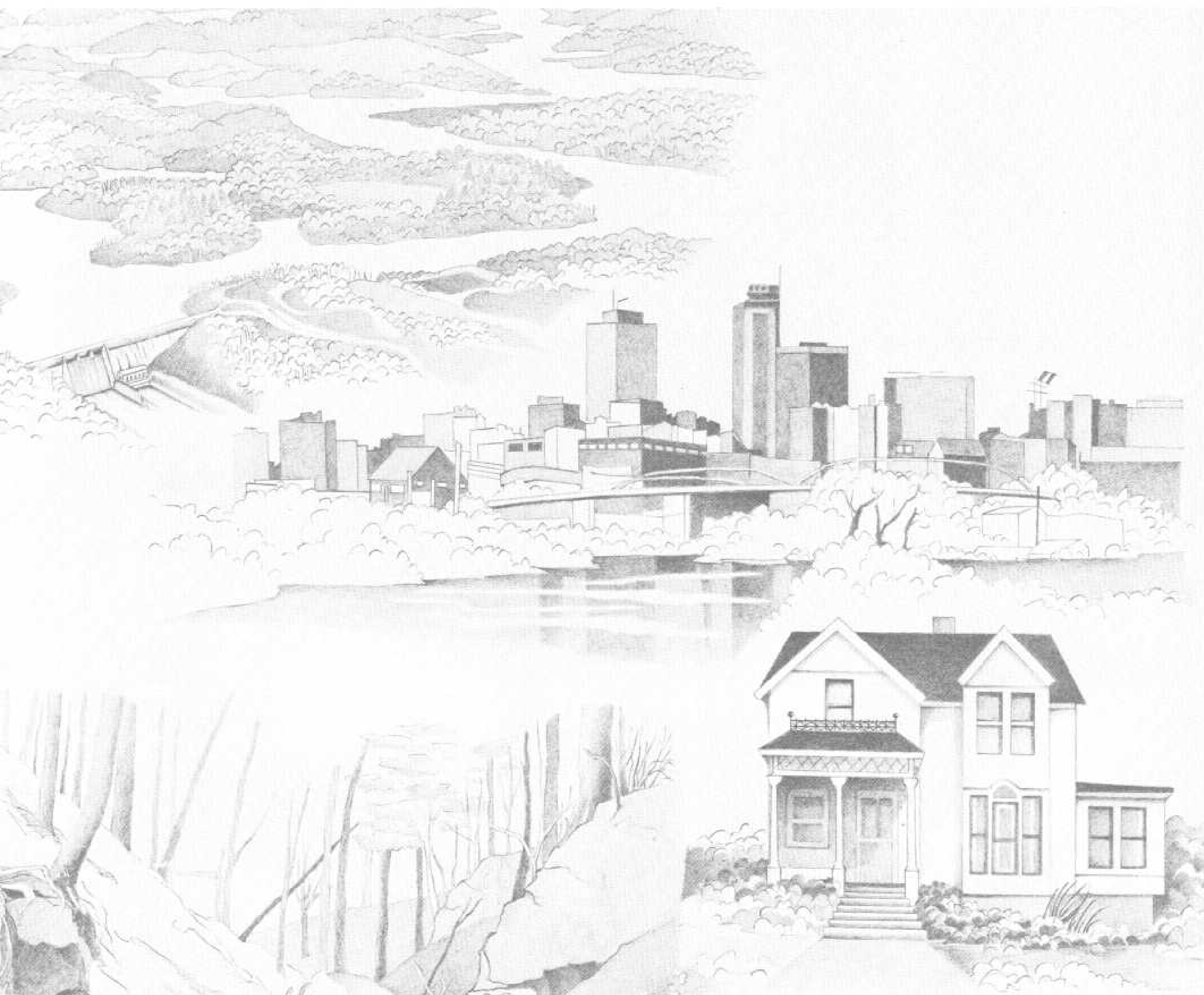
WATER-RESOURCES INVESTIGATIONS REPORT 84-4074

# DROUGHT-RELATED IMPACTS ON MUNICIPAL AND MAJOR SELF-SUPPLIED INDUSTRIAL WATER WITHDRAWALS IN TENNESSEE--PART B





Prepared by
U. S. GEOLOGICAL SURVEY

in cooperation with
TENNESSEE DEPARTMENT OF HEALTH AND ENVIRONMENT, Division of Water Management
TENNESSEE VALLEY AUTHORITY, Office of Natural Resources and Economic Development, Division of Air and Water Resources, Regional

Figure 13--Explanation

| Site No. | Facility name |
|---|---|
| 1 | Levi Strauss and Co. (Centerville) |
| 2 | M. C. West and Co. (Columbia) |
| 3 | Lewis Products (Hohenwald) |
| 4 | Lewisburg Materials (Lewisburg) |
| 5 | Dupont E.I. DeNemours and Co., Inc. (Columbia) |
| 6 | Occidental Chemical Corp., Godwin Washer Plant (Columbia) |
| 7 | Occidental Chemical Corp., Williamsport Washer Plant (Columbia) |
| 8 | Occidental Chemical Corp., Furnace Plant (Columbia) |
| 9 | Monsanto Industrial Chemicals Co. (Columbia) |
| 10 | Presnell Phosphate Co., Inc. (Columbia) |
| 11 | Stauffer Chemical Co., Inc. (Mount Pleasant) |
| 12 | Stauffer Chemical Co., Globe Plant (Mount Pleasant) |
| 13 | Stauffer Furnace Plant (Mount Pleasant) |
| 14 | True Temper Corp. (Waynesboro) |

## Water-Supply Adequacy Analysis

About 3,500 mi$^2$ or 2,240,000 acres of land and water area are drained by the Duck-Buffalo River basin. This basin's surface- and ground-water supplies are replenished by extensive rainfall whose long-term (1941-70) average equals 52.01 inches. Average annual runoff in this basin ranges from about 21 to 24 inches as one moves eastward across the basin. Generally, the months of August through October are the driest months with the greatest precipitation coming during the first 3 months of the year.

Average daily water use for public and self-supplied commercial and industrial water users exceeding 0.1 Mgal/d in the Duck-Buffalo River basin equals approximately 71.2 Mgal/d. Of this amount, about 23.1 Mgal/d are withdrawn for public-water supply use with 19.0 Mgal/d or 82 percent coming from surface-water sources and 4.1 Mgal/d or 18 percent from ground-water sources. Water use by self-supplied commercial and industrial facilities equals about 48.2 Mgal/d with 47.7 Mgal/d or 99 percent being supplied by surface-water resources and 0.5 Mgal/d or 1 percent from ground-water resources. Major self-supplied water users in this basin include Occidental Chemical Corp. (9.5 Mgal/d) and Monsanto Industrial Chemicals Co. (33.1 Mgal/d) in Maury County. Consumptive water use by self-supplied commercial and industrial facilities equals about 2.5 Mgal/d.

The majority of this basin's public and self-supplied commercial and industrial water use is supplied by surface-water resources. This is due primarily to the existence of large surface-water resources such as Normandy Reservoir, the Duck and Buffalo Rivers, and the limited ground-water development studies which have been completed in the basin to date. However, it is possible for trained geo-

