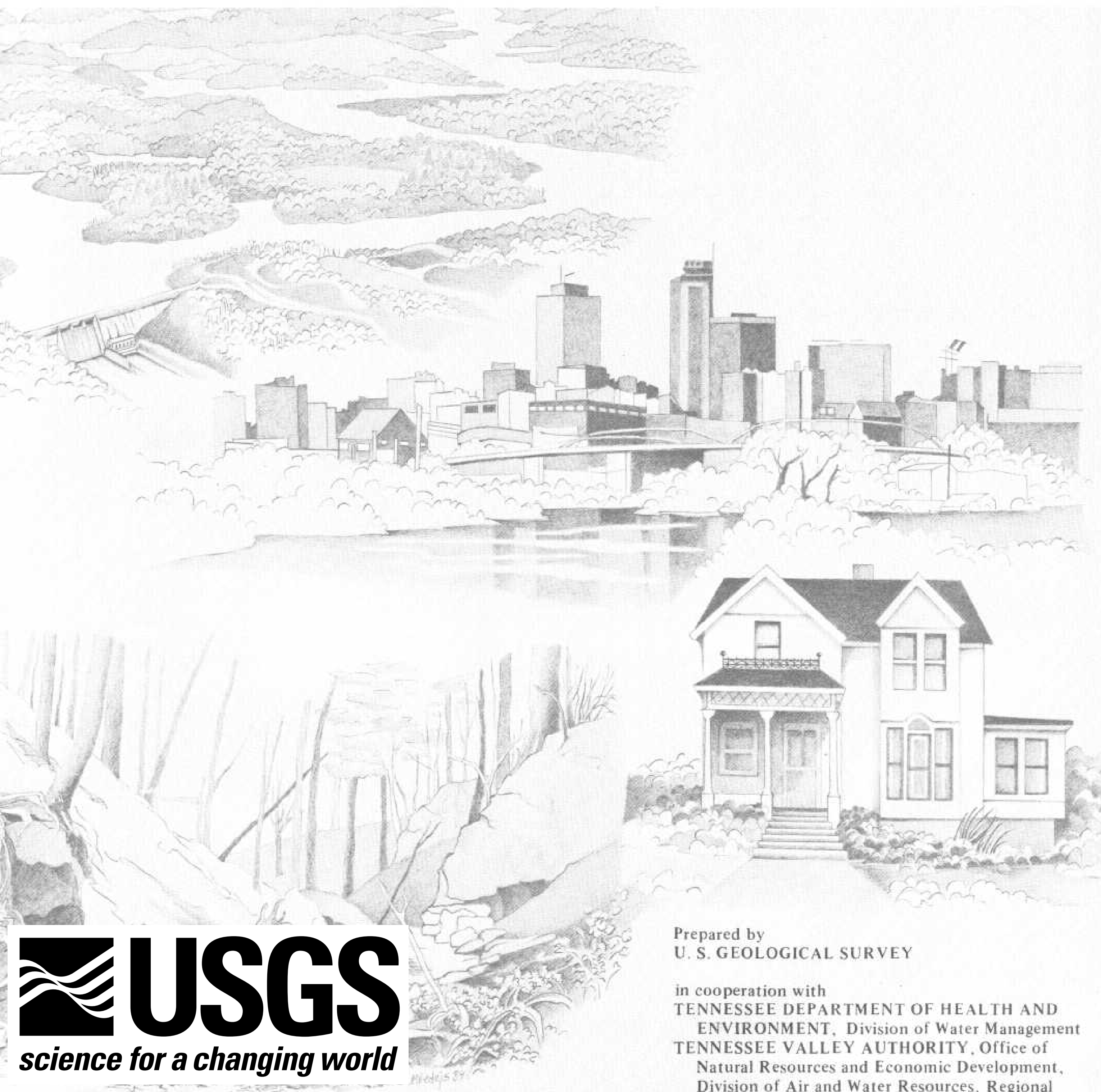
WATER-RESOURCES INVESTIGATIONS REPORT 84-4074

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



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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

the year, average rainfall ranges from 3.96 to 5.33 inches with March usually being the wettest month.

The surface-water supply for this basin is derived from precipitation and runoff within the area, streamflow including ground-water discharge entering the area from adjacent areas, and ground-water discharge to streams within the area. Average discharge data for selected hydrologic data stations are presented in table 39. Theoretically, there is a large quantity of surface water available for use in this basin. However, because of the small number of available storage sites and the increased evaporative losses of surface water that occur with this development, this quantity is not realistically obtainable.

Ground Water

West Tennessee embraces two physiographic provinces. One is the West Tennessee Plain, including the subdivision known as the West Tennessee Uplands, and the other is the Mississippi River Valley.

The West Tennessee Plain extends from the western margin of the Western Valley of the Tennessee River, or the divide, known as the West Tennessee Uplands, separating eastward flowing drainage to the Tennessee River from streams flowing westward to the Mississippi River. This area contains three major drainage basins: the Obion-Forked Deer, the Hatchie, and the Memphis Area which includes the Loosahatchie River, Wolf River, and Nonconnah Creek.

West Tennessee lies in the region known as the Mississippi embayment. This is an area in which Paleozoic limestones were downwarped in the geologic past forming a trough with its axis or deepest part roughly parallel to the present course of the Mississippi River and extending from the Gulf Coast northward to the southern tip of Illinois. Its eastern margin lies in parts of Kentucky, Tennessee, Alabama, and Mississippi while its western margin lies in parts of Missouri, Arkansas, Louisiana, and Texas. During geologic time, the sea successively advanced and receded in the trough depositing sediments consisting of uncemented sand and clay with minor amounts of other materials. Thick nonmarine sediments were also deposited. Consequently, these sands and clays are at the surface east of the Mississippi River and dip at the rate of 15 to 30 ft/mi westward toward the river where they begin to rise again and reappear west of the river although covered by alluvial deposits. Inclination of the water-bearing sands and the presence of clay layers and lenses cause the water in the sands to be under artesian pressure away from the outcrop area. In West Tennessee, the oldest sediments appear on the surface near the Tennessee River and dip westward reaching a depth of over 3,000 feet below the Mississippi River.

Inasmuch as the sand aquifers are continuous through the West Tennessee Plain and extend into other states, it is not practical to discuss them on a river basin basis but rather on a regional basis. While almost any sand body in any formation may furnish adequate supplies of freshwater for domestic use at or near its outcrop area, there are four major aquifers that are capable of furnishing relatively large supplies for municipalities and industries. From oldest to youngest these aquifers are the Coffee Sand and McNairy Sand of Cretaceous age and the Wilcox Formation and the Claiborne Formation of Tertiary

Table 39.--Average discharge data for selected hydrologic data stations, Obion-Forked Deer 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
Mississippi River at Memphis (Shelby).[a]	734.7	928,700	45	528,071	7.72	0.57
North Fork of the Forked Deer River at Dyersburg (Dyer).	6.4	939	44	1,348	19.49	1.44
South Fork of the Forked Deer River near Halls (Lauderdale).	11.3	1,014	40	1,390	18.61	1.37

a This hydrologic data station is actually located outside the Obion-Forked Deer River basin. However, its discharge data is representative of the Mississippi River in this basin.

age. In the Memphis area, the Wilcox and Claiborne aquifers are respectively known as the "1,400-foot sand", or the Fort Pillow Sand, and the "500-foot sand", or the Memphis Sand." The outcrop areas and dominant recharge areas of these aquifers occur as bands trending from south-southwest to north-northeast across West Tennessee. The eastern margin of the outcrop area of the Coffee Sand lies near the Tennessee River and the outcrop areas of the younger aquifers occur successively to the west until the Claiborne, including the Memphis Sand, is hidden from view near Paris, Jackson, and Somerville by a blanket of relatively recent loess and terrace deposits which extend westward to the Mississippi River Valley.

The Coffee Sand of Upper Cretaceous age is present in northern Mississippi and crops out in a belt in Tennessee from southwestern Hardin County to the Kentucky State line in northeastern Henry County. This outcrop belt is approximately 6 miles wide near the Mississippi-Tennessee border and becomes narrower to the north-northeast where it merges with the younger McNairy Sand near the Kentucky line. Its thickness ranges from approximately 200 feet near the Mississippi line and thins northeastward to less than 50 feet in southern Henry County. It has been estimated to underlie an area of approximately 6,000 mi^2 overall. The Coffee Sand is the oldest and smallest of the four major aquifers, and wells producing from it generally have lower yields. The larger yield wells producing from this aquifer probably do not supply much more than 300 gal/min. The Coffee Sand dips beneath the surface westward from its outcrop area and is at a depth of some 3,000 feet or more at Memphis. Water in the aquifer becomes relatively highly mineralized near the Fayette-Shelby County line.

