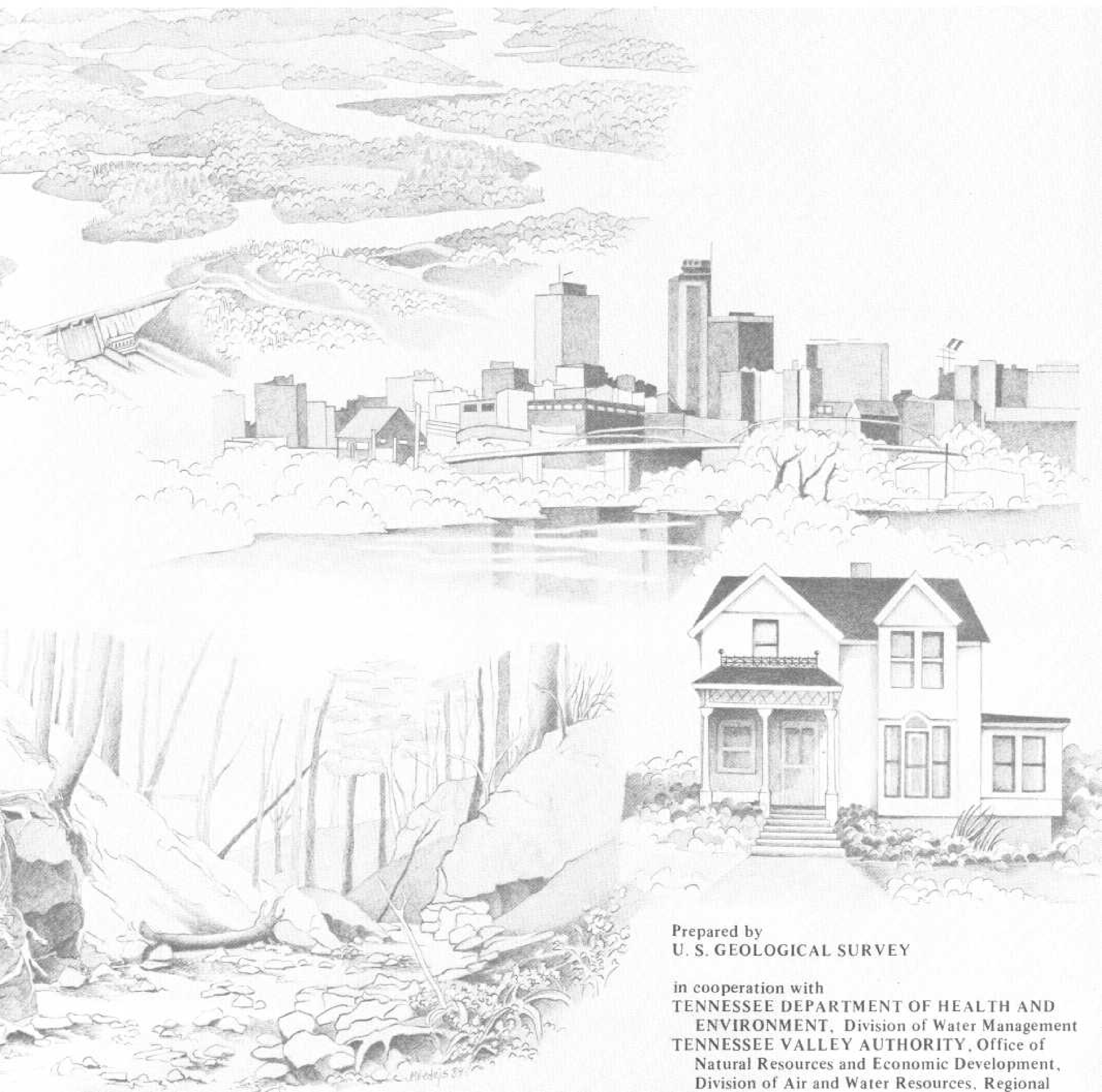
WATER-RESOURCES INVESTIGATIONS REPORT 84-4074

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

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

By Frank M. Alexander and Lee A. Keck, TDWM; Lewis G. Conn, USGS; and Stanley J. Wentz, TVA

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OFFICE OF NATURAL RESOURCES AND ECONOMIC DEVELOPMENT,

DIVISION OF AIR AND WATER RESOURCES,

REGIONAL WATER MANAGEMENT PROGRAM

Nashville, Tennessee

1984

UNITED STATES DEPARTMENT OF THE INTERIOR

WILLIAM P. CLARK, Secretary

GEOLOGICAL SURVEY

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CONVERSION FACTORS

For use of readers who prefer to use metric units, conversion factors for terms used in this report are listed below:

