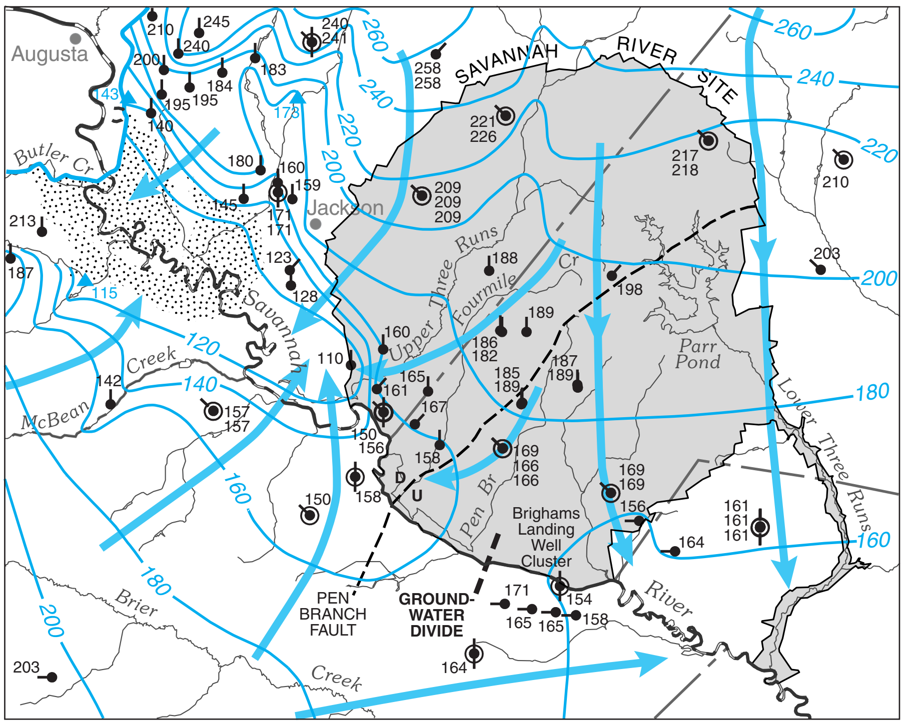
GROUND-WATER LEVELS, PREDEVELOPMENT GROUND-WATER FLOW, AND STREAM-AQUIFER RELATIONS IN THE VICINITY OF THE SAVANNAH RIVER SITE, GEORGIA AND SOUTH CAROLINA

U.S GEOLOGICAL SURVEY



Prepared in cooperation with the

U.S. DEPARTMENT OF ENERGY

GEORGIA DEPARTMENT OF NATURAL RESOURCES
ENVIRONMENTAL PROTECTION DIVISION
GEORGIA GEOLOGIC SURVEY

Water-Resources Investigations Report 97-4197

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By John S. Clarke and Christopher T. West

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U.S. DEPARTMENT OF THE INTERIOR

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CONVERSION FACTORS AND VERTICAL DATUM

CONVERSION FACTORS

Multiply	by	to obtain
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
inch per year (in/yr)	25.4	millimeter per year
square mile (mi^2)	2.590	square kilometer
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
million gallons per day (Mgal/d)	.04381	cubic meter per second
cubic foot per second per square mile ($(ft^3/sec)/mi^2$)	.01093	cubic meter per second per square kilometer

VERTICAL DATUM

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD 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.

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ABSTRACT

Ground-water levels, predevelopment ground-water flow, and stream-aquifer relations in the vicinity of the U.S. Department of Energy Savannah River Site, Georgia and South Carolina, were evaluated as part of a cooperative study between the U.S. Geological Survey, U.S. Department of Energy, and Georgia Department of Natural Resources. As part of this evaluation: (1) ground-water-level fluctuations and trends in three aquifer systems in sediment of Cretaceous and Tertiary age were described and related to patterns of ground-water use and precipitations; (2) a conceptual model ofthe stream-aquifer flow system was developed; (3) the predevelopment ground-water flow system, configuration of potentiometric surfaces, trans-river flow, and recharge-discharge relations were described; and (4) stream-aquifer relations and the influence of river incision on ground-water flow and stream-aquifer relations were described.

The 5,147-square mile study area is located in the northern part of the Coastal Plain physiographic province of Georgia and South Carolina. Coastal Plain sediments comprise three aquifer systems consisting of seven aquifers that are separated hydraulically by confining units. The aquifer systems are, in descending order: (1) the Floridan aquifer system—consisting of the Upper Three Runs and Gordon aquifers in sediments of Eocene age; (2) the Dublin aquifer system—consisting of the Millers Pond, upper Dublin, and lower Dublin aquifers in sediments of Paleocene-Late Cretaceous age; and (3) the Midville aquifer system—consisting of the upper Midville and lower Midville aquifers in sediments of Late Cretaceous age.

The Upper Three Runs aquifer is the shallowest aquifer and is unconfined to semi-confined throughout most of the study area. Ground-water levels in the Upper Three Runs aquifer respond to a local flow system and are affected mostly by topography and climate. Ground-water flow in the deeper, Gordon aquifer and Dublin and Midville aquifer systems is characterized by local flow near outcrop areas to the north, changing to intermediate flow and then regional flow downdip (southeastward) as the aquifers become more deeply buried. Water levels in these deeper aquifers show a pronounced response to topography and climate in the vicinity of outcrops, and diminish southeastward where the aquifer is more deeply buried. Stream stage and pumpage affect ground-water levels in these deeper aquifers to varying degrees throughout the study area.

The geologic characteristics of the Savannah River alluvial valley substantially control the configuration of potentiometric surfaces, ground-water-flow directions, and stream-aquifer relations. Data from 18 shallow borings indicate incision into each aquifer by the paleo Savannah River channel and subsequent infill of permeable alluvium, allowing for direct hydraulic connection between aquifers and the Savannah River along parts of its reach. This hydraulic connection may be the cause of large ground-water discharge to the river near Jackson, S.C., where the Gordon aquifer is in contact with Savannah River alluvium, and also the cause of lows or depressions formed in the potentiometric surfaces of confined aquifers that are in contact with the alluvium. Ground water in these aquifers flows toward the depressions. The influence of the river is diminished downstream where the aquifers are deeply buried, and upstream and downstream ground-water flow is possibly separated by a water divide or “saddle”. Water-level data indicate that saddle features probably exist in the Gordon aquifer and Dublin aquifer system, and also might be present in the Midville aquifer system.

Ground-water levels respond seasonally or in long term to changes in precipitation, evapotranspiration, pumpage, and river stage. Continuous water-level data and water-levels measured in a network of 271 wells during the Spring (May) and Fall (October) in 1992, indicate that seasonal water-level changes generally are less than 4 feet, and that larger changes occur near supply wells. Long-term data (more than 10 years of record) from 283 wells indicate that water levels in most aquifers declined during some period prior to 1993. Although most declines were less than 15 feet and were limited to scattered areas influenced by supply wells, widespread declines of as much as 59 feet occurred in the lower Midville aquifer in Richmond County, Georgia.

Water-level data at well-cluster sites indicate that in the vicinity of major ground-water divides, head decreases with depth; and in the vicinity of a regional drain, such as the Savannah River, head increases with depth. Although this vertical head distribution holds true over much of the study area, water-level data indicate that the Gordon, Millers Pond, and lower Dublin aquifers are apparent hydrologic “sinks” in parts of the study area, indicating a potential for vertical leakage from both above and below. Reasons for anomalously low heads in these three aquifers are unclear, but probably are related to: (1) subsurface pinchout of the aquifer, that influences flow patterns in the ground-water flow system, (2) hydraulic connection of the aquifer to river alluvium and associated large ground-water discharge, or (3) water-level declines as a result of pumpage.

Estimated average ground-water discharge to the Savannah River based on data from 1941, 1942, and 1949, was 1,220 cubic feet per second; of which 46 percent was from the local flow system, 41 percent was from the intermediate flow system, and 13 percent was from the regional flow system. Estimated ground-water discharge during the 1954 and 1986 droughts indicates that the contribution from the intermediate flow system decreased in a downstream direction, and that most ground-water discharge was from the local flow system. The decreased contribution from the intermediate flow system in downstream reaches may be related to a downdip (downstream) thickening of confining units underlying the stream, that reduces upward leakage of water.

Flow lines based on contours of the estimated predevelopment potentiometric surface of the confined Dublin and Midville aquifer systems, suggest ground-water flow beneath the floodplain of the Savannah River from one side of the river to the other side. This phenomenon, termed trans-river flow, is assumed to occur for a short distance into Georgia prior to discharge into the Savannah River alluvial valley. Trans-river flow is influenced by changes in hydraulic gradient (ground-water levels) near the river. Trans-river flow cannot be inferred from contours of the potentiometric surface of the Gordon or Upper Three Runs aquifers.

INTRODUCTION

The U.S. Department of Energy (DOE), Savannah River Site (SRS) near Aiken, S.C. (fig. 1a), has manufactured nuclear materials for the National defense since the early 1950's. A variety of hazardous materials including radionuclides, volatile organic compounds, and heavy metals, are either disposed of or stored at several locations at the SRS. Contamination of ground water has been detected at several locations within the site (fig. 1b). Concern has been raised by State of Georgia officials over the possible migration of ground water contaminated with hazardous materials, from the SRS through the aquifers underlying the Savannah River (trans-river flow), into Georgia.

The U.S. Geological Survey (USGS), in cooperation with the DOE and Georgia Department of Natural Resources (DNR), is conducting a study to describe ground-water flow and quality near the Savannah River, and to identify the potential for or possible occurrence of trans-river flow (trans-river flow study). Stream-aquifer relations are being evaluated to determine the potential for ground-water movement beneath, or discharge into, the Savannah River. Overall objectives of the trans-river flow study are to: (1) identify ground-water-flow paths, particularly in the vicinity of the Savannah River; and (2) quantitatively describe ground-water flow and stream-aquifer relations. To help determine directions of ground-water flow in the SRS region, potentiometric-surface maps were prepared and water-level fluctuations evaluated for aquifers in sediments of Cretaceous and Tertiary age.

Purpose and Scope

This report presents data and information regarding ground-water levels, predevelopment ground-water flow, and stream-aquifer relations to evaluate (1) flow conditions near the Savannah River and (2) the potential for trans-river flow beneath the river. This information also supports ongoing ground-water modeling investigations in the study area. The report describes:

- seasonal and long-term ground-water-level fluctuations and trends for three aquifer systems in sediments of Cretaceous and Tertiary age and relates these to ground-water use and precipitation;
- conceptual ground-water flow and stream-aquifer relations;
- predevelopment ground-water flow system, the configuration of potentiometric surfaces, trans-river flow, and vertical head relations; and
- stream-aquifer relations and the influence of river incision on ground-water flow and stream-aquifer relations.

Data utilized as part of this evaluation include historical and current water-level data from 516 wells, including data from 21 wells constructed at five locations for this study, and water levels measured in selected wells during Spring and Fall of 1992; geologic data collected from 18 shallow auger borings in the Savannah River alluvial valley; precipitation data from two Georgia and two South Carolina sites; stream-stage data from 61 sites; and historical ground-water use data.

Description of Study Area

The 5,147-square mile (mi^2) study area includes the Savannah River Site and adjacent parts of Georgia and South Carolina (fig. 1a). In Georgia, the study area includes all or parts of Richmond, Burke, Screven, Jenkins, Jefferson, Glascock, McDuffie, Warren, and Columbia Counties. In South Carolina, the study area includes all or parts of Aiken, Barnwell, Allendale, Edgefield and Saluda Counties.

Silviculture and agriculture are the predominant land uses in the study area; pine timber, cotton, and soybeans are the major crops. Kaolin is mined in parts of the study area. The largest cities in the study area are Augusta, Ga.—population 44,639 in 1990; and Aiken, S.C.—population 19,872 in 1990 (U.S. Department of Commerce, Bureau of the Census, 1991).

The SRS encompasses about 300 mi^2, or 6 percent of the study area, and lies in parts of Aiken, Barnwell, and Allendale Counties, S.C. The SRS has manufactured tritium and other nuclear materials for the National defense since the early 1950's.

Physiography

The study area is in the northern part of the southeastern Coastal Plain of Georgia and South Carolina (fig. 1a). The Fall Line marks the boundary between Coastal Plain sediments and crystalline rocks of the Piedmont Province and forms the approximate northern limit of the study area. Relief generally is highest near the Fall Line and is progressively less toward the south and east. Altitudes range from 650 feet (ft) near the Fall Line to less than 100 ft in the southern part of the study area and in the valleys of major streams such as the Savannah River or Brier Creek. Along the western bank of the Savannah River in southern Richmond County, and most of Burke County, Ga., a steep bluff is present. Relief along this bluff is as much as 160 ft from the top of the bluff to the valley floor.

The Coastal Plain is well to moderately dissected by streams and has a well-developed dendritic stream pattern. Streams that flow over the relatively softer Coastal Plain sediments develop wider floodplains and greater meander frequency than streams that flow over

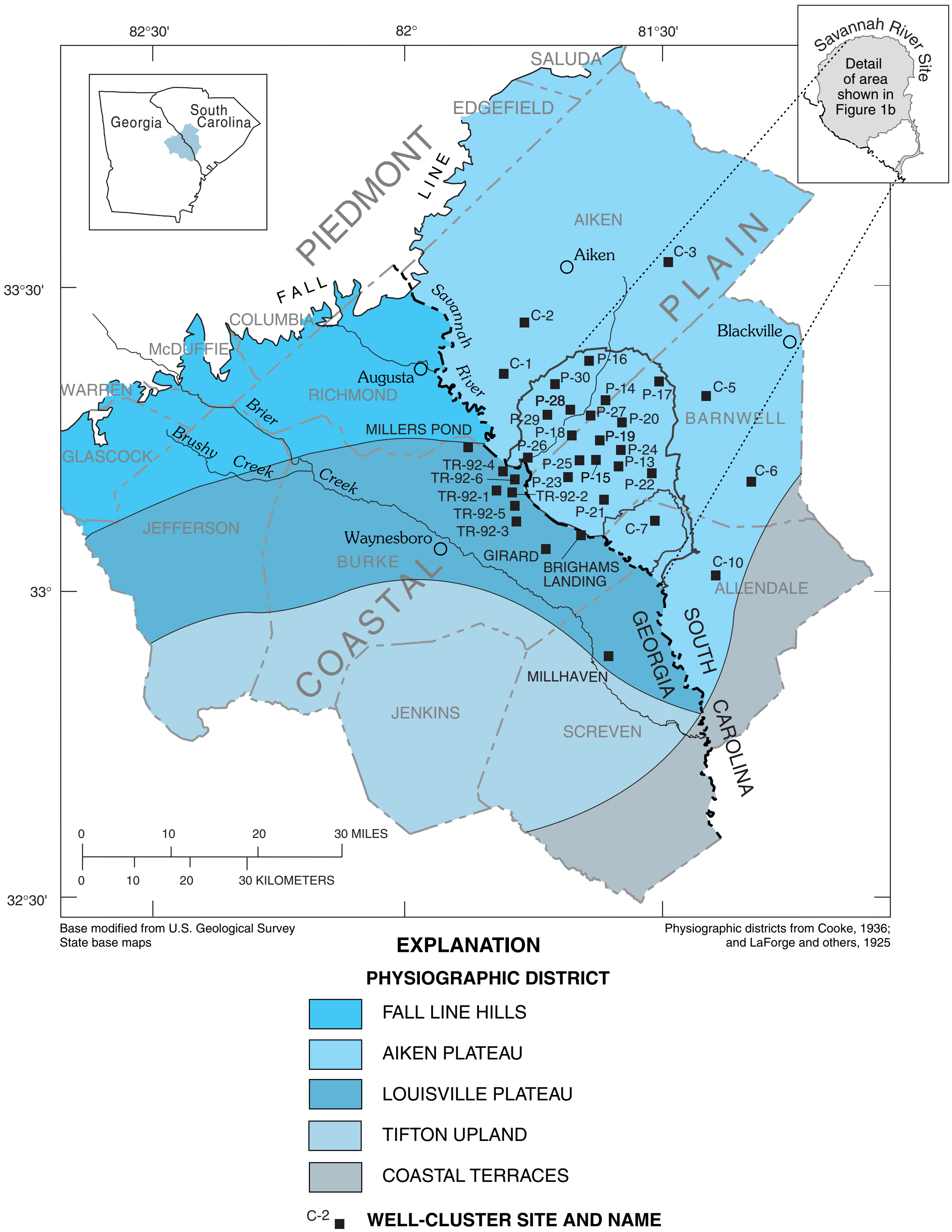


Figure 1a. Location of study area, Savannah River Site, well-cluster sites, and physiographic districts in Georgia and South Carolina.

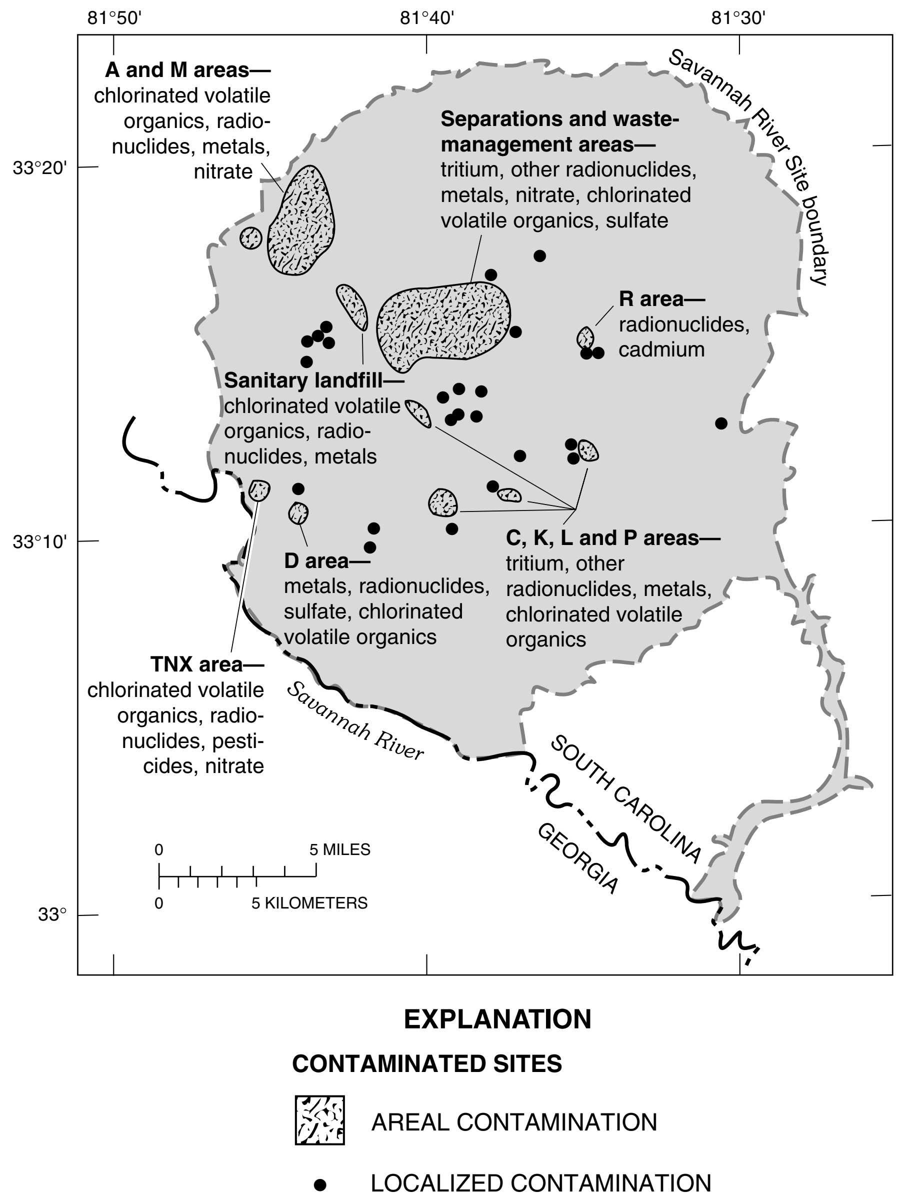


Figure 1b. Areal and local ground-water contamination at the Savannah River Site, South Carolina (modified from Westinghouse Savannah River Company, 1995).

hard crystalline rocks of the Piedmont (Clark and Zisa, 1976). The floodplains near the principal rivers, such as the Savannah River, have a wide expanse of swamp bordering both sides of the channel.

In the study area, the Coastal Plain is divided into five physiographic districts: the Coastal Terraces, Tifton Upland, Louisville Plateau, Aiken Plateau, and Fall Line Hills. The following descriptions are from Cooke (1936) for South Carolina, and LaForge and others (1925) for Georgia.

The Coastal Terraces (fig. 1a), in southern Screven County, Ga., and Allendale County, S.C., are characterized by flat topography with land-surface altitudes of generally 100 ft or less. The terraces generally are parallel to the present coastline and represent the shoreline and sea bottom left by early Pleistocene advances and retreats of the sea. The terraces form a step-like progression of decreasing altitudes toward the sea.

The Tifton Upland (fig. 1a), in Jenkins, northwestern Screven, southwestern Burke, and southern Jefferson Counties, Ga., is characterized by rolling hills and both gentle and deeply incised valleys. In this area, land-surface altitudes range from 100 to 200 ft.

The Louisville Plateau (fig. 1a), in northeastern Screven, northern Burke, and central Jefferson Counties, Ga.; and Aiken Plateau, in Aiken, Barnwell, and northern Allendale Counties, S.C., are characterized by broad interfluvial areas having narrow, steep-sided valleys and local relief of as much as 300 ft. The altitude in the Louisville Plateau generally ranges from 200 to 300 ft; whereas in the Aiken Plateau, the altitude generally ranges from 200 to 650 ft. The Louisville Plateau and Aiken Plateau are characterized by numerous undrained depressions and by Carolina Bays.

The Fall Line Hills (fig. 1a), in Richmond and northern Jefferson Counties, Ga., are characterized by rolling hills and valleys that generally correspond to the outcrop belt of Cretaceous sediments—altitudes range from 300 to more than 500 ft. The Fall Line Hills are bounded to the north by the Fall Line, marking the northernmost extent of the Coastal Plain.

Climate

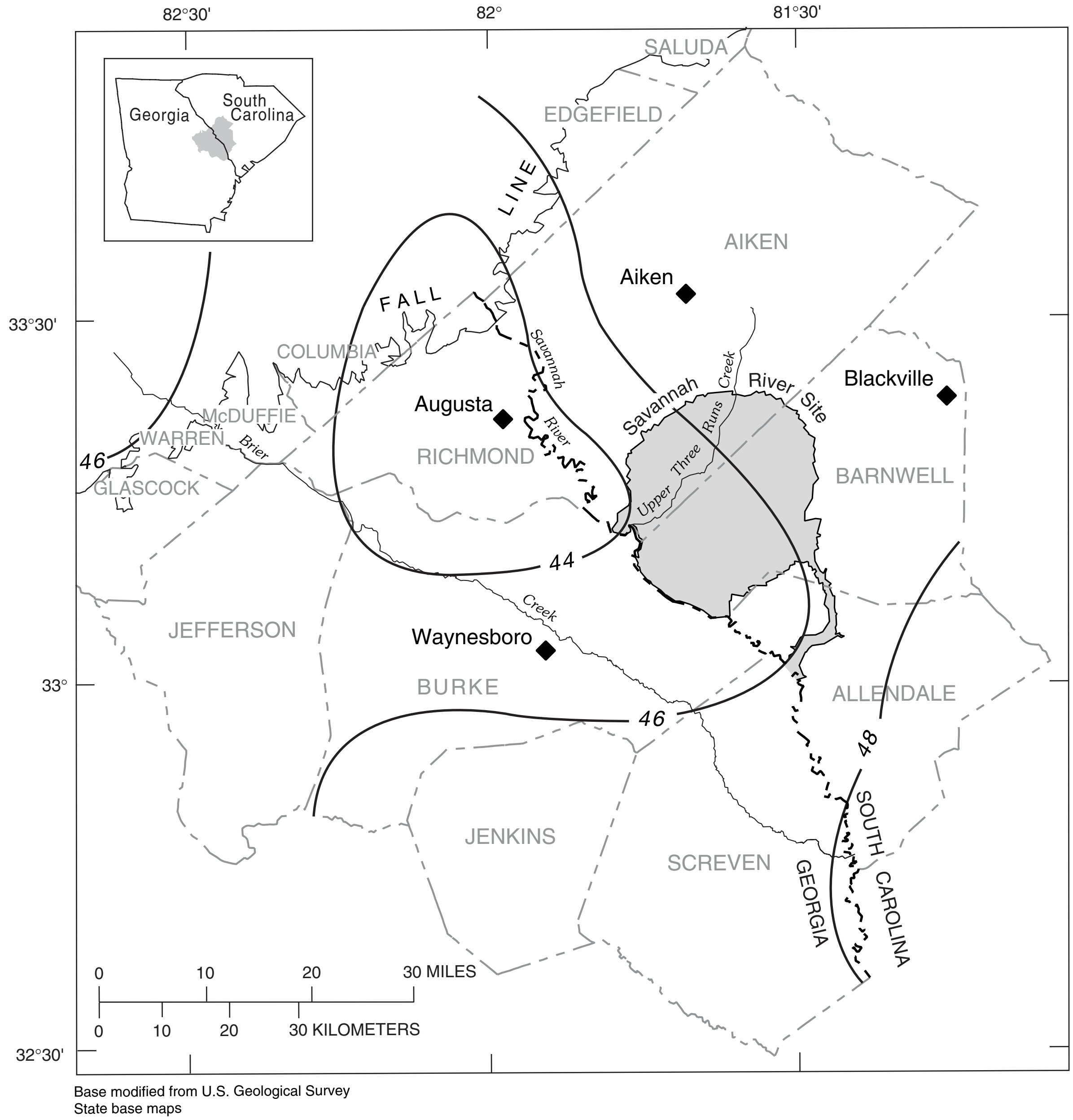
The study area is characterized by a relatively mild climate with warm, humid summers and mild winters. Climatic conditions in the study area are typified by the National Weather Service station at Augusta, Ga. The average annual temperature at Augusta during 1961-90 was 63.2 ° F, ranging from a monthly low of 43.9 ° F in January to a high of 80.8 ° F in July (National Oceanic and Atmospheric Administration, 1995). During the same period, average annual precipitation at Augusta was 44.66 inches, ranging from an average low of 2.48 inches during November to an average high of 4.65 inches during March. Precipitation is highest in the winter, when continental storm fronts from the west move through the area; and during July and August, when convective thunderstorms are prevalent. Average annual precipitation in the study area (fig. 2) for the period 1941-70, ranged from less than 44 inches in Richmond County, Ga., to greater than 48 inches in southern Screven County, Ga., and Allendale County, S.C. (Faye and Mayer, 1990).

Drainage and Runoff

The Savannah River is the major surface-water drain in the study area and forms the State line between Georgia and South Carolina (fig. 3). The river drains an area of about 10,580 mi^2 and empties into the Atlantic Ocean near Savannah, Ga. Major tributaries in the study area to the Savannah River are, in downstream order; Horse Creek, Hollow Creek, Upper Three Runs Creek, Fourmile Branch, Pen Branch, Steel Creek, and Lower Three Runs in South Carolina; and Butler Creek, Spirit Creek, McBean Creek, and Brier Creek in Georgia.

The Thurmond Lake storage reservoir upstream of Augusta, Ga.—about 30 river mi northwest of the northern boundary of the study area—was impounded in December 1951 and regulates the Savannah River in the study area. The USGS maintains streamflow-gaging stations on the Savannah River at Augusta, Ga. (02197000), Jackson, S.C., (02197320), and Burtons Ferry Bridge near Millhaven, Ga., (02197500) (fig. 3). During 1883-1951, prior to flow regulation, the mean-annual stream discharge at Augusta was 10,640 cubic feet per second (ft^3/s) (Stokes and McFarland, 1996). After flow regulation, the mean-annual stream discharge at Augusta during 1952-95 was 9,408 ft^3/s.

During 1941-70, the average annual runoff in Georgia (fig. 3) ranged from less than 0.9 cubic feet per second per square mile [$(ft^3/s)/mi^2$] of drainage area in southern Screven, Jenkins, Burke and Jefferson Counties, and in northern Richmond and Jefferson Counties; to greater than 1.1 $(ft^3/s)/mi^2$ in eastern Richmond and Burke Counties (Faye and Mayer, 1990).

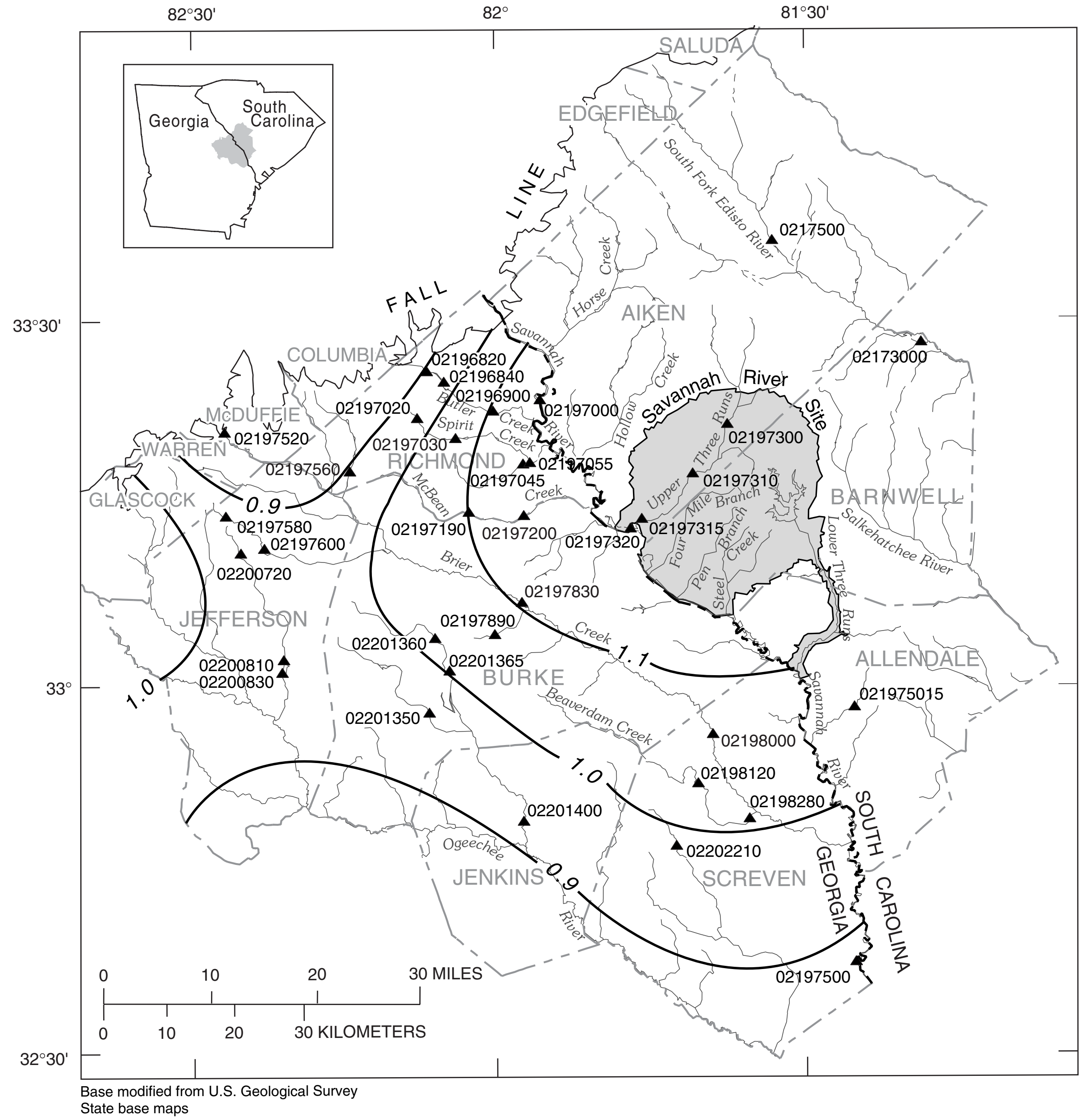


EXPLANATION

—— 44 —— **LINE OF EQUAL MEAN-ANNUAL RAINFALL, 1941–70—** INTERVAL 2 INCHES

Augusta ◆ **PRECIPITATION-MONITORING SITE AND IDENTIFICATION**

Figure 2. Mean-annual rainfall in study area, 1941–70, and locations of precipitation-monitoring sites (modified from Faye and Mayer, 1990).



EXPLANATION

—— *1.0* —— **LINE OF EQUAL MEAN-ANNUAL RUNOFF, 1941–70—** INTERVAL 0.1 CUBIC FOOT PER SQUARE MILE OF DRAINAGE AREA

▲02198120 **STREAMFLOW-GAGING STATION AND IDENTIFICATION NUMBER**

Figure 3. Mean-annual runoff in Georgia part of study area, 1941–70, and locations of selected streamflow-gaging stations (modified from Faye and Mayer, 1990).

Previous Investigations

This report is one of a series of reports describing results of the SRS trans-river flow study. Other reports prepared for the study have provided data and interpretations supportive of the interpretation of ground-water flow and stream-aquifer relations in the vicinity of SRS. These reports describe the following:

- surficial geology (Hetrick, 1992);
- lithostratigraphy of uppermost Cretaceous and lower Tertiary sediments in eastern Burke County, Ga. (Huddlestun and Summerour, 1996);
- hydrogeologic data and aquifer interconnection at well-cluster sites (Clarke and others, 1994, 1996; Leeth and others, 1996);
- hydraulic properties of aquifers (Snipes and others, 1995a,b)
- shallow subsurface geology of the Savannah River alluvial valley (Leeth and Nagle, 1996);
- selected well data (Harrelson and others, 1997);
- estimates of ground-water discharge to selected streams (Atkins and others, 1996); and
- hydrogeologic framework of Coastal Plain sediments (Falls and others, 1997).

In addition to these reports, two major investigations of stream-aquifer relations near the SRS have been conducted. Aucott, Meadows, and Patterson (1987) estimated regional ground-water discharge to large streams in the upper Coastal Plain; and Faye and Mayer (1990) evaluated ground-water flow and stream-aquifer relations in the northern part of the Coastal Plain including the Savannah River basin.

Recent investigations describing the hydrogeology of Coastal Plain sediments near the SRS include Aadland and others (1992; 1995). Recent geologic investigations include Hetrick (1992), who mapped surficial geology in the Wrens-Augusta area of Georgia; Prowell (1994), who mapped surficial geology in the area of the Barnwell 30-minute by 60-minute quadrangle in South Carolina and Georgia; and Fallaw and Price (1995), who described Cretaceous and Tertiary stratigraphy of the SRS and vicinity.

Numerous reports have been published about the hydrogeology of Coastal Plain sediments in Georgia near the SRS. These include descriptions of the geology and ground-water resources of Burke, Columbia, Glascock, Jefferson, McDuffie, Richmond, and Warren Counties (LeGrand and Furcron, 1956); the geohydrology of the Jacksonian aquifer (Vincent, 1982); the hydrogeology of the Dublin and Midville aquifer systems (Clarke and others, 1985); the hydrogeology of the Gordon aquifer system (Brooks and others, 1985); and the hydrogeology of Coastal Plain strata in Richmond and northern Burke Counties (Gorday, 1985). Summerour and others (1994) conducted an evaluation of the occurrence of tritium in shallow ground-water in Burke County, Ga. The effects of suspected Late Cretaceous and Cenozoic faulting on ground-water flow near the Savannah River in Georgia and South Carolina were evaluated by Faye and Prowell (1982). Aquifer hydraulic characteristics were described in Aucott and Newcome (1986), Faye and McFadden (1986), and Newcome (1993).

Other reports describe the geology and occurrence of ground water at the SRS and vicinity in South Carolina, including investigations by Siple (1957, 1967), and later by Logan and Euler (1989). Reports that specifically describe the subsurface hydrogeology of the SRS include Marine and Root (1975), and Root (1983) on ground-water flow; Marine and Root (1978) on Claiborne age sediments; Aadland and Bledsoe (1990) on the aquifers in Cretaceous and Tertiary sediments; Marine (1966; 1967a,b; 1979) and Christl (1964) on the crystalline bedrock underlying the SRS. The geohydrology of the Defense Waste Processing Facility at the SRS is discussed in reports by Root (1980; 1981); Parizek and Root (1986); Cook (1986); and Dennehy and others (1989). Cahill (1982) and Dennehy and McMahon (1987) describe the hydrology and geology of the low-level radioactive solid waste burial site near the town of Barnwell, S.C., south of the SRS.

Geohydrologic data from well-cluster sites near SRS are described in several reports. A total of 18 cluster-well localities on the SRS are documented in reports by Bledsoe (1984; 1987; 1988). Geohydrologic data from 5 additional cluster-well localities outside the perimeter of the SRS are presented in reports by Logan (1987), Kuntz and Griffin (1988), Kuntz and others (1989), and Gellici (1991). Borehole geophysical and other data from 23 cluster-well localities were used by Aadland and Bledsoe (1990) to correlate aquifers and confining units at the SRS and surrounding areas. Bledsoe and others (1990) and Aadland and others (1992; 1995) characterized the hydrogeology of the aquifers at the SRS using data collected at the well-cluster-site localities.

Regional hydrogeologic investigations in the study area include studies conducted as part of the U.S. Geological Survey Regional Aquifer System Analysis program. Renken and others (1989) described the configuration, extent, geologic age, and lithic character of the major aquifers and confining units that collectively comprise the southeastern Coastal Plain aquifer system. Faye and Mayer (1997) developed a digital model of regional ground-water flow through major southeastern Coastal Plain clastic aquifers in eastern Alabama, Georgia, and western South Carolina. A similar modeling investigation conducted in South Carolina is described in reports by Aucott (1988), Aucott and Speiran (1985), Aucott, Davis, and Speiran (1987), and Speiran and Aucott (1991).

Ground-water-level data for selected wells in Georgia have been described annually in reports by the USGS since 1977 (U.S. Geological Survey, 1978; Clarke and others, 1979; Mathews and others, 1980, 1981, 1982; Stiles and Mathews, 1983; Clarke and others, 1984, 1985, 1986, and 1987; Joiner and others, 1988, 1989; Peck and others, 1990, 1992, and 1993; Milby and others, 1991; Joiner and Cressler, 1994; Cressler and others, 1995; Cressler, 1996). Cressler (1996) included a discussion of ground-water conditions for 1995.

Methods of Study

Pertinent literature and hydrologic and geologic data for the trans-river flow study area were compiled from various sources, including reports and data files of the DOE, Westinghouse Savannah River Company, Inc., South Carolina Water Resources Commission, South Carolina Department of Health and Environmental Control, Georgia DNR, and USGS. Data tabulated included historical water levels, precipitation, stream discharge, and water use; hydraulic characteristics of aquifers; water chemistry; paleontology; geophysical logs; and core lithologic descriptions.

Water-level and stream-stage data were collected during 1991-92 as part of an inventory of wells and stream sites in Georgia and South Carolina adjacent to the Savannah River near the SRS. Data from 531 wells and 61 stream sites were added to the project data base as part of this effort. In September 1993, a field inventory of the Savannah River floodplain obtained data from six flowing wells critical for development of accurate potentiometric-surface maps. Where possible, floodplain wells were logged using borehole geophysics to verify well-construction features.

The literature and file search and well inventory indicated that additional geologic, hydrologic, and water-chemistry data were needed in the Savannah River floodplain and in the Georgia part of the study area to complete the objectives of the study. To provide these data, 21 wells were constructed at five locations—Millers Pond, Girard, Millhaven, Brighams Landing, and TR-92-6. Locations of well clusters installed for this study and other existing well clusters in the study area are shown in figure 1a. Data from these well clusters were presented in reports by Clarke and others (1994; 1996), Leeth and others (1996), and Harrelson and others (1997). Well-cluster sites were completed by several State and Federal agencies working in the trans-river flow study area and are designated as follows:

- *South Carolina Department of Natural Resources, Water Resources Division*—designated with the prefix “C-”, followed by a sequential site number;
- *Georgia DNR*—designated with the prefix “TR-92-”, followed by a sequential site number;
- *DOE at the SRS*—designated with the prefix “P-”, followed by a sequential site number; and
- *USGS for the trans-river flow study*—designated by geographic site name such as “Millers Pond”, “Girard”, and so forth.

Water levels were measured in selected wells in Georgia and South Carolina during the Spring and Fall of 1992 to determine seasonal fluctuations and provide data to construct potentiometric-surface maps. These data were combined with selected historical water-level data to construct potentiometric-surface maps that represent near predevelopment conditions in the major aquifers. The magnitude of seasonal water-level fluctuations was determined by comparing the difference in water levels between the Spring and Fall of 1992, and by evaluating data spanning several years from wells equipped with continuous water-level recorders. Long-term (greater than 10 years) water-level trends were determined for 274 wells using historical data.

Precipitation data collected at two Georgia and two South Carolina sites were compiled from historical data obtained from the Southeast Regional Climate Center, Columbia, S.C. (Milton Brown, Southeastern Regional Climatic Center, written commun., 1996). Historical ground-water use in the study area was determined using data from the USGS Water Use Data System (J.L. Fanning and K.H. Jones, U.S. Geological Survey, written commun., 1995); Georgia Cooperative Extension Service (Kerry Harrison, Georgia Cooperative Extension Service, written commun., 1995); and from historical data of fire-insurance underwriters (R.E. Faye, U.S. Geological Survey, written commun., 1985).

To characterize the geologic characteristics of the Savannah River alluvial valley, including the degree of paleo-river channel incision into aquifers and confining units, 18 shallow auger borings were completed during September 1993. From these data, a map was developed showing the approximate subsurface extent of hydrogeologic units beneath Savannah River alluvium. Leeth and Nagle (1996) presented an evaluation of the shallow subsurface geology of the Savannah River alluvial valley south of Augusta, Ga., and adjacent to the SRS.

A comprehensive geographic information system data base was developed to facilitate data processing, data storage, and data analysis. Data from existing digital data bases were compiled, reformatted, and added to the project data base including: (1) data from the USGS National Water Information System–Ground-Water Site Inventory System; (2) data from the SRS well inventory data base; (3) data from an archived SRS well-inventory data base that included wells inventoried during the 1950's and 1960's; and (4) data from Georgia Power Company Plant Vogtle in Burke County, Ga. Altitudes of aquifer tops and bottoms (W.F. Falls, U.S. Geological Survey, written commun., 1995) were compared to the altitude of the open interval in each well in order to assign water levels in a well to a specific aquifer or aquifer system. The project data base includes data for 3,800 wells, including well construction, aquifer tapped, water levels, aquifer hydraulic characteristics, and water use. Harrelson and others (1997) provided a listing of ground-water data from selected wells in the project data base.

Well-Numbering System

Wells located in Georgia are numbered according to a system based on the USGS index to topographic maps of Georgia. Each 7.5-minute topographic quadrangle in the State has been given a number and letter designation beginning at the southwest corner of the State. Numbers increase eastward and letters increase alphabetically northward. Quadrangles in the northern part of the area are designated by double letters. The letters "I", "II", "O", and "OO" are omitted. Wells inventoried in each quadrangle are numbered consecutively beginning with 1. Thus, the 51st well numbered on the 33X quadrangle is designated 33X051.

In South Carolina, wells are sequentially numbered in each county using an alphanumeric well designation. The alpha prefix refers to the county and the number refers to the chronological order in which wells were cataloged in that county. Thus, the 14th well inventoried in Aiken County is designated AK-14. The prefix "BW" is used for wells in Barnwell County and "AL" is used for wells in Allendale County.

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HYDROGEOLOGY

Hydrogeology of the Coastal Plain Province in the vicinity of the SRS in Georgia and South Carolina is described in the following sections. These sections define the (1) geologic setting, (2) hydrogeologic units, and (3) geologic characteristics of the Savannah River alluvial valley.

Geologic Setting

Coastal Plain sedimentary rocks in the study area consist of layers of sand, clay, and minor limestone that range in age from Late Cretaceous through Holocene. The northern limit of these strata and the contact between the Coastal Plain sediments and Piedmont crystalline rocks correspond approximately to the Fall Line, a physiographic boundary between the Piedmont and Coastal Plain (fig. 1a). The various strata dip and progressively thicken from the Fall Line to the southeast; the estimated maximum thickness is 2,700 ft in the southern part of the study area (Wait and Davis, 1986). The strata crop out in discontinuous belts that generally are parallel to the Fall Line. The sedimentary sequence unconformably overlies igneous and metamorphic rocks of Paleozoic age, and consolidated red beds of early Mesozoic age (Chowns and Williams, 1983).

The Coastal Plain deposits consist of fluvial, deltaic, and marine coastal and shelf sediments (Prowell and others, 1985). The axes of deposition of the deltaic systems have changed through geologic time because of the differential tectonism and uplift in the Appalachian region (Prowell, 1988; D.C. Prowell, U.S. Geological Survey, oral commun., 1992). Numerous marine transgressions and regressions have deposited, removed, and redistributed sediments (Colquhoun, 1981).
In the updip part of the Coastal Plain in Aiken County, S.C., and Richmond County, Ga., Coastal Plain sediments predominantly consist of nonmarine siliciclastics. Marine sediments are more abundant in the southern and southeastern parts of the study area and include carbonate-shelf deposits in several strata of Tertiary age.

The age and stratigraphic correlation of geologic units in the study area have been difficult to determine because fossil evidence is sparse, lithologies of vertically adjacent units commonly are similar, erosion has truncated units, and some units occur only in the subsurface. In addition, abrupt changes in lithology occur laterally and vertically. These changes, which juxtapose rocks characterized by different lithologic and hydrologic properties, may have been caused by abrupt changes in depositional environment, and may be complicated by erosional truncation or faulting. A variety of stratigraphic and hydrogeologic nomenclature for the area has evolved, in part as a result of the difficulties in correlation. A generalized correlation of geologic units at the P-21/P5R well-cluster site at the SRS is shown in figure 4.

Major structural features reported in the study area include the Belair Fault (Prowell and O’Connor, 1978), and the Pen Branch Fault (Price and others, 1991) (see locations, plate 1a,b,c,d). The Belair Fault is a northeast-trending high-angle reverse fault that has a maximum vertical displacement of 100 ft at the base of Coastal Plain strata (Prowell and O'Connor, 1978). The location of the Pen Branch Fault is coincident with the northwestern border of the early Mesozoic Dunbarton Basin. This northeast-trending high-angle normal fault dips to the southeast and cuts strata of Cretaceous, Paleocene, and Eocene age. This fault is downthrown on the northwestern side, and maximum displacement ranges from 100 ft at the base of Coastal Plain strata to 30 ft at the top of the Eocene Dry Branch Formation (Price and others, 1991).

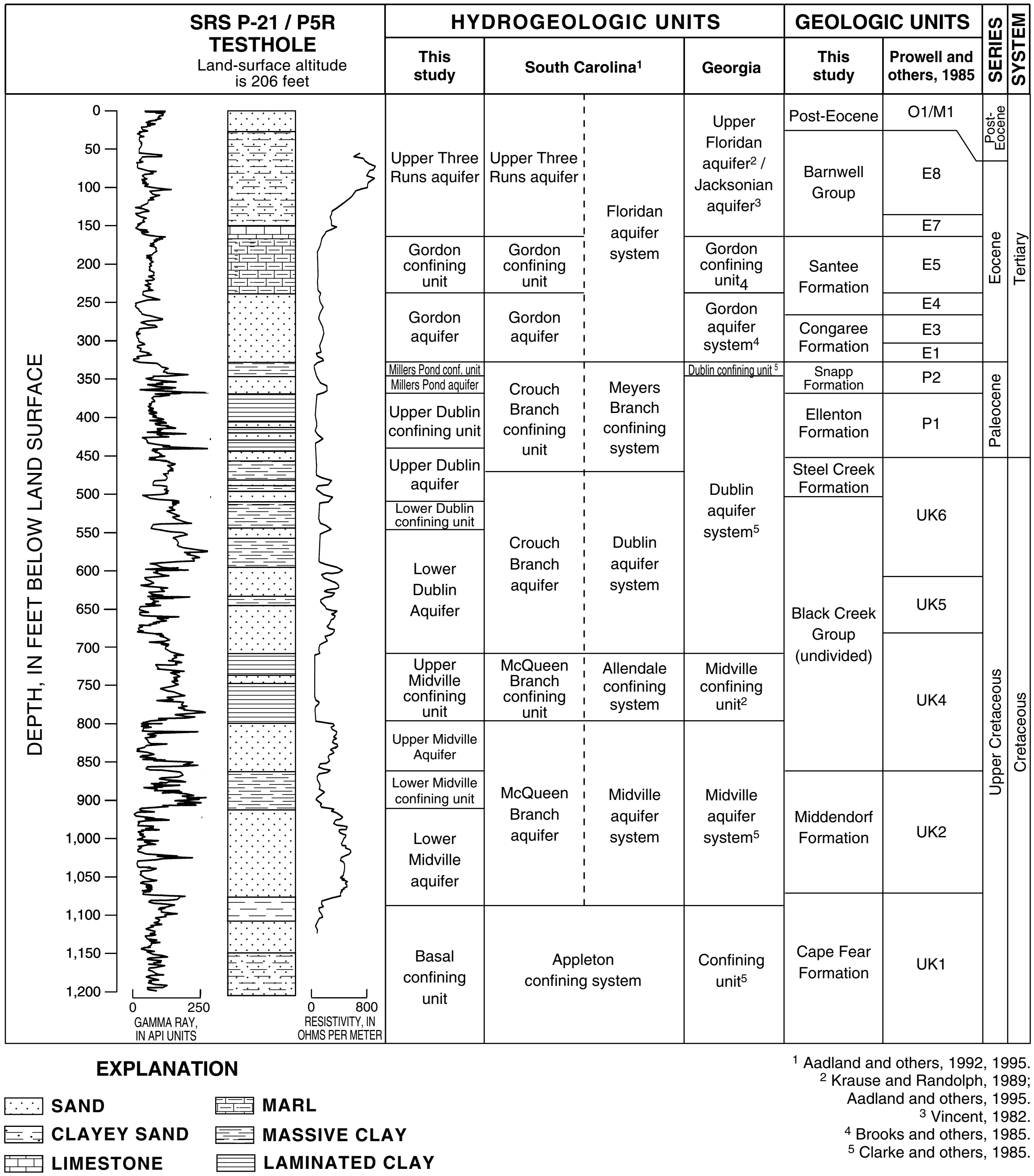


Figure 4. Comparison of hydrogeologic units and names applied to the P-21/P5R testhole at the Savannah River Site, South Carolina (modified from Falls and others, 1997).

Hydrogeologic Units

Previous investigators in Georgia (Miller, 1986; Brooks and others, 1985; Clarke and others, 1985; Krause and Randolph, 1989) and South Carolina (Logan and Euler, 1989; Bledsoe and others, 1990; Aadland and others, 1995) defined three principal aquifer systems in the trans-river flow study area . In descending order, these are: (1) the Floridan aquifer system, originally defined by Miller (1986) and later redefined by Aadland and others (1995)—comprised largely of calcareous sand and limestone of Eocene age; (2) the Dublin aquifer system (Clarke and others, 1985)—comprised of sand of Paleocene and Late Cretaceous age; and (3) the Midville aquifer system (Clarke and others, 1985)—comprised of sand of Late Cretaceous age. Although this subdivision of geologic strata was suitable for most regional-scale hydrogeologic studies, a more-detailed subdivision of units was necessary to better define vertical hydraulic differentiation near the Savannah River. The three aquifer systems were subdivided into seven discrete aquifers:

- the Floridan aquifer system was subdivided (Aadland and others, 1995) into—the Upper Three Runs aquifer and the Gordon aquifer;
- the Dublin aquifer system was subdivided (Falls and others, 1997) into—the Millers Pond aquifer, and the upper and lower Dublin aquifers; and
- the Midville aquifer system was subdivided (Falls and others, 1997) into—the upper and lower Midville aquifers.

Six of the aquifers are confined by layers of clay and silt that progressively increase in sand content in updip areas; however, the Upper Three Runs aquifer is unconfined to semi-confined. Where the confining units are more sandy, the aquifers are laterally discontinuous and the vertically contiguous aquifers coalesce. Clarke and others (1985; 1994) described the coalescence of the Dublin and Midville aquifer systems in the northern part of the study area (Dublin-Midville aquifer system), and suggested that the Gordon aquifer also may coalesce with these units in updip areas. Similar coalescence of aquifer units at SRS was identified by Aadland and Bledsoe (1990), Faye and Mayer (1997), and Aadland and others (1995). A comparison of hydrogeologic units and nomenclature applied to the P-21/P5R well-cluster site at SRS is shown in figure 4.

The Floridan aquifer system is comprised of the largely carbonate Upper and Lower Floridan aquifers, and extends into the southern part of the study area (Miller, 1986). In updip areas, terrigenous sediments of Eocene age are hydraulically connected to the Upper and Lower Floridan aquifers. To account for this connection, Krause and Randolph (1989) included these updip equivalents in their simulation of ground-water flow in the Floridan aquifer system. Updip equivalents of the Upper Floridan aquifer have been referred to in the study area as the Jacksonian aquifer (Vincent, 1982) and the Upper Three Runs aquifer (Aadland and others, 1992, 1995; Summerour and others, 1994). Updip equivalents of the Lower Floridan aquifer have been referred to as the Gordon aquifer system (Brooks and others, 1985) and the Gordon aquifer (Aadland and others, 1992, 1995; Summerour and others, 1994). Aadland and others (1995) extended the Floridan aquifer system into the northern part of the study area, where it consists of the Upper Three Runs and Gordon aquifers.

The shallowest of the seven aquifers is comprised of all sediments between land surface and the top of the Gordon confining unit, and includes lithostratigraphic equivalents of the Upper Floridan, Jacksonian, and Upper Three Runs aquifers. In this report, for the purpose of simplicity, these sediments are collectively referred to as the Upper Three Runs aquifer. This aquifer consists of sand, calcareous sand, and limestone of the Barnwell Group and younger Miocene (?) sediments, and includes the more-permeable upper layers of the Santee Formation.

The Gordon confining unit underlies the Upper Three Runs aquifer and separates the Upper Three Runs aquifer from the Gordon aquifer. The confining unit generally consists of clay and marl in the lower part of the Santee Formation. The Gordon aquifer is equivalent to the Gordon aquifer system as defined in Georgia by Brooks and others (1985), and the Gordon aquifer as correlated in South Carolina by Aadland and others (1995). In this report, for the purpose of simplicity, these sediments are collectively referred to as the Gordon aquifer. The aquifer consists of sand and calcareous sand of the Congaree Formation. The base of the Gordon aquifer is defined by the top of the Millers Pond confining unit in Barnwell and Allendale Counties in South Carolina; and Burke, Jenkins, and Screven Counties in Georgia. Where the Millers Pond confining unit is absent, the base of the aquifer is defined by the top of the upper Dublin confining unit in Aiken County, S.C., and Richmond County, Ga.

