Prepared in cooperation with the
TENNESSEE DEPARTMENT OF ENVIRONMENT
AND CONSERVATION,
DIVISION OF WATER SUPPLY

Public Water-Supply Systems and Associated Water Use in Tennessee, 2000

Water-Resources Investigations Report 03-4264

U.S. Department of the Interior
U.S. Geological Survey

Cover photographs: Left photograph is a well in Shelby County, Tennessee. Middle photograph is the Buffalo River near Lobelville, Tennessee. Right photograph is Malone Spring near Niota, Tennessee.

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By Ank Webbers

U.S. GEOLOGICAL SURVEY

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Nashville, Tennessee
2003

U.S. DEPARTMENT OF THE INTERIOR
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Denver, Colorado 80225-0286

CONTENTS

FIGURES

TABLES

Conversion Factors, Datum, and Acronyms

Multiply	By	To obtain
inch (in.)	2.54	centimeter (cm)
square mile (mi^2)	2.590	square kilometer (km^2)
gallon (gal)	3.785	liter (L)
gallon (gal)	0.003785	cubic meter (m^3)
million gallons (Mgal)	3,785	cubic meters (m^3)
acre-foot (acre-ft)	1,233	cubic meter (m^3)
gallon per minute (gal/min)	0.06309	liter per second (L/s)
gallon per day (gal/d)	0.003785	cubic meter per day (m^3/d)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsuis (°C) as follows:
°C = (°F-32)/1.8

Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29).

Acronyms

PWSID Public Water System Identification Number
TDEC Tennessee Department of Environment and Conservation
USGS U.S. Geological Survey

GLOSSARY

Hydrologic region: Hydrologic regions are used in the United States to divide and subdivide areas of drainage, based on the direction of water flow. Each division is identified by a unique hydrologic unit code (HUC) consisting of two to eight digits. A region (major geographic area) contains either the drainage area of a major river or the combined drainage areas of a series of rivers. A subregion includes the area drained by a river system, a reach of a river, and its tributaries in that reach, a closed basin(s) or a group of streams forming a coastal drainage area.

Public water supply: Public water supply refers to water withdrawn by public and private utilities for delivery to domestic, commercial, and industrial users and for municipal services such as firefighting. Water lost by leaky pipes in the distribution system (conveyance losses) and system maintenance is included in this category.

Water use: In this report, the quantity of water use for a specific category is the combination of water-supply withdrawals and public-supply deliveries. In a restrictive sense, the term refers to water that is actually used for a specific purpose such as for domestic use, irrigation, or industrial processing. More broadly, water use pertains to human interaction with the hydrologic cycle, and includes dimensions such as water withdrawal, delivery, consumptive use, wastewater release, reclaimed wastewater, return flow, and instream use.

Public Water-Supply Systems and Associated Water Use in Tennessee, 2000

By Ank Webbers

ABSTRACT

Public water-supply systems in Tennessee provide water to meet customer needs for domestic, industrial, and commercial users and municipal services. In 2000, more than 500 public water-supply systems distributed about 890 million gallons per day (Mgal/d) of surface water and ground water to a population of about 5 million in Tennessee. Surface-water sources provided 64 percent (about 569 Mgal/d) of the State's water supplies, primarily in Middle and East Tennessee. Ground water produced from wells and springs in Middle and East Tennessee and from wells in West Tennessee provided 36 percent (about 321 Mgal/d) of the public water supplies. Springs in Middle and East Tennessee provided about 14 percent (about 42 Mgal/d) of ground-water supplies used in the State. Per capita water use for Tennessee in 2000 was about 136 gallons per day. An additional 146 public water-supply systems provided approximately 84 Mgal/d of water supplies that were purchased from other water systems.

Water withdrawals by public water-supply systems in Tennessee have increased by over 250 percent; from 250 Mgal/d in 1955 to 890 Mgal/d in 2000. Although Tennessee public water-supply systems withdraw less ground water than surface water, ground-water withdrawal rates reported by these systems continue to increase. In addition, the number of public water-supply systems reporting ground-water withdrawals of 1 Mgal/d or more in West Tennessee is increasing.

INTRODUCTION

Tennessee has an abundant supply of water that is readily available within the State. Man-made lakes along major rivers such as the Tennessee River and the Cumberland River in West and Middle Tennessee, respectively, can store more than 2 trillion gallons of water. Ground water in the aquifers in Tennessee is estimated in excess of 200 trillion gallons. Approximately 1 percent of these water supplies are used by public water-supply systems, which withdraw, treat, and distribute the water to commercial, industrial, and municipal services.

The population of Tennessee in 2000 was reported as 5,689,283 by the U.S. Census Bureau (2003). As Tennessee's population has increased with time, so too has the number of people relying on public water-supply systems for their water. In 2000, a total population served of 5,019,687 was reported by the public water-supply systems in Tennessee, which is about 88 percent of the population of the State. The withdrawal rates reported by the public water-supply systems are directly influenced by the demand for water supplies across the State. Studies documenting the number of public water-supply systems and their withdrawal rates can provide local and regional government agencies with a better understanding of past, current, and future water use.