Multiply	By	To obtain
foot (ft)	0.3048	meter (m)
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
gallon per day (gal/d)	0.0038	cubic meter per day (m^3/d)
million gallon per day (Mgal/d)	3,785	cubic meter per day (m^3/d)
gallon per minute (gal/min)	0.06309	cubic meter per second (m^3/s)
cubic foot per second per square mile [(ft^3/s)/mi^2]	0.01093	cubic meter per second per square kilometer [(m^3/s)/km^2]
inch (in.)	25.4	millimeter (mm)
inch per year (in/yr)	25.4	millimeter per year (mm/a)
square mile (mi^2)	2.590	square kilometer (km^2)

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

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ABSTRACT

The Tennessee Division of Water Management conducted a water use survey of all public community water facilities and large, self-supplied commercial and industrial water users during 1982. During 1981, 463 public community water facilities supplied water to approximately 3,814,000 people or 83 percent of the 1980 population of Tennessee. Total water supplied was 566.1 million gallons per day of which 346.8 million gallons per day or 61 percent was from surface-water sources and 219.3 million gallons per day or 39 percent was from ground water. Ground water was used for public supply statewide, however, it was the sole source of public supply west of the Tennessee River basin. Of the 219.3 million gallons per day used statewide, 164.0 million gallons per day or 75 percent was used in West Tennessee.

Statewide 129 companies indicated a self-supplied water use of 0.1 million gallons per day or more. Four of these companies were in the Cumberland River basin, 40 in West Tennessee, and 85 in the Tennessee River basin. The total self-supplied water used by these companies was 1,106.7 million gallons per day of which 1,006.8 million gallons per day or 91 percent was surface water while 99.9 million gallons per day or 9 percent was ground water. The largest self-supplied user had an average demand of 454.3 million gallons per day.

Analysis of the study results and findings indicates that many communities in Tennessee do experience occasional water-supply, quantity-related shortages. Some type of problem was reported at 107 of the public water suppliers and 23 of the self-supplied commercial and industrial water users. Altogether, 172 problems were reported which could be grouped into 18 types. Occasional turbidity, inadequate storage capacity, inadequate water supply during droughts, and excessive water losses due to leaks in distribution lines accounted for 110 or 64 percent of the problems reported. Twenty five or 15 percent of the problems reported were related to water shortage. Only two large, self-supplied industries reported experiencing water shortages during periods of droughts. Both were located in the Tennessee River basin. No problems were reported by industry in the West Tennessee area or in the Cumberland River basin.

Study results also indicate that the large self-supplied commercial and industrial users in the State are generally quite knowledgeable about their water-supply needs and tend to locate in those areas which have sufficient water resources to meet their needs. It should also be noted there are many self-supplied industries which withdraw less than 100,000 gallons per day; however, in terms of total water withdrawals and employment, those industries whose use exceeds 100,000 gallons per day are generally assumed to be greater than those using less than 100,000 gallons per day.

INTRODUCTION

Tennessee has large quantities of water owing to an average annual rainfall of about 50 inches. In addition, there are many large storage reservoirs to help balance the natural variability of the supply. With good management there should be no statewide water shortage in the near future. This does not mean, however, that currently localized problems may not spread or that the people of Tennessee may not ever have widespread water problems (Johnson and others, 1968, p. 5). What was true in 1968 is still true in 1983. During the past decade, many towns and industries have encountered water-supply problems because of occasional drought periods, particularly during 1980 and 1981, and inadequate water-supply facilities.

A special joint committee established by the Ninety-First Tennessee General Assembly under House Joint Resolution 242 to evaluate Tennessee's public water policy, recognizes that Tennessee has abundant water resources. However, the committee also noted that current land and water use patterns, particularly the increase in heavy industrial development, have changed significantly in recent years. This, coupled with the State's reliance on riparian water rights and the continuing urban growth, may be placing a severe strain on the State's available water resource according to the committee.

Recent droughts, increasing water requirements for both instream and offstream uses, and nationwide concerns about future water shortages, said to be potentially more serious than the energy crisis, have resulted in a growing awareness among water resources planners and managers of the need for current and accurate information and data relative to the State's available water resources to assist decisionmakers in resolving critical water quantity and quality needs and problems. For example, one of the needs identified in Tennessee's Safe Growth Plan is the need to take a comprehensive look at the major water quantity and quality issues confronting the State and to determine the adequacy of Tennessee's water resources to meet needs during the late 1980's from both a quantity and quality standpoint (Tennessee Safe Growth Plan, 1981, p. 14-16.)

In view of these issues, the special joint committee of the Tennessee General Assembly recommended that a new study of water policy in Tennessee be conducted. On April 22, 1981, the Ninety-Second Tennessee General Assembly passed House Bill 924, which created a special interagency task force chaired by Tennessee's Division of Water Resources (now part of the Tennessee Division of Water Management) to supervise and conduct a study during 1982 and 1983 of the State's current water resources policy, use, and law.

Recognizing the broad nature of the Legislature's directive, it was determined by the task force that the study objective could best be accomplished by the conduct of two separate studies - one to analyze current State water law and a second on water policy to identify potential water management limitations under current legislation. These two studies, sponsored by the University of Tennessee Water Resources Research Center, were completed in 1983.