The Dublin aquifer system in east-central Georgia was originally defined by Clarke and others (1985) as consisting of sediments of Paleocene and Late Cretaceous age. Near the Savannah River, Clarke and others (1985) described local confining units that divide the aquifer system into an upper aquifer in Paleocene sediments and a lower aquifer in Cretaceous sediments. In South Carolina, Aadland and others (1995) redefined the Dublin to consist of Cretaceous sediments of the Crouch Branch aquifer, and the overlying Paleocene sediments as the Crouch Branch confining unit of the Meyers Branch confining system. The Dublin aquifer system in this study is divided into three aquifers and confining units that are informally named the Millers Pond, upper Dublin, and lower Dublin aquifers and confining units. This separation was deemed necessary on the basis of data collected at well-cluster sites, including differences in hydraulic head and water chemistry, and on response to pumping in adjacent zones (Clarke and others, 1994).

The Millers Pond confining unit is equivalent to the confining unit at the top of the Dublin aquifer system as originally described by Clarke and others (1985) and is comprised of a massive, white clay of the Snapp Formation of Paleocene age. The Millers Pond aquifer was named for sediments penetrated at the Millers Pond site in northern Burke County, Ga., and consists of fine to very coarse sand of the Snapp Formation that is equivalent to the upper “Paleocene” aquifer of Clarke and others (1985). This interval was identified as early Eocene age (Harris and Zullo, 1990) and late Paleocene age (P2 of Prowell and others, 1985) in previous studies.

The upper Dublin confining unit consists of laminated, black clay of the Ellenton Formation and separates the Millers Pond and the upper Dublin aquifers. The upper Dublin aquifer includes the basal sand of the Ellenton Formation and the moderately to very poorly sorted sand and sandy clay of the Steele Creek Formation. The lower Dublin confining unit comprises a white clay and silty clay which is interpreted as the top of the Black Creek Group in this study (fig. 3). The lower Dublin aquifer comprises the well-sorted to moderately sorted sand in the upper part of the Black Creek Group.

The Midville aquifer system of Clarke and others (1985) is divided into the upper and lower Midville aquifers in this study. The upper Midville confining unit, as originally defined by Clarke and others (1985) occurs between the Dublin and Midville aquifer systems and comprises the clay-dominated middle part of the Black Creek Group. The lower Midville confining unit separates the upper and lower Midville aquifers and is a 10- to 40-ft thick clay at the top of the Middendorf Formation. The upper Midville aquifer consists of sand and clayey sand in the lower part of the Black Creek Group. The lower Midville aquifer comprises the sands of the Middendorf Formation and can include a permeable sand interval at the top of the Cape Fear Formation (fig. 4).

The basal confining unit is equivalent to the Appleton confining system of Aadland and others (1995). This unit comprises the low-porosity, low-permeability sediments of the Cape Fear Formation throughout most of the study area, and the saprolite and crystalline rocks of the pre-Cretaceous basement in the updip part of the study area.

Geologic Characteristics of the Savannah River Alluvial Valley

The geologic characteristics of the Savannah River alluvial valley greatly influence configuration of potentiometric surfaces, ground-water-flow directions, and stream-aquifer relations. To determine the maximum depth of river incision and the geometric and lithologic characteristics of the Savannah River alluvial valley, 18 borings were completed and five geologic sections were constructed from the data (Leeth and Nagle, 1996). These data indicate that Savannah River alluvium is more coarse, angular, and poorly sorted than underlying formations; and lithologic differences between the alluvium and underlying strata are readily apparent, especially in areas where the underlying strata are of marine origin. The maximum thickness of the alluvial valley fill is 50 ft near the Aiken-Barnwell County, S.C., line, and thins in a downstream direction to a minimum of 34 ft near the Burke-Screven County, Ga., line. The altitude of the unconformity between the alluvium and the underlying formation ranges from 45-80 ft above sea level, which is 20-30 ft below the lowest elevation of the present-day thalweg.

To determine the effect of paleo-river channel incision on hydrogeologic units, a map showing the subsurface extent of hydrogeologic units beneath the mantle of alluvial deposits in the Savannah River floodplain was constructed (fig. 5). The map indicates that each of the seven aquifers was incised by the paleo Savannah River channel and covered with an infill of permeable alluvium, allowing direct hydraulic connection of the aquifers and river along parts of the river’s reach. In general, aquifers and confining units are

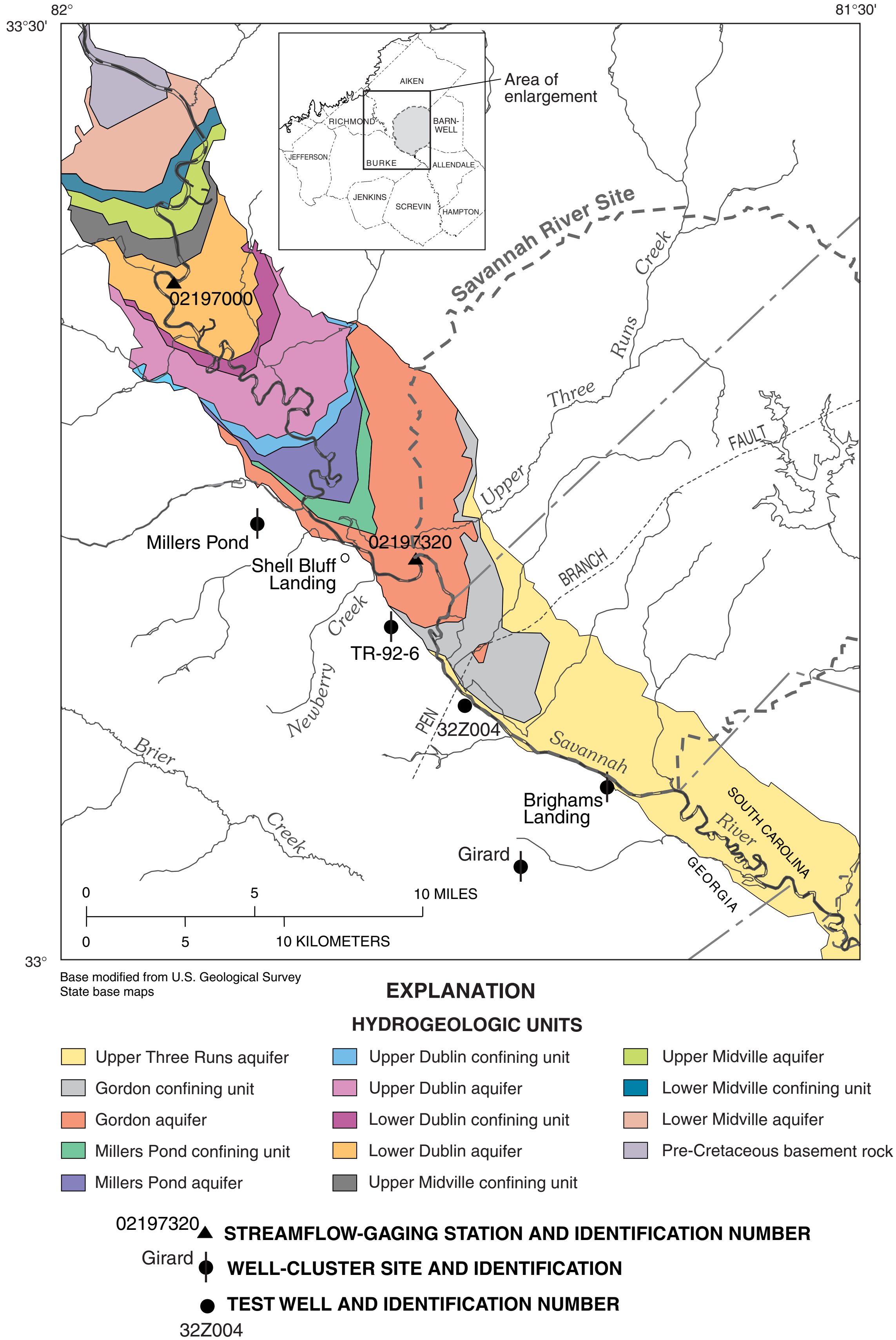


Figure 5. Subsurface extent of hydrogeologic units beneath the Savannah River alluvial valley.

exposed from downdip (downstream) to updip (upstream) in order of progressively older sediments. An exception occurs in the Gordon aquifer along the southern (upthrown) side of the Pen Branch Fault. Here, fault upthrow apparently has resulted in incision of the Gordon aquifer; however, more data are needed to confirm this possibility.

The lateral extent of the paleo-river channel incision corresponds to the width of the Savannah River alluvial valley and includes the modern-day alluvial bottom and terraces, collectively mapped by Prowell (1994) as Qal 1 and Qal 2. The width of the alluvial valley ranges from a minimum of about 0.5 mi near the Fall Line, to about 7 mi near the Richmond-Burke County line.

GROUND-WATER LEVELS

Ground-water-level data in the SRS vicinity were used to: determine the directions of ground-water flow in major aquifers; determine vertical head relations between adjacent aquifers; partially evaluate stream-aquifer relations; and delineate hydrologic boundaries for ground-water model investigations. Water-level data also were used to determine any seasonal or long-term changes that could influence stream-aquifer relations or significantly alter directions of ground-water flow. Water-level data from selected well-cluster sites are listed in table 1 and locations of well-cluster sites are shown in figure 1a. Cluster-site data were used to determine vertical head gradients within and between major aquifers. At some well-cluster sites, two or more wells are completed in the same aquifer—the average water level for these contributing intervals is presented in table 1.

Table 1. Water-level altitudes at selected well-cluster sites in the vicinity of the Savannah River Site, Georgia and South Carolina

[Where two or more wells are completed in the same aquifer, the average water level is reported (see footnotes); A, unit absent; B, well not installed into aquifer at cluster site]

Cluster site	Date(s) measured	Water levels in aquifers, in feet above sea level						
		Upper Three Runs	Gordon	Millers Pond	Upper Dublin	Lower Dublin	Upper Midville	Lower Midville
Brighams Landing	11/03/94, 04/18/95	B	121.00	B	B	154.21	B	174.97
C-1	03/30/94	B	B	B	170.98	170.81	171.68	172.5
C-2	05/08/92	415.00	B	B	241.65	240.10	239.40	237.40
C-3	07/17/91	B	252.50	B	261.80	[1]270.20	271.30	B
C-5	05/05/92	247.27	216.52	B	B	B	B	B
C-6	05/04/92	178.56	163.40	B	171.26	170.91	192.31	197.86
C-7	08/01/94	[2]171.74	[3]132.34	B	160.84	[4]161.06	189.42	189.32
C-10	12/13/95	[5]194.44	[6]135.20	B	[7]150.93	[7]150.93	192.54	192.67
Girard	05/04/92 03/13/95	221.69	B	B	B	164.15	B	180.07
Millers Pond	10/13/92 10/16/92	175.43	B	135.00	B	[8]157.22	157.17	[9]157.96
Millhaven	03/13/95	[10]100.42	B	[11]122.65	B	150.43	B	185.2
P-13	05/08/92	231.46	173.94	B	176.73	176.64	183.97	184.39
P-14	05/08/92	241.25	B	B	B	[12]191.30	B	190.72
P-15	05/08/92	232.76	179.58	B	[13]176.17	176.08	180.01	179.95
P-16	05/08/92	217.40	215.18	B	220.47	223.27	223.12	218.87
P-17	05/08/92	[14]284.01	229.85	B	217.47	216.55	217.47	217.04
P-18	05/08/92	226.62	[15]170.06	B	B	173.42	174.08	174.56

Table 1. Water-level altitudes at selected well-cluster sites in the vicinity of the Savannah River Site, Georgia and South Carolina—Continued

[Where two or more wells are completed in the same aquifer, the average water level is reported (see footnotes); A, unit absent; B, well not installed into aquifer at cluster site]

Cluster site	Date(s) measured	Water levels in aquifers, in feet above sea level						
		Upper Three Runs	Gordon	Millers Pond	Upper Dublin	Lower Dublin	Upper Midville	Lower Midville
P-19	05/08/92	[16]266.67	266.27	188.84	181.10	[17]181.07	181.56	B
P-20	05/08/92	[18]254.95	195.74	B	191.09	B	B	B
P-21	05/08/92	160.01	135.41	136.28	168.10	168.32	182.53	B
P-22	05/08/92	[19]171.12	153.90	154.58	B	[20]177.08	189.72	190.14
P-23	05/08/92	145.00	139.40	147.20	165.20	165.60	170.60	171.20
P-24	05/08/92	[21]247.49	191.47	B	182.29	182.40	184.60	182.06
P-25	05/08/92	[22]205.94	176.29	174.88	171.38	[23]171.26	175.24	175.68
P-26	05/06/92 09/24/93	A	[24]114.77	B	149.63	155.81	165.05	165.64
P-27	05/08/92	[25]254.70	181.10	B	181.83	[26]181.76	181.07	179.62
P-28	05/08/92	[27]212.74	[28]147.16	B	177.81	[29]177.78	177.48	177.09
P-29	05/08/92	170.23	[30]168.65	B	170.44	172.50	172.57	171.45
P-30	05/08/92	259.36	[31]210.59	A	[32]206.98	206.27	199.96	190.39
TR-92-1	06/17/92	184.20	150.80	150.10	149.80	B	B	B
TR-92-3	09/14/93	58.36	48.34	B	B	B	B	B
TR-92-6	01/03/96	Dry	98.40	B	B	157.89	B	157.14

[1]Average of wells AK-846 and AK-847.
[2]Average of wells AL-363 and AL-364.
[3]Average of wells AL-365 and AL-366.
[4]Average of wells AL-368 and AL-369.
[5]Average of wells AL-371, AL-372, and AL-373.
[6]Average of wells AL-365 and AL-366.
[7]Composite water level for upper and lower Dublin, well AL-375 screened in both units.
[8]Average of wells 30Z025 and 30Z026.
[9]Average of wells 30Z017 and 30Z021.
[10]Average of wells 33X051, 33X052, and 33X053.
[11]Measurement from well 33X048 completed in upper Dublin confining unit.
[12]Average of wells BW-324 and BW-325.
[13]Average of wells BW-332 and BW-333.
[14]Average of wells BW-362 and BW-381.
[15]Average of wells BW-313 and BW-436.
[16]Average of wells BW-396 and BW-397.
[17]Average of wells BW-392 and BW-393.
[18]Average of wells BW-399 and BW-400.
[19]Average of wells BW-409 and BW-410.
[20]Average of wells BW-373 and BW-406.
[21]Average of wells BW-420, BW-421, and BW-422.
[22]Average of wells BW-428 and BW-429.
[23]Average of wells BW-424 and BW-425.
[24]Average of wells AK-875 and AK-876.
[25]Average of wells BW-434 and BW-435.
[26]Average of wells BW-431 and BW-432.
[27]Average of wells AK-884, K-885, and AK-886.
[28]Average of wells AK-881, AK-882, and AK-883.
[29]Average of wells AK-880 and AK-898.
[30]Average of wells AK-889 and AK-890.
[31]Average of wells AK-895 and AK-896.
[32]Average of wells AK-861 and AK-894.

Factors Influencing Ground-Water Levels

Fluctuations and long-term trends in ground-water levels occur as a result of changes in recharge to and discharge from an aquifer. Recharge rates vary in response to precipitation, evapotranspiration, and surface-water infiltration into an aquifer. Discharge occurs as natural flow from an aquifer to streams or springs, as evapotranspiration from shallow water-table aquifers, as leakage to vertically adjacent aquifers, and as withdrawal from wells. In the trans-river flow study area, ground-water levels in confined aquifers also can be affected by changing stream stages in areas near major streams.

Ground-Water Withdrawal

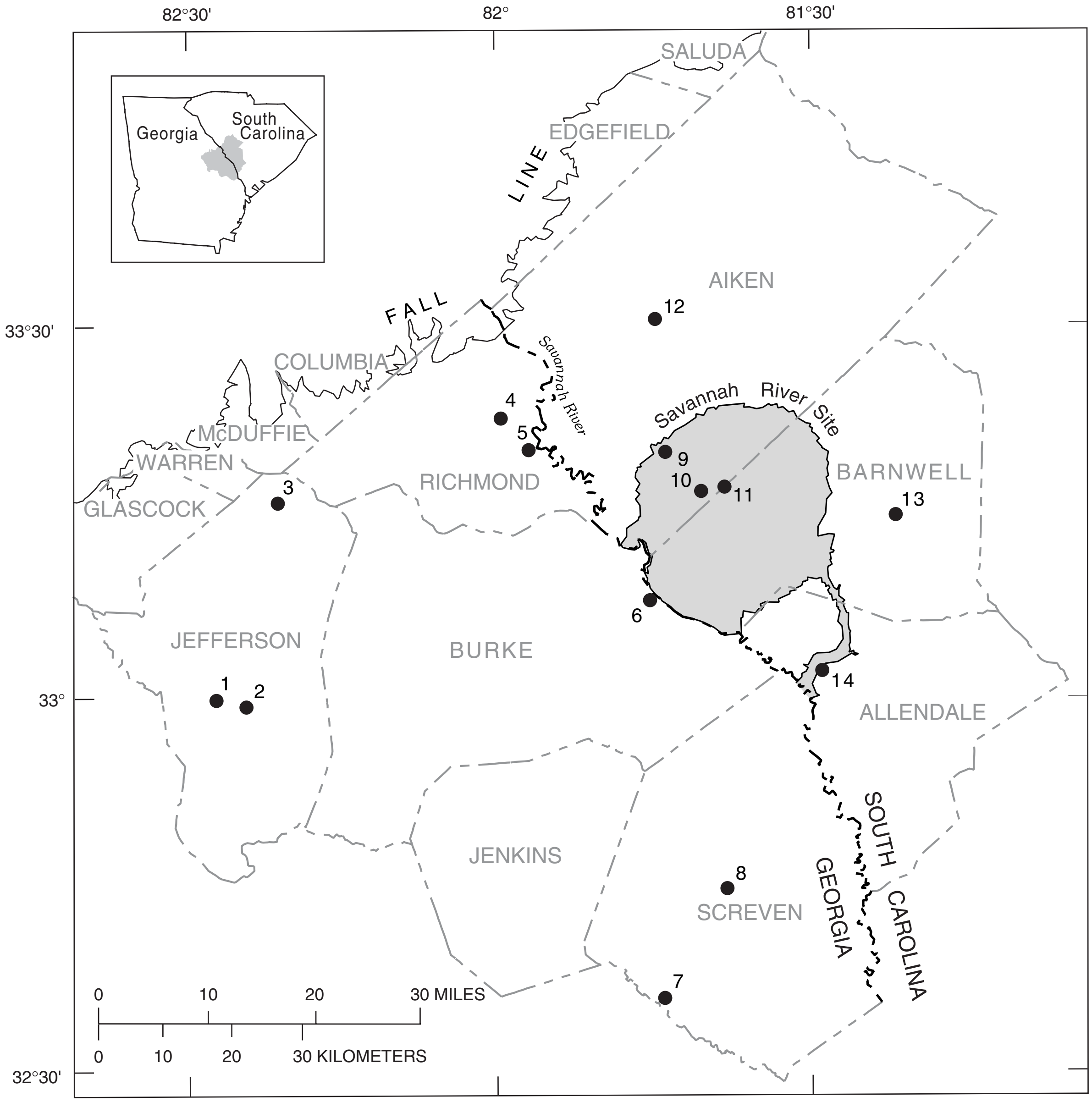
The locations of ground-water pumping centers and amounts of water withdrawn from these centers may significantly affect ground-water levels and stream-aquifer relations in the study area. Changes in pumping rates and the addition of new pumping centers may alter the configuration of potentiometric surfaces, reverse ground-water-flow directions, and increase seasonal and long-term water-level fluctuations in the aquifers. Major municipal and industrial pumping centers (those exceeding 1 million gallons per day (Mgal/d)) during 1987-92 are listed in table 2. Pumping center locations are plotted in figure 6.

Table 2. Industrial and municipal ground-water pumping centers in the vicinity of the Savannah River Site, Georgia and South Carolina, and average annual ground-water withdrawal, 1987-92

[limited to pumping centers withdrawing 1 million gallons per day or greater]

Site number	County	Site name	Type of water use	Average withdrawal during 1987-92[1/] (million gallons per day)	Aquifer
			Georgia		
1	Jefferson	J.P. Stevens, Inc.	industrial	1.40	Gordon
2	Jefferson	City of Louisville	public supply	1.37	upper Dublin
3	Jefferson	Anglo-American Clay Co.	industrial	2.0	upper Dublin, lower Dublin, upper Midville, lower Midville
4	Richmond	Richmond County Water System	public supply	11.94	upper Midville, lower Midville
5	Richmond	Olin Corp.	industrial	1.08	upper Midville, lower Midville
6	Burke	Plant Vogtle Nuclear Power Station	industrial	2.41	lower Dublin, upper Midville, lower Midville
7	Screven	King Finishing Co.	industrial	2.22	lower Dublin
8	Screven	City of Sylvania	public supply	1.09	Upper Three Runs
			South Carolina		
9	Aiken	Savannah River Site A/M area	industrial	2.46	lower Dublin, upper Midville, lower Midville
10	Aiken	Savannah River Site F- area	industrial	2.01	Gordon, upper Dublin, upper Midville, lower Midville
11	Aiken and Barnwell	Savannah River Site H-area	industrial	2.27	Gordon, upper Dublin, upper Midville, lower Midville
12	Aiken	City of Aiken	public supply	1.44	lower Dublin, upper Midville, lower Midville
13	Barnwell	Barnwell Mills, Inc.	industrial	1.23	Gordon
14	Allendale	Sandoz, Inc.	industrial	1.53	upper Dublin, lower Dublin

[1/]Data from U.S. Geological Survey Water Use Data System.



Base modified from U.S. Geological Survey
State base maps

EXPLANATION

7 **GROUND-WATER PUMPING CENTER THAT WITHDREW GREATER THAN 1 MILLION GALLONS PER DAY**—
NUMBER IS SITE IDENTIFICATION LISTED IN TABLE 2

Figure 6. Ground-water pumping centers that withdrew more than 1 million gallons per day during 1987-92.

Historical and modern pumpage data were compiled from a variety of sources to evaluate the temporal distribution of ground-water withdrawal in the study area. Data for industrial users and public supply during 1980-92 were obtained from the USGS Water Use Data System (J.L. Fanning and K.H. Jones, U.S. Geological Survey, written commun., 1995). Irrigation withdrawal for 1980-92 were estimated by the Georgia Cooperative Extension Service (Kerry Harrison, Georgia Cooperative Extension Service, written commun., 1995). Water-use data prior to 1980 were compiled from historical data (R.E. Faye, U.S. Geological Survey, written commun., 1985). Data on average-annual ground-water withdrawal at the SRS are available for 1953-92, with the exception of 1961-68, which were interpolated from 1960 and 1969 data.

Reported industrial and public supply water-use data probably has an error margin of 25 percent prior to 1980 and 10 percent during 1980-92 (R.R. Pierce, U.S. Geological Survey, oral commun., 1997). Irrigation withdrawal has an unknown margin of error, but probably exceeds 25 percent.

During periods in which withdrawal data were not available for some municipalities, a linear-regression model was developed using paired population and water-use data (49 values) to estimate ground-water pumpage. The analysis included data from 15 Georgia towns and 8 South Carolina towns, spanning the years 1953-92. The resulting regression model is:

$$W = .00001608(P) - 0.02 \qquad (1)$$

where

W is the average-annual withdrawal in Mgal/d, and P is the population served.

The correlation coefficient of the regression model was 0.88, with a P-value less than 0.0001, indicating that most of the variation in ground-water withdrawal can be explained by the regression model. Water-use data for the town of Louisville, Ga., were an exception. Major industrial users in Louisville have been supplied, in part, by municipal wells since about 1980; and total ground-water withdrawals after 1980, thus are a poor indicator of population-based water use.

Major pumping centers located adjacent to the Savannah River (fig. 6) that withdrew 1 Mgal/d or more during 1987-92 include, in Georgia, Plant Vogtle nuclear power station (site 6), the Richmond County water system (site 4), and Olin Corporation (site 5); and in South Carolina, Sandoz Corporation (site 14), and SRS (sites 9, 10, and 11). Variations in pumpage with time for these sites are shown in figure 7.

Ground-water withdrawal at the SRS occurred at several process areas across the site and are greatest at the A/M area, the F-area, and H-area (sites 9, 10, and 11, fig. 6; table 2). During 1987-92, withdrawal at these areas were about 2.5, 2.0, and 2.3 Mgal/d, respectively.

Pumping distribution in the vicinity of the SRS has varied with time. Prior to the 1950's, ground-water withdrawal was limited to scattered pumping centers near major towns such as Augusta, Ga. In late 1952, major construction began at the SRS and pumpage in the study area increased substantially, as a result of water demand for construction and an increase in the local population (fig. 7). Pumping at the SRS generally is from multi-aquifer wells completed in the Dublin and/or Midville aquifer systems. Withdrawal at the SRS was a maximum of 11 to 12 Mgal/d during the 1980's.

Supply wells at the Sandoz Corporation plant in Allendale County, S.C., withdraw water from the upper and lower Dublin aquifers; these wells are located about 1 mi east of the Savannah River (site 14, fig. 6). Large withdrawal at the Sandoz site began during the mid-1970's and increased to a maximum of about 2.5 Mgal/d in 1989 (fig. 7). By 1992, pumpage had decreased to about 1.2 Mgal/d.

In Georgia, multi-aquifer wells at Georgia Power Company Plant Vogtle nuclear plant, located about 0.5 mi west of the Savannah River, withdraw water from the Dublin and Midville aquifer systems (site 5, fig. 6). Pumping at Plant Vogtle began during site construction in the mid-1970's and remained steady at about 0.2-0.4 Mgal/d through the early 1980's (fig. 7). Withdrawal increased substantially during the middle to late 1980's as the facility was gradually brought into production; and by 1988, peaked at about 4.5 Mgal/d. During 1987-92, average withdrawal was about 2.4 Mgal/d.

Multi-aquifer wells at the Richmond County, Ga., wellfield (site 4, fig. 6), and Olin Corporation site (site 5, fig. 6) withdraw water from the upper and lower Midville aquifers, these sites are located about 3 and 1 mi west of the Savannah River, respectively. The Richmond County wellfield supplies both the city of Augusta and industrial users in the vicinity. Ground-water withdrawal for public supply at Augusta probably began during the late 1940's. Pumpage from the Richmond County wellfield increased from less than 1 Mgal/d in 1958, to about 9 Mgal/d in 1970 (fig. 7). During the 1980's and early 1990's, withdrawal at the wellfield was steady, ranging from about 9.7 to 12.7 Mgal/d. Withdrawal at the Olin Corporation site has remained steady during 1974-92, averaging about 1 Mgal/d (fig. 7).

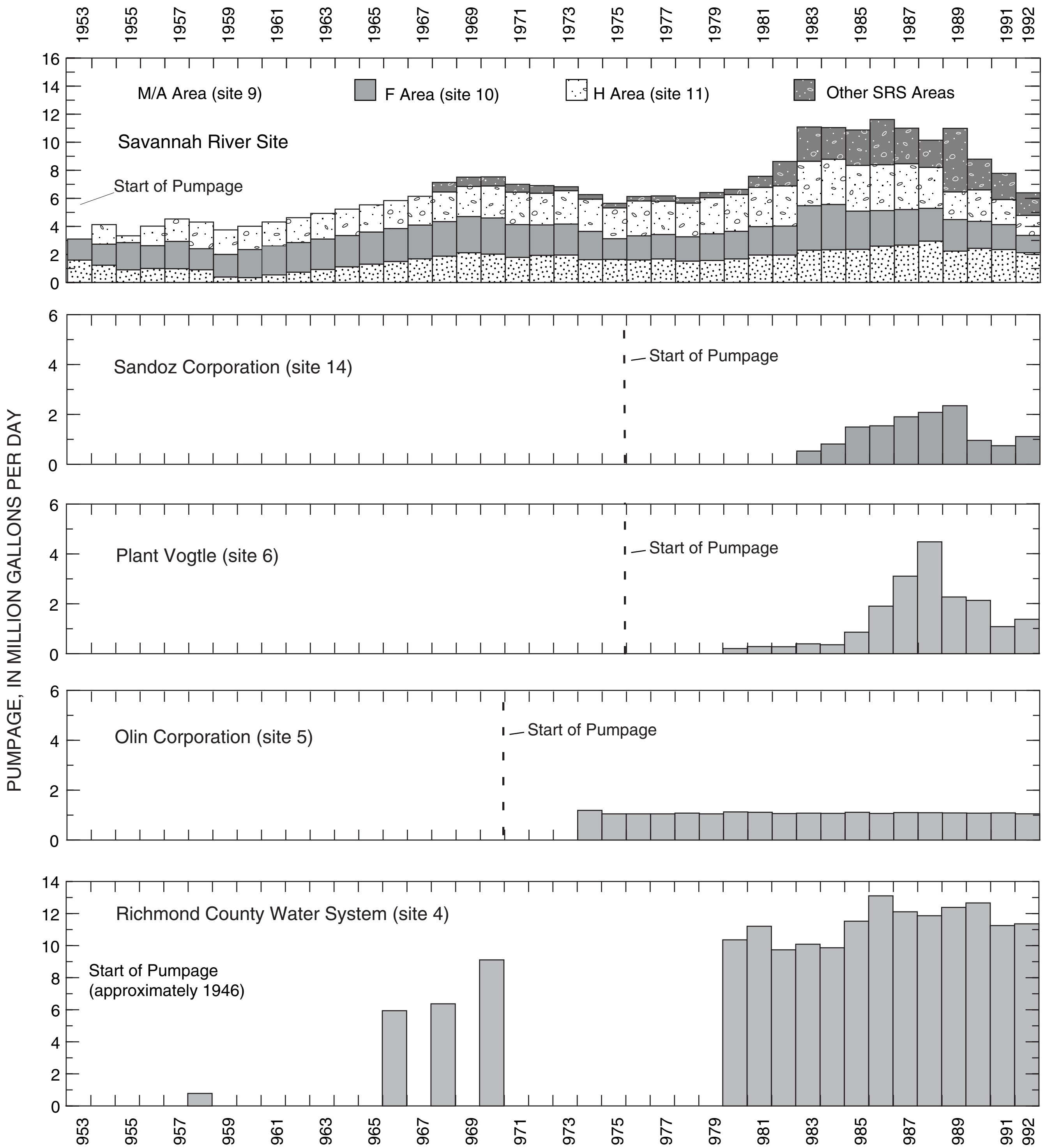


Figure 7. Ground-water withdrawal near the Savannah River, 1953-92. Blank where data not available. See figure 6 for location of sites.

Ground-water withdrawal in the vicinity of SRS increased significantly between the early 1950's and 1992. Estimated ground-water withdrawal for periods of similar pumping conditions are summarized by county and aquifer for the following periods (figs. 8 and 9):

- 1953-60—a period of increasing withdrawal at SRS;
- 1961-70—a period of relatively steady withdrawal at SRS;
- 1971-75—a period of decreasing withdrawal at SRS (see fig. 7);
- 1976-80—a period of increasing irrigation withdrawal in the southern part of the study area and relatively steady withdrawal at SRS;
- 1981-86—a period of increased withdrawal at SRS and at Plant Vogtle; and
- 1987-92—a period of decreased withdrawal at SRS and Plant Vogtle.

During 1953-60, total estimated ground-water withdrawal in the study area was greater in South Carolina than in Georgia—about 10 Mgal/d in South Carolina and about 4 Mgal/d in Georgia. By 1971-75, the largest total ground-water withdrawal occurred in Georgia; estimated ground-water withdrawal was about 27 Mgal/d in Georgia and about 20 Mgal/d in South Carolina. During 1987-92, total study area withdrawal was about 80 Mgal/d, of which about 55 Mgal/d were in Georgia and about 25 Mgal/d were in South Carolina. During each period, ground-water withdrawal was greatest in Richmond County, Ga., and in Aiken County, S.C. (fig. 8).

Percentages by aquifer of total water withdrawn during 1953-92 have remained relatively consistent in South Carolina, but have changed appreciably in Georgia (fig. 9). In South Carolina, withdrawal was nearly equally distributed between the Dublin and Midville aquifer systems. In Georgia, the Upper Three Runs aquifer was the largest source of ground water during the 1950's. By the 1960's, the Midville aquifer system had been tapped as the largest source of ground water in the Georgia part of the study area. This change resulted largely from increased municipal and industrial withdrawal in the Augusta, Ga., area where the Midville aquifer system is the principal source of ground water.

Precipitation

Precipitation data from two Georgia and two South Carolina sites (Milton Brown, Southeastern Regional Climatic Center, written commun., 1996) were evaluated to determine long-term trends that could affect ground-water levels and ground-water recharge. In Georgia, the sites are located at Augusta and Waynesboro; in South Carolina, the sites are located at Aiken and Blackville (see locations, fig. 2). The Augusta and Aiken sites are located near the recharge areas for the Gordon aquifer and the Dublin and Midville aquifer systems; whereas, the Waynesboro and Blackville sites are located near the recharge area for the Upper Three Runs aquifer.

Cumulative departure is a term used to describe the long-term surplus or deficit of precipitation over a designated period of time. It is derived by adding successive monthly values of departures from normal precipitation. Normal precipitation for a given month is defined as the average of total monthly precipitation during a specified period. For this report, the period 1948-92 was used to determine normals for computation of cumulative departures. Values for Aiken and Blackville, S.C., and Augusta and Waynesboro, Ga., (see locations, fig. 2) are shown graphically for the period July 1948 through December 1992 (fig. 10). Periods of above-normal precipitation are indicated by upward, or positive, slopes on the graph; periods of below-normal precipitation are indicated by downward, or negative, slopes on the graph.

Precipitation trends were variable at the four sites during 1948-92. Precipitation throughout the SRS area was deficient from 1948 through much of the 1950's, a period during which one of the most severe droughts of the century occurred in 1954. By the end of 1992, the long-term cumulative departure was above normal in the southern part of the study area at Waynesboro and Blackville, and below normal in the northern part of the area at Augusta and Aiken.

In South Carolina, precipitation at Aiken and Blackville was below normal during 1948-57, followed by a general above-normal trend during 1958-80. During 1981-92, however, the precipitation trend generally was below normal at Blackville and above normal at Aiken. By the end of 1992, the long-term cumulative departure was 11.5 inches above normal at Blackville, and 1.2 inches below normal at Aiken.

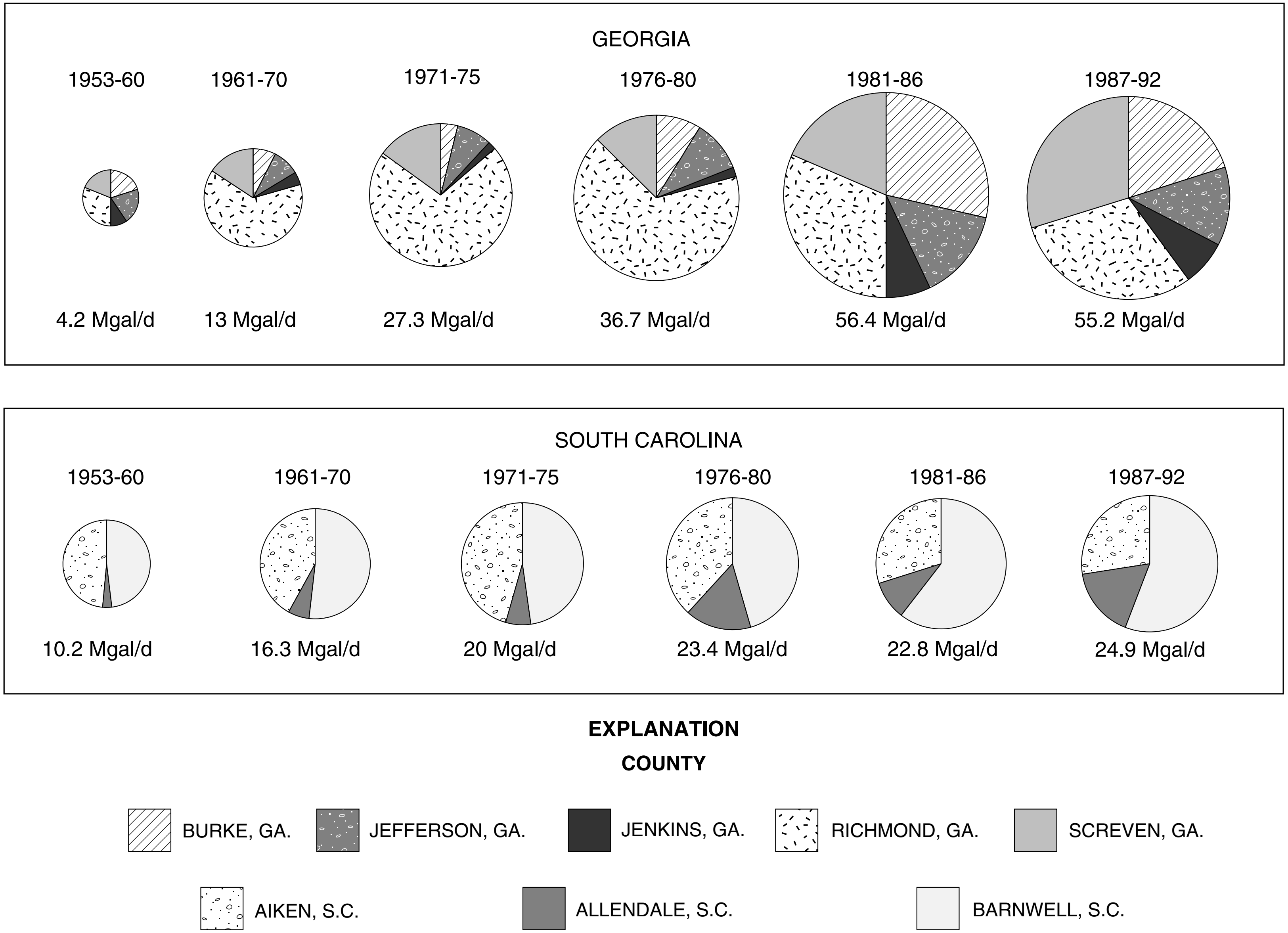


Figure 8. Estimated ground-water withdrawal by county in the vicinity of the Savannah River Site in Georgia and South Carolina, 1953-92.

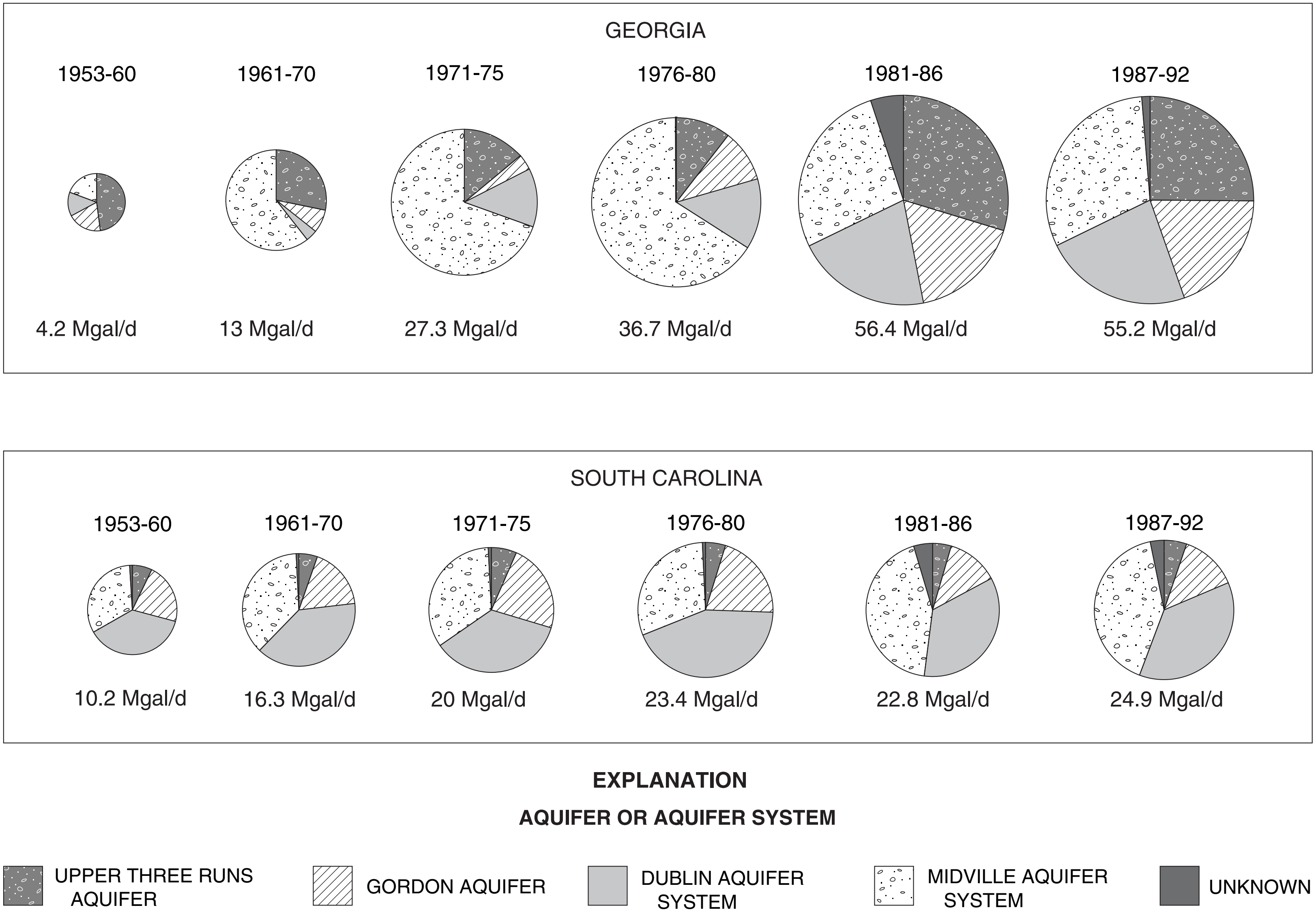


Figure 9. Estimated ground-water withdrawal by aquifer or aquifer system in the vicinity of the Savannah River Site in Georgia and South Carolina, 1953–92.

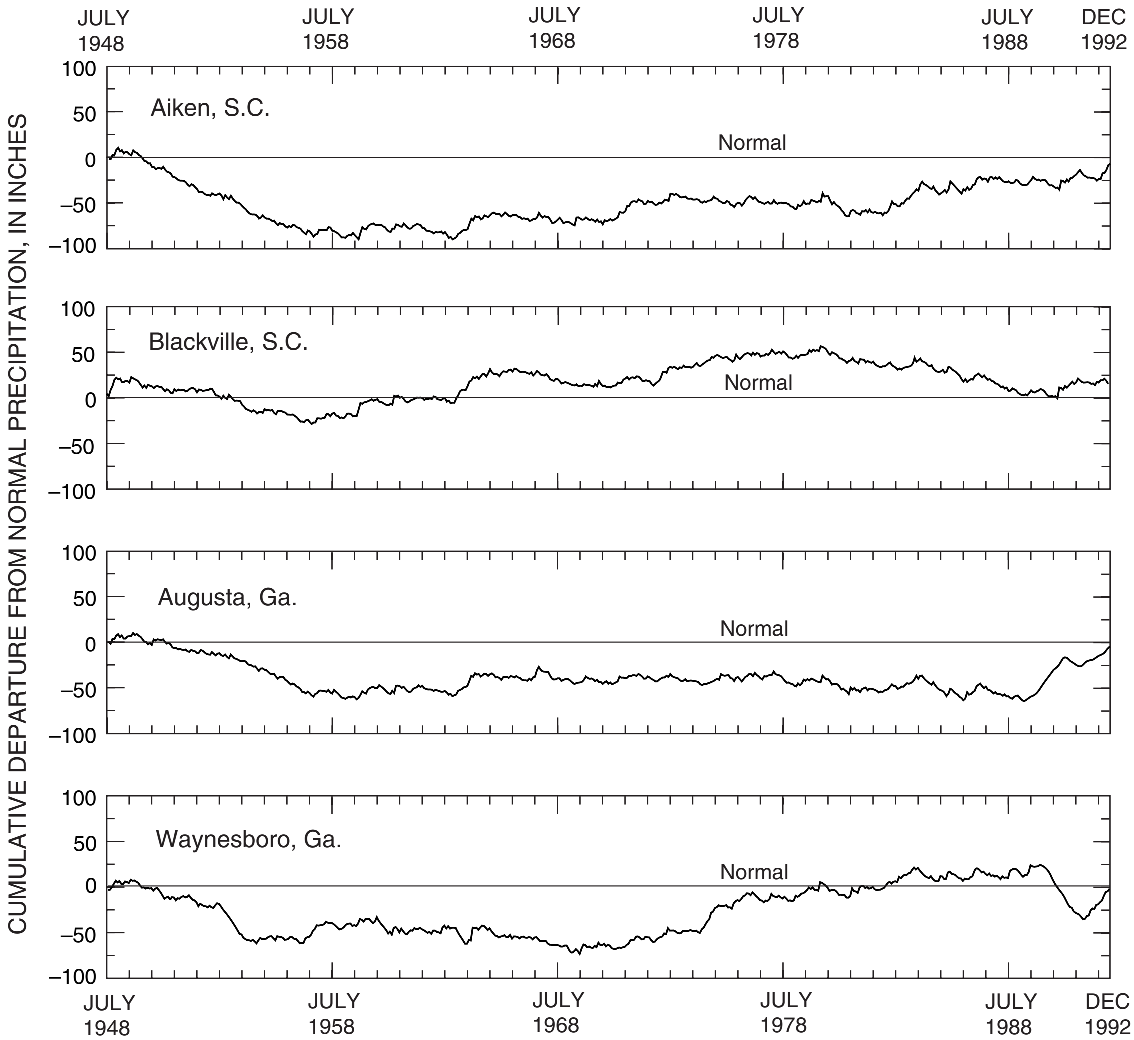


Figure 10. Cumulative departure from normal precipitation for selected sites, July 1948 through December 1992 (from Atkins and others, 1996).

In Georgia, precipitation at Augusta and Waynesboro, also was below normal during 1948-57. At Augusta, precipitation was near normal during most of the period 1958 through 1984, followed by a below-normal trend during 1985-90, and an above-normal trend during 1991-92. At Waynesboro, precipitation was below normal during much of 1958-69, above normal during 1970-84, near normal during 1984-91, and above normal during 1992. By the end of 1992, the long-term cumulative departure was 30.4 inches below normal at Augusta and 40.7 inches above normal at Waynesboro.

Seasonal Water-Level Fluctuations and Long-Term Trends by Aquifer

Ground-water levels in the vicinity of the SRS are affected by precipitation, evapotranspiration, pumpage, and stream stage. Water levels generally are highest in winter-early spring when precipitation is greatest, evapotranspiration is lowest, and irrigation withdrawals are minimal; water levels are lowest during summer and fall when precipitation is less, and evapotranspiration and irrigation pumpage is greatest.

In parts of the study area, water-level responses in adjacent aquifers may be similar. This similarity is most pronounced in the northern part of the study area and results from greater aquifer interconnection due to discontinuous or leaky confining units.

To determine the magnitude of water-level fluctuations in the aquifers during a single season, water levels were measured in 271 wells in May and October 1992 (fig. 11). The difference between the two measurements is an approximation of the seasonal water-level fluctuation in an aquifer; although the maximum range of fluctuation probably is somewhat higher, as indicated by limited data from continuous water-level hydrographs (fig. 12). When water levels in October were lower than in May, computed differences are negative, indicating seasonal decline. Conversely, when water levels in October were higher than in May, computed differences are positive, indicating seasonal rise. Water-level changes during May-October 1992 are summarized by aquifer in the boxplots shown in figure 11. For each aquifer, the majority of water-level changes (80 percent) occur between the 10^{th} and 90^{th} percentiles, with scattered outliers outside of this range.

Although continuous data during 1992 are limited, the maximum range of seasonal water-level fluctuation is indicated on the hydrograph for well 31Z033, completed in the Gordon aquifer; well 28X001, completed in the lower Midville aquifer; and well 32X040, completed in the Upper Three Runs aquifer (fig. 12). The water level in the Gordon and lower Midville aquifer wells changed little throughout the year; whereas, the water level in the Upper Three Runs aquifer well declined during summer due to local agricultural pumping. The water-level recovery in the Upper Three Runs aquifer well between August and October, indicates that the change measured by comparing May and October water levels is somewhat less than the maximum change for the year. Although it is likely that changes such as those observed in the Upper Three Runs well are local in extent and limited to areas of agricultural withdrawal, the water-level change plotted in figure 11 should be considered the minimum seasonal fluctuation for 1992.

Measurements obtained in May and October, 1992 (fig. 11) indicate that over most of the study area, the magnitude of water-level fluctuations was small (generally less than 2 ft) and equally distributed between rises (October levels greater than May) and declines (October levels lower than May). Larger changes occurred near areas of ground-water withdrawal, especially in the Upper Three Runs and Gordon aquifers, which are utilized for irrigation supply in the study area.

In addition to the 1992 synoptic water-level measurements, seasonal water-level fluctuations in the aquifers during December 1993 through December 1995 are illustrated in hydrographs showing daily mean water-levels at continuously monitored wells; and are listed in table 3 (hydrographs are shown in subsequent sections that describe water-level fluctuations and trends for each aquifer). Well-location and construction data for these continuously monitored wells are listed in the appendix. Average annual fluctuation (annual maximum minus annual minimum) during 1994 and 1995 in these wells generally was less than 4 ft; with the exception of four wells completed in the Upper Three Runs aquifer (33X051, 33X052, 33X053, and 32X040), which were influenced by nearby pumpage (table 3). Locations of wells listed in table 3 are given in subsequent sections of this report that describe water-level fluctuations and trends for each aquifer.

Water-level data were evaluated at 283 wells having at least 10 years of record to calculate the maximum observed range of long-term water-level change in the study area (fig. 13). Fluctuations that persisted for more than one year were included in these calculations. Differences were computed by comparing the maximum to the minimum observed water level in a well. Where the maximum water level occurred during an earlier year than the minimum measurement, a water-level decline (negative difference) was reported. Conversely, where the maximum water level occurred during a later year than the minimum measurement, a water-level rise (positive difference) was reported. Long-term water-level changes are summarized by aquifer in the boxplots shown in figure 13. For each aquifer, the majority of water-level changes (80 percent) occur between the 10^{th} and 90^{th} percentiles, with scattered outliers outside of this range.

Water-level changes (fig. 13) represent the most significant long-term trends observed in a given well, and could be the result of seasonal or long-term changes in precipitation, pumping; or combinations of effects of these changes, such as increased rates of vertical leakage. The small magnitude of seasonal fluctuations observed during 1992 (fig. 11) and 1994-95 (generally less than 4 ft), however, makes it likely that large (greater than 10 ft) water-level changes are the result of pumping or changes in long-term precipitation. A statistical summary of data (fig. 13) indicates that water levels in most

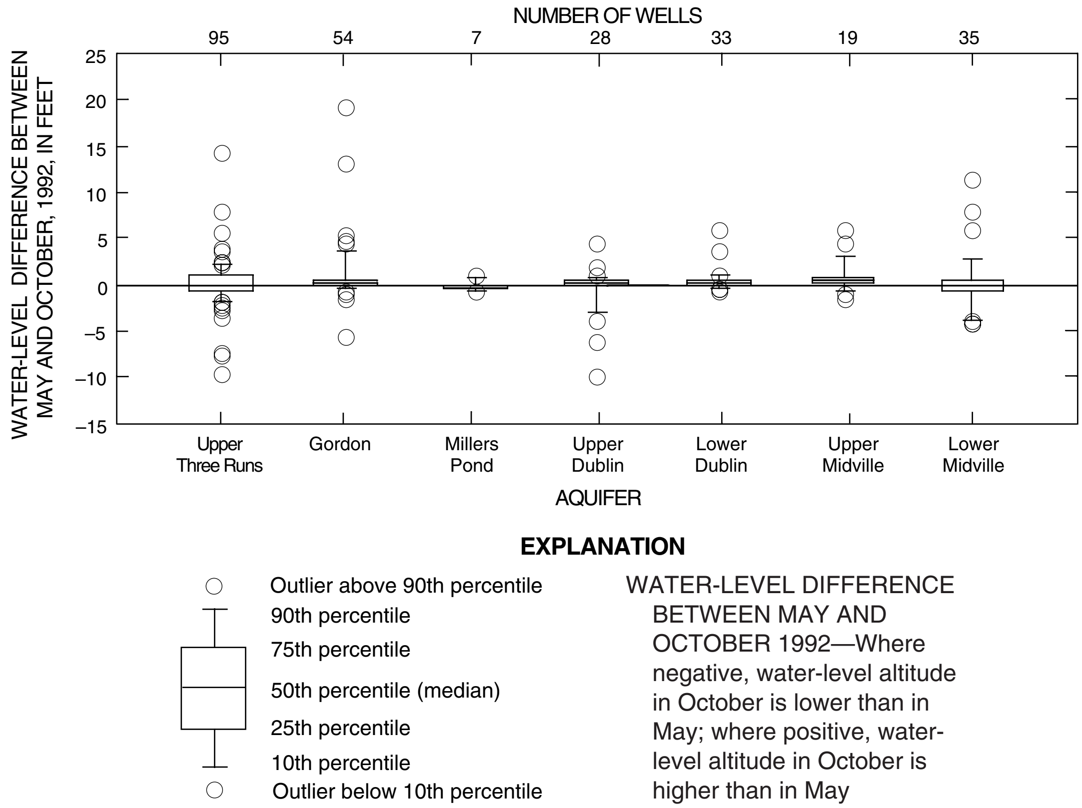


Figure 11. Seasonal water-level change in aquifers, May-October, 1992.

