GROUND-WATER RESOURCES OF THE TALLAPOOSA RIVER BASIN IN GEORGIA AND ALABAMA—*SUBAREA 5* OF THE APALACHICOLA-CHATTAHOOCHEE-FLINT AND ALABAMA-COOSA-TALLAPOOSA RIVER BASINS

U.S. GEOLOGICAL SURVEY

Prepared in cooperation with the

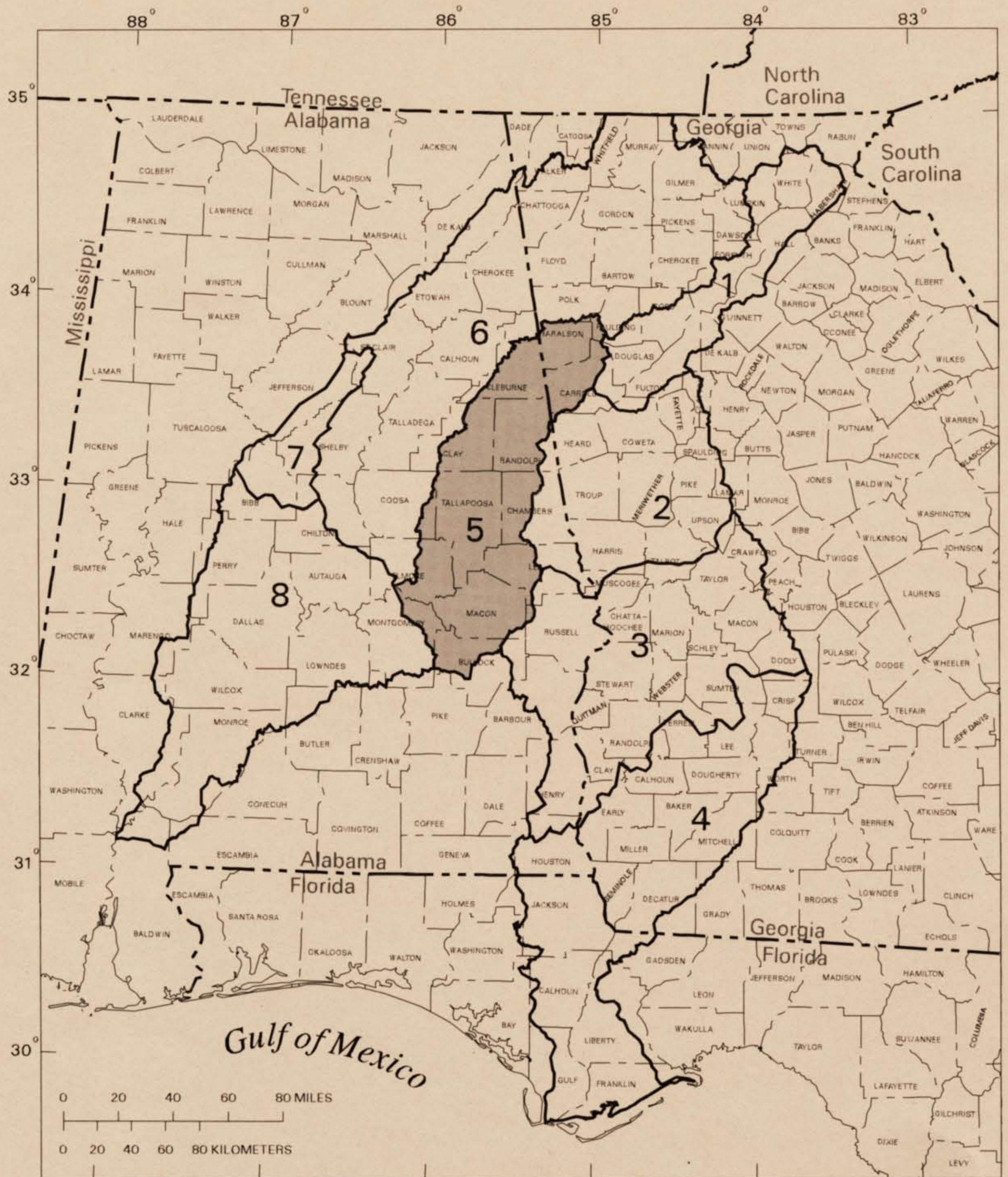
ALABAMA DEPARTMENT OF ECONOMIC AND COMMUNITY AFFAIRS
OFFICE OF WATER RESOURCES

GEORGIA DEPARTMENT OF NATURAL RESOURCES
ENVIRONMENTAL PROTECTION DIVISION

NORTHWEST FLORIDA WATER MANAGEMENT DISTRICT

U.S. ARMY CORPS OF ENGINEERS
MOBILE DISTRICT

Open-File Report 96-433



Base from 1:100000 and 1:250000
USGS Digital Line Graph

Location of subareas in the Apalachicola–Chattahoochee–Flint and Alabama–Coosa–Tallapoosa River basins. Subarea described in this report is shaded.

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U.S. ARMY CORPS OF ENGINEERS
MOBILE DISTRICT

Montgomery, Alabama

1997

U.S. DEPARTMENT OF THE INTERIOR

BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY

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CONVERSION FACTORS

Multiply	by	to obtain
	Length	
inch (in.)	25.4	millimeter
inch per year (in/yr)	25.4	millimeter per year
foot (ft)	0.3048	meter
square foot (ft^2)	0.0929	square meter
mile (mi)	1.609	kilometer
feet per mile (ft/mi)	0.1894	meter per kilometer
	Area	
acre	4,047	square meter
square mile (mi^2)	2.59	square kilometer
	Volumetric rate and volume	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
	448.831	gallon per minute
	0.6463	million gallons per day
cubic foot per second per square mile ($ft^3/s/mi^2$)	0.01093	cubic meter per second per square kilometer
gallon per minute (gal/min)	6.309×10^{-5}	cubic meter per second
	2.228×10^{-3}	cubic foot per second
	0.06308	liter per second
	1,440	gallon per day
gallon per day (gal/d)	3.785×10^{-3}	cubic meters per day
million gallons per day (Mgal/d)	1.547	cubic foot per second
	63.09	cubic meter per second
	694.44	gallons per minute
gallon per minute per foot of drawdown (gal/min/ft)	1.24×10^{-2}	cubic meters per minute per minute per meter of drawdown
acre-foot	325,900	gallon
	Transmissivity	
foot squared per day (ft^2/d)	0.0929	meter squared per day

Temperature

Temperature in degrees Fahrenheit (° F) can be converted to degrees Celsius as follows:

$$° C = 5/9 \times (° F - 32)$$

ABBREVIATIONS AND ACRONYMS

7Q2	7-day, 2-year low flow
ACF	Apalachicola-Chattahoochee-Flint River basin
ACT	Alabama-Coosa-Tallapoosa River basin
ADAPS	Automated Data Processing System
Corps	U.S. Army Corps of Engineers
MOA	Memorandum of Agreement
GWSI	Ground Water Site Inventory database
MOVE.1	Maintenance of Variance Extension, Type 1
RORA	A computer program (Rutledge, 1993)
SWGW	Surface Water-Ground Water—a computer program (Mayer and Jones, 1996)
USGS	U.S. Geological Survey

VERTICAL DATUM

Sea Level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NVGD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

GLOSSARY

7Q2—Minimum average stream discharge for 7 consecutive days for a 2-year recurrence interval.

Alluvium—Sediment transported and deposited by flowing water.

Altitude—As used in this report, refers to the distance above sea level.

Anisotropic—Condition having varying hydraulic properties of an aquifer according to flow direction.

Annual—As used in this report, refers to a water year.

Aquifer—A formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs.

Artesian—Synonymous with confined.

Baseflow—That part of the stream discharge that is not attributable to direct runoff from precipitation or melting snow; it is usually sustained by ground-water discharge.

Bedrock—A general term for the consolidated rock that underlies soils or other unconsolidated surficial material.

Clastics—Rocks composed of fragments of older rocks, for example, sandstone.

Colluvium—Heterogeneous aggregates of rock detritus resulting from the transporting action of gravity.

Cone of depression—A depression of the potentiometric surface, often in the shape of an inverted cone, that develops around a well which is being pumped.

Confined aquifer—An aquifer bounded above and below by impermeable beds or by beds of distinctly lower permeability than that of the aquifer itself; ground water in the aquifer is under pressure significantly greater than that of the atmosphere.

Continuous-record gaging station—Complete records of discharge obtained using a continuous stage-recording device through which either instantaneous or mean-daily discharge may be computed for any time, or any period of time, during the period of record.

Crystalline rock—A general term for igneous and metamorphic rocks.

Darcian flow—Flow that is laminar and in which inertia can be neglected.

Dendritic drainage—A branching stream pattern that resembles the branching of trees.

Drought—There is no accepted definition of drought. As used in this report, a period of deficient rainfall extending long enough to cause streamflow to fall to unusually low levels for the period of record.

Evapotranspiration—The combined evaporation of water from the soil surface and transpiration from plants.

Faults—Fractures in the Earth along which there has been displacement parallel to the fault plane.

Foliation—A planar or layered structure in metamorphic rocks that is caused by parallel orientation of minerals or bands of minerals.

Fluvial—Pertaining to the actions of rivers.

Fracture—Breaks in rocks due to intense folding or faulting.

Geologic contact—The boundary surface between one body of rock or sediment and another.

Ground-water recharge—The process of water addition to the saturated zone or the volume of water added by this process.

Head, static—The height above a standard datum of the surface of a column of water (or other liquid) that can be supported by the static pressure at a given point. The static head is the sum of the elevation head and the pressure head.

Head, total—The total head of a liquid at a given point is the sum of three components: (a) the elevation head, which is equal to the elevation of the point above a datum, (b) the pressure head, which is the height of a column of static water that can be supported by the static pressure at the point, and (c) the velocity head, which is the height to which the kinetic energy of the liquid is capable of lifting the liquid.

Heterogeneous—Pertaining to a substance having different characteristics in differing locations.

Hydraulic conductivity—The capacity of a rock to transmit water. It is expressed as the volume of water that will move through a medium in a unit of time under a unit hydraulic gradient through a unit area measured perpendicular to the direction of flow.

Hydraulic gradient—A change in the static pressure of ground water, expressed in terms of the height of water above a datum, per unit of distance in a given direction.

Hydrograph separation—Division of the stream hydrograph into components of aquifer discharge and surface runoff.

Igneous rock—Rocks which have solidified or crystallized from a hot fluid mass called magma.

Intergranular porosity—Porosity resulting from space between grains.

Intrusive igneous rocks—Masses of igneous rock formed by magma cooling beneath the surface.

Isotropic—Condition in which hydraulic properties of an aquifer are equal in all directions.

Joints—Fractures in rocks, often across bedding planes, along which little or no movement has taken place.

Mafic—Applied to the ferromagnesian minerals or to igneous rocks relatively rich in such minerals.

Mean annual—As used in this report, refers to the average of the annual values for a specified period of record.

Metamorphic rock—Rocks derived from pre-existing rocks by mineralogical, chemical, and structural alterations due to endogenetic processes.

Partial-record gaging station—Is a particular site where limited streamflow and/or water-quality data are collected systematically over a period of years.

Permeability—The property of a porous medium to transmit fluids under an hydraulic gradient.

Porosity—The amount of pore space and fracture openings, expressed as the ratio of the volume of pores and openings to the volume of rock.

Potentiometric surface—An imaginary surface representing the static head of ground water and defined by the level to which water will rise in a tightly cased well.

Primary porosity—Porosity due to the soil or rock matrix; the original interstices created when a rock was formed.

Recession index—The number of days required for discharge to decline one complete log cycle.

Regolith—Loose, unconsolidated and weathered rock and soil covering bedrock.

Residuum—The material resulting from the decomposition of rocks in place and consisting of the nearly insoluble material left after all the more readily soluble constituents of the rocks have been removed.

Rock—Any naturally formed consolidated material consisting of two or more minerals.

Run-off—Precipitation that flows from the surface of the land and into streams and rivers.

Saprolite—Surficial deposits produced by the decay of rocks and remaining as residuals.

Secondary openings—Voids produced in rocks subsequent to their formation through processes such as solution, weathering, or movement.

Secondary porosity—Porosity due to such phenomena as dissolution or structurally controlled fracturing.

Soil —The layer of unconsolidated material at the land surface that supports plant growth.

Specific capacity—The rate of discharge of water from the well divided by the related drawdown of the water level within the well.

Specific yield—The ratio of the volume of water which the porous medium after being saturated, will yield by gravity to the volume of the porous medium.

Storage coefficient—The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head (virtually equal to the specific yield in an unconfined aquifer).

Stream discharge—The volume of water flowing past a given point in a stream channel in a given period of time.

Transmissivity—The rate at which water of the prevailing kinematic viscosity is transmitted through a unit width of an aquifer under a unit hydraulic gradient. It equals the hydraulic conductivity multiplied by the aquifer thickness.

Trellis drainage—A river system resembling a trellis or rectangular pattern and characteristic of areas of folded sedimentary rocks where tributaries cut channels through less resistant beds.

Unconfined aquifer—An aquifer in which the water table is a free surface at atmospheric pressure.

Unit-area discharge—Stream or ground-water discharge divided by the drainage area.

Water table—Upper surface of a zone of saturation under atmospheric pressure.

Water year—The standard water-year used by the U.S. Geological Survey is from October 1 to September 30 of the second calendar year.

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ABSTRACT

Drought conditions in the 1980's focused attention on the multiple uses of the surface- and ground-water resources in the Apalachicola-Chattahoochee-Flint (ACF) and Alabama-Coosa-Tallapoosa (ACT) River basins in Georgia, Alabama, and Florida. State and Federal agencies also have proposed projects that would require additional water resources and revise operating practices within the river basins. The existing and proposed water projects create conflicting demands for water by the States and emphasize the problem of water-resource allocation. This study was initiated to describe ground-water availability in the Tallapoosa River basin of Georgia and Alabama, Subarea 5 of the ACF and ACT River basins, and to estimate the possible effects of increased ground-water use within the basin.

Subarea 5 encompasses about 4,675 square miles (mi^2) in Georgia and Alabama and contains parts of the Piedmont and Coastal Plain physiographic provinces. The Piedmont Province is underlain by a two-component aquifer system that is composed of a fractured, crystalline-rock aquifer and the overlying porous-media regolith aquifer. The Coastal Plain is underlain by a porous-media aquifer formed from the poorly consolidated deposits of sand, gravel, and clay.

The conceptual model described for this study qualitatively subdivides the ground-water flow system into local (shallow), intermediate, and regional (deep) flow regimes. Ground-water discharge to tributaries mainly is from local and intermediate flow regimes and varies seasonally. The regional flow regime probably approximates steady-state conditions and discharges chiefly to major drains such as the Tallapoosa River, and in upstream areas, also to the Little Tallapoosa River and the Tallapoosa River. Ground-water discharge to major drains originates from all flow regimes. Mean-annual ground-water discharge to streams (baseflow) is considered to approximate the long-term, average recharge to ground water. The mean-annual baseflow was estimated using an automated hydrograph-separation method, and represents discharge from the local, intermediate, and regional flow regimes of the ground-water flow system. Mean-annual baseflow in Georgia was estimated to be 534 cubic feet per second (ft^3/s) (from the headwaters to the Georgia-Alabama State line), 3,250 ft^3/s in Alabama, and 3,780 ft^3/s for all of Subarea 5 (at the Subarea 5-Subarea 8 boundary).

Stream discharge for selected sites on the Tallapoosa River and its tributaries were compiled for the years 1941, 1954, and 1986, during which sustained droughts occurred throughout most of the ACF-ACT area. Stream discharges were assumed to be sustained entirely by baseflow during the latter periods of these droughts. Estimated stream discharges near the end of the 1941, 1954, and 1986 drought years were 48, 15, and 85 ft^3/s, respectively, at the Georgia-Alabama State line; and 481, 126, and 448 ft^3/s, respectively, at the mouth of the Tallapoosa River. Estimated baseflow near the end of the individual drought years was about 9 percent of the estimated mean-annual baseflow in Subarea 5.

The potential exists for the development of ground-water resources on a regional scale throughout Subarea 5. Estimated ground-water use in 1990 was less than 1 percent of the estimated mean-annual baseflow, and about 6 percent of baseflow during the droughts of 1941, 1954, and 1986. Because ground-water use in Subarea 5 represents a relatively minor percentage of ground-water recharge, even a large increase in ground-water use in Subarea 5 in one State is likely to have little effect on ground-water and surface-water occurrence in the other. Indications of long-term ground-water level declines were not observed; however, the number and distribution of observation wells for which long-term water-level measurements are available in Subarea 5 are insufficient to draw conclusions.

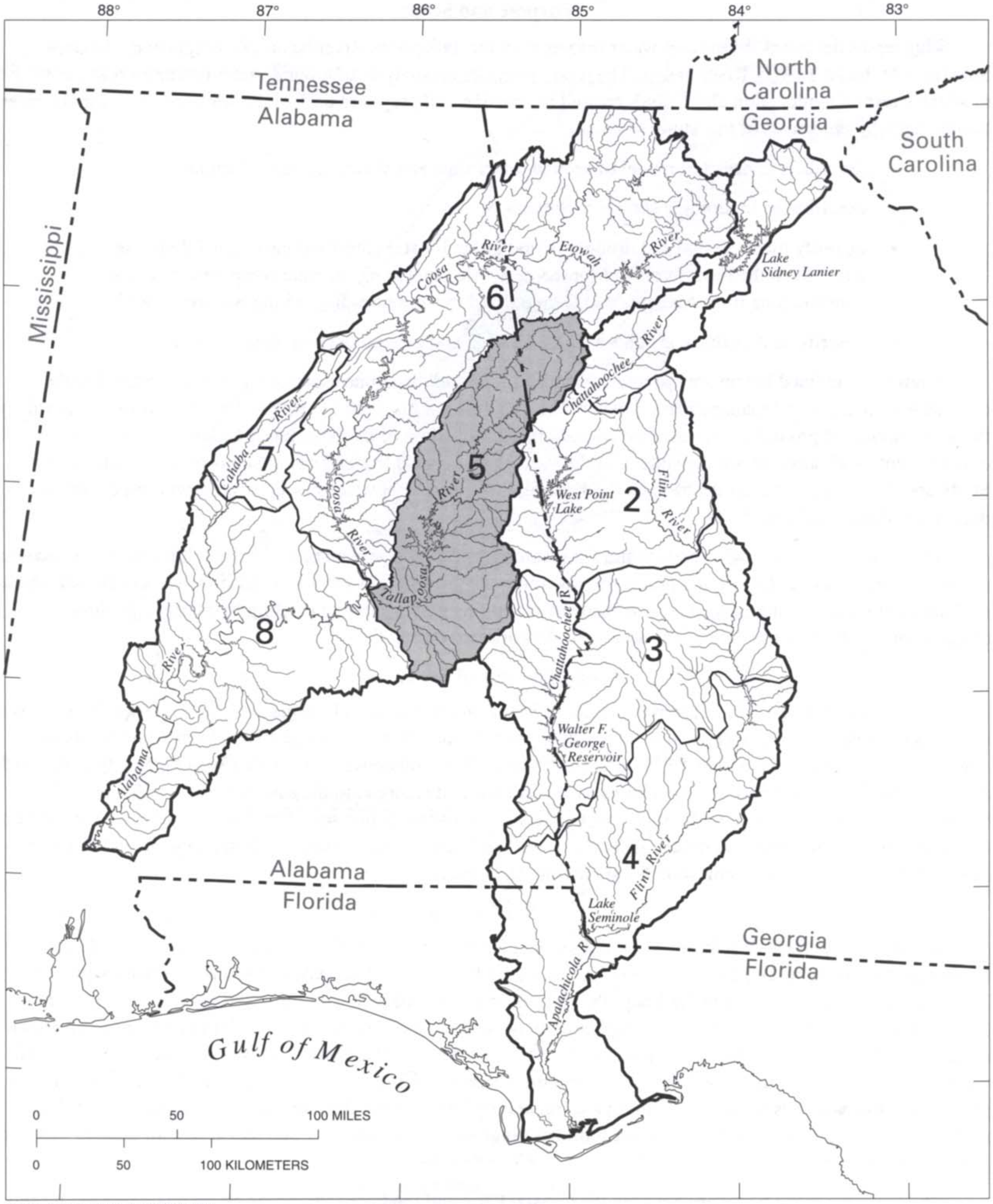
INTRODUCTION

Increased and competing demands for water and the droughts of 1980-81, 1986, and 1988 in the Apalachicola-Chattahoochee-Flint (ACF) and Alabama-Coosa-Tallapoosa (ACT) River basins have focused the attention of water managers and users in Alabama, Florida, and Georgia, on the water resources in the two basins. The ACF-ACT River basins encompass about 42,400 square miles (mi^2) and extend from near the Georgia-Tennessee State line, through most of central and southern Alabama and Georgia and part of the Florida panhandle to the Gulf of Mexico (fig. 1). Ground- and surface-water systems of the ACF-ACT River basins behave as an integrated dynamic flow system comprised of an interconnected network of aquifers, streams, reservoirs, control structures, floodplains, and estuaries. The degree of hydrologic interaction between ground water and surface water suggests that the water resources be investigated and managed as a single hydrologic entity, to account for the climatic and anthropogenic factors that influence the flow systems.

