GROUND-WATER RESOURCES OF THE CAHABA RIVER BASIN IN ALABAMA—*SUBAREA 7* OF THE APALACHICOLA-CHATTAHOOCHEE-FLINT AND ALABAMA-COOSA-TALLAPOOSA RIVER BASINS

U.S. GEOLOGICAL SURVEY

Prepared in cooperation with the

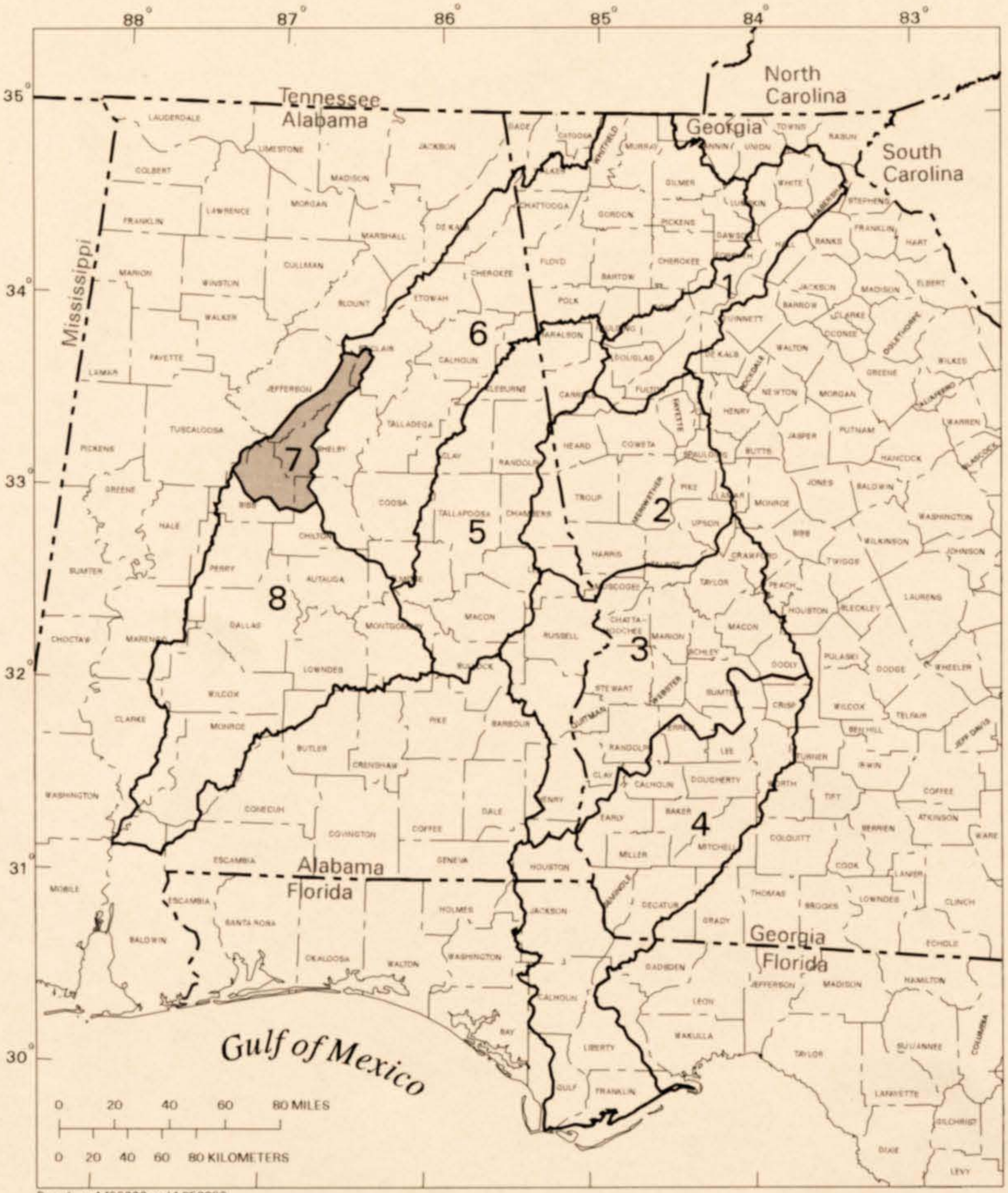
ALABAMA DEPARTMENT OF ECONOMIC AND COMMUNITY AFFAIRS
OFFICE OF WATER RESOURCES

GEORGIA DEPARTMENT OF NATURAL RESOURCES
ENVIRONMENTAL PROTECTION DIVISION

NORTHWEST FLORIDA WATER MANAGEMENT DISTRICT

U.S. ARMY CORPS OF ENGINEERS, MOBILE DISTRICT

Open-File Report 96-470



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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Montgomery, Alabama

1997

U.S. DEPARTMENT OF THE INTERIOR

BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY

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Denver, CO 80225-0286

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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

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; computer program (Hirsch, 1982)
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

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 and Alabama-Coosa-Tallapoosa 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 Cahaba River basin in Alabama, Subarea 7 of the Apalachicola-Chattahoochee-Flint and Alabama-Coosa-Tallapoosa River basins, and to estimate the possible effects of increased ground-water use within the basin.

Subarea 7 encompasses about 1,030 square miles in north-central Alabama. Subarea 7 encompasses parts of the Piedmont, Valley and Ridge, 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 characterized by little or no primary porosity or permeability; and the overlying regolith, which can behave as a porous-media aquifer. The Valley and Ridge Province is underlain by fracture- and solution-conduit aquifer systems, similar in some ways to those in the Piedmont Province. Fracture-conduit aquifers predominate in the well-consolidated sandstones and shales of Paleozoic age; solution-conduit aquifers predominate in the carbonate rocks of Paleozoic age. The Coastal Plain is underlain by southward-dipping, poorly consolidated deposits of sand, gravel, and clay of fluvial and marine origin.

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 Cahaba 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 763 cubic feet per second at Centreville, Ala., where the Cahaba River exits Subarea 7 into Subarea 8. Mean-annual baseflow represented about 48 percent of total mean-annual stream discharge for the period of record.

Stream discharge for selected sites on the Cahaba River and its tributaries were compiled for the years 1941, 1954, and 1986, during which sustained droughts occurred throughout most of the Apalachicola-Chattahoochee-Flint and Alabama-Coosa-Tallapoosa River basin area. Stream discharges were assumed to be sustained entirely by baseflow during the latter periods of these droughts. Estimated baseflow near the end of these droughts averaged was about 21 percent of the estimated mean-annual baseflow in Subarea 7 (ranged from about 16 to 25 percent for individual drought years).

The potential exists for the development of ground-water resources on a regional scale throughout Subarea 7. Estimated ground-water use in 1990 was about 2 percent of the estimated mean-annual baseflow, and 9.7 percent of the average drought baseflow near the end of the droughts of 1941, 1954, and 1986. Because ground-water use in Subarea 7 represents a relatively minor percentage of ground-water recharge, even a large increase in ground-water use in Subarea 7 is likely to have little effect on ground-water and surface-water occurrence in Alabama. Indications of long-term ground-water level declines were not observed; however, long-term water-level measurements at observation wells in Subarea 7 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.

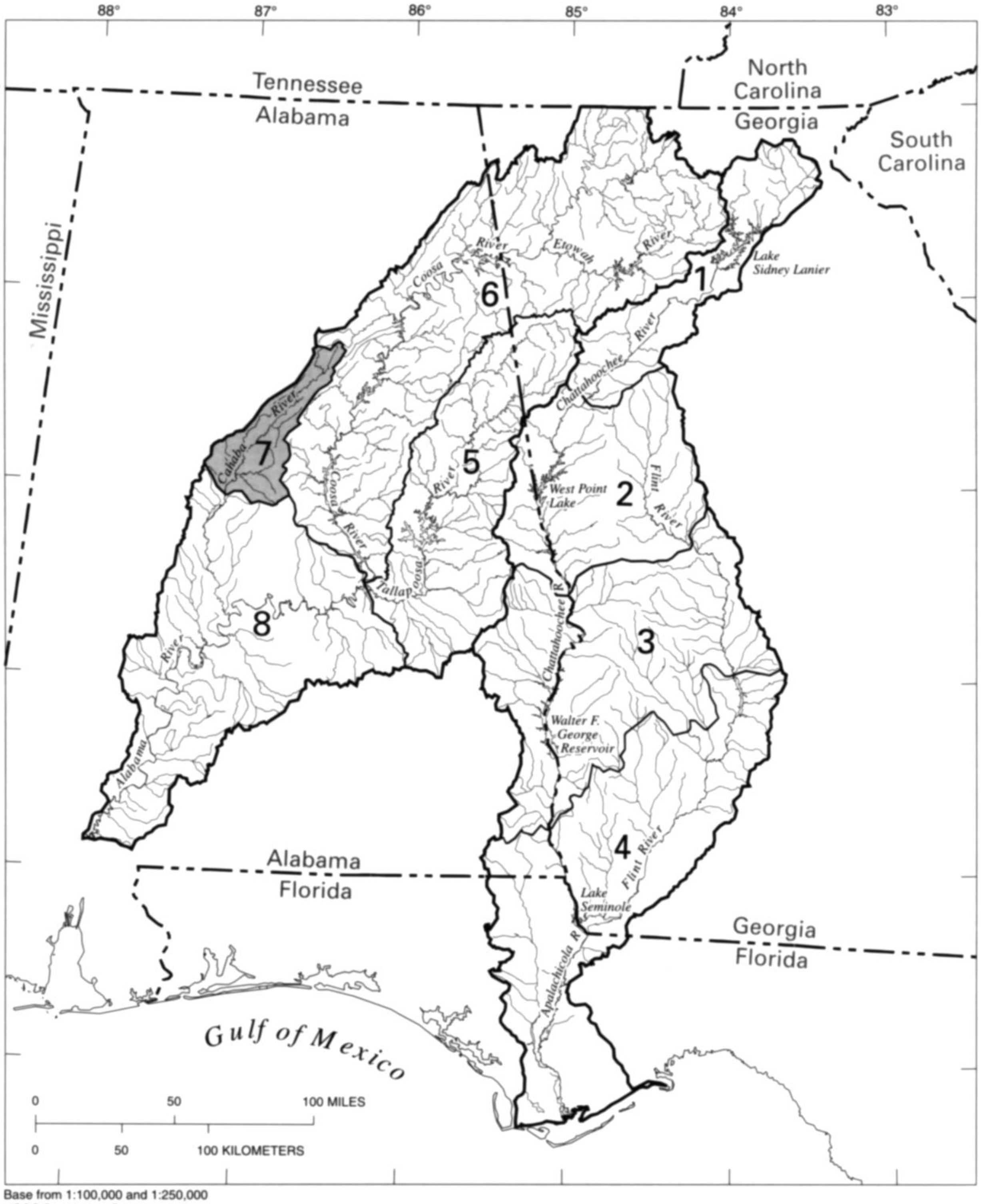

Figure 1. Subareas and major streams in the Apalachicola–Chattahoochee–Flint and Alabama–Coosa–Tallapoosa River basins.