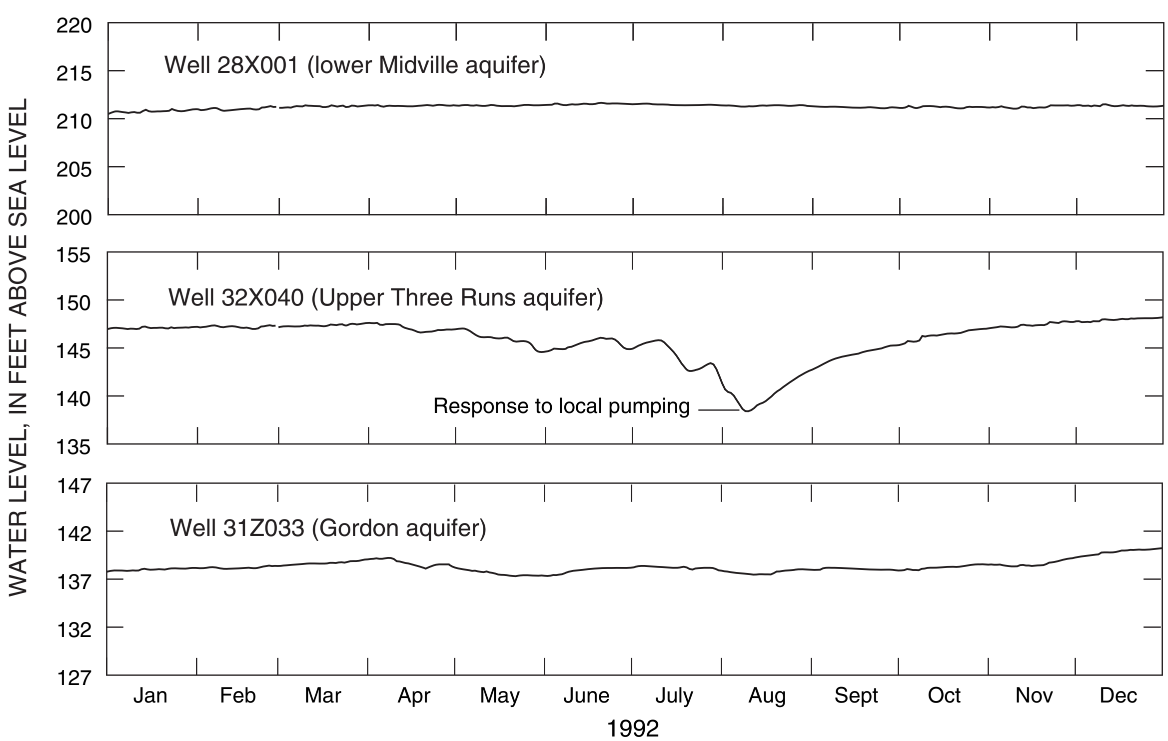


Figure 12. Daily mean water levels in wells 28X001 and 31Z033, Burke County, Georgia; and well 32X040, Screven County, Georgia, 1992. Blank where data not available.

of the aquifers declined during some period prior to 1992, as indicated by median values of water-level change less than zero. These long-term declines generally were less than 15 ft, and were limited to scattered areas influenced by supply wells. In the Gordon and upper Midville aquifers, water levels in most wells rose, as indicated by median values greater than zero. Specific periods and areas of seasonal and long-term water-level change are described and illustrated in subsequent sections of this report for each aquifer.

Table 3. Annual water-level fluctuations in selected wells in the vicinity of the Savannah River Site, Georgia and South Carolina, 1994 and 1995, based on continuous measurements

[—, no available data]

Well number	Aquifer	Annual water-level fluctuation (feet)		
		1994	1995	Average
33X051	Upper Three Runs	[1/]4.54	4.27	4.4
33X052	Upper Three Runs	[1/]4.51	5.49	5.0
33X053	Upper Three Runs	[1/]6.13	8.18	7.15
32X040	Upper Three Runs	11.33	14.0	12.66
32Y019	Upper Three Runs	—	[1/]2.76	2.76
30Z022	Upper Three Runs	3.11	2.89	3.0
BW-350	Upper Three Runs	3.03	2.43	2.73
BW-352	Gordon	1.73	1.48	1.6
BW-354	Gordon	1.87	2.06	1.96
31Z110	Gordon	[1/]2.71	[1/]5.24	3.97
31Z033	Gordon	2.35	2.83	2.59
31Z028	Millers Pond	[1/]1.0	1.36	1.18
AK-825	upper Dublin	[1/]0.98	[1/]1.15	1.06
32Y031	lower Dublin	—	[1/]1.63	1.63
33X054	lower Dublin	[1/]1.96	[1/]0.84	1.4
31Z111	lower Dublin	—	[1/]2.62	2.62
30Z026	lower Dublin	2.3	1.94	2.12
32Y029	lower Dublin	[1/]2.44	[1/]1.55	2.0
AK-824	lower Dublin	[1/]1.09	[1/]1.08	1.08
30Z023	upper Midville	2.27	1.9	2.08
AK-818	upper Midville	[1/]0.73	[1/]1.93	1.33
32Y030	lower Midville	—	[1/]2.16	2.16
33X055	lower Midville	—	[1/].61	0.61
32Y032	lower Midville	—	.91	.91
30Z017	lower Midville	1.85	1.94	1.9
30Z021	lower Midville	2.07	1.96	2.02
31Z112	lower Midville	—	[1/]1.07	1.07
BW-349	lower Midville	.86	.45	.66
AK-817	lower Midville	[1/]1.25	[1/]1.43	1.34
28X001	lower Midville[2/]	1.36	1.95	1.66

[1/]Minimum annual fluctuation, less than 300 days of record available.
[2/]Mostly completed in lower Midville; one screen partially completed in upper Midville.

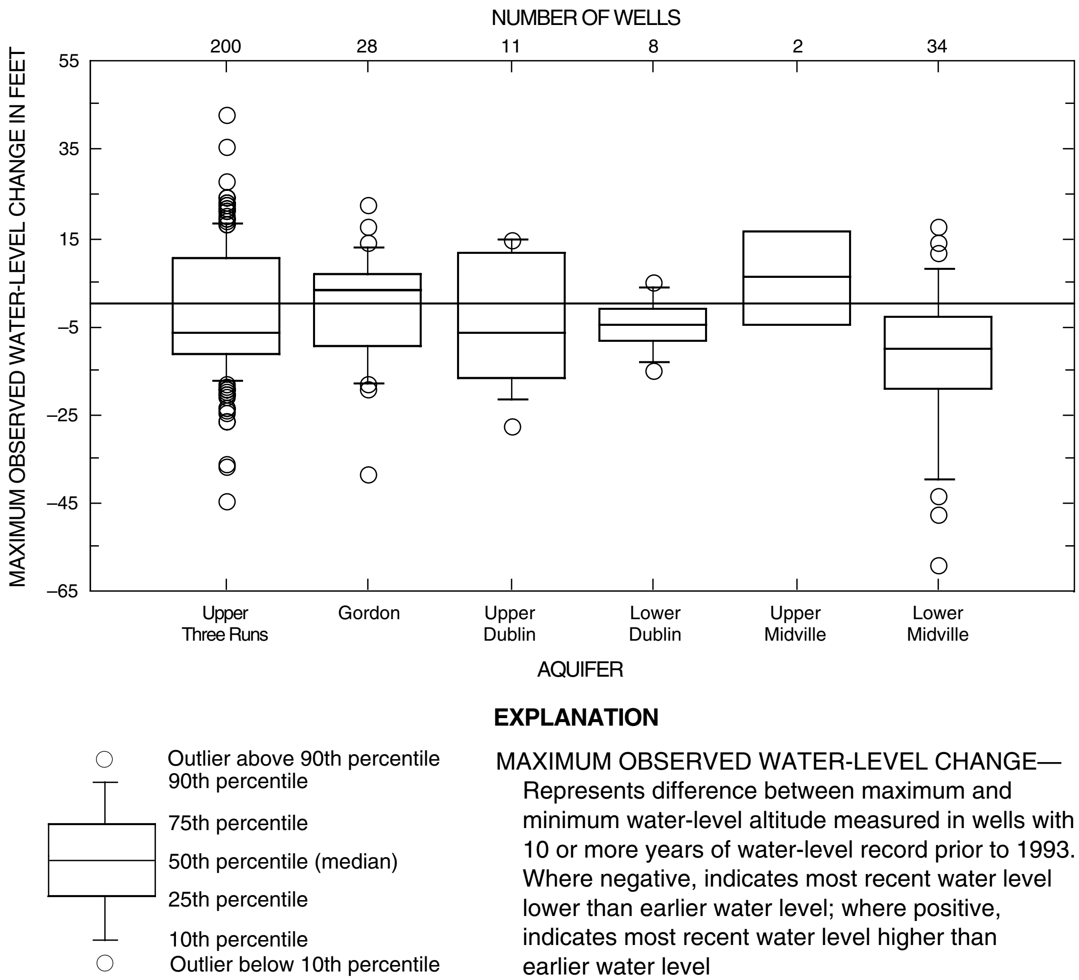


Figure 13. Maximum observed water-level change in aquifers prior to 1993. Includes only those wells with a period of water-level spanning a minimum of 10 years.

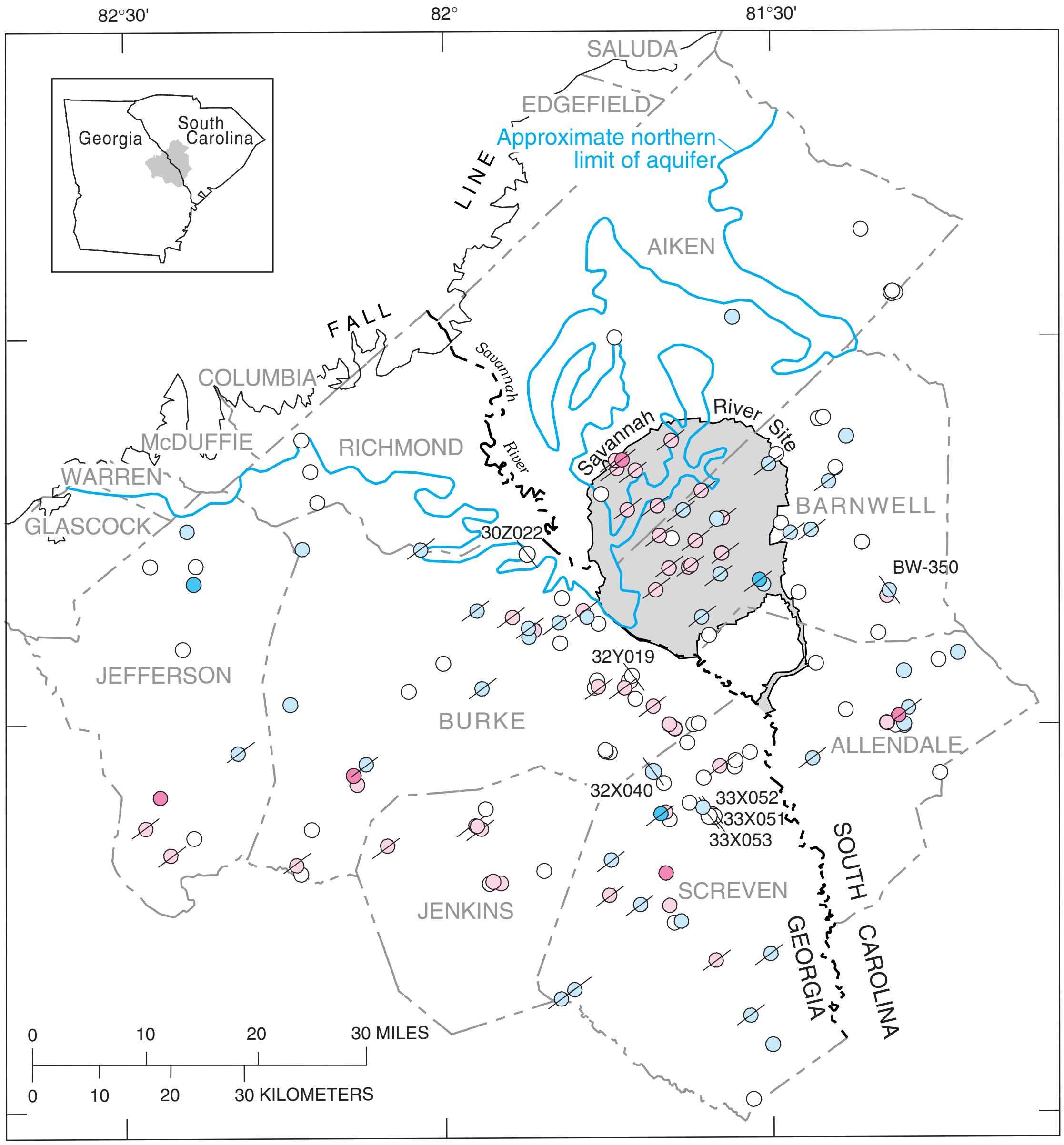
Floridan Aquifer System

In the vicinity of the SRS, the Floridan aquifer system consists of the Upper Three Runs aquifer and the Gordon aquifer (Aadland and others, 1995). Seasonal water-level fluctuations and long-term trends in the Floridan aquifer system are summarized in the following sections, by aquifer.

Upper Three Runs Aquifer

Water levels in the Upper Three Runs aquifer indicate the greatest response to aquifer recharge and discharge, because the aquifer is exposed or near land surface over much of the study area. The topographic location of a well completed in the Upper Three Runs aquifer also influences the range of annual water-level fluctuation. Water levels generally fluctuate over a greater range in the vicinity of ground-water divides (topographic highs) than in areas of natural discharge such as a stream valley (topographic low).

During October 1992, water levels in 95 wells completed in the Upper Three Runs aquifer mostly were between 2 ft lower and 2 ft higher than in May 1992 (figs. 11 and 14). Larger seasonal declines of 5 to 15 ft were limited to isolated wells in southern Jefferson, southern Burke, and central Screven Counties, Ga.; and in the northern part of SRS in southern Aiken County, S.C. During the same period, water-level rises of 5 to 15 ft were observed in northern Jefferson and northern Screven Counties, Ga.



Base modified from U.S. Geological Survey
State base maps

EXPLANATION

WELLS

○ MUNICIPAL, INDUSTRIAL, OR IRRIGATION WELL THAT WITHDRAWS WATER FROM AQUIFER

30Z022 WELL EQUIPPED WITH CONTINUOUS WATER-LEVEL RECORDER—Number is well identification

OBSERVATION OR OTHER USE WELL

WATER-LEVEL CHANGE, IN FEET—Where positive, indicates water-level altitude higher in October than in May 1992; where negative, indicates water-level altitude higher in May than in October, 1992

- +5 to +15 feet
- 0 to +5 feet
- –5 to 0 feet
- –15 to –5 feet
- ○ No data

Figure 14. Observed water-level change during May-October 1992 in wells completed in the Upper Three Runs aquifer.

Annual water-level fluctuations in the Upper Three Runs aquifer during 1994 and 1995 averaged from about 2.7 to 12.7 ft in seven wells equipped with continuous water-level recorders (figs. 15 and 16; table 3). The largest seasonal changes in the continuously monitored wells were observed in northern Screven County where the aquifer is used for irrigation.

Water-level fluctuations in three test wells at the Millhaven well-cluster site (33X051, 33X052, and 33X053), and in an abandoned stock well (32X040) in northern Screven County averaged from about 4.4 to 12.7 ft during 1994 and 1995 (fig. 15; table 3). Water levels in each of the four Screven County wells show some seasonal response to irrigation pumping and to precipitation at Midville, about 35 mi west of the Millhaven site. In particular, water levels in well 32X040, show a pronounced seasonal response to irrigation pumpage, as well as the largest average-annual fluctuation (12.7 ft) of the four wells during the period.

North of Screven County, Ga., and in the South Carolina part of the study area, water levels in the Upper Three Runs aquifer show little response to seasonal pumping. Average-annual water-level fluctuations during 1994 and 1995 in wells 32Y019 and 30Z022 in Burke County, Ga., and in well BW-350 in Barnwell County, S.C., ranged from about 2.8 to 3 ft (fig. 16; table 3). Unlike the four Screven County wells, water levels in the Upper Three Runs aquifer in Burke and Barnwell Counties show little response to seasonal irrigation pumping because the aquifer is less productive; and thus, is not widely utilized as source of water. The shallow depth of the aquifer in these areas suggests that water levels should show a rapid response to precipitation or evapotranspiration; however, water levels in the three wells show little response. This lack of response could be because of the presence of overlying clay beds that restrict direct recharge from precipitation or discharge by evapotranspiration; however, data are not available to evaluate this possibility.

Long-term water-level trends for wells completed in the Upper Three Runs aquifer largely are the result of variations in recharge and pumpage. Evaluation of data from 200 wells indicates that long-term water-level changes in the Upper Three Runs aquifer mostly range from -17 to +18 ft, and that larger changes ranging from -44 ft to +43 ft, occur in areas influenced by pumpage (figs. 13 and 17). Water-level declines in excess of 15 ft occurred in scattered wells located in northern Jefferson, northern Burke and southern Screven Counties, Ga.; and at the SRS in Aiken and Barnwell Counties, S.C. (fig. 17). Water-level declines of 5 to 15 ft were widespread in much of Screven County, Ga., probably the result of irrigation pumpage in the area. Water-level rises in excess of 15 ft occurred in southern Jefferson, Screven, and eastern Burke Counties, Ga.; in the northern part of the SRS in Aiken and Barnwell Counties, S.C; and east of the SRS in central Barnwell County, S.C.

Water-level data near Aiken and at Barnwell, S.C., do not indicate a pronounced long-term decline in response to pumping from the Upper Three Runs aquifer in South Carolina. Average withdrawal from the Upper Three Runs aquifer in South Carolina is small—during 1987-92, an estimated 1.3 Mgal/d was withdrawn in Aiken, Allendale, and Barnwell Counties (fig. 9).

Although long-term data for the Upper Three Runs aquifer are not available in the eastern part of the SRS, it is likely that water levels rose due to impoundment of Parr Pond (plate 1a). According to Langley and Marter (1973), the Parr Pond cooling water impoundment was formed during 1957-58 by damming Lower Three Runs Creek. The impoundment encompasses 2,640 acres to an average depth of about 20 ft, with a maximum depth of 55 ft near the dam.

In South Carolina, long-term water-level hydrographs for the Upper Three Runs aquifer are limited to sites at the SRS, and to a well at the town of Barnwell (BW-14, fig. 18). Well BW-14 at Barnwell is an unused public supply well influenced by pumping from nearby wells; pronounced changes in water level result from changes in local pumping rates. This causal relation also was documented by Siple (1967). Water-level response in well BW-14 to long-term precipitation trends are masked by local pumping effects.

Long-term water-level changes in the Upper Three Runs aquifer in the northern part of the SRS vary. Water-level rises and declines tend to correspond to periods of above-normal and below-normal precipitation, respectively. In some wells, water levels declined more than 15 ft, and in others, rose more than 15 ft (fig. 17). Responses to precipitation are shown on hydrographs for wells AK-2134, AK-2082, and BW-409 (fig. 18). The three wells are located at the SRS, in upland areas that are a source of recharge for the Upper Three Runs aquifer; and are thus, influenced by climatic effects. Comparison of water levels in the wells with the cumulative departure of precipitation at Aiken and Blackville, indicates that water levels are influenced by long-term precipitation trends, particularly at well AK-2082 (fig. 18). Water levels generally are highest during periods of above-normal precipitation and lowest

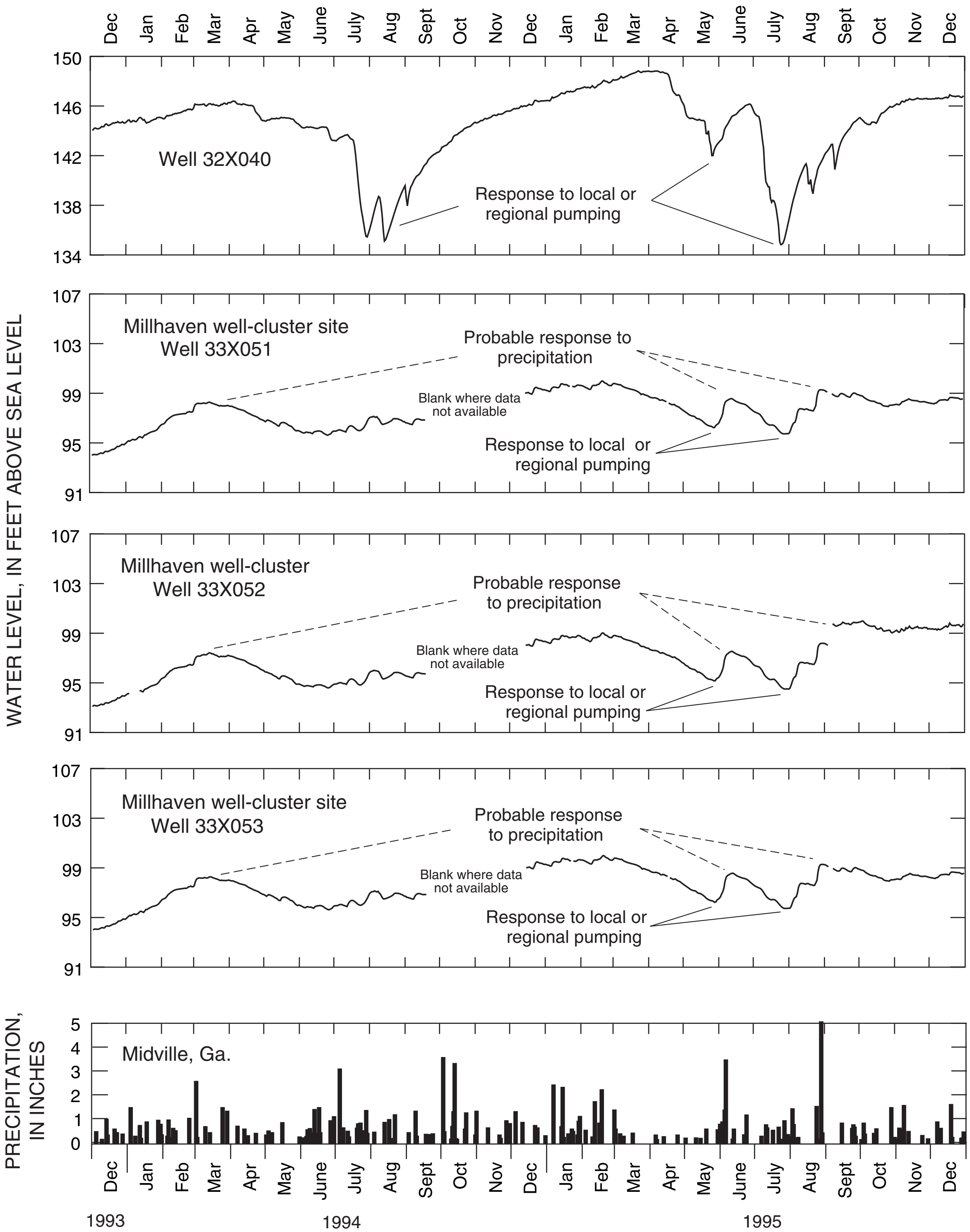


Figure 15. Daily mean water levels in selected wells completed in the Upper Three Runs aquifer in northern Screven County, Georgia, and precipitation at Midville, Georgia, December 1993-December 1995.

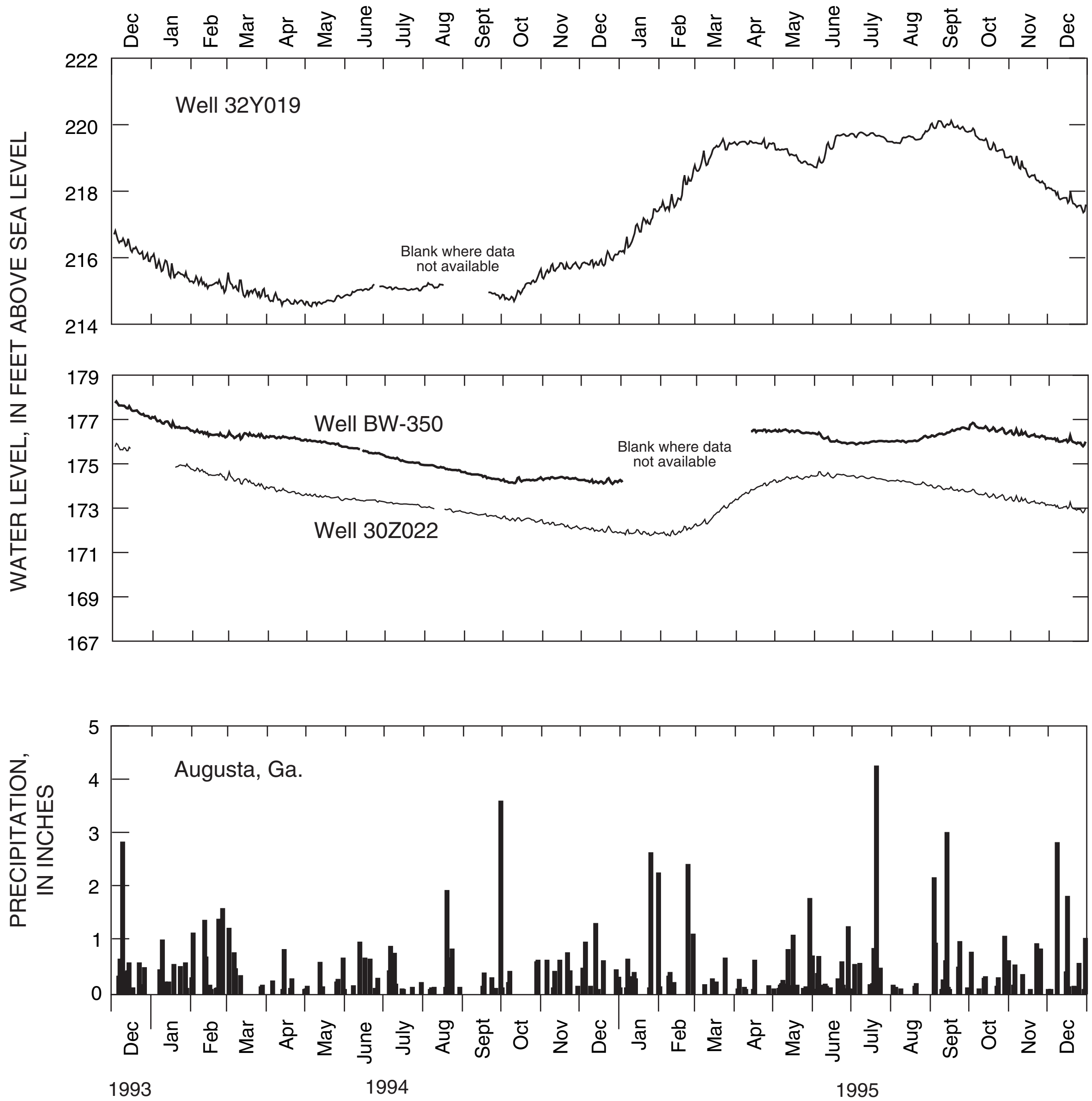
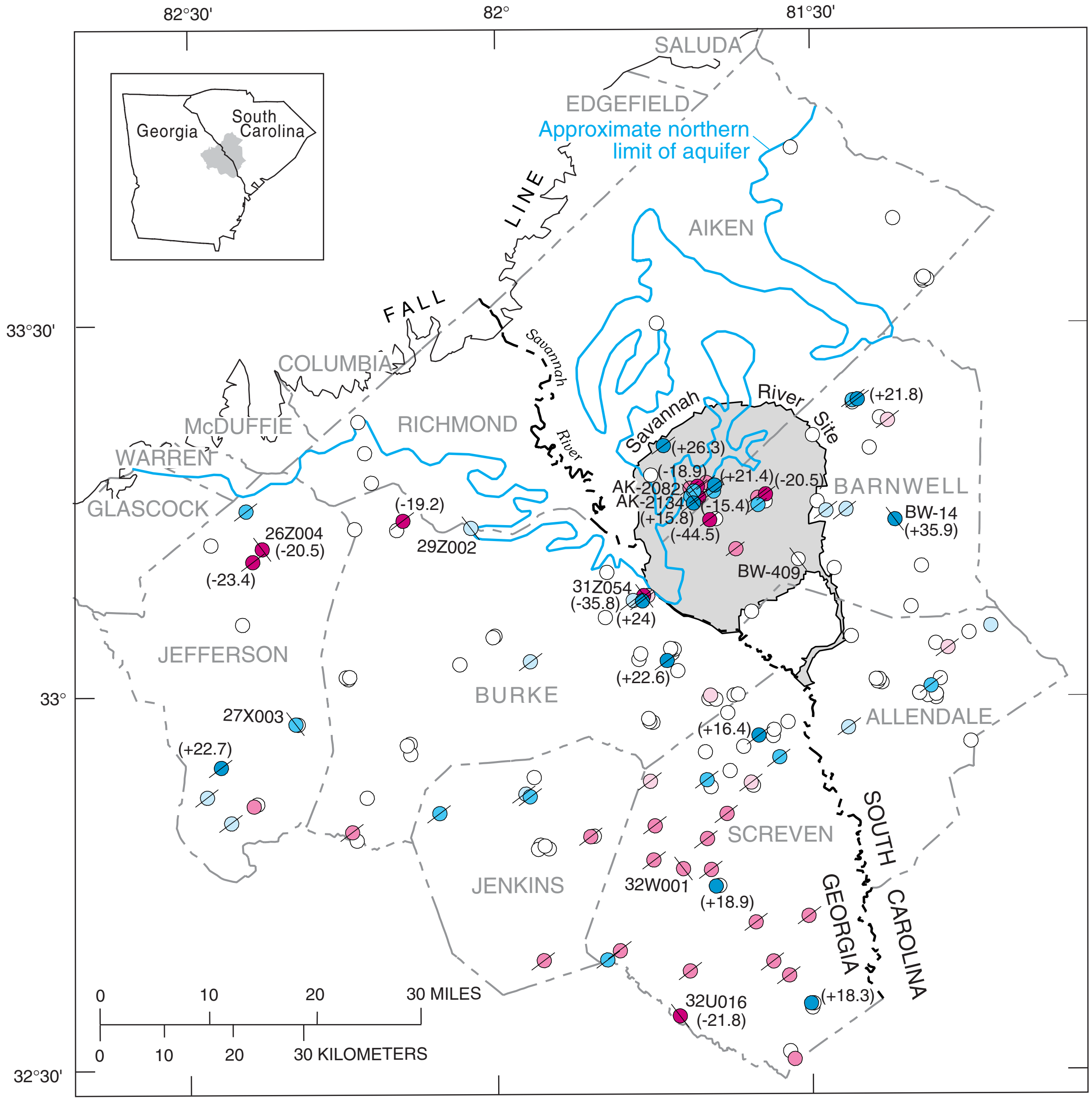


Figure 16. Daily mean water levels in the Upper Three Runs aquifer in Burke County, Georgia, and Barnwell County, South Carolina, and precipitation at Augusta, Georgia, December 1993-December 1995.



Base modified from U.S. Geological Survey State base maps

EXPLANATION

WELLS

○ MUNICIPAL, INDUSTRIAL, OR IRRIGATION WELL THAT WITHDRAWS WATER FROM AQUIFER

30Z022 WELL FOR WHICH HYDROGRAPH IS INCLUDED IN THIS REPORT—Number is well identification

OBSERVATION OR OTHER USE WELL

MAXIMUM OBSERVED WATER-LEVEL CHANGE, IN FEET– Represents range and direction of change between maximum and minimum water-level measured in wells having 10 or more years of water-level data prior to 1993

(+18) Greater than +15 (Number in parentheses is measured value)

+5 to +15

0 to +5

–5 to 0

–15 to –5

(-17) Less than –15 (Number in parentheses is measured value)

○ No data

Figure 17. Maximum observed water-level change during the period of record in selected wells completed in the Upper Three Runs aquifer.

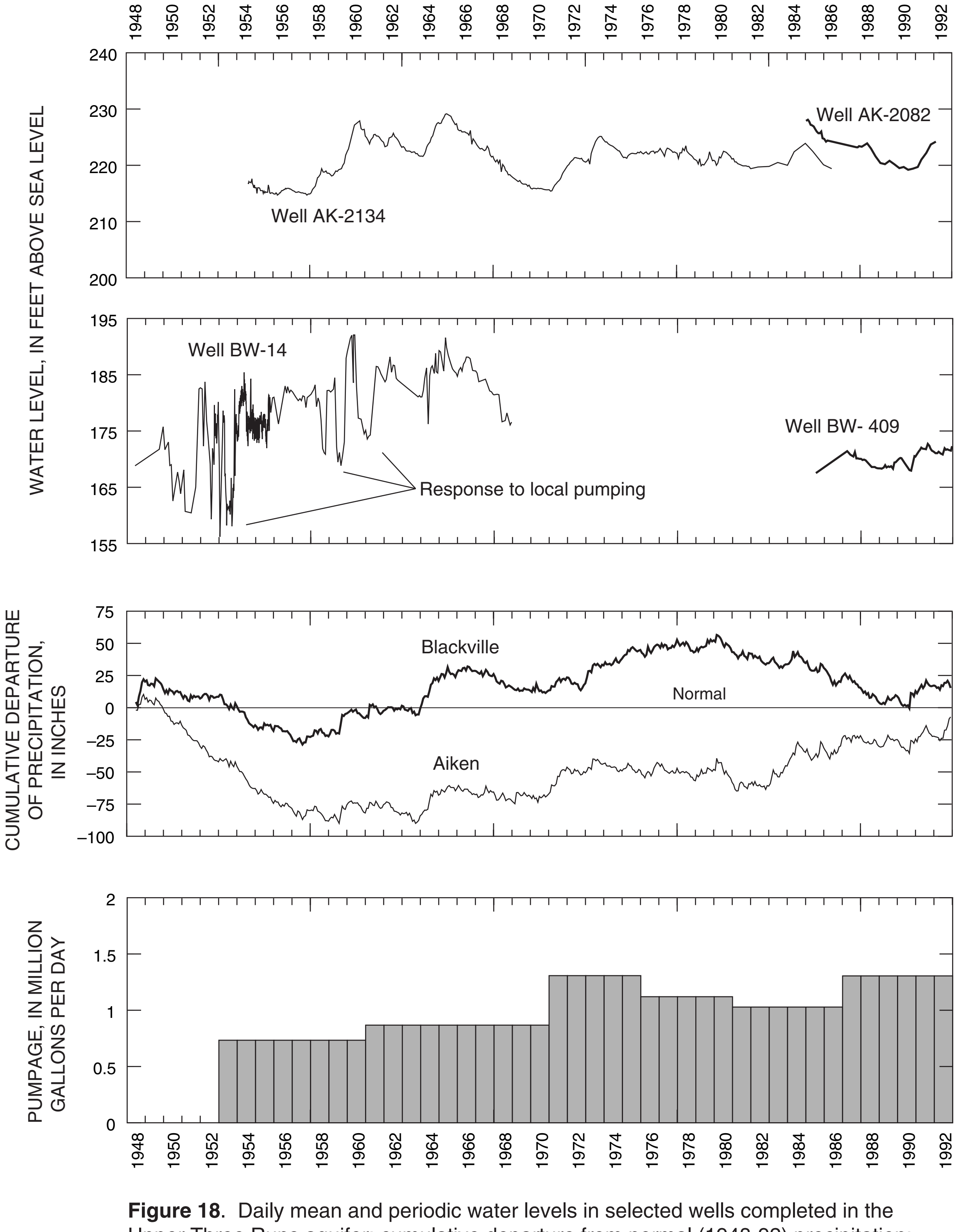


Figure 18. Daily mean and periodic water levels in selected wells completed in the Upper Three Runs aquifer; cumulative departure from normal (1948-92) precipitation; and estimated pumpage from the Upper Three Runs aquifer in the South Carolina part of the study area, 1948-1992. Blank where data not available.

during periods of below-normal precipitation. At the SRS, Siple (1967) suggested that pumping from deeper aquifers may affect ground-water levels in the Upper Three Runs aquifer (Siple's "Tertiary formations"); however, comparison of water levels at the SRS (fig. 18) with pumpage at the SRS (fig. 7), indicates little, if any, long-term influence on ground-water levels.

In Georgia, long-term water-level hydrographs for the Upper Three Runs aquifer are limited to continuous data at well 32U016 in southern Screven County, scattered periodic measurements at several wells, and periodic measurements made at well 31Z054 at Georgia Power Company Plant Vogtle in eastern Burke County (fig. 19). Sparse periodic water-level data from four wells (29Z002, 26Z004, 31Z054, and 27X003), located in the northern half of the study area, indicate little or no long-term change; however, water-level declines observed during the late 1970's to the early 1980's in well 26Z004 and 31Z054, may be attributed to increases in local pumpage. Water-level data from the four wells are insufficient to assess any relation to long-term rainfall or pumping patterns.

Water levels in wells 32U016 and 32W001, in the southern part of the study area, show long-term declines corresponding to below-normal precipitation at Augusta, Ga. Although part of this decline might be attributed to increased withdrawal from the Upper Three Runs aquifer in the Georgia part of the study area, the pronounced increase in pumpage during the early 1980's is not reflected by water-level declines in either of the wells. Another possible explanation for the long-term declines is the influence of regional pumpage from outside the study area.

Gordon Aquifer

Water levels in the confined Gordon aquifer respond to aquifer recharge and discharge in updip areas near the Fall Line. In that area, the aquifer is exposed or near land surface and overlying confining units are sandy or discontinuous, allowing more interaction with surface-water bodies and to climatic influences. Downdip, water levels are influenced by local and regional pumping and, to a lesser degree, by stream stage and precipitation. In these downdip areas, the aquifer is progressively more separated from surface-water bodies and climatic effects because it is deeply buried, and overlying confining units are thicker and more continuous, and are characterized by decreasing percentages of sand.

During October 1992, water levels in 54 wells completed in the Gordon aquifer mostly were between 1 ft lower and 3 ft higher than in May 1992 (figs. 11 and 20). Larger seasonal changes probably were due to effects of local pumpage. A seasonal decline of about 6 ft occurred in one well located near supply wells in the southern part of Jefferson County, Ga. A seasonal rise in excess of 5 ft occurred near supply wells in eastern Barnwell County, S.C., and in the northern part of the SRS in Aiken County, S.C.

In South Carolina, the maximum annual water-level fluctuation in the Gordon aquifer in wells BW-352 and BW-354 at the SCDNR-WRD C-6 well cluster site (see locations, fig. 20), averaged from 1.6 to 2 ft during 1994 and 1995 (fig. 21, table 3). Well BW-352 is completed in the uppermost part of the Gordon aquifer, and well BW-354 is completed in the lowermost part. Water-level fluctuations in the two zones are nearly identical, with water levels in well BW-354 about 6-7 ft higher than well BW-352 (fig. 21). Because the aquifer is deeply buried in this area, water levels show little response to direct recharge from precipitation; however, water levels probably are affected by long-term precipitation changes that affect recharge rates, and by regional pumping.

In Georgia, the average-annual water-level fluctuation in the Gordon aquifer was 2.6 ft in well 31Z033 and 4 ft in well 31Z110 (table 3; fig. 21). Well 31Z110 is located at the TR-92-6 well-cluster site, along the bluffs of the western bank of Savannah River, about 0.5 mi from the area where the Gordon aquifer has been incised by the paleo Savannah River channel, and about 2 mi northwest of the river (fig. 5). Water levels in well 31Z110 show a pronounced response to changes in Savannah River stage.

Evaluation of data from 28 wells completed in the Gordon aquifer indicates that maximum long-term water-level changes mostly were between -18 and +13 ft (fig. 13). Water-level declines in excess of 5 ft occurred in northern Jenkins County, northeastern Burke County, southern Jefferson County, eastern Barnwell County, near Plant Vogtle (site 6, fig. 6) in Burke County, and in the northern part of the SRS in Aiken County (fig. 22). Water-level rises of more than 5 ft occurred in Jenkins, Screven, Barnwell, and Aiken Counties. Each of the changes in excess of 5 ft occurred near supply wells completed in the Gordon aquifer.

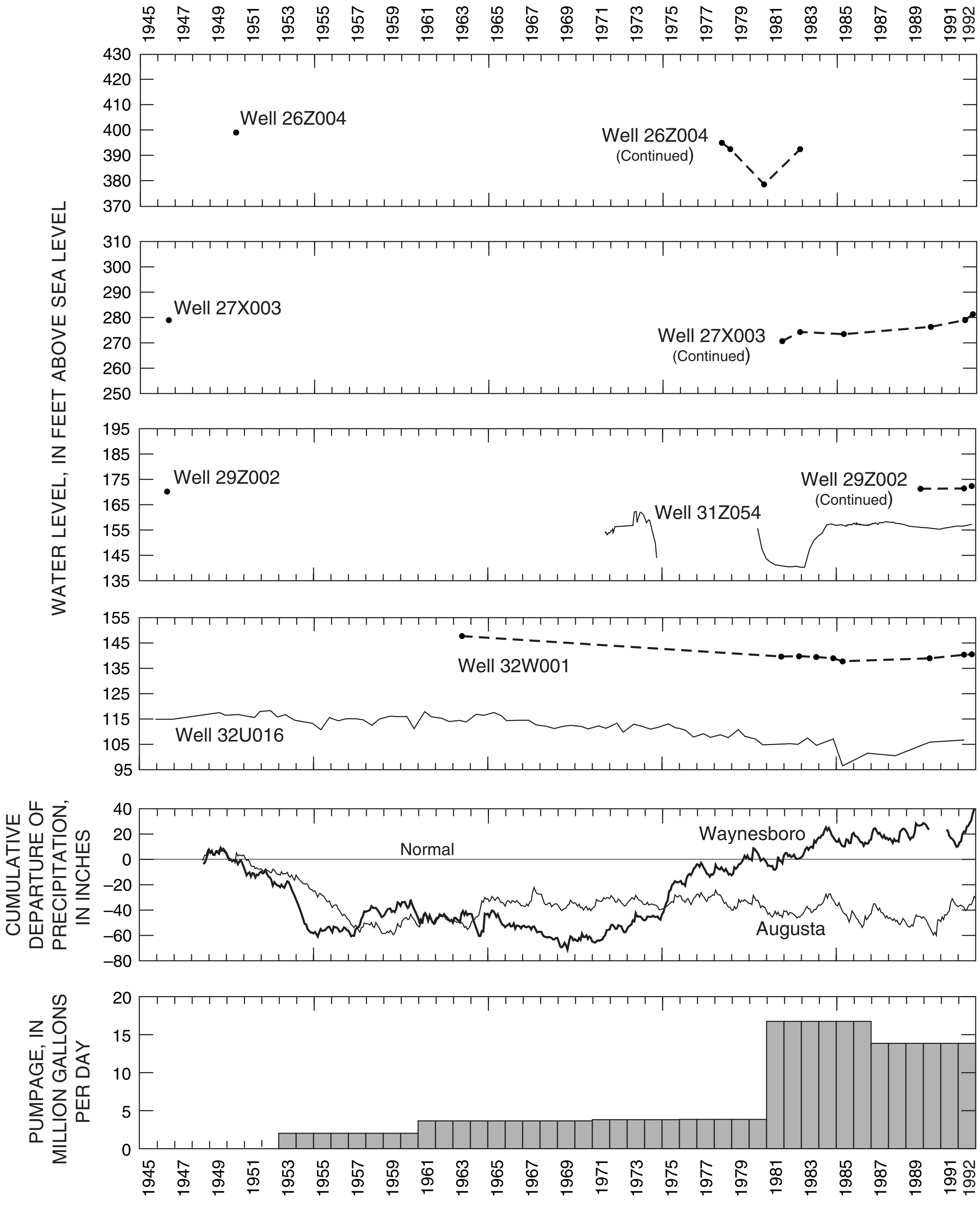
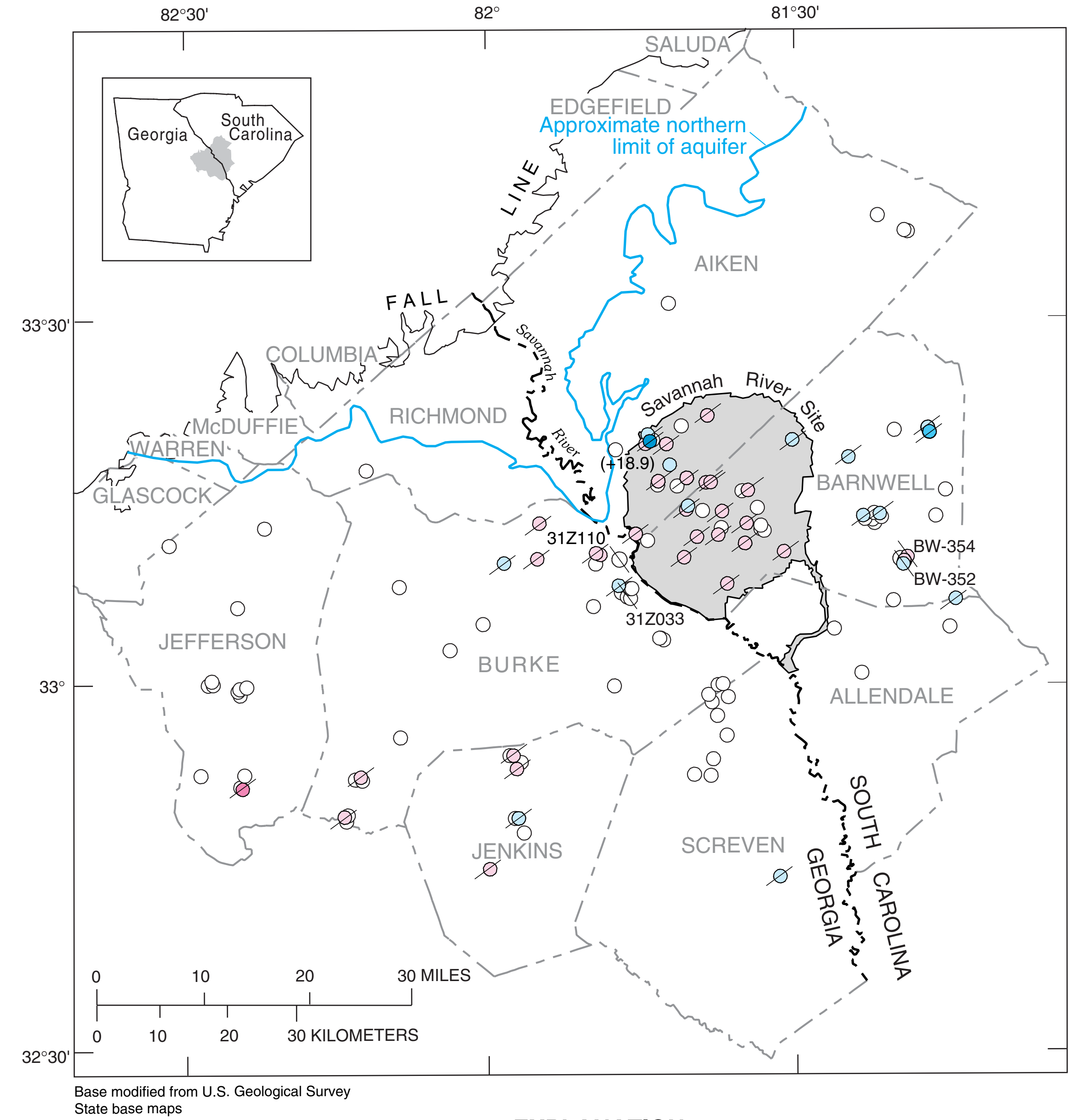


Figure 19. Daily mean and periodic water levels in selected wells completed in the Upper Three Runs aquifer; cumulative departure from normal (1948-92) precipitation; and estimated pumpage from the Upper Three Runs aquifer in the Georgia part of study area, 1948-92. Blank where data not available. Dashed where inferred.



EXPLANATION

WELLS

○ MUNICIPAL, INDUSTRIAL, OR IRRIGATION WELL THAT WITHDRAWS WATER FROM AQUIFER

31Z110 WELL EQUIPPED WITH CONTINUOUS WATER-LEVEL RECORDER—Number is well identification

OBSERVATION OR OTHER USE WELL

WATER-LEVEL CHANGE, IN FEET—Where positive, indicates water-level altitude higher in October than in May 1992; where negative, indicates water-level altitude higher in May than in October, 1992

(+18.9) Greater than +15 (Number in parentheses is measured value)

+5 to +15

0 to +5

–5 to 0

–15 to –5

○ No data

Figure 20. Observed water-level change during May-October 1992 in wells completed in the Gordon aquifer.

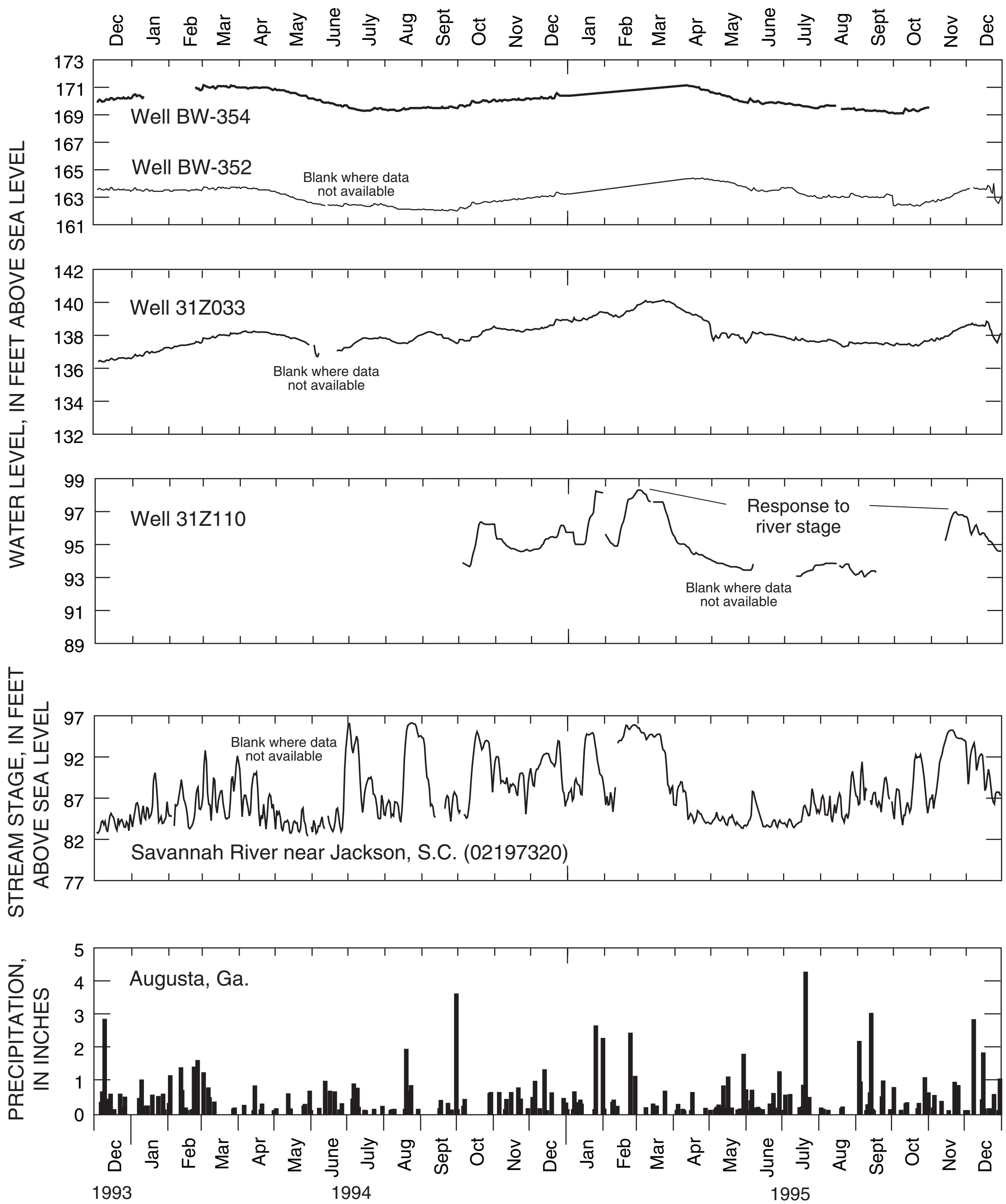
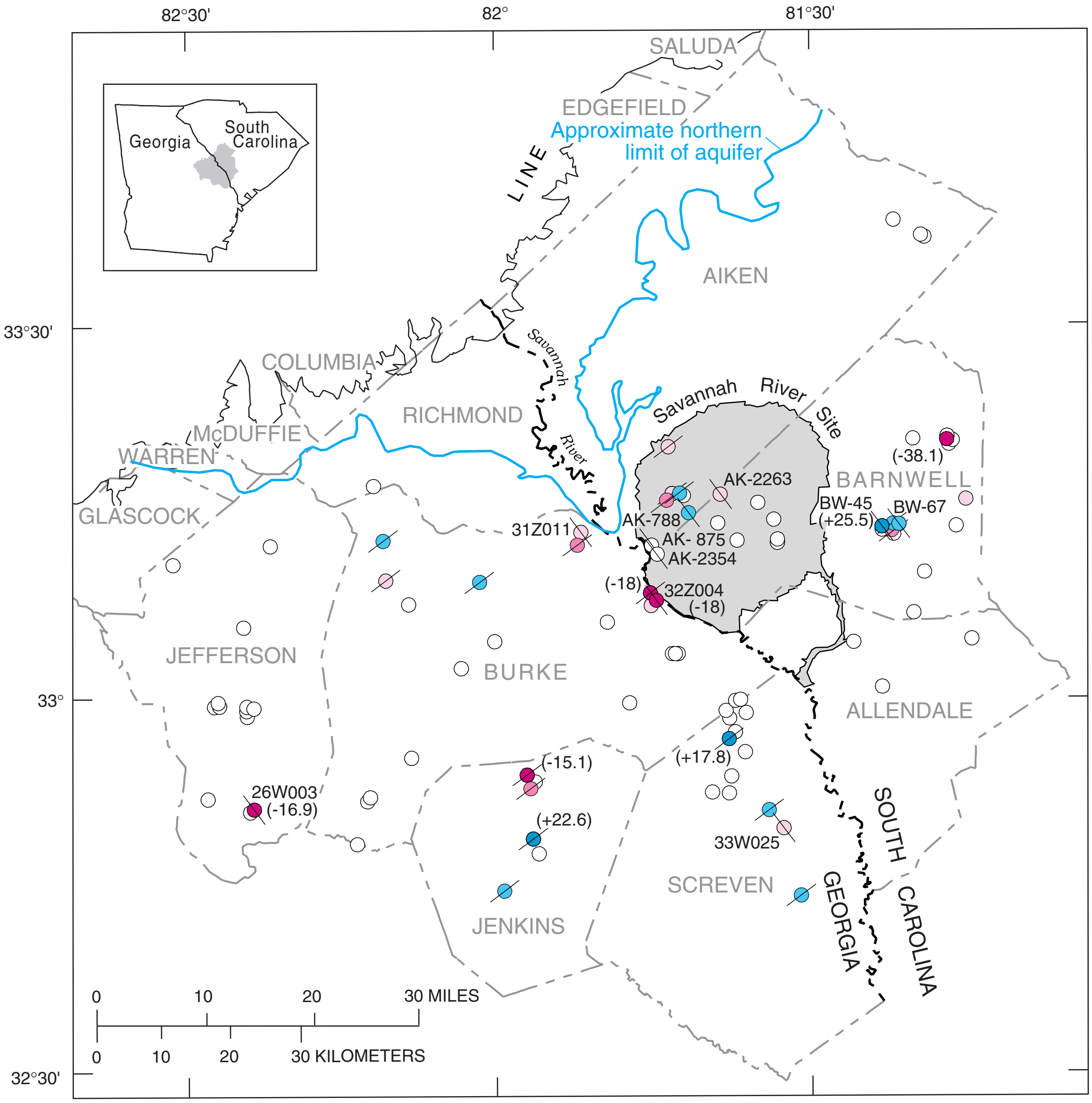


Figure 21. Daily mean water levels in selected wells completed in the Gordon aquifer in South Carolina and Georgia; daily mean stream stage at the Savannah River; and daily precipitation at Augusta, Georgia, December 1993-December 1995.