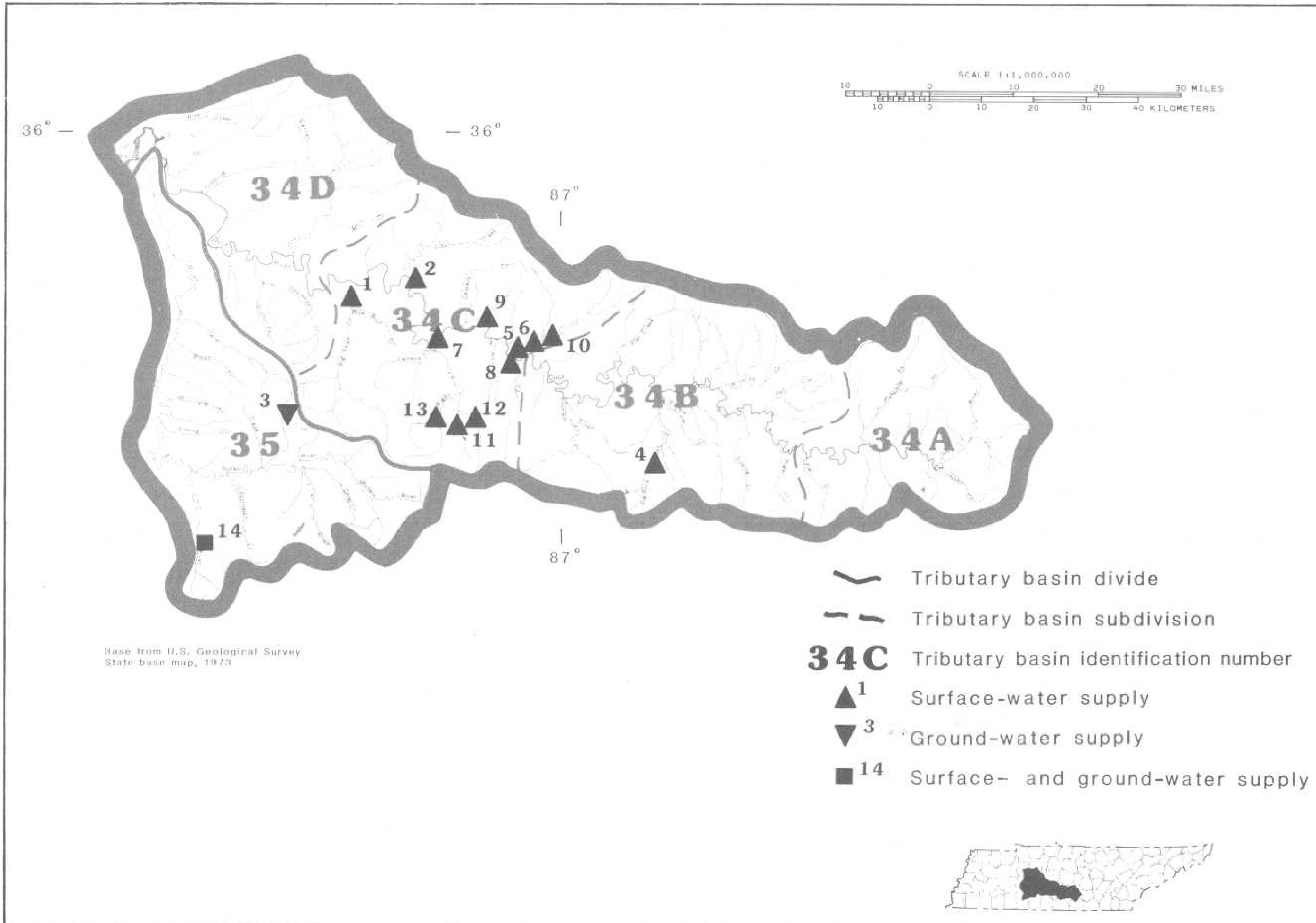



**Figure 13.--Self-supplied commercial and industrial water users, Duck-Buffalo River basin.**

hydrologists to locate well sites in the Highland Rim and Central Basin areas which could be expected to yield about 0.100 to 0.150 Mgal/d of good quality water at depths ranging from about 100 to a maximum of 300 feet.

Analysis of the public water-supply and self-supplied water user inventories indicates that a number of users are utilizing surface- and ground-water resources as their primary, and frequently only, supply source whose source capacity is either unknown or less than the user's average daily use. Specific public water systems included are the Bon Aqua Lyles UD in Hickman County; Mount Pleasant WS in Maury County; and Summertown WS in Lawrence County. Self-supplied commercial and industrial facilities included in this group are Lewis Products in Lewis County; Lewisburg Materials in Marshall County; Presnell Phosphate and Stauffer Chemical Co. in Maury County; and True Temper Corp. in Wayne County. While several of these systems and self-supplied users also purchase a part of their daily water supply from neighboring public water-supply systems which could probably provide additional water if needed, some of these systems and users may face periodic water-supply shortages during periods of extreme and (or) extended drought conditions.

Water systems which are currently utilizing surface- and (or) ground-water resources which are inadequate or of unknown capacity should consider exploring the availability of alternative, cost-effective water-supply sources to augment or meet their future water needs if necessary. While the basin's water resources are subject to contamination from a variety of sources, existing and pending Federal, State, and local statutes relative to water-quality protection and maintenance or improvement should ensure that current water quality will be maintained with little, if any, future degradation of the basin's water resources. Potential sources of contamination include (1) leachate from municipal and industrial water disposal facilities and septic tank systems; (2) agricultural pollution from fertilizers, pesticides and herbicides, and livestock wastes; and (3) runoff from surface mine lands and quarries.

Although there are periods of extended drought which cause seasonal water table declines and periodic local problems with adequate ground-water supplies, observation well data indicate there are no long-term, regional water table declines. Periodic local problems associated with a decline in an area's water table are caused by excessive withdrawals. To alleviate this problem, optimum ground-water withdrawal rates should be determined during the initial test pumping of the source.

## ELK-SHOAL RIVER BASIN

### Basin Description

The Elk-Shoal River basin encompasses 3,041 $mi^2$ of land and water area in Tennessee and consists of all or parts of the following tributary basins as delineated by the Geological Survey and Tennessee Department of Water Management in 1982.

| Tributary basin No. (fig. 14) | Basin description | Tennessee drainage area (square miles) |
|---|---|---|
| 25 | Tennessee River north-side minor tributaries from the mouth of the Sequatchie River including Crow Creek to the Tennessee-Alabama State line. | 326 |
| 26 | Tennessee River north-side minor tributaries above the Elk River to the Tennessee-Alabama State line. | 212 |
| 27A | Elk River headwaters to just above Beans Creek. | 569 |
| 27B | Elk River from just above Beans Creek to just above Richland Creek. | 726 |
| 27C | Richland Creek | 488 |
| 27D | Elk River from below Richland Creek to the Tennessee-Alabama State line. | 216 |
| 28A | Tennessee River north-side minor tributaries including the Shoal Creek area from just above Bluewater Creek to just below Butler Creek to the Tennessee-Alabama State line. | 454 |
| 28B | Tennessee River north-side minor tributaries from just below Anderson Creek to just below Second Creek to the Tennessee-Alabama State line. | 50 |

Hydrologically, the Elk-Shoal River basin includes all or major parts of Franklin, Giles, Lawrence, Lincoln, and Moore Counties and minor parts of Coffee, Grundy, Marion, Marshall, and Wayne Counties. A map of the west-central Tennessee part of the Tennessee River basin which highlights the Elk-Shoal River basin is shown in figure 14.