The McNairy Sand is present in northern Mississippi and extends across Tennessee into Kentucky. Its outcrop belt is approximately 12 miles wide in McNairy County and thins northward to less than 8 miles in Benton County. The outcrop area is narrowest near the Kentucky line. The McNairy Sand is approximately 200 feet thick in the northern end of the embayment and thickens to some 375 feet in the subsurface at Memphis. It has been estimated that this sand underlies approximately 11,000 mi^2 of Tennessee and Kentucky. The McNairy Sand is an excellent aquifer particularly at or near its outcrop area. Yields of wells drilled into it range from 250 to 500 gal/min. Like the Coffee Sand, the McNairy Sand dips westward from its outcrop area into the subsurface and lies at a depth of some 2,400 feet at Memphis. If freshwater is defined as water having a concentration of no more than 1,000 mg/L total dissolved solids, then the McNairy Sand is at the base of the zone of freshwater at Memphis as the water in it there contains the limit of total dissolved solids. Presently, it is not used as a source of water in the Memphis area.

The Wilcox Formation contains an aquifer known in the Memphis area as the "1,400-foot sand," or Fort Pillow Sand, which is present in Mississippi and extends across West Tennessee into Kentucky. Its outcrop is narrow in Tennessee due to thinning and overlap by the overlying Claiborne Formation. In some places the Wilcox is completely overlapped by the Claiborne. The outcrop area is about 13 miles wide in Hardeman County and is less than a mile wide in northern Henry County. The "1,400-foot sand," or Fort Pillow Sand, thickens from about 50 feet on the western edge of the Wilcox outcrop belt to over 300 feet thick in the subsurface in Lake, Dyer, and Lauderdale Counties near the Mississippi River. It has been estimated that the Fort Pillow Sand underlies about 7,000 mi^2 in Tennessee and Kentucky. A number of wells obtain water from it in or near its outcrop belt but few are known to exist elsewhere in Tennessee except for a large industrial user in Memphis. Well yields at Memphis are reported to range from 400 to 1,600 gal/min. The Wilcox Formation is considered to be a reserve source of water for the city of Memphis.

The Claiborne Formation is the largest aquifer in West Tennesse and contains the "500-foot sand," or the Memphis Sand in the Memphis area. It is exposed at the surface westward from its feather edge overlying the Wilcox until covered by loess and alluvial deposits when it becomes the subcrop bedrock. The Claiborne is overlain by the Jackson Formation in areas of the counties bordering the Mississippi River. The outcrop belt of the Claiborne is much wider than that of the Wilcox. The Memphis Sand thickens from a feather edge to an estimated thickness of about 900 feet at the Mississippi River in southwestern Shelby County and its areal extent is approximately 7,000 mi^2 in Tennessee and Kentucky. Its broad outcrop area and thickness make it an excellent aquifer. The city of Memphis secures its water supply from this sand which is capable of yielding as much as 2,500 gal/min to wells.

Water quality of all West Tennessee aquifers is generally good at or near their outcrop areas. However, their iron content is generally high and requires treatment. The total dissolved solids content is often less than 100 parts per million (ppm) in these areas. Water having a dissolved solids content of less than 500 ppm is usually available at depths of less than 1,000 feet, and water having a dissolved solids concentration of 1,000 mg/L or less is present in some places to depths of a little more than 2,000 feet. Iron content often decreases with depth. Water in any aquifer increases in dissolved solids content with depth. It also changes in chemical character from a calcium bicarbonate to a sodium bicarbonate type when relatively deeply buried.

The potential for ground-water development in most of the West Tennessee Plain is high. At present, no single aquifer has been developed to a point anywhere near its potential. Each major aquifer receives about 12.5 inches of recharge per year in the outcrop areas. This would represent an average recharge of about 0.6 $(Mgal/d)/mi^2$.

The Tennessee part of the Mississippi River Valley is a narrow strip of the Mississippi River flood plain extending from Memphis to the Kentucky line. At Memphis, it does not exist as the river extends to the base of the Chickasaw Bluffs which mark the western margin of the West Tennessee Plain with the exception of Presidents Island and the area south of Memphis. Northward it attains a maximum width of 10 miles. Much of the region is covered at times by the extreme high waters of the river. In the flood plain areas of Lauderdale, Dyer, and Lake Counties, the alluvium is capable of furnishing rather large quantities of water to wells. This water is generally high in iron and is not used for domestic supplies but is used for irrigation. South of Lauderdale County, the flood plain alluvium yields smaller quantities of water.

Demography

Historical (1970) and recent (1980) population, employment, and per capita personal income data for the county boundary approximation of the basin are summarized in table 40. Counties included are Carroll, Chester, Crockett, Dyer, Gibson, Lake, Madison, Obion and Weakley. Major urban or metropolitan

Table 40.--County population, employment, and per capita personal income data, Obion-Forked Deer 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
Carroll	25,741	28,285	10,513	11,321	$4,851	$5,306
Chester	9,927	12,727	3,684	5,191	3,983	4,913
Crockett	14,402	14,941	4,936	5,671	4,160	4,979
Dyer	30,427	34,663	12,211	14,036	4,735	5,556
Gibson	47,871	49,467	19,095	19,608	4,871	5,461
Lake	8,074	7,455	2,564	2,507	3,780	4,687
Madison	65,774	74,546	24,321	31,574	4,953	6,010
Obion	30,247	32,781	11,987	13,389	4,977	6,116
Weakley	28,827	32,896	11,090	13,239	4,561	5,203
Total	261,290	287,761	100,401	117,536	-	-

areas in this area and their 1980 census population include Dyersburg (15,856), Humboldt (10,209), Jackson (49,131), Martin (8,898), Milan (8,083), and Trenton (4,601).

Public and Self-Supplied Commercial and Industrial Water Users

Presently, there is a total of 54 public water-supply facilties and 10 large, self-supplied commercial and industrial water users whose use exceeds 0.1 Mgal/d in the Obion-Forked Deer River basin. Detailed inventories containing pertinent information and data relative to each community or self-supplied users' source of water, average daily water use, source capacity, population served, treatment plant and storage capacities, and water-supply quantity related problems are found in tables 19 and 20 of appendix I, respectively. Total water use or withdrawal for public and large, self-supplied commercial and industrial users in the basin equals about 48.4 Mgal/d. The general location and water-supply source of all public and large, self-supplied commercial and industrial water users inventoried in the Obion-Forked Deer River basin are shown in figures 30 and 31, respectively.

Figure 30--Explanation

Site No.	Facility name	Site No.	Facility name
1	Atwood WD	26	Halls WD
2	Cedar Grove UD	27	Jackson Utility Division
3	Huntingdon WD	28	Elbridge UD
4	McKenzie WD	29	Hornbeak UD
5	Henderson WD	30	Kenton WD
6	Alamo WD	31	Obion WD
7	Bells Public UD	32	South Fulton WD
8	County-Wide UD	33	Troy WD
9	Maury City WD	34	Union City WD
10	Dyersburg Suburban Consolidated UD	35	Dresden WD
		36	Gleason WD
11	Dyersburg WD	37	Greenfield WD
12	Newbern WD	38	Martin WD
13	Trimble WD	39	McLemoresville WD
14	Bradford WD	40	Trezevant WD
15	Dyer WD		
		41	Crockett Mills UD
16	Gibson County Municipal Water District	42	Friendship WC
		43	Gibson WD
17	Humboldt WD	44	West State UD
18	Medina WD	45	Reelfoot Lake State Park
19	Milan Department of Public Utilities		
20	Rutherford WD	46	Henry WS
21	Trenton WD		
22	Reelfoot UD		
23	Ridgely WD		
24	Tiptonville WD		
25	Gates WD		