Purpose and Scope

This report describes the ground-water resources of the Cahaba River basin in Alabama—Subarea 7 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 basin. 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 7;
- quantify mean-annual and drought period ground-water contributions to the Cahaba River from the headwaters to Centreville, Ala., and the ground water exiting Subarea 7; 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

Subarea 7 encompasses about 1,030 mi^2 in north-central Alabama (fig. 1). It is bounded to the east by the Coosa River basin (Subarea 6) and to the south by the lower part of the Cahaba River basin and the Alabama River basin (Subarea 8). To the west, Subarea 7 is bounded by the Black Warrior River basin which is outside of the ACF-ACT study area.

Physiography

About 84 percent of Subarea 7 lies within the Alabama Valley and Ridge Province. The Alabama Valley and Ridge Province in Subarea 7 (fig. 2) consists mainly of northeastward-trending chert and sandstone ridges and valleys underlain by limestone or shale (Sapp and Emplaincourt, 1975). In addition, the southernmost part of the study area, about 14 percent, is in the Coastal Plain Province. The Coastal Plain Province is underlain by sedimentary rocks which dip gently southward at about 20 to 40 feet per mile. A relatively small area in the southeastern part of Subarea 7, about 2 percent, is underlain by formations of the Piedmont physiographic province, an area underlain by igneous and metamorphic rocks.

Land-surface altitude of Subarea 7 ranges from about 250 to 1,150 feet above sea level. The most prominent features of the study area are Red Mountain and Shades Mountain which rise to altitudes of 950 and 1,150 feet above sea level.

Climate

The climate in Subarea 7 is moist and temperate, with hot summers, mild winters, and precipitation during all months of the year. Precipitation, almost all of which occurs as rainfall, averages about 54 inches annually. Rainfall is generally uniformly distributed throughout the year. However, spring is considered the “wet” season and autumn the “dry” season. Daily temperatures range from an average of about 43 degrees Fahrenheit in January to about 80 degrees Fahrenheit in July. Mean-annual temperature is about 62 degrees Fahrenheit (U.S. Department of Commerce, 1985).

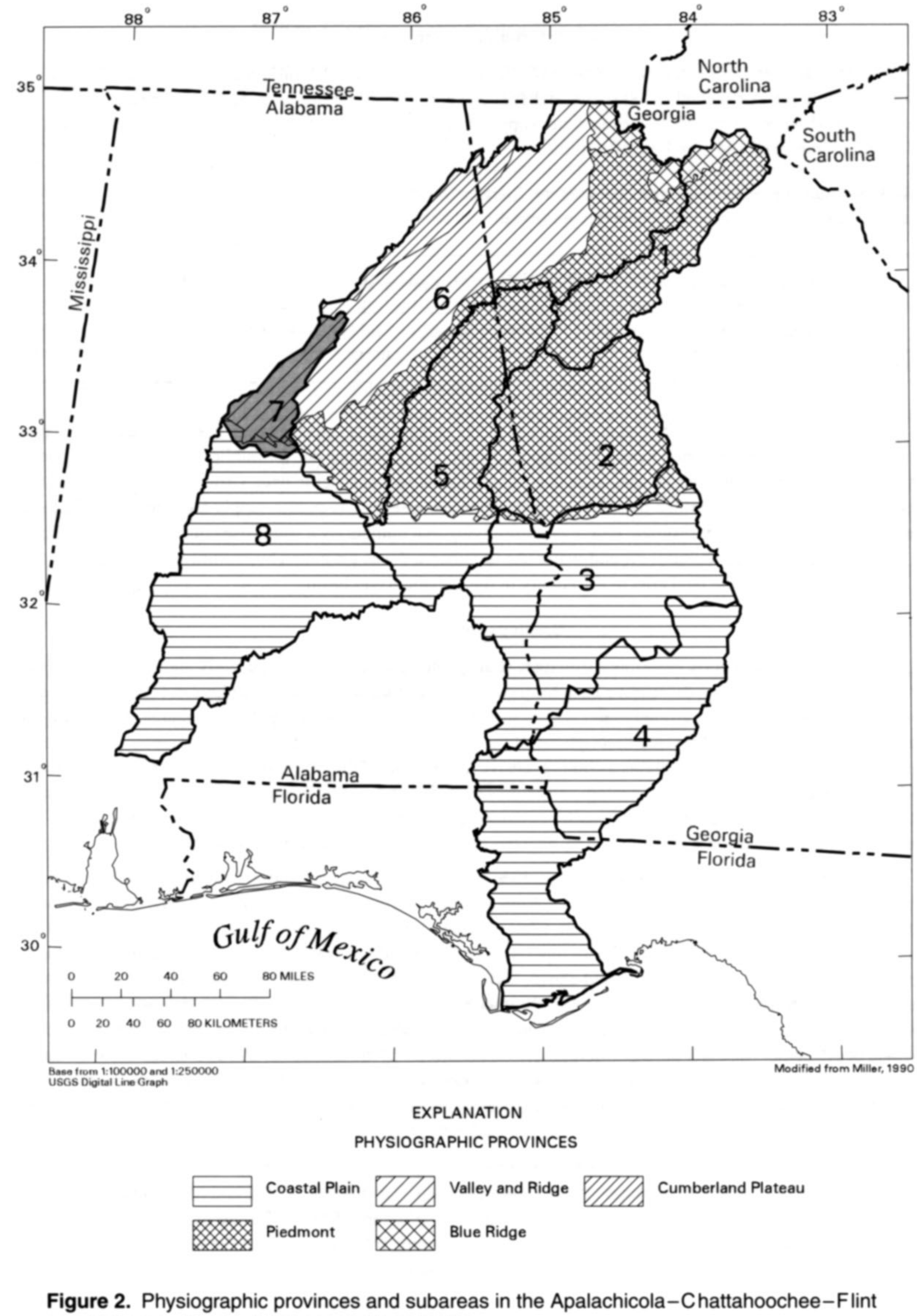

Figure 2. Physiographic provinces and subareas in the Apalachicola–Chattahoochee–Flint and Alabama–Coosa–Tallapoosa River basins.

Ground-Water Use

The estimated ground-water use in Subarea 7 during 1990 was about 10 million gallons per day (Mgal/d) or about 15.5 cubic feet per second (ft^3/s) (table; Baker and Mooty, 1993). Of this total, about 83 percent was for public water supply, about 9 percent for domestic water supply, 8 percent for agricultural use, and less than 1 percent for self-supplied industrial and commercial activities.

Table 1. Estimated ground-water use, by category, Subarea 7, 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)
Subarea 7 total	8.3	12.8	0.03	0.05	0.8	1.2	0.9	1.4	10.0	15.5

Ground-water use reported by Baker and Mooty (1993) is by county; ground-water use in those counties that are partially in Subarea 7 are reported herein for Subarea 7 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 in Subarea 7 was estimated by multiplying the reported county use by the percentage of the land area of the county in the Cahaba River basin.

Previous Investigations

Several published reports describing structure, stratigraphy, and lithology of the study area are of note. Adams and others (1926) provide the descriptive base for most geologic studies in Alabama. Johnston (1933) presented a comprehensive account of the ground-water resources in the Paleozoic rocks of northern Alabama. Drahovzal and Neathery (1971) updated and revised descriptions of the Middle and Upper Ordovician stratigraphy of the Alabama Appalachians. Thomas (1972) contains a comprehensive description of the Mississippian stratigraphy of Alabama. Kidd and Shannon (1978) described geologic structures in Jefferson County; Thomas (1985) compiled structural sections of northern Alabama. Reports describing major aquifers in the study area, recharge areas, and areas susceptible to contamination were prepared by Mooty (1987) and Planert and Pritchett (1989).

Studies of ground-water resources, which include geologic mapping and well inventories, have been made for each of the counties in the study area. These are: Bibb (Causey and others, 1978), Chilton (Ellard and Willmon, 1980), Jefferson (Moffett and Moser, 1978), St. Clair (Causey, 1963), Shelby (Shamburger and Harkins, 1980), and Tuscaloosa (Miller and Causey, 1958). These reports provide a broad and useful base of geologic and hydrologic information. In addition to the reports listed above, Davis (1980) contains periodic measurements of ground-water levels in the area from 1952 to 1977. 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. 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. These and other useful ground-water publications are listed in the selected references.

Reports describing methods of estimating streamflow and ground-water discharge to streamflow include Bingham (182), Hoos (1990), Rorabaugh (1960, 1964), Rutledge (1991, 1992, 1993), and Mayer and Jones (1996). Data collected as part of the ongoing surface-water monitoring program of the USGS are published annually in the reports “Water-Resources Data, Alabama.” 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

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 each county are often subsequently assigned a three-letter abbreviation corresponding to the county and a number corresponding to the well. For example, well CC-11 in Jefferson County also is identified as JEF-1.