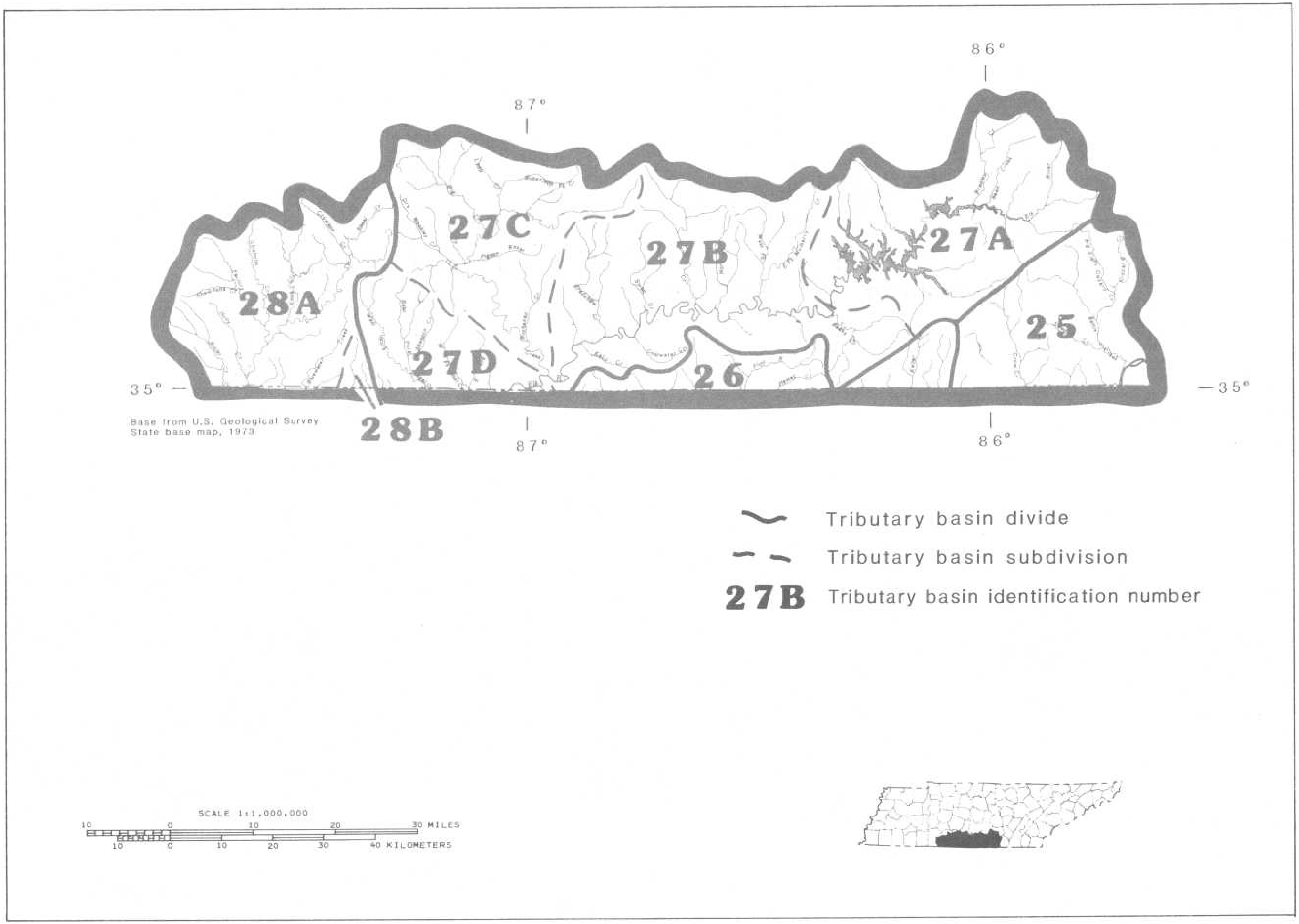



**Figure 14.--Elk-Shoal River basin.**

## Topography

This basin's topography is characterized by gently rolling to hilly terrain with some nearly level areas and meandering, low-gradient streams. Major streams and tributaries draining the Elk-Shoal River basin are:

- Elk River. Bean, Bluewater, Butler, Cane, Coldwater, Hurricane, Mulberry, Richland, and Sugar Creeks.
- Tennessee River Minor Tributaries. Flint River plus Battle, Crow, Hester, Keller, and Shoal Creeks.

Average stream slopes on the Elk River range from 1.56 ft/mi from the Tennessee-Alabama State line to river mile 90 and 2.87 ft/mi from river mile 90 to river mile 160. Basin elevations generally range from 600 to 1,800 feet with a maximum elevation of 2,000 feet above sea level.

## Hydrology

### Surface Water

This basin's surface- and ground-water resources are fed by ample rainfall whose long-term (1941-70) average equals 52.01 inches. During the 10-year period from 1970-79, average annual precipitation equaled 58.81 inches and ranged from a low of 47.57 inches in 1978 to a high of 68.48 inches in 1973. Average precipitation data for watershed subdivisions of the Elk-Shoal River basin during the 1970-79 time period are summarized in table 17. Annual 1979 and long-term (1941-70) precipitation data for selected TVA rainfall stations in the Elk-Shoal River basin in Tennessee are presented in table 18.

The months of August, September, and October are usually the driest with the average rainfall ranging from 2.57 to 3.54 inches. During the remainder of the year, average rainfall ranges from 4.05 to 5.72 inches with March having the greatest rainfall. More specifically, in the Elk-Shoal River basin an analysis of the long-term precipitation records for the 1941-70 period for selected rainfall stations (Elkhead, Pulaski, Smithtown, and Tims Ford Dam) indicates that the driest months of the year are normally June, August, and October with precipitation ranging from 3.16 to 4.11 inches. During the rest of the year, rainfall ranges from 4.15 to 7.30 inches. March is usually the wettest month.

Average annual runoff in this basin generally ranges from 24 to 30 inches with the heaviest runoff occurring in the headwaters area and eastern part of the basin. Average discharge data for selected hydrologic data stations in the Elk-Shoal River basin are summarized in table 19. The majority of this runoff occurs during the winter and spring months. It is not uncommon in the late summer and fall months during extended drought periods for small, unregulated streams to go dry, particularly along the basin's rim.

### Major Reservoirs

Major reservoirs located in this basin and their total storage in acre-feet at normal minimum pool are Tims Ford Reservoir (325,400) and Woods Reservoir

Table 17.--Precipitation data by station subdivision for the period 1970-79, Elk-Shoal River basin

| | Precipitation (inches) | | | | |
|---|---|---|---|---|---|
| Watershed description | High | Year | Low | Year | 10-year average |
| Tennessee River from Florence to Decatur, Ala. | 70.00 | 1975 | 45.20 | 1978 | 57.53 |
| Shoal Creek upstream from Iron City. | 72.90 | 1973 | 47.50 | 1978 | 60.67 |
| Elk River from Fayetteville to the Tennessee-Alabama State line. | 70.40 | 1973 | 49.10 | 1978 | 60.11 |
| Elk River upstream from Fayetteville. | 71.40 | 1973 | 45.40 | 1978 | 60.01 |
| Tennessee River from Decatur to Guntersville, Ala. | 71.20 | 1975 | 46.50 | 1978 | 59.00 |
| Flint River upstream from Chase, Ala. | 69.80 | 1973 | 44.80 | 1978 | 58.40 |
| Paint Rock River upstream from Woodville, Ala. | 71.10 | 1973 | 41.90 | 1978 | 61.26 |
| Tennessee River from the Tennessee-Alabama State line to Nickajack Dam. | 69.90 | 1977 | 42.90 | 1978 | 60.57 |
| Tennessee River from Nickajack Dam to Chickamauga Dam. | 71.40 | 1973 | 45.20 | 1978 | 60.32 |

Table 18.--Precipitation data for 1979 and for the period 1941-70 for selected rainfall stations, Elk-Shoal River basin

| Station location | Station owner | Elevation above sea level (feet) | Period of record (years) | 1979 Precipitation (inches) | Long-term annual precipitation (inches) |
|---|---|---|---|---|---|
| Elk River | | | | | |
| Bethel | TVA | 605 | 45 | 67.69 | 54.44 |
| Pulaski | TVA | 655 | 14 | 73.31 | 59.27 |
| Campbellsville | TVA | 770 | 13 | 70.38 | 58.34 |
| Lynnville | TVA | 740 | 91 | 68.44 | 54.11 |
| Diana | TVA | 725 | 19 | 60.17 | 55.92 |
| Fayetteville | TVA | 750 | 8 | 69.67 | 61.73 |
| Belleville | TVA | 755 | 38 | 70.99 | 58.70 |
| Charity Church | TVA | 810 | 13 | 62.60 | 56.04 |
| Tims Ford Dam | TVA | 770 | 12 | 65.29 | 57.14 |
| Tullahoma | TVA | 1,065 | 13 | 79.32 | 64.70 |
| Winchester | TVA | 960 | 40 | 58.06 | 51.27 |
| Estill Springs | TVA | 916 | 12 | 59.30 | 50.90 |
| Hillsboro | TVA | 1,060 | 30 | 62.88 | 55.52 |
| Elkhead | TVA | 1,045 | 19 | 62.38 | 57.05 |
| Tennessee River Minor Tributaries | | | | | |
| Elora | TVA | 930 | 38 | 63.00 | 54.78 |
| Smithtown | TVA | 670 | 29 | 74.73 | 60.74 |
| Sewanee | TVA | 1,920 | 86 | 75.27 | 60.59 |

Table 19.--Average discharge data for selected hydrologic data stations, Elk-Shoal River basin

| Station name and location (county) | River mile | Drainage area (square miles) | Period of record (years) | Average discharge: Cubic feet per second | Average discharge: Inches per year | Average discharge: Cubic feet per second per square mile |
|---|---|---|---|---|---|---|
| Tennessee River at South Pittsburg (Marion). | 418.2 | 22,640 | 50 | 38,070 | - | 1.68 |
| Elk River near Pelham (Grundy). | 194.2 | 65.6 | 29 | 143 | 29.60 | 2.18 |
| Elk River near Estill Springs (Franklin). | 167.3 | 275 | 60 | 492 | 24.30 | 1.79 |
| Elk River upstream from Fayetteville (Lincoln). | 93.9 | 827 | 46 | 1,461 | 23.99 | 1.77 |
| Elk River near Prospect (Giles). | 41.5 | 1,784 | 64 | 3,103 | 23.62 | 1.74 |
| Shoal Creek at Lawrenceburg (Lawrence). | 55.9 | 55.4 | 14 | 114 | 27.94 | 2.06 |
| Chisholm Creek at Westpoint (Lawrence). | 1.2 | 43.0 | 18 | 89.3 | 28.20 | 2.08 |
| Shoal Creek at Iron City (Lawrence). | 22.3 | 348 | 55 | 655 | 25.56 | 1.88 |

(10,700). More detailed information describing the location and operation pattern of these reservoirs follows.

### Tims Ford Reservoir

Location and drainage area.--Tims Ford Reservoir is formed by Tims Ford Dam which is located on the Elk River at river mile 133.3 in Franklin County. Tims Ford Dam controls 529 $mi^2$ of drainage area.

Reference period.--1969-81.