Purpose and Scope

The U.S. Geological Survey (USGS), in cooperation with the Tennessee Department of Environment and Conservation (TDEC), Division of Water Supply (DWS), prepared this report to provide information on water use by public water-supply systems in Tennessee. The report describes and quantifies the source and amount of water withdrawn and delivered by public water-supply systems in Tennessee for 2000, and describes the sources of water used by the public water-supply systems.

Water-use data for the calendar year 2000 were obtained from TDEC, DWS, which regulates public water-supply system withdrawals and usage within Tennessee. Water-use data prior to 2000 were obtained from historical reports. The data analyses for this report include graphic summaries, descriptions of water use, and changes in water use in Tennessee from 1950 to 2000.

Description of the Study Area

Tennessee is located in the central southeastern region of the United States, bounded by the Mississippi River on the west and extending to the Blue Ridge Physiographic Province and Appalachian Mountains on the east. Tennessee encompasses an area of 42,126 square miles (mi^2), which includes 926 mi^2 of inland water. Land-surface elevations range from about 180 feet above NGVD 29 along the Mississippi River to over 6,600 feet above NGVD 29 in the mountains of East Tennessee. Rainfall in Tennessee is approximately 50 to 54 inches per year. The three divisions of Tennessee—West, Middle, and East—are characterized by distinct differences in geology, physiography, and hydrography. In West Tennessee, thick unconsolidated sedimentary aquifers provide millions of gallons of ground water for public water supplies. In Middle and East Tennessee, public water supplies primarily come from surface water with additional supplies produced from ground water, some of which comes from springs flowing from fractured rock.

Hydrography

Tennessee's hydrography consists of surface- and ground-water resources that exhibit unique patterns of surface drainage and underground flow, respectively (table 1). Three major hydrologic regions divide the State's surface-water hydrography from West Tennessee to East Tennessee—the Lower Mississippi, the Ohio, and the Tennessee hydrologic regions (fig. 1). A small part of southeastern Tennessee is in the South Atlantic-Gulf region. Within the major hydrologic regions are smaller hydrologic subregions, containing river basins and tributaries that determine water drainage within the State.

In Middle and East Tennessee, the Ohio hydrologic region includes the Cumberland River and its tributaries, and the Tennessee hydrologic region includes the Tennessee River and its tributaries. The Cumberland and Tennessee River Basins sustain an extensive network of reservoirs that store about 8.12 million acre-feet (2,647 billion gallons) of water (Hutson, 1990). In West Tennessee, the Lower Mississippi hydrologic region drains about 8,907 mi^2 of water. Surface-water characteristics of the hydrologic subregions and major river basins in Tennessee are described in table 1.

Ground water for public supply in Tennessee is supplied by eight of the nine principal aquifers (fig. 2, table 2), which, depending on structure and material content, can store and transport water within intergranular openings, fractures, or solution-enlarged openings. The principal aquifers in Tennessee that are used for public water supply are the Alluvial, Tertiary sand, Cretaceous sand, Mississippian carbonate, Ordovician carbonate rock, Pennsylvanian sandstone, Cambrian-Ordovician carbonate, and the crystalline rock aquifers (Bradley and Hollyday, 1985). About 75 percent of the ground water used for public supplies in Tennessee is produced from the Tertiary sand aquifers, primarily the Memphis aquifer, in West Tennessee. In Middle and East Tennessee, ground water may discharge at large springs, which also are used for water supplies. Information about the aquifers and production well characteristics in Tennessee is given in table 2. Detailed descriptions and water-quality information for the aquifers in Tennessee can be found in the following reports: Brahana and Bradley (1985); Brahana, Bradley, and Mulderink (1986); Brahana, Macy, and others (1986); Brahana, Mulderink, and others (1986); Brahana, Mulderink, Macy, and Bradley (1986); Parks and Carmichael (1989); and Kingsbury and Parks (1993).

Physiography

The diverse topography of Tennessee includes eight physiographic divisions (fig. 2, table 1) that range from broad flood plains in the Coastal Plain Physiographic Province of West Tennessee, to rolling hills and karst plains in the Highland Rim and Central Basin of Middle Tennessee, to steep mountains and deep narrow valleys in the Valley and Ridge Physiographic Province of East Tennessee. The geology of Tennessee includes unconsolidated sediments of the Coastal Plain in West Tennessee; limestone and dolomite of the Highland Rim and Central Basin in Middle Tennessee; and limestone, sandstone, and shale of the Cumberland Plateau, limestone, dolomite and shale in the Valley and Ridge Province, and metamorphic and

Table 1. Surface-water characteristics of hydrologic subregions and major river basins in Tennessee