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 7, 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 Cahaba 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 Cahaba, 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 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 compose and evaluate droughts under "worst-case" conditions. An estimate also was made of the mean-annual volume of ground water discharged from Subarea 7 to Subarea 8 as baseflow in the Cahaba River. The drought-flow analysis was used to estimate drought baseflow contributions to the surface-water system during historically significant droughts and the ground water delivered from Subarea 7 to Subarea 8 near the end of these droughts.

Mean-Annual Baseflow Analysis

Discharge data from continuous-record gaging stations along the Cahaba 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 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.

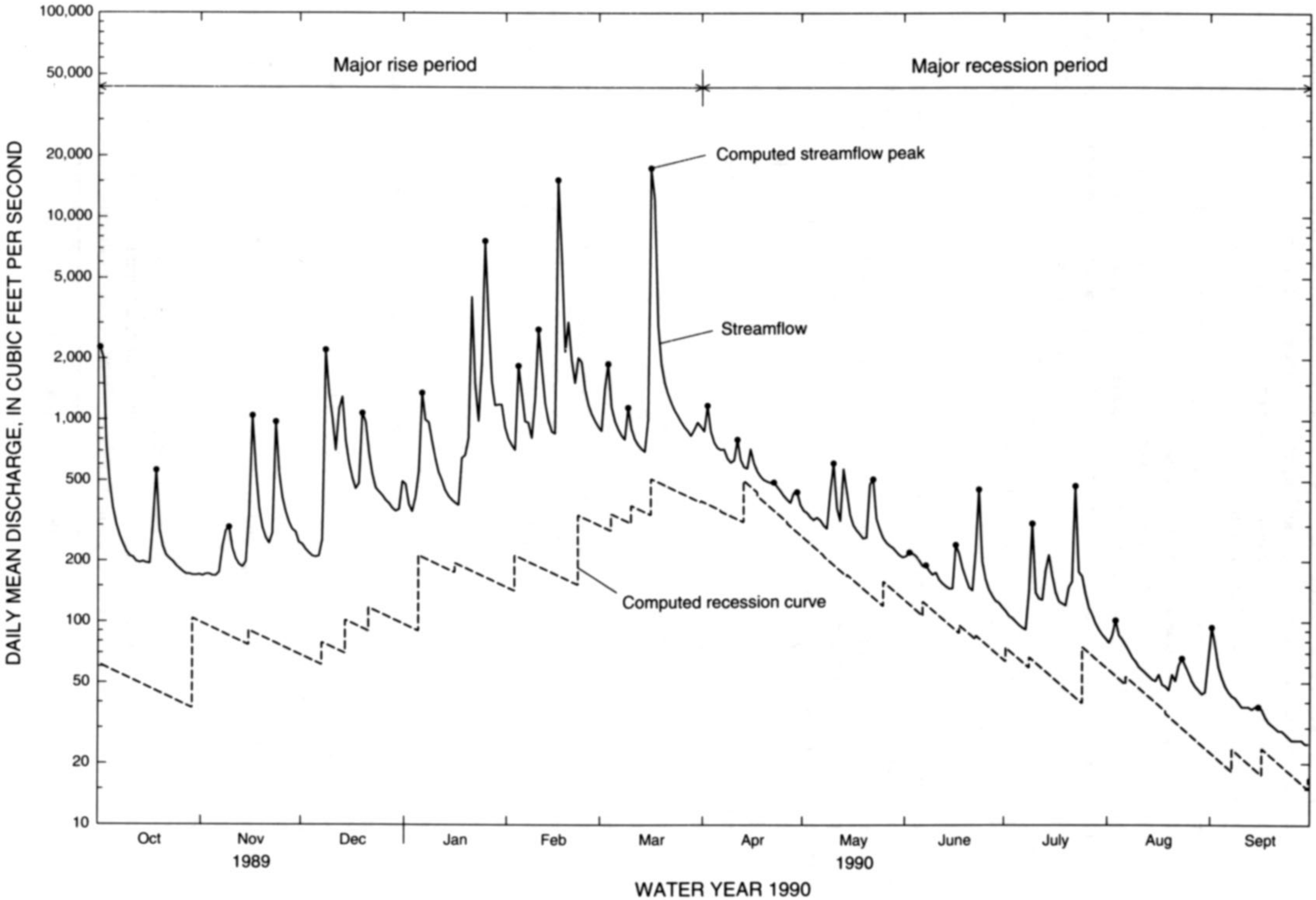

Figure 3. Streamflow hydrograph, separated by program SWGW.

Available ground-water-level data indicate that long-term changes in ground-water storage are minimal in Subarea 7. Because long-term storage changes are minimal, mean-annual ground-water discharge, estimated using the hydrograph-separation method, is considered equal to mean-annual net recharge. Also, aquifers at a regional scale in Subarea 7 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 (ft^3/s), 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 7 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 were compiled for the drought years 1941, 1954, and 1986. These data included nearly concurrent daily measurements of streamflow in the Cahaba 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 15, 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 Cahaba 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.

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

The conceptual model of the ground-water flow and stream-aquifer relations in Subarea 7 is based on previous work 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 net 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 Cahaba River in Subarea 7. Depending on local hydrogeologic conditions, all three flow regimes may not be present everywhere within the subarea.

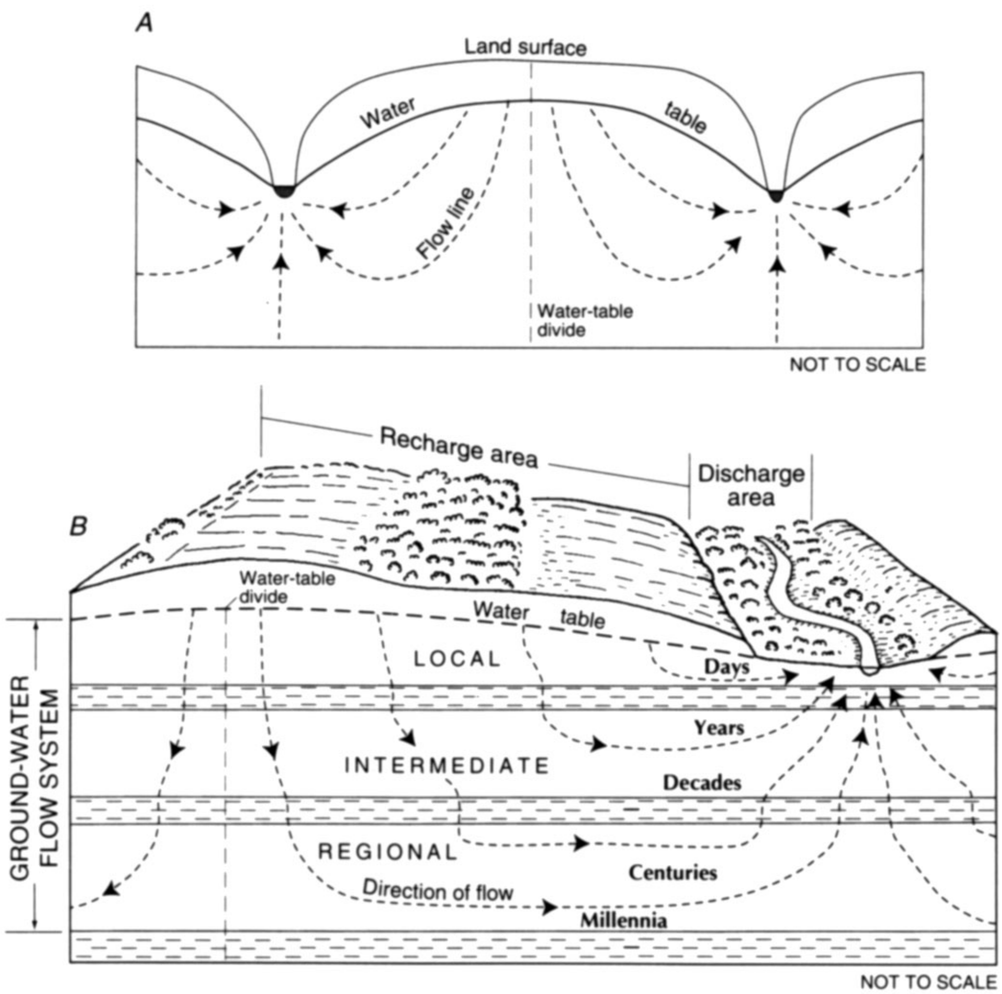

Figure 4. (*A*) Distribution of ground-water flow in an areally extensive, isotropic, homogeneous aquifer system (modified from Hubbert, 1940, and Heath, 1984) and (*B*) example of local, intermediate, and regional ground-water flow (modified from Heath, 1984).

The water table in Subarea 7 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 net recharge to the water table and net ground-water discharge to streams are variably distributed throughout the local, intermediate, and regional flow regimes. Local regimes receive the greatest net ground-water recharge to 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 Cahaba River includes contributions from the regional as well as local and intermediate regimes.

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 net 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 and Valley and Ridge Provinces 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. Further support for the assumption of Darcian flow is provided by regional scale maps of potentiometric surfaces, which demonstrate the continuity of ground-water flow through fractured rocks at a county or multi-county scale. Examples of regional scale maps of potentiometric surfaces in fractured rock aquifers are shown by Bossong (1989) and Planert and Pritchett (1989).

Results of smaller-scale studies also demonstrate the continuity of ground-water flow through fractured media. 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 7 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 7 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 7 (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 of Precambrian to Paleozoic age, 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 have 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.

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 ft, 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).

Rocks of Paleozoic age characterize the Valley and Ridge Province. These rocks are folded, faulted, and thrusted clastic and carbonate rocks of fluvial and marine origin that have been only locally metamorphosed. Typical rock types include shale, siltstone, sandstone, limestone, and dolostone.

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 and Valley and Ridge Provinces. 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 7, form narrow bands across Bibb and Chilton Counties, Ala.