Base modified from U.S. Geological Survey
State base maps

EXPLANATION

WELLS

○ MUNICIPAL, INDUSTRIAL, OR IRRIGATION WELL THAT WITHDRAWS WATER FROM AQUIFER

30Z011 WELL FOR WHICH HYDROGRAPH IS INCLUDED IN THIS REPORT—Number is well identification

OBSERVATION OR OTHER USE WELL

MAXIMUM OBSERVED WATER-LEVEL CHANGE, IN FEET– Represents range and direction of change between maximum and minimum water-level measured in wells having 10 or more years of water-level data prior to 1993

(+25.5) Greater than +15 (Number in parentheses is measured value)

+5 to +15

–5 to 0

–15 to –5

(-18) Less than –15 (Number in parentheses is measured value)

○ No data

Figure 22. Maximum observed water-level change during the period of record in wells completed in the Gordon aquifer.

Despite an increase in withdrawal from the Gordon aquifer in the study area during 1953-92, water levels in the South Carolina wells show little long-term decline in response to pumpage (fig. 23). In fact, water levels in several wells rose during this period. Water levels in two wells at the town of Barnwell, Barnwell County, S.C., indicate a possible rise from the early 1950's through 1992 (wells BW-45 and BW-67, fig. 23). This rise may be attributed to (1) above-normal precipitation at Aiken and Blackville, S.C., during much of the 1960's and 1970's; (2) reduced pumpage from the overlying Upper Three Runs aquifer at Barnwell, as was described earlier for well BW-14 (fig. 18); or (3) a combination of both.

Water-levels in wells AK-2263, AK-2354, AK-875, and AK-788, located at the SRS, show no long-term trend. Water-level data from the early 1950's for well AK-2263 indicate little change in water level. Similarly, data from the late 1970's through 1992 for wells AK-2354, AK-875, and AK-788, indicate little water-level change for this period.

In Georgia, scattered periodic data from well 31Z011, located in northeastern Burke County indicate that little water-level change occurred in that area during 1946-85 (fig. 24). In northern Screven County, water-level changes in well 33W025 were minor during 1981-92.

Data from well 32Z004, located at Georgia Power Company Plant Vogtle in Burke County, Ga., indicate that a slight downward water-level trend may have occurred from the early 1970's through 1988, followed by a slight rise from 1989 through 1992. The period of decline in this well corresponded to below-normal precipitation at Augusta during 1976-88, and to increased withdrawal from the Gordon aquifer in the Georgia part of the study area.

During 1964-76, water-levels in well 26W003, located at the town of Wadley in southern Jefferson County, Ga., showed little change. However, during 1976-92, water levels in the well declined about 12 ft; corresponding to a period of increased withdrawal from the aquifer and to a period of below-normal precipitation at Augusta during 1975-89.

Dublin Aquifer System

Water levels in the Millers Pond, upper Dublin, and lower Dublin aquifers of the Dublin aquifer system respond to aquifer recharge and discharge in updip areas near the Fall Line. In that area, the aquifers are exposed or near land surface and overlying confining units are sandy or discontinuous, allowing more interaction with surface-water bodies and climatic influences. Downdip, water levels in the aquifers are influenced by local and regional pumping, and to a lesser degree by stream stage and precipitation. In these downdip areas, the aquifers are progressively more separated from surface-water bodies and climatic effects because they are deeply buried, and overlying confining units are thicker and more continuous, and are characterized by decreasing percentages of sand.

Water levels in the Dublin aquifer system generally are highest in the winter-early spring when precipitation is greatest, evapotranspiration is lowest, and irrigation withdrawals are minimal; water levels are lowest in the summer-fall when precipitation is low, and evapotranspiration and irrigation pumpage is greatest. Seasonal water-level fluctuations and long-term trends for the Dublin aquifer system are described by aquifer in the following sections.

Millers Pond Aquifer

During October 1992, water levels in seven wells completed in the Millers Pond aquifer mostly were between 1 ft lower and 1 ft higher than in May 1992 (figs. 11 and 25). Water levels in the Millers Pond aquifer were continuously monitored in well 30Z028 at the Millers Pond well-cluster site during 1994-95. The average-annual water-level fluctuation during 1993-95 in well 30Z028 was about 1 ft (table 3, fig. 26). The well is located in northern Burke County, Ga., about 2 mi from the area where the Millers Pond aquifer was incised by the paleo Savannah River channel (fig. 5). Water levels in the well respond to changes in Savannah River stage, as shown by comparison to data at the Savannah River at Jackson, S.C. (fig. 26).

Comparison of ground-water levels in three wells at the SRS (fig. 27) to the cumulative departure of precipitation at Aiken and Blackville, S.C., indicate that water levels in the wells may be influenced by precipitation trends (fig. 28); however, there are no long-term (greater than 10 years) data available to assess the magnitude of water-level changes in the Millers Pond aquifer. Data are limited to wells located at the SRS from the mid-1980's (see locations figure 27). A slight water-level decline in these wells during 1987-90 corresponds to a period of below-normal precipitation. Conversely, a slight water-level rise during 1990-92 corresponds to a period of above-normal precipitation. Water levels in the three wells showed little response to pumpage from the Millers Pond aquifer because withdrawal was small (about 2 Mgal/d) and relatively constant during 1985-92.

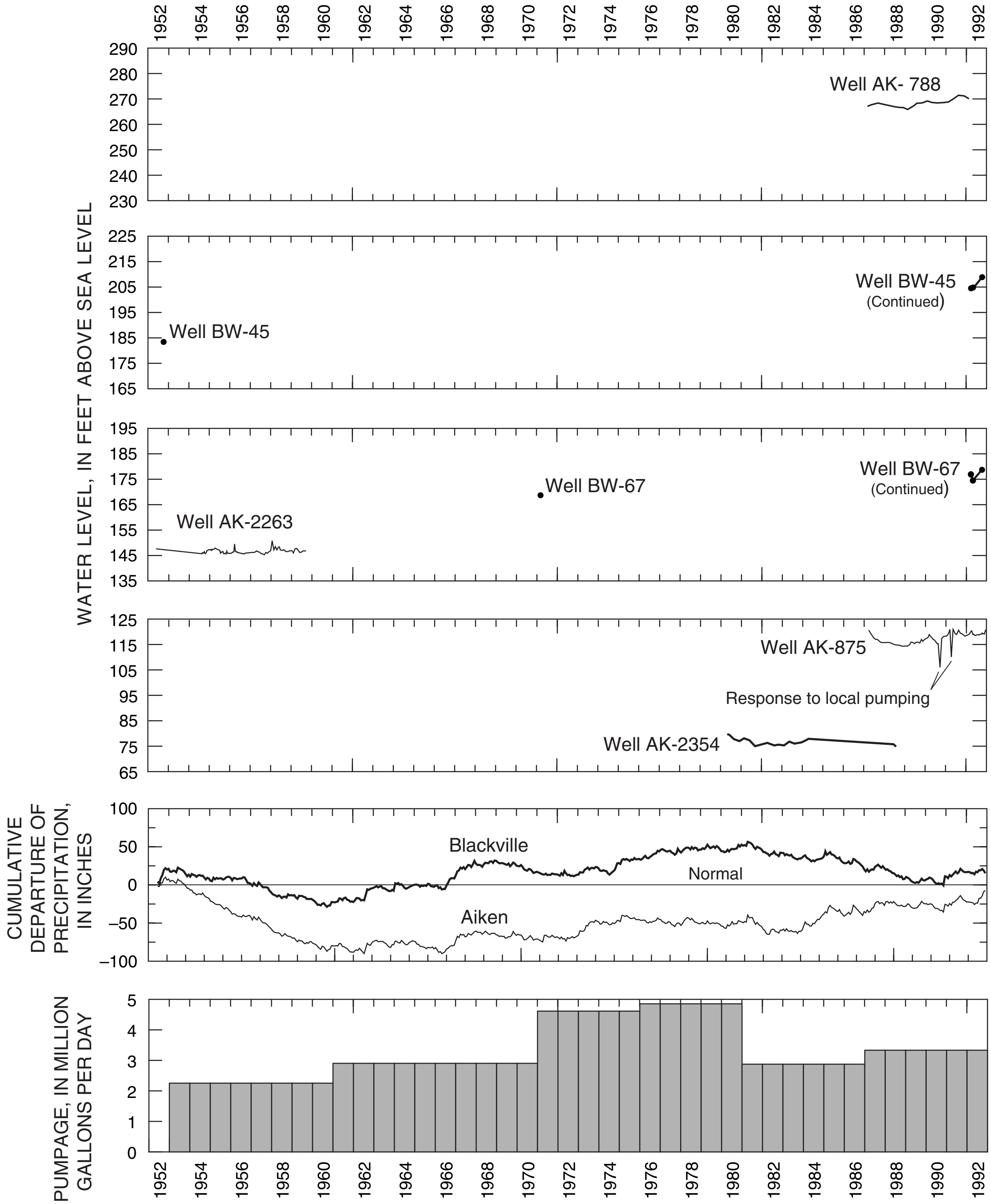


Figure 23. Daily mean and periodic water levels in selected wells completed in the Gordon aquifer; cumulative departure from normal (1948-92) precipitation; and estimated pumpage from the Gordon aquifer in the South Carolina part of study area, 1952-92. Blank where data not available.

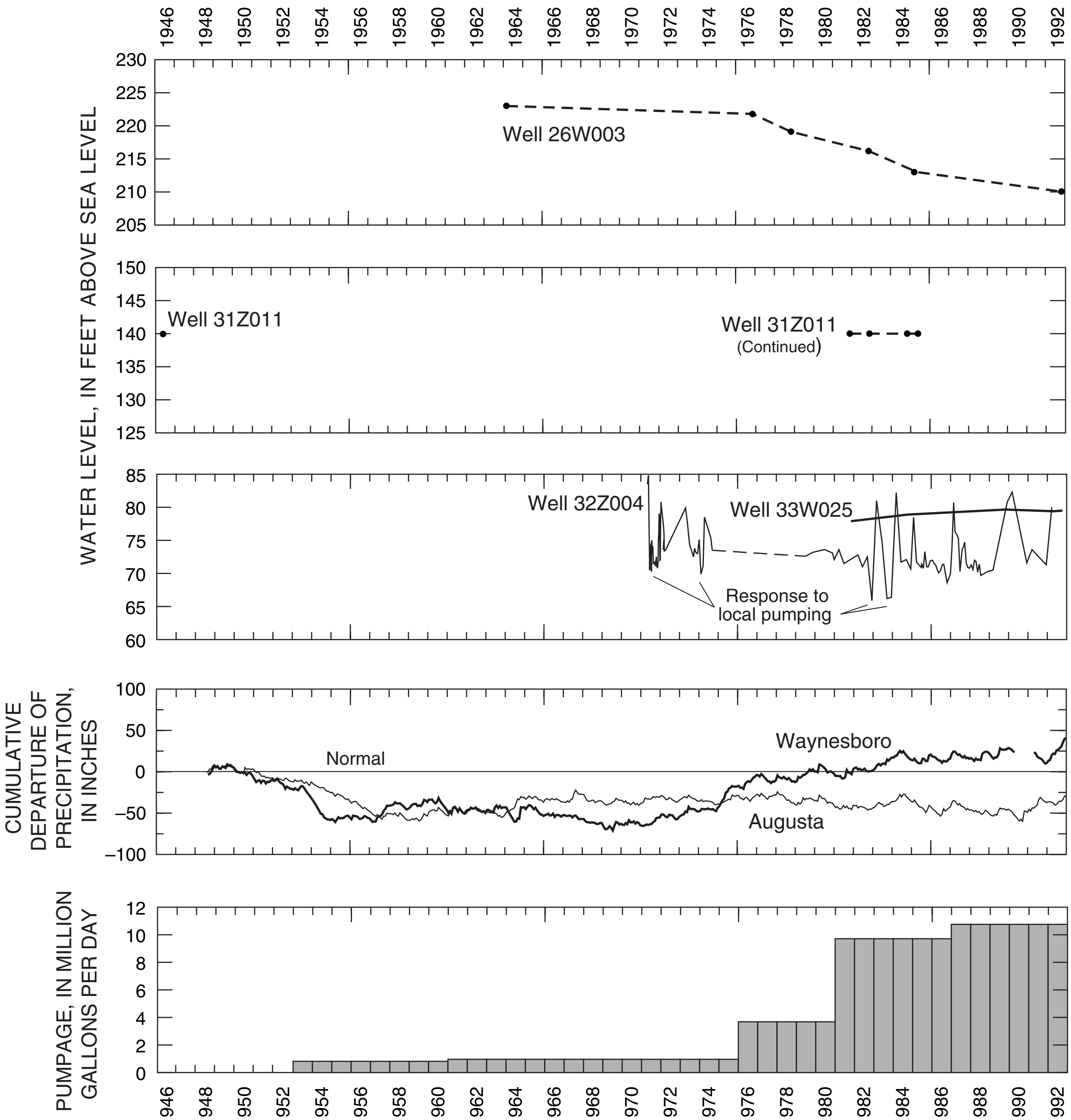
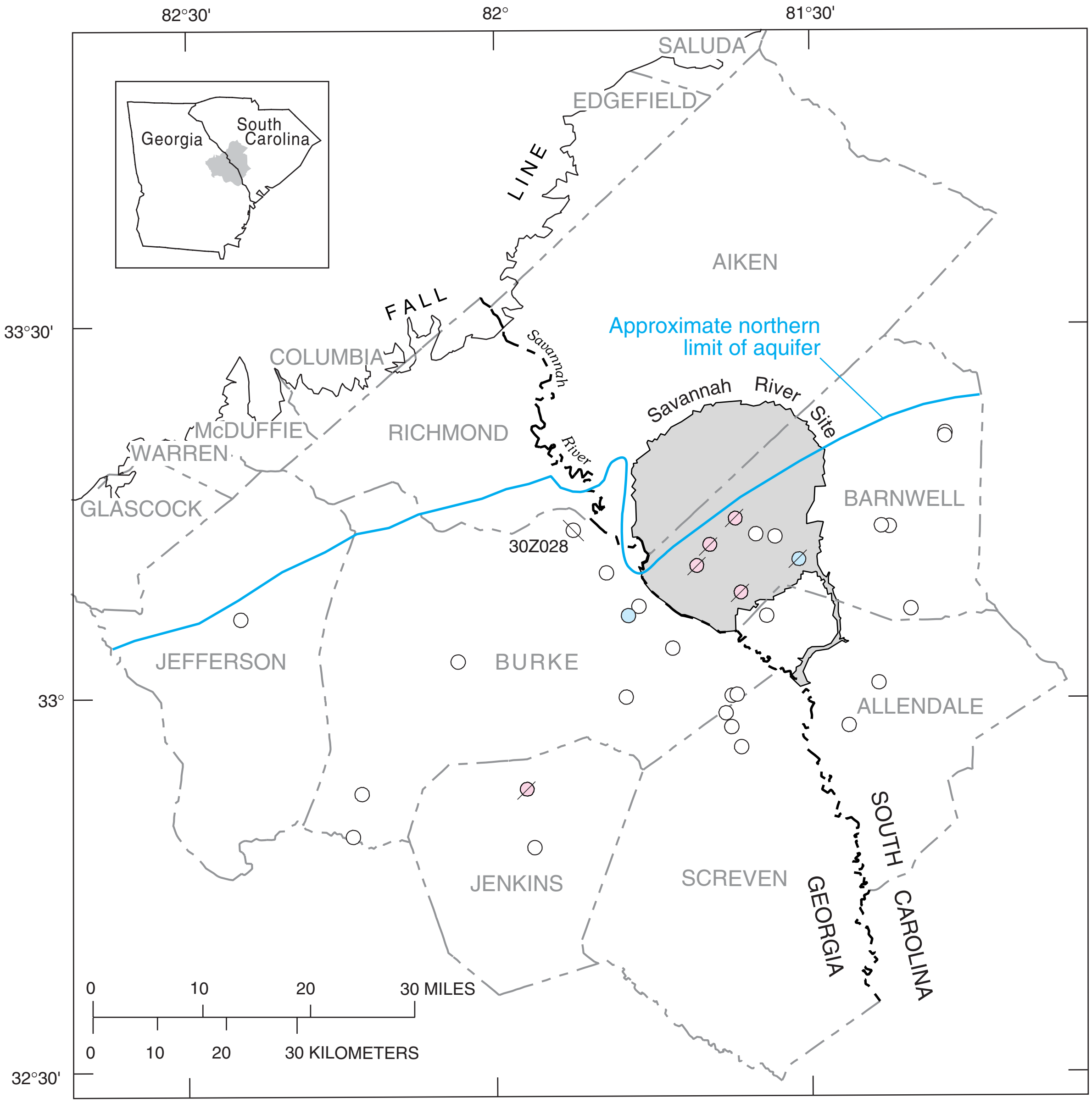


Figure 24. Periodic water levels in selected wells completed in the Gordon aquifer; cumulative departure from normal (1948-92) precipitation; and estimated pumpage from the Gordon aquifer in the Georgia part of study area, 1946-92. Blank where data not available. Dashed where inferred.



Base modified from U.S. Geological Survey
State base maps

EXPLANATION

WELLS

○ MUNICIPAL, INDUSTRIAL, OR IRRIGATION WELL THAT WITHDRAWS WATER FROM AQUIFER

30Z028 WELL EQUIPPED WITH CONTINUOUS WATER-LEVEL RECORDER—Number is well identification

OBSERVATION OR OTHER USE WELL

WATER-LEVEL CHANGE, IN FEET—Where positive, indicates water-level altitude higher in October than in May 1992; where negative, indicates water-level altitude higher in May than in October, 1992

0 to +5

–5 to 0

No data

Figure 25. Observed water-level change during May-October 1992 in wells completed in the Millers Pond aquifer.

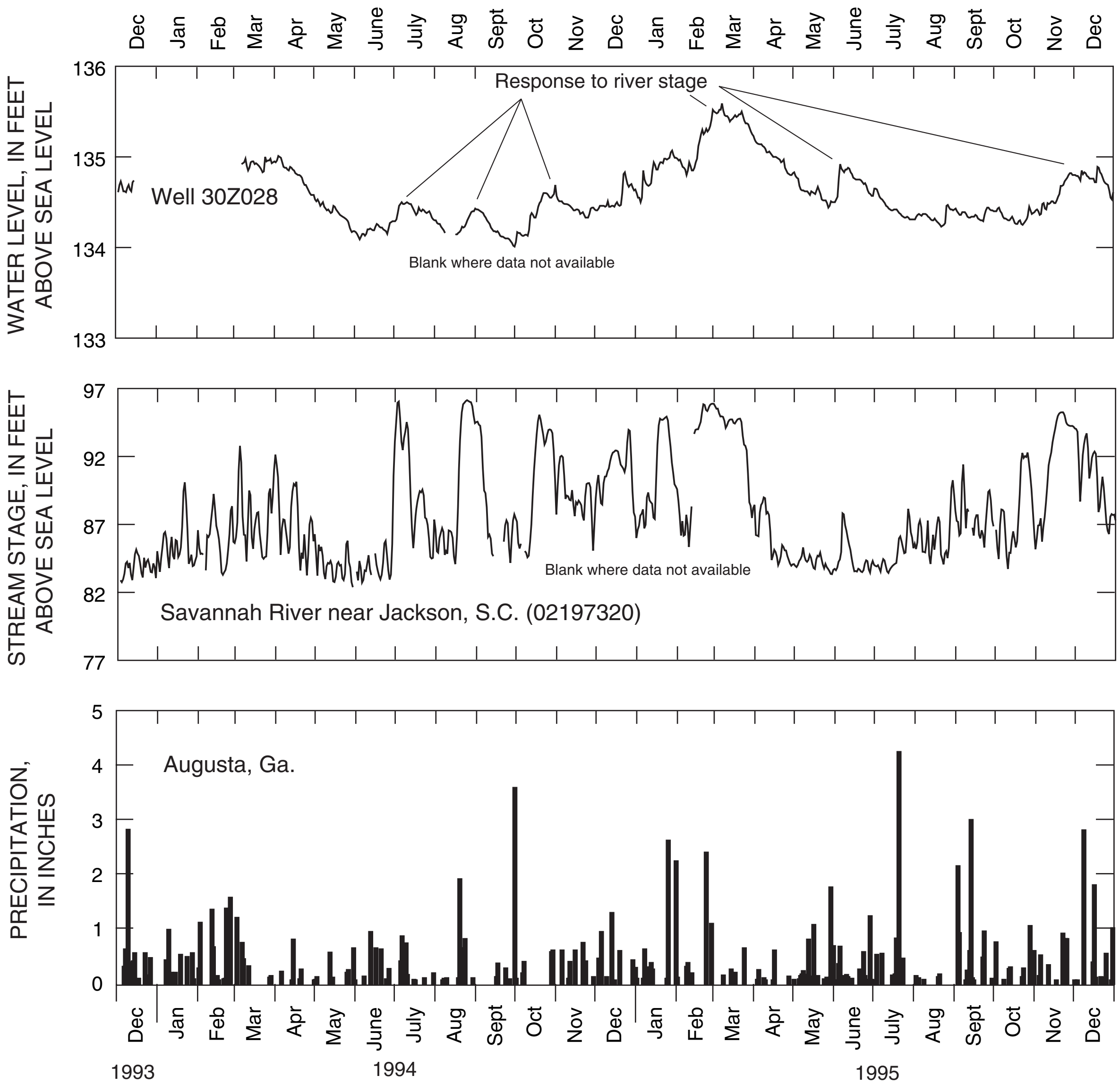


Figure 26. Daily mean water levels in well 30Z028 completed in the Millers Pond aquifer in Burke County, Georgia; daily mean stream stage at the Savannah River; and daily precipitation at Augusta, Georgia, December 1993-December 1995.

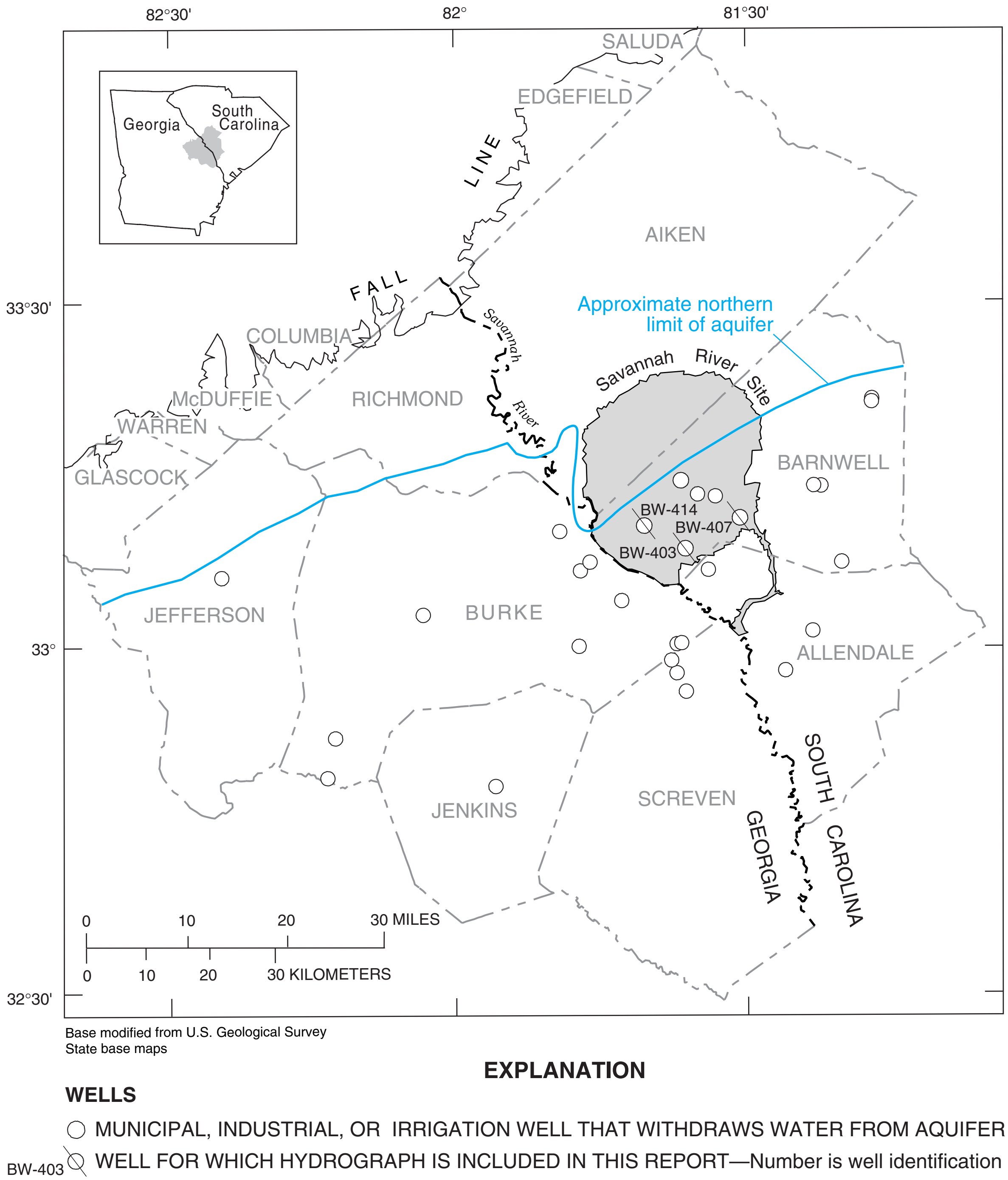


Figure 27. Location of long-term monitoring wells completed in the Millers Pond aquifer.

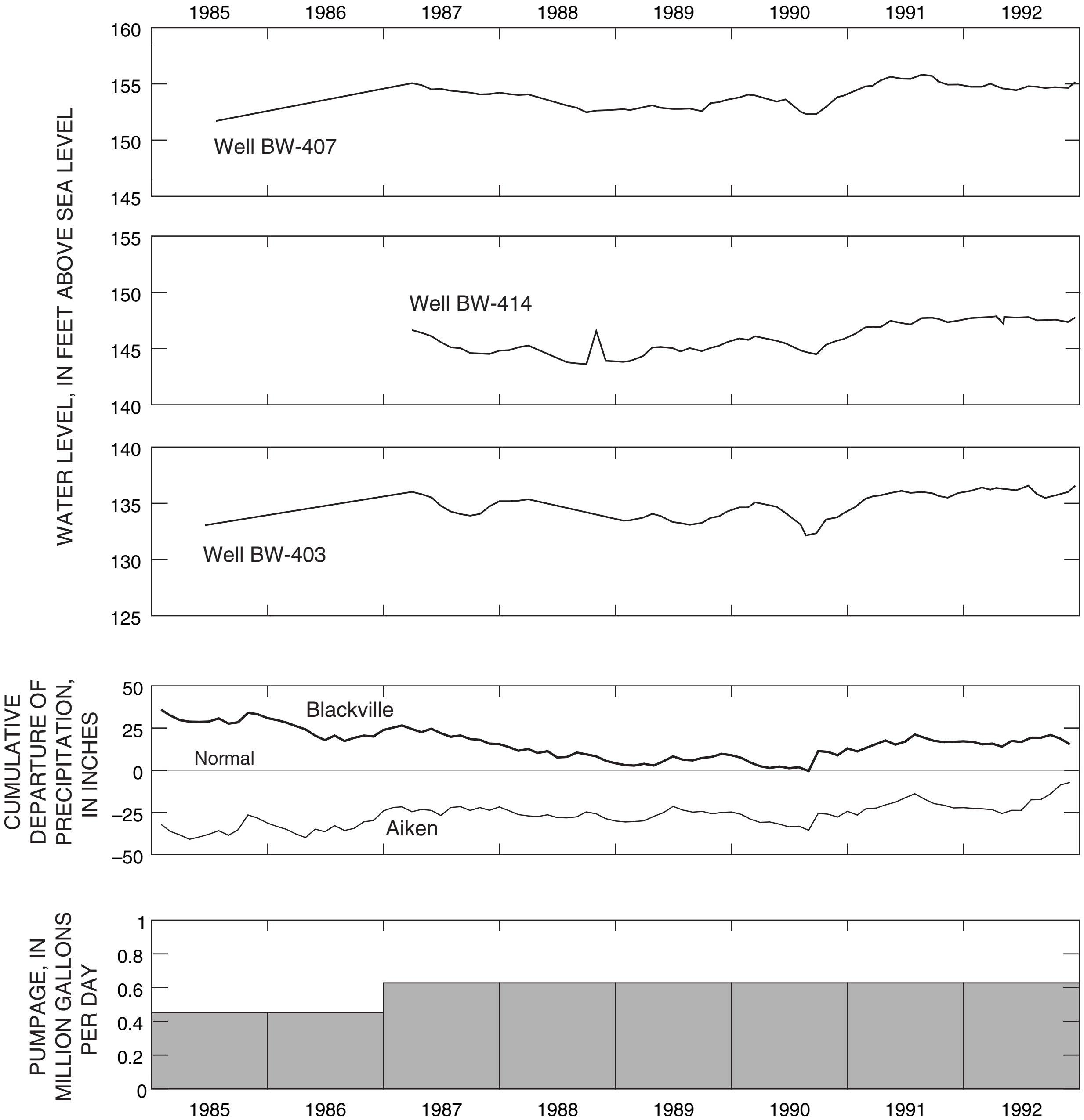


Figure 28. Periodic water levels in selected wells completed in the Millers Pond aquifer; cumulative departure from normal (1948-92) precipitation; and estimated pumpage from the Millers Pond aquifer in the South Carolina part of study area, 1985-92. Blank where data not available.

Upper Dublin Aquifer

During October 1992, water levels in 28 wells completed in the upper Dublin aquifer mostly were between 3 ft lower and 1 ft higher than in May 1992 (figs. 11 and 29). Changes greater than 5 ft occurred at isolated well sites located near supply wells east of the SRS in Barnwell County, S.C. Although there are no known supply wells in the vicinity of the decline in Barnwell County, the small seasonal change in other wells in the area suggests that the decline is a result of pumpage from a nearby well completed in the upper Dublin aquifer or from a vertically adjacent water-bearing zone.

Water levels in the upper Dublin aquifer were continuously monitored in South Carolina in well AK-825 at the SCDNR-WRD C-2 well-cluster site during 1993-95 (see location, fig. 29). The annual water-level fluctuation in well AK-825 during 1994 and 1995 averaged about 1 ft (table 3; fig. 30). Water levels were not continuously monitored in the upper Dublin aquifer in Georgia.

Maximum observed long-term water-level changes in 11 wells completed in the upper Dublin aquifer mostly ranged from -22 to +15 ft (figs. 13 and 31). Water-level declines in excess of 5 ft occurred in south-central Jefferson County, central Burke County, southwestern Screven County, southeastern Allendale County; and in the northern part of the SRS in southwestern Aiken County. A water-level rise greater than 5 ft occurred in a well located east of the SRS in Barnwell County. Each of these changes occurred near supply wells completed in the upper Dublin aquifer.

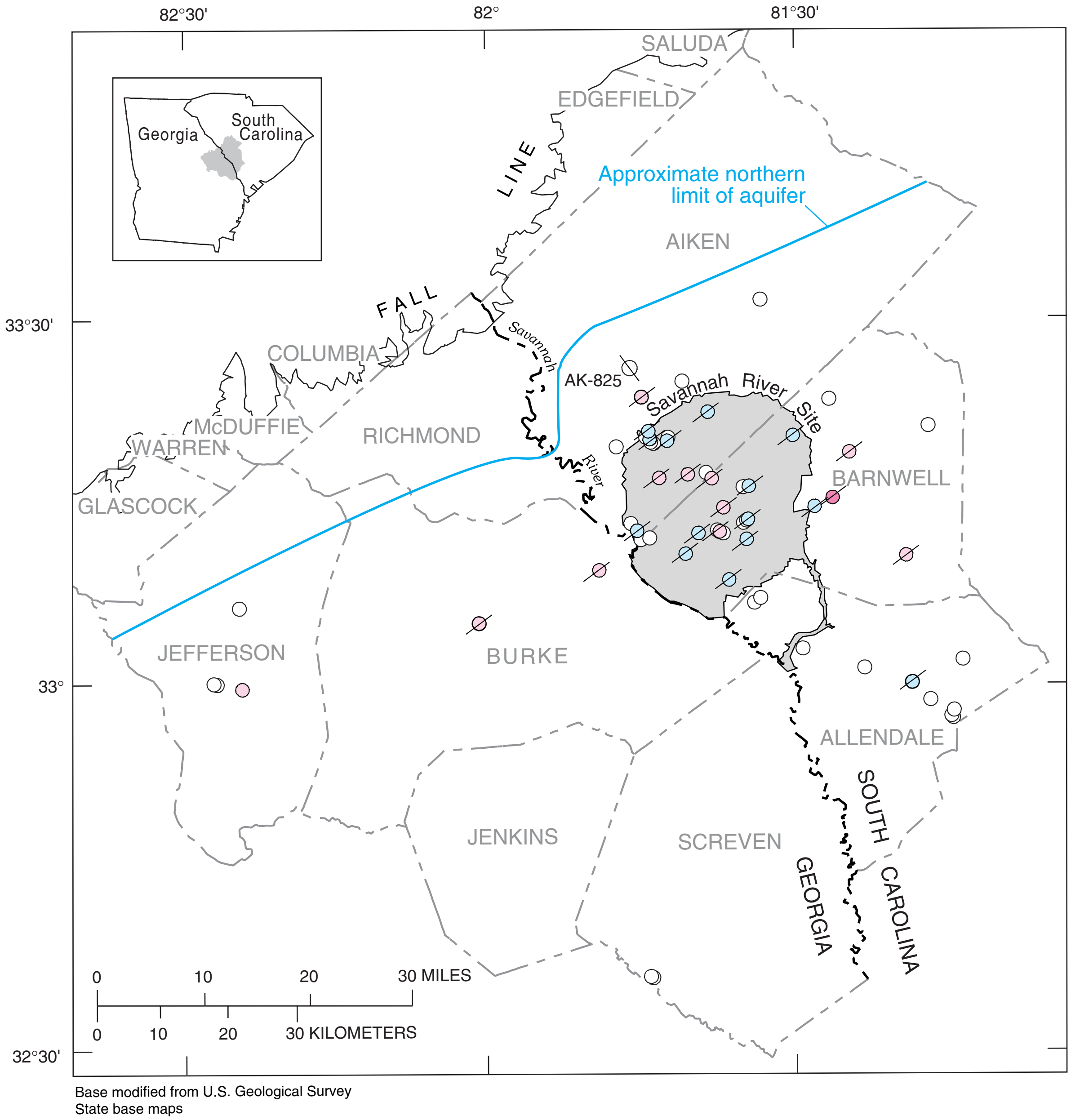
Water levels in wells AK-601, BW-265, and BW-375, located near the center of the SRS (see locations, fig. 31), generally declined during 1954-58 and 1975-82, and rose during 1982-85 and 1987-92 (fig. 32). Because pumpage from the upper Dublin aquifer was small and constant during the 1950's, it is likely that the water-level decline of about 2 ft during this period resulted mostly from below-normal precipitation (see cumulative departure graph for Aiken, fig. 32). Siple (1967) reported that during the 1950's, water levels in well BW-265 (Siple's well 27-R) likely responded more to rainfall than to pumpage. A decline of about 8 ft during 1975-82 in well AK-601 may be attributed to below-normal rainfall and to increased pumpage from the aquifer. Above-normal rainfall during 1982-92 may have produced water-level rises of about 4 ft during 1982-85 in well AK-601, and about 5 ft during 1987-92 in well BW-375.

Water levels in wells AK-468 and AK-863, located in the Savannah River alluvial valley near the SRS TNX area (see location, fig. 1b), showed little change during 1952-75, declined during 1975-88, and rose during 1988-92 (fig. 32). The lack of change during the 1950's, a period of below-normal rainfall and one of the most severe droughts on record (1954), probably indicates that water levels in this area are only minimally affected by recharge from precipitation. The decline of about 13 ft during 1975-88 corresponded to a period of increased pumpage from the aquifer. The rise of about 4 ft during 1988-92 may be the result of changes in local pumping. Siple (1967) reported that during the 1950's, water levels in well AK-468 (Siple's well S-411) were influenced by pumping at the nearby SRS D-area, with some of the response attributed to pumpage from deeper water-bearing zones beneath the upper Dublin (Siple's "Ellenton") aquifer.

Periodic measurements at well AL-24, located at the town of Allendale in eastern Allendale County, S.C., indicate that water levels in this area declined about 5 ft during 1967-92 (fig. 32). This decline corresponded to increased pumpage from the upper Dublin aquifer, although some of the change may be attributed to seasonal fluctuation.

Lower Dublin Aquifer

During October 1992, water levels in 33 wells completed in the lower Dublin aquifer mostly were between 1 ft lower and 1 ft higher than in May 1992 (figs. 11and 33). The only change greater than 5 ft occurred in a well located near a supply well in southern Richmond County, which rose about 5.6 ft. Seasonal water-level changes in the lower Dublin aquifer in South Carolina are illustrated in the hydrograph showing daily mean water levels in well AK-824 at the SCDNR-WRD C-2 well-cluster site (see location, fig. 33). At the C-2 site, water-level fluctuations in the lower Dublin aquifer (fig. 34) are nearly identical to those observed in the upper Dublin aquifer, as described earlier for well AK-825. The annual water-level fluctuation during 1994 and 1995 in the lower Dublin aquifer (well AK-824) was about the same as in the upper Dublin aquifer (well AK-825), averaging about 1 ft (table 3; figs. 30 and 34).



EXPLANATION

WELLS

○ MUNICIPAL, INDUSTRIAL, OR IRRIGATION WELL THAT WITHDRAWS WATER FROM AQUIFER

AK-825 WELL EQUIPPED WITH CONTINUOUS WATER-LEVEL RECORDER—Number is well identification

OBSERVATION OR OTHER USE WELL

WATER-LEVEL CHANGE, IN FEET—Where positive, indicates water-level altitude higher in October than in May 1992; where negative, indicates water-level altitude higher in May than in October, 1992

0 to +5

–5 to 0

–15 to –5

○ No data

Figure 29. Observed water-level change during May-October 1992 in wells completed in the upper Dublin aquifer.

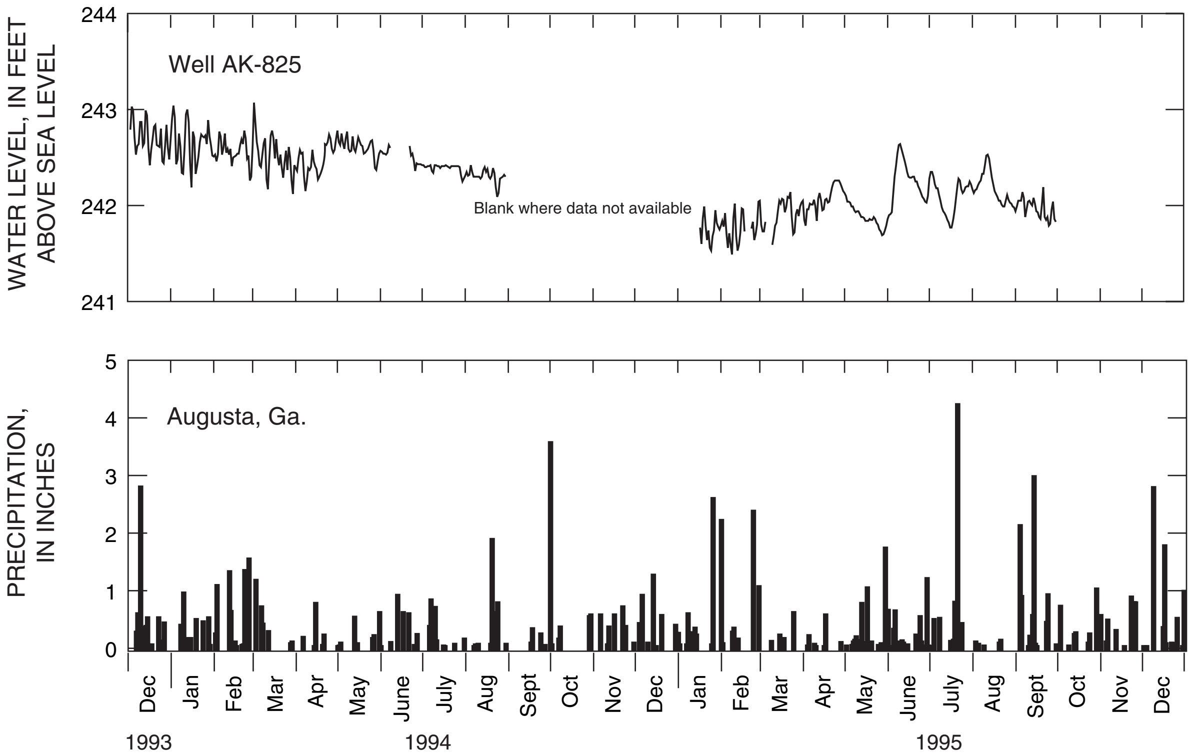
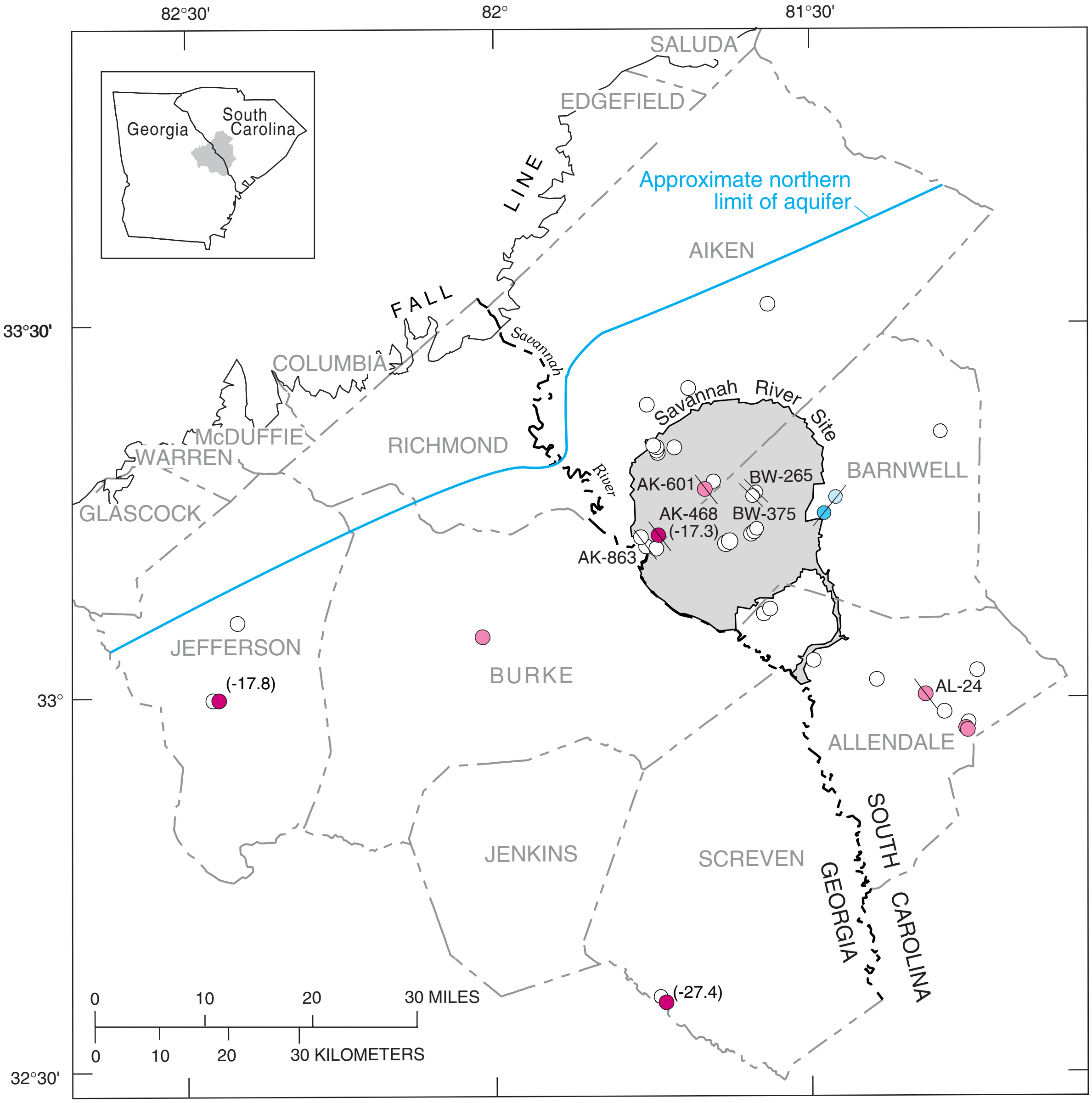


Figure 30. Daily mean water levels in well AK-825 completed in the upper Dublin aquifer in Aiken County, South Carolina; and daily precipitation at Augusta, Georgia, December 1993-December 1995.



Base modified from U.S. Geological Survey
State base maps

EXPLANATION

WELLS

○ MUNICIPAL, INDUSTRIAL, OR IRRIGATION WELL THAT WITHDRAWS WATER FROM AQUIFER

AK-601 WELL FOR WHICH HYDROGRAPH IS INCLUDED IN THIS REPORT—Number is well identification

OBSERVATION OR OTHER USE WELL

MAXIMUM OBSERVED WATER-LEVEL CHANGE, IN FEET– Represents range and direction of change between maximum and minimum water-level measured in wells having 10 or more years of water-level data prior to 1993

- +5 to +15
- 0 to +5
- –15 to –5
- (-27.4) Less than –15 (Number in parentheses is measured value)
- No data

Figure 31. Maximum observed water-level change during the period of record in wells completed in the upper Dublin aquifer.

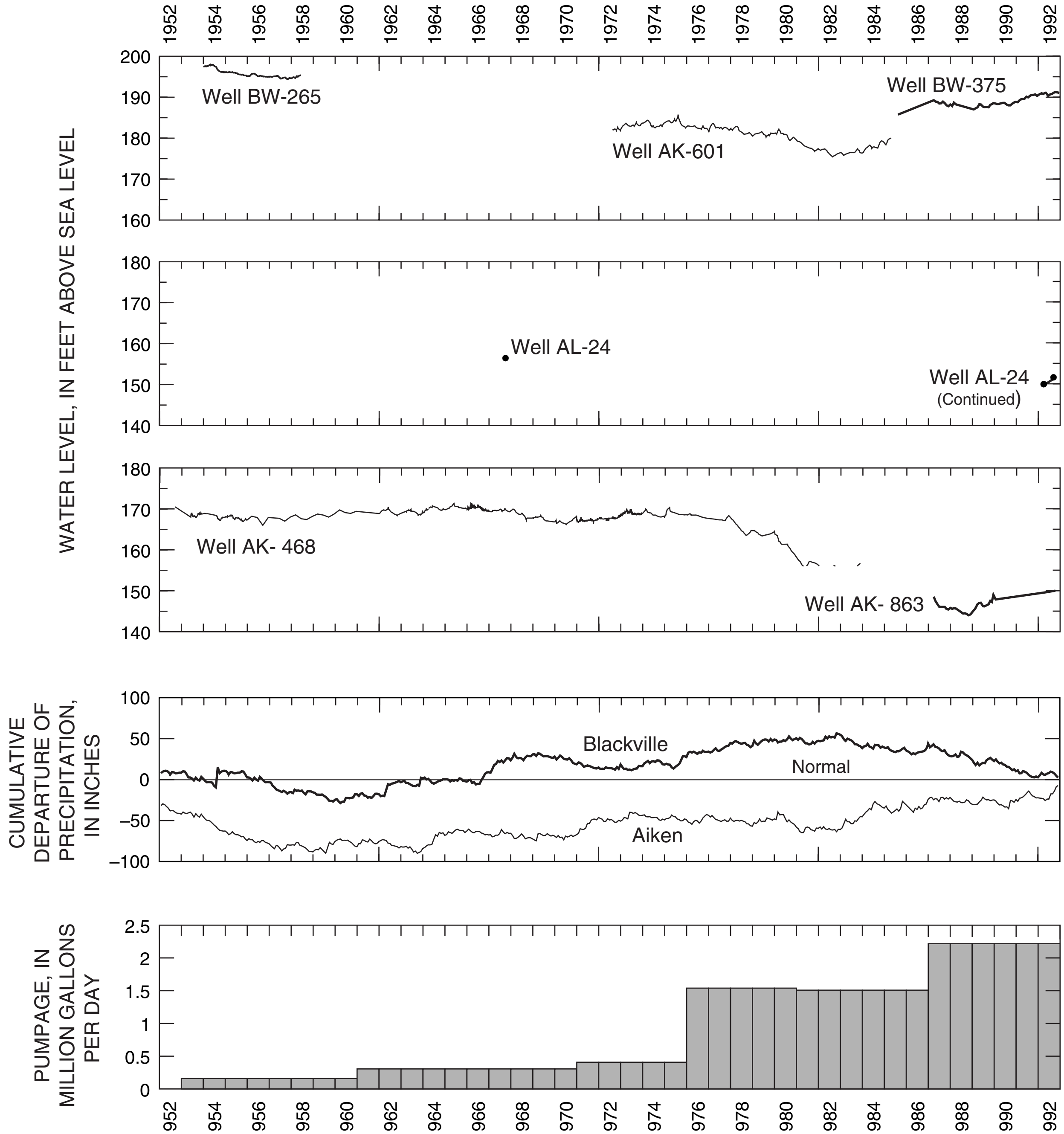
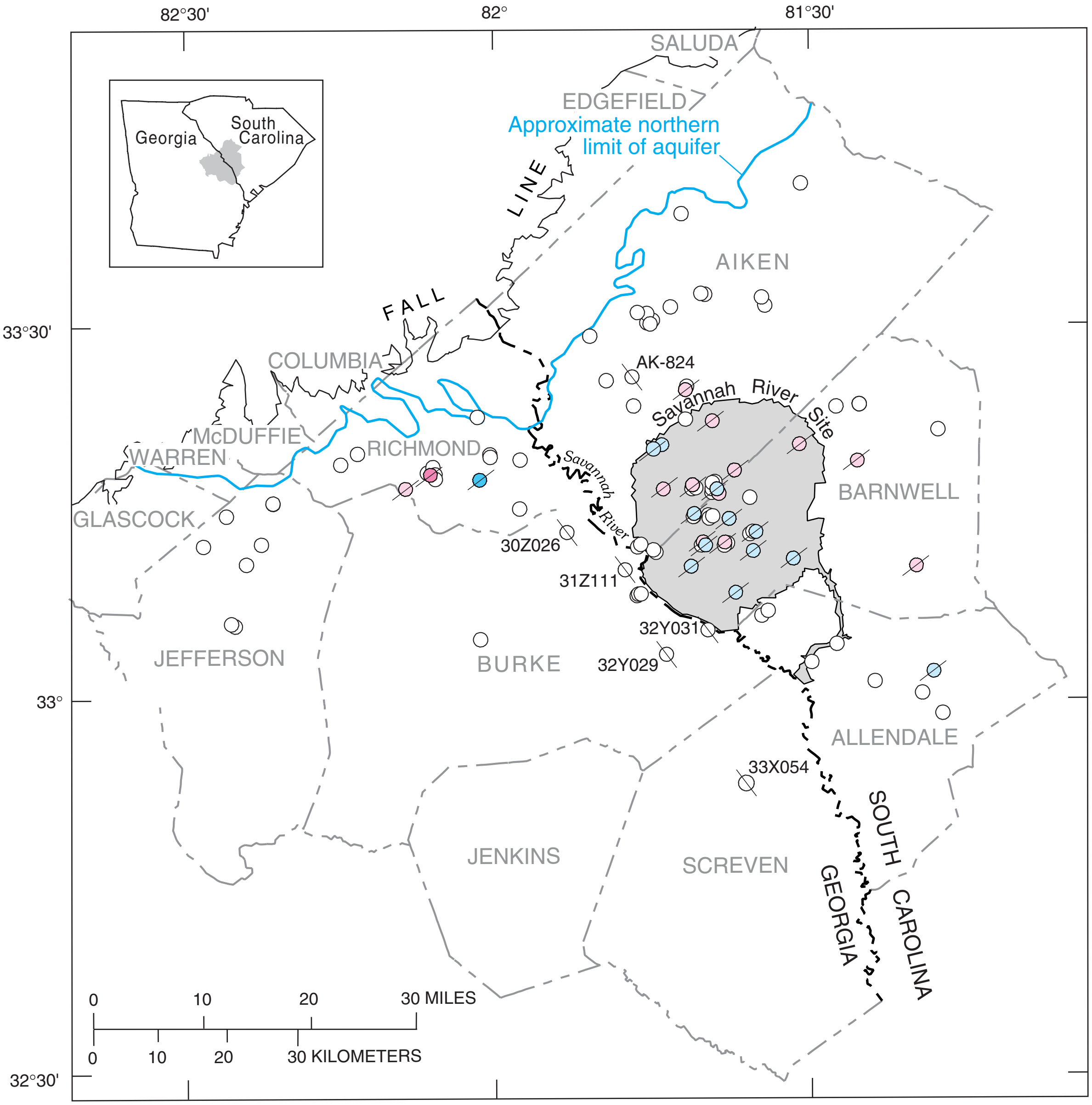


Figure 32. Daily mean and periodic water levels in selected wells completed in the upper Dublin aquifer; cumulative departure from normal (1948-92) precipitation; and estimated pumpage from the upper Dublin aquifer in the South Carolina part of study area, 1952-92. Blank where data not available.



Base modified from U.S. Geological Survey State base maps

EXPLANATION

WELLS

○ MUNICIPAL, INDUSTRIAL, OR IRRIGATION WELL THAT WITHDRAWS WATER FROM AQUIFER

32Y029 WELL EQUIPPED WITH CONTINUOUS WATER-LEVEL RECORDER—Number is well identification

OBSERVATION OR OTHER USE WELL

WATER-LEVEL CHANGE, IN FEET—Where positive, indicates water-level altitude higher in October than in May 1992; where negative, indicates water-level altitude higher in May than in October, 1992

- +5 to +15
- 0 to +5
- –5 to 0
- –5 to –15
- No data

Figure 33. Observed water-level change during May-October 1992 in wells completed in the lower Dublin aquifer.