Hydrologic subregion[1]	Major river basin and associated river	Physiographic divisions (Miller, 1974)	Response to drought	Remarks
Lower Mississippi-Hatchie	Hatchie-Obion Obion Hatchie Loosahatchie Wolf Nonconnah Forked Deer	Coastal Plain	Sustained flow from ground water in main stem during dry months. Small streams will be dry.	Few available storage sites. High sediment load and poor water quality limits use; pumps must use filters.
Cumberland (including the Green River basin in Tennessee)	Upper Cumberland Obey Caney Lower Cumberland Harpeth Stones Red	Central Basin Highland Rim Cumberland Plateau	Many small unregulated streams are characterized by no flow or low flow during dry periods. The Cumberland River is regulated.	In the Central Basin, streamflow is highly responsive to rainfall and flows are poorly sustained. Streamflows are fairly well sustained in the Highland Rim. The Sequatchie River streamflows in the Cumberland Plateau are poorly sustained.
Lower Tennessee	Lower Tennessee Duck Buffalo Beech Big Sandy	Highland Rim Central Basin Western Valley	In late summer and early fall, unregulated streams go dry or sustain low flows.	In the Central Basin, streamflow is highly responsive to rainfall and flows are poorly sustained. Streamflows are fairly well sustained in the Highland Rim. Streamflow is adequately sustained for supply in the Western Valley.
Middle Tennessee-Elk	Middle Tennessee-Elk Elk Shoal Flint	Highland Rim Cumberland Plateau Central Basin	Commonly in late summer, unregulated streams go dry, particularly along the basin rim.	In the Central Basin, streamflow is highly responsive to rainfall and flows are poorly sustained. Streamflows are fairly well sustained in the Highland Rim. In the Cumberland Plateau, streamflows are poorly sustained.
Upper Tennessee	French Broad-Holston French Broad Holston Nolichucky Upper Tennessee Clinch Powell Little Tennessee Little Tellico	Blue Ridge Valley and Ridge Cumberland Plateau	Commonly in late summer, unregulated streams go dry. Many small unregulated streams may sustain low flow with ground-water inflow.	In the Blue Ridge, steep terrain and low permeability result in high runoff rates. Many springs are in the area. Surface-water impoundments enhance water supplies in the Valley and Ridge. In the Cumberland Plateau, streamflows are poorly sustained.
Middle Tennessee-Hiwassee (including the Alabama region)	Middle Tennessee-Hiwassee Hiwassee Sequatchie	Blue Ridge Valley and Ridge Cumberland Plateau Sequatchie Valley	Commonly in late summer, unregulated streams go dry, particularly along the basin rim. Even streams having watersheds exceeding 100 square miles may cease to flow.	In the Blue Ridge, steep terrain and low permeability result in high runoff rates. Many springs are in the area. Surface-water impoundments enhance water supplies in the Valley and Ridge. In the Cumberland Plateau, streamflows are poorly sustained.
South Atlantic-Gulf[2]	Conasauga	Blue Ridge Valley and Ridge	Commonly in late summer, unregulated streams go dry, particularly along the basin rim.	In the Blue Ridge, steep terrain and low permeability result in high runoff rates. Many springs are in the area. Surface-water impoundments can enhance water supplies.

[1]Refer to figure 1 for location on map.
[2]South Atlantic-Gulf Region extending from Alabama.