Aquifers

Aquifers in Subarea 7 (fig. 5) vary widely in their lithologic and water-bearing characteristics (table 2). Three types of aquifers are present in the Subarea, identified on the basis of their ability to store and yield water: (1) porous-media; (2) solution-conduit; and (3) 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 7, 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
Valley and Ridge	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 Chilton and Elmore Counties, Alabama	100 to 200 gallons per minute (Scott and others, 1987)
Valley and Ridge	Paleozoic—sandstone, shale, and siltstone	fracture-conduit	yield highly variable, may have high iron concentrations, in limited use for public-water supply	10 to 200 gallons per minute (Bossong, 1989)
	Paleozoic—limestone, dolostone, chert	solution-conduit	widely used for public water supply, water may have high concentrations of calcium and bicarbonate	10 to 2,000 gallons per minute (Bossong, 1989)
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 sand and gravel deposits in the valley floor of the Cahaba 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 valley floor of the Cahaba River are limited in thickness and extent and form local aquifers. 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 hydraulically connected to the Cahaba River and are not major sources of ground water in Subarea 7.

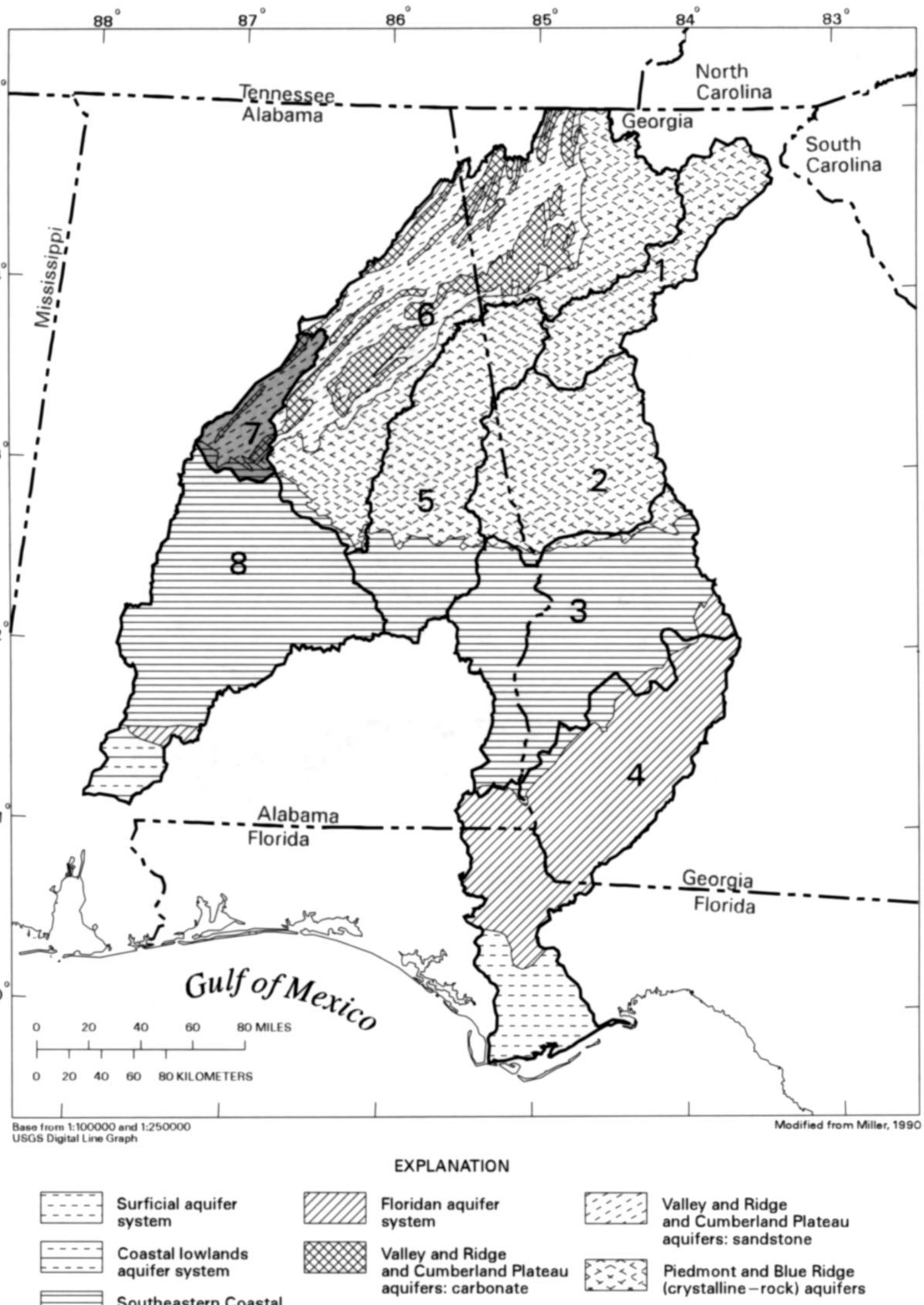

Figure 5. Major aquifers and subareas in the Apalachicola–Chattahoochee–Flint and Alabama–Coosa–Tallapoosa River basins.

The Cahaba River flows across the outcrop area of the Cretaceous sediments in northern Bibb and northwestern Chilton Counties, Ala. Aquifers in these sediments are of the porous-media type (fig. 6), and the Cahaba 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 7. These aquifers have limited thickness and extent and are not major sources of ground water in Subarea 7.

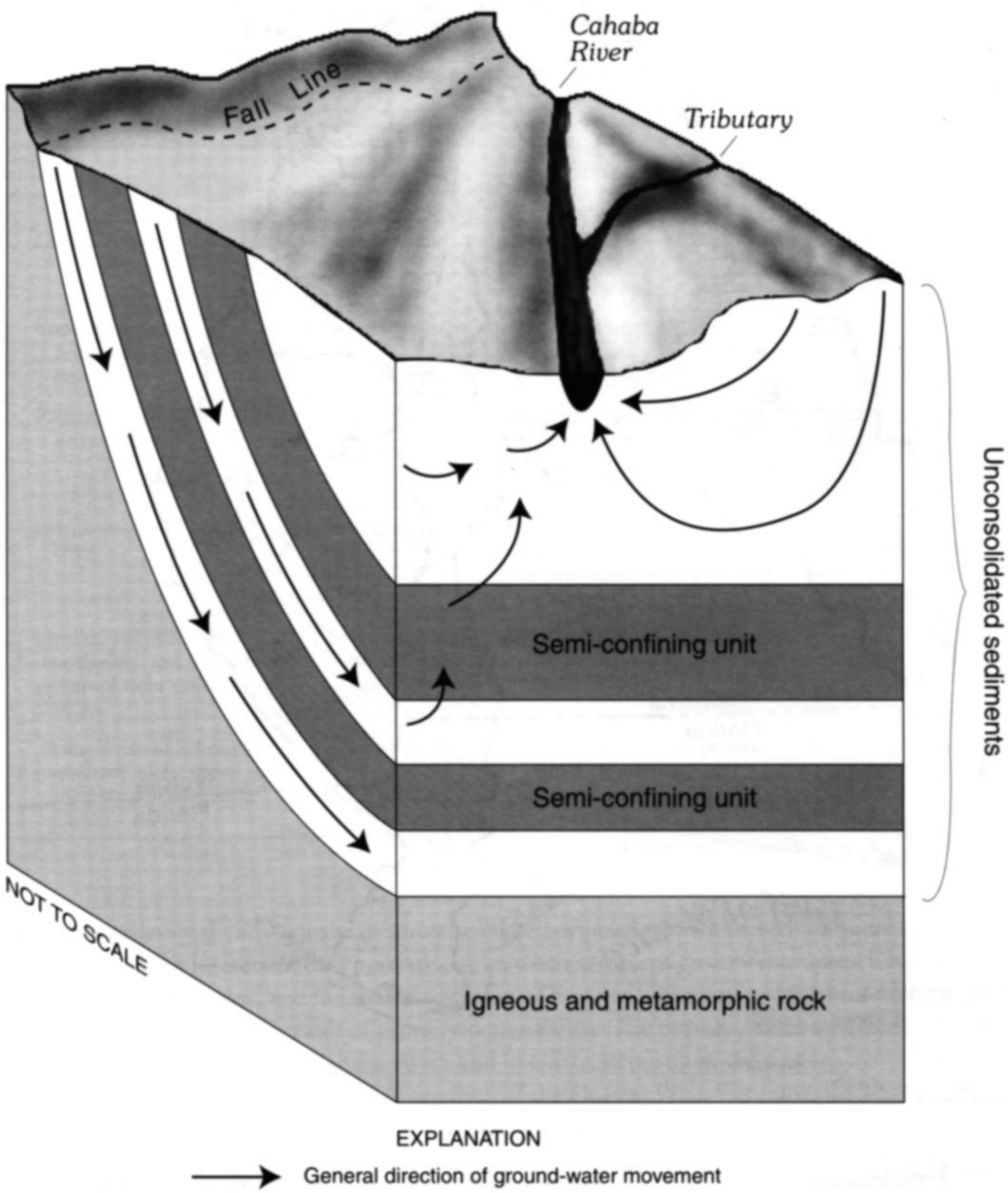

Figure 6. Conceptual ground-water and surface-water systems in Subarea 7: porous-media aquifer in unconsolidated sediments of the Coastal Plain Province.

Solution-conduit aquifers of Subarea 7 (fig. 7) occur in well-cemented carbonate rocks of the Valley and Ridge Province. The study of the occurrence and development of ground water in solution-conduit aquifers is an area of specialization and is only briefly explained here. The carbonate rocks of Subarea 7 are characterized by little primary porosity or permeability. Secondary porosity features, such as solution-enlarged fractures and bedding planes, form a system of interconnected conduits through which water moves (Bossong, 1989). The weathered zone above many of the carbonate-rock aquifers contains a layer of chert rubble that stores and transmits water slowly to the underlying fractured-rock aquifer. The carbonate-rock aquifers are anisotropic and heterogeneous because of the local and directional nature of water-bearing units in the bedrock.