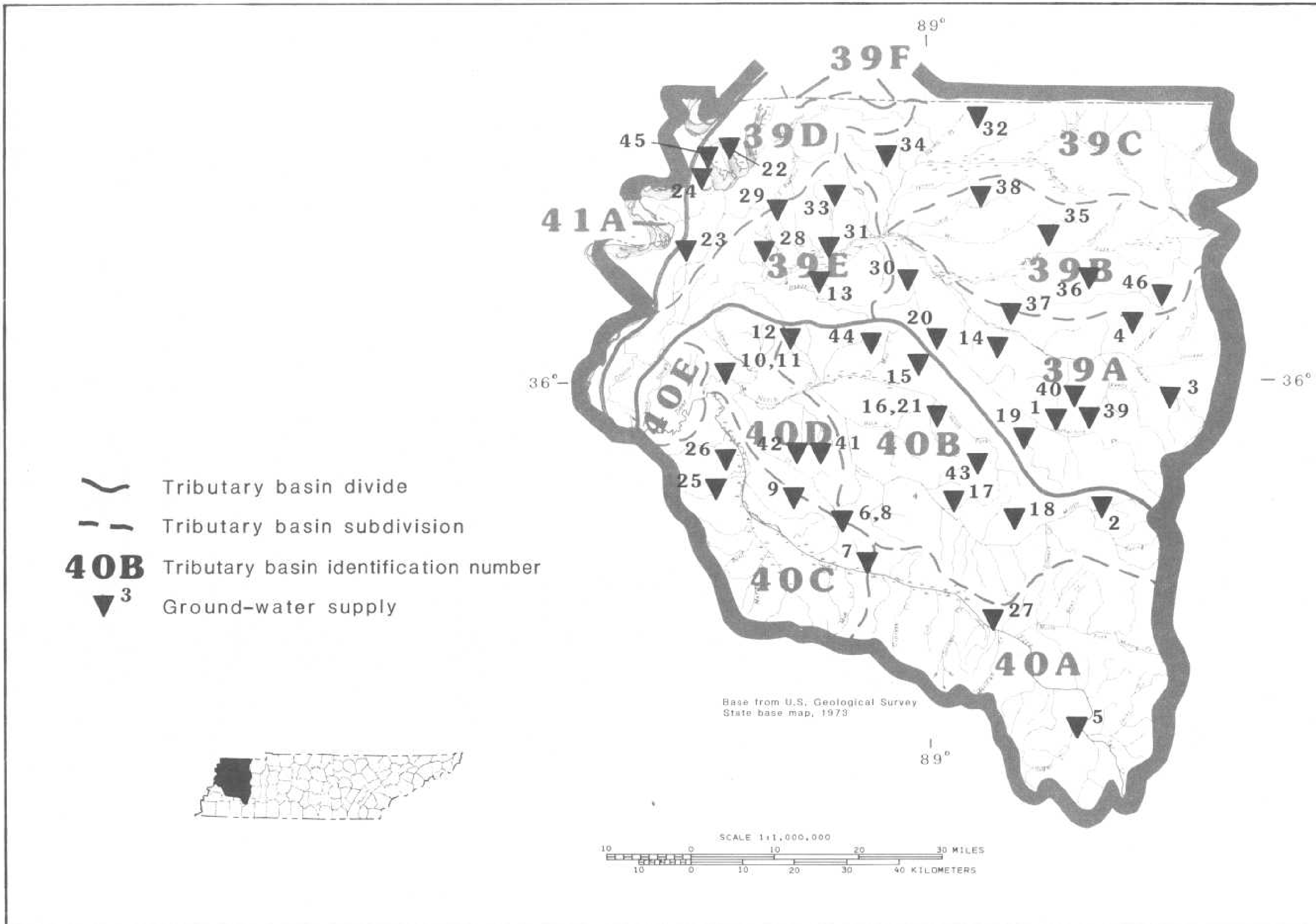

Figure 30.--Public water-supply facilities, Obion-Forked Deer River basin.

Figure 31--Explanation

Site No.	Facility name
1	Norandal USA, Inc. (Huntingdon)
2	Winter Garden, Inc. (Bells)
3	Dyersburg Fabrics, Inc. (Dyersburg)
4	Beare Co. (Humboldt)
5	Martin Marietta Sales, Inc. (Milan)
6	Consolidated Aluminum Corp. (Jackson)
7	Owens-Corning Fiberglass Co. (Jackson)
8	Goodyear Tire and Rubber Co. (Union City)
9	Kinkead Industries, Inc. (Union City)
10	Reelfoot Packing Co. (Union City)

Public water systems currently serve about 228,000 or 79 percent of the basin's 1980 population. Total water use or withdrawal for public purposes averages about 29.7 Mgal/d, all of which is withdrawn 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)
Dyersburg WD	3.500
Humboldt WD	1.000
Jackson Utility Division	8.600
Martin WD	1.300
Milan Department of Public Utilities	1.300
Union City WD	2.300

Together, these systems account for about 61 percent of the total water use for public purposes.

Self-supplied commercial and industrial users currently use or withdraw about 18.7 Mgal/d, all of which is withdrawn from ground-water sources. Major self-supplied commercial and industrial users whose average daily use exceeds 1.000 Mgal/d include the following:

Company name	Average water use (Mgal/d)
Consolidated Aluminum Corp. - Jackson	3.980
Goodyear Tire and Rubber Co. - Union City	4.752
Norandal USA, Inc. - Huntingdon	1.017
Reelfoot Packing Co. - Union City	1.500
Winter Garden, Inc. - Bells	4.400

The total consumptive use of the above industries is about 0.260 Mgal/d.

Summarized below is a list of the specific water-supply problems experienced in the basin during the period surveyed. The number in parentheses following each identified problem indicates the number of communities or self-supplied

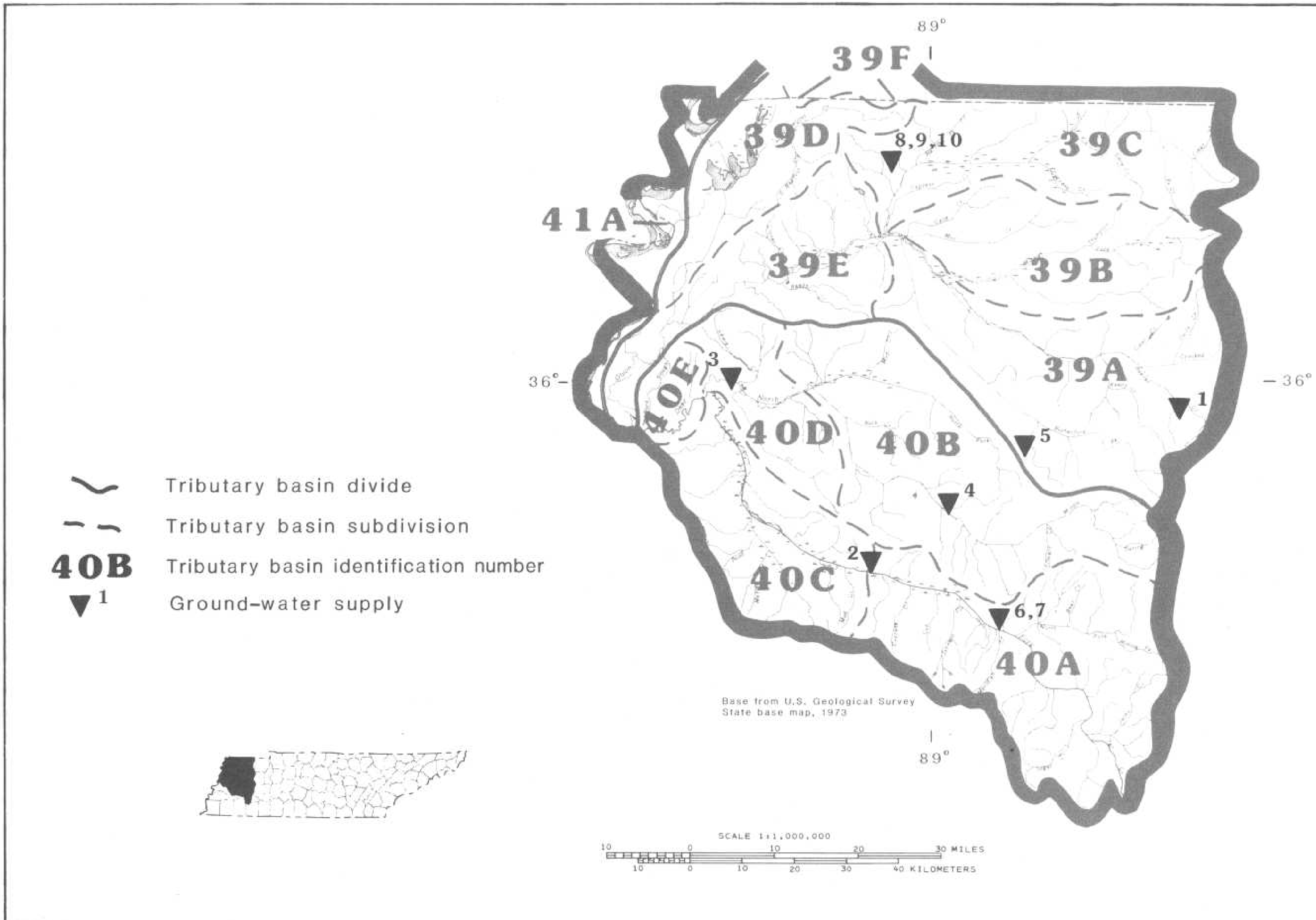

Figure 31.--Self-supplied commercial and industrial water users, Obion-Forked Deer River basin.

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.