In addition, the TDWM felt it necessary to undertake a third effort to evaluate existing water use and supply relationships in Tennessee. To facilitate accomplishment of the third study, the Tennessee Division of Water Management (TDWM) engaged the services of the Tennessee Valley Authority (TVA); U.S. Army Corps of Engineers, Memphis District (COE, Memphis); and the U.S. Geological Survey to assist in a survey and study of all public, community water-supply facilities and large, self-supplied commercial and industrial water users (100,000 gallons per day or more). Although coal-fired and nuclear power generation facilities are large water users, they were not considered or included in this study. Essentially, this study was designed to identify and describe water problems resulting from inadequate water supplies from a quantity standpoint, particularly during period of severe and (or) extended drought.

The reason for this study's concentration on water-supply, quantity-related aspects was two-fold in nature: (1) previous State and Federal agency water resources studies tended to concentrate on or emphasize the collection of water-quality-related data with limited attention to the analysis of the quantity-related aspects of these resources and (2) strict time and budgetary limitations. However, all data and information provided by individual community water systems and large, self-supplied water users regarding existing water-quality-related problems such as high turbidity, excessive iron and manganese concentrations, low dissolved oxygen levels, and so forth, were to be noted in the appropriate water-supply inventories and analysis of the adequacy of each basin's water supplies to meet current needs. As decision-makers proceed to address and deal with the State's water-related needs and problems during the 1980's, it is important that they are apprised and aware of the need to give full consideration to both water-quantity- and quality-related data and information in developing and implementing water management programs which are politically, economically, and environmentally viable.

As previously mentioned, several State and Federal agencies have been involved in the collection and evaluation of pertinent water-quantity- and quality-related data and information for existing public water-supply systems and self-supplied users. For example, in 1980 the Tennessee Department of Economic and Community Development published a document entitled Tennessee Appalachian Development Plan, Supplement I, Evaluation of Water Treatment and Distribution Facilities which provides information regarding current and projected water needs for public and industrial purposes supplied by public water systems in the Appalachian portion of East Tennessee. Recently (1981), TVA completed a survey of municipal and industrial water users and wastewater treatment facilities in the Clinch, Duck-Buffalo, and Elk-Shoal River basins in Tennessee under the Cumberlandian Mollusk Conservation Program. A cursory analysis of these studies and data collection efforts indicates that each has been designed to achieve a specific purpose ranging from water availability for industrial growth and development to the evaluation of specific stream reaches as potential transplant sites for the Cumberlandian Mollusk.

This study of drought-related impacts on major water users, however, has concentrated solely on the development of (1) inventories of community water systems and large, self-supplied users and (2) evaluation of these supplies' relative adequacy, from a quantity standpoint, to meet current needs, particularly in times of severe or extended drought. Basic data and information reflected in this study were derived from water use data and information provided by public water systems and self-supplied users through the TDWM's water use survey program during the 1979-81 time period and updated via a telephone survey during the summer of 1982. In comparing the basic data reflected in this study with data contained in other agency studies, it is apparent that some differences exist both in the type of data shown and the numerical values for specific water use data categories such as population served, average water use, and so forth. These differences can be attributed to the (1) differing purposes for which individual studies were conducted and (2) the fact that water use for municipal and industrial purposes is very dynamic and constantly changing from year-to-year.

Purpose and Scope

Because water availability is critical to Tennessee's continued economic growth and development as well as social well-being, the primary purpose of this study was to determine the impact of extended drought conditions on existing municipal, commercial, and industrial water users excluding power generation facilities. Basic information and data compiled through this study relative to existing water supplies and use, associated water-supply problems, and general conclusions and recommendations regarding problem resolution will be useful to decisionmakers at all levels of government as renewed efforts are being initiated to evaluate Tennessee's existing water law, policy, and pertinent water-related programs to determine what changes, if any, are needed to meet water management challenges of the 1980's.

Goals and Objectives

This study's primary goal was to provide decisionmakers with (1) current information and data on existing water use and supply for municipal and large self-supplied commercial and industrial water users and (2) some broad conclusions and recommendations regarding suggested program options to be considered in formulating and implementing a viable program to address and resolve or alleviate, to the extent possible, severe water-supply shortages be they drought-related or otherwise. More specifically, the study's basic objectives were to:

- Develop current inventories of (1) public, community water-supply facilities and (2) large self-supplied commercial and industrial water users whose average daily use exceeds 0.1 Mgal/d. Basically, these inventories provide recent information and data relative to existing water-supply source and use, source capacity, population served, treatment plant and storage capacity, and water-supply, particularly quantity-related, problems.
- Evaluate and categorize each of these facilities and users' ability to meet current water-supply needs according to selected categories denoting each facility or user's source of water, existence or lack of adequate impoundment facilities to meet the anticipated 90-day demand, base streamflow (3-day, 20-year on nonregulated streams and the minimum daily average flow on regulated streams) adequacy, and ground-water availability.
- Identify and discuss briefly the (1) water-related issues and problems such as deteriorating or inadequate water mains, distribution lines, and treatment plants; inadequate water quality; competing and/or conflicting water uses; and institutional issues which can seriously exacerbate or worsen drought-related water-supply shortages and (2) economic, environmental, and social implications of drought-related water-supply shortages on Tennessee's continued economic growth and development; valuable water and related land resources; and residents.