Reservoir discharge (minimum daily average flow).--During the reference period, minimum daily average discharge from Tims Ford Dam ranged from a low of about 2.0 $ft^3/s$ (1.3 Mgal/d) in 1971 to a high of about 255.0 $ft^3/s$ (164.8 Mgal/d) in 1974. The average, 1-day minimum discharge for the reference period was about 52.0 $ft^3/s$ (33.6 Mgal/d).

Average number of days of zero flow.--From 1969-81, Tims Ford Dam has averaged almost 51 days of zero discharge per year ranging from a low of no days of zero discharge in 1969 to a high of 138 days of zero discharge in 1971. Zero-discharge days were most common during the months of March, April, and May. During the reference period, there were 43 instances of zero discharge for 3 or more consecutive days from Tims Ford Dam. In nine of these instances, consecutive days of zero discharge from Tims Ford Dam ranged from a low of 9 days in 1970 to a high of 92 days in 1971.

Existing agreements regarding reservoir releases.--Tims Ford Dam is operated whenever necessary to maintain a minimum average daily flow of about 106.0 $ft^3/s$ (68.5 Mgal/d) in the Elk River at Fayetteville. On weekends from Memorial Day through September, these releases are scheduled to enhance aquatic life habitat and opportunities for canoeing and fishing.

### Woods Reservoir

Woods Reservoir is formed by Elk River Dam which is located on the Elk River at river mile 170.0 in Coffee and Franklin Counties. Elk River Dam controls 263 $mi^2$ of drainage area. Discharges from Woods Reservoir during the period from 1920-81 have ranged from a low of about 10.0 $ft^3/s$ (6.5 Mgal/d) in 1925 to a high of about 38,100 $ft^3/s$ (24,612.6 Mgal/d) in 1973. The average daily discharge during that period was about 487.0 $ft^3/s$ (314.6 Mgal/d).

## Ground Water

The Elk-Shoal River basin extends across parts of the Cumberland Plateau, Highland Rim, and Central Basin physiographic provinces. Only a very small area of the Cumberland Plateau as compared with the total area of the basin lies in Grundy, Coffee, and Franklin Counties in the extreme eastern part of the Elk-Shoal River basin. Ground water there occurs in fractures in tightly cemented sandstone. As this siliceous rock is resistant to the solvent action of ground water, the fractures are not solutionally enlarged. Consequently, ground water is difficult to obtain in significant quantities and yields to drilled wells are generally low, usually no more than 25 gal/min. Also, this area of the Elk-Shoal River basin lies on the dissected western escarpment of the Plateau where a considerable amount of ground water is discharged from springs. This situation is partly responsible for the low yields of wells. Therefore, the potential for obtaining ground-water supplies in this relatively small area other than amounts for domestic purposes is probably low on the basis of present information. The yields of springs discharging from the sandstone in this area are generally low and usually no more than 5 gal/min. Water from wells, which are generally no deeper than 200 feet, may be high in iron and is usually acidic due to dissolved carbon dioxide.

The Highland Rim physiographic province is an old erosion surface lying some 1,000 feet lower topographically than the Cumberland Plateau. The Elk-Shoal River basin extends across parts of the eastern, southern, and western Highland Rim. There are two modes of occurrence of ground water on the Highland Rim. One is at or near the contact point between the relatively thick regolith and the underlying limestone. This residual blanket, composed primarily of clay, chert blocks and fragments, siliceous silt, and some sand; is generally 30 feet or more in thickness and sometimes reaches 100 feet in thickness. The regolith is capable of storing a large amount of water but commonly furnishes a relatively small amount of water, 25 gal/min or less, to dug or drilled wells. However, a chert rubble zone sometimes occurs at or a few feet above the top of the underlying rock and is capable of furnishing several hundred gallons of water per minute to wells. An occurrence of this zone is found in the vicinity of Tullahoma where it furnishes water in sufficient amounts for industrial purposes. Water quality is usually good; however, it is often acidic due to dissolved carbon dioxide. If the water is to be used to augment a surface supply for a public system, it may require treatment to raise the pH so as to achieve compatibility.

The other occurrence of ground water on the Highland Rim is in solutionally enlarged joints (cracks) and bedding plane openings in limestone. These cracks, caused by the structural upwarping of the Nashville Dome, are subject to the dissolving action of downward percolating ground water. They are generally largest near the rock surface and in perennial stream valleys become smaller at increased depth. Most often the cracks are not significantly enlarged at depths below 250 feet. Consequently, on the basis of present information, it is not advisable to drill much deeper. Also, the chance of encountering relatively high mineral water increases with depth. Drilling into one of these water-filled openings is a "hit-or-miss" proposition and wells drilled into rock commonly gain no additional water after passing through the regolith. However, some wells encounter rather large openings within the first 100 feet below the top of rock and provide yields of 100 gal/min or more. Water quality is usually good but may be somewhat acidic. Springs are common, particularly along or near the escarpment of the Cumberland Plateau, and range in yield from a few gallons per minute to some 1,200 gal/min.

The Highland Rim is underlain at various depths by the Chattanooga Shale. The Chattanooga is a carbonaceous black shale which, when present, acts as an impervious barrier to the downward migration of ground water. It is present in most areas of the Highland Rim escarpment surrounding the Central Basin where it is nearer the land surface. Its impervious nature causes its top to be a prominent spring horizon wherever it crops out along the Highland Rim escarpment. These springs issuing from the overlying limestone are often relatively large-yielding, as much as 1,000 gal/min, particularly during the rainy season. The yields of these springs fluctuate seasonally but, because of the Highland Rim regolith's ability to store large quantities of water, they do not decrease in flow as much as most limestone springs, particularly as much as those on the floor of the Central Basin. As stated before, the Chattanooga Shale is generally nearer the land surface along the escarpment surrounding the Central Basin and on the spurs and outliers of the Highland Rim extending into the Basin. Due to its impervious character almost all of the wells encountering water-filled openings beneath the shale yield water too highly mineralized to be economically treated. Consequently, it is advisable not to drill below the top of the shale. Where the Chattanooga Shale is near the surface, small quantities of water are sometimes encountered in joints in the shale. However, since the Chattanooga Shale contains considerable quantities of the mineral pyrite (iron sulfide), this water is high in hydrogen sulfide and compounds of iron. The same is true for any springs that might issue from it.

A relatively small part of the Elk-Shoal River basin lies in the Central Basin physiographic province. The Central Basin floor is some 500 feet lower in altitude than the Highland Rim to the east and somewhat less than that on the south and west. This area contains numerous spurs and outlying remnants of the Highland Rim. Ground water is often difficult to obtain in quantity on some of these ridges because of the lack of an adequate watershed. The valleys and parts of the Central Basin floor are underlain by limestone formations of varying purity and solubility. Some of the uppermost limestone formations in this area are thin bedded with the beds separated by thin layers of clay shale. The presence of these shale layers tends to inhibit the downward migration of ground water and the joints in the rocks are enlarged to a lesser degree than in the purer limestones. Therefore, ground water is generally available only in relatively small quantities, if at all. Dry holes are common and sulfur water high in iron is often encountered. It appears that weathering of the Central Basin rocks has not progressed beyond fairly shallow depths and that the movement of groundwater is extremely slow in this part of the Elk-Shoal River basin. The larger yield wells are probably located near perennial streams. Springs in the Central Basin limestones in this area are generally low in yield and may become dry in periods of low rainfall. The quality of the spring water is generally good.

Most of the wells listed in the existing ground-water data base were drilled for domestic use and were not located as the result of local geologic investigation. Therefore, the true ground-water potential of the Elk-Shoal River basin needs further study at this time.

## Demography

Historical (1970) and recent (1980) population, total wage and salary employment including both full- and part-time workers, and per capita personal income data for the county boundary approximation of the Elk-Shoal River basin are presented in table 20. Counties included in this approximation are Franklin, Giles, Lawrence, Lincoln, and Moore. Urban and metropolitan areas in the basin and their 1980 census population include Fayetteville (7,559), Lawrenceburg (10,184), Pulaski (7,184), Tullahoma (15,800), and Winchester (5,821).