- High level of iron content in water. (6)
- Inadequate storage capacity. (6)
- Inadequate pumping and treatment facilities. (1)
- Corrosive raw and treated water. (2)
- Excessive hardness in water (1)

Water-Supply Adequacy Analysis

The Obion-Forked Deer River basin covers 4,568 mi^2 (2,923,520 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 is approximately 48 inches. The driest months of the year are usually August, September, and October with March usually being the wettest month.

Total present water use or withdrawal for public and large self-supplied commercial and industrial purposes in the Obion-Forked Deer River basin amounts to approximately 48.4 Mgal/d. Of this amount, public-water systems use about 29.7 Mgal/d, all of which is withdrawn from ground-water sources. Self-supplied commercial and industrial users use about 18.7 Mgal/d, all of which is withdrawn from ground-water sources.

Generally, the basin's public water-supply systems are adequate in quantity to meet the basin's present needs, and no single aquifer has been developed anywhere near its potential. Two public community water systems (Alamo WD and Hornbeak UD) have daily water use demands that are about equal to their pumping or treatment plant capacity. Six systems (Bradford WD, County-Wide UD, Dyersburg Suburban Consolidated UD, Milan Department of Public Utilities, Tiptonville WD, and Troy WD) have inadequate storage capacity. The Bradford WD has inadequate pumping and treatment facilities at times.

No water-supply shortage problems were reported by any of the large, self-supplied water users.

LOWER TENNESSEE RIVER BASIN

Basin Description

Tennessee's part of the Lower Tennessee River basin encompasses 3,029 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 Tennessee Department of Water Management in 1982.

Tributary basin No. (fig. 32)	Basin description	Tennessee drainage area (square miles)
22A	Hiwassee River from the Tennessee-North Carolina State line to the Ocoee River.	344
22B	Ocoee River in Tennessee	172
22C	Hiwassee River from below the Ocoee River to the river's mouth.	699
49A	Tennessee River east-side minor tributaries from Watts Bar Dam to the Hiwassee River.	171
49B	Tennessee River west-side minor tributaries from Watts Bar Dam to the Hiwassee River.	192
23A	Tennessee River north-side minor tributaries from the Hiwassee River to below North Chickamauga Creek.	380
23B	Tennessee River south-side minor tributaries from the Hiwassee River to below South Chickamauga Creek.	252
23C	Tennessee River minor tributaries on both sides of the river from below South Chickamauga Creek to the Sequatchie River.	214
24	Sequatchie River	605

Southeast Tennessee also includes 127 mi^2 of the Conasauga River basin (Tributary basin No. 38) which originates in southeast Tennessee and flows southward into Georgia.

Hydrologically, this basin encompasses all or major parts of Bledsoe, Bradley, Hamilton, Marion, McMinn, Meigs, Polk, Rhea, and Sequatchie Counties as well as minor parts of Grundy, Monroe, and Roane Counties in southeast Tennessee. A map of the east Tennessee part of the Tennessee River Basin which highlights the Lower Tennessee River basin is shown in figure 32.

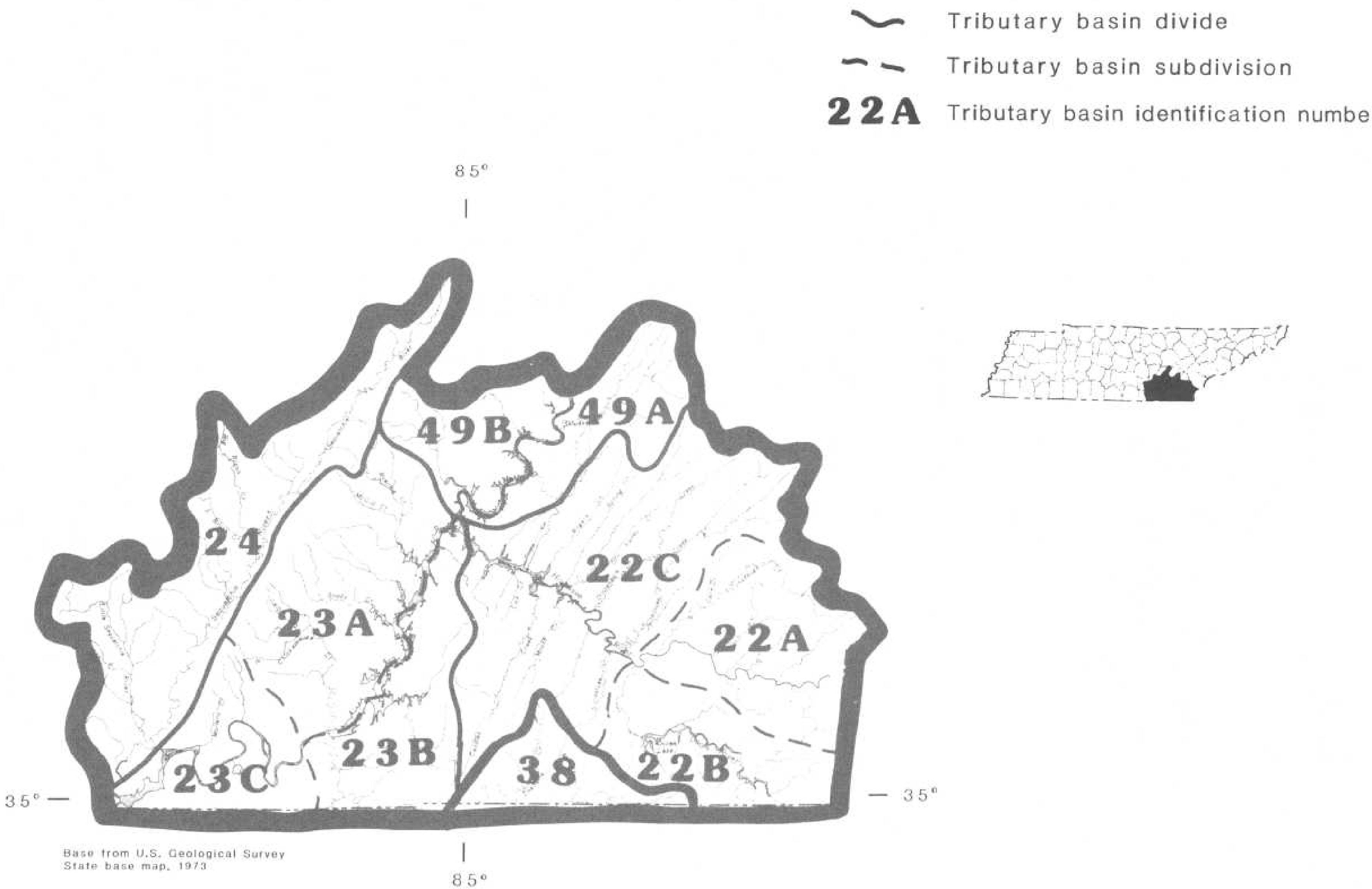

Figure 32.--Lower Tennessee River basin.

Topography

While this basin's terrain is not as rugged as that of the Little Tennessee River drainage area in the Upper Tennessee River basin, the basin is characterized by rugged terrain with streams in the upper part of the basin above the mouth of the Ocoee River flowing through steep, well-entrenched gorges. Below the mouth of the Ocoee River, the Hiwassee River flows through an ever-widening valley at or near right angles to the general northeast-southwest trend of the Tennessee Valley to its mouth below Dayton, Tennessee. Average stream slopes along the Hiwassee River in Tennessee range from about 1.39 ft/mi from river mile 0 to 44 to 21.50 ft/mi from river mile 44 to 65. Elevations in the Hiwassee River drainage area generally range from approximately 750 to 3,500 feet with a maximum elevation of about 5,000 feet above sea level.

The Sequatchie River arises in the Cumberland Plateau area and flows through a long, narrow, deeply-cut trough which nearly parallels the Tennessee Valley's northeast-southwest trend. Stream slopes along the Sequatchie River average about 2.63 ft/mi from river mile 0 to 35 and 6.22 ft/mi from river mile 35 to 70. General elevations in the Sequatchie River drainage area range from 650 to 2,000 feet above sea level. The maximum elevation in the Sequatchie River area is about 3,000 feet.

Minor tributary streams to the Tennessee River between Watts Bar Dam and the mouth of the Sequatchie River are characterized by relatively narrow, parallel ridges and broader, intervening valleys which have nearly a right-angle orientation to the Tennessee Valley itself. The average stream slope along the Tennessee River mainstem varies from 0.51 ft/mi between river mile 410 and 464 to 0.96 ft/mi from river mile 464 to 530. Watershed elevations along this reach of the Tennessee River range from about 300 to 1,200 feet above sea level.

Major streams and tributaries draining the Lower Tennessee River basin include the following:

- Hiwassee River. Ocoee River plus a number of smaller streams including Agency, Candies, Chatata, Coker, North and South Chestuee, North and South Mouse, Oostanaula, Price, Rogers, Spring, Sugar, Towee, and Turtletown Creeks.