Recent water projects and resource allocations, and other actions proposed by Federal, State, and local agencies, have resulted in conflicts among the States of Alabama, Florida, and Georgia, and the U.S. Army Corps of Engineers (Corps). The Corps has been given the authority to regulate the Nation’s surface waters through the Rivers and Harbors Act of 1927, in accordance with the U.S. House of Representatives Document Number 308, 69th U.S. Congress. Proposed projects designed to increase development and to re-allocate surface-water supplies in Georgia, based on revised operating practices of control structures for flood control, navigation, and hydropower generation, and a proposal to construct a dam and reservoir have met with opposition from Alabama and Florida. As a result, in 1991, the U.S. Congress authorized the Corps to initiate a Comprehensive Study of the ACF-ACT River basins that would “develop the needed basin and water-resources data and recommend an interstate mechanism for resolving issues” (Draft Plan of Study, Comprehensive Study, Alabama-Coosa-Tallapoosa and Apalachicola-Chattahoochee-Flint River basins, prepared by: The Comprehensive Study Technical Coordination Group, July 1991, U.S. Army Corps of Engineers, Mobile District).

In 1992, the Governors of Alabama, Florida, and Georgia; and the U.S. Army, Assistant Secretary for Civil Works, signed a Memorandum of Agreement (MOA) establishing a partnership to address interstate water-resource issues and promote coordinated systemwide management of water resources. An important part of this process is the Comprehensive Study of the ACF and ACT River basins. Since this signing, the Study Partners defined scopes of work to develop relevant technical information, strategies, and plans, and to recommend a formal coordination mechanism for the long-term, basinwide management and use of water resources needed to meet environmental, public health, and economic needs (U.S. Army Corps of Engineers, written commun., 1993). The U.S. Geological Survey (USGS) was requested to assist in the development of a scope of work for the ground-water-supply element of the Comprehensive Study, and in June 1993, was asked to conduct that study element.

Eight subareas of the ACF-ACT River basins were identified by the Study Partners and the USGS on the basis of hydrologic and physiographic boundaries. Addressing the study at the smaller, subarea scale within the ACF-ACT River basins facilitated evaluation of the ground-water resources on a more detailed scale. This report is one of a series of eight reports that present results of ground-water studies of the ACF-ACT subareas.



Base from 1:100,000 and 1:250,000
USGS Digital Line Graph

Figure 1. Subareas and major streams in the Apalachicola–Chattahoochee–Flint and Alabama–Coosa–Tallapoosa River basins.

Purpose and Scope

This report describes the ground-water resources of the Tallapoosa River basin of Georgia and Alabama—Subarea 5 of the ACF-ACT River basins. The report provides an analysis of ground-water resources that can be used to address resource-allocation alternatives created by existing and proposed uses of the water resources in the river basins. Specific objectives of this study were to:

- describe a conceptual model of ground-water flow and stream-aquifer relations;
- describe the hydrologic setting of Subarea 5;
- quantify mean-annual and drought period ground-water contributions to the Tallapoosa River from the headwaters to Montgomery, Ala., including separate computations of the contributions from Alabama and Georgia, and the ground water exiting Subarea 5; and
- describe and evaluate ground-water utilization and general development potential.

Findings contained herein are but one component of a multidiscipline assessment of issues related to the basinwide utilization and management of water. This report is not intended to provide definitive answers regarding the acceptability of ground-water-resource allocation and utilization or the potential for additional resource development. Such answers are dependent on the synthesis of results from all components of the Comprehensive Study and on subsequent consideration by the Federal, State, and local water-resource managers responsible for decision making within the basin.

The report scope includes literature and data searches and an assessment of existing geologic data. A conceptual model that describes the hydrologic processes governing the ground- and surface-water flow was developed, and an evaluation of ground-water utilization was made by compiling and evaluating existing hydrologic, geologic, climatologic, and water-use data. Field data were not collected during this study.

Physical Setting of Study Area

The Subarea 5 study area encompasses about 634 mi^2 in northwestern Georgia and about 4,041 mi^2 in Alabama (fig. 1). In Georgia, the Tallapoosa River and major tributary, the Little Tallapoosa River, form separate basins of almost equal drainage area (314 and 320 mi^2, respectively). The Tallapoosa River basin (Subarea 5) is bounded to the northwest by the Coosa River basin (Subarea 6) in Alabama and Georgia, to the southwest by the Alabama River basin (Subarea 8) in Alabama, to the southeast by the lower Chattahoochee and Flint Basins (Subarea 3) in Alabama, and to the east by the upper and middle Chattahoochee and Flint Basins (Subarea 1, 2) in Alabama and Georgia. Major streams of Subarea 5 drain southward into the Alabama River.

Physiography

Seventy-one percent of Subarea 5 lies within the Piedmont physiographic province of the Appalachian Highlands; the southern 29 percent of the basin lies within the Coastal Plain physiographic province (Sapp and Emplaincourt, 1975) (fig. 2). The Piedmont Province is characterized by a well-dissected upland with rounded interstream areas to the north and by rolling topography, indicative of a dissected peneplain of advanced erosional maturity, to the south (Chandler and Lines, 1974). Prominent topographic features generally reflect erosional and weathering resistance of the underlying geologic units. Stream patterns are dominantly dendritic; however, a modified trellis pattern is associated with divides separating linear ridges that are underlain by quartzite in the southern part of the Piedmont. Land-surface altitudes range from approximately 500 feet at Martin Lake to 1,000 feet in the northern part of the subarea.

The Fall Line is the boundary between the Coastal Plain and Piedmont Provinces and is characterized by shoals and rapids in river channels produced by preferential erosion of the poorly consolidated Coastal Plain sediments. Relief generally is highest near the Fall Line, becoming progressively lower toward the coast. The Coastal Plain Province is characterized by relatively flat to gently rolling uplands and broad, gently-sloping valleys that range in altitude from 350 to 650 feet above sea level (Kidd, 1989) near the Fall Line. Near the southern boundary of Subarea 5, the topography is characterized by sandy cuestas that are ridges characterized by fairly steep northward-facing escarpments and gently to moderately rolling backslopes (Kidd, 1987). Streams are deeply entrenched near the Fall Line and become gently to moderately incised near the southern boundary of Subarea 5.

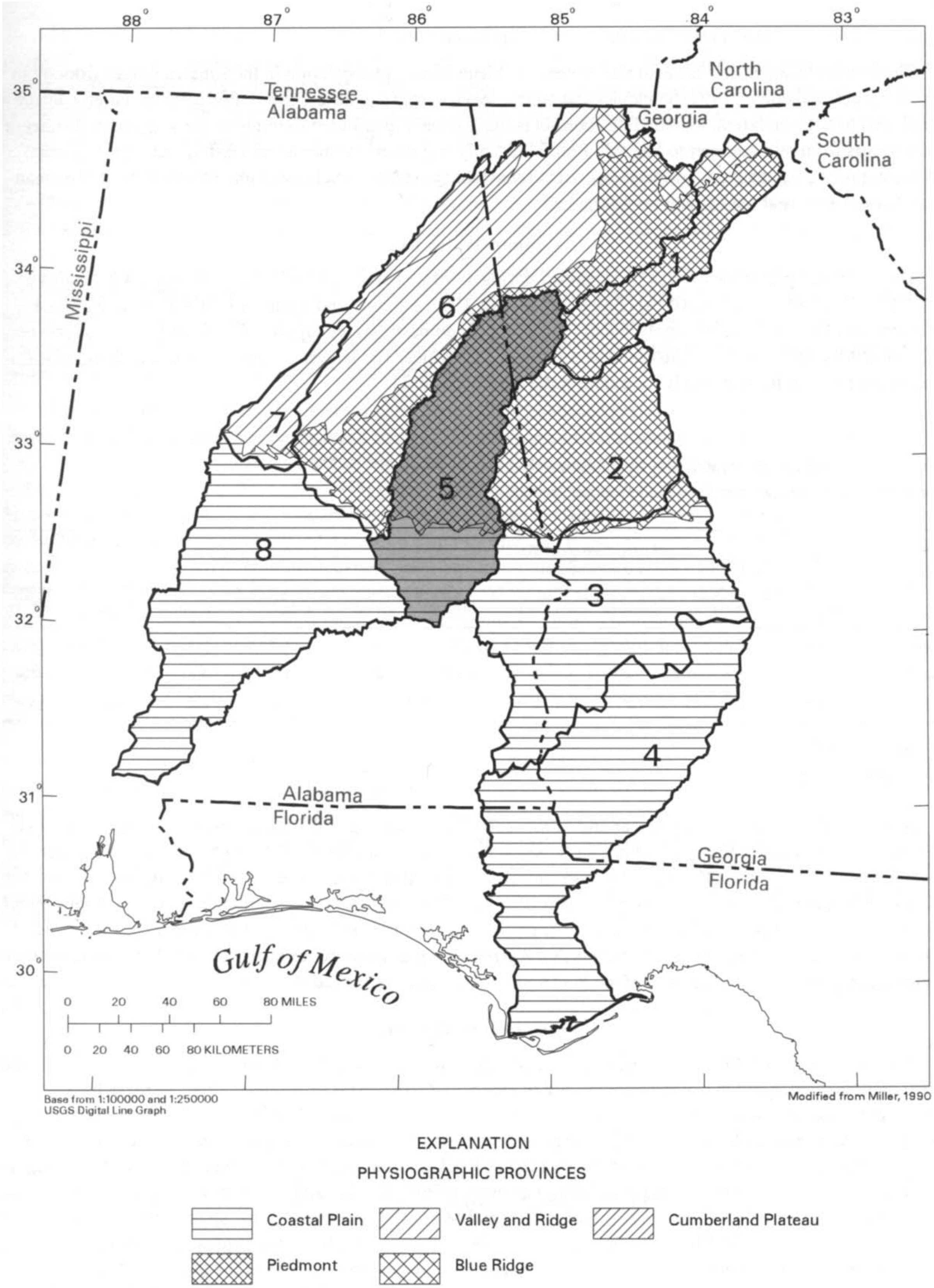


Figure 2. Physiographic provinces and subareas in the Apalachicola–Chattahoochee–Flint and Alabama–Coosa–Tallapoosa River basins.

Climate

The climate in Subarea 5 is moist and temperate. Mean-annual precipitation in the subarea ranges from 49 to 53 inches (Peck and others, 1992; Schneider and others, 1965; Carter and Stiles, 1983). Precipitation chiefly occurs as rainfall, and to a lesser extent, as snowfall. Rainfall usually is greatest in March and least in October. A general increase in rainfall occurs from northeast to southwest across the subarea (Schneider and others, 1965). The mean-annual temperature is about 61 degrees Fahrenheit.

Ground-Water Use

The estimated ground-water use in Subarea 5 during 1990 was about 14 million gallons per day (Mgal/d) or about 21.5 cubic feet per second (ft^3/s) (Baker and Mooty, 1993; Fanning and others, 1992). Of this total, about 41 percent was for public water supply, about 32 percent for domestic water supply, 24 percent for agricultural use, and 3 percent for self-supplied industrial and commercial activities. The largest ground-water use in Georgia is for domestic supply, and in Alabama is for public water supply (table 1).

Table 1. Estimated ground-water use, by category, Subarea 5, 1990
[Mgal/d, million gallons per day; ft^3/s, cubic feet per second]

State	Public water supply		Self-supplied industrial and commercial		Agricultural		Domestic		Total	
	(Mgal/d)	(ft^3/s)	(Mgal/d)	(ft^3/s)	(Mgal/d)	(ft^3/s)	(Mgal/d)	(ft^3/s)	(Mgal/d)	(ft^3/s)
Georgia[1/]	0.4	0.6	0.03	0.05	0.3	0.5	1.3	2.0	2.0	3.1
Alabama[2/]	5.3	8.2	.4	.6	3.1	4.8	3.1	4.8	11.9	18.4
Subarea total	**5.7**	8.8	**.4**	**.6**	**3.4**	**5.3**	**4.4**	**6.8**	**13.9**	**21.5**

[1/]Fanning and others (1992).
[2/]Baker and Mooty (1993).

Ground-water use reported by Baker and Mooty (1993) and Fanning and others (1992) is by county; ground-water use in those counties that are partially in Subarea 5 are reported herein for Subarea 5 only. Ground-water use for public water supply, and self-supplied industrial and commercial uses were determined by using site-specific data. Ground-water pumpage for domestic purposes was determined by subtracting the population served by public supply facilities from the total population of the county or hydrologic unit, then multiplying that number by a water-use coefficient of 75 gallons per day (gal/d) per person. Agricultural ground-water use was estimated by multiplying the reported county use by the percentage of the land area of the county in Subarea 5.

Previous Investigations

The earliest investigations that described the geology within the Piedmont province in Alabama were restricted to areal reconnaissance surveys of the geology and related mineral occurrences. Adams (1926, 1933) defined most of the rock units, drawing heavily upon the generally unpublished notes of Henry McCauley and Eugene A. Smith. Steltenpohl and others (1990) reported that the regional correlations between rock units suggested by Adams (1926, 1933) were based largely upon the work of Prouty (1923). Rock-unit nomenclature and descriptions were reported by Brooks (1896), Clements (1896), Berquist (1960), Neathery (1968), Bentley and Neathery (1970), and Sears and others (1981). Bearce (1973), Cook (1982), Tull (1982), and Mies (1991) reported on the stratigraphy and structure of the Talladega Group slates and Inner Piedmont geologic units. Szabo and others (1988) provided a general description and map of the Piedmont geology in Alabama. Crickmay (1952) described the geology of the Georgia Piedmont. McConnell and Abrams (1984) described the Piedmont geology of the Atlanta area which included parts of Subarea 5. Miller (1990) remarked on the complex relation and local variation in texture and mineralogy of the metamorphic and igneous rocks of the Piedmont Province.

The geology of the Coastal Plain in Alabama was described by Smith and others (1894). Descriptions of the regional geology and stratigraphy in the study area were given by Murray (1961) and summarized by Szabo and others (1988). Adams (1926) and Copeland (1968) reported on the surface geology of the Coastal Plain. The subsurface geology of the Coastal Plain in Alabama was discussed by Moore and Joiner (1969), Moore (1970), Davis (1987), Miller (1992), Planert and others (1993), and Mallory (1993).

LeGrand (1967), Daniel (1987), Heath (1989), Guthrie and DeJarnette (1989), and O'Connor and others, (1993) described the aquifer system in the Piedmont in the southeastern United States. Powell and Abe (1985) and Harned (1989) similarly described a conceptual ground-water flow system in the Piedmont of North Carolina and Virginia.

Few regional studies have evaluated the ground-water resources in crystalline rock aquifers of the Piedmont of the southeastern United States. Mundorff (1948), Herrick and LeGrand (1949), LeGrand (1967), Cressler and others (1983), Daniel (1987), Guthrie and DeJarnette (1989), LeGrand (1989), McKibben and Spigner (1989), Clarke and Peck (1991), Chapman and others (1993), O'Connor and others (1993), and Guthrie and others (1994) described the geologic factors that affect ground-water flow and well yield.

Well inventories and discussions of water resources were presented in water resources and water-availability reports prepared for county, and larger areas, in the Alabama Piedmont (Warman and others, 1960; Scott, 1960, 1962, 1963; Warman and Causey, 1962; Chandler and others, 1972; Lines and Scott, 1972; Scott and Lines, 1972; Chandler and Lines, 1974, 1978a, 1978b; Lines, 1975; Lines and Chandler, 1975; and Ellard, 1982). Baker (1957) discussed the relation between geology and topography and ground-water availability. A series of studies were conducted near the Heflin area of Cleburne County, Alabama, on using seismic and resistivity measurements to provide a means for more accurate delineation of regolith thickness and identification of fractured rock (Joiner and others, 1967; Scarbrough and others, 1969; Wilson and others, 1970). O'Connor and others (1993) assessed ground-water availability in Carroll, Douglas, Haralson, Polk, and Paulding Counties, Georgia, located at the headwaters of the Tallapoosa River. Cressler and others (1983) and Herrick and LeGrand (1949) described the relation between well yield and rock type for the aquifer systems in the Piedmont (Chandler, 1976; Chapman and others, 1993; Guthrie and others, 1994). Kidd (1989) and Scott, Cobb, and Castleberry (1987) discussed the hydrogeology and contamination susceptibility of Piedmont aquifers and inventoried municipal and industrial wells in the region.

Carlston (1944) described the hydrologic conditions in the Alabama portion of the Southeastern Coastal Plain aquifer system. More recent studies that discuss the hydrology and geohydrology of the Coastal Plain aquifer system include Kidd (1976), Miller (1992), Mallory (1993), and Planert and others (1993). Cook (1993) described the hydrogeology of the Eutaw aquifer in Alabama. Miller and Renken (1988) named the aquifer systems for the major rivers that transect the outcrops of the aquifers. Several Regional Aquifer-System Analysis investigations described the hydrology and provided numerical simulations of hydraulic characteristics of the Southeastern Coastal Plain aquifer system (Mallory, 1993; Planert and others, 1993; Miller, 1992; Faye and Mayer, 1990).

Well inventories and discussions of the water resources were presented in water resources and water-availability reports that were prepared for county and larger areas in the Alabama Coastal Plain of Subarea 5 (Scott, 1960; Scott, 1961, 1962; Scott and Lines, 1972; Lines, 1975; Ellard, 1982; Kidd, 1987; Scott, Cobb, and Castleberry, 1987).

One of the earliest reports discussing the surface-water resources of the ACF-ACT River basin area was "Water Powers of Alabama" (Hall and Hall, 1916). This report contains information on the dry-weather flow of streams in Alabama. Carter and others (1988) described the low-flow characteristics of the Tallapoosa River and its tributaries in Georgia. Peirce (1955) described the hydrology and surface-water resources of the ACT River basin area in Alabama to the mouth of the Cahaba River, and also included data for tributaries in the Piedmont Province of Alabama. Thompson and Carter (1955, 1963) described the effects of the drought of 1954 on streamflow in Georgia. Hale and others (1989) described the effects of the drought of 1986 on streamflow in Alabama, Georgia, North Carolina, South Carolina, Tennessee, and Virginia. Faye and Mayer (1990) described ground-water flow and stream-aquifer relations in the northern Coastal Plain part of the ACF River basin area.

Reports describing methods of estimating streamflow and ground-water discharge to streamflow include Bingham (1982), Hirsch (1982), Hoos (1990), Rorabaugh (1960, 1964), and Rutledge (1991, 1992, 1993). Data collected as part of the ongoing surface-water monitoring program of the USGS are published annually in the reports "Water-Resources Data, Alabama (or Georgia)." Other reports containing information about the surface- and ground-water resources of the ACF-ACT River basin area are listed in the "Selected References" section of this report.

Well and Surface-Water Station Numbering Systems

Wells in Georgia are numbered by a system based on the USGS topographic maps. Each 7 1/2-minute topographic quadrangle map in Georgia has been assigned a number and letter designation beginning at the southwest corner of the State. Numbers increase sequentially eastward through 39; letters advance northward through “Z”, then double-letter designations “AA” through “PP” are used. The letters “I,” “O,” “II,” and “OO” are not used. Wells inventoried in each quadrangle are numbered sequentially beginning with “1.” Thus, the second well inventoried in the Zebulon quadrangle (designated 11Y) is designated 11Y002.

The well-numbering system in Alabama is based on the Federal system of subdivision of public lands into townships and ranges. Each township is divided into 36 sections numbered from one in the northeast corner to 36 in the southeast corner. Each township is assigned a letter in the same order that sections are numbered from “A” through “X,” with “A” being assigned to the northeasternmost equal subdivision of the section and “X” to the southeasternmost subdivision. Letter designations are doubled or tripled as needed. Wells in each subdivision are numbered consecutively such as A-1, A-2.

Wells in the USGS Ground-Water Site Inventory (GWSI) data base are assigned a 15-digit identification number based on the latitude and longitude grid system. The first six digits denote the degrees, minutes, and seconds of latitude. The next seven digits the degrees, minutes, and seconds of longitude. The last two digits (assigned sequentially) identify wells within a one-second grid.