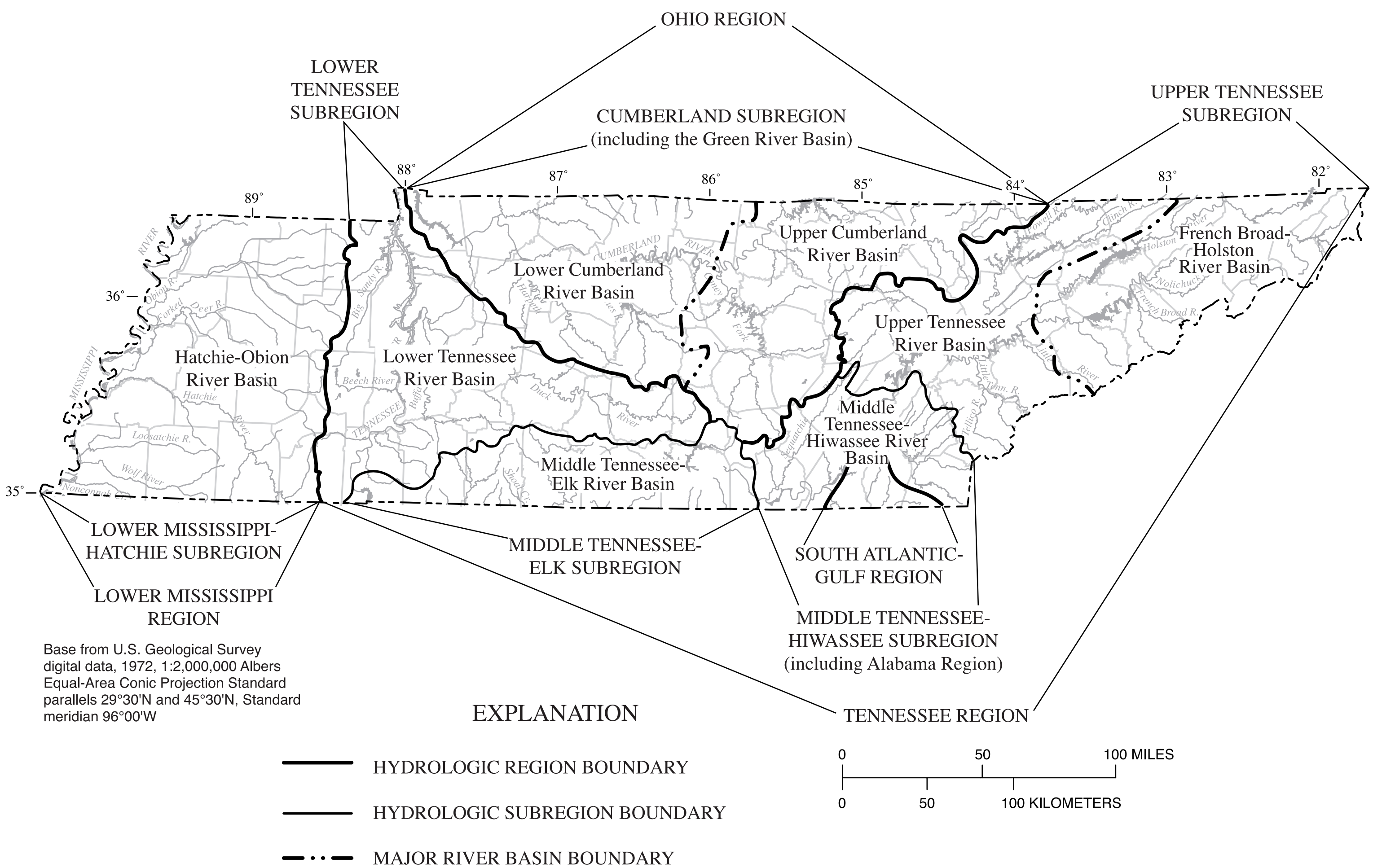

Figure 1. Major hydrologic regions and subregions and major river basins in Tennessee.