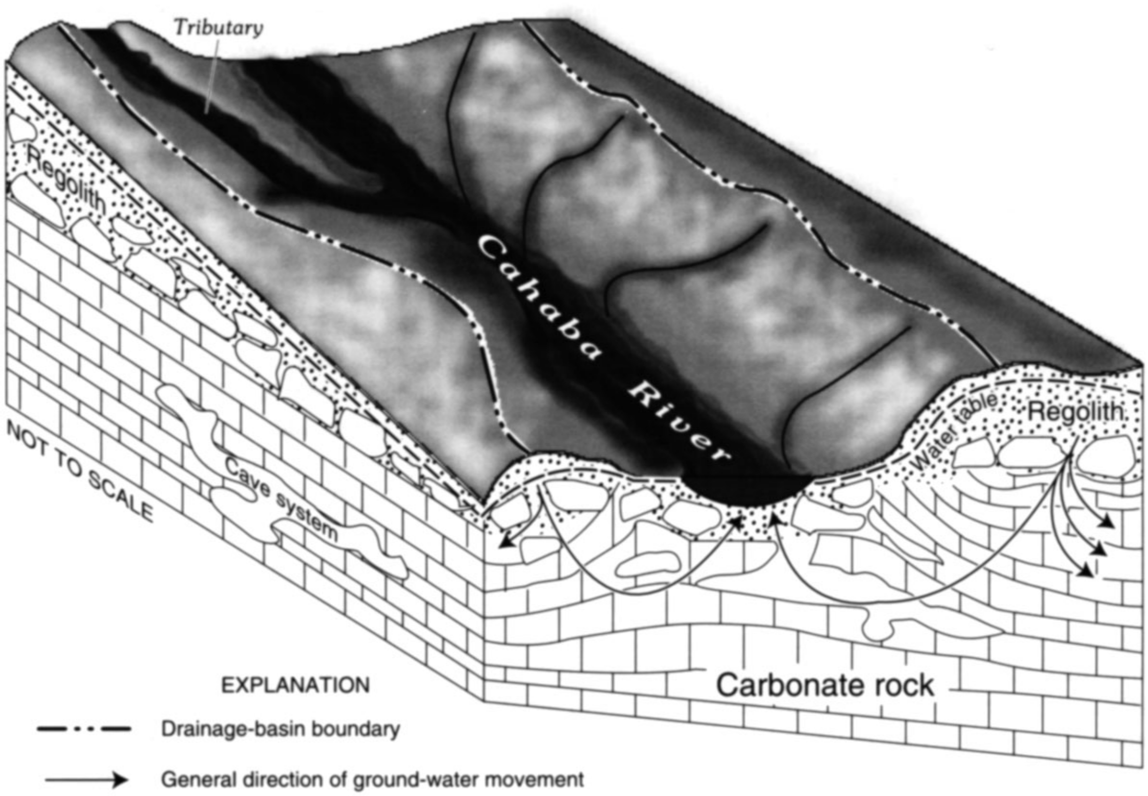

Figure 7. Conceptual ground-water and surface-water systems in Subarea 7: solution-conduit aquifer in the carbonate rocks of the Valley and Ridge Province.

Wells completed in solution-conduit aquifers may supply several thousand gallons of water per minute. Wells that do not intercept secondary permeability zones will, however, seldom supply more than 10 gallons per minute or may be dry. In Subarea 7, most public water-supply wells completed in solution-conduit aquifers yield 350 to 700 gal/min (Bossong, 1989). Folding and faulting of rocks have disrupted regional stratigraphic continuity so that the same aquifer unit may occur in adjacent valleys but not be hydraulically connected (Planert and Pritchett, 1989). As in any solution-conduit aquifer system, ground-water withdrawal and consequent water-level declines could induce sinkhole development. The likelihood of sinkhole development would depend on several factors—including, but not limited to—quantity of water withdrawn, amount of water-level decline, proximity of solution conduits to the land surface, and land-surface loading.

In Subarea 7, fracture-conduit aquifers occur in shale, siltstone, and sandstone (fig. 8) of the Valley and Ridge Province. Two general water-bearing zones comprise the ground-water flow system in fracture-conduit aquifers: (1) the shallow regolith, composed of saprolite, soil, colluvium and alluvium; and (2) the deeper, fractured bedrock. The soil and alluvium of the regolith is characteristic of a porous-media aquifer and bedrock is characteristic of a fracture-conduit aquifer. In general, the regolith consists of 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). The transition zone between saprolite and bedrock contains weathered material and boulders, and along structural features, such as foliation and jointing, generally is more permeable than the saprolite. Ground-water flow can be preferential in saprolite where weathered rock retains relict structural features (Stewart, 1964; Stewart and others, 1964).

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.

Fracture-conduit aquifers formed in shale, siltstone, and sandstone of the Valley and Ridge Province may yield quantities of water suitable for public or industrial supply. In Subarea 7, most water-supply wells completed in shale, siltstone, or sandstone yield less than 100 gal/min (Bossong, 1989). Yields from wells completed in the fractured crystalline-rock aquifers (schist, gneiss, quartzite, and granite) generally range from 1 to 25 gal/min, but may exceed 500 gal/min (Kidd, 1989). 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 solution-conduit and 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.

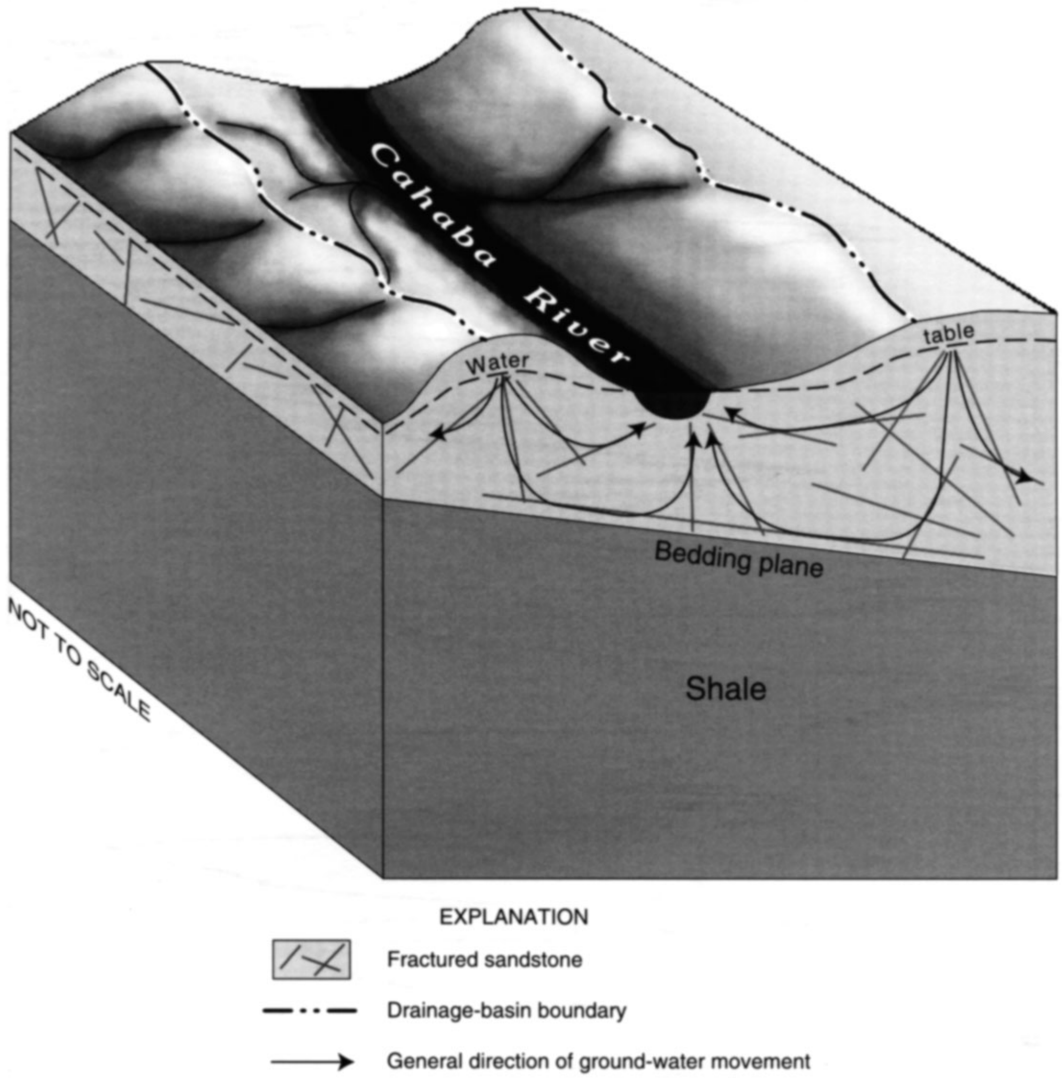

Figure 8. Conceptual ground-water and surface-water systems of Subarea 7: fracture-conduit aquifer in the clastic sedimentary rocks of the Valley and Ridge Province.

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 7, long-term water-level data were available for one well in a solution-conduit aquifer for the period 1975-89. One well outside the study area was used to represent water levels in a porous-media aquifer for the period 1975-84.

The hydrographs of well JEF-1 (fig. 9) completed in a solution-conduit aquifer in Jefferson County, Ala., and well TUS-4 (fig. 10) completed in a porous-media aquifer in Tuscaloosa County, Ala., west of the study area (fig. 11), show seasonal water-level fluctuations that probably are typical of such wells in Subarea 7. Annual low water levels occur in the fall after the dry summer months; and annual high water levels occur in the early spring because of recharge following rainfall during the winter months. Although the water level fluctuates seasonally, significant year-to-year or long-term change in the average water level in the aquifer has not occurred.