- Outline some broad, general conclusions and recommendations for decision-makers to consider relative to (1) the organizational structure and makeup or basic elements of an "emergency preparedness program" to respond to and deal with critical water-supply shortages; (2) Federal/State/local agencies' responsibilities and role in addressing and resolving or alleviating identified water-supply problem areas and issues; and (3) the next step or future planning and study activities to be undertaken to focus in greater detail on existing or potential problem areas and alternative solutions to those problems.

Previous Water Use Investigations

Although the Tennessee Division of Water Management is continually collecting water use information, only results of four surveys have been published. The first two, in 1955 and 1958, were surveys of irrigation water use only. The third in 1963, was a complete inventory, the results of which were published from 1968 to 1970 by the Division as a four-part series entitled "Water Use in Tennessee." The fourth survey was made in 1970 and the results published in 1973 in the report entitled, "Water Use in Tennessee, 1970," covering industrial, municipal, and irrigation water use. Other surveys have been made by the U.S. Department of Commerce, Bureau of Census, the Tennessee Valley Authority, the U.S. Geological Survey, Soil Conservation Service, and the U.S. Water Resources Council.

Data Collection and Presentation

The data presented in this report were collected and compiled by the COE, Memphis; TVA; Geological Survey; and the TDWM. Survey forms received from public water utilities and large, self-supplied water users by the TDWM during the 1979-82 time period were used in compiling these data. These data were updated during the summer of 1982. All counties in the Tennessee River Basin were surveyed by TVA. Those counties in the Cumberland and Green River Basins were the responsibility of the Geological Survey, while all counties west of the Tennessee River Basin were the responsibility of the COE.

Analysis of the basic study results and findings indicates that a number of Tennessee communities and self-supplied water users, particularly those located along the rim of the Tennessee Valley, are utilizing surface- and ground-water resources whose long-term, dependable capacity is less than or only slightly more than their average daily use. However, the use of these resources at capacity should not necessarily be viewed as unwise or risky. In actuality, the use of a specific water resource at or even somewhat in excess of capacity for short periods of time often reflects wise use and management of the resource provided that the resource is not being adversely affected by underground pollutants or a gradual lowering of the water table. However, it seems reasonable to assume that these same communities and self-supplied users might be subject to potentially serious water-supply shortages during severe and (or) extended drought periods. The problem will be most serious for those communities and self-supplied users whose supply systems are characterized by (1) a single source of supply with no backup or conjunctive water source, (2) by inadequate storage for treated water, and (3) excessive water losses from deteriorating water mains and distribution lines.

More detailed information and data regarding existing and potential water-supply, quantity-related problems, that is, water-supply shortages, are presented by river basin for each of the 13 major river basins in Tennessee (fig. 1). These river basins were delineated by J. W. Cragwall, Jr., U.S. Geological Survey, in 1962 and revised by J. M. Kernodle and L. A. Keck, Tennessee Division of Water Resources, in 1972 and 1982, respectively (Tennessee Department of Conservation, 1963, Revised 1972 and 1978).

Essentially, each basin's writeup includes (1) a brief description of the basin's topographic, hydrologic, and demographic characteristics; (2) pertinent information and data including maps regarding the number, water-supply source, and average daily water use of existing community water-supply systems, and large, self-supplied commercial and industrial water users; and (3) a detailed delineation of existing Valley surface-water storage facilities and discussion of the relative adequacy of each basin's existing water supplies to meet current needs including the identification of specific communities and self-supplied water users which are or have the potential for experiencing serious water-supply shortages during severe and extended drought periods.