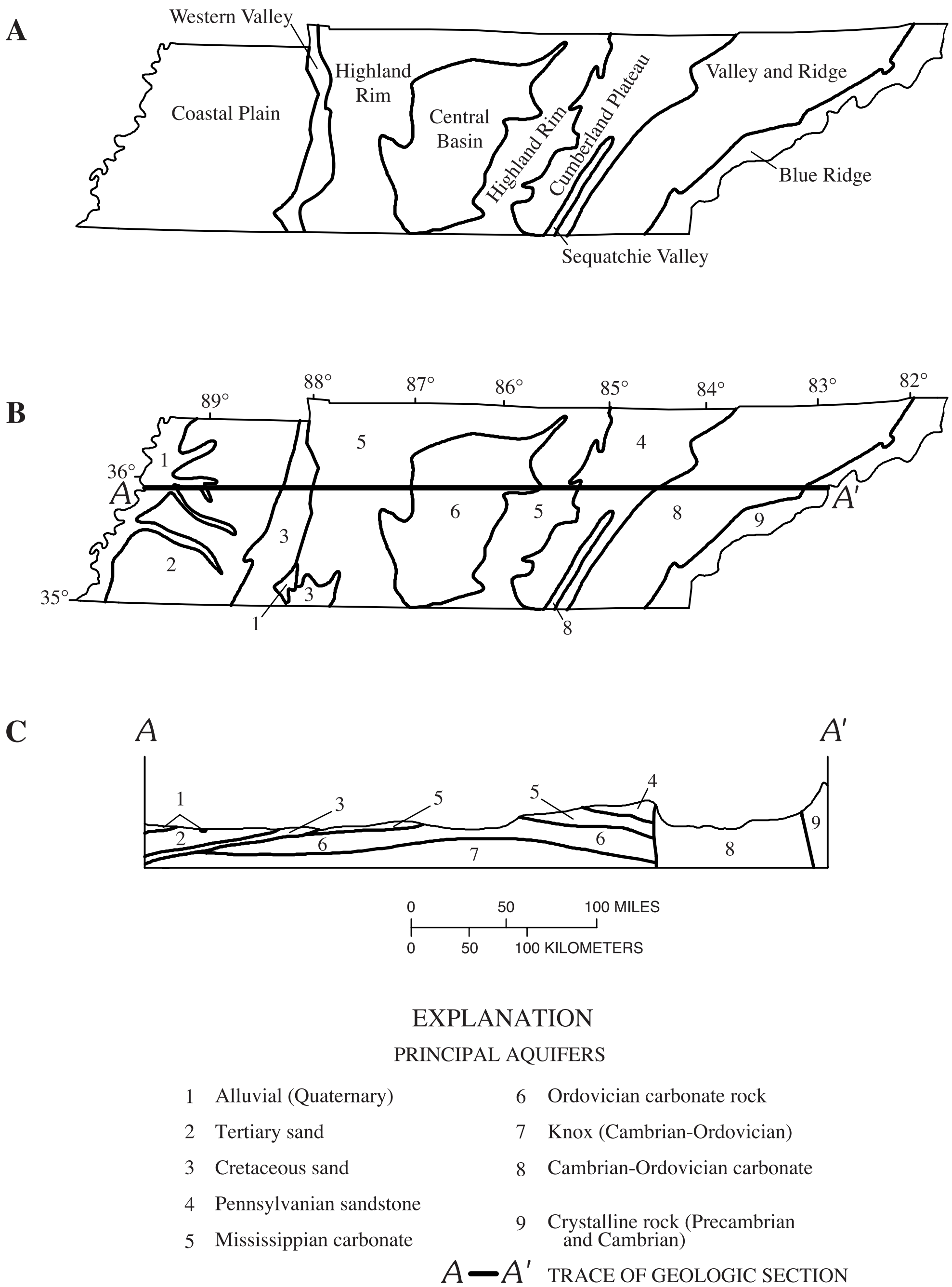

Figure 2. (A) Major physiographic divisions (modified from Fenneman, 1946, and Miller, 1974), (B) principal aquifers (modified from Hollyday and Bradley, 1985), and (C) generalized geologic section in Tennessee (Hollyday and Bradley, 1985).

Table 2. Aquifer and well characteristics in Tennessee (modified from Hollyday and Bradley, 1985)

Aquifer name[1] and description	Well characteristics: Depth (feet) — Common range	Depth (feet) — May exceed	Yield (gallons/minute) — Common range	Yield (gallons/minute) — May exceed	Remarks
Alluvial: Sand, gravel, and clay. Unconfined.	10 - 75	100	20 - 50	1,500	High iron concentrations in some areas.
Tertiary sand: Multi-aquifer unit of sand, clay, silt, and some gravel and lignite. Confined; unconfined in the outcrop area.	100 - 1,300	1,500	200 - 1,000	2,000	Includes Memphis Sand of Claiborne Group and Fort Pillow Sand of Wilcox Group. Problems with high iron concentrations in some places.
Cretaceous sand: Multi-aquifer unit of interbedded sand, clay, marl, and gravel. Confined; unconfined in the outcrop area.	100 - 1,500	2,500	50 - 500	1,000	Includes McNairy and Coffee Sands, and Tuscaloosa Formation. Water withdrawn primarily in the outcrop area.
Pennsylvanian sandstone: Multi-aquifer unit, primarily sandstone and conglomerate, interbedded shale and some coal. Unconfined near land surface; confined at depth.	100 - 200	250	5 - 50	200	Permeability is from fractures, faults, and bedding-plane openings. Principal water-bearing units are Rockcastle and Sewanee Conglomerates. High iron concentrations are a problem.
Mississippian carbonate: Multi-aquifer unit of limestone, dolomite, and some shale. Unconfined or partly confined near land surface; may be confined at depth.	50 - 200	250	5 - 50	400	Water occurs in solution and bedding-plane openings. Principal water-bearing units are Ste. Genevieve (Monteagle), St. Louis and Warsaw Limestones and Fort Payne Formation. Water generally hard; high iron, sulfide, or sulfate concentrations are a problem in some areas.
Ordovician carbonate rock: Multi-aquifer unit of limestone, dolomite, and shale. Partly confined to unconfined near land surface; confined at depth.	50 - 150	200	5 - 20	300	Principal water-bearing units are Bigby, Carters, Ridley, and Murfreesboro Limestones. Water generally hard; some high sulfide or sulfate concentrations in places.
Knox: Primarily dolomite, some limestone; confined. Does not have the structural complexity of the Cambrian-Ordovician carbonate aquifer.	700 - 1,200	1,400	1 - 10	20	Deep aquifer; present beneath most of central and western Tennessee. Away from Central Basin, water generally has high concentrations of dissolved solids.
Cambrian-Ordovician carbonate: Highly faulted multi-aquifer unit of limestone, dolomite, sandstone, and shale; structurally complex. Unconfined; confined at depth.	100 - 300	400	5 - 200	2,000	Principal water-bearing units are carbonate rocks in Chickamauga Limestone, Knox Group, and Honaker Dolomite. Water is generally hard. Brine below 3,000 feet.
Crystalline rock: Multi-aquifer unit of dolomite, granite gneiss, phyllite, and metasedimentary rocks overlain by thick regolith; alluvium and colluvium in some valleys. Generally unconfined.	50 - 150	200	5 - 50	1,000	High yields occur primarily in dolomite or deep colluvium and alluvium. Shady Dolomite is a principal aquifer. Low pH and high iron concentrations may be problems in some areas.

[1]Refer to figure 2 for location map.

igneous crystalline rocks of the Blue Ridge Physiographic Province in East Tennessee (Miller, 1974).