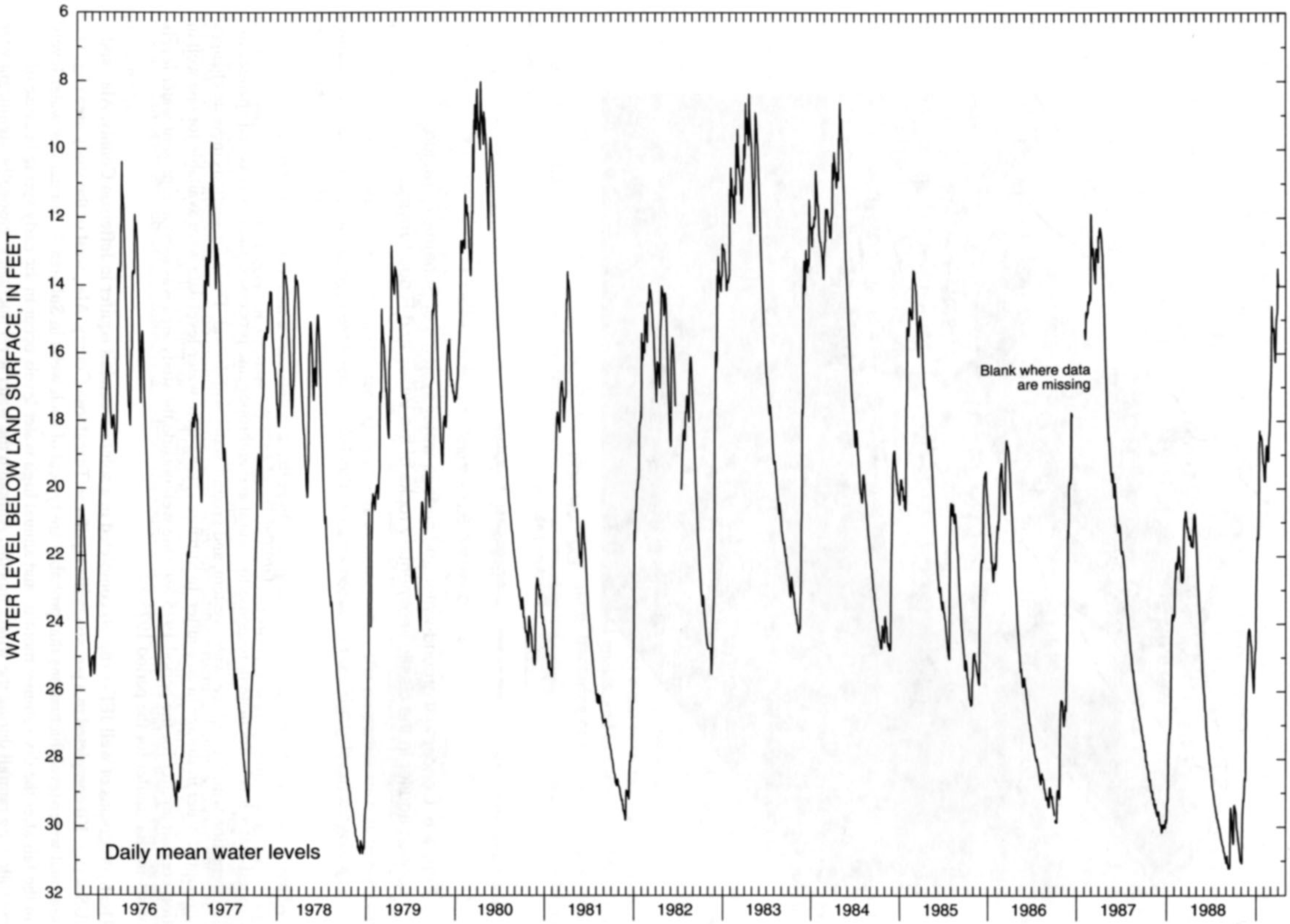

Figure 9. Water-level fluctuations in solution-conduit aquifer observation well JEF-1, Jefferson County, Alabama, October 1975-April 1989.

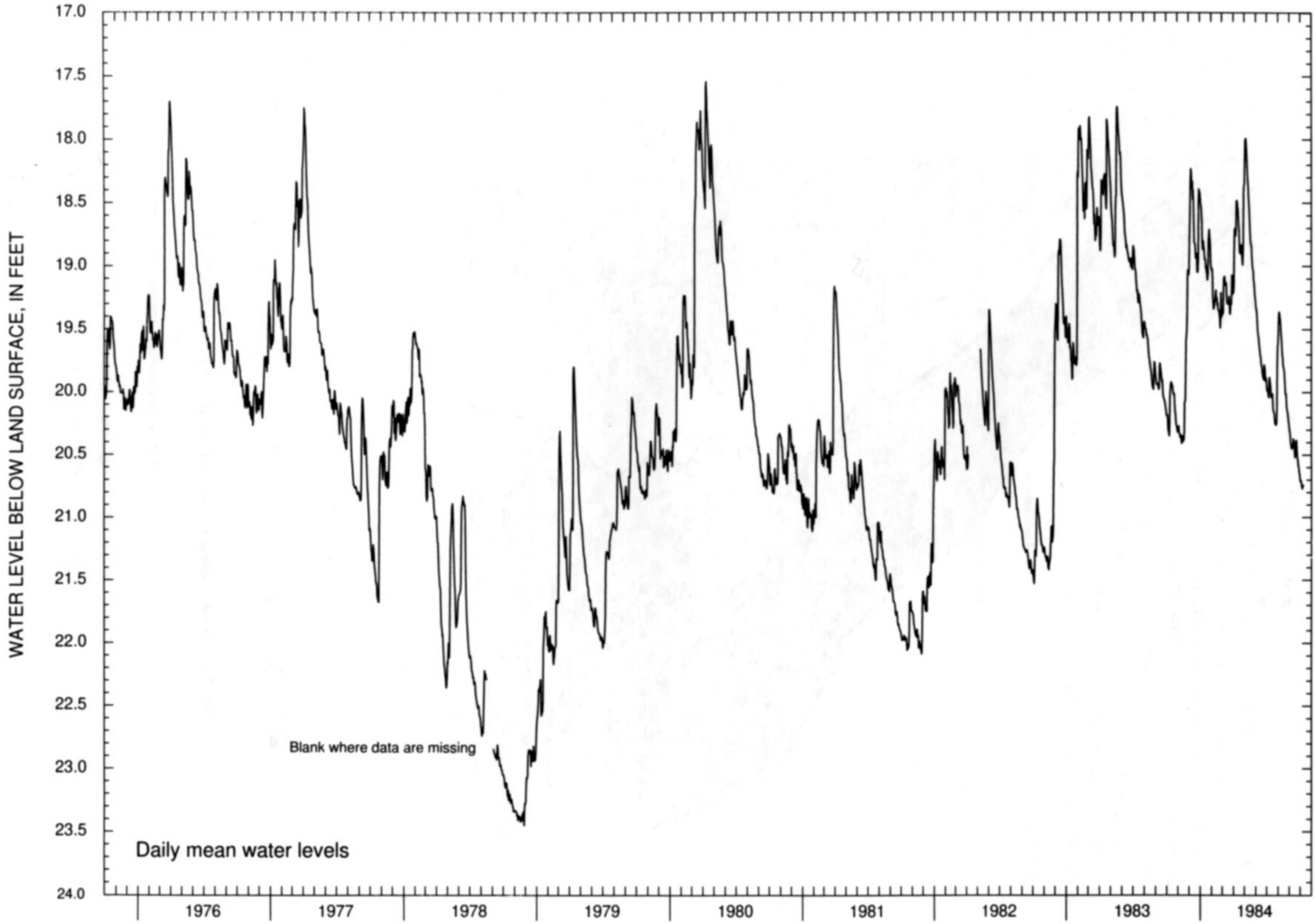

Figure 10. Water-level fluctuations in porous-media aquifer observation well TUS-4, Tuscaloosa County, Alabama, October 1975-October 1984.

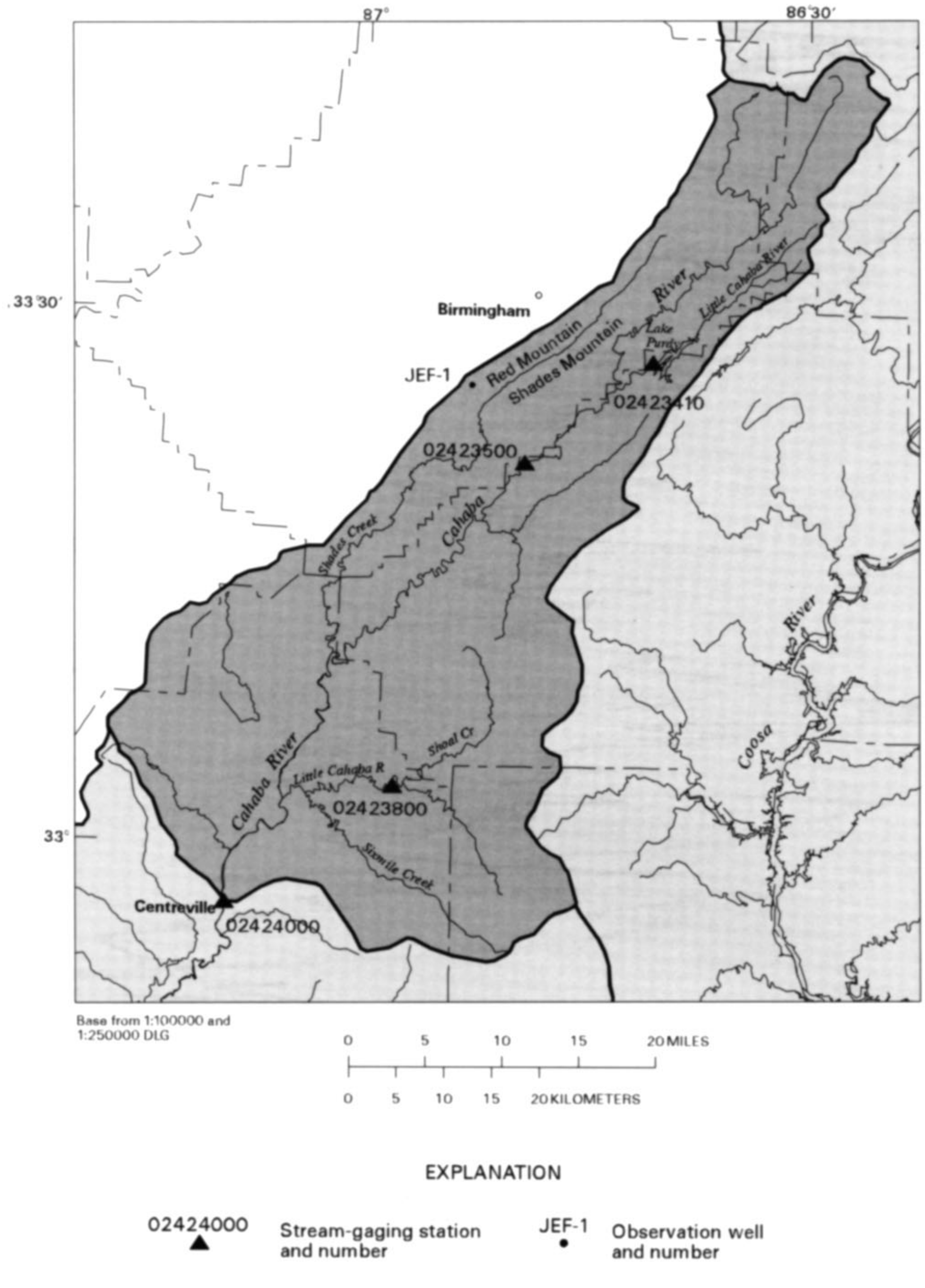

Figure 11. Selected stream-gaging stations and observation well JEF-1, Subarea 7.