Table 20.--County population, employment, and per capita personal income data, Elk-Shoal River basin

[Per capita income based on 1970 income converted to 1980 dollars]

| County | Population | | Employment | | Per capita personal income 1980 dollars | |
|---|---|---|---|---|---|---|
| | 1970 | 1980 | 1970 | 1980 | 1970 | 1980 |
| Franklin | 27,289 | 31,983 | 6,872 | 7,448 | $5,274 | $6,065 |
| Giles | 22,138 | 24,625 | 7,348 | 9,361 | 5,783 | 7,342 |
| Lawrence | 29,097 | 34,110 | 7,645 | 11,359 | 4,968 | 6,921 |
| Lincoln | 24,318 | 26,483 | 6,642 | 8,317 | 5,325 | 6,298 |
| Moore | 3,568 | 4,510 | 772 | 1,249 | 6,000 | 6,392 |
| Total | 106,410 | 121,711 | 29,279 | 37,734 | - | - |

## Public and Self-Supplied Commercial and Industrial Water Users

At present, there are a total of 37 public water-supply facilities and 10 large, self-supplied commercial and industrial water users whose use exceeds 0.1 Mgal/d in the Elk-Shoal River basin. Detailed inventories containing pertinent information and data relative to each community or self-supplied user's source of water, average daily water use, source capacity, population served, treatment plant and storage capacities, and water-supply shortage problems are found in tables 9 and 10 of appendix I, respectively. Total water use or withdrawal for public and large, self-supplied commercial and industrial users in the basin equals about 78.1 Mgal/d at the present time. The general location and water-supply source of all public and large, self-supplied commercial and industrial water users inventoried in the Elk-Shoal River basin are shown in figures 15 and 16, respectively.

Currently, public water systems serve about 88,000 or 73 percent of the basin's 1980 population. Total water use or withdrawal for public purposes averages about 12.7 Mgal/d of which about 8.6 Mgal/d or 68 percent is withdrawn from surface-water sources and 4.1 Mgal/d or 32 percent from ground-water sources. Major public water-supply facilities whose average daily use exceeds 1.0 Mgal/d include the following:

| Facility name | Average water use (Mgal/d) |
|---|---|
| Winchester UD | 1.141 |
| Pulaski WS | 1.600 |
| Lawrenceburg | 3.494 |
| Fayetteville WS | 2.444 |

These systems account for over 68 percent of the total water withdrawal for public purposes.

Self-supplied water users withdraw about 65.4 Mgal/d of which some 63.8 Mgal/d or 98 percent comes from surface-water sources and 1.6 Mgal/d or 2 percent from ground-water sources. Arnold Air Force Development Center at Tullahoma represents the principal self-supplied industrial water user (60.8 Mgal/d) in the basin. Consumptive water use by self-supplied commercial and industrial water users equals slightly over 2.9 Mgal/d.

Summarized below is a list of the specific water-supply problems now being experienced by individual communities and self-supplied commercial and industrial water users in the Elk-Shoal River basin. The number in parentheses following each identified problem indicates the number of communities and (or) self-supplied water users who are now or have experienced this problem in the past. Note, these are not listed in order of frequency of occurrence or overall severity.

- Inadequate storage capacity and transmission and distribution line facilities. (2)
- Serious water losses from leaking surface-water impoundments and deteriorating water mains and distribution lines. (2)
- Water-supply shortages during peak demand periods as well as drought periods. (3)

- Discoloration resulting from old galvanized steel transmission and distribution lines. (2)

Figure 15--Explanation

| Site No. | Facility name | Site No. | Facility name |
|---|---|---|---|
| 1 | Belvidere Rural UD | 16 | Loretto WS |
| 2 | Cowan WS | 17 | St. Joseph WS |
| 3 | Decherd Water Works | 18 | Westpoint UD |
| 4 | Estill Springs WD | 19 | Fayetteville WS |
| 5 | Huntland WS | 20 | Lincoln County Board of Public Utilities |
| 6 | Sewanee Utility Department | | |
| 7 | Winchester UD | 21 | Orme WS |
| 8 | Ardmore WS | 22 | South Pittsburg WS |
| 9 | Pulaski WS | 23 | Lynchburg WS |
| 10 | South Giles UD | | |
| 11 | Monteagle WS | | |
| 12 | Tracy City WS | | |
| 13 | Iron City UD | | |
| 14 | Lawrenceburg WS | | |
| 15 | Leoma UD | | |

## Water-Supply Adequacy Analysis

The Elk-Shoal River basin in south-central Tennessee encompasses 3,041 $mi^2$ or 1,946,000 acres of land and water area. This basin's surface- and ground-water resources are replenished by substantial rainfall whose long-term (1941-70) average equals 52.01 inches. Average annual runoff generally varies from 24 to 30 inches with the heaviest runoff occurring in the basin's head-waters area. The driest months of the year are usually August, September, and October with March being the wettest month.

Total average daily water use or withdrawal for public and large, self-supplied commercial and industrial water users in the Elk-Shoal River basin equals approximately 78.1 Mgal/d. Of that amount, about 12.7 Mgal/d are withdrawn for public water-supply purposes with 8.6 Mgal/d or 68 percent coming from surface-water sources and 4.1 Mgal/d or 32 percent from ground-water sources. Self-supplied water users withdraw approximately 65.4 Mgal/d of which 63.8 Mgal/d or 98 percent comes from surface-water sources and 1.6 Mgal/d or 2 percent from ground-water sources. Arnold Air Force Development Center at Tullahoma represents the principal self-supplied industrial water user (60.8 Mgal/d) in the basin. Consumptive water use by self-supplied commercial and industrial water users equals slightly over 2.9 Mgal/d.

Public water systems serving the communities of Cowan, Leoma, and Tracy City are dependent entirely upon ground-water supplies whose source capacity is either unknown or substantially less than the communities' average daily water use. Three other systems serving Fayetteville, Iron City, and Lawrenceburg are partially dependent upon ground-water sources whose source capacity is less than or equal to their average daily withdrawal from the ground-water source.

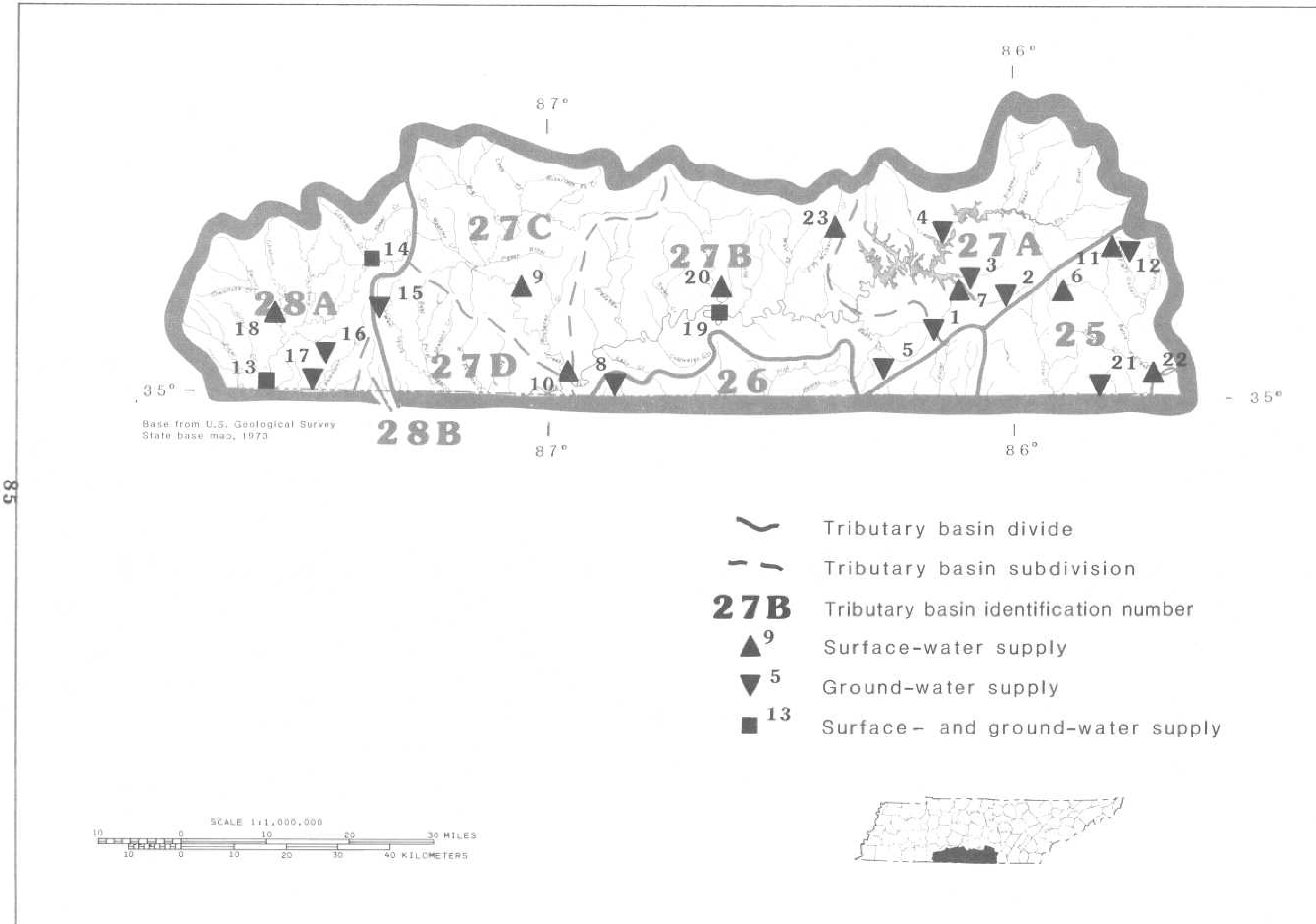



**Figure 15.--Public water-supply facilities, Elk-Shoal River basin.**

Figure 16--Explanation

| Site No. | Facility name |
|---|---|
| 1 | Arnold Air Force Development Center (Tullahoma) |
| 2 | Cumberland Mountain Sand Co. (Hillsboro) |
| 3 | Lannon Manufacturing Co., Inc. (Tullahoma) |
| 4 | Tennessee Dickel Distilling Co. (Tullahoma) |
| 5 | Giles County Materials (Pulaski) |
| 6 | Pulaski Rubber Co. (Pulaski) |
| 7 | Union Carbide Corp. (Lawrenceburg) |
| 8 | Gamble Asphalt Materials, Inc. (South Pittsburg) |
| 9 | Penn-Dixie Industries, Inc. (Richard City) |
| 10 | Jack Daniel Distillery (Lynchburg) |