The USGS established a standard identification numbering system for all surface-water stations in 1950. Stations are numbered according to downstream order. Stations on a tributary entering upstream of a main-stream station are numbered before and listed before the main-stream station. No distinction is made between continuous-record and partial-record stations. Each station has a unique eight-digit number that includes a two-digit part number (02 refers to natural drainage into the Eastern Gulf of Mexico) and a six digit downstream order number. Gaps are left in the series of numbers to allow for new stations that may be established; hence, the numbers are not consecutive. The complete number for each station includes a two-digit part number “02” plus the downstream-order number, which can be from 6 to 12 digits. All records for a drainage basin, encompassing more than one State, can easily be correlated by part number and arranged in downstream order.

Approach and Methods of Study

This study included several work elements used to appraise the ground-water resources of Subarea 5, including the description of a conceptual model of ground-water flow and stream-aquifer relations, and an assessment of ground-water availability. The approach and methods used to accomplish these tasks included:

- compilation of information and data from pertinent literature, including geologic, ground-water, streamflow, and ground-water use data;
- separation of streamflow hydrographs to estimate mean-annual ground-water contribution to the Tallapoosa River and its tributaries;
- evaluation of streamflow records and periodic discharge measurements during drought periods to estimate “worst-case” streamflow conditions; and
- comparison of 1990 ground-water use with mean-annual and drought-flow conditions to evaluate ground-water availability.

Literature and data reviews provided information necessary to describe a conceptual model of ground-water/surface-water relations. Much of the conceptual model is based on results of previous investigations by Toth (1962, 1963), Freeze (1966), Freeze and Witherspoon (1966, 1967, 1968), Winter (1976), Faye and Mayer (1990), Heath (1984, 1989), and Miller (1990). These studies suggest that large rivers, such as the Tallapoosa, and their tributaries function as hydraulic drains for ground-water flow, and that during significant droughts, most of the discharge in these streams is contributed by ground water.

Streamflow data were compiled from the USGS Automated Data Processing System (ADAPS) database. Streamflow records from continuous-record and miscellaneous discharge-measurement stations were used for hydrograph-separation analyses and drought streamflow evaluation.

Stream-aquifer relations were quantified using two approaches: (1) the hydrograph-separation method of Rorabaugh (1960, 1964) and Daniel (1976), called the recession-curve-displacement method; and (2) a drought-flow mass-balance analysis of streamflow. The hydrograph-separation method was used to estimate the mean-annual discharge of ground water (baseflow) to the basin. The mean-annual baseflow was used as a base or reference with which to compare and evaluate droughts under “worst-case” conditions. An estimate also was made of the mean-annual volume of ground water discharged to Alabama from Georgia as baseflow at the State line and from Subarea 5 to Subarea 8 as baseflow in the Tallapoosa River at the mouth. The mass-balance analysis was used to estimate drought baseflow contributions to the surface-water system during historically significant droughts and the ground water delivered as baseflow to Alabama from Georgia, and from Subarea 5 to Subarea 8 in Alabama near the end of these droughts.

Mean-Annual Baseflow Analysis

Discharge data from continuous-record gaging stations along the Tallapoosa River and its tributaries were selected for baseflow analysis based on the period of record of unregulated flow. Streamflow representative of low, average, and high years of stream discharge were evaluated by hydrograph-separation methods to estimate annual baseflow. The mean-annual baseflow was then computed as the average baseflow of the three representative flow years.

The selection process for the most representative year of low, average, and high stream discharge involved objective statistical examination of the discharge data, followed by some subjectivity in the final choice of the water year selected. Hydrographs acceptable for separation were characterized by relatively normal distributions of daily stream discharge, small ranges of discharge, and the absence of extremely high, isolated peak stream discharge. For each station, the mean annual stream discharge was computed for the period of record of unregulated flow and used as a reference mean for low-, average-, and high-flow conditions for that station. The mean- and median-annual stream discharge for those water years identified as acceptable were compared to the reference mean. Because extremely high discharge during a water year could greatly influence the mean but not the median (which is similar to the geometric mean for positively skewed data sets, such as discharge), the process of selecting representative water years for low-, average-, and high-flow conditions considered the position of the mean discharge for the selected year relative to the median and the reference mean. The hydrographs for these representative water years were examined and separated. True subjectivity in the selection process entered only at this point, such that, if acceptable hydrographs were available for several years, one year arbitrarily was chosen over the others.

The separation analyses were conducted using the computer program SWGW (Mayer and Jones, 1996) which is an automated version of the recession-curve-displacement method, often referred to as the Rorabaugh or Rorabaugh-Daniel method. The SWGW program was applied to a water-year period of streamflow data. SWGW utilizes daily mean discharge data collected at unregulated stream-gaging sites and requires at least 10 years of record to accurately estimate a recession index necessary for hydrograph-separation analysis.

The hydrograph-separation method estimates the ground-water component of total streamflow. In general, the streamflow hydrograph can be separated into two components—surface runoff and baseflow (ground-water discharge to streams). Figure 3 shows the graphical output from the SWGW program. Surface runoff is the quick response (peaks) of stream stage to precipitation and nearby overland flow.

Application of the recession-curve-displacement method requires the use of the streamflow recession index. The streamflow recession index is defined as the number of days required for baseflow to decline one order of magnitude (one log cycle), assuming no other additional recharge to the ground-water system. The streamflow recession index is a complex number that reflects the loss of ground water to evapotranspiration (Daniel, 1976) or leakage, and the influence of geologic heterogeneities in the basin (Horton, 1933; Riggs, 1963). The slope of the streamflow recession is affected by evapotranspiration, such that the streamflow recession index varies from a maximum during the major rise period to a minimum during the major recession period (fig. 3). The major rise period of streamflow generally occurs from November through March or April, when precipitation is greatest and evapotranspiration is least. The major recession period occurs during late spring through fall and coincides with a period of lesser precipitation, higher temperatures, and greater evapotranspiration (fig. 3). Two recession indices were estimated for streamflow observed at each continuous-record gaging station used in the mean-annual baseflow analysis; one index for the major rise period and one for the major recession period.

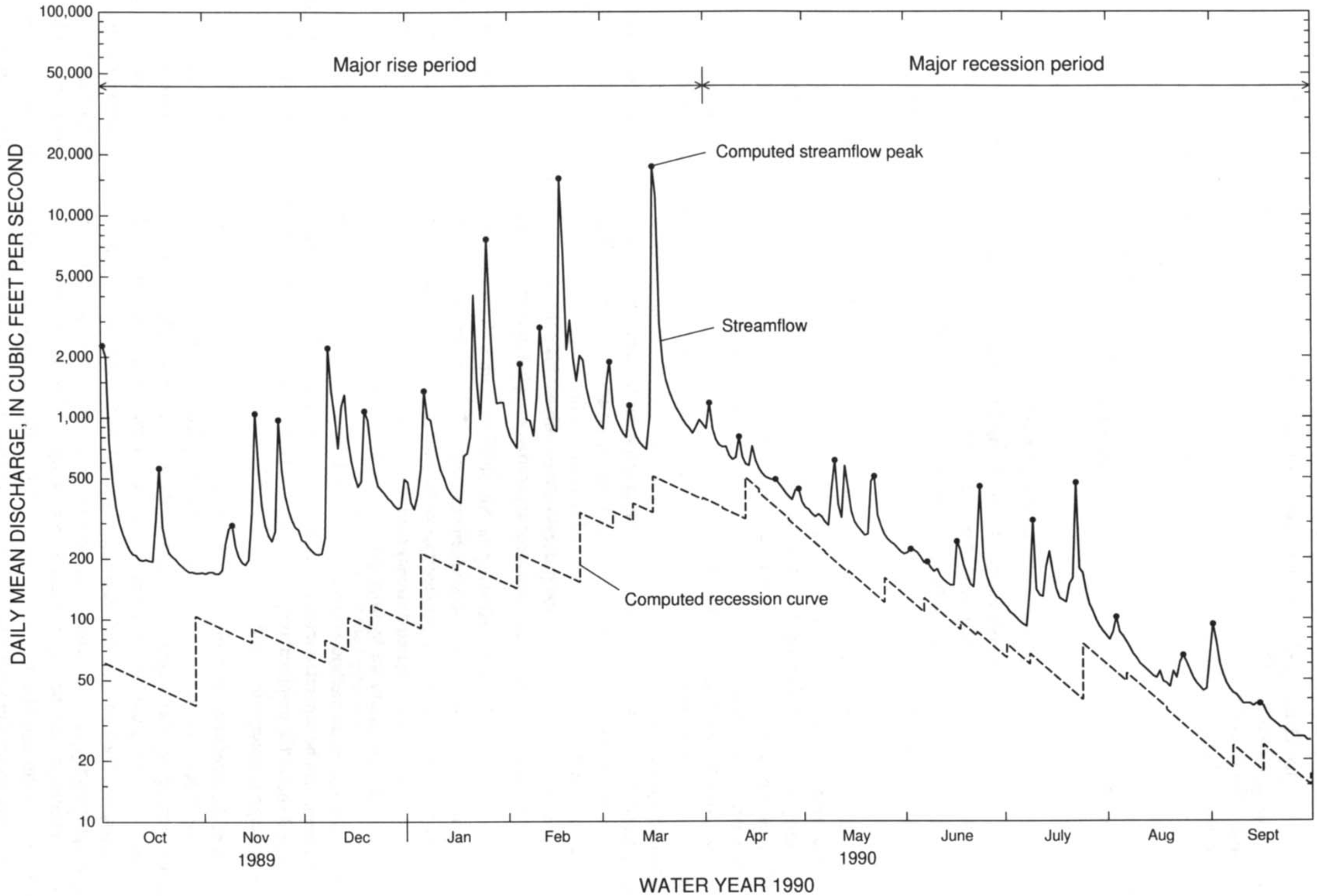


Figure 3. Streamflow hydrograph, separated by program SWGW.

Available ground-water-level data indicate that long-term changes in ground-water storage are minimal in Subarea 5. Because long-term storage changes are minimal, mean-annual ground-water discharge, estimated using the hydrograph-separation method, is considered an estimate of minimum mean-annual net recharge. Also, aquifers at a regional scale in Subarea 5 are considered, for purposes of analysis, to respond as homogeneous and isotropic media.

Results of the mean-annual baseflow analysis are based on measured and estimated data, and the analytical methods to which they are applied. Drainage areas were measured using the most accurate maps available at the time of delineation (Novak, 1985), and are reported in units of square miles. Drainage areas are reported to the nearest square mile for areas greater than 100 mi^2, to the nearest tenth of a square mile for areas between 10 and 100 mi^2; and to the nearest hundredth of a square mile for areas less than 10 mi^2, if the maps and methods used justify this degree of accuracy (Novak, 1985). Annual stream discharge, the sum of the daily mean stream discharges for a given water year, is reported in units of cubic feet per second, to the nearest cubic foot per second. Daily mean discharge is reported to the nearest tenth of a cubic foot per second for discharge between 1.0 and 9.9 ft^3/s; to the nearest unit for discharge between 10 and 100 ft^3/s; and is reported using three significant figures for discharge equal to or greater than 100 ft^3/s (Novak, 1985).

The accuracy of stream-discharge records depends primarily on: (1) the stability of the stage-discharge relation or, if the control is unstable, the frequency of discharge measurements; and (2) the accuracy of measurements of stage and discharge, and the interpretation of records. Accuracy of records of streamflow data used in this report can be found in annually published USGS data reports, for example, Pearman and others (1994). The accuracy attributed to the records is indicated under “REMARKS” in the annual data reports for each station. “Excellent” means that about 95 percent of the daily discharges are within 5 percent of the true discharge; “good,” within 10 percent; and “fair,” within 15 percent. Records that do not meet these criteria are rated “poor.” The accuracy of streamflow records at a station may vary from year to year. In addition, different accuracies may be attributed to different parts of a given record during a single year (Novak, 1985).

Results of the mean-annual baseflow analyses are inherently uncertain. The hydrograph-separation method of analysis is partly subjective, relying on the input of several user-selected variables. As such, the results of the analyses derived and reported herein, are difficult to independently confirm and are presented as estimates of unknown quality and confidence. However, because the values in this report are used in several water budgets, not only within Subarea 5 but also from subarea to subarea, hydrograph-separation results may be reported to a greater significance than the data and analyses warrant to maintain the numerical balance of the water budget; implication of accuracy to the extent shown is not intended.

Drought-Flow Analysis

Daily mean streamflow data collected at gaging stations during periods of low flow and corresponding periodic measurements of stream discharge collected at partial-record stations were compiled for the drought years 1941, 1954, and 1986. These data included nearly concurrent daily measurements of streamflow in the Tallapoosa River and periodic measurements of tributary discharge.

Standard periods of analyses for drought studies were selected for all ACF-ACT subareas. The period of analysis selected for compiling 1954 drought data was September 15 through November 1, 1954. The selected period for the 1986 drought was July 1 through August 14, 1986. Streamflow during these periods was considered to represent the “worst case” of ground-water storage and availability throughout the ACF-ACT study area. Discharge data were sparse during the 1941 drought; therefore, a standard period of analysis was not selected for the entire ACF-ACT study area.

The period of “worst-case” conditions may not include the minimum streamflow that occurred during a drought at a streamflow measurement site. Minimum drought flows typically occur at different times at different stations within large watersheds, such as the Tallapoosa River basin. Rather, the “worst-case” evaluation was designed to describe streamflow during the advanced stages of each drought; thus, providing a near-contemporaneous summary of streamflow conditions during periods of low flow throughout the ACF-ACT study area.

The estimated "worst-case" distribution of Tallapoosa River streamflow near the end of the 1941, 1954, and 1986 drought periods was determined by balancing mass in the stream network in a general downstream direction during a relatively short interval of time. The tributary discharge to the Tallapoosa River during drought periods was calculated using a unit-area discharge extrapolated to the entire drainage area of the tributary. Unit-area discharges are based on streamflow measurements that generally are inclusive of only part of the tributary drainage, and may not be representative of an average unit-area discharge for the entire tributary drainage. Therefore, most unit-area discharges used to estimate discharge at ungaged and unmeasured tributaries were based on streamflow data measured near the mouths of tributaries to better represent the entire tributary contributing area.

Because daily discharge or periodic discharge measurements did not exist for some sites during all or some of the three drought periods, estimates of the daily discharge at those sites during the drought periods were based on correlation methods that use relations of available discharge data from other periods. The logarithms of these discharge data were correlated with the logarithms of concurrent daily discharges at selected continuous-record gaging stations (index stations). The relation was defined by a line of correlation determined by a technique known as MOVE.1—Maintenance of Variance Extension, Type 1 (Hirsch, 1982)—or by a graphically determined best-fit line (Riggs, 1972). The MOVE.1 technique was used instead of ordinary least-squares regression to develop these relations because it produces an estimate that is less biased than the ordinary least-squares regression.

Drought streamflow daily discharges were estimated for 1941, 1954, and 1986 for partial-record and continuous-record stations where at least 10 discharge measurements were available, using the MOVE.1 line and the concurrent daily discharge for the index station. This estimating technique transfers a selected daily discharge from the index station using the MOVE.1 line of correlation to determine the corresponding daily discharge for the partial-record station or continuous-record station (dependent station). This technique assumes that daily discharges will occur concurrently at the dependent station and the index station and that the two stations drain hydrologically and geologically similar basins in close geographical proximity. Partial-record stations having fewer than 10 discharge measurements, or where relations between dependent stations and index stations were not linear, were correlated with index stations by a graphical technique. A graphically determined best-fit line through an x-y plot of concurrent daily discharge for the index station and discharge data for the dependent station was used for estimating daily discharges (Riggs, 1972).

CONCEPTUAL MODEL OF GROUND-WATER FLOW AND STREAM-AQUIFER RELATIONS

The conceptual model of the ground-water flow and stream-aquifer relations in Subarea 5 is based on previous work done in other areas by Toth (1962, 1963), Freeze (1966), Freeze and Witherspoon (1966, 1967, 1968), Winter (1976), and Faye and Mayer (1990). These studies suggest that recharge originates from precipitation that infiltrates the land surface, chiefly in upland areas, and percolates directly, or leaks downward to the water table. Ground water subsequently flows through the aquifer down the hydraulic gradient and either discharges to a surface-water body or continues downgradient into confined parts of an aquifer. Major elements of this conceptual model include descriptions of flow regimes, stream-aquifer relations, recharge to ground water, and ground-water discharge to streams.

Toth (1963) observed that most ground-water flow systems could be qualitatively subdivided into paths of local (shallow), intermediate, and regional (deep) flow. Local flow regimes are characterized by relatively shallow and short flow paths that extend from a topographic high to an adjacent topographic low. Intermediate flow paths are longer and somewhat deeper than local flow paths and contain at least one local flow path. Regional flow paths (fig. 4) begin at or near the major topographic (drainage) divide and terminate at regional drains, which is the Tallapoosa River in Subarea 5. Depending on local hydrogeologic conditions, all three flow regimes may not be present everywhere within the subarea.

The water table in Subarea 5 probably is a subdued replica of the land-surface topography but generally has less relief. The presence of ground-water flow regimes depends largely on the configuration of the water table, such that recharge occurs in highland areas and discharge occurs in lowland areas. Quantities of recharge to the water table and ground-water discharge to streams are variably distributed throughout the local, intermediate, and regional flow regimes. Local regimes receive the greatest ground-water recharge from the water table and provide the most ground-water discharge to streams. Ground-water discharge to tributary drainages primarily is from local and intermediate flow regimes; ground-water discharge to regional drains, such as the Tallapoosa River includes contributions from the regional as well as local and intermediate regimes.

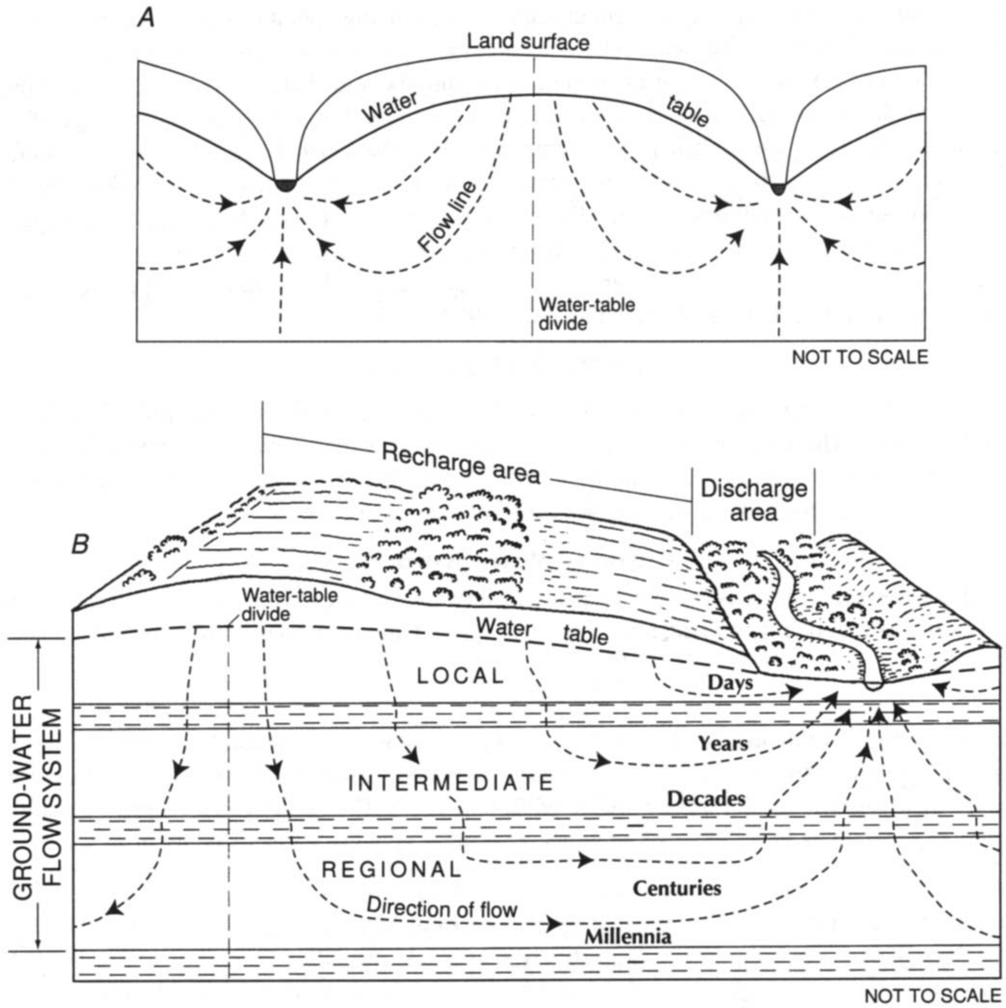


Figure 4. (*A*) Distribution of ground-water flow in an areally extensive, isotropic, homogeneous aquifer system (modified from Hubbert, 1940, and Heath, 1984) and (*B*) example of local, intermediate, and regional ground-water flow (modified from Heath, 1984).