Previous Investigations

A review of previous investigations describing water use by public water-supply systems in Tennessee from 1950 to 1995 indicate that (1) water withdrawals by public water-supply systems in Tennessee have increased since the 1950s, (2) surface water provided most (60-64 percent) of Tennessee's public water supplies, and (3) surface-water use has increased at a faster rate than ground-water use (MacKichan, 1951, 1957; Murray and Reeves, 1972, 1977; Hutson, 1989, 1991, 1999; Hutson and Morris, 1992; Solley and others, 1993). MacKichan (1951) prepared one of the earliest water-use reports in Tennessee. The combined municipal supplies of ground water and surface water were estimated at 160 Mgal/d in 1950, with ground-water use estimated to be 85 Mgal/d and surface-water use estimated to be 75 Mgal/d. In 1955, total public water withdrawals for Tennessee were an estimated 250 Mgal/d (MacKichan, 1957). By 1970, total public water withdrawals had reached approximately 440 Mgal/d (Murray and Reeves, 1977). From 1988 to 1990, surface-water withdrawals decreased slightly from 446 to 426 Mgal/d, respectively, which corresponded with a decrease in the population of Tennessee from 4.92 to 4.88 million. Ground-water withdrawals in the State, however, increased slightly during the same time period by 7 Mgal/d from 262 Mgal/d (Hutson and Morris, 1992) to 269 Mgal/d (Solley and others, 1993). In 1995, total withdrawals by public water-supply systems reached 779 Mgal/d (Hutson, 1999), which is a 53-percent increase since 1980 (510 Mgal/d). According to Hutson and Morris (1992), overall growth in public water supplies during 1988 was attributed to changing water-use demands and changing water-use patterns in the commercial and industrial sectors. However, the number of water systems distributing public water supplies in Tennessee decreased from 541 in 1988 (Hutson and Morris, 1992) to 530 systems in 1995 (Hutson, 1999).

Approach and Methods

To assess water use in Tennessee, data were collected and analyzed for public water-supply systems active between January 1 and December 31, 2000. The public water-supply systems included investor-owned water companies, private water companies, municipal water departments, regional water authorities, institutions, residential developments, mobile home parks, and homeowner associations. Each water system supplied TDEC, DWS, with monthly operating reports that included information on the source of water, mean daily or monthly water withdrawal rates, and the population served. In some instances, phone calls were made directly to a public water-supply system to supplement missing data.

Monthly and annual average water withdrawals of each public water-supply system were separated into categories of surface water, ground water, and purchased water. The withdrawal rates of systems using surface- and ground-water supplies were calculated and compared with historic withdrawal rates and with changes in the population served. The amounts of water purchased by public water-supply systems are not included in the calculations for the amount of water withdrawn from the surface-water basins or from the aquifers. The amount of purchased water used by a system is included in the gross per capita water use listed in the supplemental tables (A, B, and C) near the end of this report.

Acknowledgments

The author thanks the managers of the public water-supply systems for providing data on which this report is based. The author also thanks David Draughon, Director of the Division of Water Supply, and Jeff Bagwell of the Tennessee Department of Environment and Conservation, who initiated the data-collection program and coordinated transmittal of survey forms from the public water-supply systems to the TDEC Environmental Field Office managers and staff in Chattanooga, Cookeville, Jackson, Johnson City, Knoxville, and Nashville, Tennessee.

PUBLIC WATER-SUPPLY SYSTEMS

Public water-supply systems may use a readily available river or stream as a surface-water source, withdraw water from a drilled well or spring as a ground-water source, or purchase water from another water system. In 2000, Tennessee was served by 526 public water-supply systems with 380 systems providing non-purchased ground-water or surface-water supplies. The remaining 146 systems provided about 84 Mgal/d of purchased water supplies to Tennessee residents. Purchased supplies are water purchased or obtained from another public water-supply system (Hutson, 1999).

Of the 380 public water-supply systems using non-purchased water, 144 systems withdrew surface water for their public water supplies and 256 systems withdrew ground water, with about 20 of these systems using both surface and ground water. These numbers represent an increase of 30 systems using surface water and an increase of 46 systems using ground water, since 1995 (Hutson, 1999). Supplements A, B, and C list each public water-supply system based on water withdrawal from one of three major hydrologic regions in Tennessee. The supplemental tables provide information about the water source(s) for each public water-supply system; the amount of water withdrawn, sold, or purchased; the population served by each system; the gross per capita water use for each system; and the storage and design capacities of each supply system when such information is known. An index of all the public water-supply systems in Tennessee from which water-use data were available is included in the report. The index is sorted by system name and provides the public water-supply system identification number and the page number in the supplemental tables where data for the system are located.

Each of Tennessee's 95 counties was served by at least one public water-supply system in 2000 (fig. 3). The largest ground-water withdrawal rate (about 167 Mgal/d) by a single public water-supply system was reported by Memphis Light, Gas and Water (MLGW), which served 644,275 people in Shelby County in 2000. The greatest number of individual public water-supply systems (17) was recorded in Gibson County.