- Sequatchie River. Little Sequatchie River and Big Brush, Crystal, Hicks, McWilliams, Skillern, and Woodcock Creeks.

- Tennessee River Minor Tributaries. Big Possum, Clear, Decatur, Long Savannah, Lookout, Middle, Mullins, North and South Chickamauga, Richland, Rock, Running Water, Sale, Sewee, Soddy, Wolftever, and Yellow Creeks.

Hydrology

Surface Water

This basin's surface- and ground-water resources are fed by an abundant rainfall whose long-term (1941-70) average ranges from 57.90 inches above Charleston on the Hiwassee River to 51.10 inches above Chattanooga. Over the

10-year period from 1970-79, average annual precipitation above Charleston was 62.14 inches and ranged from 47.96 inches in 1978 to 69.51 inches in 1973. During the same period, the average annual precipitation above Chattanooga was 55.99 inches with a low of 45.90 inches in 1978 and a high of 62.21 inches in 1973. Average annual precipitation data for watershed subdivisions in the Lower Tennessee River basin during the 1970-79 time period are summarized in table 41. Annual 1979 and long-term (1941-70) precipitation data for selected TVA rainfall stations in the Lower Tennessee River basin are presented in table 42.

Normally, the months of May, September, and October are the driest months in the Hiwassee River drainage area above Charleston with the average rainfall ranging from 3.34 to 4.10 inches. Above Chattanooga, the driest months are usually September, October, and November with rainfall averaging from 2.91 to 3.77 inches. During the remainder of the year, rainfall generally averages from 4.25 to 6.25 inches above Charleston and 3.86 to 5.31 inches above Chattanooga with March having the highest rainfall.

Average annual runoff in this part of the basin ranges from about 22 to 32 inches with the heaviest runoff occuring along the Tennessee State line in the Hiwassee River gorge area. Average discharge data for selected hydrologic data stations in the Lower Tennessee River basin are presented in table 43. Most of this runoff occurs during the winter and spring months.

Major Reservoirs

Major reservoirs located in the basin and their total storage in acre-feet at normal minimum pool are Chickamauga Reservoir (392,000), Nickajack Reservoir (220,100), Parksville (Ocoee No. 1) Reservoir (53,500), Ocoee No. 2 Reservoir (silted in), and Ocoee No. 3 Reservoir (220). In addition, several reservoirs including Watts Bar Reservoir (796,000) on the Tennessee River in the Upper Tennessee River basin; Apalachia Reservoir (49,000) on the Hiwassee River in North Carolina, and Toccoa Reservoir (12,000) on the Toccoa River in Georgia also have a significant impact on streamflows in the Lower Tennessee River basin. Guntersville Reservoir (879,700), which is located on the Tennessee River primarily in northeast Alabama, backs water up to Nickajack Dam about 8.2 river miles above the Tennessee-Alabama State line. Detailed information describing the location and operation pattern of each reservoir, with the exception of Guntersville Lake, follows:

Apalachia Reservoir

Location and drainage area.--Apalachia Reservoir is formed by Apalachia Dam which is located on the Hiwassee River at river mile 66.0 in Cherokee County, North Carolina. Apalachia Dam controls 1,018 mi^2 of drainage area.

Reference period.--1960-81.

Reservoir discharge (minimum daily average flow).--Minimum daily average discharge from Apalachia Dam during the 1960-81 time period ranged from a low of about 4.0 ft^3/s (2.6 Mgal/d) in 1969 to a high of about 517.0 ft^3/s (334.1 Mgal/d) in 1973. The average, 1-day minimum discharge during the reference period was about 108.8 ft^3/s (70.3 Mgal/d).

Table 41.--Precipitation data by watershed subdivision for the period 1970-79, Lower Tennessee River basin

Watershed description	Precipitation (inches)				
	High	Year	Low	Year	10-year average
Hiwassee River from Reliance to Hiwassee Dam.	70.70	1979	49.50	1978	60.97
Ocoee River from Ocoee Dam No. 1 to Blue Ridge Dam.	71.50	1973	46.40	1978	63.10
Hiwassee River from Charleston to Reliance and the Ocoee River downstream from Ocoee Dam No. 1.	65.90	1979	46.80	1978	57.18
Tennessee River from Chickamauga Dam to Watts Bar Dam.	70.00	1973	46.10	1978	59.05
Sequatchie River upstream from Whitwell.	75.10	1973	49.30	1978	55.11
Tennessee River from Nickajack Dam to Chickamauga Dam.	71.40	1973	45.20	1978	60.32

Table 42.--Precipitation data for 1979 and for the period 1941-70 for selected rainfall stations, Lower Tennessee River basin

Station location	Station owner	Elevation above sea level (feet)	Period of record (years)	1979 Precipitation (inches)	Long-term annual precipitation (inches)
Hiwassee River					
Big Spring	TVA	730	45	60.22	53.84
Cleveland substation	TVA	850	40	68.24	52.22
Charleston	TVA	720	87	68.54	53.41
Athens	TVA	900	18	65.81	59.55
Double Springs	TVA	850	36	64.08	52.54
Parksville Dam	TVA	750	55	68.47	53.71
Ocoee Dam No. 2 powerhouse.	TVA	860	65	72.94	54.81
Copperhill	NWS	1,535	66	66.55	57.25
Turtletown	TVA	1,600	45	70.86	59.92
Tennessee River and Minor Tributaries from Nickajack Dam to Watts Bar Dam					
Lockhart Tower	TVA	2,140	44	75.13	61.60
Dunlap	TVA	730	56	63.74	54.35
Cagle	TVA	2,060	40	86.15	55.32
Nickajack Dam	TVA	645	16	66.27	56.55
Chattanooga airport	NWS	685	101	68.55	51.92
Chickamauga Dam	TVA	700	44	66.27	53.90
Ooltewah	TVA	765	40	74.93	53.00
Morgantown	TVA	740	40	67.07	54.26
Dayton	NWS	830	23	66.61	56.73
Center Point (Bogge Crossroad).	TVA	765	24	62.15	53.35

Table 43.--Average discharge data for selected hydrologic data stations operated by the U.S. Geological Survey, Lower Tennessee 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
Sewee Creek near Decatur (Meigs).	5.7	117	46	197	22.87	1.68
Richland Creek near Dayton (Rhea).	5.2	50.2	26	108	29.22	2.15
Hiwassee River near McFarland (Polk).	53.2	1,136	38	2,447	29.25	2.15
Ocoee River at Emf (Polk)	19.6	524	68	1,225	32.52	2.40
Ocoee River at Parksville (Polk).	11.5	595	64	1,342	30.63	2.26
South Chestuee Creek near Benton (Bradley).	9.3	31.8	23	54.3	23.19	1.71
Oostanaula Creek near Sanford (McMinn).	5.7	57.0	26	97.4	23.21	1.71
Wolftever Creek near Ooltewah (Hamilton).	16.1	18.8	16	34.8	25.14	1.85
Tennessee River at Chattanooga (Hamilton).	467.6	21,400	106	37,280	-	1.74
Sequatchie River near Whitwell (Marion).	25.1	402	60	751	25.37	1.87

Average number of days of zero flow.--From 1960-81, Apalachia Dam has averaged slightly over 12 days of zero discharge per year ranging from a low of no days of zero discharge in every year since 1977 to a high of 37 days of zero discharge in 1964. Zero-discharge days were most common during the months of March, April, and May. During the reference period, there were 22 instances of zero discharge for 3 or more consecutive days from Apalachia Dam. In four of these instances, consecutive days of zero discharge from Apalachia Dam ranged from a low of 7 days on three occasions in 1966 and 1967 to a high of 15 days in 1969.

Existing agreements regarding reservoir releases.--Apalachia and Ocoee No. 1 Dams are operated conjunctively so that the sum of the two releases equals no less than 600.0 ft^3/s (387.8 Mgal/d) on an average daily basis.

Toccoa Reservoir

Location and drainage area.--Toccoa Reservoir is formed by Blue Ridge Dam which is located on the Toccoa (Ocoee) River at river mile 53.0 in Fannin County, Georgia. Blue Ridge Dam controls 232 mi^2 of drainage area.

Reference period.--1960-80.

Reservoir discharge (minimum daily average flow).--Minimum daily average discharge from Blue Ridge Dam during the 21-year reference period ranged from a low of approximately 3.0 ft^3/s (1.9 Mgal/d) in 1970 to a high of approximately 110.0 ft^3/s (71.1 Mgal/d) in 1974. The average, 1-day minimum discharge for the reference period was about 28.2 ft^3/s (18.2 Mgal/d).