Seasonal variation in rainfall affects the local ground-water flow regime most significantly, and affects the regional flow regime least significantly. Generally, regional flow probably approximates steady-state conditions, and long-term recharge to and discharge from this regime will not vary significantly.

Continuum methods of analysis of ground-water flow, such as hydrograph separation, are based on assumptions of laminar flow through a medium characterized by systematic changes in primary porosity and permeability. Such media generally are classified as porous media. Ground-water flow through porous media is commonly termed Darcian flow. Fractured rock media in the Piedmont Province contain virtually no primary porosity or permeability and virtually all ground-water flow occurs through secondary openings. For purposes of analysis, continuum methods based on assumptions of Darcian flow are applied to ground-water flow through fractured rock media.
Such approaches commonly are justified on a regional scale because fracture systems typically are ubiquitous and intersecting.

Results of smaller-scale studies also demonstrate the continuity of ground-water flow through fractured media under pumping conditions. For example, long-term ground-water pumping operations near Ridgeway, S.C., began in the fall of 1988 to dewater fractured Piedmont rocks to accommodate open-pit mining of gold-bearing ore (Glenn and others, 1989). Detailed ground-water monitoring around and within the mined areas indicated that after less than one year of pumping, drawdown extended in an oblong distribution for more than 1 mi beyond the center of pumping. Drawdown decreased uniformly with distance from pumped wells. Nelson (1989) used water-level data from numerous monitoring wells at a 120-acre study site constructed in fractured Piedmont rocks to describe stream-aquifer relations (non-pumping conditions) near the Rocky River in North Carolina. Nelson (1989) concluded that the Rocky River was a drain for ground water discharged from Piedmont rocks, and that observed hydraulic relations between the fractured-rock aquifer and the river and within the aquifer at various depths were consistent with porous media concepts of ground-water flow, as described by Toth (1962, 1963).

HYDROLOGIC SETTING

The hydrologic framework of Subarea 5 contains dynamic hydrologic systems consisting of aquifers, streams, reservoirs, and floodplains. These systems are interconnected and form a single hydrologic entity that is stressed by natural hydrologic and climatic factors and by anthropogenic factors. For this discussion, the hydrologic framework is separated into two systems: the ground-water system and surface-water system.

Ground-Water System

The ground-water system forms as geology and climate interact. Geology primarily determines the aquifer types present, as well as the natural quality and quantity of ground water. Climate primarily influences the quantity of ground water.

Geology

A detailed description of the diverse and complex geology of Subarea 5 is beyond the scope of this study; however, a brief description of the geology of the subarea is presented, based on selected published descriptions of various geologic investigations (see the section “Selected References”). The geology in each physiographic province of Subarea 5 (fig. 2) generally is unique to each province; therefore, geology is discussed by province.

The Piedmont Province is characterized by complex sequences of igneous rocks and metamorphic rocks of late Precambrian to Permian age (Miller, 1990); isolated igneous rocks of Mesozoic age also are present (D.C. Prowell, U.S. Geological Survey, oral commun., 1996). Collectively, these rocks are called crystalline rocks. The metamorphic rocks originally were sedimentary, volcanic, and volcaniclastic rocks that have been altered by several stages of regional metamorphism to slate, phyllite, schist, gneiss, quartzite, and marble; a variety of cataclastic rocks also are present. The metamorphic rocks are extensively folded and faulted. The intrusive igneous rocks, dominantly granites and lesser amounts of diorite and gabbro, occur as widespread plutons. The rocks are characterized by a complex outcrop and subsurface distribution pattern, as shown on geologic maps of various scales (Szabo and others, 1988). Because rock characteristics can vary significantly on the scale of a few tens of feet within the same lithologic unit, detailed geologic-unit differentiation can be accomplished only on the scale of a topographic quadrangle, or larger. The Piedmont contains major fault zones that generally trend northeast-southwest and form the boundaries between major rock groups (Georgia Geologic Survey, 1976).

The crystalline igneous and metamorphic rocks largely are covered by a layer of weathered rock and soil known as regolith. The regolith ranges in thickness from a few to more than 150 feet, depending upon the type of parent rock, topography, and hydrogeologic history. From the land surface, the regolith consists of a porous and permeable soil zone that grades downward into a clay-rich, relatively impermeable zone that overlies and grades into porous and permeable saprolite, generally referred to as a transition zone (Heath, 1989). The transition zone grades downward into unweathered bedrock. In general, the massive granite and gabbro rocks are poorly fractured and are characterized by a thin soil cover. In contrast, the schists and gneisses are moderately to highly fractured. The weathering of the rocks is erratic and usually deep; remnants of the original texture and foliation are retained in the saprolite in many places (Clarke, 1963).

Sediments of Cretaceous age in the Coastal Plain Province mostly are undeformed, poorly consolidated, clastic deposits of estuarine, deltaic, and shallow marine origin and form a southward-thickening wedge that overlies rocks of the Piedmont Province. These sediments dip gently to the south and southeast. Typical sediment types are clay, sand, and gravel. The outcrops of Cretaceous sediments, which contain sand and gravel aquifers in limited use in Subarea 5, form narrow bands across Elmore, Macon, Russell, Montgomery, and Bullock Counties, Ala.

Aquifers

Aquifers in Subarea 5 (fig. 5) vary widely in their lithologic and water-bearing characteristics (table 2). Two types of aquifers are present in the Subarea, identified on the basis of their ability to store and yield water: (1) porous-media; and (2) fracture-conduit aquifers (table 2). These aquifer types differ fundamentally in origin and water-supply potential. Aquifers are not hydraulically isolated within physiographic provinces, which also could be considered “hydrogeologic provinces.” Ground water flows from one hydrogeologic unit to another; for example, where the units are juxtaposed, ground water can flow from the fracture-conduit aquifers of the Piedmont to the porous-media aquifers of the Coastal Plain.

Table 2. Generalized geologic units in Subarea 5, and water-bearing properties, chemical characteristics, and well yields
[—, no available data]

Physiographic province	Geologic age and lithology	Aquifer type	Water-bearing properties and chemical characteristics	Well yield
Coastal Plain	Cenozoic—sand and gravel	porous-media	generally adequate only for domestic use, may have high iron concentrations	10 gallons per minute typical
Coastal Plain	Cretaceous—sand and gravel beds of the Coker and Gordo Formations	porous-media	used for limited public water supply in Bullock, Macon, and Lee Counties, Alabama	100 to 200 gallons per minute (Kidd, 1987)
Piedmont	regolith: soil, alluvium, colluvium, and saprolite derived from various aged rocks	porous-media; preferential flow	generally suitable for domestic use only	—
	Precambrian to Paleozoic—quartzite, slate, gneiss, schist, marble, phyllite, granite	fracture-conduit	local, discontinuous properties, well yields variable, water quality generally good	1 to 25 gallons per minute typical; may exceed 500 gallons per minute (Kidd, 1989; Guthrie and others, 1994)

Porous-media aquifers typically consist of unconsolidated or poorly consolidated sediments. In these aquifers, ground water moves through interconnected pore spaces between sediment grains. The space between sediment grains is termed voids or interstices, and the interconnection of these spaces allows water to flow through the sediments. Such flow is said to be the result of primary permeability. The porous-media aquifers occur in the regolith of the Piedmont Province, in sand and gravel deposits in the floodplain of the Tallapoosa River, and in clastic deposits in the southeastern Coastal Plain (figs. 1 and 2). For a more complete discussion of aquifers of the Coastal Plain Province, the reader is referred to Miller (1990).

Lenticular, discontinuous sand and gravel deposits in the floodplain of the Tallapoosa River are limited in thickness and extent and form local aquifers. These aquifers are hydraulically connected to the Tallapoosa River. Ground-water flow generally is toward the river, but may be reversed temporarily near the river during periods of high streamflow. Wells completed in these sediments generally yield small quantities of water. These aquifers are not major sources of ground water in Subarea 5.

The Tallapoosa River flows across the outcrop area of the Cretaceous sediments in northwestern Elmore County, Ala. Aquifers in these sediments are of the porous-media type (fig. 6), and the Tallapoosa River receives water discharged from these aquifers. Water not intercepted by the river or by ground-water withdrawal flows downgradient through the aquifers beyond Subarea 5.

In Subarea 5, fracture-conduit aquifers occur in igneous and metamorphic rocks (fig. 7) of the Piedmont Province. Two general water-bearing zones compose the ground-water flow system in fracture-conduit aquifers: (1) the shallow regolith, composed of soil, alluvium, colluvium, and saprolite; and (2) the deeper, fractured bedrock. In general, the regolith consists of a porous, permeable soil at land surface, grading downward into a highly weathered, clay-rich relatively impermeable zone that overlies a less-weathered and more permeable transition zone (Heath, 1989). In some instances, ground water in the regolith is similar to that in porous media, where intergranular porosity is present in the soil or alluvium, or where rocks have been deeply weathered, and retain few structural characteristics. Porosity of the regolith can range from 20 to 30 percent (Heath, 1984). Ground-water flow can be preferential in saprolite, where weathered rock retains relict structural features (Stewart, 1964; Stewart and others, 1964). The bedrock is characteristic of a fracture-conduit aquifer.

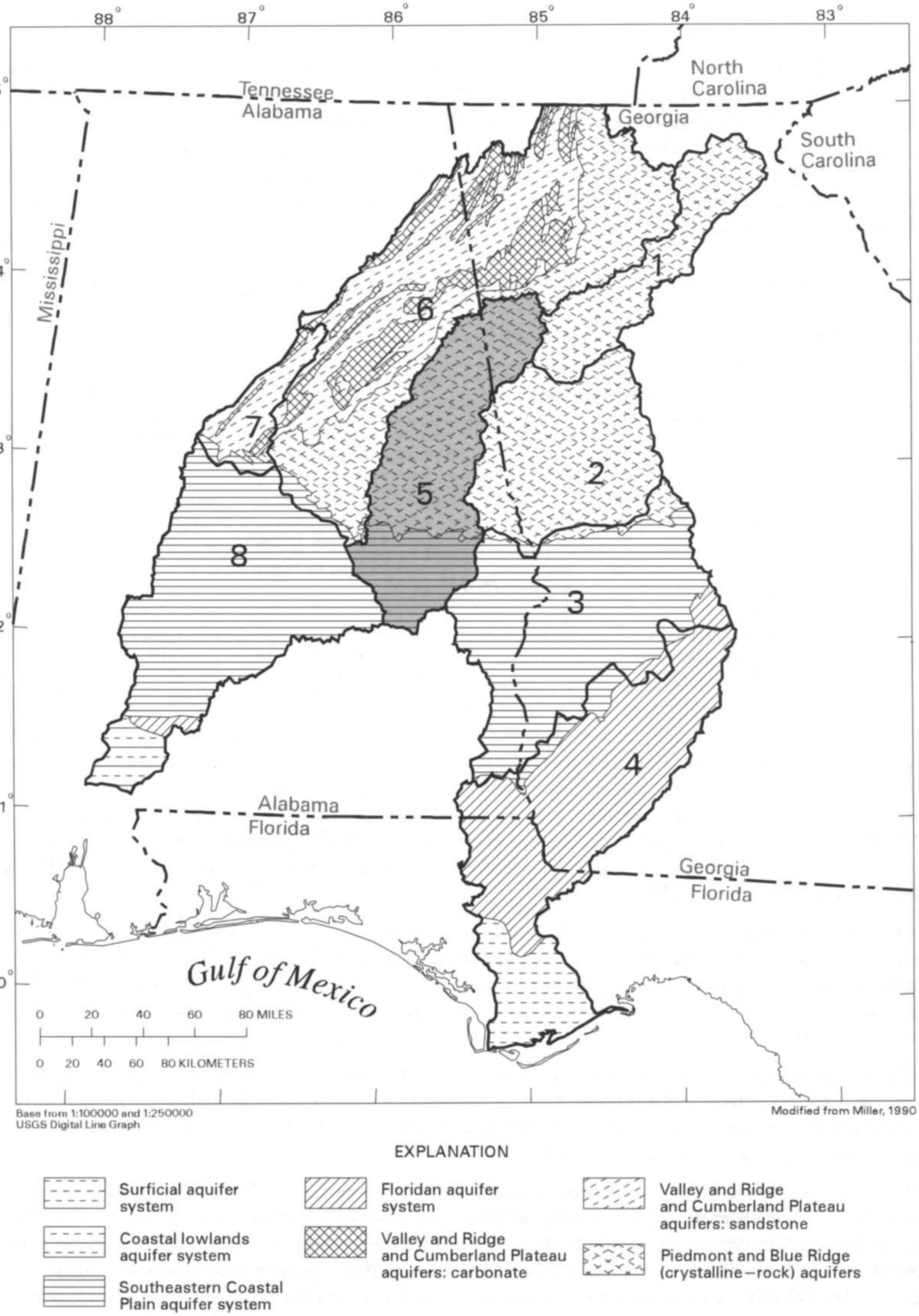


Figure 5. Major aquifers and subareas in the Apalachicola–Chattahoochee–Flint and Alabama–Coosa–Tallapoosa River basins

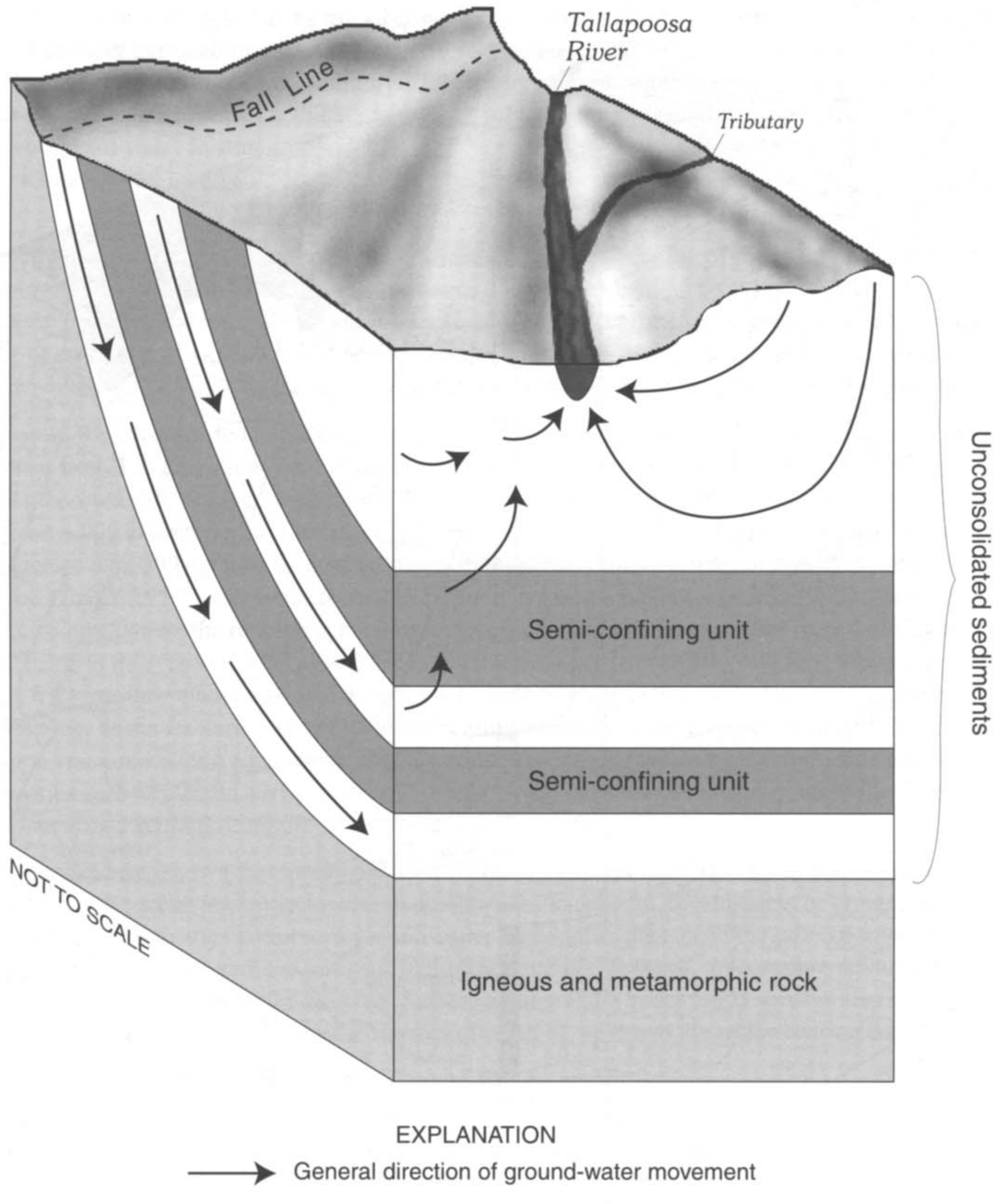


Figure 6. Conceptual ground-water and surface-water systems in Subarea 5: porous-media aquifer in unconsolidated sediments of the Coastal Plain Province.

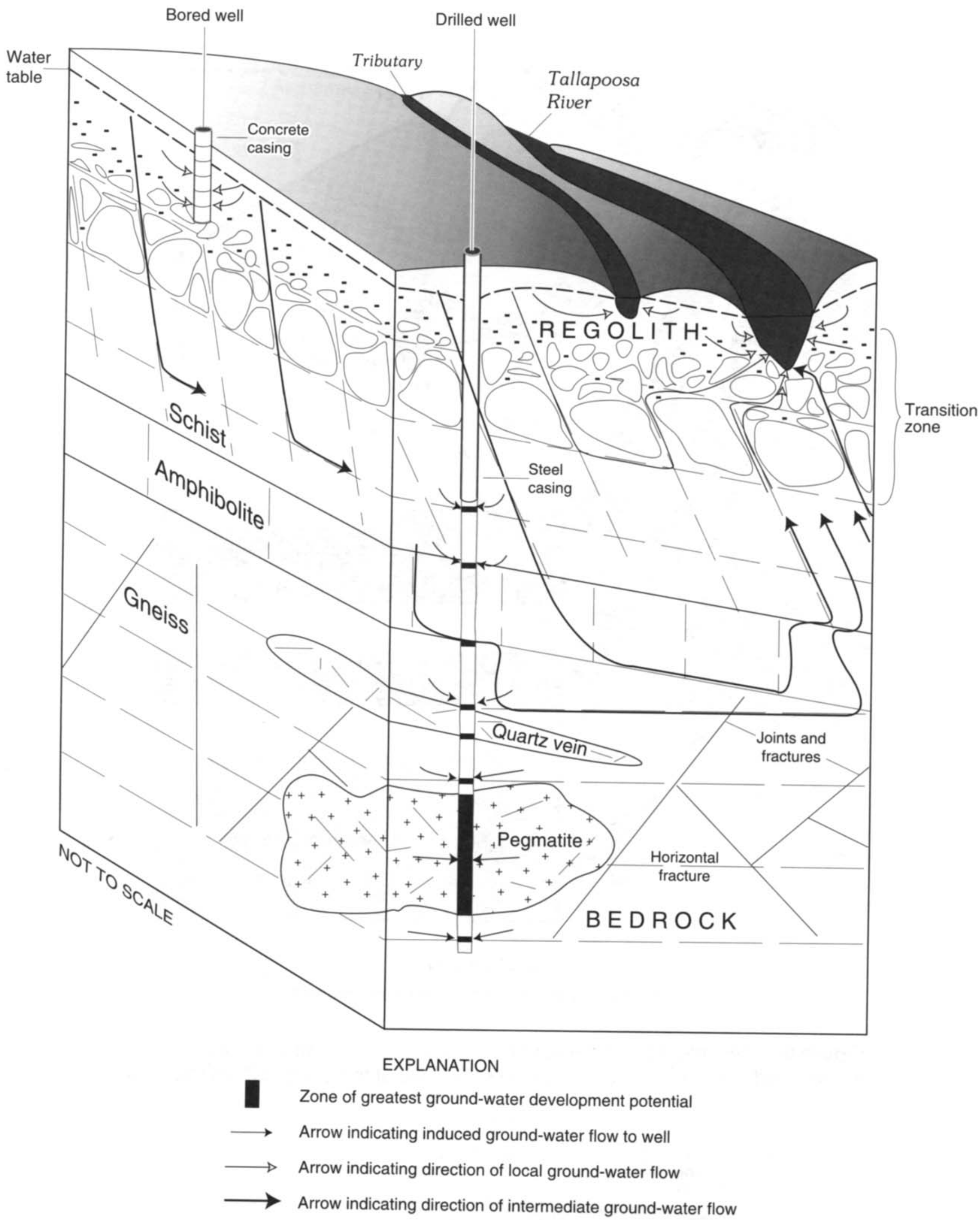


Figure 7. Conceptual ground-water and surface-water systems in Subarea 5: fracture-conduit aquifer in the igneous and metamorphic rocks of the Piedmont Province.

