.310	1.05	2.53	3.45	3.75	4.10	2.82	1.52	.930	.636	.442	.341
				Max	1.61	3.89	7.33	9.81	9.25	14.23	7.01	4.24	3.70	2.25	5.13	1.41

Range of suspended-sediment yield and corresponding discharge and total recoverable iron for selected sites

Site no.	Station name	Maximum sediment yield (tons/d)/mi²	Corresponding discharge (ft³/s)/mi²	Corresponding total recoverable iron (µg/L)	Minimum sediment yield (tons/d)/mi²	Corresponding discharge (ft³/s)/mi²	Corresponding total recoverable iron (µg/L)
2	West Fork Cane Branch near Parkers Lake, Ky.	381	115	--	0.0031	0.192	--
4	Buck Creek near Shopville, Ky.	.552	3.72	--	.0002	.0109	--
6	New River at Fork Mountain, Tenn.	.0712	2.64	400	.0009	.0237	510
11	New River at Stainville, Tenn.	.258	3.65	1,200	.0021	.0955	380
12	Beech Fork at Shea, Tenn.	.0860	1.08	1,400	.0043	1.58	280
14	Green Branch near Hembree, Tenn.	.0797	1.01	890	.0797	1.01	890
16	Smoky Creek at Hembree, Tenn.	.256	2.33	--	.0003	.0535	300
18	Smoky Creek at Smoky Junction, Tenn.	.945	5.18	1,200	.0024	.0305	1,500
22	Montgomery Fork at Montgomery, Tenn.	.633	2.17	4,900	.0005	.0543	190
25	New River at Cordell, Tenn.	105	39.4	--	.0004	.0192	310
26	Buffalo Creek near Winona, Tenn.	38.8	39.1	10,000	.0012	.0471	790
28	Buffalo Creek at Winona, Tenn.	.770	3.54	---	.770	3.54	--
29	Paint Rock Creek near Huntsville, Tenn.	19.8	8.14	24,000	.0028	.0791	660
31	Brimstone Creek near Robbins, Tenn.	14.4	7.58	18,000	.0008	.0201	690
33	New River at New River, Tenn.	547	92.1	83,000	.0004	.0314	470
35	North Prong Clear Fork near Grimsley, Tenn.	.0262	1.07	330	.0004	.0114	510
36	Long Branch near Grimsley, Tenn.	.0721	.739	1,300	.0008	.0090	4,400
37	Clear Fork at Gatewood, Tenn.	.513	1.84	3,200	.0001	.0111	760
41	Crooked Creek near Allardt, Tenn.	.0470	1.60	1,000	.0004	.0414	630
43	Clear Fork near Burrville, Tenn.	.0633	1.97	490	.0003	.0192	180
47	Bone Camp Creek near Burrville, Tenn.	.0652	2.00	460	.0013	.0826	480
50	Black Wolf Creek near Glenmary, Tenn.	.0318	1.53	570	.0029	.0188	370
51	White Oak Creek at Rugby, Tenn.	3.31	6.72	1,100	.0000	.0014	360
53	Clear Fork near Robbins, Tenn.	40.8	92.3	4,900	.0000	.0066	480
62	South Fork Cumberland River at Leatherwood Ford near Oneida, Tenn.	.0831	2.56	660	.0022	.0633	610
64	South Fork Cumberland River near Stearns, Ky.	.421	3.19	890	.0008	.0577	140
77	East Fork Obey River at Obey City, Tenn.	5.35	28.3	3,700	.0318	1.68	2,300
78	Hurricane Creek at Camp Ground, Tenn.	13.3	53.4	3,200	.0000	.0013	430
82	East Fork Obey River near Wilder, Tenn.	12.0	29.5	7,600	.0026	.0300	28,000
83	Buffalo Cove Creek near Boatland, Tenn.	9.74	21.6	2,200	.0013	.205	160
84	East Fork Obey River near Jamestown, Tenn.	17.9	37.8	8,000	.0002	.0495	300
85	West Fork Obey River near Allred, Tenn.	7.68	20.1	3,900	.0010	.169	170
87	West Fork Obey River near Alpine, Tenn.	21.1	41.4	5,600	.0003	.130	160
90	Wolf River at Wolf River, Tenn.	24.4	42.7	5,200	.0022	.415	230
91	Rotten Fork Wolf River near Pall Mall, Tenn.	28.5	27.7	3,900	.0032	.0926	380
93	Wolf River near Byrdstown, Tenn.	2.27	10.4	--	.0014	.170	200
98	Cumberland River at Celina, Tenn.	.0011	.104	--	.0011	.104	--

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