Surface-Water System

The surface-water system in Subarea 7 includes the Cahaba River and its tributaries (fig. 11). The drainage area of the Cahaba River basin encompasses about 1,030 mi^2 in Alabama. 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 USGS began operating surface-water discharge measurement stations in Subarea 7 in 1901. Table 3 contains a list of representative discharge stations currently or historically operated by the USGS, the drainage area measured by each station, and the mean-annual discharge at the station determined for the period of record. The estimated mean-annual stream discharge of the Cahaba is 1,598 ft^3/s from Subarea 7 into Subarea 8.

Table 3. Selected active and discontinued continuous-record stream-gaging stations in the Cahaba River basin, Subarea 7
[F, fracture-conduit aquifer in clastic rocks; S, solution-conduit aquifer; P, porous media]

Station number	Station name	Drainage area (square miles)	Type of stream	Major aquifer drained	Period of record of flow (water year)	Mean-annual stream discharge (cubic feet per second)
02423410	Little Cahaba River below Lake Purdy Dam near Cahaba Heights, Ala.	42.7	tributary	F,S	1984-present	65.4[1/]
02423500	Cahaba River near Acton, Ala.	230	regional	F,S	1938-57	318[2/]
02423800	Little Cahaba River near Brierfield, Ala.	148	tributary	P,F,S	1958-70	195[1/]
02424000	Cahaba River at Centreville, Ala.	1,027	regional	P,F,S	1901-08, 1929-32 1935-present	1,598[1/]

[1/]Pearman and others (1994).
[2/]U.S. Geological Survey (1970).

Major streams in Subarea 7 (fig. 11) are the Cahaba River, Little Cahaba River (Jefferson County), Shades Creek, Sixmile Creek, Little Cahaba River (Bibb County), and Shoal Creek. The drainage system in Subarea 7 has become adjusted to the geologic structure, which has resulted in a trellis drainage pattern. The major streams are perennial, but many tributary streams are intermittent.

Streamflow at the Cahaba River near Acton (02423500), at Centreville (02424000), and at the Little Cahaba River below Lake Purdy Dam (02423410) have been affected since 1911 by periodic discharges from Lake Purdy. Lake Purdy, located in the central part of Subarea 7 (fig. 11), is an impoundment of the Little Cahaba River (table 4). The principal function of Lake Purdy is to supplement the city of Birmingham water supply during periods of low flow on the Cahaba River, which is the principal source of drinking water for Birmingham. Lake Purdy Dam was originally constructed at a height of 40 feet and created a lake with a storage capacity of 4,600 acre-feet. In 1929, an additional 20 feet was added to the height of the dam, increasing the lake's storage capacity to 17,500 acre-feet and surface area to 1,050 acres (city of Birmingham, Birmingham Waterworks, data files). This is the only major impoundment in Subarea 7.

Table 4. Major impoundment in the Cahaba River basin, Subarea 7

Impoundment structure	Station number	Location	Installation date	Major uses	Total storage capacity[1/] (acre-feet)
Lake Purdy Dam	02423409	Jefferson County, Ala.	1911	supplemental municipal water supply, city of Birmingham, Ala.	17,500

[1/]City of Birmingham, Birmingham Waterworks, data files.

The streamflow downstream of Birmingham also is affected by withdrawals and return flows from several water-supply and wastewater-treatment facilities. With the exception of the data at Little Cahaba River below Lake Purdy Dam (02423410), immediately downstream of Lake Purdy, neither the regulation by Lake Purdy Dam nor the withdrawals and return flows are sufficiently disruptive of streamflow at gaging stations to preclude hydrograph-separation analysis. The periods of record for stations listed in table 3 are the entire periods and are not segregated to correspond to periods of unregulated flow or periods of minimal withdrawals and return flows. Similarly, the mean-annual stream discharge listed for these stations was computed using discharge data for the entire period of record.

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 boundaries defining Subarea 7. 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 Cahaba River and its major tributary, Little Cahaba River in the southern part of Subarea 7. 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 three continuous-record gaging stations in the Cahaba River basin (table 5). 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, 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 one station representing discharge from carbonate rocks, was 0.307 $ft^3/s/mi^2$; and for two stations representing discharge from fractured carbonate rocks and porous media was, 0.821 $ft^3/s/mi^2$.

The mean-annual baseflow in the Cahaba River and tributaries where it enters Subarea 8 is estimated to be 763 ft^3/s (table 5). A profile of mean-annual baseflow in the Cahaba River and corresponding drainage area is shown in figure 12 and summarized in table 6. Estimated mean-annual baseflow in the Cahaba River is about 48 percent of the mean-annual stream discharge where the Cahaba River exits Subarea 7 and enters Subarea 8.

Table 5. Mean-annual stream discharge, estimated annual and mean-annual baseflow, and unit-area mean-annual baseflow at selected gaged streams in the Cahaba River basin, Subarea 7

[F, fracture-conduit aquifer in clastic rocks; S, solution-conduit aquifer in carbonate rocks; P, porous-media aquifer]

Station number	Station name	Type of stream	Drainage area (square miles)	Major aquifer type	Recession index: Winter (days)	Recession index: Summer (days)	Water year	Flow conditions	Mean-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)
02423500	Cahaba River near Acton, Ala.	regional	230	F,S	62.3	43.4	1944	Low	[6/]311	38.3	70.7	0.307
							1950	Average	233	54.9		
							1946	High	537	119		
02423800	Little Cahaba River near Brierfield, Ala.	tributary	148	P,F,S	70	50	1960	Low	149	115	133	.899
							1969	Average	190	125		
							1964	High	234	158		
02424000	Cahaba River at Centreville, Ala.	regional	1,027	P,F,S	71	49	1931	Low	831	490	763	.743
							1958	Average	1,551	750		
							1949	High	2,827	1,050		
Drainage area and mean-annual baseflow exiting Subarea 7			**1,027**							**763**		

1/ From U.S. Geological Survey data reports, for example: U.S. Geological Survey (1963).
2/ Estimated using the SWGW 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.
6/ The mean-annual stream discharge is skewed high by a period of high runoff. The median-daily discharge in 1944 is about 25 ft^3/s, which corresponds to a low-flow year.

Table 6. Estimated mean-annual baseflow at selected gaged streams in Subarea 7
[—, not applicable]

Station number or estimation site	Station name	Drainage area (square miles)	Mean-annual stream discharge[1/] (cubic feet per second)	Mean-annual baseflow (cubic feet per second)	Unit-area mean-annual baseflow[2/] (cubic feet per second per square mile)
02423500	Cahaba River near Acton, Ala.	230	318	70.7	0.307
02423800	Little Cahaba River near Brierfield, Ala.	148	195	133	.899
02424000	Cahaba River at Centreville, Ala.	1,027	1,598	763	.743
Cumulative drainage area, stream discharge, and estimated mean-annual baseflow, Cahaba River basin, Subarea 7		**1,027**	**1,598**	**763**	—

[1/]From table 3.
[2/]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.

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 continuous-record gaging stations during the later drought periods were assumed to provide a quantitative estimate of drought flow from Subarea 7 into Subarea 8. Where available, streamflow data for a day or an interval of a few days were compiled.

Estimated and measured streamflow near the end of the 1941, 1954, and 1986 drought years at selected sites on the Cahaba 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 in the Cahaba River. Estimated streamflows where the Cahaba River exits Subarea 7 into Subarea 8 near the end of the 1941, 1954, and 1986 droughts were 188, 124, and 169 ft^3/s, respectively; and the average streamflow (table 11) was 160 ft^3/s.

Table 7. Stream discharge during the month of October of the drought of 1941, Subarea 7

Station number	Station name	Type of stream	Drainage area (square miles)	Date	Stream discharge[1/] (cubic feet per second)	Unit-area discharge[2/] (cubic feet per second per square mile)
02423500	Cahaba River near Acton, Ala.	regional	230	10/23/41	6.7	0.029
02424000	Cahaba River at Centreville, Ala.[3/]	regional	1,027	10/22/41	188	.183

[1/]Daily mean discharge.
[2/]Discharge divided by the drainage area.
[3/]Represents Cahaba River basin in Subarea 7.

Table 8. Stream discharge during the month of September of the drought of 1954, Subarea 7

Station number	Station name	Type of stream	Drainage area (square miles)	Date	Stream discharge[1/] (cubic feet per second)	Unit-area discharge[2/] (cubic feet per second per square mile)
02423500	Cahaba River near Acton, Ala.	regional	230	09/29/54	0	0
02424000	Cahaba River at Centreville, Ala.[3/]	regional	1,027	09/30/54	124	.121

[1/]Daily mean discharge.
[2/]Discharge divided by the drainage area.
[3/]Represents Cahaba River basin in Subarea 7.