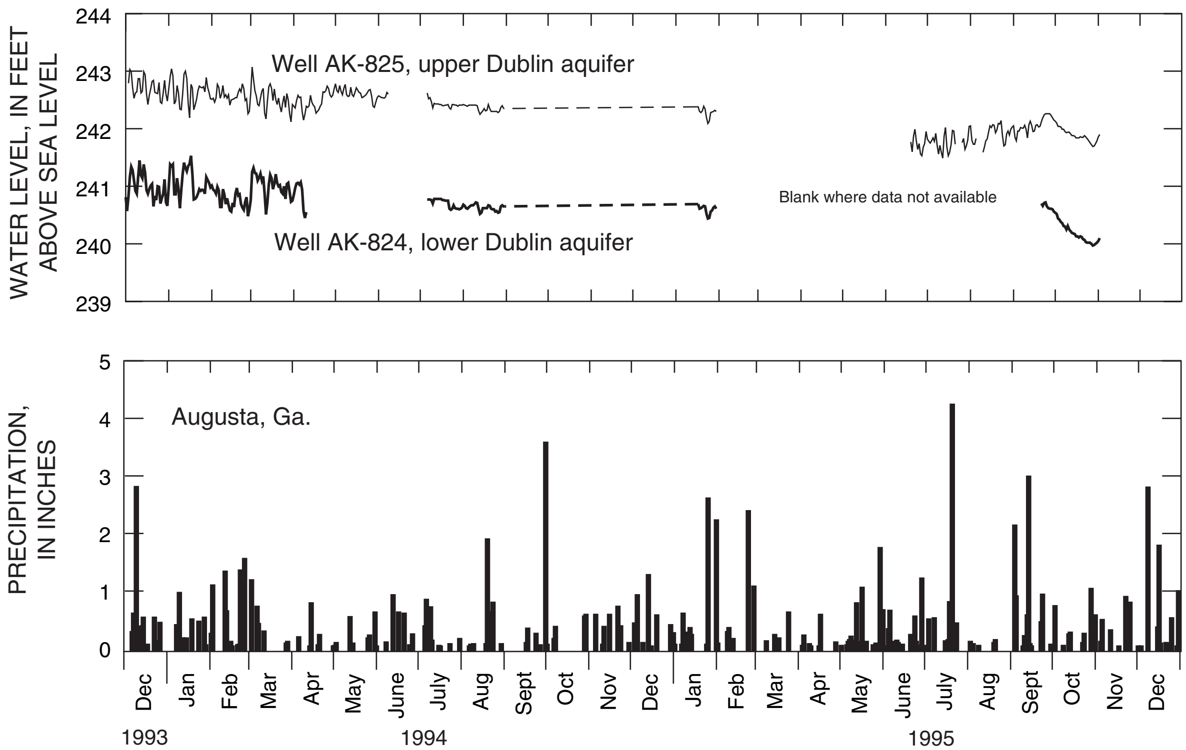


Figure 34. Daily mean water levels in the upper and lower Dublin aquifers at the C-2 well-cluster site, Aiken County, South Carolina, and daily precipitation at Augusta, Georgia, December 1993-December 1995. Dashed where inferred.

In Georgia, average-annual water-level fluctuations in the lower Dublin aquifer ranged from about 1.1 to 2.6 ft during 1994 and 1995 (table 3, figs. 34 and 35). Water levels were monitored in well 30Z026 at the Millers Pond well-cluster site; well 33X054 at the Millhaven well-cluster site; well 32Y029 at the Girard well-cluster site; well 31Z111 at the TR-92-6 well-cluster site; and well 32Y031 at the Brighams Landing well-cluster site (see locations, fig. 33).

The average annual water-level fluctuation during 1994 and 1995 in well 30Z026 was about 2.1 ft (table 3; fig. 35). The well is located in northern Burke County, Ga., about 5.5 mi from the area where the lower Dublin aquifer was incised by the paleo Savannah River channel, and about 2 mi west of the river (fig. 5). Water levels in the well respond to changes in Savannah River stage, as shown by comparison to data at the Savannah River at Jackson, S.C. (fig. 35).

Although water-level data during 1994-95 are sparse, water levels in the lower Dublin aquifer at the TR-92-6 well-cluster site (well 31Z111), and the Brighams Landing well-cluster site (well 32Y031) also respond to changes in river stage. Water-level data for 1996 and 1997 (not shown) indicate a pronounced response to changes in river stage at the two sites. The two sites are near the area where the paleo Savannah River channel incised the lower Dublin aquifer (about 9.5 mi at TR-92-6 and 17 mi at Brighams Landing), and are responding to changes in river stage where the aquifer is hydraulically connected to river alluvium.

Water levels in wells 33X054 and 32Y029 may be responding to areal pumpage (fig. 35). In well 32Y029, pronounced water-level declines during July-August 1994, and August-September 1995 may be the result of changes in pumpage. In well 33X054, Clarke and others (1996) reported a slight decline during 1994 that may have been the result of increased pumpage.

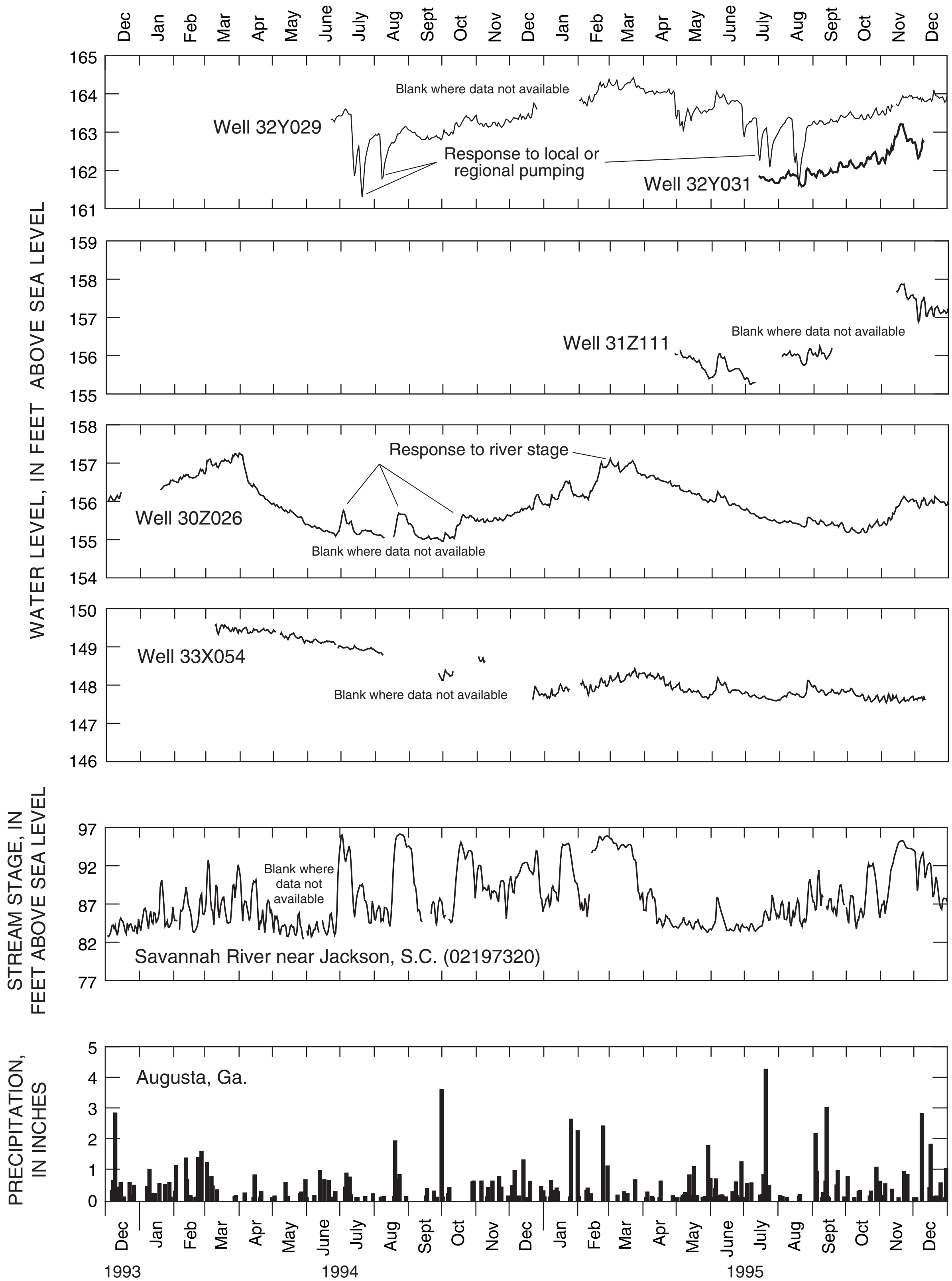


Figure 35. Daily mean water levels in selected wells completed in the lower Dublin aquifer in Burke and Screven Counties Georgia; daily mean stream stage at the Savannah River; and daily precipitation at Augusta, Georgia, December 1993-December 1995.

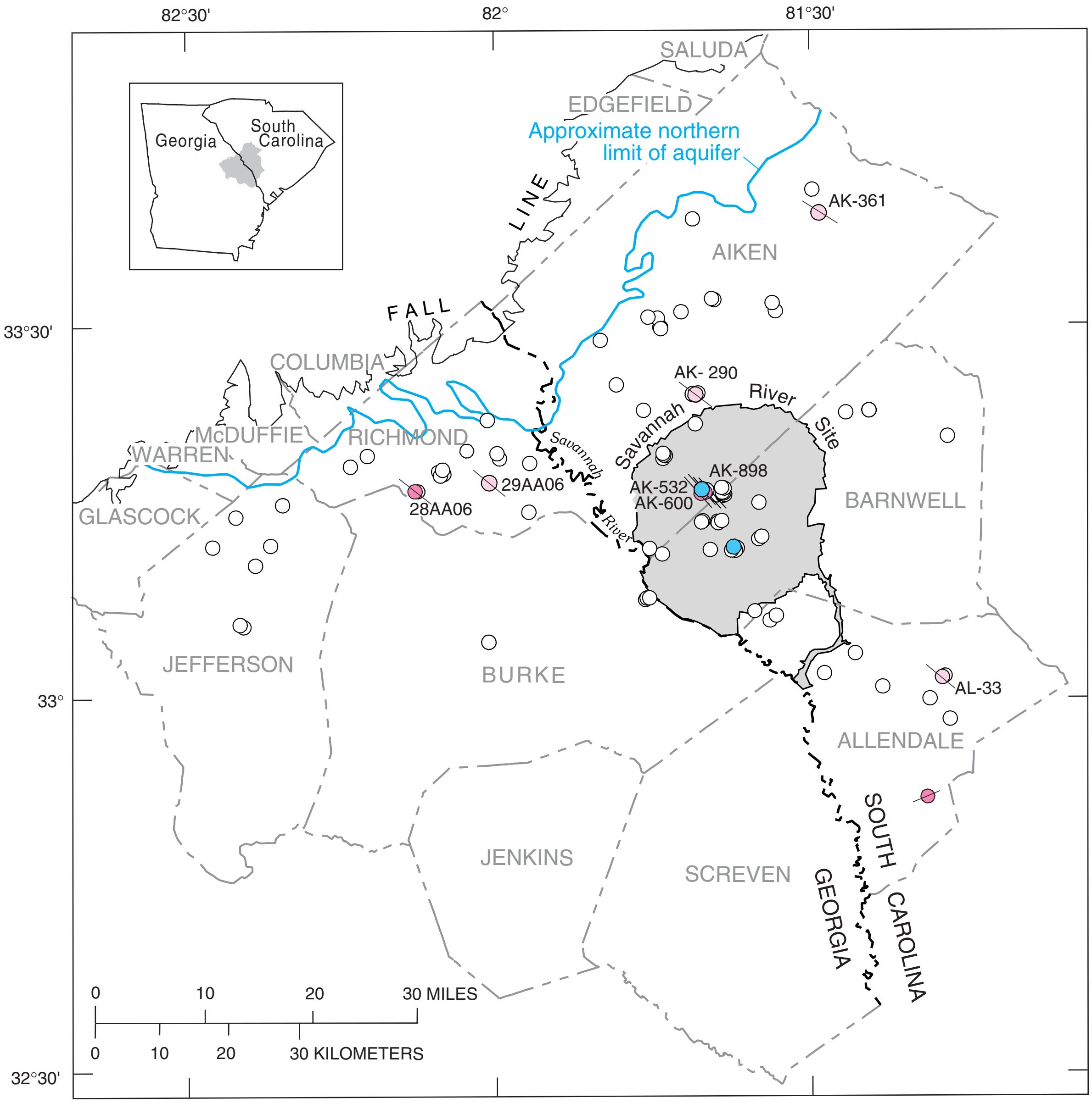
Evaluation of data from eight wells completed in the lower Dublin aquifer indicates that maximum long-term water-level trends mostly ranged from -14 to +4 ft (figs. 13, 36-38). Water-level declines of 5 to 15 ft occurred in the northern part of the SRS in Aiken County, in southern Allendale County, and in south-western Richmond County. Each of these changes occurred near supply wells completed in the lower Dublin aquifer. Water-level rises exceeding 5 ft were not observed in the lower Dublin aquifer. In Georgia and South Carolina, long-term trends in the lower Dublin aquifer are derived from hydrographs of periodic water levels (figs. 37 and 38). In South Carolina, water-level data for the lower Dublin aquifer are limited to scattered periodic measurements obtained during the early 1950's to late 1980's, with more frequent, monthly measurements available from the early 1970's to the present (1997) on the SRS. In Georgia, water-level data are limited to scattered periodic measurements in two wells.

Water levels in wells AK-532, AK-600, and AK-898, located near supply wells in the center of the SRS at the F and H areas (sites 10 and 11, fig. 6), are influenced by ground-water pumpage and possibly by long-term precipitation trends. Water levels in the lower Dublin aquifer near the center of the SRS showed a general decline from 1951-82, and rose during 1982-85 and 1986-92 (fig. 37). The declines occurred during periods of generally below-normal precipitation at Aiken, S.C., which is near the recharge area for the lower Dublin aquifer. The greatest decline (about 12 ft) occurred during 1951-71 in well AK-532, followed by a decline of about 9 ft in well AK-600 during 1975-82. The decline during 1951-71 corresponded to a general increase in ground-water withdrawal from the lower Dublin aquifer in the South Carolina part of the study area (fig. 37), with much of this increase occurring at the SRS (fig. 7). The decline during 1975-82 occurred during a period of decreased withdrawal from the lower Dublin aquifer in the South Carolina part of the study area. Although total withdrawal from the aquifer in South Carolina was lower during 1980-83, withdrawal at the SRS showed a pronounced increase, which, together with below-normal precipitation at Aiken and Blackville, probably accounts for the observed decline. The water-level rises during 1982-85 and 1986-92 correspond to periods of above-normal precipitation at Aiken and Blackville, and to relatively constant withdrawal from the lower Dublin aquifer in the South Carolina part of the study area. The water-level rise noted during 1986-92 also corresponds to a pronounced decrease in ground-water withdrawal at the SRS (fig. 7).

Widely scattered periodic water-level measurements for wells AK-290 and AK-361, located north of the SRS near recharge areas to the lower Dublin aquifer, indicate little water-level change during 1954-92 (fig. 37). Although water levels in the wells probably responded primarily to precipitation and evapotranspiration, insufficient data are available to evaluate this relation.

During 1982-92, water levels in well AL-33, located south of the SRS in eastern Allendale County, S.C., declined about 4 ft. Water levels in this area are influenced primarily by changes in pumpage, although this slight decline may represent seasonal fluctuation.

Although periodic measurements are widely scattered over time, water levels in wells 28AA06 and 29AA06, located in southern Richmond County near recharge areas to the lower Dublin aquifer, tend to respond primarily to precipitation and local pumpage (fig. 38). In well 28AA06, water levels declined about 5 ft during 1967-89, corresponding to a period of below-normal precipitation at Augusta, Ga., and to a slight increase in ground-water withdrawal from the lower Dublin aquifer in the Georgia part of the study area. During 1989-92, the water level in well 28AA06 rose slightly, corresponding to a period of above-normal precipitation. The water level in well 29AA06, tends to respond more to local pumpage than to precipitation. From 1978-84, water levels in well 29AA06 rose about 5 ft during a period of below-normal precipitation. The lack of correlation between water-level changes and precipitation in well 29AA06 indicates that other factors such as changes in nearby pumpage may influence water levels in the well.



Base modified from U.S. Geological Survey State base maps

EXPLANATION

WELLS

MUNICIPAL, INDUSTRIAL, OR IRRIGATION WELL THAT WITHDRAWS WATER FROM AQUIFER

AK-532 WELL FOR WHICH HYDROGRAPH IS INCLUDED IN THIS REPORT—Number is well identification

OBSERVATION OR OTHER USE WELL

MAXIMUM OBSERVED WATER-LEVEL CHANGE, IN FEET– Represents range and direction of change between maximum and minimum water-level measured in wells having 10 or more years of water-level data prior to 1993

+5 to +15

–5 to 0

–15 to –5

No data

Figure 36. Maximum observed water-level change during the period of record in wells completed in the lower Dublin aquifer.

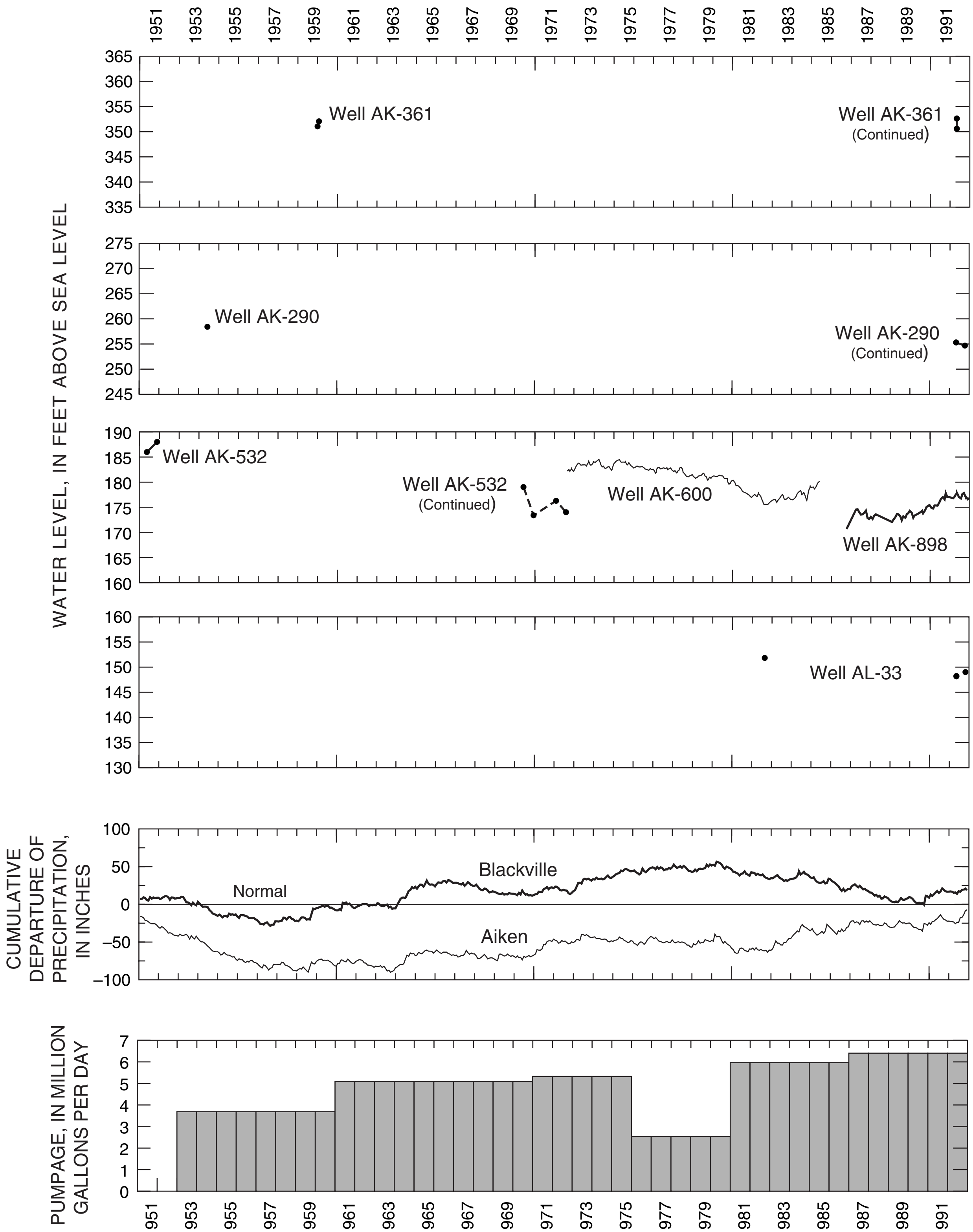


Figure 37. Daily mean and periodic water levels in selected wells completed in the lower Dublin aquifer; cumulative departure from normal (1948-92) precipitation; and estimated pumpage from the lower Dublin aquifer in the South Carolina part of study area,1951-92. Blank where data not available. Dashed where inferred.

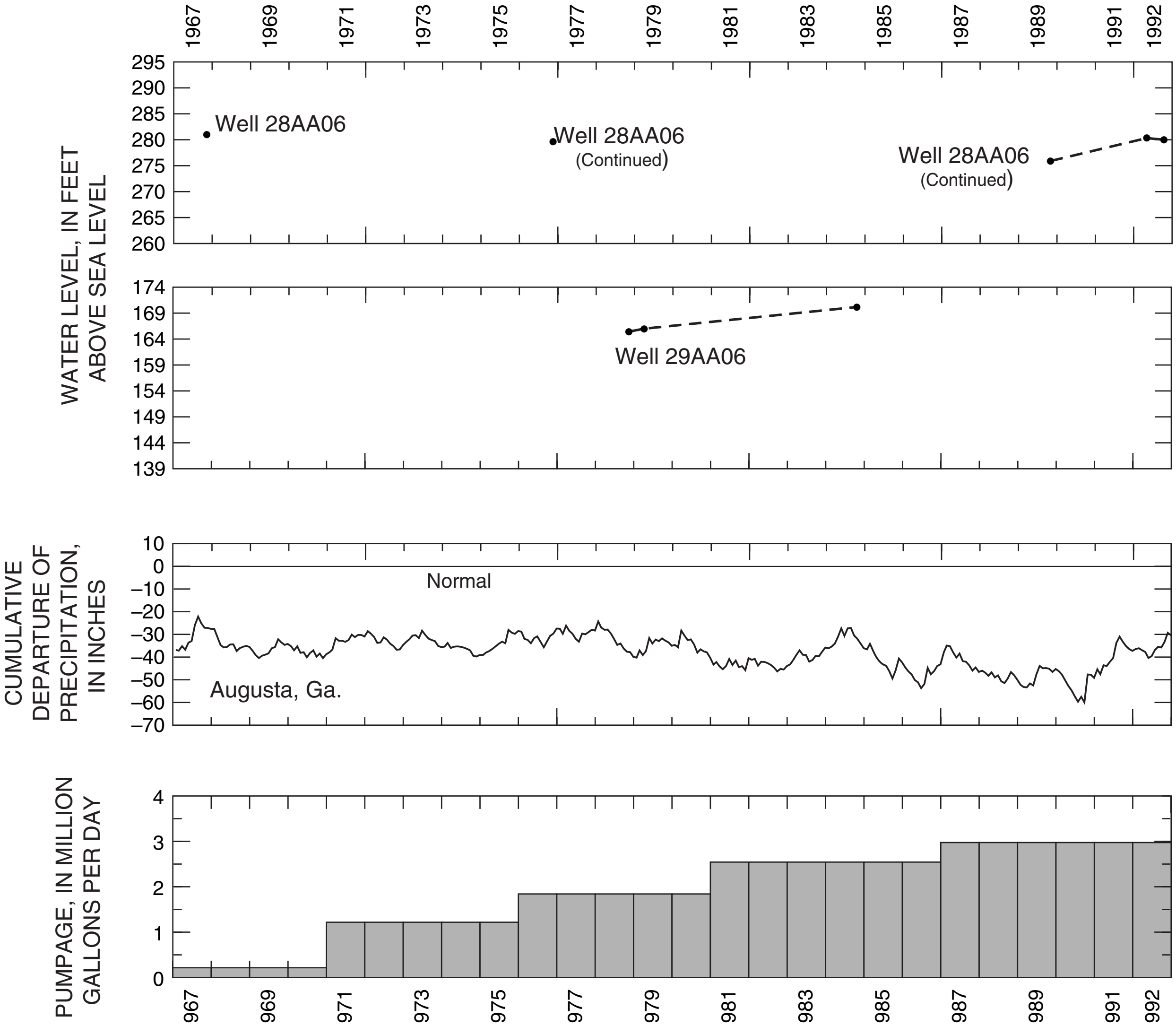


Figure 38. Periodic water levels in selected wells completed in the lower Dublin aquifer; cumulative departure from normal (1948-92) precipitation at Augusta, Georgia; and estimated pumpage from the lower Dublin aquifer in the Georgia part of study area, 1967-92. Blank where data not available. Dashed where inferred.

Midville Aquifer System

Water levels in the upper and lower Midville aquifers of the Midville aquifer system respond to aquifer recharge and discharge in updip areas near the Fall Line. In that area, the aquifers are exposed or near land surface and overlying confining units are sandy or discontinuous, allowing more interaction with surface-water bodies and to climatic influences. Downdip, water levels in the aquifers are influenced by local and regional pumping and, to a lesser degree, by stream stage and precipitation. In these downdip areas, the aquifers are progressively more separated from surface-water bodies and climatic effects because they are deeply buried and overlying confining units are thicker and more continuous, and are characterized by decreasing percentages of sand.

Water levels in the Midville aquifer system generally are highest in the winter-early spring when precipitation is greatest, evapotranspiration is lowest, and irrigation withdrawals are minimal; water levels are lowest in the summer and fall when evapotranspiration and irrigation pumpage are greatest. Seasonal water-level fluctuations and long-term trends for the Midville aquifer system are described in the following sections.

Upper Midville Aquifer

During October 1992, water levels in 19 wells completed in the upper Midville aquifer mostly were between 1 ft lower and 3 ft higher than in May 1992 (figs. 11, 39). The only change greater than 5 ft (about +6 ft) occurred in a well located near a supply well in northwestern Jefferson County.

In South Carolina, water levels in the upper Midville aquifer in well AK-818 at the SC-WRD C-2 well-cluster site, may respond to pumpage (fig. 40). The water-level decline during July-August 1995 indicates that nearby pumping may affect water levels in the well. The annual water-level fluctuation during 1994 and 1995 in well AK-818 was about 1.3 ft (table 3; fig. 40).

In Georgia, the average annual water-level fluctuation during 1994 and 1995 in well 30Z023 was about 2 ft (table 3; fig. 40). The well is located in northern Burke County, Ga., about 9.5 mi from the area where the upper Midville aquifer was incised by the paleo Savannah River channel, and about 2 mi west of the river (fig. 5). Water levels in the well respond to changes in Savannah River stage, as shown by comparison to data at the Savannah River at Jackson, S.C. (station 02197320, fig. 35).

Long-term water-level data for the upper Midville aquifer are sparse. Maximum observed water-level fluctuations prior to 1993 were +16 ft in one Georgia well, and -4 ft in one South Carolina well (figs. 13, and 41-43). These changes occurred near supply wells completed in the upper Midville aquifer.

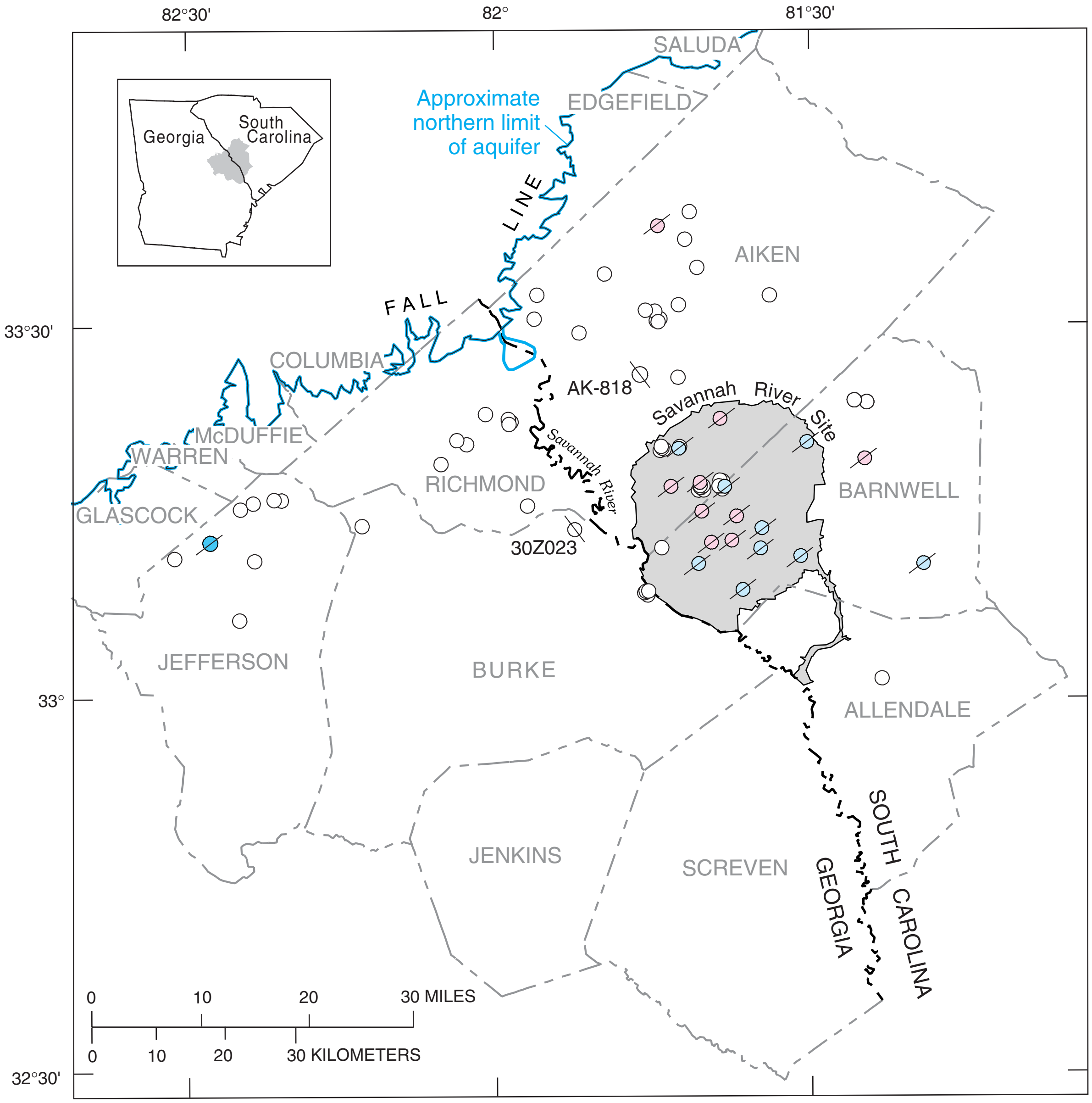
In the South Carolina wells, water-levels appear to respond to long-term precipitation patterns; as indicated by comparison to the cumulative departure of precipitation at Aiken and Blackville, S.C. (fig. 42). For example, in well BW-44, located at the town of Williston, water levels declined about 3 ft during 1952-57, corresponding to a period of below-normal precipitation at Aiken and Blackville; rose about 7 ft during 1957-65, corresponding to a period of above-normal precipitation at Blackville; and declined about 8 ft during 1965-71, corresponding to a period of below-normal precipitation at Aiken and Blackville. Water-level data during 1973-86 are not available; however, in more recent years data are available for wells BW-382 at the town of Williston, and wells BW-383 and AK-864 at the SRS. During 1988-92, water levels in these three wells rose, corresponding to a period of above-normal precipitation at Aiken and Blackville.

Water levels in the South Carolina wells show no apparent response to a continual increase in ground-water withdrawal from the upper Midville aquifer in the study area (about 6.7 Mgal/d during 1987-92). This lack of response was described by Siple (1967) who suggested that water levels in well BW-44 may be influenced more by precipitation than by pumpage because of its proximity to the recharge area.

In Georgia, water levels in well 26Z006, located in northern Jefferson County, possibly are influenced by changes in local pumpage and by precipitation (fig. 43). During 1975-80, water levels in this well rose about 16 ft, despite a period of below-normal precipitation at Augusta, and constant average withdrawal from the upper Midville aquifer. Conversely, during 1980-92, water levels in this well declined about 14 ft, corresponding to a period of largely below-normal precipitation at Augusta. The lack of response to precipitation during 1975-80 may indicate that water levels were responding mostly to changes in local pumpage. The water-level decline during 1980-92 may indicate a greater response to precipitation than pumpage, because pumpage from the upper Midville aquifer generally remained constant.

Lower Midville Aquifer

During October 1992, water levels in 35 wells completed in the lower Midville aquifer mostly were between 4 ft lower and 3 ft higher than in May 1992 (figs. 11 and 44). However, water-level rises of about 8 to 12 ft occurred in two wells located near supply wells at the Richmond County well field (site 4, fig. 6), and in a well located near supply wells in south-central Richmond County where the water level rose about 6 ft.



Base modified from U.S. Geological Survey State base maps

EXPLANATION

WELLS

○ MUNICIPAL, INDUSTRIAL, OR IRRIGATION WELL THAT WITHDRAWS WATER FROM AQUIFER

30Z023 WELL EQUIPPED WITH CONTINUOUS WATER-LEVEL RECORDER—Number is well identification

OBSERVATION OR OTHER USE WELL

WATER-LEVEL CHANGE, IN FEET—Where positive, indicates water-level altitude higher in October than in May 1992; where negative, indicates water-level altitude higher in May than in October, 1992

+5 to +15

0 to +5

–5 to 0

○ No data

Figure 39. Observed water-level change during May-October 1992 in wells completed in the upper Midville aquifer.

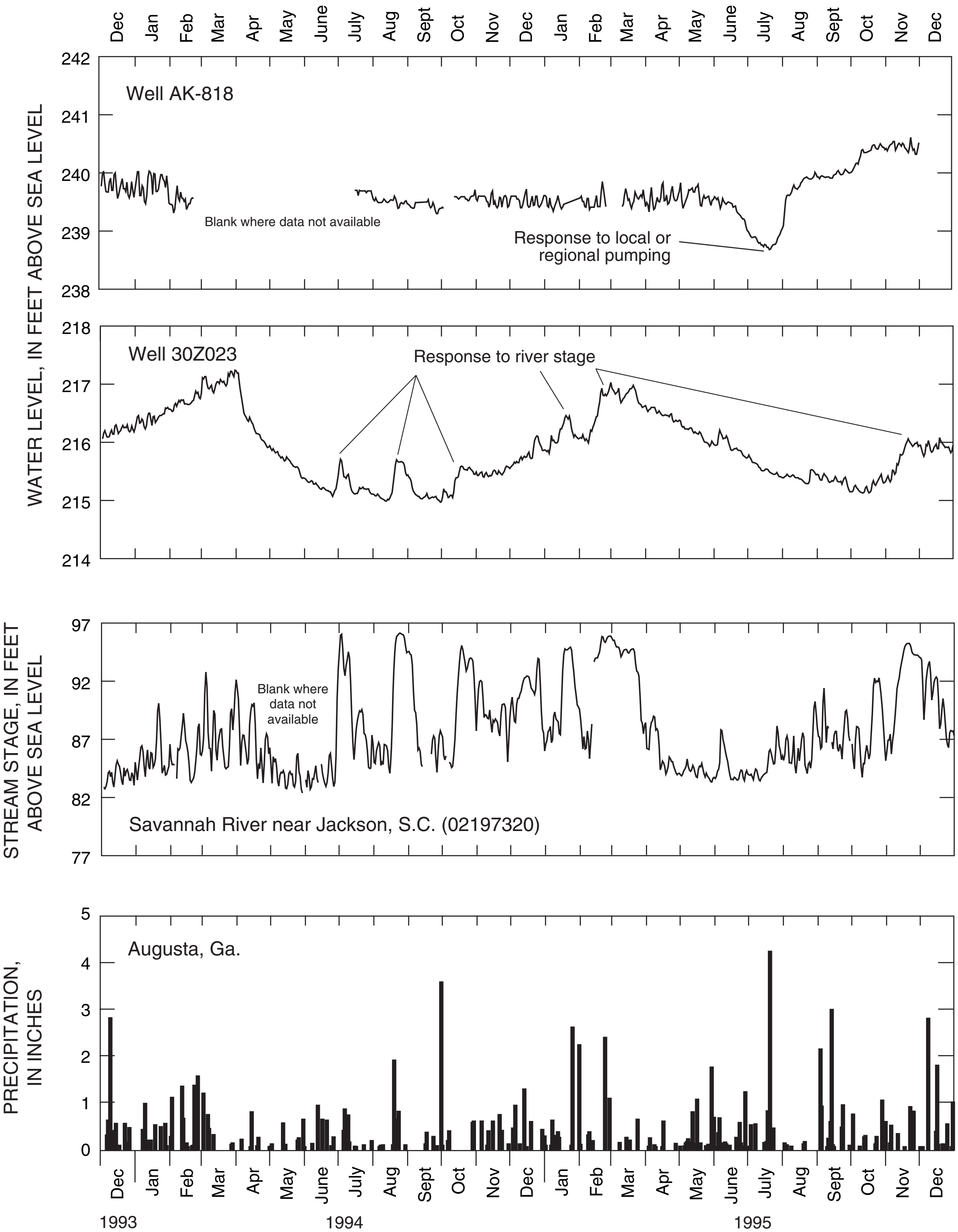
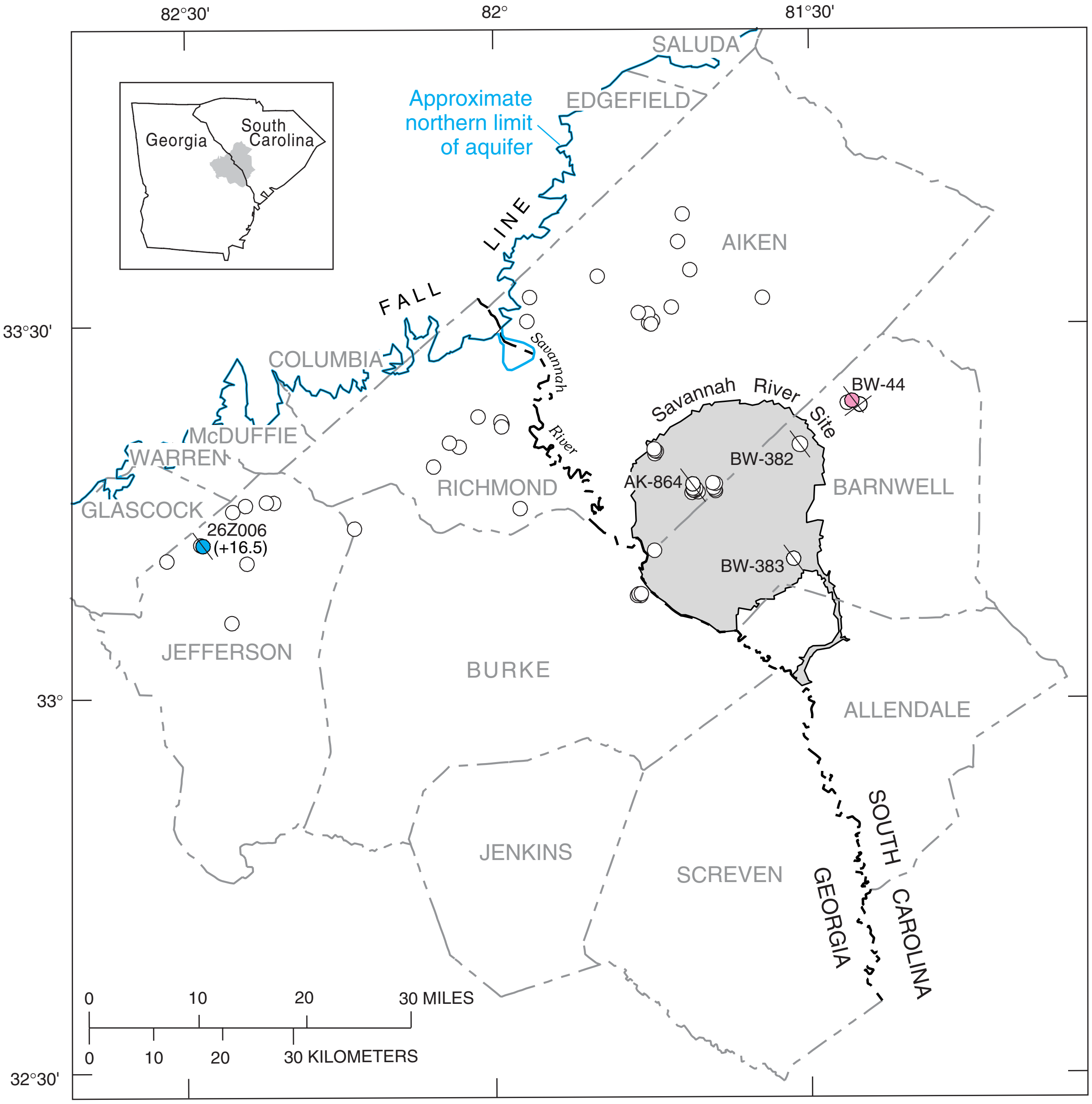


Figure 40. Daily mean water levels in the upper Midville aquifer in Burke County, Georgia, and Aiken County, South Carolina; daily mean stream stage at the Savannah River; and daily precipitation at Augusta, Georgia, December 1993-December 1995.



Base modified from U.S. Geological Survey State base maps

EXPLANATION

WELLS

MUNICIPAL, INDUSTRIAL, OR IRRIGATION WELL THAT WITHDRAWS WATER FROM AQUIFER

26Z006 WELL FOR WHICH HYDROGRAPH IS INCLUDED IN THIS REPORT—Number is well identification

OBSERVATION OR OTHER USE WELL

MAXIMUM OBSERVED WATER-LEVEL CHANGE, IN FEET– Represents range and direction of change between maximum and minimum water-level measured in wells having 10 or more years of water-level data prior to 1993

(+16.5) Greater than +15 (Number in parentheses is measured value)

–15 to –5

No data

Figure 41. Maximum observed water-level change during the period of record in wells completed in the upper Midville aquifer.

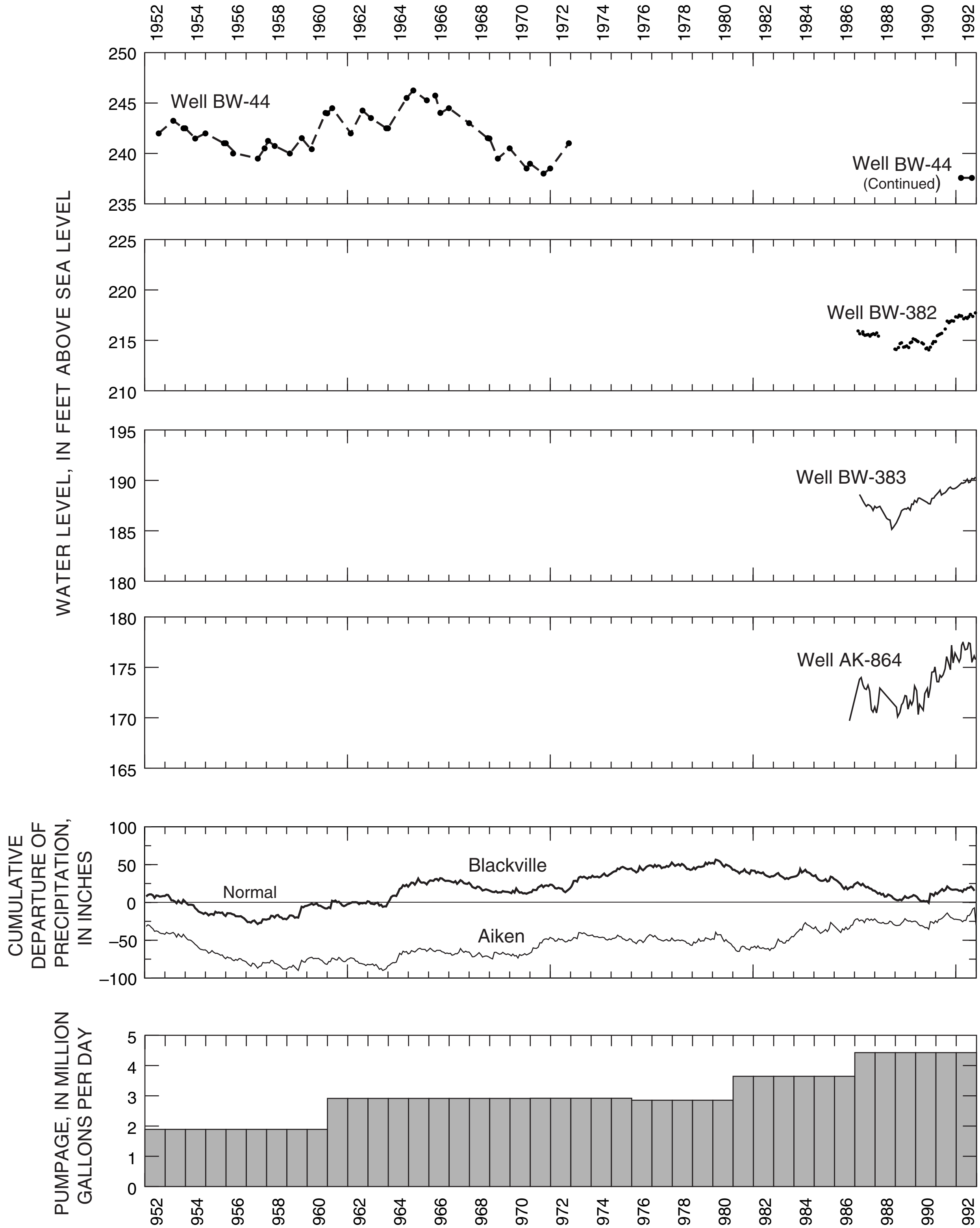


Figure 42. Periodic water levels in selected wells completed in the upper Midville aquifer; cumulative departure from normal (1948-92) precipitation; and estimated pumpage from the upper Midville aquifer in the South Carolina part of study area, 1952-92. Blank where data not available. Dashed where inferred.

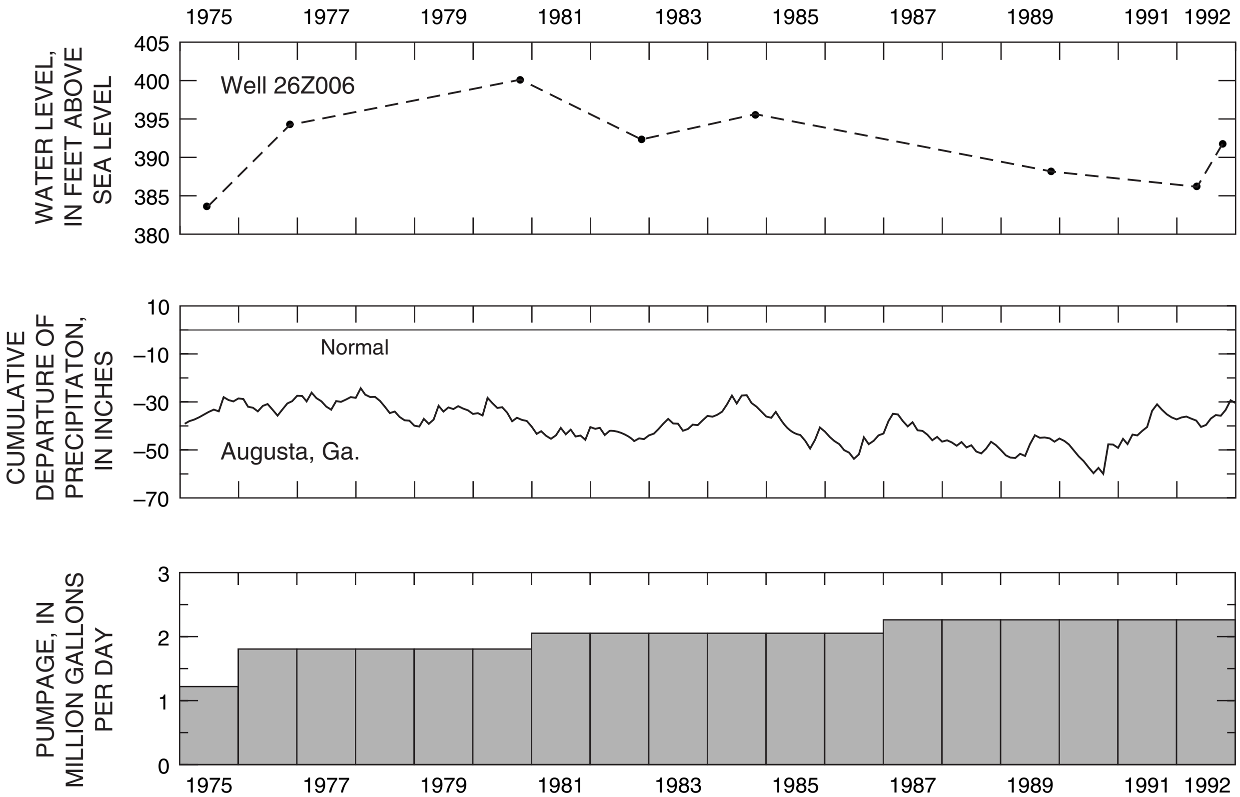
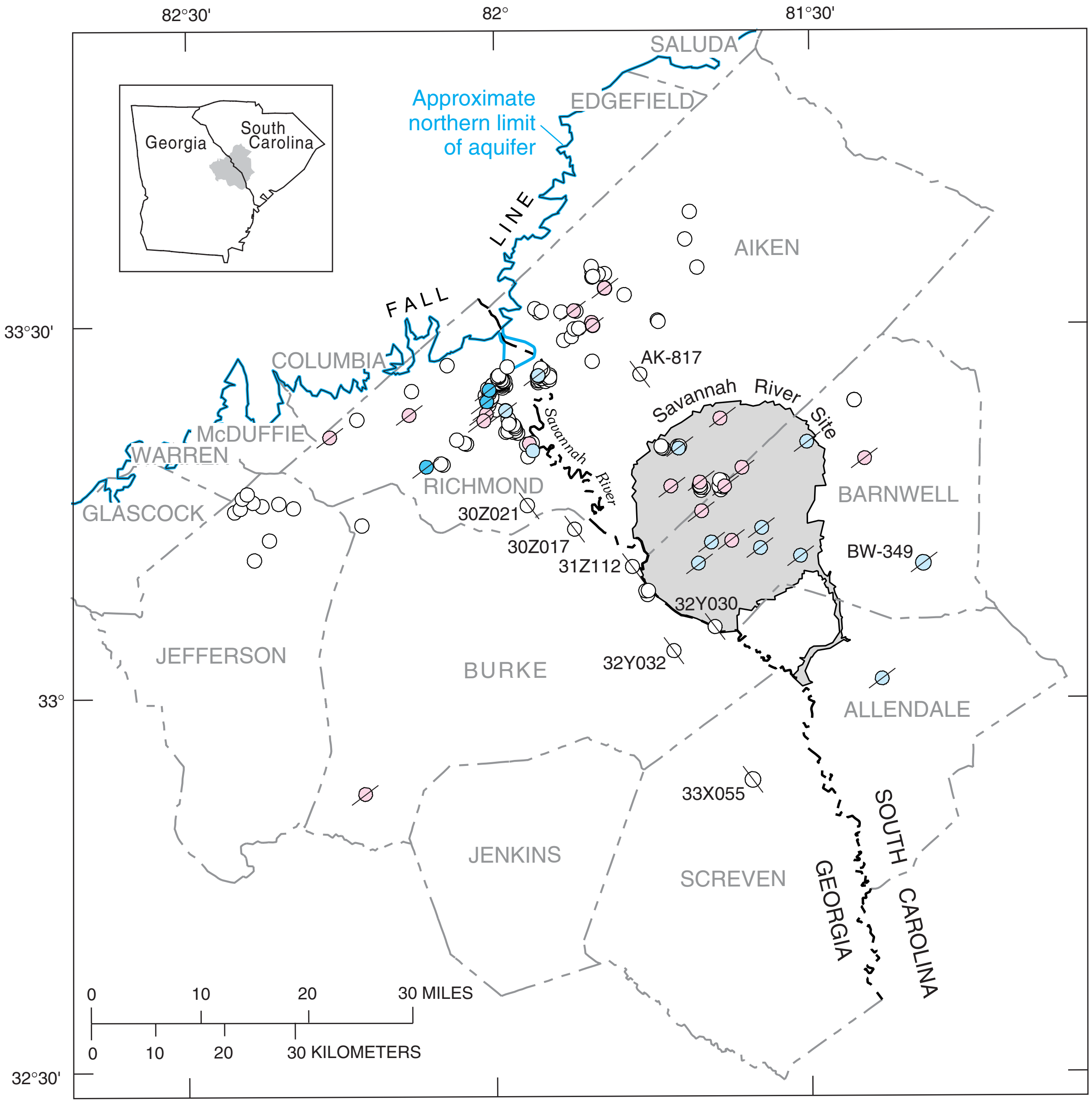


Figure 43. Periodic water levels in well 26Z006, completed in the upper Midville aquifer in Jefferson County, Georgia; cumulative departure from normal (1948-92) precipitation at Augusta, Georgia; and estimated pumpage from the upper Midville aquifer in the Georgia part of study area, 1975-92. Blank where data not available. Dashed where inferred.



Base modified from U.S. Geological Survey
State base maps

EXPLANATION

WELLS

- MUNICIPAL, INDUSTRIAL, OR IRRIGATION WELL THAT WITHDRAWS WATER FROM AQUIFER
- 33X055 WELL EQUIPPED WITH CONTINUOUS WATER-LEVEL RECORDER—Number is well identification
- OBSERVATION OR OTHER USE WELL

WATER-LEVEL CHANGE, IN FEET—Where positive, indicates water-level altitude higher in October than in May 1992; where negative, indicates water-level altitude higher in May than in October, 1992

- +5 to +15
- 0 to +5
- –5 to 0
- No data

Figure 44. Observed water-level change during May-October 1992 in wells completed in the lower Midville aquifer.

Seasonal water-level changes in the lower Midville aquifer in South Carolina indicate possible responses to precipitation and regional pumpage (fig. 45). At the SCDNR-WRD C-2 well-cluster site, daily mean water levels in the lower Midville aquifer in well AK-817 (fig. 45), are nearly identical to those observed in the upper Midville aquifer, described earlier for well AK-818 (fig. 40). Water levels in both wells may respond to precipitation and regional pumping. The annual water-level fluctuation during 1994 and 1995 in the lower Midville aquifer (well AK-817) was about the same as in the upper Midville aquifer (well AK-818), averaging about 1.3 ft (table 3). At the SCDNR-WRD C-6 well-cluster site, water levels in well BW-349 showed little response to precipitation, but may respond to regional pumpage. This site is located about 16 mi east of the Savannah River and south of the recharge area. During 1994 and 1995, the average-annual water-level fluctuation in well BW-349 was about 0.7 ft (table 3; fig. 45).