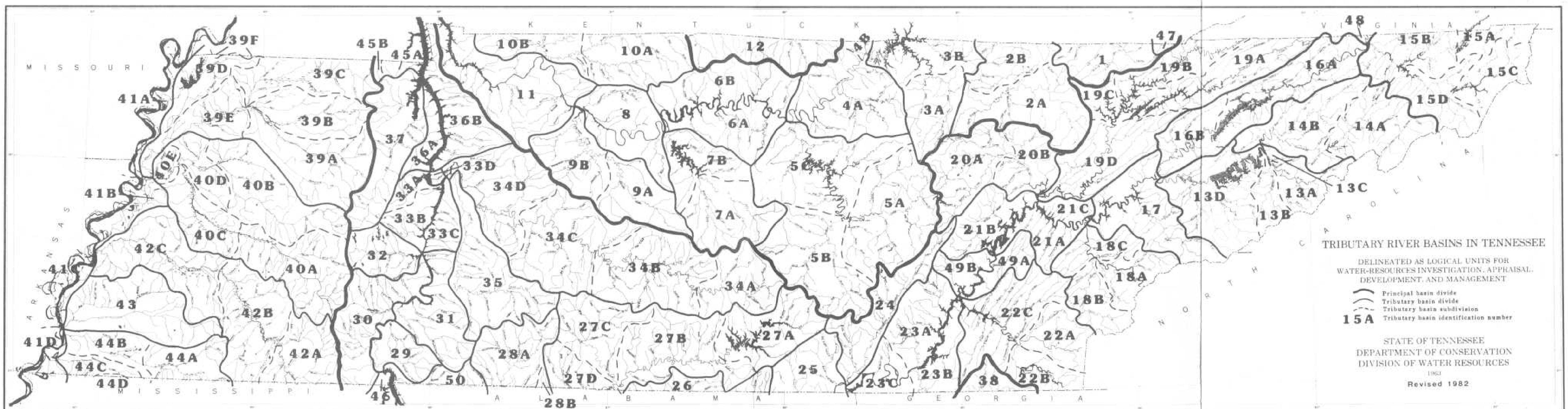
Maps depicting the general location and water-supply source of all public and large, self-supplied commercial and industrial water users inventoried with the exception of those public and self-supplied users who purchase their entire water supply from another public water-supply facility are included in each basin's writeup. The name of each facility and (or) self-supplied user depicted on the map is provided in the explanation following each map along with its corresponding number from the map.

Each basin's writeup also provides detailed information and data describing the basin's major water storage facilities in terms of location; controlled drainage area; reference period; and individual reservoir operation patterns relative to the (1) minimum daily average flow or reservoir discharge on those days in which reservoir releases occurred; (2) complete cessation of reservoir releases for one or more entire calendar days (Tennessee Valley Authority, 1982); and (3) existing mutual agreements between TVA, COE, and Valley water users regarding specified reservoir releases to provide adequate downstream flows for both instream (navigation, recreation, water quality, and so forth) and offstream (industrial, water supply, and so forth) purposes (Tennessee Valley Authority, 1978).

Basic information and data relative to existing public water-supply systems and self-supplied water users were developed through the preparation of the tabular inventories of (1) public water-supply facilities and (2) large, self-supplied commercial and industrial water users from available information and data compiled by Tennessee's DWR through its ongoing water use survey efforts during recent years (Tennessee Department of Conservation, 1979-81) and updated by the study participants during the summer of 1982. Copies of these inventories for each basin are included in Appendix I.

Demography

Population and economic data included in this report were obtained from the Department of Commerce and TVA. Hydrologic data were developed from the



Base from U.S. Geological Survey
State base map, 1973

Figure 1.--Study area and major surface drainage basins.

Tennessee Division of Water Management, U.S. Geological Survey, Corps of Engineers, National Weather Service, and Tennessee Valley Authority. Specific resource material utilized is listed in Selected References.

ACKNOWLEDGMENTS

The authors are grateful to those who aided in the collection of data for this study. City officials and representatives of industry fully cooperated in supplying information on water use, source of supplies, and water related problems. Special acknowledgment is given to TVA for their role in developing the basic study work plan, report format, and overall direction of the project. Invaluable assistance was provided by the following agencies and their personnel:

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CLINCH RIVER BASIN

Basin Description

The Tennessee part of the Clinch River basin covers 2,612 square miles (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. 2)	Basin description	Tennessee drainage area (square miles)
19A	Clinch River from the Tennessee State line to Norris Dam excluding the Powell River and minor tributaries.	596
19B	Powell River from the Tennessee State line to the river's mouth.	387
19C	Minor Clinch River west-side tributaries between the Powell River and Norris Dam.	128
19D	Clinch River from Norris Dam to the river's mouth.	636
20A	Obed River	520
20B	Emory River excluding the Obed River	345

Hydrologically, this basin encompasses all or major parts of Anderson, Campbell, Claiborne, Cumberland, Hancock, Morgan, Roane, and Union Counties and minor parts of Fentress, Grainger, Hamblen, Knox, and Loudon Counties. A map of the east Tennessee part of the Tennessee River basin which highlights the Clinch River basin is shown in figure 2.

Topography

As a whole, the Clinch River basin consists of the area drained by the Clinch and Emory Rivers. The area drained by the Clinch River is a broad, lowland belt characterized by minor parallel ridges and intervening valleys corresponding to the northeast-southeast trend of the Tennessee Valley region. The Clinch River and its major tributary, the Powell River, plus a number of smaller streams including Bear, Beaver, Big War, Buffalo, Bullrun, Cove, Davis, Hinds, Indian, Mulberry, Poplar, Sycamore, and White Creeks flow in broad, winding courses in the intervening valleys with relatively flat valley slopes. Average stream slopes in the Tennessee part of the Clinch River drainage area equal about 1.50 ft/mi from river mile 0 to river mile 80 and 2.92 ft/mi from river mile 80 to the Tennessee State line. Elevations in this area range from about 800 to 4,000 feet above sea level.