In fracture-conduit aquifers, nearly all ground-water movement is through fractured or broken rock and through openings between cleavage planes. Secondary porosity is created by faulting and fracturing and is enhanced by weathering along these openings. The bedrock below the weathered zone and beyond fractures typically has little or no porosity or primary permeability. Ground-water storage primarily is in the overlying weathered rock (regolith or saprolite, which behaves like a porous-media aquifer). The volume of water in storage is controlled by the porosity and thickness of the regolith, which is thicker in marble, schist, and gneiss, and in valleys (Kidd, 1989); to a lesser degree, the volume of water in storage is controlled by the amount of fracturing of the rock. Because of the limited storage in fractures, water levels in fracture-conduit aquifers respond rapidly to pumping and to seasonal changes in rainfall.

The fracture-conduit aquifers are anisotropic and heterogeneous because of the highly complex and locally variable geologic characteristics controlling the presence of the water-bearing units in the bedrock and regolith. Rock types, structural features, and regolith thickness vary locally and affect the storage capacity and hydraulic conductivity of an aquifer (LeGrand, 1967, 1989; Cressler and others, 1983; Daniel, 1987; Guthrie and DeJarnette, 1989; Clarke and Peck, 1991; Chapman and others, 1993; O'Connor and others, 1993; Guthrie and others, 1994).

Yields from wells completed in the fractured crystalline-rock aquifers (schist, gneiss, quartzite, and granite) generally range from 1 to 25 gallons per minute (gal/min), but may exceed 500 gal/min (Kidd, 1989). Guthrie and others (1994) reported that yields of wells in the Piedmont of Alabama range from 0 to 700 gal/min. Yields at only 9 percent of the 1,900 inventoried wells were 50 gal/min or greater. Yields at less than 1 percent of the inventoried wells were greater than 300 gal/min. In the Piedmont of Alabama, yields from wells drilled in mica schist generally are the highest (Baker, 1957); and yields from wells drilled in granite and other igneous rocks are the lowest. Yields from wells in valleys, where the regolith is thickest, average four times as much as that from wells located on hilltops where the regolith is thin (Baker, 1957). Well depth generally ranges from 100 to 500 feet. Wells may yield water from several fractures throughout a borehole, or from a single productive fracture. Conversely, a borehole may not intersect a fracture, or the fracture may not be water bearing. Because of the complex nature of the secondary permeability in fracture-conduit aquifers, production zones generally are of limited extent. Quantitative estimates of aquifer properties such as transmissivity, hydraulic conductivity, and storage coefficient are difficult to assess because of the highly localized geologic controls on secondary permeability.

Recent studies have shown that a thorough evaluation of hydrogeologic settings in areas characterized by fracture-conduit aquifers can lead to an increased likelihood of successful development of ground-water resources. Most municipal, industrial, and commercial ground-water exploration plans now include consultation with hydrogeologists, who evaluate surficial geology, including structural features, topographic relations to geologic features, existing well information, and land use. Surface and borehole geophysical surveys also may be conducted to delineate subsurface features that indicate the sources of water to wells and the water-bearing properties of the rocks.

Ground-Water Levels

Ground-water levels fluctuate in response to natural and anthropogenic processes, such as seasonal changes in rainfall, interaction with the surface-water system, and ground-water withdrawal. These fluctuations indicate changes in the amount of water in storage in an aquifer. In Subarea 5, long-term water-level data were available for four wells in fracture-conduit aquifers for the period 1968-93; and eight wells in the porous-media aquifers of the Coastal Plain for the period 1972-94. The water levels usually were measured biannually.

Annual low water levels generally occur in the fall after the dry summer; and annual high water levels occur in the early spring because of recharge following rainfall during the winter. Although the water level fluctuates seasonally, significant year-to-year or long-term change in the average water level in the aquifer may not have occurred. This suggests that mean-annual recharge and discharge are approximately equal, and during the period of record, permanent changes in storage in the aquifer probably have not occurred.

Ground-water levels in observation wells in Subarea 5 ranged from 8 to 40 feet below land surface in the regolith wells, from 1 to 60 feet below land surface in the fracture-conduit aquifers, and from 10 to 440 ft below land surface in the porous-media aquifers. In general, shallow, bored wells that are completed in regolith are more susceptible to water-level decline during droughts. Wells that are completed in bedrock often are more capable of sustaining yields during droughts.

The hydrographs of well I-17 completed in a fracture-conduit aquifer in Clay County, Ala., and well O-01 completed in the regolith aquifer in Randolph County, Ala., show water-level fluctuations that probably are typical of such wells in Subarea 5 (fig. 8). No significant long-term change in the average water level in the aquifers was observed. A long-term change of decreasing water levels was observed in porous-media aquifer well F-1 in Bullock County, Ala. However, the number and distribution of wells having long-term water-level records in Subarea 5 is insufficient to make additional conclusions.

Surface-Water System

The surface-water system in Subarea 5 includes the Tallapoosa River and its tributaries. The drainage area of the Tallapoosa River basin encompasses about 4,041 mi^2 in Alabama and about 634 mi^2 in Georgia (U.S. Army Corps of Engineers, 1985a,b). The major tributaries to the Tallapoosa River include the Little Tallapoosa River, Hillabee Creek, and Uphapee Creek. In Georgia, the Tallapoosa River and its tributary, the Little Tallapoosa River, form separate basins of almost equal drainage area (314 and 320 mi^2, respectively). Downstream, the Little Tallapoosa River flows into the Tallapoosa River near Wedowee, Ala. The Tallapoosa River joins the Alabama River near Montgomery, Ala., in Subarea 8.

For this report, the mean-annual stream discharge of a surface-water drainage measured at a gaging station is defined as the arithmetic average of all reported annual discharges for the period of record. Note that, by definition, the stream discharge includes both surface runoff and baseflow.

The continuous-record station closest to the Georgia-Alabama State line on the Tallapoosa River is the Tallapoosa River near Heflin, Ala. (station 02412000; mean-annual stream discharge of 689 ft^3/s); the closest on the Little Tallapoosa is the Little Tallapoosa River near Newell, Ala. (station 02413300; mean-annual stream discharge of 598 ft^3/s) (table 3, fig. 9). However, no continuous-record stations exist on the Tallapoosa and Little Tallapoosa Rivers in Georgia to effectively bracket the mean-annual stream discharge at the Georgia-Alabama State line. A MOVE.1 relation (Hirsch, 1982) was developed to estimate the mean-annual stream discharge at two partial-record stations in Georgia: the Tallapoosa River below Tallapoosa, Ga., (station 02411930) using the Tallapoosa River near Heflin station as an index station and the Little Tallapoosa River below Bowden, Ga., (station 02413210) using the Little Tallapoosa River near Newell, Ala. (fig. 9). The estimated mean-annual stream discharge was 417 ft^3/s at the Tallapoosa River below Tallapoosa, Ga., station and 370 ft^3/s at the Little Tallapoosa River below Bowden, Ga., station. Therefore, the estimated mean-annual stream discharge from Georgia into Alabama is between about 420 and 690 ft^3/s for the Tallapoosa River and between about 370 and 600 ft^3/s for the Little Tallapoosa River.

Table 3. Selected active and discontinued continuous-record stream-gaging stations in the Tallapoosa River basin, Subarea 5

[I, fracture-conduit aquifer in igneous or metamorphic rocks; P, porous-media aquifer in clastic rocks]

Station number	Station name	Drainage area (square miles)	Type of stream	Major aquifer drained	Period of record of unregulated flow	Mean-annual stream discharge (cubic feet per second)
02411800	Little River near Buchanan, Ga.	20.2	tributary	I	1959-1985	[1]34
02412000	Tallapoosa River near Heflin, Ala.	448	regional	I	1952-1993	[2]689
02412500	Tallapoosa River at Ofelia, Ala.	792	do.	I	1939-1951	[3]1,139
02413000	Little Tallapoosa River at Carrollton, Ga.	95.1	tributary	I	1937-1955	[1]131
02413300	Little Tallapoosa River near Newell, Ala.	406	do.	I	1975-1993	[3]598
02413500	Little Tallapoosa River near Wedowee, Ala.	591	do.	I	1939-1952	[2]858
02414500	Tallapoosa River at Wadley, Ala.	1,675	regional	I	1923-1982	[2]2,421
02415000	Hillabee Creek near Hackneyville, Ala.	190	tributary	I	1952-1970; 1985-1993	[4]303
02416000	Tallapoosa River at Sturdivant, Ala.	2,480	regional	I	1900-1926	[4]4,045
02419000	Uphapee Creek near Tuskegee, Ala.	333	tributary	P	1939-1970; 1974-1993	[3]428

[1]Stokes and others (1995).
[2]U.S. Geological Survey (1963).
[3]Pearman and others (1994).
[4]U.S. Geological Survey (1960).

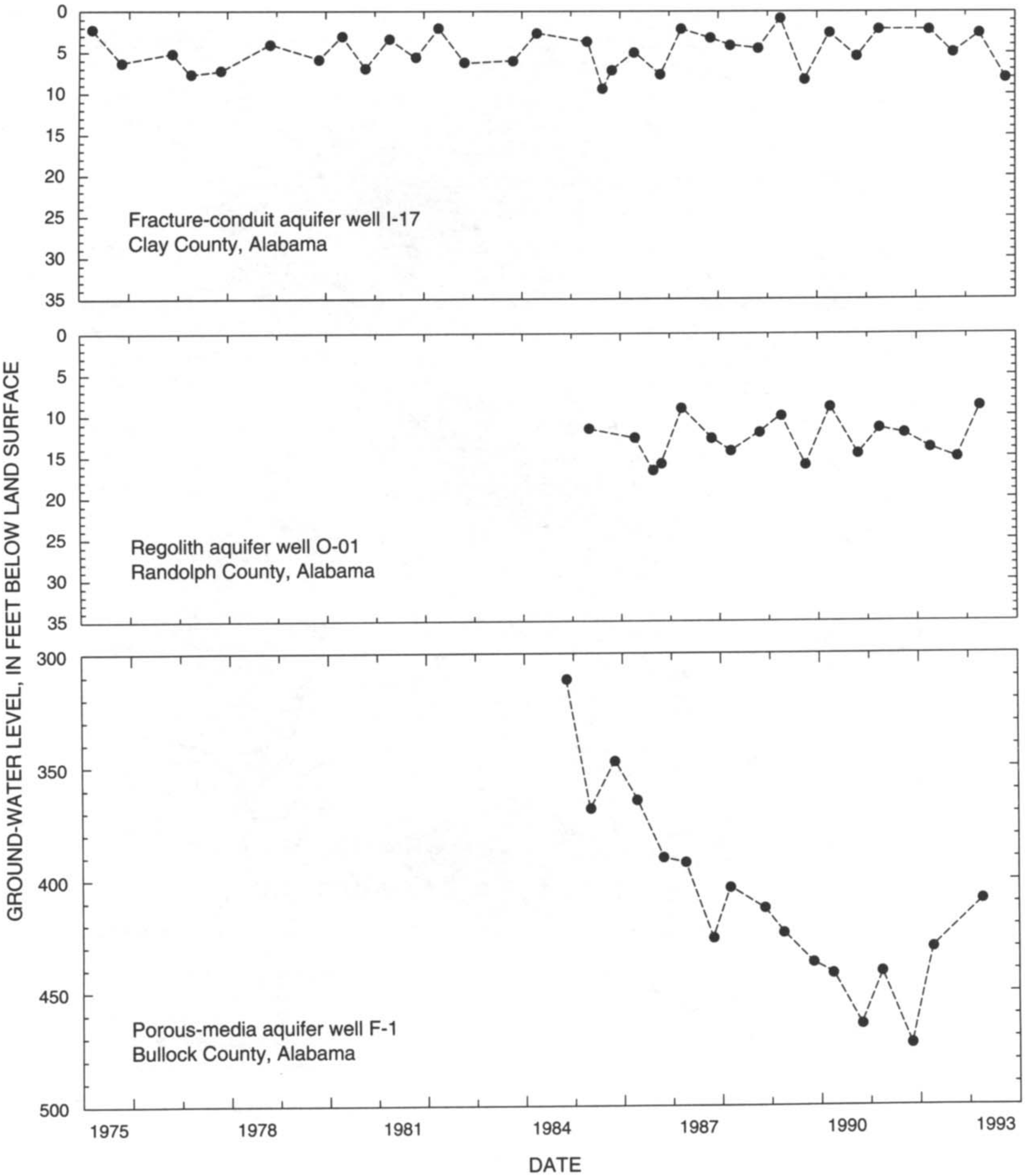


Figure 8. Water-level fluctuations in fracture-conduit aquifer well I-17, Clay County, Alabama, 1975-93; in regolith aquifer well O-01, Randolph County, Alabama, 1985-93; and in porous-media aquifer well F-1, Bullock County, Alabama, 1984-93. Locations of wells shown in figure 9.

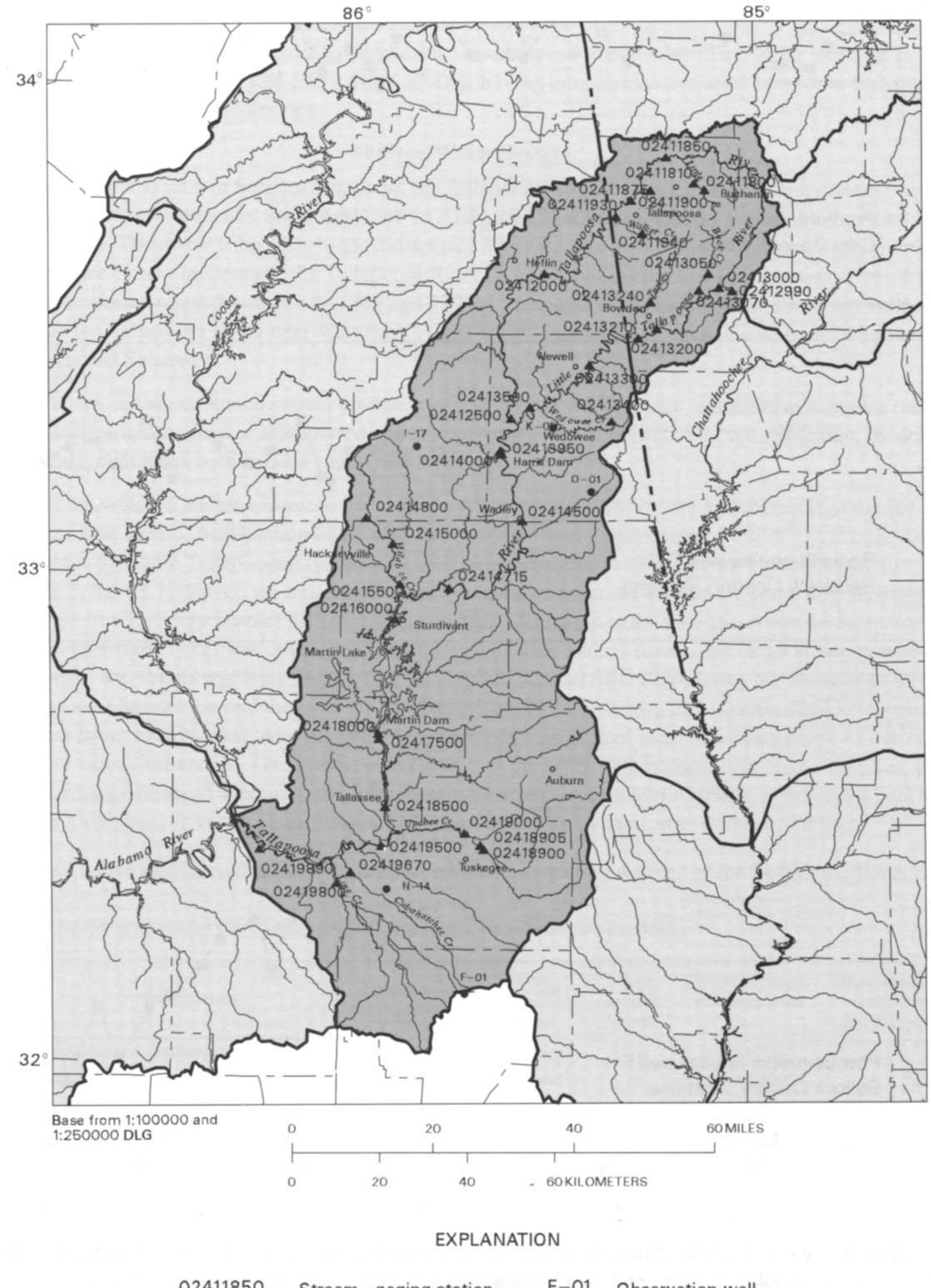


Figure 9. Selected stream-gaging stations and observation wells F-01, N-14, O-01, I-17, and K-05, Subarea 5.

The most downstream continuous-record gaging stations with stream discharge that is unregulated by releases from impoundments is the Tallapoosa River at Studivant (station 0241600) (table 3; fig. 9). The mean-annual stream discharge at the mouth of the Tallapoosa River was estimated by use of unit-area discharges 12.8 miles upstream at the Tallapoosa River near Montgomery (station 02419890) (fig. 9). The unit-area discharges were based on a MOVE.1 relation using three years of concurrent stream discharge data between the Tallapoosa River near Montgomery and the Tallapoosa River below Tallasee (station 02418500), which served as an index station. Monthly mean stream discharges were utilized for selected reaches of the Tallapoosa River to account for the short-term variations caused by upstream regulation. Therefore, the estimated mean-annual stream discharge of the Tallapoosa River to the Alabama River (into Subarea 8) is about 5,100 ft^3/s.

Streamflow characteristics of the tributaries of the Tallapoosa River in Subarea 5 vary with geology. Seven-day two-year low flows (7Q2) in tributaries draining terranes underlain by igneous and metamorphic rocks in both Georgia and Alabama range from about 0.16 to 0.28 cubic foot per second per square mile ($ft^3/s/mi^2$). The range of estimated 7Q2 flow for tributaries draining clastic sediments is about 0.04 to 0.08 $ft^3/s/mi^2$. The largest drainage system in Subarea 5 is the Tallapoosa River, which integrates and is influenced by the streamflow characteristics of its tributaries. Estimated 7Q2 flow for the Tallapoosa River ranges from about 0.21 to 0.27 $ft^3/s/mi^2$.

The Tallapoosa River basin contains two major and two minor impoundments in the Piedmont Province in Alabama (fig. 9; table 4). The impoundments mainly are used for power generation, flood control, and recreation. Total reservoir storage of the major impoundments is 2,047,700 acre-feet.

Table 4. Major impoundments in the Tallapoosa River basin, Subarea 5

Impoundment structure	Station number	Location	Installation date	Major uses	[1/]Total storage capacity (acre-feet)
Harris Dam	02413950	Wedowee, Ala.	1982	power generation, flood control, recreation	425,700
Martin Dam	02417500	Tallassee, Ala.	1926	power generation, flood control, recreation	1,622,000

[1/]Pearman and others (1994).

GROUND-WATER DISCHARGE TO STREAMS

Streamflow is comprised of two major components—a typical hydrograph integrates these components as:

- overland or surface runoff, represented by peaks, indicating rapid response to precipitation; and
- baseflow, represented by the slope of the streamflow recession, indicating ground-water discharge to the stream.

In relation to the conceptual model, baseflow in streams is comprised of contributions from the local, intermediate, or regional ground-water flow regimes. Estimates of recharge to the ground-water system are minimum estimates because the budgets were developed as ground-water discharge to streams, and do not include ground water discharged as evapotranspiration, to wells, or ground water that flows downgradient into other aquifers beyond the topographic boundary defining Subarea 5. Local flow regimes likely are the most affected by droughts. Discharge measured in unregulated streams and rivers near the end of a drought should be relatively steady and composed largely of baseflow.

Mean-Annual Baseflow

Mean-annual baseflow was determined by estimating mean-annual ground-water discharge to the Tallapoosa River and its major tributaries. Streamflow data used to determine mean-annual ground-water discharge at continuous-record gaging stations were selected according to periods of record when flow was unregulated. The hydrograph-separation program SWGW (Mayer and Jones, 1996) was applied to estimate mean-annual baseflow at eight continuous-record gaging stations in the Tallapoosa River basin (table 5), including three stations in Alabama on the Tallapoosa River. For each gaging station, two recession indices are listed in table 5; one represents the rate of streamflow recession during the major rise period, generally in winter; and the other during the major recession period, generally in summer. Some variables that are supplied by the user to SWGW for each hydrograph separation are not listed in table 5, but can be obtained from the U.S. Geological Survey, Alabama District Office, Montgomery, Ala. These variables include the time-base (in days) from the peak to the cessation of surface runoff, the time period (the beginning and ending months) for application of the summer recession index, and the adjustment factor for the displacement of the recession curve. See Rutledge (1993) for a discussion of time-base, and Mayer and Jones (1996) for a discussion of the other user-supplied variables.