However, each of these latter systems withdraws the major part of its daily water use from the following surface-water sources; Elk River (Fayetteville), Hawley Creek (Iron City), and Shoal Creek (Lawrenceburg); whose source capacity is more than adequate to meet the community's total daily water use, if necessary. Currently, Cowan and Tracy City are experiencing periodic water-supply shortages during drought periods. These communities need to actively seek additional and (or) alternative, cost-effective water-supply sources. Should these systems wish to expand their ground-water use, well sites can be located which will intersect solution cavities in the carbonate bedrock underlying much of this area and produce up to 0.100 to 0.200 Mgal/d of good quality water. For best results, however, these well sites should be located by a trained ground-water hydrologist.

Analysis of the inventory of self-supplied commercial and industrial water users indicates that a number of these users are utilizing surface- and ground-water sources whose source capacity is either unknown or considerally less than the facility's average daily use. At present, however, only Cumberland Mountain Sand Co. near Hillsboro is experiencing any water-supply shortages during drought periods. Those not experiencing any water quantity-related problems at the present time include Tennessee Dickel Distilling Co. in Coffee County; Giles County Materials and Pulaski Rubber Co. in Giles County; Gamble Asphalt Materials and Penn-Dixie Industries in Marion County; and Jack Daniels in Moore County. Since most of these users are (1) characterized by relatively limited ground-water use and (2) served by either major surface-water sources such as the Tennessee River and Tims Ford Reservoir or by public water-supply systems served by surface-water sources with source capacities generally well in excess of their average daily use, no serious water-supply shortages are anticipated for any of these facilities.

Water systems which are currently utilizing surface- and (or) ground-water resources which are inadequate or of unknown capacity should consider exploring the availability of alternative, cost-effective water-supply sources to augment or meet their future water needs if necessary. While the basin's water resources are subject to contamination from a variety of sources; existing and pending Federal, State, and local statutes relative to water-quality protection and maintenance or improvement should ensure that current water quality will be maintained with little, if any, future degradation of the basin's water

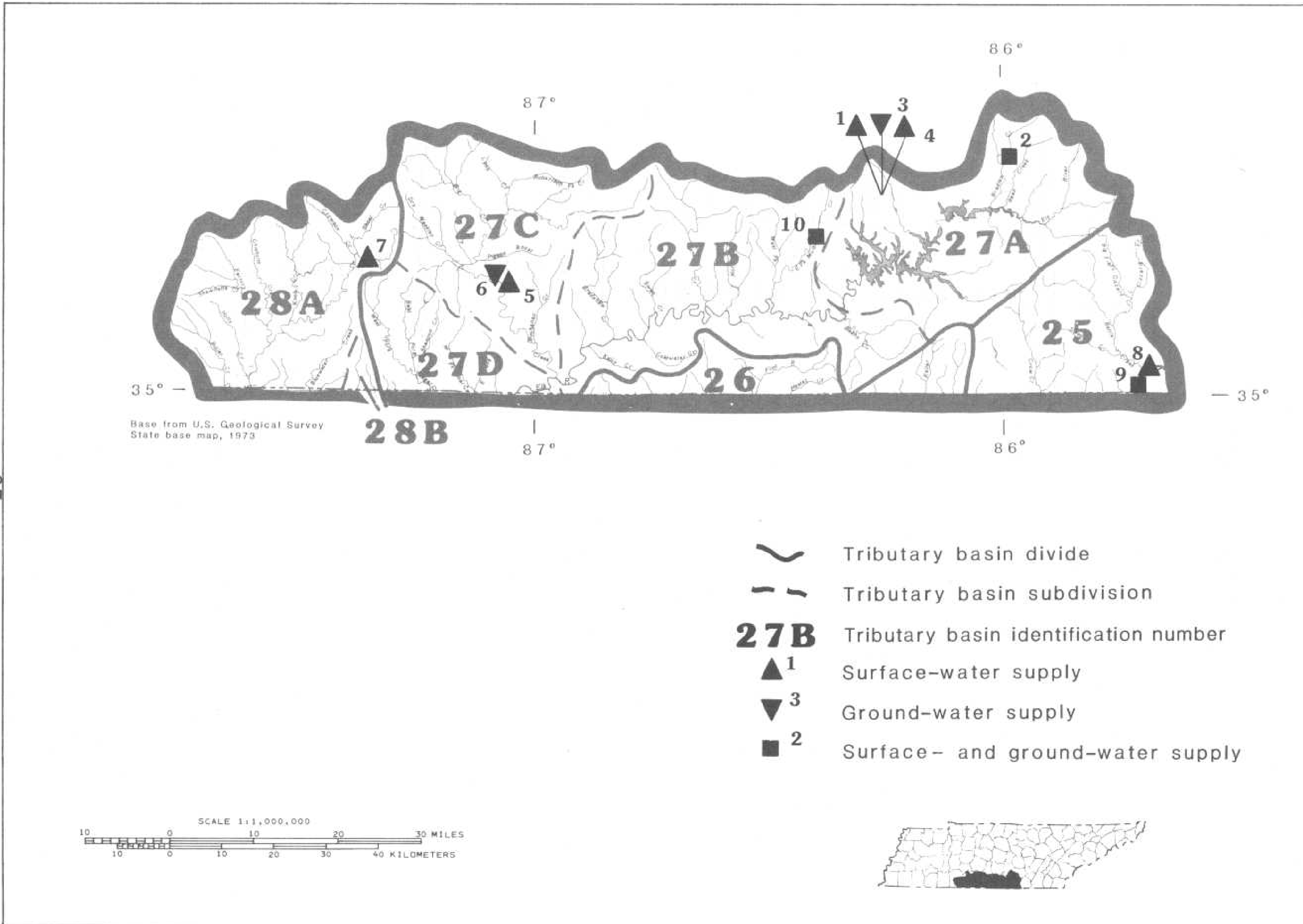



**Figure 16.--Self-supplied commercial and industrial water users, Elk-Shoal River basin.**

resources. Potential sources of contamination include (1) leachate from municipal and industrial water disposal facilities and septic tank systems; (2) agricultural pollution from fertilizers, pesticides and herbicides, and livestock wastes; and (3) runoff from surface mine lands and quarries.

Although there are periods of extended drought which cause seasonal water table declines and periodic local problems with adequate ground-water supplies, observation-well data indicate that there are no long-term, regional water table declines. Periodic local problems associated with a decline in an area's water table are caused by excessive withdrawals. To alleviate this problem, optimum ground-water withdrawal rates should be determined during the initial test pumping of the source.

## FRENCH BROAD RIVER BASIN

### Basin Description

The Tennessee part of the French Broad River basin covers 2,298 $mi^2$ of land and water area and consists of all or parts of the following tributary basins as delineated by the Geological Survey and the Tennessee Department of Water Management in 1982.

| Tributary basin No. (fig. 17) | Basin description | Tennessee drainage area (square miles) |
|---|---|---|
| 13A | French Broad River from the Tennessee State line to the Pigeon River. | 217 |
| 13B | Pigeon River and tributaries from the Tennessee State line to the river's mouth. | 153 |
| 13C | French Broad River and tributaries from the mouth of the Pigeon River to the mouth of the Nolichucky River. | 28 |
| 13D | French Broad River below the Nolichucky River to the river's mouth. | 770 |
| 14A | Nolichucky River from the Tennessee State line to Nolichucky Dam. | 557 |
| 14B | Nolichucky River from Nolichucky Dam to the river's mouth. | 573 |

Hydrologically, this basin encompasses all or major parts of Cocke, Greene, Jefferson, Sevier, Unicoi, and Washington Counties as well as minor parts of Blount, Hamblen, Hawkins, and Knox Counties. A map of the east Tennessee part of the Tennessee River basin which highlights the French Broad River basin is shown in figure 17.