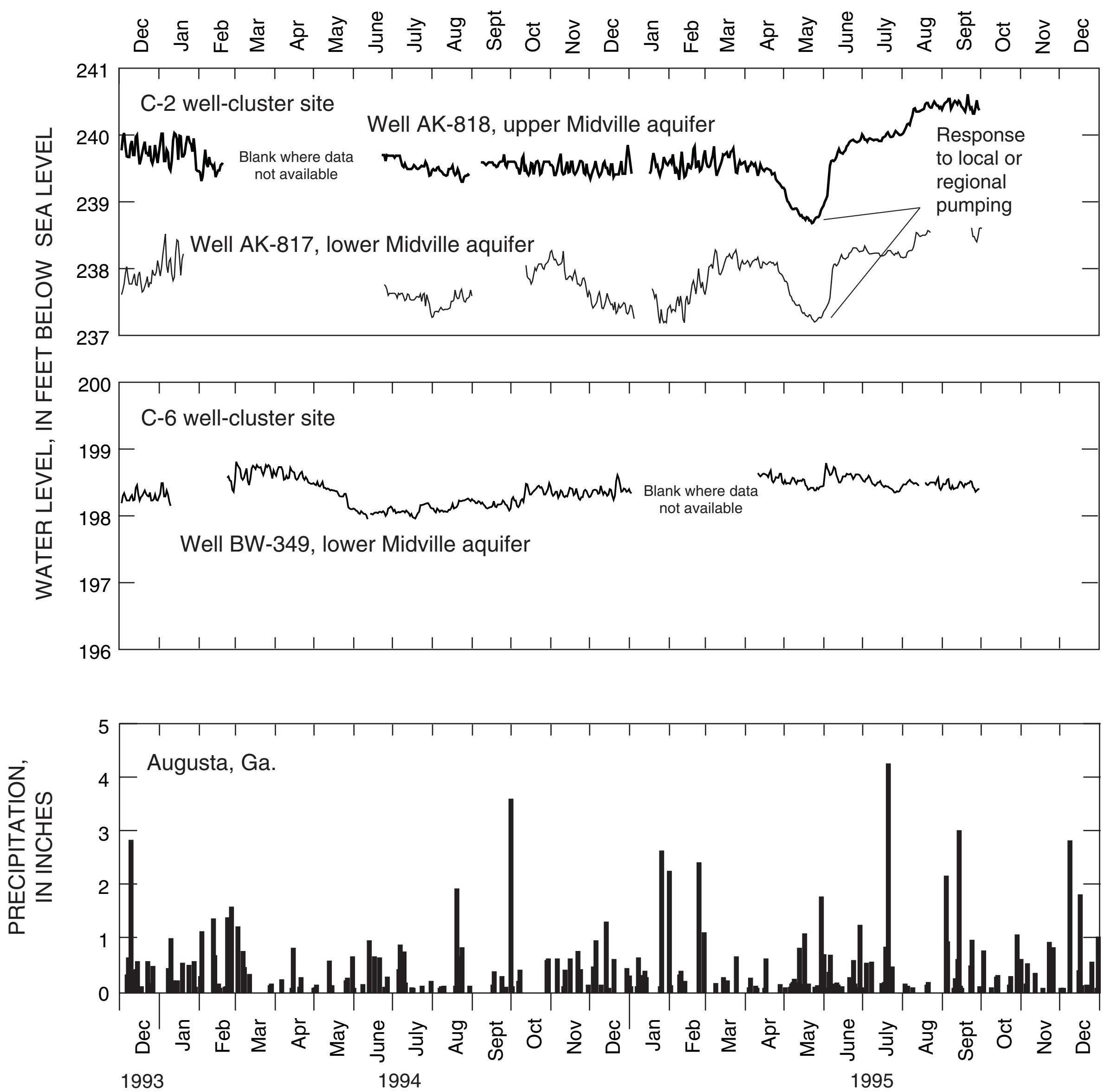


Figure 45. Daily mean water levels in the lower Midville aquifer at the C-6 well-cluster site, Barnwell County, South Carolina, and in the upper and lower Midville aquifers at the C-2 well-cluster site, Aiken County, South Carolina; and daily precipitation at Augusta, Georgia, December 1993-December 1995.

In Georgia, the average-annual water-level fluctuation in the lower Midville aquifer during 1994 and 1995 ranged from 0.6 to 2.2 ft (table 3; figs. 46 and 47). Water levels were continuously monitored in well 32Y030 at the Brighams Landing well-cluster site; in wells 30Z021 and 30Z017 at the Millers Pond well-cluster site; in well 32Y032 at the Girard well-cluster site; in well 31Z112 at the TR-92-6 well-cluster site; in well 33X055 at the Millhaven well-cluster site; and in well 28X001 at Midville, Ga. Well 28X001 is mostly completed in the lower Midville aquifer, with a small percentage completed in the upper Midville aquifer; thus, water-levels mostly are representative of the lower Midville. The largest annual fluctuation occurred at the Brighams Landing site in well 32Y030, averaging 2.2 ft during 1994-95.

Water levels in wells 30Z017 and 30Z021 at the Millers Pond well-cluster site in northern Burke County, and in well 32Y032 at the Girard well-cluster site in east-central Burke County, respond to Savannah River stage, as indicated by pronounced water-level rise during periods of high river stage (fig. 46). For example, water-level rises in the wells during June and August 1995 corresponded to pronounced increases in river stage. The two wells at the Millers Pond site are about 10.5 mi from the area where the lower Midville aquifer was incised by the paleo Savannah River channel, and about 2 mi west of the river (fig. 5). Well 32Y032, at the Girard site, is about 23 mi from the area where the lower Midville aquifer was incised by the paleo Savannah River channel, and about 4 mi west of the river (fig. 5). Water levels in the wells at Millers Pond and Girard respond to changes in Savannah River stage, as shown by comparison to data at the Savannah River at Jackson, S.C. (station 02197320, fig. 46).

Although water-level data during 1994-95 are sparse, water levels in the lower Midville aquifer at the TR-92-6 well-cluster site (well 31Z112), and the Brighams Landing well-cluster site (well 32Y030) also responded to changes in river stage (fig. 46). Water-level data for 1996 and 1997 (not shown) indicate a pronounced response to changes in river stage at the two sites. The two sites are near the area where the paleo Savannah River incised the lower Midville aquifer (about 15 mi at TR-92-6 and 22.5 mi at Brighams Landing), and are responding to changes in river stage where the aquifer is hydraulically well-connected to river alluvium.

During 1994 and 1995, the average-annual water-level fluctuation in well 28X001, located in southwestern Burke County, was about 1.7 ft (table 3; fig. 47). Because the well is located far from the recharge area, water levels do not appear to be affected by concurrent precipitation, but probably are influenced by regional pumpage.

In the lower Midville aquifer, the maximum observed water-level change prior to 1993 in 34 wells mostly was between -40 and +8 ft (figs.13 and 48). Water-level declines in excess of 5 ft occurred near supply wells in Richmond, Aiken, and Barnwell Counties. The largest and most widespread declines occurred near the Richmond County well field and Olin Corporation sites in Richmond County (sites 4 and 5, fig. 6), where declines of as much as 59 ft occurred. In south-central Richmond County, a decline of about 25 ft was recorded in a well located near industrial-supply wells. Elsewhere in the study area, water-level declines of 5 to 15 ft occurred near supply wells at the center of the SRS (sites 10 and 11, fig. 6), near Aiken (site 12, fig. 6), and in western Richmond County. Water-level rises of about 17 ft were observed in a well located near supply wells in north-central Richmond County, and about 14 ft in a well north of the SRS in Aiken County (fig. 48).

In South Carolina, wells BW-274, BW-430, AK-582, BW-316, and AK-183 are located near the outcrop areas for the lower Midville aquifer and water-levels respond, at least partially, to long-term precipitation patterns, as indicated by comparison to graphs showing the cumulative departure of precipitation at Aiken and Blackville (fig. 49). This causal relation was reported for well AK-183 by Siple (1967). A period of below-normal precipitation during 1952-57 correlates with a decline of about 4 ft in well AK-183; above-normal precipitation during 1958-60 apparently corresponds to a rise of about 4 ft. Similarly, in well AK-582, below-normal precipitation during 1974-82 relates to a decline of about 10 ft; above-normal precipitation during 1983-84 corresponds to a rise of about 5 ft. Above-normal precipitation during 1989-92 correlates well with water-level rises in wells BW-430 and BW-316. Water-level declines observed in wells BW-274 and AK-582, appear to correspond to an increase in pumpage from the lower Midville aquifer in South Carolina.

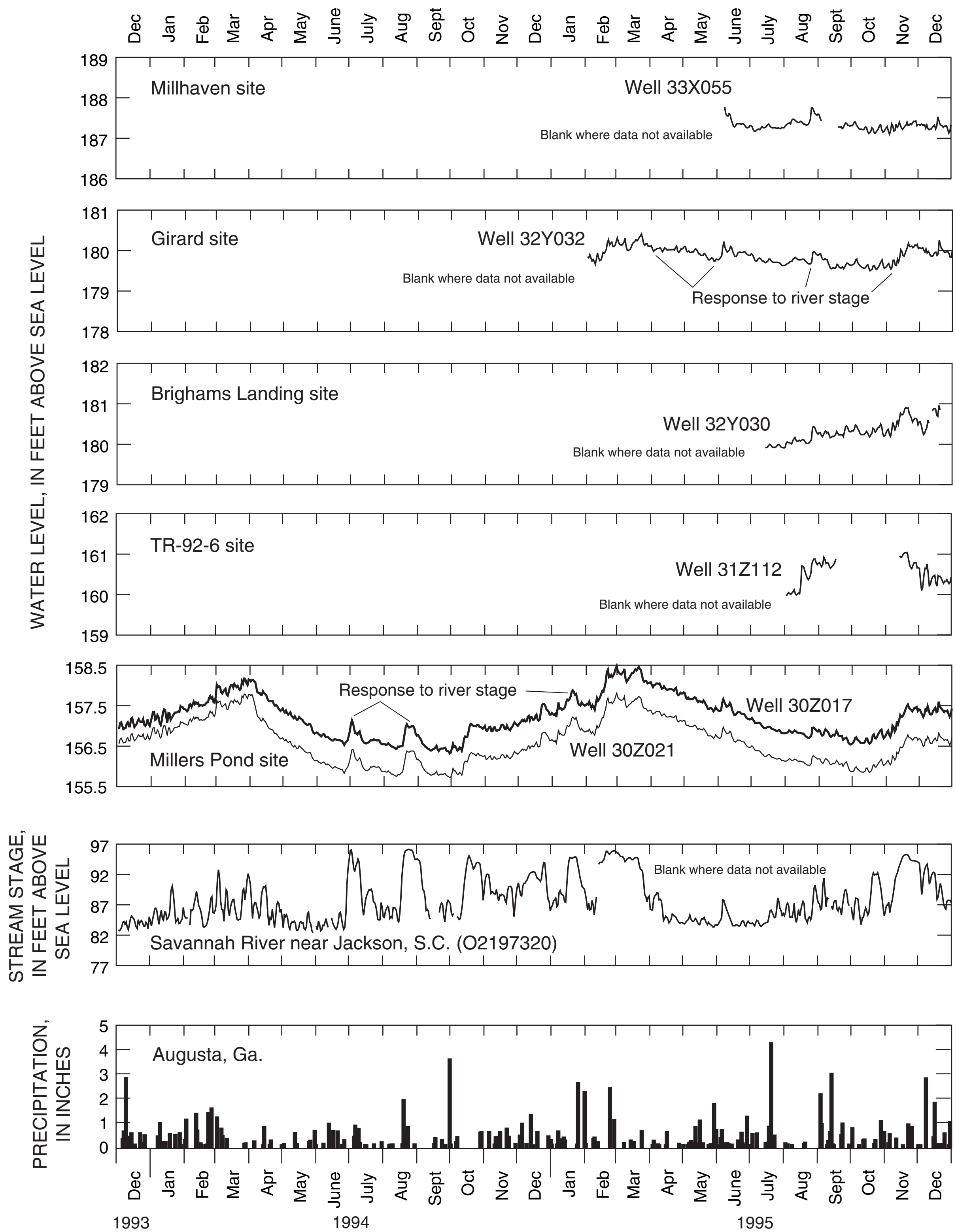


Figure 46. Daily mean water levels in selected wells completed in the lower Midville aquifer at well-cluster sites, Burke and Screven Counties Georgia; daily mean stream stage at the Savannah River; and daily precipitation at Augusta, Georgia, December 1993-December 1995.

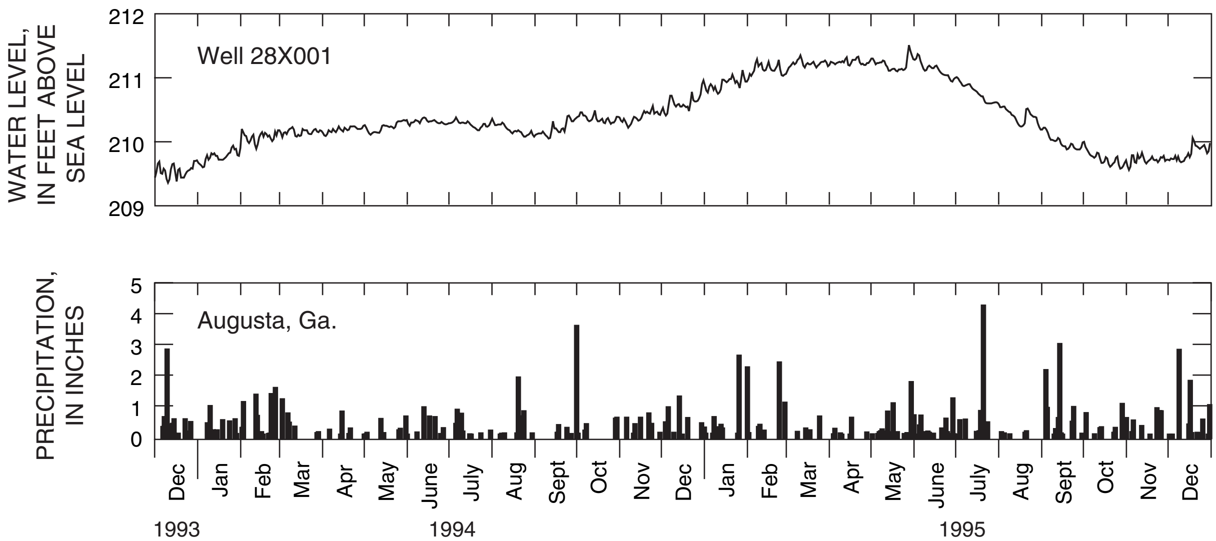
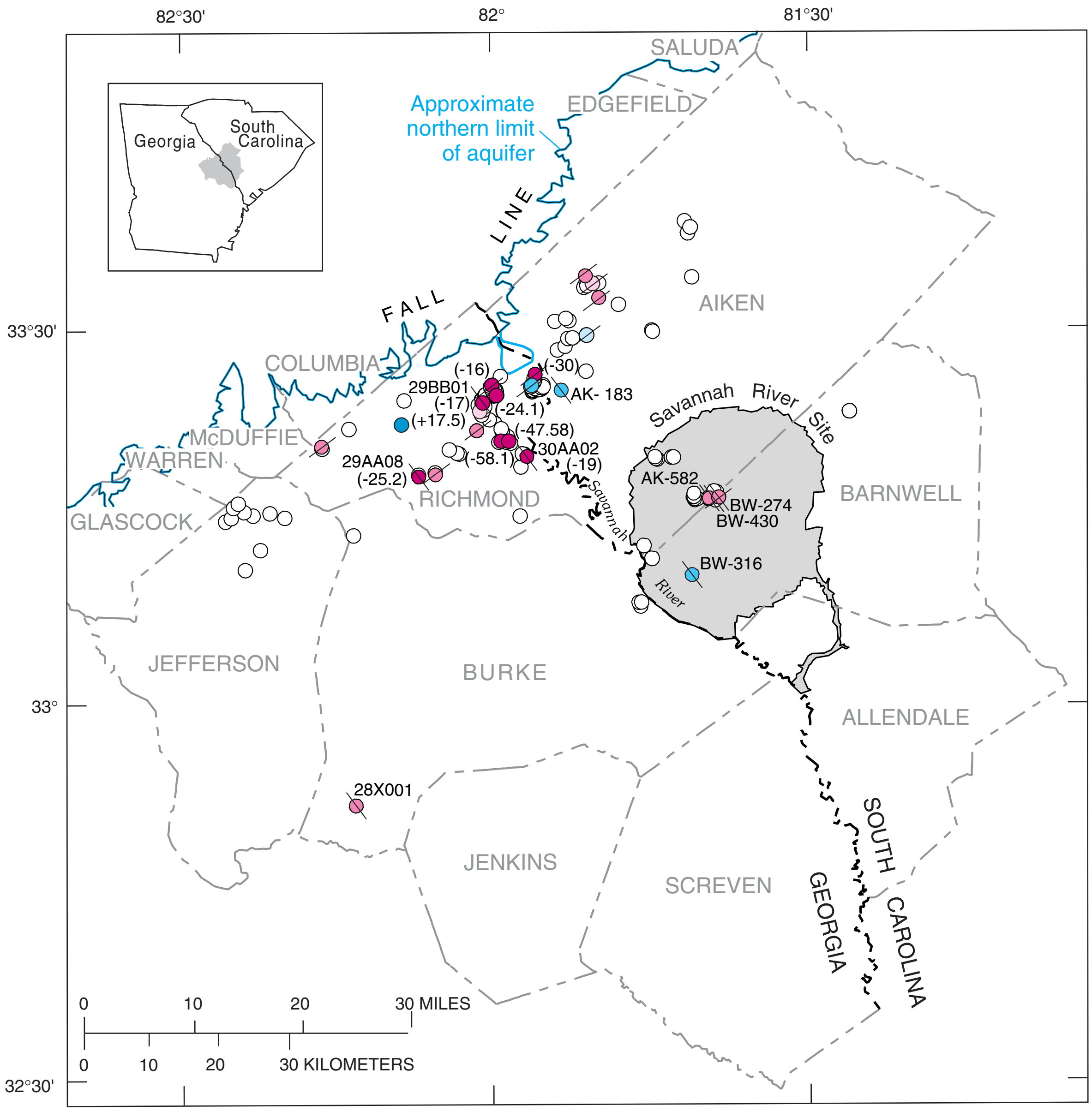


Figure 47. Daily mean water levels in well 28X001 completed in the upper and lower Midville aquifers, Burke County, Georgia; and daily precipitation at Augusta, Georgia, December 1993-December 1995.



Base modified from U.S. Geological Survey
State base maps

EXPLANATION

WELLS

○ MUNICIPAL, INDUSTRIAL, OR IRRIGATION WELL THAT WITHDRAWS WATER FROM AQUIFER

WELL FOR WHICH HYDROGRAPH IS INCLUDED IN THIS REPORT—Number is well identification

OBSERVATION OR OTHER USE WELL

MAXIMUM OBSERVED WATER-LEVEL CHANGE, IN FEET– Represents range and direction of change between maximum and minimum water-level measured in wells having 10 or more years of water-level data prior to 1993

(+17.5) Greater than +15 (Number in parentheses is measured value)

+5 to +15

0 to +5

–5 to 0

–15 to –5

(-25.2) Less than –15 (Number in parentheses is measured value)

No data

Figure 48. Maximum observed water-level change during the period of record in wells completed in the lower Midville aquifer.

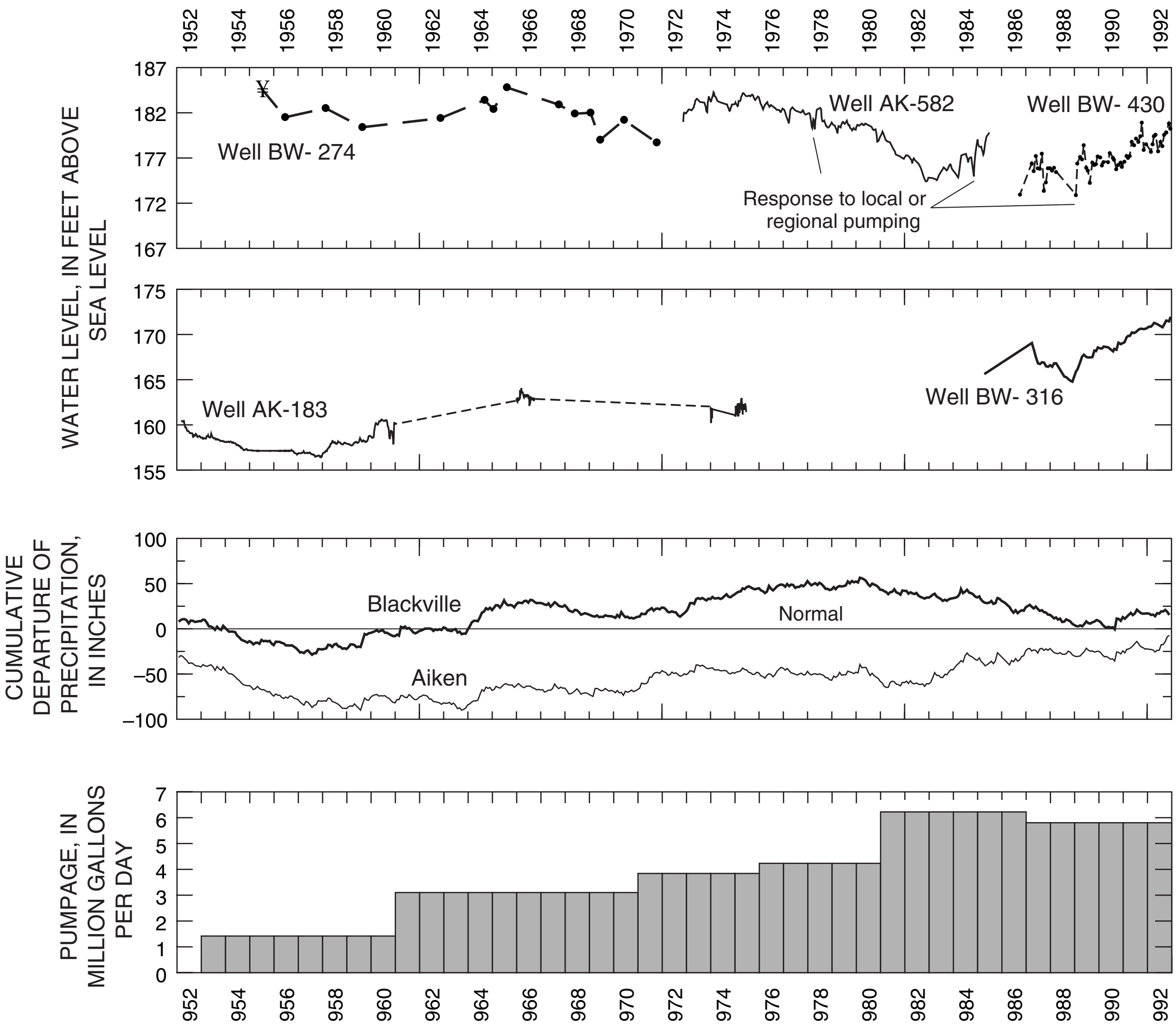


Figure 49. Daily mean and periodic water levels in selected wells completed in the lower Midville aquifer in South Carolina; cumulative departure from normal (1948-92) precipitation; and estimated pumpage from the lower Midville aquifer in the South Carolina part of the study area, 1952-92. Blank where data not available. Dashed where inferred.

In Georgia, water levels in the lower Midville aquifer apparently respond to changes in long-term precipitation and pumpage (fig. 50). In Richmond County, water levels in wells 29AA08, 29BB01, and 30AA02 generally declined during 1966-92. Because these wells are located near the recharge areas of the lower Midville aquifer, part of this decline probably can be attributed to below-normal precipitation during much of this period. In addition to the precipitation deficit, increased pumpage during the 1970’s may have contributed to the water-level decline (the wells are located near pumping centers 4 and 5, fig. 6). The largest declines (about -24 ft) occurred in well 29AA08 during 1982-92, and in well 29BB01 during 1966-89 (fig. 50). Water-level rises during 1989-92 in wells 29BB01 and 30AA02 may be the result of increased recharge caused by above-normal precipitation.

Water levels in the lower Midville aquifer south of the recharge areas also may be responding to long-term precipitation patterns. For example, during 1980-88, water levels in well 28X001, located south of the recharge area of the lower Midville aquifer in southwestern Burke County, declined about 8 ft, in response to a period of below-normal precipitation. Water levels in the well rose about 2 ft during 1989-92, corresponding to a period of generally above-normal precipitation.

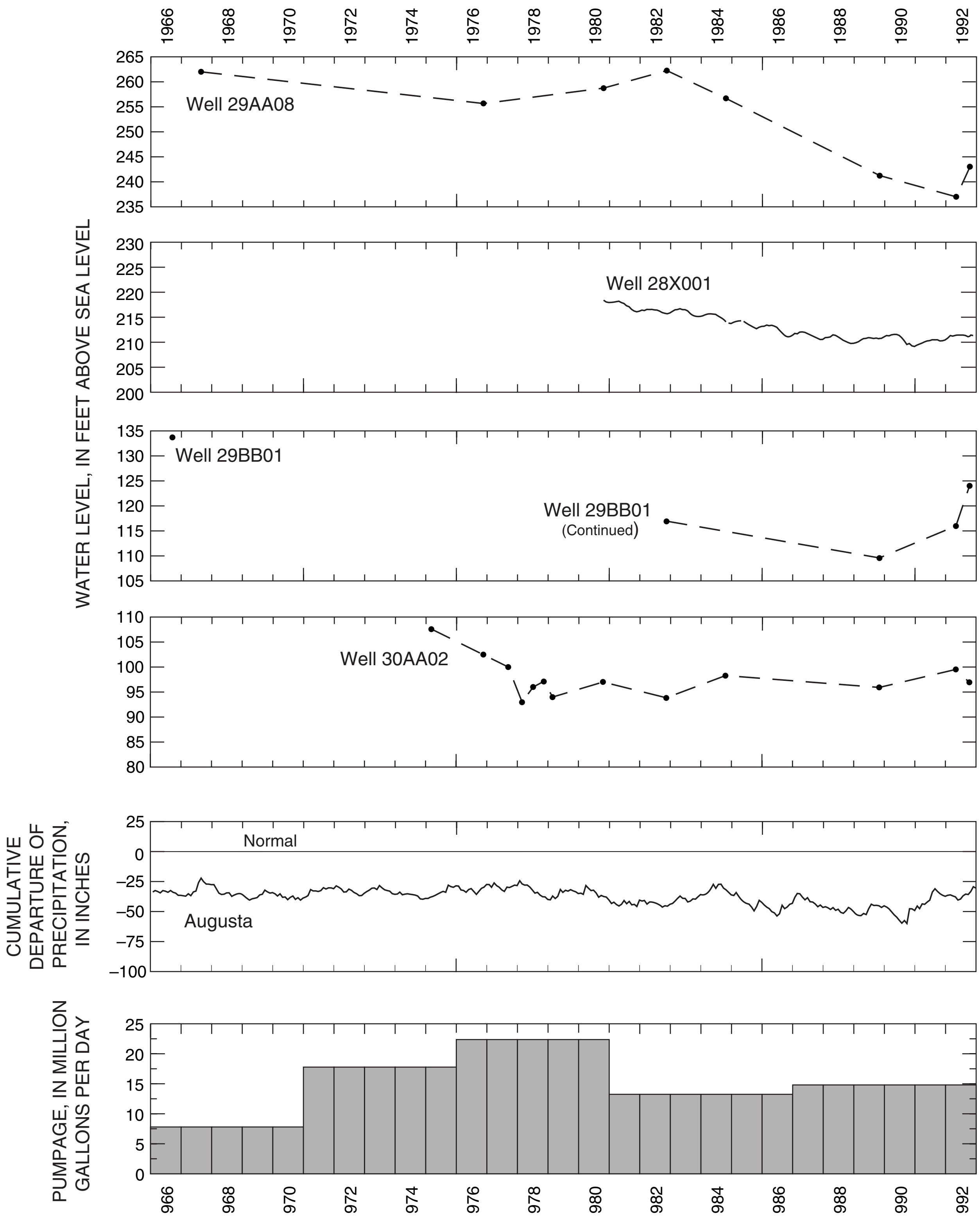


Figure 50. Daily mean and periodic water levels in selected wells completed in the lower Midville aquifer in Georgia; cumulative departure from normal (1948–92) precipitation at Augusta, Georgia; and estimated pumpage from the lower Midville aquifer in the Georgia part of the study area,1966–92. Blank where data not available. Dashed where inferred.

Vertical Head Differentiation Within Aquifers and Aquifer Systems

The presence of low permeability clay layers can result in vertical head differentiation within an aquifer or aquifer system. This differentiation is most pronounced where clay layers are of low permeability and are laterally extensive, and in the vicinity of aquifer recharge and discharge areas, where there are large vertical hydraulic gradients. Head data at well-cluster sites were evaluated to determine vertical head differentiation within aquifers or aquifer systems (tables 1, 4, and 5).

In parts of the study area, the Upper Three Runs aquifer consists of several water-bearing zones characterized by varying degrees of hydraulic separation. At the Millhaven well-cluster site in northern Screven County, Clarke and others (1996) described three water-bearing zones in the Upper Three Runs aquifer that are hydraulically separated by varying degrees. Only minor head differences occurred between zones at the Millhaven site; however, at several other well-cluster sites, significant head differences were observed between the different water-bearing zones of the Upper Three Runs aquifer (table 4). Aadland and others (1995) reported head differences as great as 15.8 ft in the Upper Three Runs aquifer at the SRS H-area, and attributed the difference in head to the low hydraulic conductivity of the "tan clay" zone at the base of the Dry Branch Formation. Head differences generally are greatest in the vicinity of topographic highs that are recharge areas with downward hydraulic gradients. For example in December 1995, at the C-10 cluster, located in an upland area in Allendale County, S.C., heads (in ft above sea level) of 232.04, 193.13, and 157.20 were observed in the upper, middle, and lower zones of the aquifer, respectively (table 4). Siple (1967), discussed the "fairly common" occurrence of perched water zones in the Hawthorne Formation (upper part of the Upper Three Runs aquifer) in topographically high areas southeast of the SRS, such as the C-10 site location.

In parts of the study area, the Gordon aquifer consists of three water-bearing zones showing some degree of hydraulic separation (table 5). Head differences between the three zones are minimal (generally less than 1.6 ft), with the exception of aquifer recharge or discharge areas where there are pronounced vertical gradients. The greatest head difference within the Gordon aquifer (7.8 ft) was observed at the P-26 well-cluster site, located in the Savannah River alluvial valley, an area of pronounced aquifer discharge to the river (fig. 1).

Table 4. Water-level altitudes in water-bearing zones of the Upper Three Runs aquifer at selected well-cluster sites

[B, well not installed into zone at cluster site]

Cluster site	Date measured	Water levels, by water-bearing zone of the Upper Three Runs aquifer, in feet above sea level			
		Upper	Middle	Lower	Average
C-6	05-04-92	178.56	B	177.93	178.24
C-7	08-01-94	167.07	B	176.4	171.74
C-10	12-13-95	232.04	193.13	157.20	194.12
Millhaven	03-13-95	99.46	99.57	102.23	100.42
P-13	05-08-92	231.46	B	220.05	225.76
P-15	05-05-92	232.67	B	216.65	224.46
P-17	05-01-92	285.57	B	282.45	284.01
P-19	05-08-92	267.02	B	266.32	266.67
P-20	05-08-92	270.72	B	239.18	254.95
P-22	05-04-92	171.24	B	170.99	171.12
P-24	05-08-92	270.53	251.38	220.55	247.94
P-25	05-08-92	213.17	B	198.72	205.94
P-27	05-08-92	266.48	B	242.92	254.70
P-28	05-07-92	216.92	211.33	209.98	212.74

Table 5. Water-level altitudes in water-bearing zones of the Gordon aquifer at selected well-cluster sites

[B, well not installed into zone at cluster site]

Cluster site	Date measured	Water levels, by water-bearing zone of the Gordon aquifer, in feet above sea level			
		Upper	Middle	Lower	Average
C-6	05-04-92	160.69	B	163.40	162.04
P-18	05-08-92	170.30	B	169.82	170.06
P-26	05-08-92	110.78	B	118.76	114.70
P-28	05-08-92	146.06	147.68	147.75	147.16
P-29	05-08-92	168.95	B	168.35	168.65
P-30	05-08-92	211.30	B	210.05	210.59

In the Dublin aquifer system, head differences are most pronounced between the Millers Pond aquifer and the underlying upper Dublin aquifer, ranging from 0.3 to 31.8 ft (table 1). Head differences between the upper and lower Dublin aquifers are lower, ranging from 0.03 ft to 6.2 ft (table 1). Larger head differences between the Millers Pond and upper Dublin aquifers probably are the result of a thicker and less permeable intervening confining unit. In the Dublin aquifer system, head differences are greatest in the vicinity of aquifer recharge and discharge areas, because of large vertical components of flow. For example, the vertical head difference at the P-26 well cluster, located in the Savannah River alluvial valley (discharge area) is the greatest head difference reported between the upper and lower Dublin aquifers (6.2 ft).

In the Midville aquifer system, head differences between the upper and lower Midville aquifers mostly are less than 1 ft, and range from 0.1 to 9.6 ft (table 1). Head differences tend to be least where lateral flow predominates and greatest in the vicinity of aquifer recharge and discharge areas, where there are large vertical components of flow. For example, the vertical head difference: (1) at the P-30 well cluster, which is located in a topographically high area at the SRS (recharge area) is 9.6 ft; and (2) at the C-6 well cluster, located in the Salkahehatchie River valley (discharge area) is 5.6 ft (table 1). Although the P-26 well cluster is located in the Savannah River valley, there is little vertical head gradient between the upper and lower Midville aquifers (0.6 ft). This low vertical gradient indicates that ground-water flow in the Midville aquifer system is predominantly lateral in that area.

PREDEVELOPMENT GROUND-WATER FLOW

Under predevelopment conditions, the ground-water flow regime in the vicinity of the Savannah River Site was in a state of dynamic equilibrium—recharge was equal to discharge, no change in aquifer storage took place, and ground-water-level fluctuations were largely seasonal. In general, the period prior to major construction and production at the SRS (late 1952) is believed to be representative of predevelopment, steady-state conditions in the study area. Prior to 1952, ground-water withdrawal was minimal and limited to widely scattered pumping centers such as Augusta, Ga., and Barnwell and Allendale, S.C. In late 1952, large ground-water withdrawal began at SRS (fig. 7), and water-level declines in several aquifers occurred in scattered areas.

Since predevelopment, the ground-water-flow system has changed little over most of the study area. Siple (1967) described the continuing contemporaneity of ground-water conditions in the SRS area based on the similarity of water-level measurements made in 1954, to measurements made in 1960 and 1963. Contemporaneity also was observed during the present study—evaluation of water-level data related to 283 wells with 10 or more years of record prior to 1993, indicates that water levels generally have declined little with time. Most declines were less than 15 ft, and occurred seasonally or in conjunction with long periods of deficient rainfall. Larger declines occurred in limited areas in response to ground-water pumping at and south of the SRS, and in the Augusta, Ga., area.

Conceptualization of Ground-Water Flow

According to Toth (1962; 1963), under steady-state conditions, most ground-water-flow systems can be divided into three subsystems—local, intermediate, and regional (fig. 51). Each of the three subsystems probably occur in the study area.

Local-flow systems are characterized by relatively shallow and short flowpaths that extend from a topographic high (recharge area) to an adjacent topographic low (discharge area). Intermediate flowpaths include at least one local flow system between their respective points of recharge and discharge, and are somewhat longer and deeper than local flowpaths. Regional (or deep) flowpaths begin at or near a major ground-water divide and terminate at a regional drain, such as the Savannah River. The number, distribution, and depth of influence of local flow regimes largely are a function of water-table configuration and aquifer thickness relative to watershed relief (Faye and Mayer, 1990). For example, near the Fall Line, where aquifer sediments are thin compared with topographic relief, local-flow regimes may predominate, and intermediate and regional flow regimes may not occur. Because of their relative depths, effects of climatic variation are largest in local (shallow) flow systems and least in regional (deep) flow systems. According to Toth (1963), net recharge and, consequently, the amount of ground-water flow are distributed according to flow system, with flow and net recharge being greatest in local flow systems and least in regional flow systems.

Toth's (1962, 1963) concepts were further evaluated by Freeze and Witherspoon (1967), who conducted an evaluation of steady-state flow in regional ground-water basins, using digital simulations. Among their conclusions were: (1) factors that affect steady-state regional ground-water-flow patterns within a non-homogenous, anisotropic basin are the ratio of basin depth to its lateral extent, water-table configuration, and stratigraphy and resulting subsurface variations in permeability; (2) the presence of a major valley will tend to concentrate discharge in the valley; (3) in hummocky terrain, numerous sub-basins will be superposed on the regional system; (4) the presence of a buried aquifer of significant permeability will have a pronounced effect on regional ground-water flow, acting as a "highway" to transmit water to the principal discharge area, and will affect the magnitude and position of the recharge areas; and (5) stratigraphic pinchouts at depth can create recharge or discharge areas where they would not be anticipated on the basis of the water-table configuration.

In the vicinity of the SRS, recharge to the hydrologic system is provided by rainfall that ranges from 44 to 48 in/yr (fig. 2). Most of the recharge is discharged from the shallow, local and intermediate flow systems into small streams, or is lost as evapotranspiration. In the intermediate flow system, some of this water is discharged to major tributaries of the Savannah River and some discharges directly into the Savannah River valley. A smaller percentage of recharge infiltrates through clayey confining units and enters the deeper regional flow system. In the regional flow system, some of the water is discharged into the Savannah River valley and some moves southeastward out of the study area. In the Savannah River basin, Faye and Mayer (1990) estimated that about 54 percent of ground-water recharge entered the intermediate and regional flow systems; the remaining 46 percent entered the local flow system. Ground-water flow in the intermediate and regional flow systems is of primary concern to this study because of the greater potential for trans-river ground-water flow beneath the Savannah River valley than in the local flow system.

The Upper Three Runs aquifer is unconfined to semi-confined throughout most of the study area, and thus, ground-water flow mostly is part of the local flow system. Ground-water flow in the deeper, confined aquifers is characterized by local flow near outcrop areas to the north that transforms to intermediate and regional flow downdip (southeastward) where the aquifers are deeply buried.

Potentiometric Surfaces

The potentiometric surface of an aquifer is an imaginary surface representing the altitude to which water would rise in tightly cased wells that penetrate an aquifer. This surface is represented on potentiometric-surface maps with contours showing lines of equal water-level altitude, or head. Usually, areas of high head represent recharge to the aquifer; areas of low head represent discharge. For aquifers that exhibit isotropic flow properties, directions of ground-water movement are perpendicular to potentiometric contours, from areas of high to low head. Where the altitude of land surface is lower than the altitude of the potentiometric surface, flowing wells are possible. For example, in the Savannah River valley, the altitude of land surface is

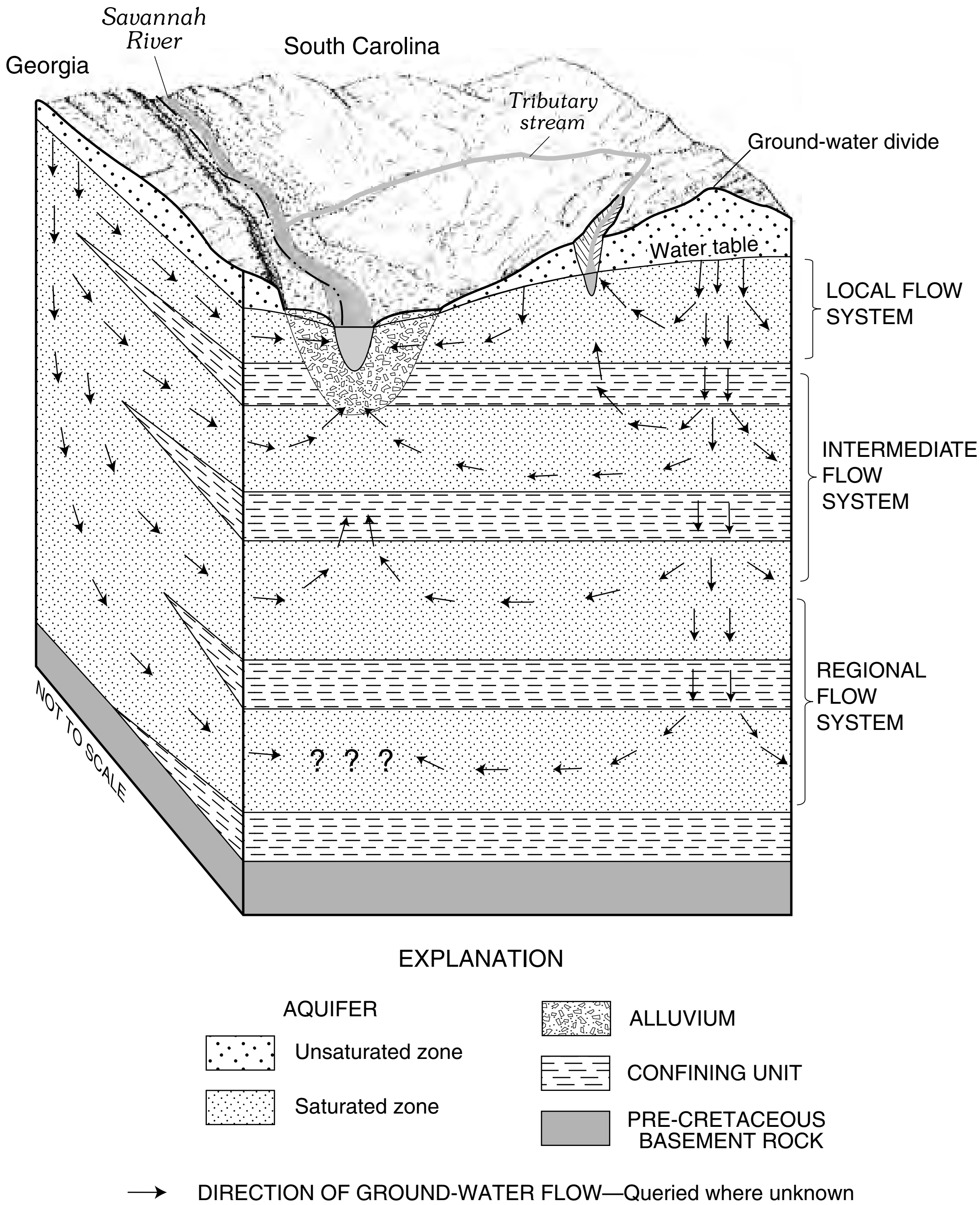


Figure 51. Schematic diagram of the hydrologic flow system in the vicinity of the Savannah River Site, Georgia and South Carolina. Modified from Atkins and others (1996).

low (generally less than 100 ft) and flowing wells are prominent. At the Brighams Landing site in the Savannah River valley (fig. 1), three flowing wells were constructed with heads from 36 to 90 ft above land surface (table 1 and appendix).

Ground-water-flow directions, recharge and discharge areas, and hydrologic boundaries for predevelopment conditions are indicated on maps of the potentiometric surface for the Upper Three Runs aquifer, the Gordon aquifer, the upper and lower Dublin aquifers (composite), and the upper and lower Midville aquifers (composite) (plate 1a,b,c,d). Because of sparse data, a map was not completed for the Millers Pond aquifer; however, flow patterns likely are intermediate between the Gordon and upper Dublin aquifers.

Maps showing the estimated predevelopment potentiometric surfaces (plate 1a,b,c,d) were contoured based on historical data from published reports and from an archived SRS data base that includes wells measured during the 1950's. Water-level data from all seasons were included. Seasonal water-level fluctuations in the aquifers are believed to be minimal, as indicated by previous comparisons of seasonal water-level changes. In areas of outcrop or subsurface contact with alluvium, where the aquifers generally are unconfined, the altitude of stream stage measured during May 1992 was considered to be an approximation of the water-table surface. Because of a sparsity of historical (pre-1953) water-level data over much of the study area, measurements made during 1953-95 in wells located away from pumping centers at the SRS, Augusta, Ga., and Aiken, S.C., also were utilized as control points for constructing the predevelopment maps. When more than one such measurement was available for a well, the highest water-level altitude was assumed to approximate predevelopment conditions and was used to construct the map of the potentiometric surface. Although seasonal and pumpage-induced water-level changes were considered minimal, the possibility of these changes means that the maps should be considered only as an approximation of the predevelopment potentiometric surface. Symbols on the potentiometric-surface maps indicate the year of water-level measurement. Post-1953 data include water levels from 271 wells measured during May and October 1992; pressure-head data from six flowing wells in the Savannah River valley, measured in September 1993; and water levels measured in 49 wells during 1992-95 at selected well-cluster sites (table 6).

Construction of potentiometric maps involved the following procedure:

- Well and stream data were first "computer contoured" to provide an unbiased interpolation of data; and
- Computer contours were examined and adjusted, based on understanding of the conceptual model of the ground-water system and hydrogeologic framework.

In areas near the Savannah River, flow direc-tions in the Gordon and upper and lower Dublin aquifers are less certain because of flat lateral hydraulic gradients and a lack of well data. For this reason, alternative interpretations of potentiometric contours for these aquifers near the river are presented as insets on plate 1b and 1c, respectively.

Table 6. Number of wells, by period, used to construct predevelopment potentiometric-surface maps

Aquifer	Number of wells, by year, used to construct predevelopment potentiometric maps								Total
	During or before 1953	1954-60	1961-70	1971-75	1976-80	1981-86	1987-92	After 1992	
Upper Three Runs	53	5	14	0	4	17	59	7	159
Gordon	26	3	2	4	4	18	54	13	124
upper Dublin and lower Dublin	35	9	5	1	0	8	24	12	94
upper Midville and lower Midville	16	6	17	5	12	18	48	17	139

Previous Studies of Potentiometric Surfaces

Several previous investigators presented maps showing the potentiometric surface of aquifers equivalent to the Upper Three Runs aquifer. These investigators include, but are not limited to—Vincent (1982), who mapped the predevelopment and 1981 potentiometric surfaces of the Jacksonian aquifer in the Georgia part of the study area; Clarke (1987), who mapped the May 1985 potentiometric surface of the Upper Floridan aquifer in Georgia and adjacent parts of South Carolina and Florida; Summerour and others (1994), who mapped the configuration of the Upper Three Runs aquifer in eastern Burke County, Ga., in September 1993; and Aadland and others (1995), who mapped the potentiometric surface of the Upper Three Runs aquifer at the SRS during March-April 1991. Each of these maps indicate that the Upper Three Runs aquifer (or equivalent aquifer) shows a pronounced response to streams and topography, and that the Savannah River is the principal drain in the area.

Maps showing the potentiometric surface of the Gordon aquifer and its equivalents have been prepared by several earlier investigators. These include, but are not limited to—Faye and Prowell (1982), who mapped the 1945-81 potentiometric surface of sediments of late Paleocene through middle Eocene age; Bechtell Corp. (1982), who mapped the May-June 1982 potentiometric surface of Tertiary sediments; Brooks and others (1985), who mapped the predevelopment and November 1981 potentiometric surface of the Gordon aquifer system; Aucott and Speiran (1985), who mapped the predevelopment potentiometric surface of Eocene formations; and Bledsoe and others (1990), who mapped the July 1990 potentiometric surface of the Congaree Formation on SRS. Each of these maps indicate that the Gordon aquifer (or its equivalent) shows a pronounced response to streams in northern parts of the area that diminishes toward the southern parts of the area, and that the Savannah River is the principle drain.

Maps showing the potentiometric surface of the Dublin aquifer system and equivalent aquifers have been prepared by several earlier investigators. These include, but are not limited to—Faye and Prowell (1982), who mapped the potentiometric and 1945-81 surface of sediments of Late Cretaceous and early Paleocene age; Bechtell Corp. (1982), who mapped the potentiometric surface of Cretaceous sediments during May-June 1982; Aucott and Spieran (1985), who mapped the predevelopment potentiometric surface of the Black Creek Formation; and Bledsoe and others (1990), who mapped the July 1990 potentiometric surface of the Peedee/Black Creek Formation at the SRS. Each of these maps indicate that the Savannah River is the principle drain for the Dublin aquifer system.

Maps showing the potentiometric surface of the Midville aquifer system and equivalent aquifers have been prepared by several earlier investigators. These include, but are not limited to—Siple (1960, 1967), who mapped the potentiometric surface of sediments equivalent to the Dublin-Midville aquifer system of Clarke and others (1985); Gorday (1985), who mapped the potentiometric surface of basal Cretaceous sediments; Aucott and Spieren (1985), who mapped the potentiometric surface of the Middendorf Formation during predevelopment; Clarke and others (1985), who mapped the potentiometric surface of the Dublin-Midville aquifer system during predevelopment and during October 1980; and Bledsoe and others (1990), who mapped the potentiometric surface of the Black Creek/Middendorf Formation at the SRS during July 1990. Each of these maps indicate that the Savannah River is the principle drain for the Midville aquifer system.

Upper Three Runs Aquifer

The predevelopment potentiometric-surface map for the Upper Three Runs aquifer is an approximation of the head at the base of the aquifer, and was constructed using data from 159 wells and 46 stream-stage sites (plate 1a; table 6). Because of head differences in the Upper Three Runs aquifer, where data from two or more zones were available, the head in the deepest zone was used for construction of the potentiometric-surface map.

Ground-water flow in the Upper Three Runs aquifer is characterized mostly by local flow regimes, and the configuration of the potentiometric surface is influenced by surface topography and streams because of the shallow depth of the aquifer (plate 1a). Flowpaths in the Upper Three Runs aquifer are short, generally from a topographic high (recharge area) toward the nearest surface-water drain (discharge area) (plate 1a). Ground-water discharge to streams is illustrated by potentiometric contours that point upstream in an inverted “V” pattern, indicating ground-water flow toward the stream. The low potentiometric altitude of the Upper Three Runs aquifer in valley floors results in an upward hydraulic gradient in underlying units whereby the Upper Three Runs aquifer receives flow from underlying units, much of which is discharged into the stream. Surface-water drains include, but are not limited to—the Savannah River, Ogeechee River, South Fork of the Edisto River, Salkehatchie River, Brier

Creek and Upper Three Runs Creek. Ground-water also can discharge at contact springs in some of the deeper valleys; these springs are present along valley walls during wet periods. Such springs have been observed along the western bluffs of the Savannah River valley and along Upper Three Runs Creek.

The Upper Three Runs aquifer is recharged by precipitation along topographic highs. Along interstream drainage divides, recharge to deeper aquifers also occurs because the high potentiometric altitude in the Upper Three Runs aquifer creates a potential downward hydraulic gradient. In parts of the area, closed contours in the potentiometric surface of the Upper Three Runs aquifer exist in areas of topographic highs and represent areas of potential recharge to the deeper aquifers (plate 1a). Maps of the Upper Three Runs aquifer prepared by Summerour and others (1994) and Aadland and others (1995) also show an abundance of closed contours that represent potentiometric highs. Such potentiometric highs are present along the drainage divide between Brier Creek and the Savannah River, and near the center of the SRS at the headwaters of Fourmile Branch, Pen Branch, and Mill Creek. A potentiometric high of large areal extent is present northeast of the SRS near Windsor, S.C. A potentiometric high of small areal extent is present near the Savannah River bluff and the Pen Branch Fault in Burke County, Ga. Although these highs may represent areas of recharge to the aquifer, it is possible that, because of hydraulic separation within the aquifer, these highs represent levels in a shallower water-bearing zone. More well data are needed in the vicinity of these highs to assess whether the heads shown in plate 1a are representative of the base of the aquifer or of a shallower zone.

The lateral hydraulic gradient in the Upper Three Runs aquifer is steep in the northern parts of the study area (plate 1a) due to the large difference in altitude between interstream divides and the adjacent valley floor. The highest water-level altitudes occur near the Fall Line, where altitudes were observed as high as 382 ft in Georgia and 435 ft in South Carolina. The lateral hydraulic gradient is flat in the marshy Savannah River floodplain, where the altitude of the potentiometric surface is less than 100 ft.

Near New Ellenton, S.C., and in the vicinity of other sandy ridges, sediments equivalent to the Upper Three Runs aquifer may be unsaturated and the water table may occur in the Gordon aquifer (R.E. Faye, U.S. Geological Survey, written commun., 1985; Faye and Mayer, 1990). A similar situation occurs at the TR-92-6 well-cluster site, located at the top of the Savannah River bluff in Burke County, Ga. At that locality, the Upper Three Runs aquifer is unsaturated due to a prominent change in topography at the river bluff, about 160 ft above the valley floor.

Gordon Aquifer

The predevelopment potentiometric-surface map for the Gordon aquifer was constructed using data from 124 wells and 7 stream-stage sites (plate 1b; table 6). Because of the observed head differences, where data from multiple zones were available, the average head was used for construction of the potentiometric-surface map (see section “Vertical Head Differentiation in Aquifers and Aquifer Systems”).

In areas away from the Savannah River, the configuration of the potentiometric surface of the Gordon aquifer (plate 1b) is similar to that of the Upper Three Runs aquifer (plate 1a). Faye and Prowell (1982) suggested that the Upper Three Runs aquifer (their “late Eocene and younger sediments”) and the Gordon aquifer (their “A2 aquifer”) are hydraulically connected in southern parts of the area, because of the transition of the intervening confining unit from predominantly clay to the north, to more permeable limestone and sandy limestone to the south. In these areas, the potentiometric surfaces of both aquifers indicate discharge into streams, with a somewhat more pronounced response evident in the Upper Three Runs aquifer.

In the study area, the Gordon aquifer is characterized by local, intermediate, and regional flow systems (fig. 51). Local flow systems predominate in the northern part of the study area where the aquifer crops out or is at shallow depths, and the potentiometric surface shows a pronounced response to topographic and climatic variation. In that area, flowpaths in the Gordon aquifer are short, generally from a topographic high (recharge area) toward the nearest surface-water drain (discharge area) (plate 1b). Intermediate and regional flow systems are prevalent in the southern parts of the area where the aquifer is more deeply buried and the response to topographic and climatic effects diminishes. In these areas, flowpaths are longer, generally from a recharge area located near a major ground-water divide, toward larger tributary streams or a regional drain.

The Gordon aquifer is directly recharged by precipitation where the aquifer is exposed or near land surface. Major ground-water divides are present near interstream drainage divides and include areas between the Ogeechee River and Brier Creek, and the Savannah River and Brier Creek in Georgia; and areas between Upper Three Runs Creek and Hollow Creek, Upper Three Runs and Parr Pond, and the South Fork of the Edisto River and Salkehatchie River in South Carolina.