Average number of days of zero flow.--From 1960-80, Blue Ridge Dam has averaged over 28 days of zero discharge per year ranging from a low of no days of zero discharge from 1960-64 to a high of 68 days of zero discharge in 1970. Zero-discharge days occurred most frequently during the months of December through March. During the reference period, there were 75 instances of zero discharge for 3 or more consecutive days from Blue Ridge Dam. In 16 of these instances during 1965-67, 1969-71, 1974, 1977, and 1980; consecutive days of zero discharge ranged from a low of 7 days in a number of years to a high of 16 days in 1969.

Existing agreements regarding reservoir releases.--None.

Chickamauga Reservoir

Location and drainage area.--Chickamauga Reservoir is formed by Chickamauga Dam which is located on the Tennessee River at river mile 471.0 in Hamilton County. Chickamauga Dam controls 20,790 mi^2 of drainage area.

Reference period.--1960-81.

Reservoir discharge (minimum daily average flow).--Minimum daily average discharge from Chickamauga Dam during the reference period ranged from a low of about 1,700 ft^3/s (1,098.7 Mgal/d) in 1967 to a high of about 20,500

ft^3/s (13,249.6 Mgal/d) in 1979. The average, 1-day minimum discharge over the reference period was about 7,072 ft^3/s (4,570.8 Mgal/d).

Average number of days of zero flow.--None.

Existing agreements regarding reservoir releases.--TVA attempts to provide for adequate releases from Chickamauga Dam to maintain a minimum daily average flow of about 6,000 ft^3/s (3,877.9 Mgal/d) below the dam.

Nickajack Reservoir

Location and drainage area.--Nickajack Reservoir is formed by Nickajack Dam which is located on the Tennessee River at river mile 424.7 in Marion County. Nickajack Dam controls 21,870 mi^2 of drainage area.

Reference period.--1960-81.

Reservoir discharge (minimum daily average flow).--Minimum daily average discharge from Nickajack Dam during the 1960-81 time period ranged from a low of about 1,300 ft^3/s (840.2 Mgal/d) in 1981 to a high of about 19,800 ft^3/s (12,797.1 Mgal/d) in 1979. The average, 1-day minimum discharge for the 1960-81 time period was about 7,786 ft^3/s (5,032.2 Mgal/d).

Average number of days of zero flow.--None.

Existing agreements regarding reservoir releases.--None.

Parksville Reservoir

Location and drainage area.--Parksville Reservoir is formed by Ocoee No. 1 Dam which is located on the Ocoee River at river mile 11.9 in Polk County. Ocoee Dam controls 595 mi^2 of drainage area.

Reference period.--1960-81.

Reservoir discharge (minimum daily average flow).--Minimum daily average discharge from Ocoee No. 1 Dam during the reference period ranged from a low of about 50.0 ft^3/s (32.3 Mgal/d) in 1970 to a high of about 708.0 ft^3/s (457.6 Mgal/d) in 1973. The average, 1-day minimum discharge during the reference period was about 157.9 ft^3/s (102.1 Mgal/d).

Average number of days of zero flow.--None.

Existing agreements regarding reservoir releases.--Ocoee No. 1 and Apalachia Dams are operated conjunctively so that the sum of the two releases equals no less than 600 ft^3/s (387.8 Mgal/d) on an average daily basis.

Ocoee No. 2 Reservoir

Location and drainage area.--Ocoee No. 2 Reservoir is formed by Ocoee No. 2 Dam which is located on the Ocoee River at river mile 24.2 in Polk County. Ocoee No. 2 Dam controls 512 mi^2 of drainage area.

Reference period.--1960-81.

Reservoir discharge (minimum daily average flow).--Minimum daily average discharge from Ocoee No. 2 Dam for the reference period ranged from a low of about 10.0 ft^3/s (6.5 Mgal/d) in 1980 to a high of about 974 ft^3/s (629.5 Mgal/d) in 1973. The average, 1-day minimum discharge for the reference period was about 352 ft^3/s (227.5 Mgal/d). Since Ocoee No. 2 Reservoir is filled with silt and the dam's power generation facilities ceased operation in 1976 due to flume failure, all flows, that is, reservoir releases from Ocoee No. 3 Dam, are passed through the reservoir to Parksville Reservoir.

Average number of days of zero flow.--None.

Existing agreements regarding reservoir releases.--None.

Ocoee No. 3 Reservoir

Location and drainage area.--Ocoee No. 3 Reservoir is formed by Ocoee No. 3 Dam which is located on the Ocoee River at river mile 29.2 in Polk County. Ocoee No. 3 Dam controls 492 mi^2 of drainage area.

Reference period.--1960-81.

Reservoir discharge (minimum daily average flow).--Minimum daily average discharge from Ocoee No. 3 Dam during the reference period ranged from a low of about 25.0 ft^3/s (16.2 Mgal/d) in 1981 to a high of about 884 ft^3/s (571.3 Mgal/d) in 1973. The average, 1-day minimum discharge during the reference period was about 331 ft^3/s (213.9 Mgal/d).

Average number of days of zero flow.--During the reference period, Ocoee No. 3 Dam has averaged almost 2 days of zero discharge per year ranging from a low of no days of zero discharge in numerous years to a high of 13 days in 1981. Zero-discharge days, when they did occur, were most common during the months of September and October. During the reference period, there were two instances, both in 1981, of zero discharge for 3 consecutive days from Ocoee No. 3 Dam.

Existing agreements regarding reservoir releases.--None.

Watts Bar Reservoir

Location and drainage area.--Watts Bar Reservoir is formed by Watts Bar Dam which is located on the Tennessee River at river mile 529.9 in Meigs and Rhea Counties. Watts Bar Dam controls 17,310 mi^2 of drainage area.

Reference period.--1960-81.

Reservoir discharge (minimum daily average flow).--Minimum daily average discharge from Watts Bar Dam for the 1960-81 time period ranged from a low of about 100 ft^3/s (64.6 Mgal/d) in 1963 to a high of about 16,600 ft^3/s (10,728.9 Mgal/d) in 1979. The average, 1-day minimum discharge during the reference period was about 5,195 ft^3/s (3,358.0 Mgal/d).

Average number of days of zero flow.--Zero-discharge days from Watts Bar Dam are rare with only 7 days having been recorded during the reference period. To date, there has been only one instance of zero discharge for 3 consecutive days and that occured in 1969.

Existing agreements regarding reservoir releases.--None.

Ground Water

The eastern part of the Lower Tennessee River basin lies in the Blue Ridge physiographic province and includes parts of Polk, McMinn, and Monroe Counties. The extreme western part of the basin lies on the Cumberland Plateau and includes parts of Hamilton, Sequatchie, Bledsoe, Marion, Grundy, and Rhea Counties. All of the remainder of the Lower Tennessee River basin lies in the Valley and Ridge province with the exception of the valley of the Sequatchie River. However, the rock formations underlying the Sequatchie Valley and the valleys of its tributaries are similar to those underlying the Valley and Ridge province. Consequently, the availability of ground water is essentially the same. Ground water is confined to fractures and openings in the underlying rock formations caused by severe folding and faulting of the rocks by the Unaka Mountain building forces. The number and size of these fractures are controlled both by the composition of the rock, distance from the Unaka Mountains, and by circulating ground water.

The Blue Ridge part of the Lower Tennessee River basin is underlain primarily by noncarbonate rocks such as sandstone, siltstone, shale, and conglomerate. Fractures in these rocks are not significantly enlarged by solution that may be caused by percolating ground water. Consequently, the yields of wells drilled on the mountains are generally low, ranging from 1 to 25 gal/min. Wells encountering little or no water are common on the mountain tops. The valleys often have a relatively thick regolith consisting of sand, clay, and rock fragments. Here, dug wells commonly furnish domestic supplies. Some wells have been located on the basis of geologic data and supply 100 gal/min or more. These were located near faults or a series of faults. Normally, wells drilled on the mountains and in the valleys do not exceed 250 feet in depth. Springs are common but furnish relatively small amounts of water in comparison with those in areas underlain by carbonate rocks. Ground-water quality is usually acceptable.

The area of the Lower Tennessee River basin lying in the Valley and Ridge province 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 somewhat by solution, but to a much lesser degree than the openings in the carbonate rocks. Ground water in quantities sufficient for domestic purposes are generally obtained from limestones and dolomites. Domestic supplies can usually be found in the sandstones 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 several gallons per minute to 50 gal/min. However yields from 100 to 250 gal/min are common. Some unpublished well logs indicate that open fractures yield water locally at depths greater than 350 feet. Moderately large to large springs are common in the limestone and dolomites. Water quality is usually acceptable.