### Topography

The French Broad River meanders through a rather broad valley to its junction with the Holston River about 4.5 river miles above Knoxville. From the Tennessee-North Carolina State line to a point about 2 miles upstream from Bridgeport, Tennessee, near river mile 85; the river valley is characterized by deep, precipitous gorges and high, craggy ridges. Average stream slope in this part of the basin equals about 13.10 feet per river mile. Below Bridgeport, the river valley is characterized by relatively flat valley slopes with an average stream slope equal to about 2.43 feet per river mile. Basin elevations generally range from 900 to 5,000 feet above sea level. Major tributaries to the French Broad River include the Nolichucky and Pigeon Rivers and several smaller streams such as the Little Pigeon River and Boyds, Dumplin, Gulf Fork, Big, Long, Sinking, and Trail Fork Big Creeks. Other tributaries

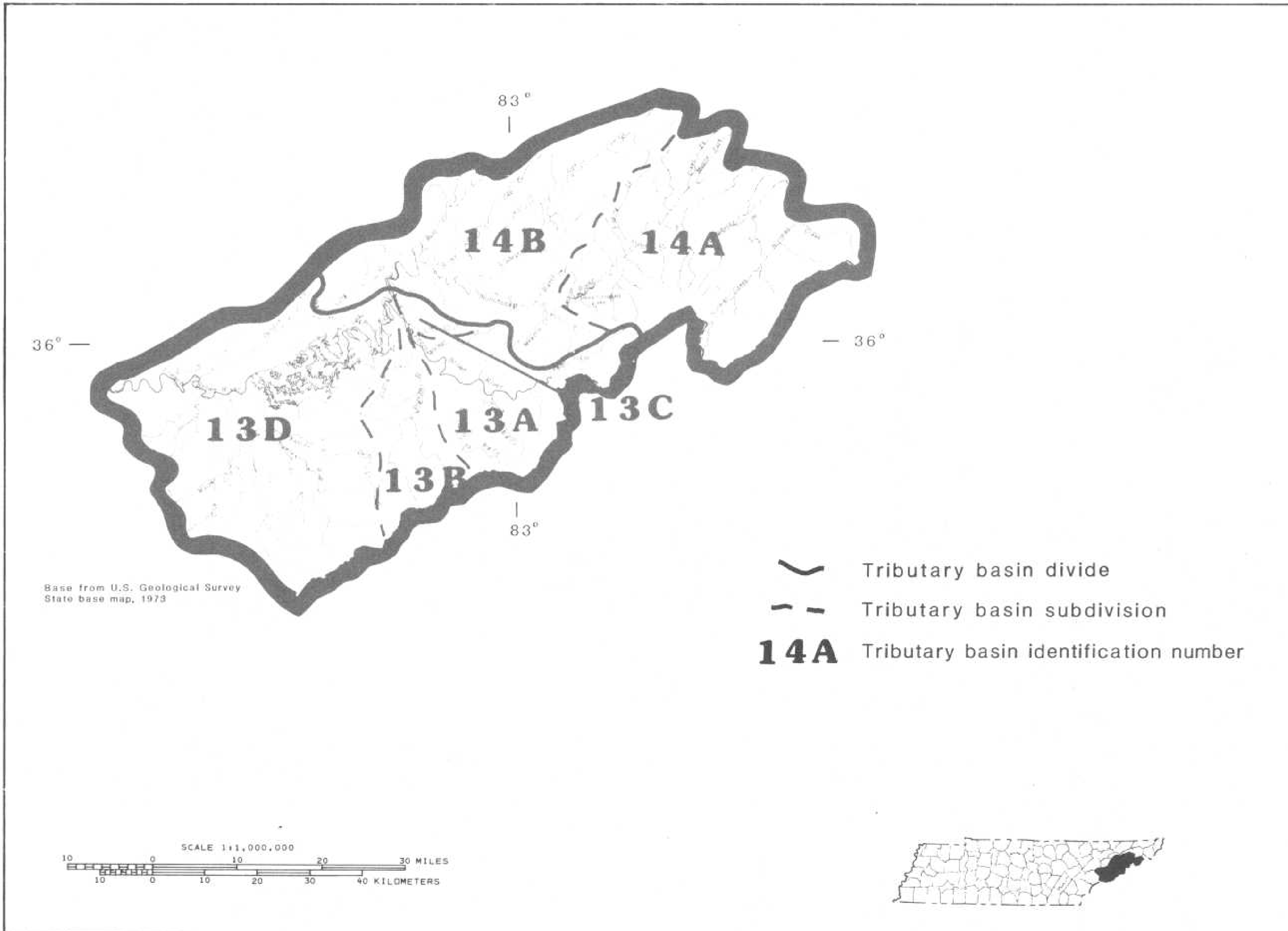



**Figure 17.--French Broad River basin.**

to the Nolichucky, Pigeon, and Little Pigeon River include Bent, Big Limestone, English, Jennings, Lick, Long, Meadow, North and South Indian, Richland, Waldon, and Webb Creeks plus the East and West Forks of the Little Pigeon River.

## Hydrology

### Surface Water

This basin's surface- and ground-water resources are replenished by an abundant rainfall whose long-term (1941-70) average ranges from 51.53 inches above Newport to 49.20 inches above Douglas Dam to 47.28 inches above Knoxville. Average annual precipitation for each of these areas during the period 1970-79 is shown below:

- Above Newport average annual precipitation was 55.22 inches and ranged from 42.41 inches in 1970 to 66.26 inches in 1979.

- Above Douglas Dam average annual precipitation was 52.64 inches and ranged from 41.46 inches in 1970 to 59.84 inches in 1979.

- Above Knoxville average annual precipitation was 51.19 inches and ranged from 40.73 inches in 1970 to 57.23 inches in 1972.

Average precipitation data for the period 1970-79 for watershed subdivisions of the French Broad River basin are presented in table 21. Annual 1979 and long-term (1941-70), precipitation data for selected TVA, NWS, and U.S. Department of Interior (USDI) rainfall stations in the Tennessee part of the French Broad River basin are presented in table 22.

Normally, the months of September, October, and November are the driest months with average rainfall ranging from 3.49 to 3.88 inches above Newport; 3.16 to 3.56 inches above Douglas Dam; and 2.85 to 3.35 inches above Knoxville. During the other months, rainfall generally averages about 3.91 to 5.52 inches above Newport; 3.81 to 5.30 inches above Douglas Dam; and 3.80 to 5.14 inches above Knoxville. July normally has the heaviest rainfall throughout the Tennessee part of the French Broad River basin.

Average annual runoff in the Tennessee part of the French Broad River basin ranges from approximately 16 to 22 inches as one moves east and northeastward from Knoxville except for the eastern edge of the basin, particularly the Great Smoky Mountains area, where the average annual runoff ranges from 38 to 40 inches. A summary of average discharge data for selected hydrologic data stations in the French Broad River basin is presented in table 23. Most of this runoff occurs during the winter and spring months. During extended drought periods in the late summer and fall months, it is not unusual for small, unregulated streams to be characterized by low streamflows.

### Major Reservoirs

Major reservoirs located in this basin and their total storage in acre-feet at normal minimum pool are Davy Crockett Reservoir (minimal) created by Nolichucky

Table 21.--Precipitation data by watershed subdivision for the period 1970-79, French Broad River basin

| Watershed description | Precipitation (inches) | | | | |
|---|---|---|---|---|---|
| | High | Year | Low | Year | 10-year average |
| Nolichucky River upstream from Embreeville. | 64.70 | 1979 | 44.70 | 1970 | 55.53 |
| Nolichucky River upstream from Morristown to Embreeville. | 56.10 | 1972 | 34.40 | 1978 | 45.57 |
| French Broad River from Newport to Asheville. | 53.80 | 1974 | 36.00 | 1970 | 47.20 |
| French Broad River from Newport to Douglas Dam including the Nolichucky River downstream from Morristown and the Tennessee part of the Pigeon River. | 59.00 | 1972 | 38.10 | 1970 | 48.32 |
| French Broad River from Knoxville to Douglas Dam. | 62.80 | 1972 | 43.30 | 1970 | 52.85 |