The mean-annual baseflow, in cubic feet per second; and the related unit-area baseflow, in cubic feet per second per square mile, were computed for each station. Mean unit-area baseflow estimated for seven stations representing discharge from igneous and metamorphic rocks was 0.902 $ft^3/s/mi^2$. Unit-area baseflow estimated at one continuous-record gaging station in unconsolidated clastic sediments of the Coastal Plain Province of Subarea 5 was 0.429 $ft^3/s/mi^2$.

Mean-annual baseflow in the Tallapoosa River and tributaries at the Georgia-Alabama State line was estimated using representative unit-area mean-annual baseflow derived from the hydrograph-separation analyses to estimate discharge from ungaged drainages. An estimate of the mean-annual baseflow near the headwaters of the Tallapoosa River in Georgia was computed by applying the unit-area stream discharge at Little River near Buchanan, Ga. (02411800), to the areas of Mud and McClendon Creeks drained at their confluence with the Tallapoosa River.

Because streamflow in the Tallapoosa River below Sturdivant, Ala. (02416000) was affected by regulated discharges from impoundments for all or most of the periods of record, two methods were applied to streamflow data to extrapolate the mean ground-water discharge from the Tallapoosa River at Sturdivant to the Subarea 5-Subarea 8 boundary at the mouth of the Tallapoosa River: (1) application of representative unit-area baseflows derived from hydrograph-separation analyses; and (2) a net-gain analysis between surface-water stations.

Because the contribution by the fractured-rock and regolith aquifers of the Piedmont Province ended approximately at the Tallapoosa River station below Tallassee, Ala. (02418500), the unit-area mean-annual baseflow computed for Tallapoosa River at Sturdivant (1.02 $ft^3/s/mi^2$) was used to extrapolate the mean-annual baseflow to the Tallassee station (table 6). The mean-annual baseflow contribution for the intervening drainage between the Tallapoosa River below Tallassee and the Tallapoosa River at Milstead, Ala., was estimated using the computed unit-area baseflow of Uphapee Creek near Tuskegee, Ala. (02419000) (0.429 $ft^3/s/mi^2$). An analysis of net gains was made using 3 years of concurrent discharge record between Tallapoosa River at Milstead and Tallapoosa River near Montgomery, Ala. (02419890). The net gains were calculated for discrete periods that reflected relatively steady-state baseflow conditions. The average of the calculated net gains (179 ft^3/s) was assumed to represent the mean baseflow for that reach. The unit-area baseflow (0.205 $ft^3/s/mi^2$) was estimated from the intervening drainage area between the selected stations and the average of the calculated net gains. The unit-area stream discharge estimated from the net-gain analysis was used to extrapolate the mean-annual baseflow to the mouth of the Tallapoosa River.

The mean-annual baseflow in the Tallapoosa River and its tributary, the Little Tallapoosa River is estimated to be 268 ft^3/s and 266 ft^3/s, respectively, producing a total mean-annual baseflow of 534 ft^3/s at the Georgia-Alabama State line (table 6). The estimated cumulative contribution of mean-annual baseflow at the mouth of the Tallapoosa River entering the Alabama River (at the boundary with Subarea 8) is 3,780 ft^3/s (table 6). The difference of 3,246 ft^3/s (reported herein as 3,250 ft^3/s) is the estimated mean-annual baseflow in the Tallapoosa River basin in Alabama. Mean-annual baseflow and drainage area at selected sites on the Tallapoosa and Little Tallapoosa Rivers are shown in figures 10 and 11, respectively, and summarized in table 6.

Table 5. Mean-annual stream discharge, estimated annual and mean-annual baseflow, and unit-area mean-annual baseflow at selected gaged streams in the Tallapoosa River basin, Subarea 5

[I, fracture-conduit aquifer in igneous and metamorphic rocks; P, porous-media aquifer in clastic rocks]

Station number	Station name	Type of stream	Drainage area (square miles)	Major aquifer type	Recession index		Water year	Flow conditions	Annual stream discharge[1/] (cubic feet per second)	Annual baseflow[2/,3/] (cubic feet per second)	Mean-annual baseflow[3/,4/] (cubic feet per second)	Unit-area mean-annual baseflow[3/,5/] (cubic feet per second per square mile)
					Winter (days)	Summer (days)						
02411800	Little River near Buchanan, Ga.	tributary	20.2	I	95	49	1981	Low	22.8	5.9		
							1965	Average	35.3	19.7	18.3	0.906
							1973	High	46.9	29.3		
02412000	Tallapoosa River near Heflin, Ala.	regional	448	I	107	62	1986	Low	293	240		
							1969	Average	696	370	383	.855
							1990	High	1,040	540		
02413000	Little Tallapoosa River near Carrollton, Ga.	tributary	95.1	I	95	51	1941	Low	85.3	47.5		
							1944	Average	130.0	67	73.5	.773
							1949	High	236.0	106		
02413300	Little Tallapoosa River near Newell, Ala.	do.	406	I	87	60	1986	Low	277	163		
							1992	Average	569	380	337	.830
							1983	High	780	468		
02413500	Little Tallapoosa River near Wedowee, Ala.	do.	591	I	93	57	1941	Low	484	301		
							1947	Average	825	529	528	.893
							1946	High	1,211	754		
02414500	Tallapoosa River at Wadley, Ala.	regional	1,675	I	97	60	1981	Low	1,637	953		
							1978	Average	2,573	1,530	1,750	1.04
							1973	High	4,075	2,760		
02416000	Tallapoosa River at Sturdivant, Ala.	do.	2,480	I	81	38	1914	Low	1,999	1,370		
							1913	Average	3,963	2,670	2,520	1.02
							1912	High	5,879	3,530		
02419000	Uphapee Creek near Tuskegee, Ala.	tributary	333	P	55	35	1951	Low	125	62.3		
							1943	Average	599	164	143	.429
							1948	High	616	203		

[1/]From annually published U.S. Geological Survey data reports, for example: Pearman and others (1994) or Stokes and McFarlane (1994).

[2/]Estimated using the SWGW computer program (Mayer and Jones, 1996).

[3/]Values are reported to three significant digits to maintain the numerical balance of the water budget; implication of accuracy to the degree shown is not intended.

[4/]Estimated by averaging discharges for low, average, and high flow years for the period of unregulated flow.

[5/]Discharge divided by drainage area.

Table 6. Estimated mean-annual baseflow at selected gaged streams, estimation sites, the Georgia-Alabama State line, and exiting Subarea 5

[—, not applicable]

Station number or estimation site	Station name	Drainage area (square miles)	Mean-annual stream discharge (cubic feet per second)	Mean-annual baseflow[1/] (cubic feet per second)	Unit-area mean-annual baseflow[1/] (cubic feet per second per square mile)
02411800	Little River near Buchanan, Ga.	20.2	[2/]34	[3/]18.3	0.906
02411930	Tallapoosa River below Tallapoosa, Ga.	272	[4/]417	—	—
Estimation site	Tallapoosa River at Georgia-Alabama State line	314	—	[5/]268	—
02412000	Tallapoosa River near Heflin, Ala.	448	[2/]689	[3/]383	.855
02413000	Little Tallapoosa River near Carrollton, Ga.	95.1	[2/]131	[3/]73.5	.773
02413210	Little Tallapoosa River below Bowden, Ga.	245	[4/]370	—	—
Estimation site	Little Tallapoosa River at Georgia-Alabama State line	320	—	[5/]266	—
Drainage area and mean-annual baseflow, Tallapoosa River basin at Georgia-Alabama State line		**634**	—	[6/]**534**	—
02413300	Little Tallapoosa River near Newell, Ala.	406	[2/]598	[5/]337	.830
02413500	Little Tallapoosa River near Wedowee, Ala.	591	[2/]858	[3/]528	.893
02414500	Tallapoosa River at Wadley, Ala.	1,675	[2/]2,421	[3/]1,750	1.04
02416000	Tallapoosa River at Sturdivant, Ala.	2,480	[2/]4,045	[3/]2,520	1.02
02418500	Tallapoosa River below Tallassee, Ala.	[7/]3,328	—	[8/]3,390	—
02419000	Uphapee Creek near Tuskegee, Ala.	333	[2/]428	[3/]143	.429
02419500	Tallapoosa River at Milstead, Ala.	3,770	—	[9/]3,580	—
02419890	Tallapoosa River near Montgomery, Ala.	4,646	[4/]5,070	[10/]3,760	.809
Drainage area and estimated stream discharge and mean-annual baseflow, Tallapoosa River basin		**4,675**	[11/]**5,100**	[11/]**3,780**	—

[1/]Values are reported to three significant digits to maintain the numerical balance of the water budget; implication of accuracy to the degree shown is not intended.

[2/]From table 3.

[3/]From table 5.

[4/]Estimate based on Maintenance-of-Variance-Extension technique.

[5/]Estimate based on the unit-area discharge of downstream station.

[6/]Sum of measured and estimated mean-annual baseflow.

[7/]Drainage area approximately represents the total drainage in the Tallapoosa River basin underlain by the Piedmont Province.

[8/]Estimate based on unit-area discharge at Tallapoosa River at Sturdivant, Ala. (02416000).

9/Estimate based on unit-area discharge at Uphapee Creek near Tuskegee, Ala. (02419000) applied to the intervening drainage area between Tallapoosa River below Tallassee and Tallapoosa River at Milstead.

10/Estimate based on unit-area discharge computed using net discharge gain of 180 ft^3/s and intervening drainage area between the Tallapoosa River at Milstead and the Tallapoosa River near Montgomery, Ala.

11/Estimate based on unit-area discharge at Tallapoosa River near Montgomery, Ala. (02419890).

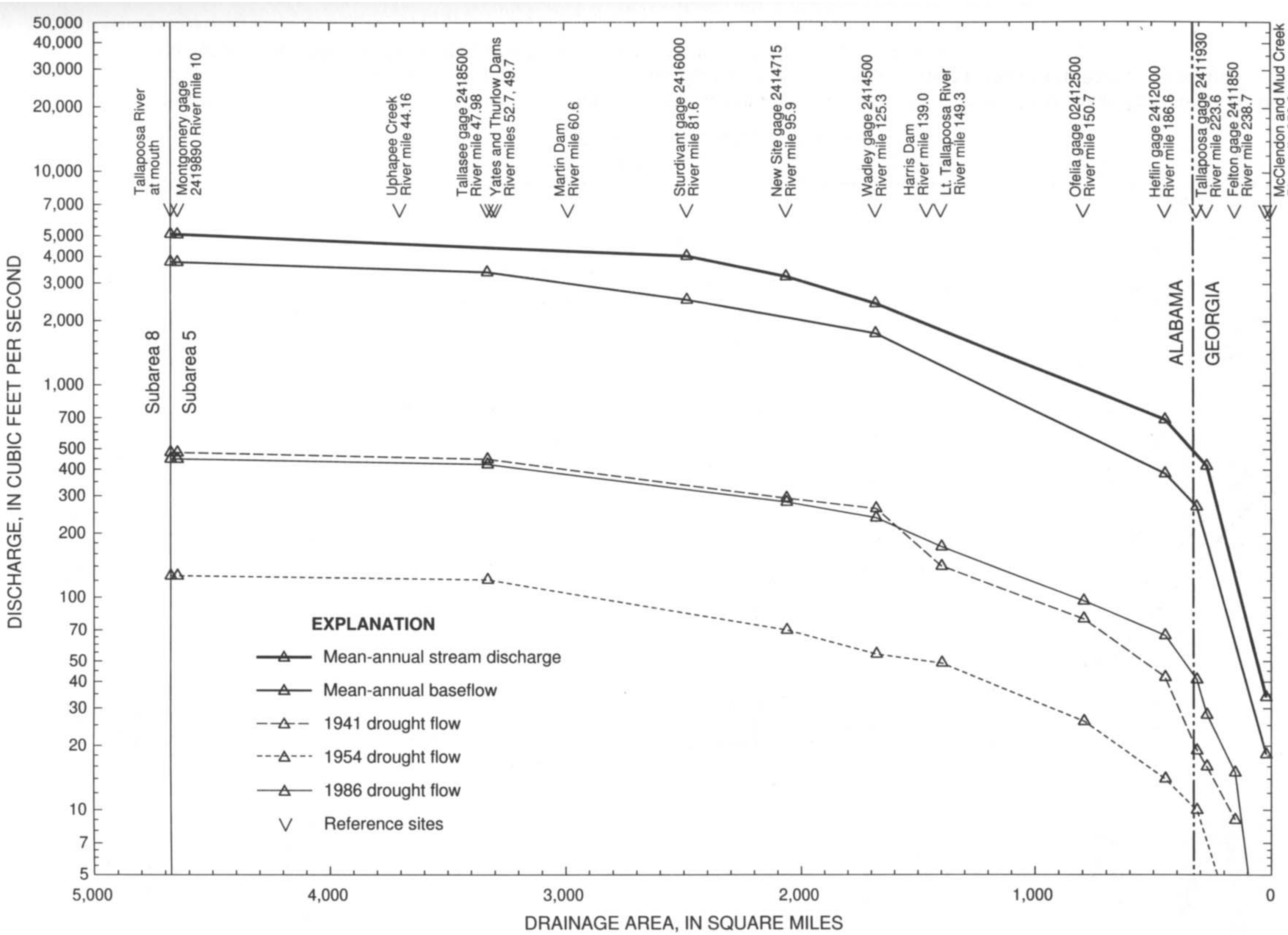


Figure 10. Relations among mean-annual stream discharge, mean-annual baseflow,and drought flow, Tallapoosa River, Subarea 5. [Note: Triangles represent estimated or measured discharges; lines connecting triangles represent interpolated discharge. River mile is measured upstream from the mouth of the Tallapoosa River.]

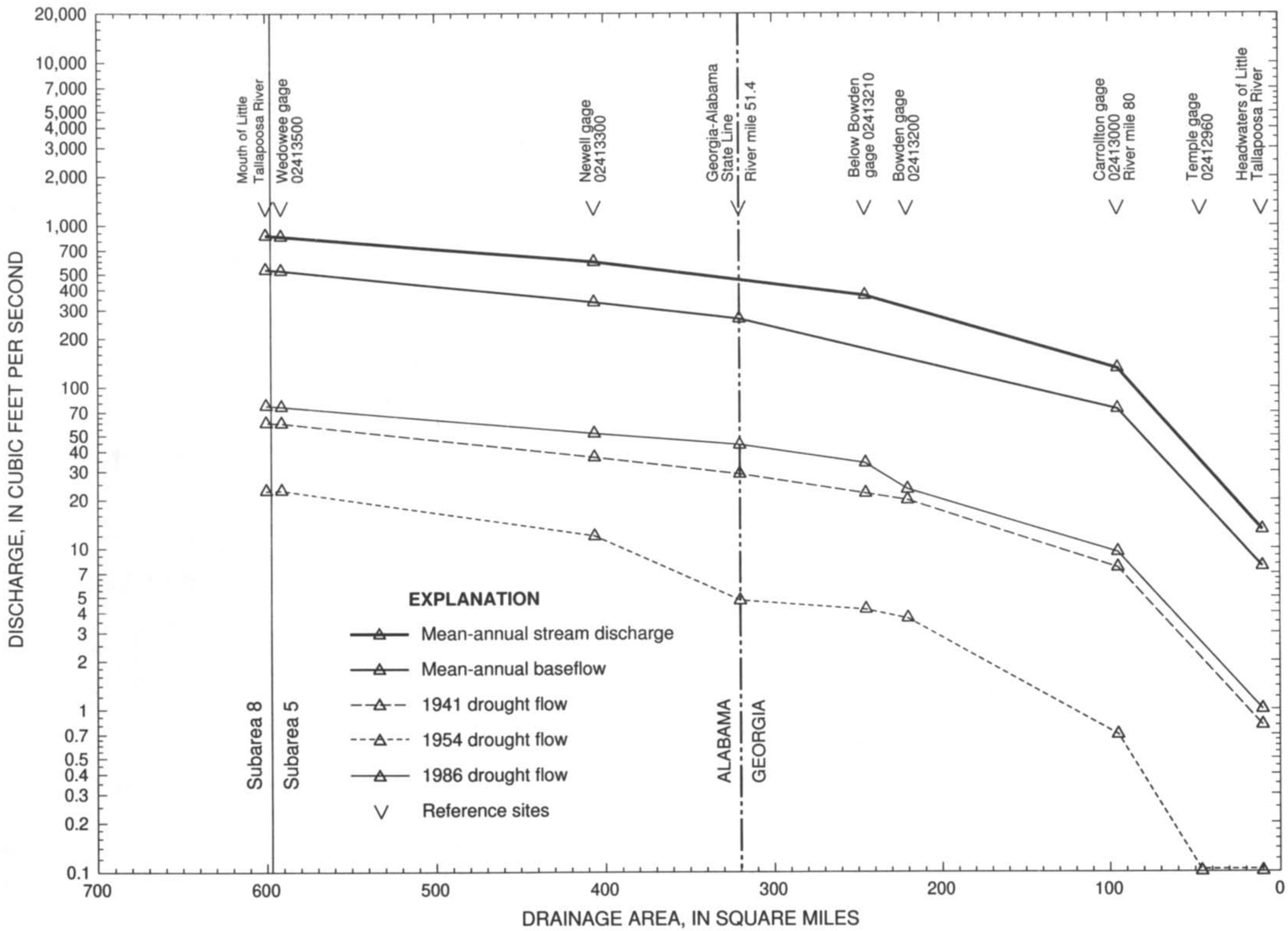


Figure 11. Relations among mean-annual stream discharge, mean-annual baseflow, and drought flow, Little Tallapoosa River, Subarea 5. [Note: Trianges represent estimated or measured discharges; lines connecting triangles represent interpolated discharge. River mile is measured upstream from the mouth of the Little Tallapoosa River.]

Drought Flow for 1941, 1954, and 1986

Regional drought periods of 1938-45, 1950-63, and 1984-88 were marked by severe droughts in the years of 1941, 1954, and 1986 in the ACF and ACT River basins. Typically, the lowest mean-annual streamflow for the period of record occurred during one of these years. Streamflow was assumed to be sustained entirely by baseflow near the end of these droughts. Near-synchronous discharge measurements at partial-record gaging stations or daily mean streamflow at continuous-record gaging stations during these periods were assumed to provide a quantitative estimate of near minimum baseflow across the Georgia-Alabama State line and from Subarea 5 into Subarea 8. Where available, streamflow data for an interval of a few days were compiled; and where not available, streamflow was estimated using various techniques—discussed below.

Estimated and measured streamflow near the end of the 1941, 1954, and 1986 drought years at selected sites on the Tallapoosa River and its tributaries are shown in tables 7, 8, and 9, respectively, and summarized in table 10. Streamflow near the end of the drought of 1954 represented the minimum baseflow of record in the Tallapoosa River in Georgia and Alabama. Estimated streamflow at the Georgia-Alabama State line near the end of the 1941, 1954, and 1986 droughts was 48, 15, and 85 ft^3/s, respectively (tables 7, 8, and 9); streamflow range was 70 ft^3/s and the average streamflow (table 11) was 49 ft^3/s. Estimated streamflows at the mouth of the Tallapoosa River near the end of the 1941, 1954, and 1986 droughts were 481, 126, and 448 ft^3/s, respectively; streamflow range was 355 ft^3/s, and the average streamflow (table 10) was 352 ft^3/s.

Baseflow near the end of these droughts averaged about 9 percent of the estimated mean-annual baseflow to the surface-water system in Georgia; about 9 percent of the estimated mean-annual baseflow in Alabama; and about 9 percent of the estimated mean-annual baseflow at the mouth of the Tallapoosa River (Subarea 5-Subarea 8 boundary). In relation to the conceptual model of ground-water flow and stream-aquifer relations, the mean-annual baseflow estimated for the Tallapoosa River represents ground-water discharge from the local, intermediate, and regional flow regimes. Baseflow during droughts indicates greatly reduced contributions from the local and intermediate flow regimes. Drainage areas, drought flows, and baseflows in the Tallapoosa River basin near the end of the 1941, 1954, and 1986 droughts are plotted in figures 10 and 11, and summarized in tables 10 and 11.