Table 9. Stream discharge during the month of July of the drought of 1986, Subarea 7

Station number	Station name	Type of stream	Drainage area (square miles)	Date	Stream discharge[1/] (cubic feet per second)	Unit-area discharge[2/] (cubic feet per second per square mile)
02423500	Cahaba River near Acton, Ala.	regional	230	07/10/86	7.6	0.033
02424000	Cahaba River at Centreville, Ala.[3/]	regional	1,027	07/10/86	169	.165

[1/]Daily mean discharge.
[2/]Discharge divided by the drainage area.
[3/]Represents Cahaba River basin in Subarea 7.

Baseflow near the end of these droughts averaged about 21 percent of the estimated mean-annual baseflow to the surface-water system in Subarea 7 (ranged from about 16 to 25 percent for individual drought years). Streamflow profiles for the Cahaba River were plotted from estimated and measured streamflow at selected stations for the 1941, 1954, and 1986 drought years (fig. 12). In relation to the conceptual model of ground-water flow and stream-aquifer relations, the mean-annual baseflow estimated for the Cahaba 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 Cahaba River basin near the end of the 1941, 1954, and 1986 droughts are summarized in tables 10 and 11 and plotted in figure 12.

Table 10. Relations among mean-annual stream discharge, estimated mean-annual baseflow, and drought flow in the Cahaba River, Subarea 7
[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, in cubic feet per second				
			Mean-annual stream discharge[1/]	Estimated mean-annual baseflow[2/]	Drought[3/] of 1941	Drought[4/] of 1954	Drought[5/] of 1986
02423500	Cahaba River near Acton, Ala.	230	318	70.7	6.7	0	6.4
02423800	Little Cahaba River near Brierfield, Ala.	148	195	133	—	—	—
02424000	Cahaba River at Centreville, Ala[5/]	1,027	1,598	763	188	124	169
Cumulative drainage area, estimated stream discharge, and baseflow in Subarea 7		**1,027**	**1,598**	**763**	**188**	**124**	**169**

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

Table 11. Estimated drought flows and mean-annual baseflow in the Cahaba River and tributaries; and ratio of average drought flow to mean-annual baseflow, Subarea 7

	Drought flows, in cubic feet per second				Mean-annual baseflow[1/] (in cubic feet per second	Ratio of average drought flow to mean-annual baseflow (percent)
	1941[2/]	1954[3/]	1986[4/]	Average drought flow		
Flow exiting Subarea 7	188	124	169	160[5/]	763	21

[1/]From tables 6 and 10.
[2/]From table 7.
[3/]From table 8.
[4/]From table 9.
[5/]Average drought flow exiting Subarea 7, 1941, 1954, and 1986.

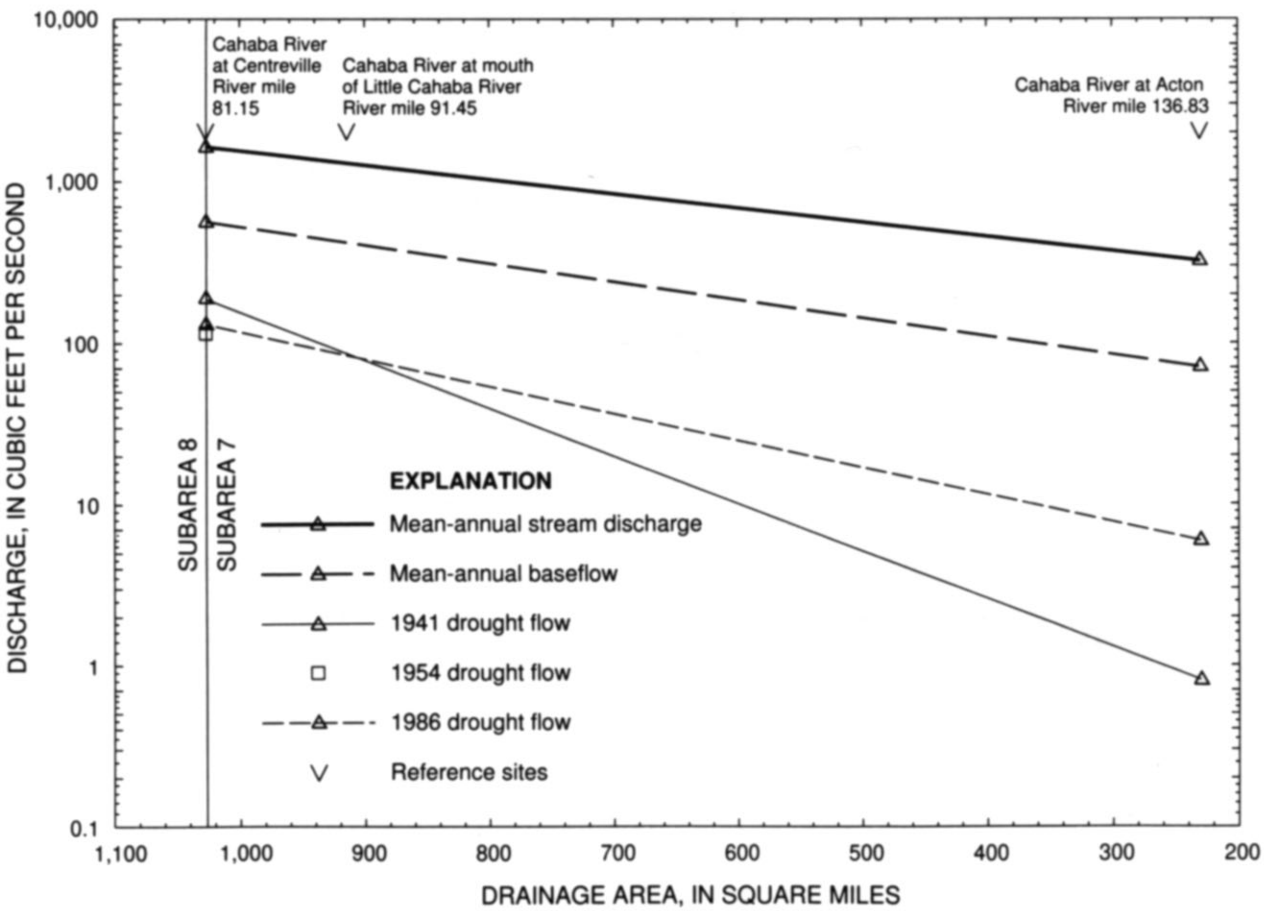

Figure 12. Relations among mean-annual stream discharge, mean-annual baseflow, and drought flow, Cahaba River, Subarea 7. [Note: Triangles represent estimated or measured discharges; lines connecting triangles represent interpolated discharge. River mile is measured upstream from the mouth of the Cahaba River.]

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.

Ground-water use of about 15.5 ft^3/s in 1990 in Subarea 7 represented 2.0 percent of the mean-annual baseflow in the surface-water system and 9.7 percent of the average of the 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 12.5 percent of the minimum drought flow. Local problems of ground-water overuse were not identified. However, long-term water-level data at wells in Subarea 7 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 drought flow, Subarea 7

Ground-water use, 1990 (cubic feet per second)	Baseflow to the Cahaba 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
[1/]15.5	763	[2/]160	[3/]124	2.0	9.7	12.5

[1/]From Baker and Mooty (1993).
[2/]Average drought flow exiting Subarea 7, 1941, 1954, and 1986.
[3/]Minimum stream discharge during 1986 drought.

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 7 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 only into 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 7. 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 Paleozoic-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 Subarea 7. 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 50-100 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 Cahaba River basin in Alabama, Subarea 7 of the ACF-ACT River basins, and to estimate the possible effects of increased ground-water use in the basin.

Subarea 7 encompasses about 1,030 square miles in Alabama. Subarea 7 is bounded to the east by the Coosa River basin (Subarea 6) and to the south by the lower part of the Cahaba River basin (Subarea 8). To the west, the study area is bounded by the Black Warrior River basin, which is outside of the ACF-ACT study area.

Rocks of the Piedmont Province generally are subdivided into a two-component aquifer system composed of a fractured crystalline-rock aquifer characterized by little or no primary porosity or permeability, and an overlying, weathered regolith composed of soil, alluvium, colluvium, and saprolite, that responds hydraulically as a porous-media aquifer. The Valley and Ridge Province is characterized by fracture- and solution-conduit aquifers, similar in some ways to aquifers in the Piedmont Province. Fracture-conduit aquifers are predominant in the well-consolidated sandstone and shale of Paleozoic age; and solution-conduit aquifers are predominant in the carbonate rocks of Paleozoic age. The Coastal Plain is characterized by southward-dipping, poorly consolidated Cretaceous-age sand, gravel, and clay deposits of fluvial and marine origin.

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 Cahaba River. 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 7 was estimated using an automated hydrograph-separation method. Mean-annual baseflow to the Cahaba River and tributaries was estimated to be about 763 cubic feet per second where the Cahaba River enters Subarea 8 at Centreville, Ala. Mean-annual baseflow of the Cahaba River represents about 48 percent of the mean-annual stream discharge at Centreville.

Stream discharges for selected sites on the Cahaba 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 baseflow near the end of these droughts ranged from about 16 to 25 percent for individual drought years and averaged about 21 percent of the estimated mean-annual baseflow in Subarea 7.

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, particularly water-use 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 7.

The potential exists for the development of ground-water resources on a regional scale throughout Subarea 7. Ground-water use in 1990 represented about 2 percent of the estimated mean-annual baseflow, and about 9.7 percent of average drought baseflow during the droughts of 1941, 1954, and 1986. Because ground-water use in Subarea 7 represents a relatively minor percentage of ground-water recharge, even a large increase in ground-water use in Subarea 7 probably would have little effect on the quantity of ground water and surface water in the Subarea. Long-term ground-water level declines were not observed; however, long-term water-level data at wells in Subarea 7 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 Cahaba River basin, Subarea 7, of the ACF-ACT River basins. In Subarea 7, 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 7.

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 7.

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