Table 22.--Precipitation data for 1979 and for the period 1941-70 for selected rainfall stations, French Broad River basin

| Station location | Station owner | Elevation above sea level (feet) | Period of record (years) | 1979 Precipitation (inches) | Long-term annual precipitation (inches) |
|---|---|---|---|---|---|
| Sevierville | TVA | 920 | 36 | 42.95 | 46.67 |
| Gatlinburg | NWS | 1,454 | 54 | 66.05 | 55.31 |
| Douglas Dam | TVA | 958 | 38 | 46.49 | 44.52 |
| Bulls Gap | TVA | 1,140 | 45 | 46.39 | 44.11 |
| Nolichucky Dam | TVA | 1,260 | 35 | 36.20 | 42.00 |
| Greeneville | NWS | 1,320 | 47 | 47.02 | 41.62 |
| Centerville | TVA | 1,815 | 27 | 50.04 | 47.69 |
| Erwin | TVA | 1,640 | 52 | 50.57 | 45.46 |
| Clingmans Peak | NWS | 6,525 | 26 | 108.87 | 72.00 |
| Newport | TVA | 1,040 | 37 | 42.91 | 43.66 |
| Cosby No. 4 | USDI | 1,720 | 39 | 65.40 | 55.75 |
| Waterville | NWS | 1,440 | 49 | 54.30 | 47.28 |

Table 23.--Average discharge data for selected hydrologic data stations operated by the U.S. Geological Survey, French Broad River basin

| Station name and location (county) | River mile | Drainage area (square miles) | Period of record (years) | Average discharge: Cubic feet per second | Average discharge: Inches per year | Average discharge: Cubic feet per second per square mile |
|---|---|---|---|---|---|---|
| French Broad River near Newport (Cocke). | 77.5 | 1,858 | 62 | 3,009 | 21.99 | 1.62 |
| Cosby Creek upstream from Cosby (Cocke). | 10.7 | 10.1 | 14 | 28.5 | 38.32 | 3.79 |
| Pigeon River at Newport (Cocke). | 6.8 | 666 | 63 | 1,258 | - | 1.89 |
| Nolichucky River at Embreeville (Washington). | 89.0 | 805 | 61 | 1,374 | 23.18 | 1.71 |
| Little Pigeon River at Sevierville (Sevier). | 4.4 | 353 | 60 | 573 | 22.04 | 1.62 |
| French Broad River near Knoxville (Knox). | 7.5 | 5,101 | 35 | 7,966 | 21.21 | 1.56 |

Dam and Douglas Reservoir (223,000). Due to excessive sedimentation from upstream mica and feldspar mining operations, Davy Crockett Reservoir has been virtually filled with sediment allowing the Nolichucky River to flow directly through the reservoir with no flow retention or further sediment deposition. Consequently, the outdated generating facilities at Nolichucky Dam were retired in August 1972 and the dam strengthened and modified to permit the reservoir's use as a waterfowl refuge. Detailed information describing Douglas Reservoir's location and operation pattern follows:

### Douglas Reservoir

Location and drainage area.--Douglas Reservoir is formed by Douglas Dam which is located on the French Broad River at river mile 32.3 in Cocke, Jefferson, and Sevier Counties. Douglas Dam controls 4,541 $mi^2$ of drainage area.

Reference period.--1960-81.

Reservoir discharge (minimum daily average flow).--Minimum daily average discharge from Douglas Dam during the reference period ranged from a low of about 22.0 $ft^3/s$ (14.2 Mgal/d) in 1967 to a high of about 712.0 $ft^3/s$ (460.2 Mgal/d) in 1978. The average, 1-day minimum discharge over the reference period was about 173.0 $ft^3/s$ (111.8 Mgal/d).

Average number of days of zero flow.--During the period from 1960-81, Douglas Dam has averaged slightly over 17 days of zero discharge per year ranging from a low of 2 days of zero discharge in 1979 to a high of 47 days of zero discharge in 1970. Zero-discharge days were most common during the months of April and May. During the 1960-81 time period, there were 30 instances of zero discharge for 3 or more consecutive days from Douglas Dam. In six of these instances during the years of 1963, 1966-68, and 1970, consecutive days of zero discharge from Douglas Dam ranged from a low of 6 days in several years to a high of 18 days in 1968.

Existing agreements regarding reservoir releases.--Reservoir releases from Douglas Dam are correlated with releases from Cherokee Dam to provide a minimum average daily flow of 2,000 $ft^3/s$ (about 1,292.6 Mgal/d) past Knoxville.

## Ground Water

Ground water in the French Broad River basin in Tennessee occurs in fractures in the underlying rock formations that have been subjected to severe folding and faulting. Approximately one-third of the basin area lying along the eastern margin is located in the Blue Ridge physiographic province. The mountains in this area are underlain primarily by noncarbonate rocks such as shale, sandstone, siltstone, and highly siliceous crystalline rock. Fractures in these rocks are not significantly enlarged by the dissolving action of percolating ground water. Consequently, well yields are generally low ranging from a few gallons per minute to 25 gal/min. Domestic supplies are generally obtained from dug wells and springs. However, larger yields are often obtained in the valleys where carbonate rock formations are located. Moderately large yield wells and large springs are common in the valley areas. Reported well depths range from some 15 feet to usually not more than 200 feet. The shallower wells are those dug in the regolith, i.e., sand, clay, and rock fragments, while the majority are drilled wells. A number of wells have been reported as dry holes or as supplying an insignificant amount of water. However, in recent years, wells have been drilled that are capable of supplying 100 gal/min or more at several locations in the Blue Ridge province. The sites for these wells were picked after a detailed geologic study was made of the area. Higher yield wells were found at or near fault zones covered by relatively thick regolith. In view of this finding and lack of data in some areas, the true potential for the development of significant ground-water supplies in the Blue Ridge part of the French Broad River basin needs further study at the present time. A number of municipalities in this area derive their water supplies from large springs. The ground-water quality is usually acceptable.

The remaining area of the Tennessee part of the French Broad River basin lies in the Valley and Ridge province. This area is primarily underlain by carbonate rock formations such as limestone and dolomite together with calcareous shale and limy sandstone. Ground water occurs in fractures and bedding plane openings in the limestone and dolomite formations which have been enlarged in varying degrees by the dissolving action of circulating ground water. Water occurs in fractures in the sandstone which may be enlarged somewhat by solution, but to a much lesser degree than the openings in the carbonate rocks. Ground water in quantities sufficient for domestic purposes can usually be obtained in areas underlain by the soluble carbonates and fractured sandstones. Although ground water moves through openings in shale beds, shale is an effective barrier to vertical ground-water movement and generally yields only limited ground water. Domestic supplies can usually be found in the sandstone at depths of 100 feet or less. Wells in dolomite and limestone are deeper on the average with the majority ranging from 50 to 200 feet in depth. These enlarged openings generally become smaller and less numerous with depth and it is generally not advisable to drill deeper than 300 to 350 feet on the basis of presently available information. Most of the wells reported in the Valley and Ridge province yield from 3 to 50 gal/min. However, yields from 100 to 250 gal/min are common. Larger yield wells (100 gal/min or more) are usually located near perennial streams. Water quality is usually acceptable; however, water from the Sevier Shale is locally high in sulfur and iron. It should be emphasized that the existing water-well data base is composed of wells drilled primarily for domestic needs which can be satisfied with relatively small supplies. Also, choices of favorable locations for drilling based on geologic studies are extremely limited. Springs flowing from openings in carbonate rocks are numerous. Pending further studies, the potential for the development of large ground-water supplies cannot be predicted with certainty.

## Demography

Historical (1970) and recent (1980) population, total wage and salary employment including both full- and part-time workers, and per capita personal income data for the county boundary approximation of the French Broad River basin are presented in table 24. Counties included in this approximation are Cocke, Greene, Jefferson, Sevier, and Unicoi. Major urban or metropolitan areas in the Tennessee part of the basin and their 1980 census population include Banner Hill (2,913), Erwin (4,739), Gatlinburg (3,210), Greeneville (14,097), and Newport (7,580).

Table 24.--County population, employment, and per capita personal income data, French Broad River basin

[Per capita income based on 1970 income converted to 1980 dollars]

| County | Population | | Employment | | Per capita personal income 1980 dollars | |
|---|---|---|---|---|---|---|
| | 1970 | 1980 | 1970 | 1980 | 1970 | 1980 |
| Cocke | 25,283 | 28,792 | 6,164 | 6,915 | $4,650 | $5,272 |
| Greene | 47,630 | 54,422 | 16,191 | 20,187 | 5,424 | 6,395 |
| Jefferson | 24,940 | 31,284 | 7,630 | 9,230 | 5,363 | 6,646 |
| Sevier | 28,241 | 41,418 | 7,754 | 15,184 | 5,809 | 6,968 |
| Unicoi | 15,254 | 16,362 | 4,119 | 4,429 | 5,615 | 6,611 |
| Total | 141,348 | 172,278 | 41,858 | 55,945 | - | - |