PUBLIC WATER SUPPLIES AND WATER USE DURING 2000

During 2000, non-purchased water supplies withdrawn by Tennessee's public water-supply systems was about 890 Mgal/d, which is a combined withdrawal of 64 percent surface water (568.78 Mgal/d) and 36 percent ground water (320.72 Mgal/d) (fig. 4). The amount of public water-supply withdrawals of surface water and ground water in 2000 marks a 450-percent increase (730 Mgal/d) since 1950. A discussion of surface- and ground-water withdrawals during 2000 and how they compare to previous years' withdrawals follows.

Surface Water

In 2000, surface water provided approximately 569 Mgal/d of the total non-purchased public water supplies distributed by water systems in Tennessee. This quantity represents an increase of about 69 Mgal/d (about 14 percent) since 1995 (500 Mgal/d) (fig. 5). The ratio of surface-water to ground-water withdrawals for 1995 and 2000 are higher than in previous years, suggesting a more intensive demand for surface-water supplies. Ninety public water systems in 2000 withdrew surface-water supplies of 1 Mgal/d or more. The largest surface-water withdrawals by public water-supply systems in the State occurred in counties located in the Ohio and Tennessee hydrologic regions and came primarily from the Cumberland River (173.30 Mgal/d) and the Tennessee River (100.17 Mgal/d). Other rivers in Tennessee provided about 178 Mgal/d of the State's potable water supplies in 2000 (table 3).

Surface-water use increased in 2000 in Middle and East Tennessee, but was not a factor in West Tennessee. Water-supply systems serving the Metropolitan Nashville/Davidson County area served over 514,000 customers in 2000 and withdrew about 120 Mgal/d

Table 3. Surface-water withdrawals from Tennessee rivers in 2000
[Withdrawals in million gallons per day]

River name	Surface-water withdrawal
Cumberland	173.30
Tennessee	100.17
South Holston	23.99
Clinch	20.83
Duck	19.74
East Fork Stones	18.13
Little	12.28
Hiwassee	11.87
Watauga	10.91
Barron Fork	10.86
Nolichucky	10.10
Priest Lake/Stones	9.87
Holston	9.58
French Broad	7.99
Little Tennessee	3.66
Harpeth	2.57
Sequatchie	2.28
Caney Fork	1.48
Piney	1.21
Buffalo	0.75