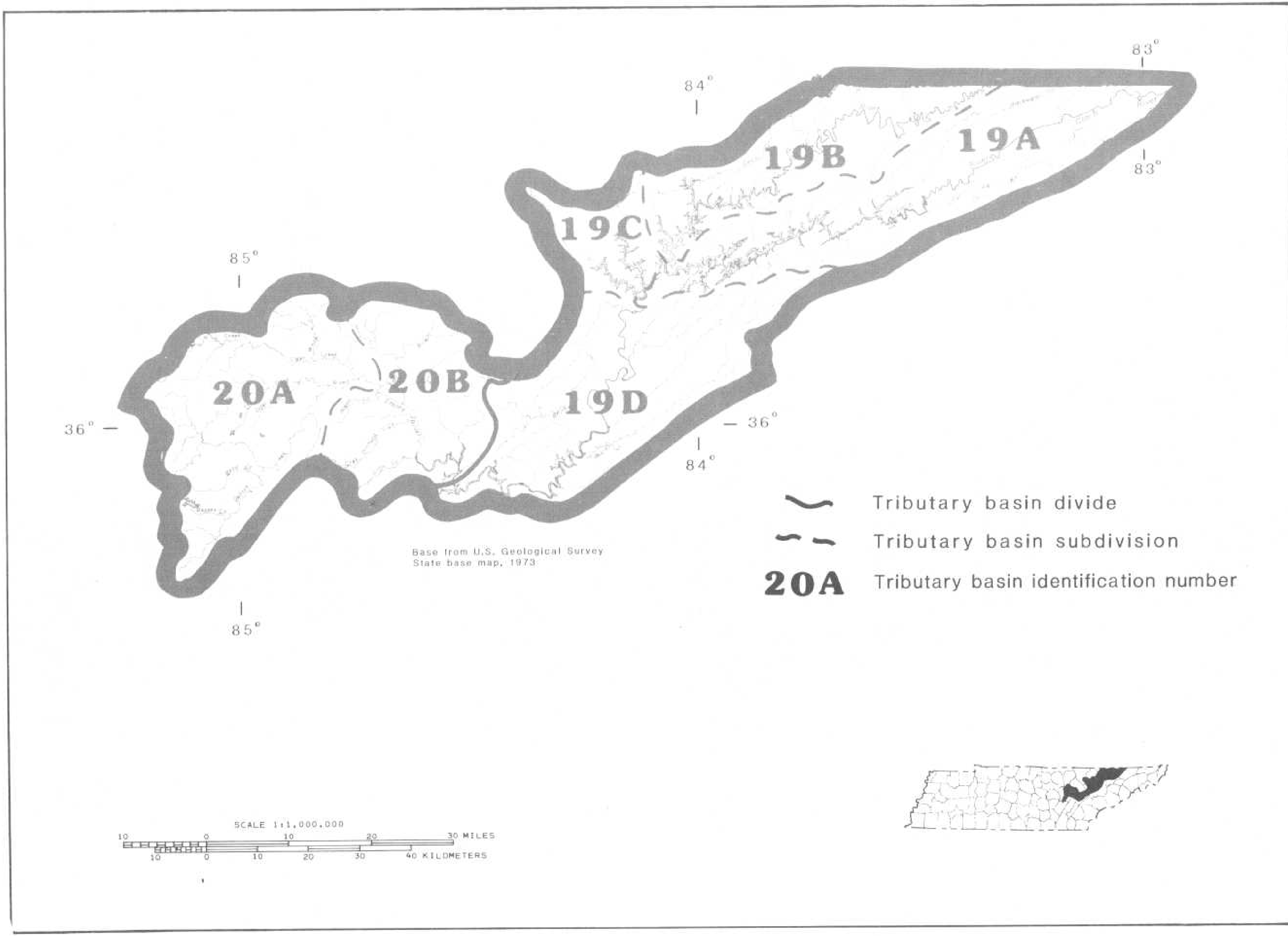

Figure 2.--Clinch River basin.

The Emory River and its principal tributaries including the Obed and Little Emory Rivers and Clear, Clifty, Cook, Crab Orchard, Crooked Fork, Daddys, Drowning, Greasy, Island, and Rock Creeks drain the generally flat uplands of the Cumberland Plateau. These streams are characterized by meandering courses with steep side slopes which have cut deeply into the Plateau's surface. Average stream slopes in this area range from 1.00 ft/mi from river mile 0 to river mile 13 and 21.60 ft/mi above river mile 13 including the Obed River and Daddys Creek. The elevations in this area range from about 800 to 2,500 feet above sea level.