The western part of the Lower Tennessee River basin lying in parts of Hamilton, Sequatchie, Marion, Rhea, Grundy, and Bledsoe Counties is located in the Cumberland Plateau physiographic province. Ground water in the Cumberland Plateau province occurs in fractures in tightly cemented sandstones and silty shales. As these siliceous rocks have not been structurally disturbed to the extent of those in the Valley and Ridge province, with the exception of the eastern escarpment of the Plateau, fractures are not as numerous. Also, fractures in the Plateau rocks are resistant to enlargement by the solvent action of ground water. Consequently, ground water is more difficult to obtain in significant quantities. Yields to drilled wells are generally less than 25 gal/min. However, in areas of more severe faulting near surface streams, well yields of 100 gal/min or more have been recorded. Well depths are usually 200 feet or less. However, unpublished well logs indicate that the Sewanee Conglomerate, in some local areas, can yield good-quality water from depths of at least 500 feet. With the exception of water produced in some local areas from the Sewanee Conglomerate, ground water from Plateau wells of less than 150 feet in depth is usually rather high in iron. In most cases the water is acidic due to dissolved carbon dioxide. Water encountered at or near coal seams or carbonaceous shale is usually high in sulfates and sometimes very acidic due to the decomposition of pyrite to sulfuric acid. Springs generally have low yields (less than 25 gal/min) and often go dry in times of low rainfall.

Ground water in the Lower Tennessee River basin is essentially confined to fractures in the rocks. In areas where fractures are numerous and particularly where they have been enlarged by solution relatively large yield wells are possible. Most of the wells listed in the existing ground-water data base were drilled for domestic use and were not located as a result of local geologic investigation. Therefore, the true ground-water potential of the Lower Tennessee River basin cannot be accurately assessed at present.

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 Lower Tennessee River basin are summarized in table 44. Individual counties included in this approximation are Bledsoe, Bradley, Hamilton, Marion, McMinn, Meigs, Polk, Rhea, and Sequatchie Counties. It should be noted that Hamilton, Marion, and Sequatchie Counties make up the Tennessee part of the Chattanooga, Tennessee-Georgia, Standard Metropolitan Statistical Area (SMSA). Large urban or metropolitan areas in the Tennessee part of the basin and their 1980 census population are Athens (12,080), Chattanooga (169,558), Cleveland (26,415), Collegedale (4,607), Dayton (5,913), Dunlap (3,681), East Ridge (21,236), Etowah (3,758), Jasper (2,633), Red Bank (13,299), Signal Mountain (5,818), and Soddy-Daisy (8,388).

Table 44.--County population, employment, and per capita personal income data, Lower Tennessee 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
Bledsoe	7,643	9,478	1,249	1,722	$4,026	$4,505
Bradley	50,686	67,547	20,130	25,794	6,447	7,239
Hamilton	255,077	287,740	126,204	152,669	7,916	9,005
Marion	20,577	24,416	3,908	5,437	5,253	6,504
McMinn	35,462	41,878	13,419	16,781	5,891	6,512
Meigs	5,219	7,431	997	1,500	4,817	6,041
Polk	11,669	13,602	3,893	3,712	5,448	6,210
Rhea	17,202	24,235	4,910	11,761	4,894	7,639
Sequatchie	6,331	8,605	1,118	1,813	4,593	4,997
Total	409,866	484,932	175,900	221,189	-	-

Public and Self-Supplied Commercial and Industrial Water Users

Currently, there are a total of 39 public water-supply facilities and 18 large, self-supplied commercial and industrial water users whose use exceeds 0.1 Mgal/d in the Lower Tennessee 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 table 21 and 22 of appendix I, respectively. Total water use or withdrawal at the present time for public and large, self-supplied commercial and industrial purposes in the Lower Tennessee River basin amounts to approximately 246.6 Mgal/d exclusive of the withdrawal for Southern Cellulose Products, Inc., which is confidential in nature. The general location and water-supply source of all public and large, self-supplied commercial and industrial water users inventoried in the Lower Tennessee River basin are depicted in figures 33 and 34, respectively.

Figure 33--Explanation

Site No.	Facility name	Site No.	Facility name
1	Pikeville WS	16	Sequatchie Water Works
2	Hiwassee Utilities Commission	17	Whitwell WS
		18	Athens Utilities Board
3	Cleveland Utilities Board	19	Englewood WS
4	Ocoee UD	20	Etowah WS
5	Big Creek UD		
		21	Benton WS
6	Daisy-Soddy Falling Water UD	22	Riceville UD
7	Mowbray Mountain UD	23	Decatur WS
8	Sale Creek UD	24	Cherokee Mills UD
9	Union Fork-Bakewell UD	25	Copperhill WS
10	Savannah Valley UD		
		26	Delano WS
11	Tennessee-American Water Co.	27	Ducktown WS
12	Eastside UD	28	Dayton WS
13	Hixson UD	29	Graysville WS
14	Waldens Ridge UD	30	Dunlap WS
15	Jasper WS		

Public water systems currently serve about 451,000 people or 93 percent of the basin's 1980 population. Average daily water use for public purposes equals about 69.0 Mgal/d, of which approximately 56.2 Mgal/d or 81 percent is withdrawn from surface-water sources and 12.8 Mgal/d or 19 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)
Hiwassee Utilities Commission	3.000
Cleveland Utilities Board	6.500

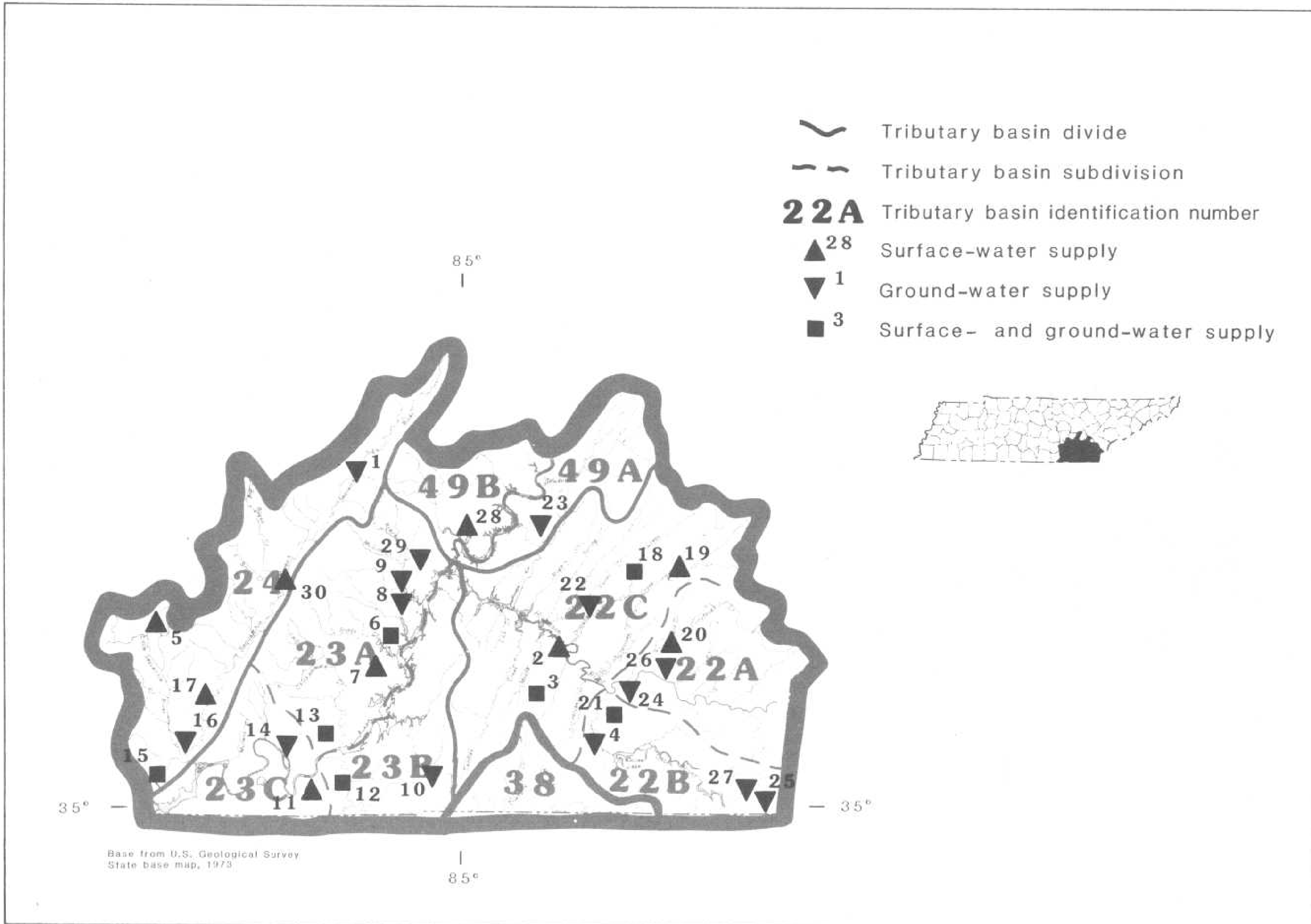

Figure 33.--Public water-supply facilities, Lower Tennessee River basin.