Table 7. Stream discharge during the months of October and November of the drought of 1941, Subarea 5
[—, not applicable]

Station number or estimation site	Station name	Type of stream	Drainage area (square miles)	Date	Stream discharge (cubic feet per second)	Unit-area discharge (cubic feet per second per square mile)
02411850	Tallapoosa River near Felton, Ga.	regional	152	—	[1]9	—
02411900	Tallapoosa River at Tallapoosa, Ga.	do.	236	10/20/41	[2]14	0.059
02411930	Tallapoosa River below Tallapoosa, Ga.	do.	272	—	[1]16	—
Estimation site	Tallapoosa River at the Georgia–Alabama State line		314	—	[1]19	—
02412000	Tallapoosa River near Heflin, Ala.	do.	448	10/20/41	[2]42	.094
02412500	Tallapoosa River at Ofelia, Ala.	do.	792	10/20/41	[3]79	.100
02412990	Curtiss Creek near Carrollton, Ga.	tributary	6.64	10/20/41	[2]1.2	.181
02413000	Little Tallapoosa River near Carrollton, Ga.	do.	95.1	10/20/41	[3]7.6	.080
02413050	Buck Creek near Carrollton, Ga.	do.	21.2	10/20/41	[2]3.7	.175
Estimation site	Buck Creek at mouth	do.	35.1	—	[1]6.1	—
02413200	Little Tallapoosa River near Bowden, Ga.	do.	220	10/20/41	[2]20	.091
02413210	Little Tallapoosa River below Bowden, Ga.	do.	245	—	[1]22	—
Estimation site	Little Tallapoosa River at the Georgia-Alabama State line		320	—	[1]29	—
Cumulative drainage area and stream discharge in the Tallapoosa River and its tributaries at Georgia-Alabama State line			**634**	—	**[4]48**	
02413300	Little Tallapoosa River near Newell, Ala.	tributary	406	10/20/41	[2]37	.091
02413475	Wedowee Creek near Wedowee, Ala.	do.	46.6	10/20/41	[2]5.3	.114
Estimation site	Wedowee Creek at mouth	do.	51.1	—	[1]6	—
02413500	Little Tallapoosa River near Wedowee, Ala.	do.	591	10/20/41	[3]60	.102
Estimation site	Tallapoosa River at the confluence of Little Tallapoosa River	regional	1,395	—	[5]140	.101
02414000	Tallapoosa River near Cragford, Ala.	do.	1,450	10/20/41	[6]186	.128
02414500	Tallapoosa River at Wadley, Ala.	do.	1,675	10/20/41	[3]262	.156
02414520	High Pine Creek near Roanoke, Ala.	tributary	16.4	10/20/41	[7]1.5	.091
02414580	High Pine Creek at Abanda, Ala.	do.	75.6	10/20/41	[2]4.5	.060
Estimation site	High Pine Creek at mouth	do.	78.8	—	[1]4.7	—
02414640	Finley Creek at mouth near Lafayette, Ala.	do.	11.6	10/20/41	[2]1.8	.155
02414670	Chattahospee Creek near Lafayette, Ala.	do.	73.0	10/20/41	[2]6.7	.092
Estimation site	Chattahospee Creek at mouth	do.	119	—	[1]11	—
02414715	Tallapoosa River near New Site, Ala.	regional	2,058	10/20/41	[8]294	.143
02415000	Hillabee Creek near Hackneyville, Ala.	tributary	190	10/20/41	[7]27	.142
02415500	Hillabee Creek near Alexander City, Ala.	do.	277	11/10/41	[1]39	—
02418020	Channahatchee Creek near Eclectic, Ala.	tributary	17.0	10/20/41	[2]0	0
Estimation site	Channahatchee Creek at backwater	do.	42.8	—	[9]7	—
02418200	Sougahatchee Creek near Auburn, Ala.	do.	52.9	10/20/41	[7]8.2	.155
02418264	Sougahatchee Creek near Notasulga, Ala.	do.	216	10/20/41	[7]19	.088
02418500	Tallapoosa River below Tallasee, Ala.	regional	3,328	—	[8]448	.134
02418750	Chewacla Creek near Auburn, Ala.	tributary	34.1	10/20/41	[7]1.5	.044
02418800	Chewacla Creek near Society, Ala.	do.	101	10/20/41	[7]6.2	.061
Estimation site	Chewacla Creek at mouth	do.	148	—	[1]9	—
02418900	Uphapee Creek near Pleasant Hill, Ala.	do.	256	10/20/41	[7]8.2	.032
02419000	Uphapee Creek near Tuskegee, Ala.	do.	333	10/20/41	[3]13	.039

Table 7. Stream discharge during the months of October and November of the drought of 1941, Subarea 5—Continued

[—, not applicable]

Station number or estimation site	Station name	Type of stream	Drainage area (square miles)	Date	Stream discharge (cubic feet per second)	Unit-area discharge (cubic feet per second per square mile)
Estimation site	Uphapee Creek at mouth	do.	420	—	[1]16	—
02419560	Tumkehatchee Creek near Tallasee, Ala.	do.	30.8	10/20/41	[2].3	.010
Estimation site	Tumkehatchee Creek at mouth	do.	34.5	—	[1].3	—
02419625	Calabee Creek near Tuskegee, Ala.	do.	124	10/20/41	[7].1	.001
Estimation site	Calabee Creek at mouth	do.	154	—	[1].1	—
02419670	Cubahatchee Creek near Shorter, Ala.	do.	122	10/20/41	[10]2.4	.020
Estimation site	Cubahatchee Creek at mouth	do.	134	—	[1]2.6	—
02419800	Line Creek near Shorter, Ala.	do.	308	10/20/41	[10].86	.003
Estimation site	Line Creek at mouth	do.	317	—	[1]1	—
02419890	Tallapoosa River near Montgomery, Ala.	regional	4,646	—	[8]480	.103
Cumulative drainage area and estimated stream discharge at the mouth of the Tallapoosa River in Subarea 5			**4,675**	—	[11]**481**	—

[1]Estimate based on unit-area discharge at upstream station(s).
[2]Estimated discharge from graphical correlation with continuous record station on the same reach.
[3]Daily mean discharge.
[4]Sum of all measured and estimated ground-water discharge to the Tallapoosa River and its tributaries in Georgia.
[5]Estimate based on average unit-area discharges of the Tallapoosa River at Ofelia, Ala., and the Little Tallapoosa River near Wedowee, Ala.
[6]Estimate based on average unit-area discharges of the Tallapoosa River at the confluence of Little Tallapoosa River and the Tallapoosa River at Wadley, Ala.
[7]Estimated discharge from Maintenance-Of-Variance-Extension technique.
[8]Estimate based on unit-area discharge computed using the sum of tributary discharges and respective drainage areas intermediate to this station and the nearest upstream Tallapoosa River station.
[9]Estimate based on unit-area discharge of Sougahatchee Creek near Auburn, Ala., (02418200).
[10]Discharge measurement.
[11]Estimate based on unit-area discharge computed using the sum of tributary discharges and respective drainage areas intermediate to the Tallapoosa River below Tallassee, Ala., and Tallapoosa River near Montgomery, Ala., stations.

Table 8. Stream discharge during the months of September and October of the drought of 1954, Subarea 5
[—, not applicable]

Station number or estimation site	Station name	Type of stream	Drainage area (square miles)	Date	Stream discharge (cubic feet per second)	Unit-area discharge (cubic feet per second per square mile)
02411800	Little River near Buchanan, Ga.	tributary	20.2	09/18/54	[1]0.9	0.045
02411810	Little River at State Route 120 near Buchanan, Ga.	do.	26.8	09/18/54	[2]1.4	.052
Estimation site	Little River at mouth	do.	36.5	—	[3]1.9	—
02411850	Tallapoosa River near Felton, Ga.	regional	152	09/18/54	[2]0	0
02411890	Beach Creek near Buchanan, Ga.	tributary	27	10/01/54	[2]2.5	.093
Estimation site	Beach Creek at mouth	do.	36.9	—	[3]3.4	—
02411940	Walker Creek near Tallapoosa, Ga.	do.	18.8	10/01/54	[2]2.1	.112
Estimation site	Walker Creek at mouth	do.	35.9	—	[3]4	—
Estimation site	Tallapoosa River at the Georgia-Alabama State line	regional	314	—	[3]10	—
02412000	Tallapoosa River near Heflin, Ala.	regional	448	10/01/54	[4]14	.031
02412050	Cane Creek near Heflin, Ala.	tributary	52.8	10/01/54	[5]1.5	.028
Estimation site	Cane Creek at mouth	do.	62.7	—	[3]1.8	—
02412290	Chulafinee Creek at Hollis, Ala.	do.	24.0	10/01/54	[5].7	.029
Estimation site	Chulafinee Creek at mouth	do.	27.7	—	[3].8	—
02412400	Ketchepedrakee Creek near Delta, Ala.	do.	37.0	09/18/54	[5].2	.005
Estimation site	Ketchepedrakee Creek at mouth	do.	54.2	—	[3].3	—
02412475	Mad Indian Creek near Barfield, Ala.	do.	20.7	10/01/54	[5]2.1	.101
Estimation site	Mad Indian Creek at mouth	do.	31.0	—	[3]3.1	—
02412500	Tallapoosa River at Ofelia, Ala.	regional	792	10/01/54	[2]26	.033
02412930	Holly Creek near Temple, Ga.	tributary	9.6	09/28/54	[2].15	.016
Estimation site	Holly Creek at mouth	do.	11.1	—	[3].2	—
02412960	Little Tallapoosa River near Temple, Ga.	do.	46.0	09/28/54	[2]0	0
02412980	Little Tallapoosa River above Carrollton, Ga.	do.	80.5	—	[3].6	—
02412990	Curtiss Creek near Carrollton, Ga.	do.	6.64	09/23/54	[5].2	.030
02413000	Little Tallapoosa River near Carrollton, Ga.	do.	95.1	10/01/54	[4].7	.007
02413050	Buck Creek near Carrollton, Ga.	do.	21.2	09/23/54	[2].64	.030
Estimation site	Buck Creek at mouth	do.	35.1	—	[3]1	—
02413130	Buffalo Creek at Carrollton, Ga.	do.	4.6	09/23/54	[2].0	0
Estimation site	Buffalo Creek at mouth	do.	27.5	—	[3].8	—
02413180	Indian Creek near Rooperville, Ga.	do.	13.0	09/22/54	[2].26	.020
Estimation site	Indian Creek at mouth	do.	72.7	—	[3]1.5	—
02413200	Little Tallapoosa River near Bowden, Ga,	do.	220	09/22/54	[2]3.7	.017
02413210	Little Tallapoosa River below Bowden, Ga.	do.	245	—	[3]4.2	—
02413240	Turkey Creek near Bowden, Ga.	do.	39.9	09/22/54	[2]0	0
Estimation site	Little Tallapoosa River at the Georgia-Alabama State line	do.	320	—	[3]4.8	—
Cumulative stream discharge in the Tallapoosa River and its tributaries at the Georgia-Alabama State line			**634**	**—**	**[6]15**	
02413300	Little Tallapoosa River near Newell	tributary	406	09/30/54	[5]12	.030
02413400	Wedowee Creek above Wedowee, Ala.	do.	6.87	10/01/54	[1].5	.073
02413475	Wedowee Creek near Wedowee, Ala.	do.	46.6	10/01/54	[5]2.5	.054
Estimation site	Wedowee Creek at mouth	do.	51.1	—	[3]3	—

Table 8. Stream discharge during the months of September and October of the drought of 1954, Subarea 5—Continued

[—, not applicable]

Station number or estimation site	Station name	Type of stream	Drainage area (square miles)	Date	Stream discharge (cubic feet per second)	Unit-area discharge (cubic feet per second per square mile)
02413500	Little Tallapoosa River near Wedowee, Ala.	tributary	591	09/30/54	[2]23	.039
Estimation site	Tallapoosa River at the confluence of Little Tallapoosa River	regional	1,395	—	[7]49	—
02413800	Fox Creek near Lineville, Ala.	tributary	30.4	10/01/54	[5]2.5	.082
Estimation site	Fox Creek at mouth	tributary	37.3	—	[3]3	—
02414000	Tallapoosa River near Cragford, Ala.	regional	1,450	10/01/54	[1]50	.034
02414020	Crooked Creek near Lineville, Ala.	tributary	35.2	10/01/54	[5]1.0	.028
02414030	Crooked Creek at Cragford, Ala.	do.	54.4	10/01/54	[5]7.5	.138
Estimation site	Crooked Creek at mouth	do.	98.4	—	[3]14	—
02414500	Tallapoosa River at Wadley, Ala.	regional	1,675	10/01/54	[4]54	.032
02414522	High Pine Creek near Roanoke, Ala.	tributary	17.2	10/01/54	[1].1	.006
02414580	High Pine Creek at Abanda, Ala.	do.	75.6	10/01/54	[5].3	.004
Estimation site	High Pine Creek at mouth	do.	78.8	—	[3].3	—
02414595	Chikasanoxee Creek at Milltown, Ala.	do.	56.6	10/01/54	[5]2.1	.037
Estimation site	Chikasanoxee Creek at mouth	do.	75.9	—	[3]3	—
02414640	Finley Creek at mouth near Lafayette, Ala.	do.	11.6	10/01/54	[5].3	.026
02414670	Chattahospee Creek near Lafayette, Ala.	do.	73.0	10/01/54	[5]4.0	.055
Estimation site	Chattahospee Creek at mouth	do.	119	—	[3]7	—
02414720	Emuckfaw Creek near Alexander City	do.	65.0	10/01/54	[5]4.5	.069
Estimation site	Emuckfaw Creek at mouth		65.7	—	[3]4.5	—
02414715	Tallapoosa River near New Site, Ala.	regional	2,058	—	[1]70	.034
02415000	Hillabee Creek near Hackneyville, Ala.	tributary	190	10/01/54	[4]12	.063
02415500	Hillabee Creek near Alexander City, Ala.	do.	277	10/01/54	[5]16	.058
02416480	Big Sandy Creek at Dadeville, Ala.	do.	154	10/01/54	[5]4.7	.031
02416500	Big Sandy Creek at Dadeville, Ala.	do.	195	—	[3]6	—
02418020	Channahatchee Creek near Eclectic, Ala.	do.	17.0	10/01/54	[5]0	0
Estimation site	Channahatchee Creek at backwater	do.	42.8	—	[8]2	—
02418179	Sougahatchee near Auburn, Ala.	do.	32.5	10/01/54	[1]2.1	.065
02418200	Sougahatchee Creek near Auburn, Ala.	do.	52.9	10/01/54	[1]2.6	.049
02418260	Sougahatchee Creek near Notasulga, Ala.	do.	167	10/01/54	[2]4.0	.024
02418264	Sougahatchee Creek at backwater	do.	216	—	[3]5	—
02418500	Tallapoosa River below Tallasee, Ala.	regional	3,328	—	[7]121	.036
02418750	Chewacla Creek near Auburn, Ala.	tributary	34.1	10/01/54	[1].2	.006
02418800	Chewacla Creek near Society Hill, Ala.	do.	101	10/01/54	[1]1.4	.014
Estimation site	Chewacla Creek at mouth	do.	148	—	[3]2	—
02418900	Uphapee Creek near Pleasant Hill, Ala.	do.	256	09/29/54	[2].62	.002
02419000	Uphapee Creek near Tuskegee, Ala.	do.	333	10/01/54	[4]2.0	.006
Estimation site	Uphapee Creek at mouth	do.	420	—	[3]2.5	—
02419560	Tumkeehatchee Creek near Tallasee, Ala.	do.	30.8	10/01/54	[5]0	0
Estimation site	Tumkeehatchee Creek at mouth	do.	34.5	—	[3]0	—
02419625	Calebee Creek near Tuskegee, Ala.	do.	124	10/01/54	[1]0	0
Estimation site	Calebee Creek at mouth	do.	154	—	[3]0	—

Table 8. Stream discharge during the months of September and October of the drought of 1954, Subarea 5—Continued
[—, not applicable]

Station number or estimation site	Station name	Type of stream	Drainage area (square miles)	Date	Stream discharge (cubic feet per second)	Unit-area discharge (cubic feet per second per square mile)
02419670	Cubahatchee Creek near Shorter, Ala.	do.	122	10/01/54	[1]0.3	.002
Estimation site	Cubahatchee Creek at mouth	do.	134	—	[3].3	—
02419800	Line Creek near Shorter, Ala.	do.	308	10/01/54	[1].1	.0003
Estimation site	Line Creek at mouth	do.	317	—	[3].1	—
02419840	Chubbehatchee Creek at mouth near Ware, Ala.	do.	66.9	10/01/54	[5].5	.007
02419890	Tallapoosa River near Montgomery, Ala.	regional	4,646	—	[7]126	.027
Cumulative drainage area and estimated stream discharge at the mouth of the Tallapoosa River in Subarea 5			**4,675**	**—**	**[9]126**	**—**

[1]Estimated discharge from Maintenance-of-Variance-Extension technique.
[2]Discharge measurement.
[3]Estimate based on unit-area discharge of station(s) on the same reach.
[4]Daily mean discharge.
[5]Estimated discharge from graphical correlation with continuous record station on the same reach.
[6]Sum of all measured and estimated ground-water discharge to the Tallapoosa River and its tributaries in Georgia.
[7]Estimate based on unit-area discharge computed using the sum of tributary discharges and respective drainage areas intermediate to this station and the nearest upstream Tallapoosa River station.
[8]Estimate based on unit-area discharge on Sougahatchee Creek near Auburn, Ala. (02418200).
[9]Estimate based on unit-area discharge computed using the sum of tributary discharges and respective drainage areas intermediate to the Tallapoosa River below Tallahassee, Ala., and Tallapoosa River near Montgomery, Ala., stations.

Table 9. Stream discharge during the month of July of the drought of 1986, Subarea 5
[—, not applicable]

Station number or estimation site	Station name	Type of stream	Drainage area (square miles)	Date	Stream discharge (cubic feet per second)	Unit-area discharge (cubic feet per second per square mile)
02411800	Little River near Buchanan, Ga.	tributary	20.2	07/09/86	1/1.1	0.054
Estimation site	Little River at mouth	tributary	36.5	—	2/2	—
02411850	Tallapoosa River near Felton, Ga.	regional	152	07/09/86	1/15	.099
02411875	Tallapoosa near Tallapoosa, Ga.	do.	191	07/16/86	1/22.0	.115
02411930	Tallapoosa River below Tallapoosa, Ga.	do.	272	07/16/86	1/28	.103
02411940	Walker Creek near Tallapoosa, Ga.	tributary	18.8	07/08/86	1/5.7	.303
Estimation site	Walker Creek at mouth	tributary	35.9	—	2/11	—
Estimation site	Tallapoosa River at the Georgia-Alabama State line	regional	314	—	3/41	—
02412000	Tallapoosa River near Heflin, Ala.	regional	448	07/09/86	4/66	.147
02412050	Cane Creek near Heflin, Ala.	tributary	52.8	07/08/86	5/7.0	.133
Estimation site	Cane Creek at mouth	do.	62.7	—	2/8.3	—
02412290	Chulafinee Creek at Hollis, Ala.	do.	24	07/08/86	5/1.8	.075
Estimation site	Chulafinee Creek at mouth	do.	27.7	—	2/2.1	—
02412400	Ketchepedrakee near Delta, Ala.	do.	37.0	07/08/86	5/.7	.019
Estimation site	Ketchepedrakee Creek at mouth	do.	54.2	—	2/1	—
02412475	Mad Indian Creek near Barfield, Ala.	do.	27.0	07/08/86	5/3.3	.122
Estimation site	Mad Indian Creek at mouth	do.	31.0	—	2/3.8	—
02412500	Tallapoosa River at Ofelia, Ala.	regional	792	—	2/96	.121
02413070	Buck Creek near Carrollton, Ga.	tributary	31.4	07/08/86	1/4.4	.140
Estimation site	Buck Creek at mouth	do.	35.1	—	2/5	—
02413200	Little Tallapoosa River near Bowden, Ga.	do.	220	07/08/86	1/23	.105
02413210	Little Tallapoosa River below Bowden, Ga.	do.	245	07/08/86	1/34	.139
Estimation site	Little Tallapoosa River at the Georgia-Alabama State line	do.	320	—	2/44	—
Cumulative drainage area and stream discharge in the Tallapoosa River and its tributaries at the Georgia-Alabama State Line			**634**	—	**6/85**	—
02413300	Little Tallapoosa River near Newell, Ala.	tributary	406	07/08/86	4/52	.128
02413400	Wedowee Creek above Wedowee, Ala.	do.	6.87	07/08/86	7/1.0	.146
02413475	Wedowee Creek near Wedowee, Ala.	do.	46.6	07/08/86	5/5.6	.120
Estimation site	Wedowee Creek at mouth	do.	51.1	—	2/6.1	—
02413500	Little Tallapoosa River near Wedowee, Ala.	do.	591	—	2/76	.128
Estimation site	Tallapoosa River at confluence with Little Tallapoosa River	regional	1,395	—	3/173	—
02413800	Fox Creek near Lineville, Ala.	tributary	30.4	07/08/86	5/5.6	.184
Estimation site	Fox Creek at mouth	do.	37.3	—	2/7	—
02414020	Crooked Creek near Lineville, Ala.	do.	35.2	07/08/86	5/3.4	.097
02414030	Crooked Creek at Cragford, Ala.	do.	54.4	07/08/86	5/13	.239
Estimation site	Crooked Creek at mouth	do.	98.4	—	2/24	—
02414500	Tallapoosa River at Wadley, Ala.	regional	1,675	—	3/237	.141
02414522	High Pine Creek near Roanoke, Ala.	tributary	17.2	07/08/86	5/.8	.047
02414580	High Pine Creek at Abanda, Ala.	do.	75.6	07/08/86	3/5.5	.073
Estimation site	High Pine Creek at mouth	do.	78.8	—	2/6	—
02414595	Chikasanoxee Creek at Milltown, Ala	tributary	56.6	07/08/86	5/5.6	.099
Estimation site	Chikasanoxee Creek at mouth	do.	75.9	—	2/7.5	—
02414670	Chattahospee Creek near Lafayette, Ala.	do.	73.0	07/08/86	5/10	.137