Potentiometric gradients in the Gordon aquifer are steep in the northern parts of the study area (plate 1b) due to large differences in altitude between interstream divides and the adjacent valley floor. For example, in Upper Three Runs Creek, a steep hydraulic gradient is evident between the valley floor and adjacent interstream divides to the northwest and southeast. The highest potentiometric altitudes are in the northern part of the study area near the Fall Line, where altitudes of about 270 ft have been measured in both Georgia and South Carolina. The lowest potentiometric altitudes occur in stream valleys, such as the Savannah River where water levels have been measured as low as 85 ft.

The Savannah River, South Fork of the Edisto River, Brier Creek, and Upper Three Runs Creek are the major surface-water drains of the Gordon aquifer. Ground-water discharge is depicted by potentiometric contours that point upstream in an inverted “V” pattern, indicating ground-water flow toward the stream.

In the vicinity of the Savannah River alluvial valley, ground-water discharge is illustrated by potentiometric altitudes of 120 ft or lower on plate 1b. Potentiometric altitudes in the Gordon aquifer in the Savannah River valley are lower than 100 ft over a large area (plate 1b), and are the result of reduced heads where groundwater discharges into the river alluvium. This discharge occurs where the Gordon aquifer is incised by the paleo Savannah River channel and is hydraulically well-connected to the river (fig. 5; plate 1b). South of this area, an anomalously low head (85 ft above sea level) was measured at well 32Z004 (see appendix); this well is located in the Savannah River alluvial valley along the upthrown (southeastern) side of the Pen Branch Fault (fig. 5). Here, the Gordon aquifer appears to have been incised by the paleo Savannah River and is hydraulically connected to the alluvium, allowing an outlet for ground-water discharge from the aquifer. Two interpretations of ground-water flow near the river are:

- The river valley acts as a continuous line sink whereby potentiometric contours point upstream in an inverted “V” pattern surrounding the river and receives aquifer discharge from both sides of the river (see inset, plate 1b). This configuration is similar to that presented by Faye and Prowell (1982), Brooks and others (1985), and Aucott and Sperian (1985);
- The river valley acts as a line sink as described above, but the zone of discharge is subdivided into an upstream area and downstream area separated by a ground-water divide (plate 1b). The ground-water divide or “saddle” as referred to by Siple (1960, 1967), transects the Savannah River near the Burke-Screven County line. In the vicinity of the saddle, part of ground-water flow is upriver toward the area where the Gordon aquifer is in contact with river alluvium; and part of ground-water flow is downriver toward the coast. This configuration is similar to that presented by Bechtell Corp. (1982) for their “Tertiary aquifer” (equivalent to the Gordon aquifer). Although alternative interpretations are possible, preliminary results of a ground-water-flow model simulation of the SRS area show a close match to this interpretation.

Additional well data in the alluvial valley would help better define ground-water flow conditions in the vicinity of the saddle.

Near the Pen Branch Fault in the central part of the SRS, water levels in the Gordon aquifer at the P-19 well-cluster site (well BW-395, appendix) are anomalously high, producing a mound in the potentiometric surface (plate 1b). The high water level in the well may be the result of the offset of the Pen Branch Fault, whereby sediments of the Gordon aquifer are juxtaposed against sediments of the Upper Three Runs aquifer (Aadland and others, 1991). Because the units are in hydraulic connection near the fault, water levels and water chemistry of the Gordon aquifer are similar to those of the Upper Three Runs aquifer.

Dublin Aquifer System

The Dublin aquifer system consists of the Millers Pond aquifer, and the upper and lower Dublin aquifers (fig. 4). Because insufficient data are available to make separate potentiometric-surface maps for the upper and lower Dublin aquifers, a composite map representing both aquifers was constructed using water-level measurements from 94 wells and five stream-stage sites (plate 1c; table 6). Although it is part of the Dublin aquifer system, Millers Pond aquifer data were not used to construct the composite map because of a high degree of hydraulic separation (and head differences) between the Millers Pond aquifer and the Dublin aquifers. The composite map is considered representative of the potentiometric surface for both Dublin aquifers, with the possible exception of representations in recharge and discharge areas. Because of minimal hydraulic separation and similar values of head for the upper and lower Dublin aquifers, ground-water flow directions in the two aquifers are similar.

The Dublin aquifer system is characterized by local, intermediate, and regional flow systems. Local flow systems predominate in the northern part of the study area where the aquifers comprising the Dublin aquifer system crop out or are at shallow depths, and the potentiometric surface shows a pronounced response to topographic and climatic variation. In that area, flowpaths in the Dublin aquifer system are short, generally from a topographic high toward the nearest surface-water drain (plate 1c). Intermediate and regional flow systems prevail in the southern parts of the area where the aquifer is more deeply buried and the response to topographic and climatic effects diminishes. In these areas, flowpaths are longer, generally from a recharge area located near a major ground-water divide, toward larger tributary streams or a regional drain.

The Dublin aquifer system is recharged by precipitation in topographically high areas where the aquifers are exposed or near land surface. Major ground-water divides are present near interstream drainage divides, and include, the area between the Ogeechee River and Brier Creek in Georgia; and the area between the South Fork of the Edisto River and Salkehatchie River in South Carolina (plate 1c).

Potentiometric gradients in the Dublin aquifer system are steep in the northern parts of the study area (plate 1c) because of large differences in altitude between interstream divides and the adjacent valley floor. The highest potentiometric altitudes occur in the northern part of the study area near the Fall Line, where altitudes as high as 334 ft in South Carolina and 281 ft in Georgia have been measured. Potentiometric-surface altitudes are less than 120 ft in the Savannah River valley north of the SRS.

The Savannah River, South Fork of the Edisto River, and Upper Three Runs Creek are the major surface-water drains of the Dublin aquifer system. Ground-water discharge is depicted by potentiometric contours that point upstream in an inverted “V” pattern, indicating ground-water flow toward the stream.

In the vicinity of the Savannah River, ground-water discharge is illustrated by potentiometric altitudes of 160 ft or lower on plate 1c. Potentiometric altitudes in the Dublin aquifer system in the Savannah River valley are lower than 140 ft over a large area (plate 1c), and are the result of reduced heads where groundwater discharges into the river alluvium. This discharge occurs where the Dublin aquifer system has been incised by the paleo Savannah River channel (fig. 5) and is hydraulically well-connected to the river (plate 1c). Two interpretations of ground-water flow near the river are:

- The river valley acts as a continuous line sink whereby potentiometric contours point upstream in an inverted “V” pattern surrounding the river and receives aquifer discharge from both sides of the river (see inset, plate 3c). This configuration is similar to that presented by Faye and Prowell (1982) and Clarke and others (1985); or
- The river valley acts as a line sink as described above, but the zone of discharge is subdivided into an upstream area and downstream area separated by a ground-water divide (plate 1c). The ground-water divide or “saddle” as referred to by Siple (1960, 1967), transects the Savannah River near the Brighams Landing well-cluster site. In the vicinity of the saddle, part of the ground-water flow is upriver toward the area where the Dublin aquifer system is in contact with river alluvium; and part of the ground-water flow is downriver toward the coast. Several previous investigators (Faye and Prowell, 1982; Bechtell Corp., 1982; Aadland and others, 1995) also identified the possible occurrence of a “saddle” in sediments equivalent to the Dublin aquifer system. Although alternative interpretations are possible, preliminary results of a ground-water-flow model simulation of the SRS area show a close match to this interpretation.

Additional well data in the alluvial valley would help better define ground-water flow conditions in the vicinity of the saddle.

Midville Aquifer System

The Midville aquifer system consists of the upper and lower Midville aquifers (fig. 4). Because insufficient data are available to construct separate maps for the upper and lower Midville aquifers, a composite map representing the potentiometric surface of both aquifers was compiled based on water-level measurements from 139 wells and two stream-stage sites (plate 1d; table 6). The composite map is representative of the potentiometric surface for both aquifers, with the possible exception of representations in recharge and discharge areas. Because of minimal hydraulic separation and similar values of head for the upper and lower Midville aquifers, ground-water flow directions in the two aquifers are similar.

The Midville aquifer system is characterized by local, intermediate, and regional flow systems. Local flow systems predominate in the northern part of the study area where the aquifers composing the Midville aquifer system crop out or are at shallow depths, and the potentiometric surface shows a pronounced response to topographic and climatic variation. In that area, flowpaths in the Midville aquifer system are short, generally from a topographic high (recharge area) toward the nearest surface-water drain (discharge area) (plate 1d). Intermediate and regional flow systems are prevalent in southern parts of the area where the aquifer is more deeply buried and the response to topographic and climatic effects diminishes. In those areas, flowpaths are longer, generally from a recharge area located near a major ground-water divide, toward larger tributary streams or a regional drain.

The Midville aquifer system is recharged by precipitation in topographically high areas where the aquifers are exposed or near land surface. In much of the study area, these recharge areas correspond to interstream drainage divides. Major ground-water divides occur near interstream drainage divides, and include the area between the Ogeechee River and Savannah River in Georgia; and the areas between the South Fork of the Edisto River and Savannah River, and Salkehatchie River and Savannah River in South Carolina (plate 1d).

Potentiometric gradients in the Midville aquifer system are steep in the northern parts of the study area (plate 1d) due to large differences in altitude between interstream divides and the adjacent valley floor. The highest potentiometric altitudes occur in the northern part of the study area toward the Fall Line, where water-level altitudes of as high as 550 ft in Georgia were reported by Clarke and others (1985); during the current SRS study, water-level altitudes as high as 445 ft have been measured in South Carolina. In the Savannah River valley, potentiometric-surface altitudes are less than 200 ft, with altitudes less than 100 ft in a depression surrounding the Savannah River about 14 mi upriver from the SRS.

The Savannah River, Horse Creek, Spirit Creek, and Butler Creek are major surface-water drains of the Midville aquifer system. Ground-water discharge is illustrated by potentiometric contours that point upstream in an inverted “V” pattern, indicating ground-water flow toward the stream (plate 1d). In addition, ground-water discharge along the Savannah River is illustrated by potentiometric contours that point downstream, as shown by the 140-180 ft contours, and by closed depressions surrounding the river, as shown by the 100 and 120 ft contours. The occurrence of a depression near the Savannah River in the potentiometric surface of sediments equivalent to the Midville aquifer system was identified by Siple (1960, 1967), Aucott and Spieran (1985), and Bledsoe and others (1990). Since these earlier investigations, construction of test wells at well-cluster sites in and near the Savannah River alluvial valley (fig. 1, table 1) have provided additional data to help better define the configuration of the potentiometric surface of the Midville aquifer system and the extent of the depression in the river valley.

Potentiometric altitudes in the Midville aquifer system in the Savannah River valley are lower than 180 ft over a large area (plate 1d), and are the result of reduced heads where ground-water discharges into the river alluvium. This discharge occurs where the Midville aquifer system has been incised by the paleo Savannah River channel (fig. 5) and is hydraulically well-connected to the river (plate 1d). The lowest altitude (less than 100 ft) is located near the area where the river has incised the upper Midville confining unit, about 14 mi upriver from the SRS.

Recharge-Discharge Relations

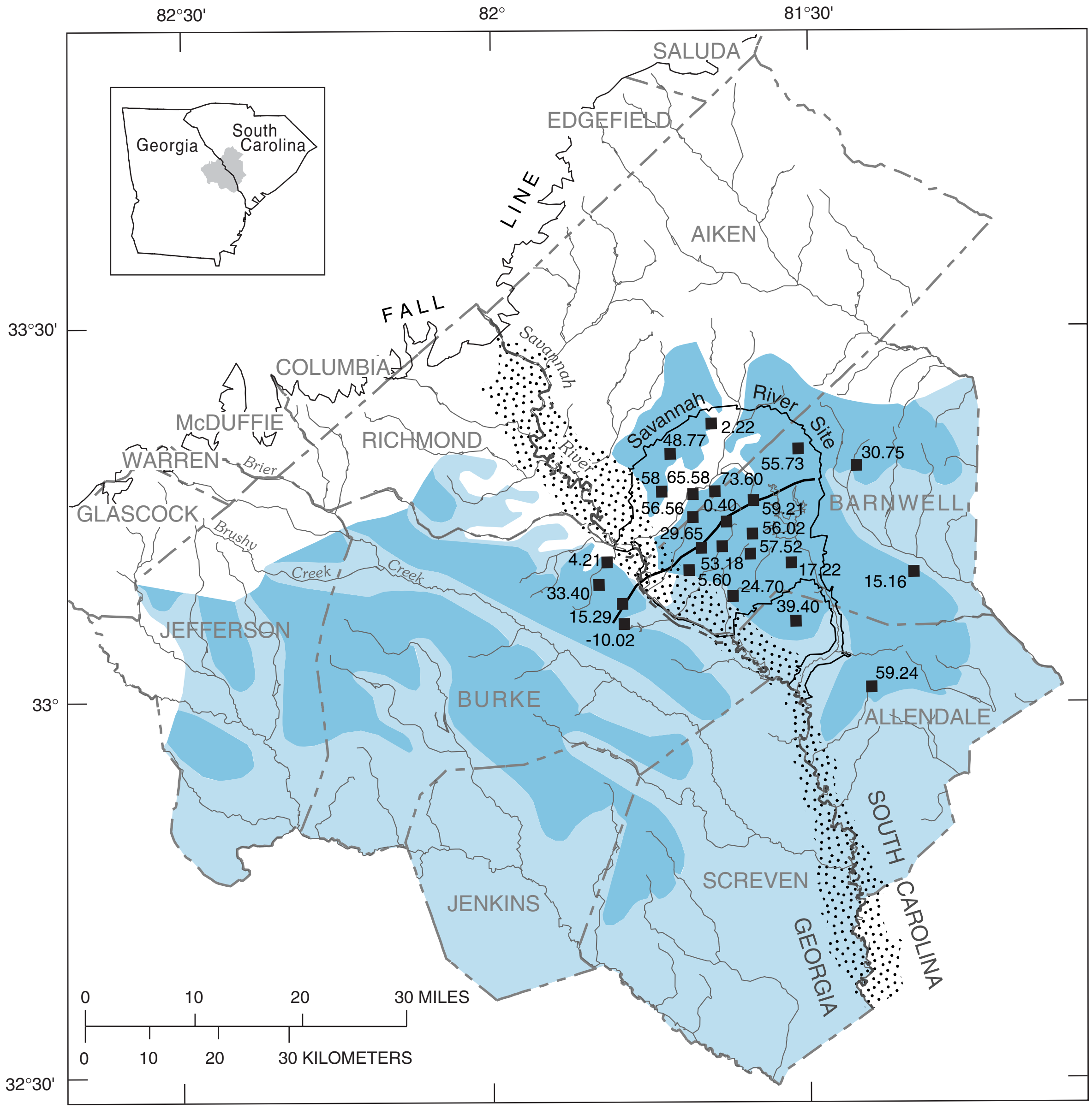
The vertical distribution of hydraulic head indicates areas of potential recharge to and discharge from the ground-water system. In areas of potential downward flow (higher head in upper unit than in underlying unit), ground-water recharge can occur; in areas of potential upward flow (higher head in underlying unit than in upper unit), ground-water discharge can occur. Where vertical head differences are near zero, there is little or no vertical component of flow. Head differences between vertically adjacent units tend to be highest in the vicinity of aquifer recharge and discharge areas where flow is predominantly vertical. Head differences are intensified in recharge and discharge areas where the vertical hydraulic conductivity of aquifers and confining units is low.

Areas of potential recharge and discharge are indicated on maps showing head differences between the Upper Three Runs and Gordon aquifers, the Gordon and upper and lower Dublin aquifers, and the upper and lower Dublin and upper and lower Midville aquifers (figs. 52-54). These maps were constructed by computing the head difference between adjacent aquifers, using data from well-cluster sites (table 1), and by comparing potentiometric-surface maps of adjacent aquifers in areas where cluster-site data were unavailable. Areas of potential downward ground-water flow are indicated on the maps as positive values, where head in the overlying aquifer is higher than head in the underlying aquifer (downward gradient). Areas of potential upward ground-water flow are indicated on the maps as negative values, where head in the underlying aquifer is higher than head in the overlying aquifer (upward gradient). Where data from two or more water-bearing zones within an aquifer were available at a well-cluster site, average values were used to compute head differences shown in figures 52-54. Although data are not available for comparison in the northern parts of the study area, higher topography in this area makes it likely that vertical head gradients between aquifers mostly are downward, indicating potential recharge; with the exception of areas in major stream valleys that are discharge areas.

In the Upper Three Runs aquifer, the high relief and hilly topography cause predominantly local flow with relatively short flowpaths. Thus, topography plays an important role in defining the position of areas of potential downward and upward flow. In interstream areas throughout most of the study area, the potential for flow between the Gordon aquifer and overlying Upper Three Runs aquifer is downward, indicating possible recharge by ground-water leakage from the Upper Three Runs aquifer to the Gordon aquifer (fig. 52). Conversely, in stream valleys and throughout much of the southern part of the study area, the potential for ground-water flow is upward, indicating possible discharge from the Gordon aquifer to the Upper Three Runs aquifer. Along the Savannah River bluffs in central Burke County, Georgia, areas of potential recharge abruptly change to areas of potential discharge, because of steep topographic and water-table gradients.

Head differences indicating potential downward flow between the Upper Three Runs and Gordon aquifers were measured at all but one well-cluster site; these differences range from 0.4 ft at the P-19 well cluster, to 73.6 ft at the P-27 well cluster (table 1, fig. 52). The small head difference at the P-19 site may be the result of greater hydraulic connection between the Upper Three Runs and Gordon aquifers, due to offset by the Pen Branch Fault. Large head differences such as those observed at the P-27 well cluster are common in upland areas at the SRS and adjacent areas, and probably are due to a combination of high head in the Upper Three Runs aquifer and low vertical hydraulic conductivity of the Gordon confining unit. The only head difference that suggests upward flow (potential discharge) was observed at the TR-92-3 site in Georgia, where a head difference of about -10 ft was measured. Because the site is located adjacent to a creek, head differences indicative of ground-water discharge can be expected to occur. Although well-cluster site data are limited, similar head relations probably also occur in other stream valleys.

In parts of the study area, the flow potential between the Upper Three Runs and Gordon aquifers (derived using potentiometric-surface maps) beneath some streams apparently is downward, suggesting influent (losing) streams. Although such flow conditions are possible during drought conditions, it is unlikely that these head relations are representative of long-term average conditions. The apparent downward flow potential may be the result of (1) insufficient data to delineate potentiometric contours in the vicinity of streams; or (2) hydraulic separation between the Upper Three Runs and Gordon aquifers because of lower permeability of the Gordon confining unit in the vicinity of the stream. Similar downward flow potential between the Gordon and upper and lower Dublin aquifers, and upper and lower Dublin and upper and lower Midville aquifers was detected beneath some streams, suggesting that the streams are hydraulically separated from these deeper aquifers.



Base modified from U.S. Geological Survey
State base maps

EXPLANATION

SAVANNAH RIVER ALLUVIAL VALLEY

POTENTIAL DOWNWARD FLOW— Vertical head gradient between Upper Three Runs and Gordon aquifers is downward. Determined from well-cluster site data and estimated from potentiometric- surface maps

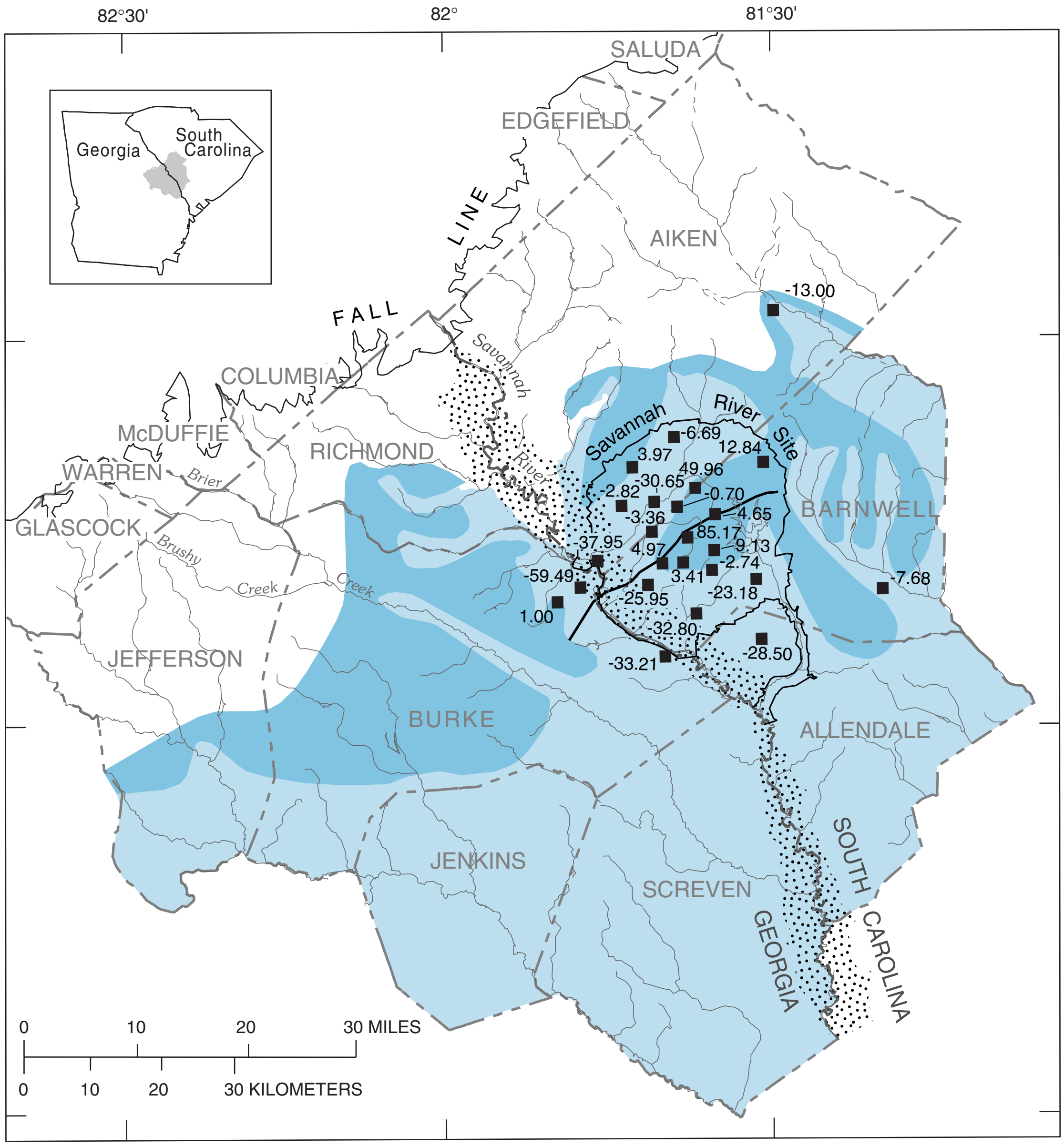
POTENTIAL UPWARD FLOW—Vertical head gradient between Upper Three Runs and Gordon aquifers is upward. Determined from well-cluster site data and estimated from potentiometric-surface maps

AREA WHERE ONE OR MORE AQUIFERS PINCHES OUT OR DATA ARE INSUFFICIENT TO DETERMINE HEAD DIFFERENCE

APPROXIMATE LOCATION OF PEN BRANCH FAULT

59.24 DATA POINT—Number is difference in water-level altitude between Upper Three Runs and Gordon aquifers in feet. Where positive, head in Upper Three Runs aquifer is higher than in Gordon aquifer; where negative, head in Upper Three Runs aquifer is lower than in Gordon aquifer. See Table 1 for water-level data

Figure 52. Generalized vertical head difference between the Upper Three Runs and Gordon aquifers. See table 1 for water-level data.



Base modified from U.S. Geological Survey
State base maps

EXPLANATION

SAVANNAH RIVER ALLUVIAL VALLEY

POTENTIAL DOWNWARD FLOW— Vertical head gradient between Gordon and upper/lower Dublin aquifers is downward. Determined from well-cluster-site data and estimated from potentiometric-surface maps

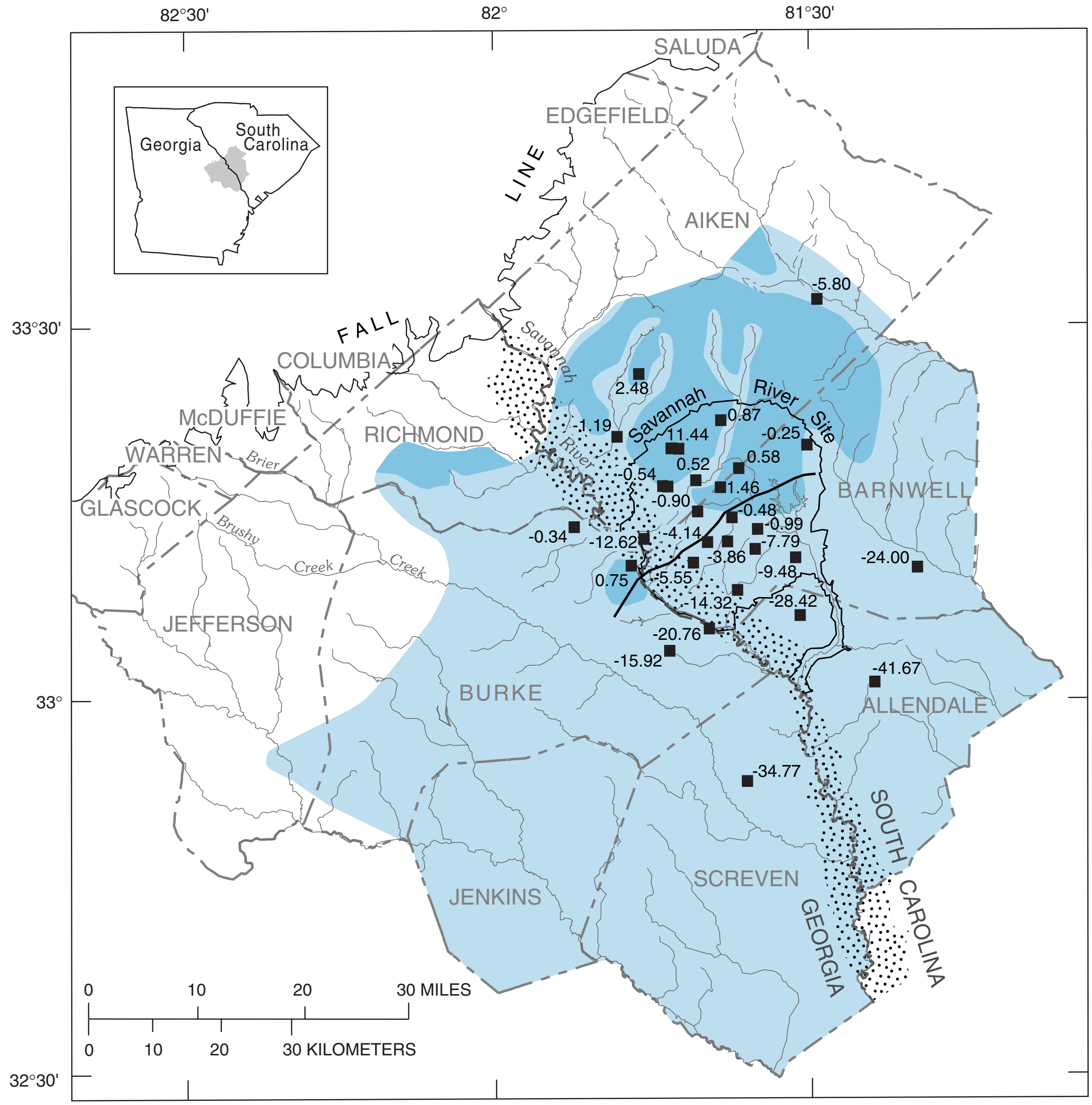
POTENTIAL UPWARD FLOW—Vertical head gradient between Gordon and upper/lower Dublin aquifers is upward. Determined from well-cluster-site data and estimated from potentiometric-surface maps

AREA WHERE ONE OR MORE AQUIFERS PINCHES OUT OR DATA ARE INSUFFICIENT TO DETERMINE HEAD DIFFERENCE

APPROXIMATE LOCATION OF PEN BRANCH FAULT

-15.73 DATA POINT—Number is difference in water-level altitude between Gordon and upper/lower Dublin aquifers in feet. Where positive, head in Gordon aquifer is higher than in upper/lower Dublin aquifer; where negative, head in Gordon aquifer is lower than in upper/lower Dublin aquifer. See table 1 for water-level data

Figure 53. Generalized vertical head difference between the Gordon and upper/lower Dublin aquifers. See table 1 for water-level data.



Base modified from U.S. Geological Survey
State base maps

EXPLANATION

SAVANNAH RIVER ALLUVIAL VALLEY

POTENTIAL DOWNWARD FLOW— Vertical head gradient between upper/lower Dublin and upper/lower Midville aquifers is downward. Determined from well-cluster-site data and estimated from potentiometric-surface

POTENTIAL UPWARD FLOW—Vertical head gradient between upper/lower Dublin and upper/lower Midville aquifers is upward. Determined from well-cluster-site data and estimated from potentiometric-surface maps

AREA WHERE ONE OR MORE AQUIFERS PINCHES OUT OR DATA ARE INSUFFICIENT TO DETERMINE HEAD DIFFERENCE

APPROXIMATE LOCATION OF PEN BRANCH FAULT

-34.77 DATA POINT—Number is difference in water-level altitude between upper/lower Dublin and upper/lower Midville aquifers in feet. Where positive, head in upper/lower Dublin aquifers is higher than in upper/lower Midville aquifers; where negative, head in upper/lower Dublin aquifers is lower than in upper/lower Midville aquifers. See table 1 for water-level data

Figure 54. Generalized vertical head difference between the upper/lower Dublin and upper/lower Midville aquifers. See table 1 for water-level data.

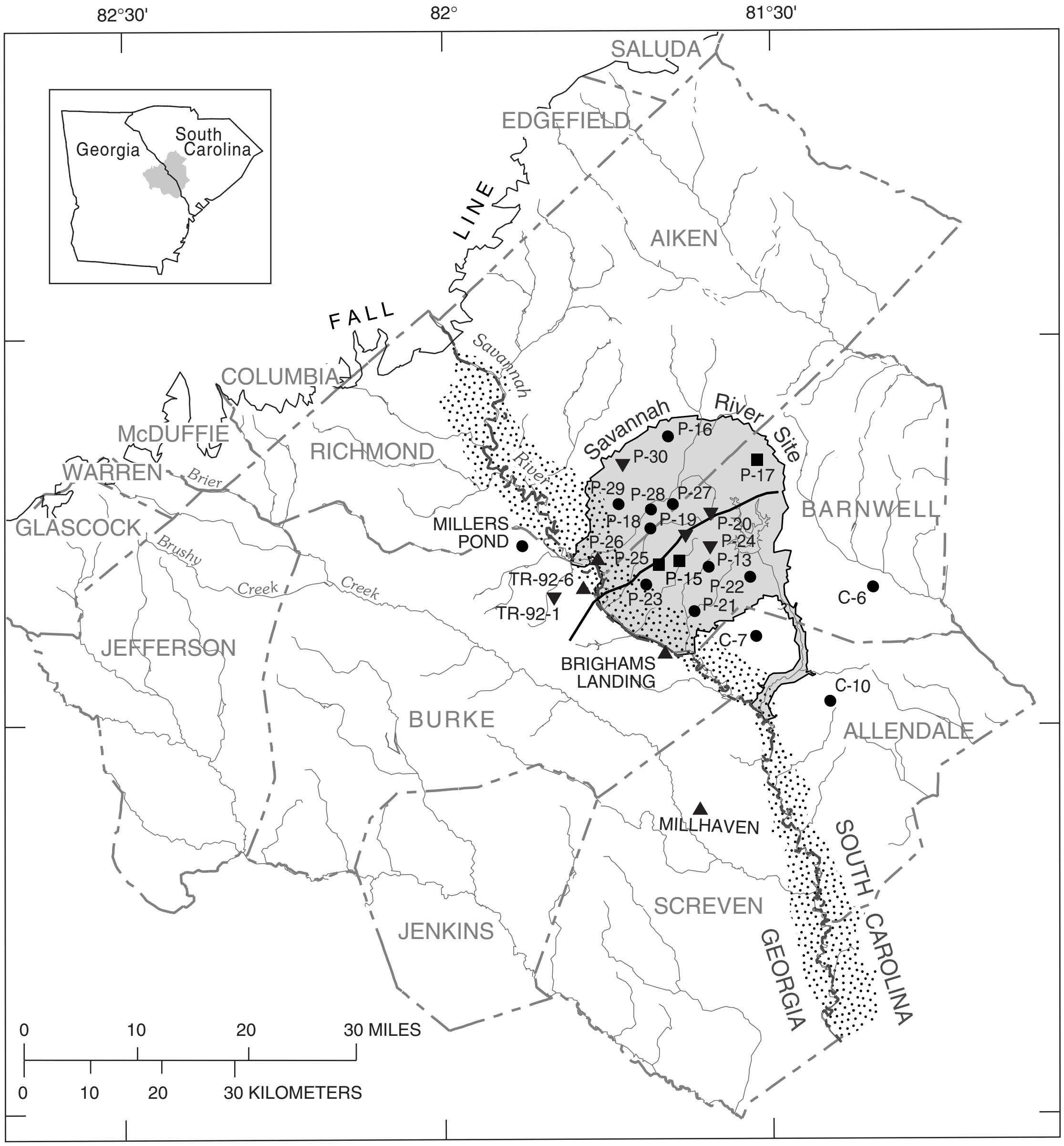
Vertical head relations between the Gordon and upper and lower Dublin average aquifers are similar to those observed between the Upper Three Runs and Gordon aquifers, but the extent of potential downward ground-water flow (potential recharge) is limited to areas farther to the north (fig. 53). Data from well-cluster sites indicate that the potential for downward flow between the Gordon and upper and lower Dublin aquifers is prominent in topographically high areas near the center of the SRS, with head differences ranging from about +3.4 ft at the P-15 site to +85.2 at the P-19 site (fig. 53; table 1). The higher head difference at the P-19 site probably results from higher heads in the Gordon aquifer due to its hydraulic connection with the Upper Three Runs aquifer near the Pen Branch Fault. The potential for flow between the Gordon and upper and lower Dublin aquifers is upward over much of the southern part of the study area, in the Savannah River alluvial valley, and in other major stream valleys. In particular, large head differences occur in and adjacent to the Savannah River alluvial valley and near Upper Three Runs Creek. In the Savannah River alluvial valley, differences range from about -32.8 ft at the P-21 site, to -38 ft at the P-26 site (fig. 53; table 1). Along the western bluffs of the Savannah River, at the TR-92-6 site, the vertical head difference between the Gordon and upper and lower Dublin aquifers is about -59.5 ft. Although this site is in a topographically high location (land surface altitude about 250 ft), the head in the Gordon aquifer is low (about 98 ft above sea level) and near river stage, indicating that the influence of the Savannah River drain has extended beyond the river valley. The proximity of the TR-92-6 site to the area where the Gordon aquifer has been incised by the paleo Savannah River (fig. 5), may explain why heads in the Gordon aquifer are relatively low at the TR-92-6 site.

The potential for ground-water flow between the upper and lower Dublin aquifers and the upper and lower Midville aquifers is upward in most of the study area (fig. 54). Exceptions occur in upland areas at and near the SRS, and in isolated areas in Georgia where the potential for flow is downward. Although data are not available for comparison in the northern parts of the study area, hilly topography makes it likely that the potential for flow mostly is downward, and represents areas of recharge to the Midville aquifer system. Head differences between the two aquifer systems in these northern areas probably are minimal because the intervening upper Midville confining unit is thin or absent. Clarke and others (1985) and Aadland and others (1995) reported that the likely hydraulic interconnection of the Dublin and Midville aquifer systems in the northern part of the study area probably is due to the absence of an intervening confining unit.

Head differences indicating potential upward flow between the upper and lower Dublin average and upper and lower Midville average aquifers appear to increase to the south and exceed -9 ft in much of the southern part of the study area. The larger head differences in the south probably are the result of downdip thickening of the upper Midville confining unit that separates the Dublin and Midville aquifer systems. Head differences were greatest at the Millhaven (about -34.7 ft) and C-10 (about -41.7 ft) well-cluster sites, where the upper Midville confining unit is 158 ft and 180 ft thick, respectively (fig. 54; table 1).

Head differences indicating potential downward ground-water flow between the upper and lower Dublin and upper and lower Midville aquifers ranged from about +0.5 to +11.4 ft at well-cluster sites at the SRS (fig. 54; table 1). In Georgia, an isolated area of potential downward flow occurs along the bluffs of the Savannah River at the TR-92-6 well-cluster site. At that site, the vertical head difference is about +0.8 ft; whereas, at the nearby P-26 well-cluster site, about 3 mi across the river in the Savannah River alluvial valley, the difference is about -12.6 ft (fig. 54; table 1). Reasons for the anomalous condition at the TR-92-6 site are not clear; however, the reasons may be related to the proximity of the site to the Pen Branch Fault and possible hydraulic interconnection between the Dublin and Midville aquifers.

Generally, the vertical distribution of hydraulic head in the stream-ground-water system is related to topographic location. In the vicinity of a major ground-water divide, head decreases with depth, probably to near the base of the regional flow system. In the vicinity of a regional drain, such as the Savannah River, head increases with depth. Such variations in head are shown by data from well-cluster sites (fig. 55; table 1). Well-cluster P-30 at the SRS, is located in a topographically high area at the confluence of several streams. Water levels measured during May 1992 (table 1) indicate that the head is progressively lower in deeper units, with altitudes ranging from about 259 ft in the Upper Three Runs aquifer, to about 190 ft in the lower Midville aquifer. Conversely, the head at the P-26 well-cluster site in the Savannah River alluvial valley, is progressively higher in deeper aquifers. In May 1992 and September 1993, water-level altitudes measured at the P-26 site ranged from about 115 ft in the Gordon aquifer, to about 166 ft in the lower Midville aquifer.



Base modified from U.S. Geological Survey
State base maps

EXPLANATION

SAVANNAH RIVER ALLUVIAL VALLEY

APPROXIMATE LOCATION OF PEN BRANCH FAULT

WELL-CLUSTER SITE AND IDENTIFICATION

- TR-92-6 ▲ Head gradients are upward
- TR-92-1 ▼ Head gradients are downward
- C-6 ● Head in Gordon and/or Millers Pond aquifers is lower than in overlying and underlying aquifers
- P-25 ■ Head in the lower Dublin aquifer is lower than in overlying and underlying aquifers

Figure 55. Vertical head relations at selected well-cluster sites. See table 1 for head data.

Although the relation of vertical hydraulic head distribution to topographic location holds true over much of the study area, in parts of the area, the Gordon, Millers Pond, and lower Dublin aquifers (table 1, fig. 55) are apparent hydrologic “sinks”; in which the hydraulic head is higher in overlying and underlying units, indicating a potential for vertical leakage of ground water into the aquifer from both above and below. In the Gordon aquifer, this anomalous condition is demonstrated by head data at the P-23 well cluster at the SRS (table 1). Water-level altitudes at P-23 during May 1992 were 139.4 ft in the Gordon aquifer, 145.0 ft in the overlying Upper Three Runs aquifer, and 147.2 ft in the underlying Millers Pond aquifer. In the lower Dublin aquifer, head data at the P-25 well cluster in May 1992, indicate that the head in the lower Dublin aquifer was about 171.3 ft; in the underlying upper Midville aquifer was about 175.2 ft; and in the overlying upper Dublin and Millers Pond aquifers was about 171.4 and 174.9 ft, respectively.

Observation of the “hydrologic sink condition” in the Georgia part of the study area is limited by a lack of water-level data; however, Clarke and others (1994) reported that vertical gradients at the Millers Pond well-cluster site in Burke County, Ga., suggest that the Millers Pond aquifer (described as the “upper part of the Dublin aquifer system”) is a potential hydrologic sink, and that the low head in the unit may be caused by hydraulic connection with the river. The absence of a test well in the Gordon aquifer at this site makes it unclear whether the lowest head occurs in the Millers Pond aquifer or in the Gordon aquifer.

Reasons for anomalously low heads in the Gordon, Millers Pond, and upper Dublin aquifers are unclear. Anomalously low heads may be related to (1) subsurface pinchout of the aquifers, that influences flow patterns in the stream-aquifer system; (2) hydraulic connection of the aquifers to river alluvium and associated high ground-water discharge rates that lowers heads; (3) water-level declines as a result of pumpage; or (4) any combination of these reasons.

The influence of a lensoidal (discontinuous) aquifer on ground-water flow was evaluated by Freeze and Witherspoon (1967) based on digital simulation of a hypothetical ground-water basin. That study indicated that such discontinuous aquifers may be characterized by lower heads than in surrounding units (hydrologic “sink” condition) along the upstream end of the aquifer. It is possible that similar flow conditions occur in the vicinity of the SRS, where the Millers Pond aquifer pinches out in the subsurface in the northern part of the study area, and similar pinchouts in the Gordon and lower Dublin aquifers also are possible. Clarke and others (1995) reported that the Gordon aquifer is only about 8 ft thick at the Millers Pond site in Burke County, Ga.; thus, subsurface pinchout of the unit is possible.

High rates of ground-water discharge near areas where an aquifer is in hydraulic connection with the Savannah River may cause lower heads in the aquifer than in vertically adjacent units. The Gordon aquifer, in particular, is in contact with river alluvium over the largest area of any of the six confined aquifers (Gordon, Millers Pond, upper Dublin, lower Dublin, upper Midville, and lower Midville aquifers; fig. 5). Rates of discharge may be accentuated by large transmissivity of the aquifer; however, more aquifer-test data are needed to evaluate the distribution of transmissivity near the river.

Water-level declines resulting from ground-water pumpage may produce lower heads in the pumped aquifer than in vertically adjacent units. Available water-level data for the Gordon, Millers Pond and upper Dublin aquifers do not indicate pronounced water-level response to pumpage in the areas where the anomalously low heads occur. Additional water-level monitoring in these areas would help determine the influence of pumpage on ground-water levels in these three aquifers.

STREAM-AQUIFER RELATIONS

In the vicinity of the SRS, the ground-water and surface-water systems interact dynamically throughout the year, varying seasonally. A schematic diagram that illustrates ground-water-flow conditions in the Savannah River valley area in the vicinity of the SRS is shown in figure 51. The Savannah River serves as the major drain for the hydrologic system in the study area. For purposes of this investigation, the present-day Savannah River floodplain is considered to represent the same or nearly the same hydrologic condition as the river (fig. 51). This assumption is valid because the river floodplain acts as a hydrologic “sink” into which ground water from surrounding and underlying units discharges. This “sink” is considered to have formed as the paleo Savannah River channel eroded through the uppermost confining units and subsequently was filled with permeable alluvium. In addition to the Savannah River, most streams in the SRS vicinity are incised into the Upper Three Runs aquifer, and a small number of streams are incised into deeper units in areas of high relief near the Savannah River valley, in northern parts of the study area.

Flow mechanisms of the surface-water and ground-water systems are vastly different—streams exhibit swift open-channel flow, and aquifers exhibit slow porous-media flow (Atkins and others, 1996). Streamflow is comprised of two major components—overland (or surface) runoff, and baseflow. Baseflow in streams is comprised of contributions from the local, intermediate, or regional ground-water flow systems. Streamflow is assumed to be sustained entirely by baseflow during extended periods of drought. Local flow systems are most affected by droughts.

Stream baseflow, estimated using hydrograph-separation techniques and synoptic measurements of drought streamflow, is an approximation of the quantity of ground water discharged to a stream under a variety of climatic conditions. Ground water discharges to (and at times, sustains) streams by the amount equal to ground-water recharge under steady-state conditions. Thus, mean-annual ground-water discharge to streams (baseflow) is considered to approximate the long-term average rate of ground-water recharge. For drought conditions, estimates of ground-water discharge to streams derived from streamflow data are considered minimum values of aquifer recharge because of little, if any, contribution from the local flow system. Estimates of ground-water discharge to the Savannah River and selected tributaries are described in the following sections. These data were largely from Atkins and others (1996)—who estimated ground-water discharge using an automated hydrograph-separation method and analysis of drought streamflow during 1954 and 1986; Faye and Mayer (1990)—who estimated ground-water discharge using hydrograph-separation techniques and analysis of drought streamflow during 1954; and Aucott, Meadows, and Patterson (1987)—who derived estimates on the basis of river gains observed along selected stream reaches during 1968.

The quantity of ground-water discharge is dependent, in part, on the size of the drainage basin—large basins tend to have larger discharges, and small basins tend to have lower discharges. To eliminate the effect of drainage basin size and to facilitate comparisons among drainage basins of varying sizes, estimates of ground-water discharge were weighted according to drainage-basin area and reported in inches per year using the relation:

$$Dw = 13.5736\,(Q/DA) \qquad (2)$$

where

Dw is the area-weighted ground-water discharge, in inches per year;

Q is the gain in streamflow representing ground-water discharge, in cubic feet per second;

DA is the drainage basin area, in square miles; and

13.5736 is a conversion constant.

Savannah River

Regional drainage of ground water from local, intermediate, and regional flow systems by discharge to the Savannah River can be used to approximate long-term average rates of recharge to the ground-water flow system (Atkins and others, 1996). Mean-annual ground-water discharge to the Savannah River was estimated by Faye and Mayer (1990) by computing the gain in stream discharge between the Augusta (02197000) streamflow gage (as determined using hydrograph separation), and the Millhaven (02197500) streamflow gage (as estimated from net-annual stream discharge). Because these estimates were derived from net-annual streamflow values at the Millhaven gage, these estimates included contribution from surface runoff, and should thus, be considered to represent the maximum aquifer discharge for that reach. Estimates from Faye and Mayer (1990) represent the combined contribution from the local, intermediate, and regional ground-water systems (table 7). Ground-water discharge ranged from 910 ft^3/s during a drought year (1941), to 1,670 ft^3/s during a wet year (1949), and averaged 1,220 ft^3/s (table 7). Of the average discharge, the local flow system contributed an estimated 560 ft^3/s and the intermediate and regional flow systems contributed an estimated 660 ft^3/s (Faye and Mayer, 1990). Aucott, Meadows, and Patterson (1987) estimated that ground-water discharge from the regional flow system to the Savannah River along the same reach was about 154 ft^3/s, based on synoptic streamflow measurements during September-October 1968, and on comparisons to flow-duration curves for unregulated streams in the study area (table 7). Thus, estimates of the percent contribution of the average ground-water discharge to the Savannah River from local, intermediate, and regional systems are as follows:

- 46 percent (560 ft^3/s) is from the local flow system,
- 41 percent (506 ft^3/s) is from the intermediate flow system, and
- 13 percent (154 ft^3/s) is from the regional flow system.

Table 7. Summary of estimated ground-water discharge to the Savannah River in the vicinity of the Savannah River Site, Georgia and South Carolina

Date	Stream discharge, in cubic feet per second		Net gain in stream discharge (estimated ground-water discharge)		Remarks
	Savannah River at Augusta, Ga. (02197000)	Savannah River at Burtons Ferry Bridge, near Millhaven, Ga. (02197500)	cubic feet per second	inches per year	
Water ear 1941[1/, 2/]	2,430	[3/]3,340	[2/]910	10.8	Dry year.
Water year 1942[2/]	2,840	[3/]3,930	[2/]1,090	13.0	Average year.
Water year 1949[2/]	5,370	[3/]7,040	[2/]1,670	19.8	Wet year.
Mean of 1941, 1942 and 1949 water years[2/]	3,550	[3/]4,770	[2/]1,220	14.5	Mean of dry, average, and wet years.
10/—/41	2,320	2,980	[4/]660	7.8	Synoptic measurements during dry period, including tributary inflow
9/24/68-10/7/68	6,721	6,944	[5/]223	2.6	Synoptic measurements during dry period, excluding tributary inflow

[1/]A 12-month period, October 1 through September 30. The water year is designated by the calendar year in which it ends and which includes 9 of the 12 months. Thus, the year ending September 30, 1941, is called the “1941 water year.”

[2/]Mean-annual discharge.

[3/]Equals the sum of the reported net-annual stream discharge gain between the Savannah River gages at Augusta, Ga., and Millhaven, Ga., during the given water year and corresponding ground-water discharge at Augusta, Ga. computed by hydrograph separation.

[4/]From Faye and Mayer, 1990.

[5/]Aucott, Meadows, and Patterson, 1987.

An approximation of long-term average recharge can be made by weighting these values according to drainage area. Thus, estimated average ground-water recharge in the Savannah River basin is 14.5 inches, of which 6.8 inches is to the local flow system, 5.8 inches is to the intermediate flow system, and 1.9 inches is to the regional flow system. Mean-annual precipitation in the basin ranges from 44 to 48 inches (fig. 2).

In an attempt to define specific areas of large ground-water contribution to flow of the Savannah River, data for nine periods of sustained low flow during 1986-90 were evaluated for the 34-mi reach between gages near Augusta, Ga. (02197000), and Jackson, S.C (02197320) (G.G. Patterson, U.S. Geological Survey, written commun., 1992). In this reach, a gain of about 180 ft^3/s more than contributed by tributary inflow was computed, despite substantial losses to evapotranspiration. Two gain-loss tests, under controlled low-flow in September 1990 and September 1991, provided more specific identification of a large-inflow reach. During the 1990 test, a 7-mi reach from Shell Bluff Landing, Ga., to the Jackson, S.C. gage (fig. 5) received about 300 ft^3/s more inflow than from tributaries. During the 1991 test, a 2-mi reach from Shell Bluff Landing, Ga., to the mouth of Newberry Creek, Ga., received about 200 ft^3/s more inflow than contributed from tributaries. In this area, the Gordon aquifer underlies the alluvium, allowing a direct pathway for discharge of ground water through the relatively permeable alluvium and to the river (fig. 5, plate 1b).

Other Streams

Estimates of mean-annual ground-water discharge to selected streams in Georgia and South Carolina, based on hydrograph separation (Atkins and others, 1996), represent an estimate of discharge from local and intermediate flow systems to streamflow (table 8). Mean-annual ground-water discharge to tributaries mainly is from the local and intermediate flow systems. In the lower reaches of larger tributary streams, regional flow also may contribute to ground-water discharge. According to Faye and Mayer (1990), the lower the tributary stream order, the greater the relative contribution from the local flow system.

Ground-water discharge to tributaries during drought periods is mostly derived from the intermediate flow system, with minimal contribution from the local and regional flow systems (Faye and Mayer, 1990). In general, ground-water discharge from the intermediate flow system during the droughts of 1954 and 1986 (Atkins and others, 1996; table 9) was small in areas near the Fall Line and in the southern part of the study area. The largest contributions occurred in (1) Richmond County, Ga., in an area generally north of and including McBean Creek, and (2) in Aiken and northern Barnwell County, S.C. Larger contributions in these areas may have been related to the relatively deep incision of streams that expose confined aquifers and allow large quantities of ground-water to discharge.

The percentage contribution from the local and intermediate flow systems were determined by Atkins and others (1996) by subtracting the intermediate flow-system discharge (as estimated from drought streamflow, table 9) from mean-annual ground-water discharge determined from hydrograph separation (table 8). In a downstream direction, the percentage contribution from the local and intermediate flow systems to streamflow is variable in the Brier Creek and Upper Three Runs Creek basins—contribution from the intermediate flow system decreases, and contribution from the local flow system increases in a downstream direction (Atkins and others, 1996). The ground-water contribution from the local flow system in the Upper Three Runs basin ranged from 72 percent of the total ground-water discharge in the upper two-thirds of the basin, to 100 percent in the lower one-third of the basin. Discharge from the local flow system in the central part of Brier Creek basin was 95 percent of the total ground-water discharge. The decreased contribution from the intermediate flow system in downstream reaches may be related to downdip (downstream) thickening of confining units, that subsequently reduces upward leakage of water to the stream.

Comparison of area-weighted estimates for the two drought years, 1954 and 1986, indicate that ground-water contribution to streamflow generally was lower in 1986 than in 1954, despite a more severe precipitation deficit during the early 1950's. Lower stream flows during 1986 than in 1954 probably are the result of measurement error or one or more of the following factors, each of which can reduce the amount of local ground-water flow available to discharge into the creek: (1) large surface-water withdrawal from the creek; (2) increased ground-water withdrawal from the surficial Upper Three Runs aquifer; (3) changes in agricultural crop patterns that increase the amount of evapotranspiration.

Influence of River Incision

The depth of incision by the paleo Savannah River channel into hydrogeologic units in the Savannah River alluvial valley is an important control on the configuration of potentiometric surfaces and associated ground-water flow directions, and on stream-aquifer relations. Faye and Mayer (1990) suggested that net ground-water discharge to regional drains like the Savannah River is controlled, in part, by incision of the regional drain. LeGrand and Pettyjohn (1981) suggested that large ground-water discharge into rivers like the Savannah is common where consequent streams flow downdip across gently and uniformly dipping sedimentary formations (homoclinal flanks) comprised of alternating sequences of aquifers and confining units. Such discharge zones or "artesian water gaps" can be formed where a major confining unit is breached by a downcutting river, exposing the underlying aquifer (fig. 56). This breach of the confining unit allows water in the underlying confined aquifer to discharge into the river in places where the hydraulic head in the aquifer is higher than the water level in the river, and may allow ground-water flow in an updip or upriver direction. Each of the seven aquifers was incised by the paleo Savannah River channel and covered with an infill of permeable alluvium, allowing direct hydraulic interconnection between the respective aquifer and the river along parts of the river's reach (fig. 5).