Hydrology

Surface Water

This basin's surface- and ground-water resources are fed by an abundant rainfall whose long-term, 30-year (1941-70), average is 46.81 inches above Norris Dam. From 1970-79, average annual precipitation on the Clinch River above Norris Dam was 52.94 inches and ranged from 45.30 inches in 1976 to 61.29 inches in 1972. Average precipitation data for the 1970-79 period for watershed subdivisions of the Clinch River basin are presented in table 1. Annual 1979 and long-term (1941-70) precipitation data for selected TVA and National Weather Service (NWS) rainfall stations in the Tennessee part of the area drained by the Clinch and Emory Rivers (Tennessee Valley Authority, 1979a) are summarized in table 2.

Usually, the months of September, October, and November are the driest months with average annual rainfall ranging from 2.44 to 3.46 inches above Norris Dam on the Clinch River. Other months generally average about 3.66 to 5.07 inches above Norris Dam with July being the wettest month. Analysis of long-term precipitation data at selected hydrologic data stations below Norris Dam (Melton Hill Dam) and in the Emory River part of the basin (Crossville, Hebbertsburg, and Kingston) indicates that the driest months of the year are usually August, September, and October with precipitation ranging from 2.78 to 3.83 inches. Other months generally range from 3.80 to 6.52 inches at these stations with March being the wettest month.

Average annual runoff in the Tennessee part of the Clinch River basin ranges from about 19 to 30 inches as one moves southwestward through the basin from the Tennessee-Virginia State line. Average discharge data for selected hydrologic data stations in the Clinch River basin (U.S. Geological Survey, 1981) are presented in table 3.

The majority of this runoff occurs during the winter and spring months. In the late summer and fall months, particularly during drought periods, it is not unusual 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 Melton Hill Reservoir (94,100) and Norris Reservoir (630,000). Detailed information describing the reservoirs' location and operation pattern follows:

Table 1.--Precipitation data by watershed subdivision for the period 1970-79, Clinch River basin

Watershed description	Precipitation (inches)				
	High	Year	Low	Year	10-year average
Powell River upstream from Arthur	64.40	1972	46.80	1976	55.84
Clinch River upstream from Tazewell	58.50	1972	41.00	1970	49.98
Clinch River from Norris Dam to Tazewell and the Powell River downstream from Arthur.	67.80	1973	47.10	1976	56.04
Clinch River from Kingston to Norris Dam.	72.40	1973	49.80	1970	58.80
Emory River upstream from Oakdale	75.10	1973	49.90	1976	60.38

Table 2.--Precipitation data for 1979 and for the period 1941-70 for selected rainfall stations, Clinch River basin

Station location	Station owner	Elevation above sea level (feet)	Period of record (years)	1979 Precipitation (inches)	Long-term annual precipitation (inches)
Kingston steam plant	TVA	790	29	71.45	51.33
Petros	TVA	1,375	45	83.14	60.95
Isoline	TVA	1,880	13	74.51	63.81
Clarkrange	TVA	1,770	44	62.78	50.81
Hebbertsburg	TVA	1,770	45	65.81	53.07
Crossville	NWS	1,810	68	65.02	56.82
Lantana	TVA	2,010	39	63.25	51.45
Big Lick	TVA	1,800	30	65.77	58.50
Frankfort	TVA	1,460	25	52.90	46.06
Crossville Airport	NWS	1,881	26	64.56	56.33
Melton Hill Dam	TVA	941	19	63.01	54.11
Bull Run steam plant	TVA	836	17	64.91	53.84
Oak Ridge	NWS	905	33	67.30	52.60
Norris Dam	TVA	920	36	70.00	50.29
La Follette	TVA	1,250	46	64.63	51.30
Arthur	TVA	1,250	44	62.37	51.11
White Hollow	TVA	1,640	45	55.77	47.03
Thorn Hill	TVA	1,420	33	54.18	48.17

Table 3.--Average discharge data for selected hydrologic data stations operated by the U.S. Geological Survey, Clinch 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
Clinch River upstream from Tazewell (Claiborne).	159.8	1,474	62	2,116	19.49	1.44
Powell River near Arthur (Claiborne).	65.4	685	61	1,154	22.88	1.68
Bullrun Creek near Halls Crossroads (Knox).	16.3	68.5	23	103	20.42	1.50
Clinch River at Melton Hill Dam tailwater (Loudon).	23.1	3,343	31	4,690	-	1.40
Poplar Creek near Oak Ridge (Roane).	13.8	82.5	20	181	29.79	2.19
East Fork Poplar Creek near Oak Ridge (Roane).	3.3	19.5	20	52.8	-	2.71
Obed River near Lancing (Morgan).	1.5	518	19	1,089	28.55	2.10
Emory River at Oakdale (Morgan).	18.3	764	53	1,476	26.23	1.93

Melton Hill Reservoir

Location and drainage area.--Melton Hill Reservoir is formed by Melton Hill Dam which is located on the Clinch River at river mile 23.1 in Loudon and Roane Counties. Melton Hill Dam controls 3,343 mi^2 of drainage area.

Reference period.--1962-81.