Facility name	Average water use (Mgal/d)
Tennessee-American Water Co.	42.200
Eastside UD	3.013
Hixson UD	4.000
Athens Utilities Board	2.225
Etowah WS	1.559

Together, these systems account for approximately 91 percent of the total water use for public purposes.

Figure 34--Explanation

Site No.	Facility name
1	Hardwick Stove Co. (Cleveland)
2	Magic Chef, Inc. (Cleveland)
3	Olin Corp. (Charleston)
4	Carbonic Industries Corp. (Harrison)
5	C. F. Industries, Inc. (Harrison)
6	Chattem Drug and Chemical Co. (Chattanooga)
7	Cumberland Corp. (Chattanooga)
8	Dixie Yarns, Inc. (Chattanooga)
9	DuPont Co. (Chattanooga)
10	General Portland, Inc. (Chattanooga)
11	Scholze Tannery (Chattanooga)
12	Southern Cellulose Products, Inc. (Chattanooga)
13	Tennessee Paper Mills, Inc. (Chattanooga)
14	General Portland, Inc. (Jasper)
15	Bowaters Southern Paper Corp. (Calhoun)
16	Ten Mile Stone Co., Inc. (Ten Mile)
17	Cities Service Co. (Copperhill)
18	Alco Chemical Corp. (Chattanooga)

Self-supplied commercial and industrial users currently use or withdraw about 177.5 Mgal/d, of which some 174.6 Mgal/d or 98 percent is withdrawn from surface-water sources and some 2.9 Mgal/d or 2 percent from ground-water sources. Major self-supplied industrial water users include DuPont Co. (10.400 Mgal/d) in Hamilton County, Bowaters Southern Paper Co. (80.000 Mgal/d) in McMinn County, and Cities Service Co. (72.000 Mgal/d) in Polk County. Consumptive water use by large, self-supplied commercial and industrial water users in the basin equals about 2.3 Mgal/d exclusive of the consumptive use for Southern Cellulose Products, Inc. which is less than 0.1 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 Lower Tennessee River basin. The number in

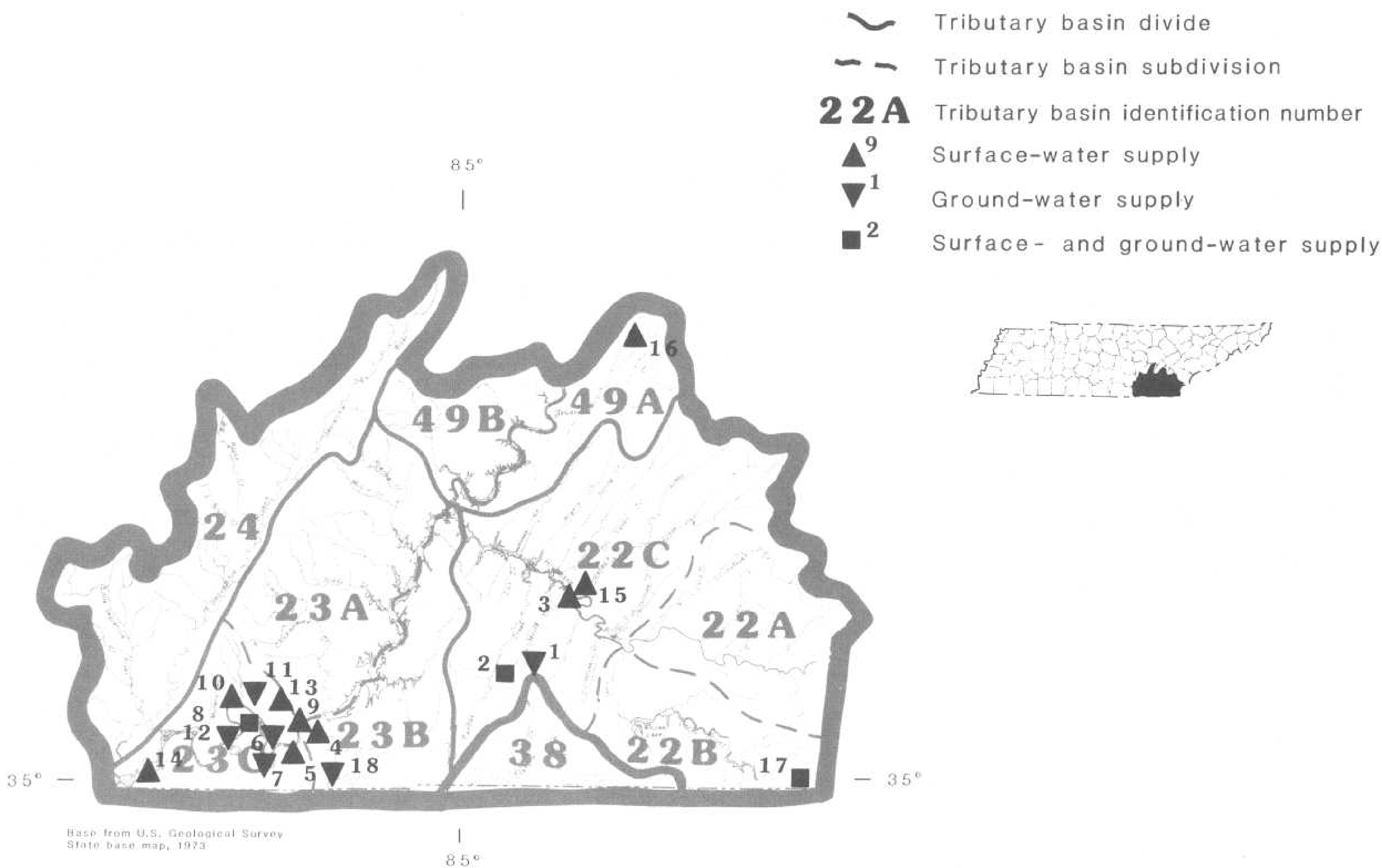

Figure 34.--Self-supplied commercial and industrial water users, Lower Tennessee River basin.

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.

- Occasional turbidity following heavy rainfall and flooding. (6)
- Inadequate storage capacity. (4)
- Periodic water-supply shortages during the late summer and fall months. (2)
- Serious water losses due to breaks in deteriorating water mains and distribution lines. (6)
- Occasional pumping problems at water-supply intake facilities along the Hiwassee River due to low river levels during periods of nonpower generation at Apalachia Dam. (1)
- Clogging of water-supply intake facilities as a result of the buildup of leaves and mud around the intake pumps. (1)

Water Supply Adequacy Analysis

The Lower Tennessee River drains approximately 3,029 mi^2 or 1,939,000 acres of land and water area. Surface- and ground-water resources in this basin are fed by an abundant rainfall whose long-term (1941-70) average varies from 51.10 inches above Chattanooga on the Tennessee River to 57.90 inches above Charleston on the Hiwassee River. Average annual runoff in the Lower Tennessee River basin ranges from 22 to 32 inches with the heaviest runoff occurring in the Hiwassee River gorge area along the Tennessee State line. In general, the months of September, October, and November are the driest months in this area with March having the highest rainfall.

Average daily water use or withdrawal for public and large, self-supplied water users in the Lower Tennessee River basin equals about 246.6 Mgal/d. Approximately, 69.0 Mgal/d of this amount is withdrawn for public water-supply purposes with 56.2 Mgal/d or 81 percent being withdrawn from surface water supplies and 12.8 Mgal/d or 19 percent from ground-water supplies. Commercial and industrial water users utilize some 177.5 Mgal/d of which 174.6 Mgal/d or 98 percent are withdrawn from surface-water sources and 2.9 Mgal/d or 2 percent from ground-water sources. Major self-supplied industrial water users include DuPont Co. (10.400 Mgal/d) in Hamilton County; Bowaters Southern Paper Co. (80.000 Mgal/d) in McMinn County; and Cities Service Co. (72.000 Mgal/d) in Polk County. Consumptive water use by self-supplied commercial and industrial water users equals only 2.3 Mgal/d exclusive of Southern Cellulose Products' consumptive use which is less than 0.1 Mgal/d.

While many of this basin's public and self-supplied water users are served via surface- and (or) ground-water sources whose long-term, dependable source capacity is well in excess of or amply adequate to meet the community or user's water withdrawal demands, others listed below are utilizing water sources whose source capacity is either unknown or less than or nearly equal to their average daily withdrawal. The figure in parentheses following each source indicates what percentage of that facility or user's total water demand is supplied by that source.