Potentiometric-surface maps (plate 1a,b,c,d) indicate that over much of the study area, the Savannah River valley is the major drain for aquifers in sediments of Late Cretaceous through Tertiary age. Discharge areas along the river valley are characterized as potentio-

Table 8. Mean-annual ground-water discharge to selected streams in the vicinity of the Savannah River Site, Georgia and South Carolina, based on hydrograph separation

[Modified from Atkins and others, 1996; —, not applicable; mi^2, square miles; ft^3/s, cubic feet per second; in/yr, inches per year]

Station number	Station name	Intermediate drainage area (mi^2)	Period of record: Years evaluated	Period of record: Mean-annual ground-water discharge (ft^3/s)	Period of record: Mean-annual gain in ground-water discharge (ft^3/s)	Period of record: Mean-annual gain in ground-water discharge (in/yr)	1987-92: Mean-annual ground-water discharge (ft^3/s)	1987-92: Mean-annual gain in ground-water discharge (ft^3/s)	1987-92: Mean-annual gain in ground-water discharge (in/yr)
	Upper Three Runs basin, S.C.								
—	intermediate area between stream headwaters and Upper Three Runs near New Ellenton, S.C.	87		—	100	15.6	—	96	15
02197300	Upper Three Runs near New Ellenton, S.C.	—	1967-93	100	—	—	96	—	—
—	intermediate area between Upper Three Runs near New Ellenton and above Road C at the Savannah River Site, S.C.	89		—	94	14.3	—	82	12.5
02197310	Upper Three Runs above Road C at Savannah River Site, S.C.	—	1975-93	194	—	—	178	—	—
—	intermediate area between Upper Three Runs above Road C and at Road A at the Savannah River Site, S.C.	27		—	21	10.6	—	22	11
02197315	Upper Three Runs at Road A at the Savannah River Site, S.C.	—	1975-93	215	—	—	200	—	—
	Butler Creek basin, Ga.								
—	intermediate area between stream headwaters and Butler Creek at Fort Gordon, Ga.	7.5		—	1.4	**2.5**	—	1.4	**2.5**
02196820	Butler Creek at Fort Gordon, Ga.		1969-90	1.4	—	—	1.4	—	—
	Brier Creek basin below the Fall Line, Ga.								
—	intermediate area between the Fall Line and Brier Creek near Waynesboro, Ga.	418		—	[1]284	[2]9.2	—	—	—
02197830	Brier Creek near Waynesboro, Ga.	—	1970-93	321	—	—	234	—	—
—	intermediate area between Brier Creek near Waynesboro, Ga., and near Millhaven, Ga.	173		—	126	9.9	—	75	5.9
02198000	Brier Creek near Millhaven, Ga.	—	1938-93	447	—	—	309	—	—
	Brushy Creek basin, Ga.								
—	intermediate area between stream headwaters and Brushy Creek near Wrens, Ga.	28		—	14	6.8	—	14	6.8
02197600	Brushy Creek near Wrens, Ga.	—	1959-93	14	—	—	14	—	—

[1]Mean-annual gain computed by multiplying the intermediate drainage area times the unit-area mean-annual discharge for Brushy Creek near Wrens, Ga., and Brier Creek near Waynesboro, Ga.

[2]Unit-area mean-annual ground-water discharge for Brushy Creek near Wrens, Ga., and Brier Creek near Waynesboro, Ga.

Table 9. Estimated ground-water discharge to selected streams in the vicinity of the Savannah River Site, Georgia and South Carolina, during the 1954 and 1986 droughts

[Modified from Atkins and others (1996); —, not applicable; mi^2, square mile; ft^3/s, cubic feet per second; in/yr, inches per year; <.,less than]

Stream name and state	Intermediate area of stream reach	Intermediate drainage area (mi^2)	1954 drought			1986 drought		
			Date(s)	Net gain in stream discharge (ft^3/s)	Net gain in stream discharge (in/yr)	Date(s)	Net gain in stream discharge (ft^3/s)	Net gain in stream discharge (in/yr)
Savannah River basin								
Butler Creek, Ga.	between stream headwaters and station 02196820	7.5	—	—	—	07/24/86	[1/]0.28	0.5
Butler Creek, Ga.	between stream headwaters and station 02196840	13.5	10/05/54	[2/]0.58	.58	—	—	—
Butler Creek, Ga.	between stations 02196840 and 02196900	15.9	10/05/54 10/06/54	[2/]8.7	7.4	—	—	—
Spirit Creek, Ga.	between stream headwaters and station 02197030	49.3	10/05/54	[2/]33.7	9.3	07/23/86	[2/]38	10.5
Spirit Creek, Ga.	between stream headwaters and station 02197020	18	10/05/54	[2/]12.7	9.6	—	—	—
Spirit Creek, Ga.	between stations 02197020 and 02197030	32.3	10/05/54	[2/]21.7	9.1	—	—	—
Spirit Creek, Ga.	between stations 02197030 and 02197045	20.8	10/05/54	[2/]0	0	—	—	—
Little Spirit Creek, Ga.	between stream headwaters and station 02197055	28.3	10/05/54	[2/]5.5	2.6	—	—	—
McBean Creek, Ga.	between stream headwaters and station 02197200	71.41	10/04/54	[2/]41.1	7.8	07/24/86	[1/]24	4.6
McBean Creek, Ga.	between stream headwaters and gage 02197190	41.4	10/06/54	[2/]19.7	6.5	—	—	—
McBean Creek, Ga.	between stations 02197190 and 02197200	30	10/04/54	[2/]21.7	9.8	—	—	—
Upper Three Runs, S.C.	between stream headwaters and stations 02197300	87	—	—	—	07/20/86	[1/]67	10.4
Upper Three Runs, S.C.	between stations 02197300 and 02197310	89.0	—	—	—	07/20/86	[1/]26	4.0
Upper Three Runs, S.C.	intermediate area between gages 02197310 and 02197315	27	—	—	—	07/20/86	0	0
Brier Creek, S.C.	between stream headwaters and station 021975015	15.2	—	—	—	07/22/86	[2/].23	.21
Sandy Run Creek, Ga.	between stream headwaters and station 02197560	31.4	10/06/54	[2/]11.1	4.8	07/23/86	[2/]11	4.8
Brushy Creek, Ga.	between stream headwaters and station 02197600	28.0	—	—	—	07/24/86	[1/]4.6	2.2
Brushy Creek, Ga.	between stream headwaters and station 02197580	1.4	10/06/54	[2/]0	0	—	—	—
Brushy Creek, Ga.	between stations 02197580 and 02197590	8	10/06/54	[2/]1.6	2.7	—	—	—
Brushy Creek, Ga.	between stations 02197590 and 02197640	31.3	10/05/54	[2/]8.9	3.9	—	—	—
Brier Creek, Ga.	between stream headwaters and stations 02197520	55.0	10/14/54	[1/].01	<.1	07/24/86	[1/].23	<.1

Table 9. Estimated ground-water discharge to selected streams in the vicinity of the Savannah River Site, Georgia and South Carolina, during the 1954 and 1986 droughts—Continued

[Modified from Atkins and others (1996); —, not applicable; mi^2, square mile; ft^3/s, cubic feet per second; in/yr, inches per year; <.,less than]

Stream name and state	Intermediate area of stream reach	Intermediate drainage area (mi^2)	1954 drought			1986 drought		
			Date(s)	Net gain in stream discharge		Date(s)	Net gain in stream discharge	
				(ft^3/s)	(in/yr)		(ft^3/s)	(in/yr)
Brier Creek, Ga.	between stations 0219557 and 02197830	302	10/04/54	[2]86.2	3.9	—	—	—
Brier Creek, Ga.	between stations 0219520 and 02197830	418	10/04/54 10/14/54	107.0	3.5	07/24/86	[1]66.8	2.2
Brier Creek, Ga.	between stations 02197830 and 02198000	173	10/06/54	[2]0	0	07/24/86	[1]6.0	.5
McIntosh Creek, Ga.	between stream headwaters and station 02197890	131	10/05/54	[2]0.9	.1	—	—	—
Beaverdam Creek, Ga.	between stream headwaters and stations 02198120	85	07/29/54	[2]1.3	.2	—	—	—
Beaverdam Creek, Ga.	between stations 02198120 and 02198280	58	07/29/54	[2]25.4	5.9	—	—	—
Ogeechee River basin								
Big Creek, Ga.	between stream headwaters and station 02200720	8.1	10/06/54	[2]2.4	4.0	—	—	—
Big Creek, Ga.	between stations 02200720 and 02200810	48.8	10/06/54	[2]2.3	6.3	—	—	—
Big Creek Tributary, Ga.	between stream headwaters and station 02200830	2.3	10/06/54	[2]0.08	.5	—	—	—
Buckhead Creek, Ga.	between stream headwaters and station 02201350	63.7	10/05/54	[2]0	0	—	—	—
Rocky Creek, Ga.	between stream headwaters and station 02201360	31.7	10/05/54	[2].12	.1	—	—	—
Rocky Creek, Ga.	between stations 02201360 and 02201365	3.1	10/05/54	[2]0	0	—	—	—
Little Buckhead Creek, Ga.	between stream headwaters and station 02201400	29.7	09/10/54	[2]0.02	<.1	—	—	—
Ogeechee Creek, Ga.	between stream headwaters and station 02202210	14.0	09/09/54	[2]0	0	—	—	—
Edisto River basin								
South Fork Edisto River, S.C.	between stations 02172500 and 0217300	522	09/10/54	[1]129	3.4	—	—	—

[1]Daily mean discharge.
[2]Discharge measurement.

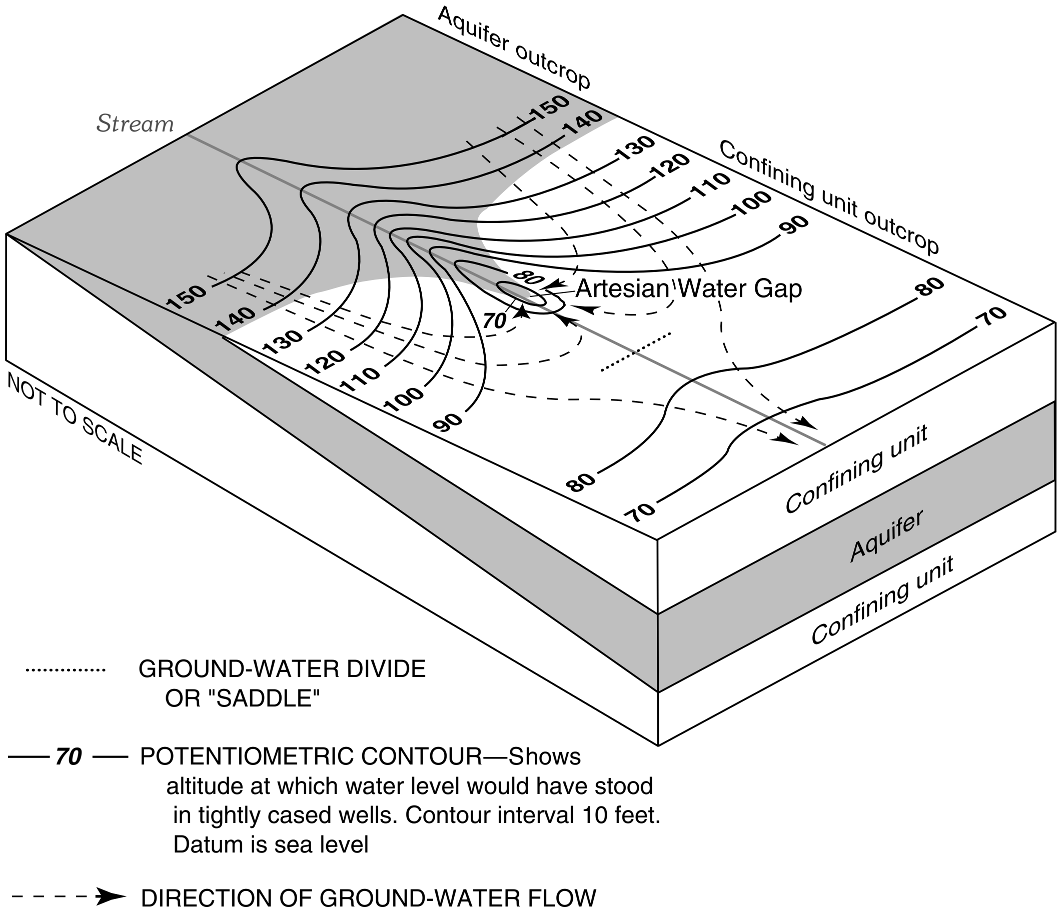


Figure 56. Schematic diagram of artesian water gap and related pattern of ground-water flow (modified from LeGrand and Pettyjohn, 1981).

metric lows or depressions on the potentiometric-surface maps. The location and areal extent of the depressions vary depending on where the aquifer is in direct or nearly direct contact with river alluvium, and on the transmissivity of the aquifer. Freeze and Witherspoon (1967) suggested that as the ratio of horizontal to vertical permeability increases, the hinge line separating areas of ground-water recharge from areas of ground-water discharge moves upslope, creating a large discharge area. Thus, for the same volume of discharge from a given aquifer, the higher the transmissivity, the shallower the depression and greater its areal extent. This relation is demonstrated by comparing the size of the depression for the Midville aquifer system, as defined by the 180-ft contour (plate 1d), to the depression for the Dublin aquifer system, as defined by the 160-ft contour (plate 1c). The higher transmissivity of the Midville aquifer system results in a more areally extensive depression than for the less transmissive Dublin aquifer system.

Downstream of each depression, a ground-water divide, or “saddle” in the potentiometric surface occurs perpendicular to the river and separates upstream ground-water flow from downstream ground-water flow (fig. 56). This saddle is defined by potentiometric contours that transect the river and by flow lines that (1) bend upstream on the upstream side of the saddle; and (2) bend downstream on the downstream side of the saddle. The presence of a saddle near the Savannah River in an aquifer comprised of Cretaceous sediments was originally proposed by Siple (1960, 1967) and later by LeGrand and Pettyjohn (1981). Ground-water gradients in the vicinity of the saddle are essentially flat, and thus, may change in conjunction with changes in ground-water pumpage near the river. Saddles are depicted on the potentiometric surfaces of the: (1) Gordon aquifer (plate 1b), between the 120 ft contours that cross the river near the Burke-Screven County line, and near the Brighams Landing well-cluster site; and (2) upper and lower Dublin aquifers (plate 1c) between the 160 ft contours that cross the river near the Brighams Landing well-cluster site, and about 5.5 mi upriver of that well-cluster site. In the upper and lower Midville aquifers, available data and potentiometric contours (plate 1d) show only partial formation of a saddle; however, relatively high water-level altitudes at the C-13 well-cluster site (about 188 ft in July 1996, Constance Gawne, South Carolina Department of Natural Resources, oral commun., July 1996) make the presence of a saddle likely. The potentiometric-surface map for the Upper Three Runs aquifer (plate 1a) does not indicate a saddle feature, possibly because the Upper Three Runs aquifer is in hydraulic connection with Savannah River alluvium throughout the river's course. Therefore, an "artesian water gap" that could result in an upriver component of flow and associated saddle has not formed, as indicated by water-level data.

Hydraulic interconnection resulting from river incision may be the cause of high rates of discharge in the Savannah River valley (fig. 3). Patterson (1992) reported that ground-water discharge to the Savannah River in the vicinity of the SRS in September 1991 was highest along a 2-mi reach north of USGS streamflow gage 02197320, near Jackson, S.C. These high flows occur in an area where the Gordon aquifer is in contact with Savannah River alluvium (fig. 5), allowing a direct pathway for discharge of ground water into the river.

Trans-River Flow

Trans-river flow is a term that describes a condition whereby ground water originating on one side of a river migrates beneath the river floodplain to the other side of the river. Although some ground water could discharge into the river floodplain on the opposite side of the river from its point of origin, this flow likely would return to the river. This return flow would occur because there is a slight topographic gradient toward the river along the floodplain. Factors controlling the potential for trans-river flow include: (1) vertical and horizontal hydraulic conductivity of aquifers and confining units; (2) thickness and areal extent of confining units; and (3) hydraulic gradient. Hydraulic gradients and the potential for trans-river flow may be altered by ground-water withdrawal, particularly at pumping centers located near the river (see locations, fig. 6). Pumped wells on one side of the river could intercept water originating from the other side prior to its discharge into the alluvial valley. In general, a greater potential for trans-river flow occurs in areas where aquifers are hydraulically separated from the Savannah River, and are thus, isolated from changes in the position of the river.

Potentiometric-surface maps (plate 1a,b,c,d) can be used to delineate lateral flow directions, and thus, give an indication of the possibility of trans-river flow in an aquifer. For aquifers that exhibit isotropic flow properties, directions of ground-water movement are perpendicular to potentiometric contours, from areas of high to low head. Because ground-water flow in the vicinity of regional drains has a significant vertical component, flow directions derived from potentiometric-surface maps should be considered only a partial representation of potential trans-river flow in an aquifer. Actual occurrence of trans-river flow includes a significant vertical component that cannot be determined from potentiometric-surface maps. Characterization of such three-dimensional flow can be derived from dense networks of vertically-clustered piezometers or by using digital simulation techniques.

The potentiometric surface of the Upper Three Runs aquifer (plate 1a) does not indicate the occurrence of lateral trans-river flow. Flow lines indicate that water in the Upper Three Runs aquifer generally flows laterally toward the river from the east and west and discharges into the Savannah River. Because the Upper Three Runs aquifer is incised and in hydraulic connection with Savannah River alluvium throughout the river's course, the river serves as a discharge boundary for ground-water flow from both Georgia and South Carolina.

In the Gordon aquifer (plate 1b), flow lines indicate that there is little potential for lateral trans-river flow. In general, water in the Gordon aquifer flows toward the Savannah River from the east and west and discharges into the river. In the area north of the Burke-Screven line, the potentiometric surface is characterized by flat, horizontal hydraulic gradients and flow is either:

- toward the river from both east and west (see inset, plate 1b); or
- characterized by a ground-water divide or saddle (plate 1b)—whereby part of the flow is upriver toward the area where the Gordon aquifer was incised by the ancient Savannah River channel (northern discharge zone), and part of the flow is downstream towards the coast (southern discharge zone).

In the northern discharge zone, as depicted by 120-ft or lower contours (plate 1b), it is possible that trans-river flow toward either the eastern or western side of the river occurs as water moves toward the area where the aquifer is in hydraulic contact with alluvium and ultimately discharges. Additional data and digital simulation techniques would enhance understanding of ground-water flow conditions in the floodplain area.

In the upper and lower Dublin aquifers, flow lines indicate a potential for lateral trans-river flow toward the eastern and western sides of the Savannah River (plate 1c). Trans-river flow toward the eastern side of the river may occur in the area between the confluence of McBean Creek and the Savannah River, and the confluence of Upper Three Runs Creek and the Savannah River. Trans-river flow toward the western side of the river may occur in the vicinity of a large meander of the Savannah River near the Aiken-Barnwell County line and near the Brighams Landing well-cluster site. In the area between the Brighams Landing well-cluster site and south of the Pen Branch fault, the potentiometric surface of the upper and lower Dublin aquifers is characterized by relatively flat hydraulic gradients and flow is either:

- toward the river from both east and west (see inset, plate 1b), or
- characterized by a ground-water divide or saddle (plate 1c)—whereby part of the flow is upriver toward the area where the aquifer was incised by the paleo Savannah River channel (northern discharge zone) and part of the flow is downstream toward the coast (southern discharge zone).

In the northern discharge zone, as depicted by 160-ft or lower contours (plate 1c), it is possible that trans-river flow from either the eastern or western side of the river occurs as water moves toward the area where the aquifer is in hydraulic contact with alluvium and ultimately discharges. Additional data and digital simulation techniques would enhance understanding of ground-water flow in the floodplain area.

In the southern discharge zone of the upper and lower Dublin aquifers, water-chemistry data from the Brighams Landing well-cluster site in Georgia supports the possibility of trans-river flow toward the western side of the river. Chemical and isotopic composition of water from the lower Dublin aquifer at Brighams Landing suggests mixing of ground water from both sides of the river, and, thus, supports the possibility of trans-river flow from the eastern toward the western side of the river (W.F. Falls, U.S. Geological Survey, written commun., 1997).

In the upper and lower Midville aquifers, flow lines indicate a potential for lateral trans-river flow from the Brighams Landing site northward to central Richmond County (plate 1d). Here, water from the eastern and western sides of the river may flow toward the other side of the river as it moves toward its ultimate discharge in the area where the aquifer is hydraulically connected with Savannah River alluvium. In addition, flow lines in northern Richmond County suggest possible trans-river flow from the eastern side of the river toward a 120-ft depression in the potentiometric surface on the western side of the river. Additional data and digital simulation techniques would enhance understanding of ground-water flow in the floodplain area.

SUMMARY AND CONCLUSIONS

Ground-water levels and stream-aquifer relations in the vicinity of the U.S. Department of Energy Savannah River Site (SRS) were evaluated as part of a cooperative study between the U.S. Geological Survey, U.S. Department of Energy, and Georgia Department of Natural Resources. The study involved (1) description of ground-water-level fluctuations and trends and relating to ground-water use and precipitation; (2) conceptual description of stream-aquifer relations near the SRS; (3) description of the predevelopment ground-water-flow system, configuration of potentiometric surfaces, trans-river flow, and recharge-discharge relations in three aquifer systems in Cretaceous and Tertiary sediments in the vicinity of SRS; and (4) description of stream-aquifer relations and the influence of river incision on ground-water flow and stream-aquifer relations.

The study area encompasses 5,147-square miles in the northern part of the Coastal Plain of Georgia and South Carolina. Coastal Plain strata in the study area consist of sequences of sand, clay, and lesser amounts of limestone that progressively thicken from the Fall Line to the southeast; estimated maximum thickness is 2,700 feet in the southern part of the study area. These sediments comprise three aquifer systems consisting of seven aquifers that are separated hydraulically to varying degrees. The aquifer systems are, in descending order: (1) the Floridan aquifer system—consisting of the Upper Three Runs and Gordon aquifers in sediments of Eocene age; (2) the Dublin aquifer system—consisting of the Millers Pond, upper Dublin, and lower Dublin aquifers in sediments of Paleocene-Late Cretaceous age; and (3) the Midville aquifer system—consisting of the upper Midville and lower Midville aquifers in sediments of late Cretaceous age. The aquifers are confined by layers of clay and silt that are progressively more sandy in updip areas. Where the confining units are more sandy, they are laterally discontinuous and the aquifer systems coalesce.

Fluctuations and long-term trends in ground-water levels occur as a result of changes in recharge to and discharge from an aquifer. Recharge varies in response to precipitation, evapotranspiration, and surface-water infiltration into an aquifer. Discharge occurs as natural flow from an aquifer to streams and springs, as leakage to vertically adjacent aquifers, as evapotranspiration from shallow water-table aquifers, and as withdrawal from wells.

Ground-water withdrawal in the vicinity of the SRS showed a pronounced increase from the early 1950's through 1992. During 1953-60, estimated ground-water withdrawal was about 10 million gallons per day (Mgal/d) in South Carolina and about 4 Mgal/d in Georgia. During 1971-75, estimated ground-water withdrawal was about 27 Mgal/d in Georgia and about 20 Mgal/d in South Carolina. During 1987-92, total study area withdrawal was about 80 Mgal/d; about 55 Mgal/d was in Georgia, and about 25 Mgal/d in South Carolina. Centers of pumpage located adjacent to the Savannah River that withdrew 1 Mgal/d or greater during 1987-92 include in Georgia—Plant Vogtle nuclear power station, the Richmond County water system, and Olin Corporation; and in South Carolina—Sandoz, Inc., and the SRS.

Precipitation throughout the SRS vicinity was below normal from 1948 through much of the 1950's, a period during which one of the most severe droughts of the century occurred in 1954. By the end of 1992, the long-term cumulative departure was above normal in the southern part of the study area at Waynesboro, Ga., and Blackville, S.C., and below normal in the northern part of the area at Augusta, Ga., and Aiken, S.C.

The Upper Three Runs aquifer is the shallowest of the seven aquifers and shows pronounced water-level response to topography and climate. During 1992, the seasonal water-level change between Spring (May) and Fall (October) in 95 wells completed in the Upper Three Runs aquifer generally was less than 2 feet. Continuous water-level data from seven wells indicate that the largest seasonal changes were in northern Screven County, Ga., where nearby wells withdraw water for irrigation. Evaluation of data from 200 wells indicates that long-term water-level change in the Upper Three Runs aquifer varied mostly between -17 and +18 feet, with greater changes of -44 to +43 feet in isolated areas influenced by pumpage. Comparison of water levels to precipitation and to regional pumpage indicates that long-term water-level trends in the Upper Three Runs aquifer mostly are influenced by cumulative precipitation trends.

Water levels in the Gordon aquifer are affected by precipitation, stream stage, and pumpage. During 1992, the seasonal water-level change between Spring (May) and Fall (October) in 54 wells completed in the Gordon aquifer generally was between -1 and +3 feet. Evaluation of data from 28 wells indicates that long-term water-level change in the Gordon aquifer varied between -18 and +13 feet. Changes greater than 5 feet occurred near supply wells completed in the Gordon aquifer.

Water levels in the Dublin aquifer system are affected by precipitation, evapotranspiration, pumpage, and stream stage. Minimal hydraulic separation between the upper and lower Dublin aquifers makes it likely that ground-water flow and water-level changes in the two aquifers are similar. During 1992, the seasonal water-level change between the Spring (May) and Fall (October) generally was less than 1 foot in seven wells completed in the Millers Pond aquifer; between 3 feet and 1 foot higher in 29 wells completed in the upper Dublin aquifer; and less than 1 foot in 33 wells completed in the lower Dublin aquifer. Changes greater than 5 feet occurred in isolated wells located near supply wells. Long-term (greater than 10 years) water-level changes in 11 wells completed in the upper Dublin aquifer, varied between -22 and +15 feet and between -14 and +4 feet in eight wells completed in the lower Dublin aquifer. There are no long-term (greater than 10 years) data available to assess the magnitude of water-level changes in the Millers Pond aquifer.

Water levels in the upper and lower Midville aquifers are affected by precipitation, evapotranspiration, pumpage, and stream stage. Minimal hydraulic separation of the upper and lower Midville aquifers (0.1 to 9.57 feet), makes it likely that ground-water flow in the two aquifers is similar. During October 1992, water levels were from 1 foot lower to 3 feet higher than in May 1992 in 19 wells completed in the upper Midville aquifer, and from 4 feet lower to 3 feet higher than in May 1992 in 35 wells completed in the lower Midville aquifer. Changes greater than 5 feet occurred near supply wells. Long-term (greater than 10 years) water-level changes in one Georgia and one South Carolina well completed in the upper Midville aquifer were +16 and -4 feet, respectively. Evaluation of long-term (greater than 10 years) data from 34 wells indicates that water level changes in the lower Midville aquifer were mostly from -40 to +8 feet, with declines in excess of 5 feet occurring near supply wells. The largest water-level declines of the seven aquifers occurred in the lower Midville aquifer near the Richmond County well field and Olin Corporation sites in Richmond County, Ga., where declines of up to 59 feet occurred.

The presence of low permeability clay layers can result in vertical head differentiation within an aquifer or aquifer system. This differentiation is most pronounced where clay layers are of low permeability and are laterally extensive; and in the vicinity of aquifer recharge and discharge areas, where there are large vertical hydraulic gradients. In parts of the study area, the Upper Three Runs and Gordon aquifers consist of 2 to 3 water-bearing zones showing different degrees of hydraulic separation. At the C-10 well-cluster site, located in an upland area in Allendale County, S.C.; heads of 232.04, 193.13, and 157.20 feet were observed in the upper, middle, and lower zones of the Upper Three Runs aquifer, respectively. The greatest head difference within the Gordon aquifer (7.8 feet) was observed at the P-26 well-cluster site, located in the Savannah River alluvial valley, an area of pronounced aquifer discharge to the river. In the Dublin aquifer system, head differences are most pronounced between the Millers Pond aquifer and the underlying upper Dublin aquifer, ranging from 0.3 to 31.8 feet. Head differences between the upper and lower Dublin aquifers are lower, ranging from 0.03 to 6.18 feet. Larger head differences between the Millers Pond and upper Dublin aquifers probably are the result of a thicker and less permeable intervening confining unit. In the Midville aquifer system, head differences between the upper and lower Midville aquifers mostly are less than 1 foot, and range from 0.1 to 9.57 feet.

In general, the period prior to major construction and production at the Savannah River Site (late 1952) is believed to be representative of predevelopment, steady-state conditions in the study area. Prior to that year, ground-water withdrawals were small and limited to widely scattered pumping centers such as Augusta, Ga., and Barnwell and Allendale, S.C. In late 1952, large water withdrawal began at the SRS and water-level declines in several aquifers occurred in scattered areas; however, since predevelopment, the ground-water-flow system has changed little over most of the study area.

Recharge to the ground-water system is provided by rainfall that ranges from 44 to 48 inches per year. Most of the recharge is discharged from the shallow (local) flow system into small streams, or is lost to evapotranspiration. A smaller percentage of recharge infiltrates through clayey confining units and enters the deeper intermediate and regional flow systems. In the intermediate flow system, some of this water is discharged to major tributaries of the Savannah River and some discharges directly into the Savannah River valley. In the regional flow system, some of the water is discharged into the Savannah River valley and some moves southeastward out of the study area.

The configuration of the potentiometric surfaces are dominated by surface topography and streams throughout the study area, for the largely unconfined Upper Three Runs aquifer; and in northern areas where the confined Gordon aquifer and Dublin and Midville aquifer systems are at or near land surface. For each of the aquifers, major surface-water drains include the Savannah River, South Fork of the Edisto River, Brier Creek, and Upper Three Runs Creek. Major ground-water divides occur near interstream drainage divides and include the area between the Ogeechee River and Brier Creek in Georgia, and between the South Fork of the Edisto River and Salkehatchie River in South Carolina.

Areas of potential recharge and discharge to the ground-water system are inferred from the vertical distribution of hydraulic head among the aquifers. In areas of potential downward flow (higher head in upper unit than underlying unit), ground-water recharge can occur; in areas of potential upward flow (higher head in underlying unit than upper unit), ground-water discharge can occur. Where vertical head differences are near zero, there is little or no vertical component of flow. Head differences between vertically adjacent units tend to be greatest in the vicinity of aquifer recharge and discharge areas where flow is predominantly vertical. Head differences are enhanced in recharge and discharge areas where the vertical hydraulic conductivity of aquifers and confining units is low.

Water-level data at well-cluster sites indicate that in the vicinity of major ground-water divides, head decreases with depth; and in the vicinity of a regional drain, such as the Savannah River, head increases with depth. Although this vertical head distribution holds true over much of the study area, in specific locations the Gordon, Millers Pond, and lower Dublin aquifers are apparent hydrologic “sinks”, containing a lower hydraulic head than overlying and underlying aquifers. Thus, in these areas, there is a potential for vertical leakage from both above and below the aquifer. Reasons for anomalously low heads in the Gordon, Millers Pond, and upper Dublin aquifers are unclear, but probably are related to (1) subsurface pinchout of the aquifer, which influences flow patterns in the stream-aquifer system; (2) hydraulic connection of the aquifer with river alluvium (and associated high ground-water discharge); or (3) water-level declines as a result of pumpage.

Stream baseflow, estimated using hydrograph-separation techniques and synoptic measurements of drought streamflow, is an approximation of ground-water discharge to streams. Estimated average ground-water discharge to the Savannah River is 1,220 cubic feet per second, of which 46 percent is from the local flow system, 41 percent was from the intermediate flow system, and 13 percent was from the regional flow system. Estimated ground-water discharge during the 1954 and 1986 droughts indicate that the contribution from the intermediate flow system decreases in a downstream direction, with most ground-water discharge contributed by the local flow system. The decreased baseflow contribution from the intermediate flow system in downstream reaches may be related to a downdip (downstream) thickening of confining units that reduce upward vertical leakage of ground water to the stream.

Comparison of baseflow estimates for two drought periods, 1954 and 1986, indicate that ground-water discharge was lower in 1986 than in 1954, despite a more severe precipitation deficit during the early 1950’s. Lower flows during 1986 could be the result of (1) measurement error; (2) larger surface-water withdrawal from a creek; (3) increased ground-water withdrawal from the surficial Upper Three Runs aquifer, reducing the amount of local ground-water flow available to discharge into a creek; (4) changes in agricultural crop patterns that increase the amount of evapotranspiration; or (5) a combination of the above factors.

Geologic characteristics of the Savannah River alluvial valley significantly affect configuration of potentiometric surfaces, ground-water-flow directions, and stream-aquifer relations. The present-day Savannah River floodplain is considered to represent the same hydrologic condition as the river itself because the river floodplain acts as a hydrologic “sink” into which ground water from adjacent and underlying units may discharge. This floodplain and hydrologic “sink” are considered to have been formed as the river eroded through the uppermost confining units and subsequently was filled with permeable alluvium. Eighteen shallow borings indicate that Savannah River alluvium is more coarse, angular, and poorly sorted than underlying formations; lithologic differences between these strata are readily apparent, especially in areas where the underlying strata are of marine origin. Each of the seven aquifers was incised by the paleo Savannah River channel and covered with an infill of permeable alluvium, allowing direct hydraulic connection between the aquifers and the river along parts of the river’s reach. This hydraulic connection may be the cause of high runoff rates in the Savannah River valley, especially in Richmond and Burke Counties, Ga. Discharge to the river in September 1991 was highest along a 2-mile reach north of U.S. Geological Survey stream-gaging station 02197320, near Jackson, S.C. These high flows occurred in an area where the Gordon aquifer is in contact with Savannah River alluvium, allowing a direct pathway for discharge of ground water to the river.

The influence of river incision into aquifers on ground-water flow near the Savannah River also is indicated on estimated predevelopment potentiometric-surface maps. On these maps, discharge areas along the river valley are characterized as potentiometric lows, or depressions. The location and areal extent of these depressions vary depending on contact of the aquifer with river alluvium, and on aquifer transmissivity. Generally, for a given amount of ground-water discharge to a stream from two different aquifers, the aquifer having a higher transmissivity will have a shallower depression with larger areal extent. Ground water flows toward the depression from all directions; however, downstream from the depressions, the influence of the river on ground-water flow is diminished to where ground-water flow is southeastward, parallel to the river channel.

Downstream of each depression in the potentiometric surface, a ground-water divide or “saddle” underlying the river may separate upstream from downstream ground-water flow. Hydraulic gradients in the vicinity of the saddle are flat, and thus, may be more responsive to changes in ground-water withdrawal near the river than in areas where gradients are steep. Saddle features are a possible interpretation of available water-level data for the Gordon aquifer and the upper and lower Dublin aquifers. The presence of a saddle is not indicated by available water-level data for the upper and lower Midville aquifers; however, high water-level altitudes at the C-13 well-cluster site in Allendale County, S.C., make its presence likely. A saddle feature in the potentiometric surface of the Upper Three Runs aquifer cannot be inferred from water-level data.

Trans-river flow is a term that describes a condition under which ground water originating on one side of a river migrates beneath the river floodplain to the other side of the river. Although some ground water could discharge into the river floodplain on the opposite side of the river from its point of origin, such flow likely would return to the river because flow in the alluvium is toward the river. Factors controlling the potential for trans-river flow include (1) vertical and horizontal hydraulic conductivity of aquifers and confining units; (2) thickness and areal extent of confining units; and (3) hydraulic gradient. Hydraulic gradient and the corresponding potential for trans-river flow may be altered by ground-water withdrawal, particularly at pumping centers located near the Savannah River. Pumped wells on one side of the river could intercept ground water that originates on the other side, thus altering the predevelopment patterns of ground-water discharge into the alluvial valley.

Flow lines on potentiometric-surface maps of the confined Dublin and Midville aquifer systems suggest possible occurrence of lateral trans-river flow for a short distance into Georgia prior to discharge into the Savannah River alluvial valley. Possible occurrence of trans-river flow in the Dublin aquifer system also is suggested by chemical and isotopic composition of water from the Brighams Landing well-cluster site in Georgia, which indicates mixing of ground water from both sides of the river. Potentiometric-surface maps for the Upper Three Runs aquifer and Gordon aquifers do not indicate the possible occurrence of lateral trans-river flow. Because ground-water flow in the vicinity of regional drains has a significant vertical component, flow directions derived from potentiometric-surface maps should be considered only a partial representation of potential trans-river flow in an aquifer. Characterization of three-dimensional flow can be derived from dense networks of vertically-clustered piezometers or by using digital simulation techniques.

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APPENDIX

Data for selected wells in the vicinity of the Savannah River Site, Georgia and South Carolina

Appendix—Data for selected wells in the vicinity of the Savannah River Site, Georgia and South Carolina

[Aquifer: UTR, Upper Three Runs; G, Gordon; MP, Millers Pond; UD, upper Dublin; LD, lower Dublin; UM, upper Midville; LM, lower Midville.
Well cluster: USGS, U.S Geological Survey; SCWRD-DNR, South Carolina Department of Natural Resources-Water Resources Division; GGS, Georgia Geologic Survey; SRS, Savannah River Site; —, not applicable. Open interval: ?, unknown]

County	Well number	Owner and well name	Well cluster	Year drilled	Latitude Longitude	Land-surface altitude (feet)	Open interval(s) below land surface (feet)		Aquifer	Water level	
							Top	Bottom		Feet above (+) or below (-) land surface	Date measured
Georgia											
Burke	28X00	USGS Midville TW-1	—	1980	32°52'32" 82°13'15"	269.00	903 1,025	923 1,045	LM	-49.07	06/04/1980
Burke	30Z017	USGS Millers Pond TW-1	USGS Millers Pond	1992	33°13'48" 81°52'44"	243.00	705	735	LM	-84.92	10/13/1992
Burke	30Z021	USGS Millers Pond TW-2	USGS Millers Pond	1992	33°13'48" 81°52'44"	243.00	595	625	LM	-84.77	05/04/1992
Burke	30Z022	USGS Millers Pond TW-4	USGS Millers Pond	1992	33°13'48" 81°52'44"	242.00	80	100	UTR	-65.11	05/04/1992
Burke	30Z023	USGS Millers Pond TW-3	USGS Millers Pond	1992	33°13'48" 81°52'44"	242.00	518	548	UM	-84.83	10/13/1992
Burke	30Z026	USGS Millers Pond TW-7	USGS Millers Pond	1992	33°13'48" 81°52'44"	242.00	445	475	LD	-84.89	10/13/1992
Burke	30Z028	USGS Millers Pond TW-5A	USGS Millers Pond	1992	33°13'48" 81°52'44"	242.00	210	250	MP	-107.00	10/16/1992
Burke	31Z011	Miller Pond	—	—	33°14'07" 81°52'13"	140.00	?	50	G	+3.00	05/21/1946
Burke	31Z033	Auner Delaigle	—	1980	33°08'02" 81°46'53"	200.00	80	325	G	-67.30	08/27/1991
Burke	31Z054	Vogtle observation well 129	—	1971	33°08'38" 81°45'46"	215.00	92	97	UTR	-61.00	09/30/1971
Burke	31Z110	GGS TR92-6B	GGS/USGS TR-92-6	1993	33°10'44" 81°47'09"	253.97	180	200	G	160.14	10/04/1994
Burke	31Z111	GGS TR92-6C	GGS/USGS TR-92-6	1994	33°10'44" 81°47'09"	252.33	610	620	LD	-95.96	04/28/1995
Burke	31Z112	GGS TR92-6D	GGS/USGS TR-92-6	1995	33°10'44" 81°47'09"	250	800	831.5	LM	-96.13	07/13/1995
Burke	32Y019	USGS Girard TW-1	USGS Girard	1992	33°03'53" 81°43'15"	254.00	49	72	UTR	-32.31	05/04/1992

Appendix—Data for selected wells in the vicinity of the Savannah River Site, Georgia and South Carolina—Continued

[Aquifer: UTR, Upper Three Runs; G, Gordon; MP, Millers Pond; UD, upper Dublin; LD, lower Dublin; UM, upper Midville; LM, lower Midville. Well cluster: USGS, U.S Geological Survey; SCWRD-DNR, South Carolina Department of Natural Resources-Water Resources Division; GGS, Georgia Geologic Survey; SRS, Savannah River Site; —, not applicable. Open interval: ?, unknown]

County	Well number	Owner and well name	Well cluster	Year drilled	Latitude Longitude	Land-surface altitude (feet)	Open interval(s) below land surface (feet)		Aquifer	Water level	
							Top	Bottom		Feet above (+) or below (-) land surface	Date measured
Burke	32Y029	USGS Girard TW-2	USGS Girard	1994	33°03'53" 81°43'15"	254.00	743	773	LD	-89.85	03/13/1995
Burke	32Y030	USGS Brighams Landing TW-1	USGS Brighams Landing	1994	33°05'48" 81°39'11"	85.00	920	970	LM	+89.97	11/03/1994
Burke	32Y031	USGS Brighams Landing TW-2	USGS Brighams Landing	1994	33°03'48" 81°39'11"	85.00	502	552	LD	+69.21	11/03/1994
Burke	32Y032	USGS Girard TW-3	USGS Girard	1994	33°03'54" 81°43'13"	255.00	1,143	1,175	LM	-74.93	03/13/1995
Burke	32Y033	USGS Brighams Landing TW-3	USGS Brighams Landing	1995	33°05'48" 81°39'11"	85.00	150	200	G	+36.00	04/18/1995
Burke	32Z004	Vogtle Obs Well 27	—	1971	33°08'36" 81°44'55"	200.00	180	190	G	-16.50	05/06/1971
Jefferson	26AA02	Huber 3	—	1971	33°15'37" 82°25'15"	420.00	170	190	LM	-12.00	03/01/1964
Jefferson	26W003	Wadley, Ga., 2	—	1964	32°51'48" 82°23'59"	235.00	203 222	213 280	UTR	-12.00	03/01/1964
Jefferson	26Z004	Wrens, Ga.	—	1950	33°12'55" 82°28'03"	423.00	117	137	UTR	-24.00	07/04/1950
Jefferson	26Z006	Stapelton, Ga.	—	1956	33°12'55" 82°28'12"	432.00	?	300	UTR	-48.40	06/17/1975
Jefferson	27X003	R.G. Scrubs	—	—	32°58'23" 82°19'52"	305.00	?	36	UTR	-26.00	08/22/1946
Richmond	28AA06	Oak Ridge Water	—	1967	33°17'26" 82°08'22"	412.00	300	340	LD	-131.0	11/12/1967
Richmond	29AA06	Pine Hill 3	—	1977	33°18'06" 82°01'09"	180.00	199	249	LD	-14.57	11/16/1978
Richmond	29AA08	Babock-Wilcox Plt	—	1967	33°18'55" 82°07'06"	412.00	442	482	LM	-150.00	08/24/1967

Appendix—Data for selected wells in the vicinity of the Savannah River Site, Georgia and South Carolina—Continued

[Aquifer: UTR, Upper Three Runs; G, Gordon; MP, Millers Pond; UD, upper Dublin; LD, lower Dublin; UM, upper Midville; LM, lower Midville.
Well cluster: USGS, U.S Geological Survey; SCWRD-DNR, South Carolina Department of Natural Resources-Water Resources Division; GGS, Georgia Geologic Survey; SRS, Savannah River Site; —, not applicable. Open interval: ?, unknown]

County	Well number	Owner and well name	Well cluster	Year drilled	Latitude Longitude	Land-surface altitude (feet)	Open interval(s) below land surface (feet)		Aquifer	Water level	
							Top	Bottom		Feet above (+) or below (-) land surface	Date measured
Richmond	29BB01	Richmond County 10	—	1966	33°25'05" 82°00'55"	148.00	55	85	LM	-14.30	09/20/1966
Richmond	29BB07	Richmond County 9	—	1958	33°25'22" 82°00'40"	140.00	90	110	LM	-13.00	12/08/1958
Richmond	29Z002	Chon, Su Kun	—	1946	33°14'11" 82°02'42"	170.00	?	30	UTR	+12.00	08/08/1946
Richmond	30AA02	Olin 1	—	1964	33°20'40" 81°56'55"	130.00	270	315	LM	-18.00	08/01/1964
Richmond	30AA03	Olin 2	—	1970	33°20'44" 81°57'03"	132.00	267	317	LM	-27.00	05/05/1971
Screven	32U016	Wyant, W.W.	—	1935	32°34'35" 81°42'55"	100.00	90	25	UTR	+15.63	06/08/1939
Screven	32W001	C. Bazemore	—	1961	32°46'29" 81°42'25"	244.00	189	210	UTR	-96.29	07/11/1963
Screven	32X040	Millhaven Plantation	—	1991	32°56'49" 81°41'06"	170.00	225	251	UTR	-24.31	08/23/1991
Screven	33W025	Louis Pfeiffer	—	—	32°50'09" 81°32'45"	73.8	—	400	G	+11.4	08/13/1963
Screven	33X051	USGS Millhaven TW-1	USGS Millhaven	1993	32°53'25" 81°35'43"	110.00	50	80	UTR	-13.49	06/21/1993
Screven	33X052	USGS Millhaven TW-2	USGS Millhaven	1993	32°53'25" 81°35'43"	110.00	155	205	UTR	-15.13	06/21/1993
Screven	33X053	USGS Millhaven TW-3	USGS Millhaven	1993	32°53'25" 81°35'43"	110.00	225	280	UTR	-14.49	06/21/1993
Screven	33X054	UGSG Millhaven TW-4	USGS Millhaven	1993	32°53'25" 81°35'43"	110.00	857	907	LD	+40.51	09/01/1993
Screven	33X055	USGS Millhaven TW-5	USGS Millhaven	1994	32°53'25" 81°35'43"	110.00	1,340	1,380	LM	+79.10	09/22/1994

Appendix—Data for selected wells in the vicinity of the Savannah River Site, Georgia and South Carolina—Continued

[Aquifer: UTR, Upper Three Runs; G, Gordon; MP, Millers Pond; UD, upper Dublin; LD, lower Dublin; UM, upper Midville; LM, lower Midville. Well cluster: USGS, U.S Geological Survey; SCWRD-DNR, South Carolina Department of Natural Resources-Water Resources Division; GGS, Georgia Geologic Survey; SRS, Savannah River Site; —, not applicable. Open interval: ?, unknown]

County	Well number	Owner and well name	Well cluster	Year drilled	Latitude Longitude	Land-surface altitude (feet)	Open interval(s) below land surface (feet)		Aquifer	Water level	
							Top	Bottom		Feet above (+) or below (-) land surface	Date measured
					South Carolina						
Aiken	AK-183	NR Beech Island	—	—	33°25'50" 81°53'15"	254.00	290	320	LM	-93.49	03/12/1952
Aiken	AK-290	New Ellenton	—	1954	33°25'10" 81°41'01"	420.00	392	412	LD	-161.60	06/17/1954
Aiken	AK-361	Rawls Corp.	—	—	33°39'45" 81°28'50"	380.00	?	191	LD	-28.96	01/01/1960
Aiken	AK-440	Burnettown	—	1969	33°30'19" 81°50'52"	305.00	160	170	LM	-103.00	05/22/1969
Aiken	AK-468	S-411	—	—	33°13'20" 81°44'05"	156.00	265	270	UD	+14.50	09/18/1952
Aiken	AK-477	Burnettown	—	1977	33°30'14" 81°50'45"	310.00	173	213	LM	-103.00	09/23/1977
Aiken	AK-532	SRS 221F	—	—	33°17'16" 81°40'09"	315.00	545	565	LD	-129.00	05/14/1951
Aiken	AK-582	SRS P3A	—	—	33°17'05" 81°39'00"	277.70	761	772	LM	-96.71	11/17/1972
Aiken	AK-600	SRS P3B	—	—	33°17'06" 81°39'00"	277.60	538	548	LD	-95.40	08/21/1972
Aiken	AK-601	SRS P3C	—	—	33°17'06" 81°39'00"	278.30	400	410	UD	-107.00	08/01/1962
Aiken	AK-777	Breezy Hill	—	1962	33°33'14" 81°49'33"	250.00	40	45	LM	-20.00	03/01/1962
Aiken	AK-788	SRS HC 1A	—	1964	33°17'07" 81°38'35"	300.80	206	211	G	-33.72	03/10/1987
Aiken	AK-817	SCDNR C-2	SCDNR WRD C-2	1987	33°26'16" 81°46'12"	418.80	520	530	LM	-184.82	07/30/1987
Aiken	AK-818	SCDNR C-2	SCDNR WRD C-2	1987	33°26'15" 81°46'12"	418.20	410	420	UM	-182.40	07/30/1987

Appendix—Data for selected wells in the vicinity of the Savannah River Site, Georgia and South Carolina—Continued

[Aquifer: UTR, Upper Three Runs; G, Gordon; MP, Millers Pond; UD, upper Dublin; LD, lower Dublin; UM, upper Midville; LM, lower Midville. Well cluster: USGS, U.S Geological Survey; SCWRD-DNR, South Carolina Department of Natural Resources-Water Resources Division; GGS, Georgia Geologic Survey; SRS, Savannah River Site; —, not applicable. Open interval: ?, unknown]

County	Well number	Owner and well name	Well cluster	Year drilled	Latitude Longitude	Land-surface altitude (feet)	Open interval(s) below land surface (feet)		Aquifer	Water level	
							Top	Bottom		Feet above (+) or below (-) land surface	Date measured
Aiken	AK-824	SCDNR C-2	SCDNR WRD C-2	1988	33°26'15" 81°46'12"	418.70	350	360	LD	-178.87	10/25/1988
Aiken	AK-825	SCDNR C-2	SCDNR WRD C-2	1988	33°26'15" 81°46'12"	420.00	216	226	UD	-158.35	03/16/1988
Aiken	AK-863	SRS P-26TD	SRS P-26	1986	33°12'52" 81°45'32"	151.00	240	250	UD	- 2.44	04/01/1987
Aiken	AK-864	SRS P-28TB	SRS P-26	1986	33°17'29" 81°40'29"	282.20	618	639	UM	-112.50	10/02/1986
Aiken	AK-875	SRS P-26A	SRS P-26	1986	33°12'52" 81°45'32"	151.20	120	130	G	- 30.54	04/01/1987
Aiken	AK-898	SRS P-28TD	—	1986	33°17'30" 81°40'28"	281.20	494	505	LD	-10.50	04/01/1987
Aiken	AK-2082	SRS FTF19	—	—	33°16'56" 81°40'40"	285.30	57	87	UTR	-7.40	01/22/1985
Aiken	AK-2134	SRS Z8	—	—	33°16'46" 81°40'47"	277.50	63	64	UTR	-60.60	08/24/19
Aiken	AK-2263	SRS Z20A	—	—	33°15'39" 81°41'44"	241.00	136	137	G	-93.38	5/01/1980
Aiken	AK-2354	SRS XSB4	—	—	33°12'37" 81°45'37"	130.00	38	58	G	-50.21	5/01/1980
Allendale	AL-1	Town of Fairfax	—	1952	32°57'20" 81°14'20"	140.00	750	750	UD	+35.40	02/02/1952
Allendale	AL-24	Town of Allendale	—	1967	33°00'16" 81°18'22"	182.00	686	746	UD	-25.50	10/04/1967
Allendale	AL-33	Oswald, Ben	—	1978	33°02'14" 81°17'15"	180.00	?	777	LD	-28.17	09/02/1982
Barnwell	BW-14	Town of Barnwell	—	1971	33°14'39" 81°21'50"	225.00	201	222	G	-33.00	02/09/1971

Appendix—Data for selected wells in the vicinity of the Savannah River Site, Georgia and South Carolina—Continued

[Aquifer: UTR, Upper Three Runs; G, Gordon; MP, Millers Pond; UD, upper Dublin; LD, lower Dublin; UM, upper Midville; LM, lower Midville.
Well cluster: USGS, U.S Geological Survey; SCWRD-DNR, South Carolina Department of Natural Resources-Water Resources Division; GGS, Georgia Geologic Survey; SRS, Savannah River Site; —, not applicable. Open interval: ?, unknown]

County	Well number	Owner and well name	Well cluster	Year drilled	Latitude Longitude	Land-surface altitude (feet)	Open interval(s) below land surface (feet)		Aquifer	Water level	
							Top	Bottom		Feet above (+) or below (-) land surface	Date measured
Barnwell	BW-44	Town of Williston	—	1952	33°24'08" 81°24'53"	352.00	589	599	UM	-110.00	09/10/1952
Barnwell	BW-45	Town of Barnwell	—	—	33°14'26" 81°22'56"	224.00	216	246	G	-40.50	10/07/1952
Barnwell	BW-67	Town of Barnwell	—	1971	33°14'36" 81°21'17"	215.00	318	318	G	-46.25	03/15/1971
Barnwell	BW-265	SRS PW-27R	—	—	33°16'26" 81°34'59"	304.00	282	288	UD	-106.49	12/30/1953
Barnwell	BW-272	SRS PW-44H	—	—	33°17'07" 81°38'20"	303.00	475	486	DM	-110.00	03/18/1952
Barnwell	BW-273	SRS PW-45H	—	—	33°17'07" 81°38'20"	297.00	555	570	DM	-112.50	03/24/195
Barnwell	BW-274	SRS PW-48H	—	—	33°17'13" 81°38'20"	294.00	496	501	LM	-109.30	06/28/1955
Barnwell	BW-316	SRS P-23TA	SRS P-23	1985	33°10'57" 81°40'43"	180.60	800	821	LM	-14.98	04/15/1985
Barnwell	BW-349	SCDNR C-6	SCDNR WRD C-6	—	33°10'44" 81°18'51"	208.70	1,030	1,040	LM	-17.02	07/30/1987
Barnwell	BW-350	SCDNR C-6	SCDNR WRD C-6	1987	33°10'44" 81°18'51"	207.30	155	165	UTR	-32.64	09/24/1987
Barnwell	BW-352	SCDNR C-6	SCDNR WRD C-6	1988	33°10'44" 81°18'51"	205.00	278	288	G	-43.95	05/20/1988
Barnwell	BW-354	SCDNR C-6	SCDNR WRD C-6	1988	33°10'44" 81°18'51"	205.00	396	406	G	-44.25	05/20/1988
Barnwell	BW-375	SRS P-20TD	SRS P-20	1985	33°16'30" 81°34'25"	287.40	435	445	UD	-101.65	08/15/1985
Barnwell	BW-382	SRS P-17TB	SRS P-17	1985	33°20'40" 81°30'01"	332.30	689	700	UM	-116.31	04/01/1987

Appendix—Data for selected wells in the vicinity of the Savannah River Site, Georgia and South Carolina—Continued

[Aquifer: UTR, Upper Three Runs; G, Gordon; MP, Millers Pond; UD, upper Dublin; LD, lower Dublin; UM, upper Midville; LM, lower Midville. Well cluster: USGS, U.S Geological Survey; SCWRD-DNR, South Carolina Department of Natural Resources-Water Resources Division; GGS, Georgia Geologic Survey; SRS, Savannah River Site; —, not applicable. Open interval: ?, unknown]

County	Well number	Owner and well name	Well cluster	Year drilled	Latitude Longitude	Land-surface altitude (feet)	Open interval(s) below land surface (feet)		Aquifer	Water level	
							Top	Bottom		Feet above (+) or below (-) land surface	Date measured
Barnwell	BW-383	SRS P-22TB	SRS P-22	1985	33°11'28" 81°30'47"	215.20	769	780	UM	-26.60	04/01/1987
Barnwell	BW-395	SRS P-19B	SRS P-19	1985	33°14'46" 81°36'58"	297.7	220	240	G	-36.00	03/22/1985
Barnwell	BW-403	SRS P-21A	SRS P-21	1985	33°08'48" 81°36'26"	207.30	351	361	MP	-74.25	06/18/1985
Barnwell	BW-407	SRS P-22A	SRS P-22	1985	33°11'28" 81°30'48"	215.70	349	360	MP	-64.00	07/23/1985
Barnwell	BW-409	SRS P-22C	SRS P-22	1985	33°11'28" 81°30'47"	215.20	125	136	UTR	-47.68	07/17/1985
Barnwell	BW-414	SRS P-23A	SRS P-23	1985	33°10'57" 81°40'43"	180.00	210	220	MP	-37.43	09/10/1985
Barnwell	BW-430	SRS P-27TA	SRS P-27	1985	33°17'09" 81°38'05"	273.60	807	825	LM	-100.60	10/07/1986