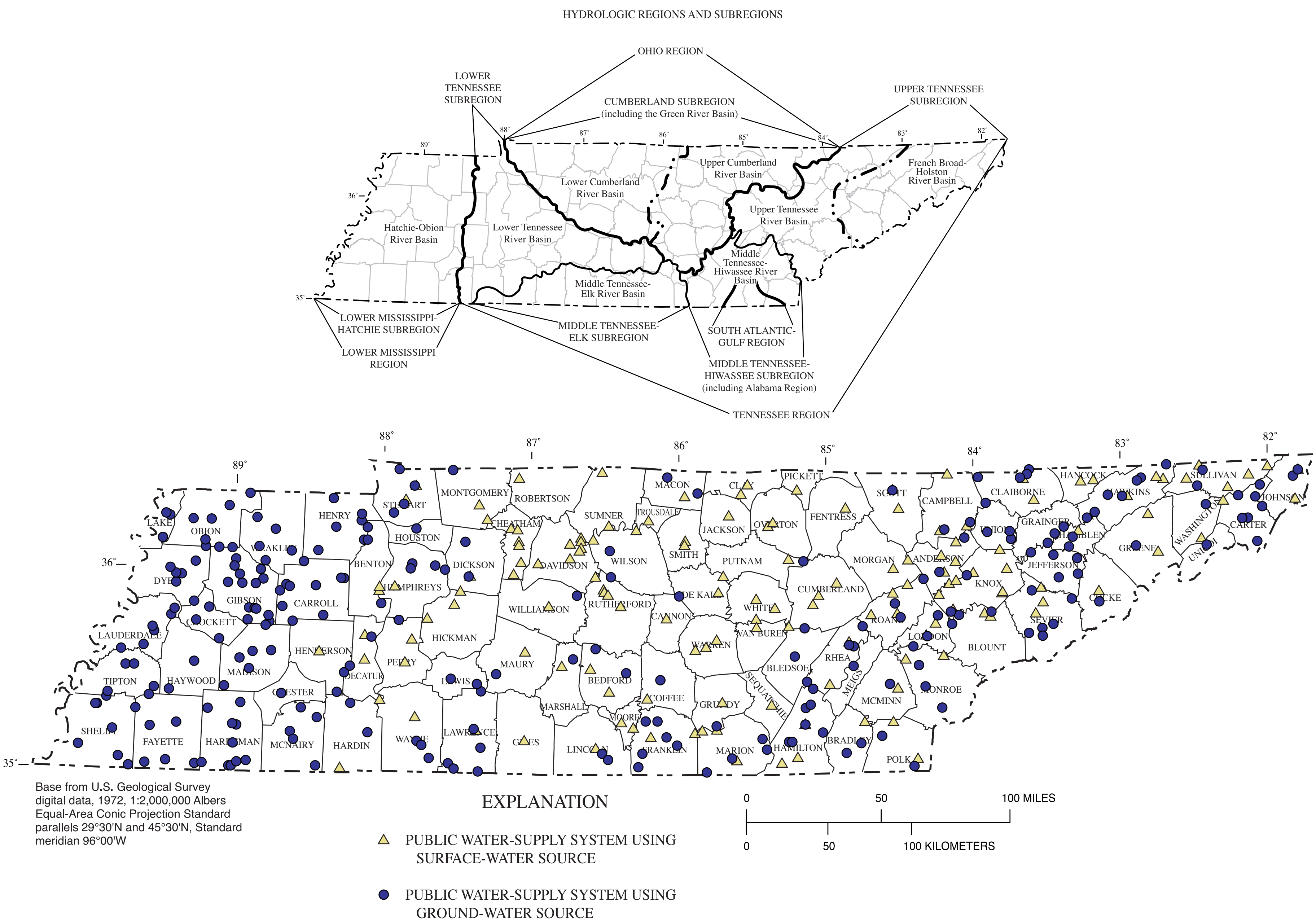

Figure 3. Distribution of public water-supply systems using surface water or ground water in Tennessee in 2000.

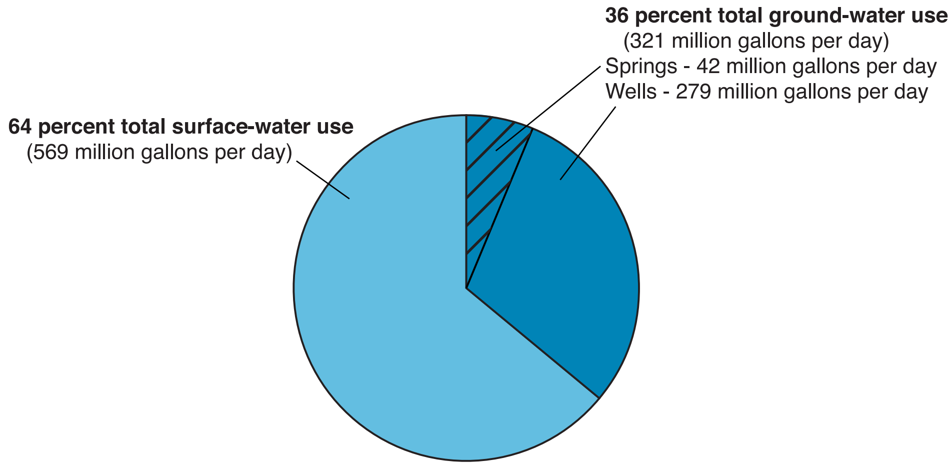

Figure 4. Sources of water for public water-supply systems in Tennessee in 2000.

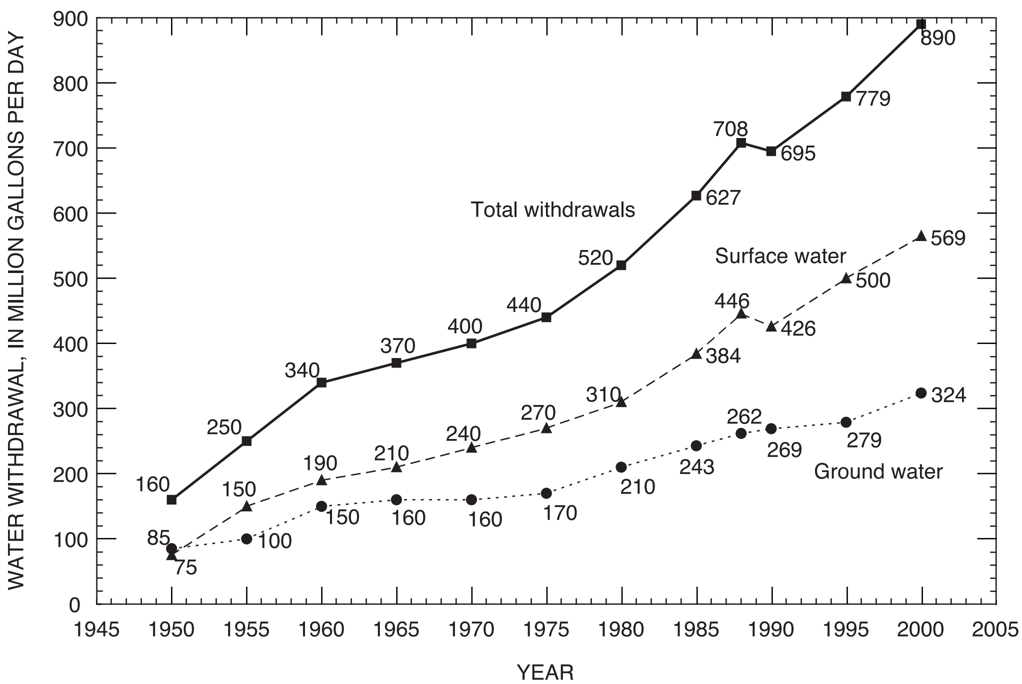

Figure 5. Surface-water and ground-water withdrawals by public water-supply systems in Tennessee, 1950 to 2000.