Table 9. Stream discharge during the month of July of the drought of 1986, Subarea 5—Continued
[—, not applicable]

Station number or estimation site	Station name	Type of stream	Drainage area (square mile s)	Date	Stream discharge (cubic feet per second)	Unit-area discharge (cubic feet per second per square mile)
Estimation site	Chattahospee Creek at mouth	do.	119	—	[2]16	—
02414720	Emuckfaw Creek near Alexander City, Ala.	do.	65.0	07/08/86	[5]10	.154
Estimation site	Emuckfaw Creek at mouth	do.	65.7	—	[2]10	—
02414715	Tallapoosa River near New Site, Ala.	regional	2,058	—	[3]281	.137
02415000	Hillabee Creek at county road near Hackneyville, Ala.	tributary	190	07/08/86	[4]30	.158
02415500	Hillabee Creek near Alexander City, Ala.	do.	277	—	[2]44	—
02416480	Sandy Creek near Dadeville, Ala.	do.	154	07/08/86	[5]12	.078
02416500	Big Sandy Creek at mouth	do.	195	—	[2]15	—
02418020	Channahatchee Creek near Eclectic, Ala.	do.	17.0	07/08/86	[5]0	0
Estimation site	Channahatchee Creek at backwater	do.	42.8	—	[8]3.6	—
02418179	Sougahatchee Creek near Auburn, Ala.	do.	32.5	07/08/86	[7]5.3	.163
02418200	Sougahatchee Creek near Auburn, Ala.	do.	52.9	07/08/86	[7]7.4	.140
02418260	Sougahatchee Creek near Reeltown, Ala.	do.	194	07/08/86	[7]17	.088
02418264	Sougahatchee Creek at backwater	do.	216	—	[2]19	—
02418500	Tallapoosa River below Tallassee Ala.	regional	3,328	—	[3]423	.127
02418900	Uphapee Creek near Pleasant Hill, Ala.	tributary	256	—	[7]7.1	.028
02419000	Uphapee Creek at Highway 81 near Tuskegee, Ala.	do.	333	07/08/86	[4]11	.033
Estimation site	Uphapee Creek at mouth	do.	420	—	[2]14	—
02419625	Calabee Creek near Tuskegee, Ala.	do.	124	07/08/86	[7].1	.001
Estimation site	Calabee Creek at mouth	do.	154	—	[2].2	—
02419670	Cubahatchee Creek near Shorter, Ala.	do.	122	07/08/86	[7]1.8	.015
Estimation site	Cubahatchee Creek at mouth	do.	134	—	[2]2	—
02419800	Line Creek at near Shorter, Ala.	do.	308	07/08/86	[7]1.0	.003
Estimation site	Line Creek at mouth		317		[2]1	—
Estimation site	Chubbehatchee Creek at mouth near Ware, Ala.	do.	66.9	07/08/86	[5]2.5	.037
02419890	Tallapoosa River near Montgomery, Ala.	regional	4,646	—	[3]447	.096
Cumulative drainage area and stream discharge at the mouth of the Tallapoosa River in Subarea 5			**4,675**	**—**	[9]**448**	**—**

[1]Discharge measurement.
[2]Estimate based on unit-area discharge of station(s) on the same reach.
[3]Estimate based on unit-area discharge computed using the sum of tributary discharges and respective drainage areas intermediate to this station and the nearest upstream Tallapoosa River station.
[4]Daily mean discharge.
[5]Estimated discharge from graphical correlation with continuous record station.
[6]Sum of all measured and estimated ground-water discharge to the Tallapoosa River and its tributaries in Georgia.
[7]Estimated discharge from Maintenance-of-Variance-Extension technique.
[8]Estimate based on unit-area discharge of Sougahatchee Creek near Auburn, Ala. (02418200), as applied to intervening drainage between site 02418020 and this site.
[9]Estimate based on unit-area discharge computed using the sum of tributary discharges and respective drainage areas intermediate to the Tallapoosa River below Tallassee, Ala., and Tallapoosa River near Montgomery, Ala., stations.

Table 10. Relations among mean-annual stream discharge, and estimated mean-annual baseflow and drought flow in the Tallapoosa River and major tributary, Little Tallapoosa River, Subarea 5

[Mean-annual stream discharge is mean for the period of record; —, no available data]

Station number or estimation site	Station name	Drainage area (square miles)	Stream discharge (cubic feet per second)				
			Mean-annual stream discharge[1/]	Mean-annual baseflow[1/]	Drought[2/] of 1941	Drought[3/] of 1954	Drought[4/] of 1986
02411800	Little River near Buchanan, Ga.	20.2	34	18.3	—	0.9	1.1
02411850	Tallapoosa River near Felton, Ga.	152	—	—	9	0	15
02411930	Tallapoosa River below Tallapoosa, Ga.	272	417	—	16	—	28
Estimation site	Tallapoosa River at Georgia-Alabama State line	314	—	268	19	10	41
02412000	Tallapoosa River near Heflin, Ala.	448	689	383	42	14	66
02412500	Tallapoosa River at Ofelia, Ala.	792	—	—	79	26	96
02413000	Little Tallapoosa River near Carrollton, Ga.	95.1	131	73.5	7.6	.7	—
02413210	Little Tallapoosa River below Bowden, Ga.	245	370	—	22	4.2	34
Estimation site	Little Tallapoosa River at Georgia-Alabama State line	320	—	266	29	4.8	44
Cumulative stream discharge and baseflow in the Tallapoosa River and tributaries at Georgia-Alabama State line		**634**	**—**	**534**	**48**	**15**	**85**
02413300	Little Tallapoosa River near Newell, Ala.	406	598	337	37	12	52
02413500	Little Tallapoosa River near Wedowee, Ala.	591	858	528	60	23	76
02414500	Tallapoosa River at Wadley, Ala.	1,675	2,421	1,750	262	49	237
02416000	Tallapoosa River at Sturdivant, Ala.	2,480	4,045	2,520	—	—	—
02418500	Tallapoosa River below Tallassee, Ala.	3,328	—	3,390	448	121	423
02419000	Uphapee Creek near Tuskegee, Ala.	333	428	143	13	2	11
02419500	Tallapoosa River at Milstead, Ala.	3,770	—	3,580	—	—	—
02419890	Tallapoosa River near Montgomery, Ala.	4,646	5,070	3,760	480	126	447
Cumulative drainage area and estimated stream discharge and baseflow at the mouth of the Tallapoosa River in Subarea 5		**4,675**	**5,100**	**3,780**	**481**	**126**	**448**

[1/]From tables 5 and 6.
[2/]From table 7.
[3/]From table 8.
[4/]From table 9.

Table 11. Estimated drought flows and mean-annual baseflow in the Tallapoosa River basin; and ratio of average drought flow to mean-annual baseflow, Subarea 5

State	Drought flows (cubic feet per second)				Mean-annual baseflow (cubic feet per second)[4/]	Ratio of average drought flow to mean-annual baseflow (percent)
	1941[1/]	1954[2/]	1986[3/]	Average drought flow		
Georgia	48	15	85	49	534	9
Alabama	433	111	363	302	3,250	9
Alabama (exiting Subarea 5)	**481**	**126**	**448**	**352**	**3,780**	**9**

[1/]From table 7.
[2/]From table 8.
[3/]From table 9.
[4/]From tables 6 and 10.

GROUND-WATER UTILIZATION AND GENERAL DEVELOPMENT POTENTIAL

Ground-water utilization is defined as the ratio of ground-water use in 1990 to mean-annual ground-water recharge. The degree of ground-water utilization is scale dependent. For example, local ground-water pumping may result in substantial storage change and water-level declines near a center of pumping; whereas, such pumping relative to the entire Subarea would be small compared to mean-annual recharge. Because ground-water use in Subarea 5 represents a relatively minor percentage of ground-water recharge, even a large increase in ground-water use in Subarea 5 in one State is likely to have little effect on ground-water and surface-water occurrence in the other.

Ground-water use of about 21.5 ft^3/s in 1990 in Subarea 5 was 0.6 percent of the mean-annual baseflow and 6 percent of the average drought flow near the end of the droughts of 1941, 1954, and 1986 (table 12). For the worst-case scenario, in which flow decreased to the minimum during the period of analysis, 1990 ground-water use represented 17 to 21 percent of the minimum drought flows. Local problems of ground-water overuse were not identified. However, the number and distribution of wells having long-term water-level data for wells in Subarea 5 are few in number and poorly distributed areally; and conclusions regarding regional water-level declines or storage change cannot be reasonably drawn.

Table 12. Relation between 1990 ground-water use and ground-water discharge during mean-annual baseflow, average drought flow, and minimum drought flow, Subarea 5

	Ground-water use, 1990 (cubic feet per second)	Baseflow to the Tallapoosa River and tributaries (cubic feet per second)			Ratio of ground-water use to baseflow (percent)		
		Mean-annual baseflow	Average drought baseflow	Minimum drought baseflow	Mean-annual baseflow	Average drought baseflow	Minimum drought baseflow
Georgia	1/3.1	534	49	2/15	0.6	6	21
Alabama	3/18.4	3,250	302	4/111	.6	6	17
Subarea 5	**21.5**	**3,780**	**5/352**	**4/126**	**.6**	**6**	**17**

1/From Fanning and others (1992).
2/Minimum stream discharge during 1954 drought.
3/From Baker and Mooty (1993).
4/Minimum stream discharge during 1941 drought.
5/Average drought flow exiting Subarea 5; 1941, 1954, and 1986.

In general, ground-water resources are underutilized throughout the study area. The rural population relies on ground water as their principal source of water supply; whereas, more densely populated areas rely on surface-water resources. However, wells supplied water to many communities prior to the development of large surface-water reservoirs. In recent years, suburban communities have developed ground-water supplies in response to curtailed surface-water supplies.

A general assessment of ground-water development potential in Subarea 5 would reflect, in part, the cumulative effects of current and anticipated future hydrologic stresses imposed on the ground-water resources, and to a lesser extent, the current availability of surface-water supplies. The nature of such an assessment is necessarily limited by a lack of knowledge of current hydrologic conditions and the lack of agreed upon standards by which Federal, State, or local water-resource managers evaluate the effects of additional stress and future development. Current pumpage and streamflow conditions might be unknown in some areas, making the results of an evaluation of development potential highly uncertain. Future stresses also might be linked to water-management practices that have yet to be formulated, or to water-management decisions that have yet to be made. Therefore, an assessment of ground-water development potential provides insight into only one aspect of the broader question of how water-management decisions affect ground-water availability; specifically, whether existing hydrologic data document flow-system behavior adequately to allow the potential effects of future development on the flow system to be adequately evaluated and understood. Further, an assessment of ground-water development potential does not account for the suitability of existing ground-water resource management approaches or the effects of future approaches on further resource development. Such answers partly are dependent on the synthesis of results from the various Comprehensive Study components and subsequent consideration by the Federal, State, or local water managers responsible for decision-making within the basin.

The identification of areas that could be developed for ground-water supply to replace or supplement surface-water sources could not be determined from available data for Subarea 5. Because geologic controls affecting ground-water availability are highly variable, even on a local scale, regional evaluations are inherently characterized by a high degree of uncertainty. Ground-water availability may be a constraint in areas underlain by Piedmont crystalline-rock terranes more because of the difficulty in locating water-bearing voids in the rocks, rather than because of a lack of water. Ground-water resources probably could provide supplemental supplies during peak demand periods throughout most suburban areas of the Subarea 5. In more rural areas, ground-water supplies could serve as a primary resource depending upon demands. Generally, wells need only supply about 5 gal/min for domestic users, and may not be drilled to a depth that taps the available ground-water supply at a site. Most municipal or industrial users generally require well yields of at least 50 to 100 gal/min or more, and wells for such supplies likely are drilled to a depth sufficient to intersect as many water-bearing zones as feasible. Municipal and industrial users also tend to drill multiple wells to obtain the required ground-water supply.

SUMMARY

Drought conditions in the 1980's have focused attention on the multiple uses of the surface- and ground-water resources in the Apalachicola-Chattahoochee-Flint (ACF) and Alabama-Coosa-Tallapoosa (ACT) River basins in Alabama, Florida, and Georgia. Federal, State, and local agencies also have proposed projects that are likely to result in additional water use and revisions of reservoir operating practices within the river basins. The existing and proposed water projects have created conflicting demands for water and emphasized the problem of allocation of the resource. This study was initiated to describe ground-water availability in the Tallapoosa River basin of Georgia and Alabama, Subarea 5 of the ACF-ACT River basins, and to estimate the possible effects of increased ground-water use in the basin.

Subarea 5 encompasses about 634 square miles (mi^2) in northwestern Georgia and about 4,041 mi^2 in Alabama. The major rivers of Subarea 5 are the Little Tallapoosa and the Tallapoosa. The Little Tallapoosa River joins the Tallapoosa River near Wedowee, Ala. The Tallapoosa River flows southwestward and joins with the Coosa River near Wetumpka, Ala., to form the Alabama River (Subarea 8).

The Piedmont Province is characterized by a two-component aquifer system composed of a fractured crystalline-rock aquifer characterized by little or no primary porosity or permeability; the overlying weathered regolith, composed of soil, alluvium, colluvium, and saprolite, that responds hydraulically as a porous-media aquifer. The Coastal Plain is characterized by southward-dipping, poorly consolidated Cretaceous-age sand, gravel, and clay deposits of fluvial and marine origin that form a porous-media aquifer system.

The conceptual model of ground-water flow and stream-aquifer relations subdivides the ground-water flow system into local (shallow), intermediate, and regional (deep) flow regimes. The regional flow regime probably approximates steady-state conditions and water discharges chiefly to the Tallapoosa River system. Ground-water discharge to tributaries primarily is from the local and intermediate flow regimes. Ground water that discharges to regional drains is composed of local, intermediate, and regional flow regimes. Mean-annual ground-water discharge to streams (baseflow) is considered to approximate the long-term, average recharge to ground water.

Mean-annual baseflow in Subarea 5 was estimated using an automated hydrograph-separation method. Mean-annual baseflow to the Tallapoosa River and tributaries was estimated to be about 534 cubic feet per second (ft^3/s) in Georgia (from the headwaters to the Georgia-Alabama State line); about 3,250 ft^3/s in Alabama; and about 3,780 ft^3/s at the mouth of the Tallapoosa River (at the Subarea 5-Subarea 8 boundary).

Stream discharges for selected sites on the Tallapoosa River and tributaries were compiled for the years 1941, 1954, and 1986, during which historically significant droughts occurred throughout most of the ACF-ACT River basins. Stream discharge was assumed to be sustained entirely by baseflow during the latter periods of these droughts. Estimated streamflows near the end of the 1941, 1954, and 1986 drought years were 48, 15, and 85 ft^3/s, respectively, at the Georgia-Alabama State line and 481, 126, and 448 ft^3/s, respectively, at the mouth of the Tallapoosa River. Estimated baseflow near the end of the individual droughts was about 9 percent of the estimated mean-annual baseflow in Subarea 5.

The limited scope, lack of field-data collection, and the short duration of the ACF-ACT River basin study has resulted in incomplete descriptions of ground- and surface-water-flow systems, which may affect the future

management of water resources in the basins. For example, the extent and continuity of local and regional flow systems and their relation to geology is largely unknown. Similarly, quantitative descriptions of stream-aquifer relations, ground-water flow across State lines, water quality, drought flows, and ground-water withdrawal and subsequent effects on the flow systems (the availability and utilization issue) are highly interpretive; therefore, the descriptions should be used accordingly.

Estimates of water use and ground-water discharge to streams are dependent on methodologies employed during data collection, computation, and analyses. Results reported herein are limited by a lack of recent data and the non-contemporaneity of all data. Analyses using limited data may not adequately describe stream-aquifer relations. Most importantly, analyses in this report describe only two hydrologic conditions—(1) mean-annual baseflow and (2) drought-flow conditions during 1941, 1954 and 1986. Analyses derived from extrapolation to other hydrologic conditions, such as much longer drought periods or increased ground-water withdrawal should be used with caution. Special concern also should be directed to the effects of increased post-1990 withdrawal on ground-water discharge to streams in Subarea 5.

The potential exists for the development of ground-water resources on a regional scale throughout Subarea 5. Ground-water use in 1990 represented about 0.6 percent of the estimated mean-annual baseflow, and about 6 percent of the average drought flow during the droughts of 1941, 1954, and 1986. Because ground-water use in Subarea 5 represents a relatively minor percentage of ground-water recharge, even a large increase in ground-water use in Subarea 5 in one State probably would have little effect on the quantity of ground water and surface water in the other. Long-term ground-water level declines were observed in porous media well F-1 in Bullock County, Ala.; however, long-term water-level data at wells in Subarea 5 are few in number and poorly distributed areally, and conclusions regarding regional water-level declines or storage changes cannot be reasonably drawn.

SUGGESTIONS FOR FURTHER STUDY

This report presents a discussion of ground-water resources and interaction of ground- and surface-water systems in the Tallapoosa River basin, Subarea 5, of the ACF-ACT River basins. In Subarea 5, ground-water availability is addressed only from a regional perspective using historical data. Data collection was not a part of this study; therefore, lack of streamflow and ground-water data necessitated that estimation methods be used extensively to describe stream-aquifer relations. Additional data, particularly data describing surface- and ground-water conditions on a local scale, are needed to further refine and quantify the interaction of ground- and surface-water systems in the Subarea. Analyses of these data could better describe stream-aquifer relations, as well as ground-water availability and development potential in Subarea 5.

Although the overall objectives of this study were to evaluate the ground-water resources and supply, the data used to accomplish these objectives were stream-discharge data. Stream-discharge data were sufficient to meet study objectives; however, such data either were not totally adequate or were not available at critical sites. Future stream-discharge data collection to support resource management should emphasize (1) continuous-record data at critical hydrologic and political boundaries for a period of years; and (2) concurrent stream-discharge measurements at critical sites during drought periods.

Continuous stream-discharge data collected over a period of years at critical locations provide the basic information essential to basinwide water-resource planning and management. Current data coverage is incomplete. For example, stream-gaging stations located on major tributary streams would have eliminated or reduced the need to extrapolate and interpolate data from stations distant from these boundaries, and consequently, would have improved the accuracy of estimates of ground-water contributions.

The collection of drought-flow data obviously is contingent on the occurrence of a drought; thus, collection of drought data is not routine and is not easily planned. A contingency plan to collect drought data should be in place. The plan could consider, but not be limited to, logistics, manpower needs, and the preselection of stream data-collection locations. For more rigorous planning, field reconnaissance of preselected stream sites could be conducted.

Data-base development also is critical to resource management. Data elements, such as well construction and yield; hydraulic characteristics of aquifers; water quality; and ground-water withdrawals—both areally and by aquifer—are particularly important. Seepage runs (detailed streamflow measurements of drainage systems made concurrently during baseflow conditions) can be used to identify individual ground-water flow systems and improve the understanding of stream-aquifer relations, especially in crystalline and mixed-rock terranes. Once identified, a flow system can be studied in detail to define its extent, recharge and discharge areas, movement of water, chemical quality, and the amount of water that can be withdrawn with inconsequential or minimal effects. These detailed studies might include test drilling, borehole geophysical logging, applications of surface geophysics, aquifer testing, a thorough water-withdrawal inventory, and chemical analyses of ground water to delineate the extent of the ground-water flow system and evaluate its potential as a water supply. Evaluation of several such flow systems would greatly improve the understanding of ground-water resources throughout the subarea. Because aquifer properties vary substantially on a local scale and data are sparse, field studies are needed to obtain quantitative definitions of the hydraulic interactions of aquifers and streams in Subarea 5.

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