Reservoir discharge (minimum daily average flow).--Minimum daily average discharge from Melton Hill Dam during the reference period ranged from a low of approximately 8.0 ft^3/s (5.2 Mgal/d) in 1970 to a high of approximately 723.0 ft^3/s (467.3 Mgal/d) in 1974. The average, 1-day minimum discharge during the reference period was approximately 265.9 ft^3/s (171.9 Mgal/d).

Average number of days of zero flow.--Over the 20-year period from 1962-81, Melton Hill Dam has averaged slightly over 40 days of zero discharge per year ranging from a low of no days of zero discharge in 1979 to a high of 224 days of zero discharge in 1962. Since 1962, the greatest number of days of zero discharge equaled 74 days in 1966 with 1979 being the only year in which there were no days of zero discharge from the reservoir. Days of zero-discharge were most common during the months of March, April, and May. Through the reference period, there have been 53 instances of zero discharge for 3 or more consecutive days from Melton Hill Dam. In seven of these instances during the years of 1965-68 and 1981, consecutive days of zero discharge from Melton Hill Dam ranged from a low of 7 days in several years to a high of 29 days in 1966.

Existing agreements regarding reservoir releases.--None.

Norris Reservoir

Location and drainage area.--Norris Reservoir is formed by Norris Dam which is located on the Clinch River at river mile 79.8 in Anderson and Campbell Counties. Norris Dam controls 2,912 mi^2 of drainage area.

Reference period.--1960-81.

Reservoir discharge (minimum daily average flow).--Minimum daily average discharge from Norris Dam during the 1960-1981 time period ranged from a low of about 5.0 ft^3/s (3.2 Mgal/d) in 1975 to a high of about 127.0 ft^3/s (82.1 Mgal/d) in 1978. The average, 1-day minimum discharge from Norris Dam during the reference period was about 50.9 ft^3/s (32.9 Mgal/d).

Average number of days of zero flow.--From 1960-81, Norris Dam has averaged slightly over 44 days of zero discharge per year ranging from a low of 2 days of zero discharge in 1979 to a high of 102 days of zero discharge in 1966. Zero discharge days were most common during the months of March, April, and May. During the reference period, there were 98 instances in which zero discharge from Norris Dam extended over 3 or more consecutive days. On 23 of these occasions during the years of 1960-64, 1966-69, 1971, 1975, 1978 and 1981, consecutive days of zero discharge from Norris Dam ranged from a low of 7 days in several years to a high of 27 days in 1967.

Existing agreements regarding reservoir releases.--None.

In addition to these reservoirs, several smaller water-supply impoundments including Cove, Davis Branch, Holiday Hills, Meadow Park, and Ollis Creek Lakes plus Brushy Mountain Prison's reservoir are also located in this basin. Further information regarding the estimated storage capacity of these reservoirs is found in table 1 of appendix I.

Ground Water

The Clinch River and its tributaries drain parts of the Cumberland Plateau and Valley and Ridge physiographic provinces. Water occurs in limited fractures in the sandstone underlying the Cumberland Plateau and in solutionally enlarged openings in the carbonate rocks of the Valley and Ridge province. The average yields and water quality of wells and springs in these areas are quite different. Most of the Clinch River basin lies in the Valley and Ridge province. This area is characterized by northeast-trending parallel valleys and ridges. The ridges are capped by resistant sandstones, silty shales, and silt stones, while the valleys are primarily underlain by more soluble calcareous rocks such as limestone, dolomite, and limy shale rocks. The rocks in the Valley and Ridge province contain little or no primary porosity; however, secondary porosity in the form of solution cavities in the calcareous has been developed by circulating ground water. On the ridges, domestic supplies are obtained from dug wells, drilled wells, and springs. Well yields are generally low, normally ranging from a few gallons per minute to 15 gal/min from depths of 200 feet or less. Ground water in the valleys is generally easier to obtain than on the ridges. Domestic supplies are available from drilled and dug wells as well as springs. Yields of wells normally average 25 gal/min or less from depths of 300 feet or less; however, as the fractures in the calcareous rocks have been enlarged to varying degrees by the dissolving action of circulating ground water, yields of 100 gal/min or more are common. Moderately large (50-100 gal/min) to large (>100 gal/min) springs are numerous in the Valley and Ridge part of the Clinch River basin, with the exception of Hancock and Campbell Counties. A number of municipalities use springs for public water supplies. Water quality is generally good, with the most objectionable property of water from calcareous rocks being hardness which, in most cases, is 100 mg/L.

Ground water in the Cumberland Plateau areas of the Clinch River basin occurs in fractures in tightly cemented sandstones. 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 low; however, in areas of more severe fracturing, near surface streams, well yields of 100 gal/min or more have been recorded. Well depths are usually 200 feet or less. However, some unpublished well logs are reported to indicate that the Sewanee Conglomerate can yield good-quality water from depths of at least 500 feet in Cumberland County and other local areas of the Cumberland Plateau. With the exception of water produced 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