Stream Base Flow and Potentiometric Surface of the Upper Floridan Aquifer in South-Central and Southwestern Georgia, November 2008

Scientific Investigations Report 2010–5095

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

Cover. Background: Spring Creek near Reynoldsville, Seminole County, Georgia. Photo by Jonathan J. Graham, USGS. Insets: selected southwestern Georgia wells. Photos by Lynn J. Torak, USGS.

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Conversion Factors and Datums

Multiply	By	To obtain
	Length	
inch	2.54	centimeter (cm)
inch	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
mile, nautical (nmi)	1.852	kilometer (km)
yard (yd)	0.9144	meter (m)
	Volume per unit time (includes flow)	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
gallon per minute (gal/min)	0.06309	liter per second

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

$$°F = (1.8 \times °C) + 32$$

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

$$°C = (°F - 32) / 1.8$$

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

Horizontal coordinate information is referenced to North American Datum of 1983 (NAD 83).

Altitude, as used in this report, refers to distance above the vertical datum.

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Abstract

An investigation to document groundwater levels and stream base flow in the lower Chattahoochee–Flint and western and central Aucilla–Suwanee–Ochlockonee River basins during low-flow conditions was conducted by the U.S. Geological Survey in November 2008. During most of 2008, moderate to severe drought conditions prevailed throughout southwestern Georgia. Groundwater levels were below median daily levels throughout most of 2008; however, in some wells, groundwater levels rose to median daily levels by November. Discharge in most of the streams in the study area also had risen to median levels by November.

The potentiometric surface of the Upper Floridan aquifer was constructed from water-level measurements collected in 21 counties from 376 wells during November 1–10, 2008. The potentiometric surface indicates that groundwater in the study area generally flows to the south and toward streams except in reaches discharging to the Upper Floridan aquifer. The degree of connection between the Upper Floridan aquifer and streams decreases east of the Flint River where the overburden is thicker. Decreased connectivity between ground and surface water is evident from the stream-stage altitudes measured in November 2008 east of the Flint River, which are not similar to water-level altitudes measured in the Upper Floridan aquifer.

Stream-stage measurements were collected at 111 sites—26 U.S. Geological Survey streamgaging sites and 85 additional synoptic sites without gages. Streamflow measurements were made at 87 of the sites during November 2008 and were used to estimate base flow. The measurements indicate that stream reaches range from losing up to 10 cubic feet per second to gaining up to 4,559 cubic feet per second; five stream reaches were determined to be losing stream reaches. Of the 11 stream reaches in the Alapaha River subbasin, 7 were dry when measured in November 2008.

Introduction

Severe drought and increased groundwater pumping to support agriculture during 2007–2008 in south-central and southwestern Georgia resulted in record-low groundwater levels and streamflow in the lower Chattahoochee–Flint (CF) and western and central parts of the Aucilla–Suwanee–Ochlockonee River (ASO) basins. Documentation of these historic hydrologic conditions through measurement of groundwater levels, stream stage, and streamflow provides essential data to help evaluate the effects of climate and groundwater pumping on water resources and aquatic biota in the area.

Because groundwater is the major source of water in the basins and the potential exists for pumping-induced streamflow reduction that could affect downstream users, a quantitative understanding of stream-aquifer relations is essential to effectively manage water resources in the lower CF and ASO River basins. The U.S. Geological Survey (USGS) conducted an investigation to document groundwater levels and stream base flow in the lower CF and ASO River basins during low-flow conditions in November 2008. These data may be used to manage the water supply, protect water quality and aquatic habitats, inform recreational users (U.S. Geological Survey, 2006), and provide a basis for accurate calibration of groundwater-flow models to simulate water-management scenarios for the region.

Purpose and Scope

This report presents groundwater-level, streamflow, and stream-stage data collected by the USGS, in November 2008, within a 21-county area including the lower CF and western and central ASO River basins in Georgia (fig. 1). During November 3–6, 2008, stream-stage measurements were made at 111 sites and streamflow measurements were made at 87 of the 111 sites. The other 24 sites had no flow. Groundwater-level measurements were made in 376 wells during November 1–10, 2008. Data and analyses presented in the report include a potentiometric-surface map of the Upper Floridan aquifer based on field measurements made in November 2008, and a groundwater-seepage map indicating reaches where streams gained or lost water or were dry as a result of surface-water interaction with the Upper Floridan aquifer during November 2008.

Description of the Study Area

The study area is located in the Coastal Plain Physiographic Province in southwestern Georgia (fig. 1). The study area includes all or parts of 21 counties in the lower CF River basin, and the western and central parts of the ASO River basin. The study area contains all or parts of seven Hydrologic Unit Code (HUC) subbasins (Seaber and others, 1987; Jones and Torak, 2006) in the lower CF River basin (HUCs beginning with 0313) and all or parts of seven HUC subbasins in the northern ASO River basin (HUCs beginning with 0311 and 0312). Although not in the study area, a few groundwater levels were measured in wells in HUC 03070104 subbasin of the Ocmulgee River basin to better define the potentiometric surface of the Upper Floridan aquifer (fig. 1; table 1). The study area extends through the Gulf Trough, a northeast-southwest trending geologic feature composed of fine-grained, dense, low-permeability limestone overlain by a thick sequence of Oligocene to Miocene sediments (Zimmerman, 1977). The position of the low-permeability sediments of the Gulf Trough next to the high-permeability limestone presents a barrier to groundwater flow southeastward in the Upper Floridan aquifer (Torak, and others, 2010; fig. 1). The physiography, hydrogeology, and climate of the area are described in detail in Torak and Painter (2006). A brief description of each is summarized in the following sections.

Table 1. All or part of the subbasins in the study area of south-central and southwestern Georgia.

Hydrologic Unit Code	Subbasin name
Ocmulgee River basin	
03070104	Lower Ocmulgee River
Aucilla River basin	
03110103	Aucilla River
03110202	Alapaha River
03110203	Withlacoochee River
03110204	Little River
Ochlockonee River basin	
03120001	Apalachee Bay–St. Marks
03120002	Upper Ochlockonee River
03120003	Lower Ochlockonee River
Chattahoochee–Flint River basin	
03130004	Lower Chattahoochee River
03130006	Middle Flint River
03130007	Muckalee–Kinchafoonee Creeks
03130008	Lower Flint River
03130009	Ichawaynochaway Creek
03130010	Spring Creek
03130011	Upper Apalachicola River

Physiography

In the study area, the Coastal Plain Physiographic Province is a low-lying karst region that includes the Dougherty Plain and Tifton Upland Districts, which are separated by the Solution Escarpment (fig. 1; Clarke and Zisa, 1976; Torak and Painter, 2006). The Dougherty Plain is flat to gently rolling and characterized by karst topography including internal drainage and limestone dissolution features. Numerous sinkholes commonly form in the area and collect runoff, many providing direct recharge to the Upper Floridan aquifer (Torak and Painter, 2006). The Solution Escarpment separates the Dougherty Plain and Tifton Upland Districts and provides as much as 125 feet (ft) of relief forming a topographic and surface-water divide between the Flint and Ochlockonee River basins (Torak and others, 2010). The Tifton Upland District is characterized by high hills and dendritic drainage, resulting in relief up to 200 ft (Torak and others, 1996). The Gulf Trough, which bisects the Tifton Uplands, extends across most of the Coastal Plain of Georgia and consists of fine-grained, dense, low-permeability limestone overlain by a thick sequence of Oligocene to Miocene sediments (Zimmerman, 1977).

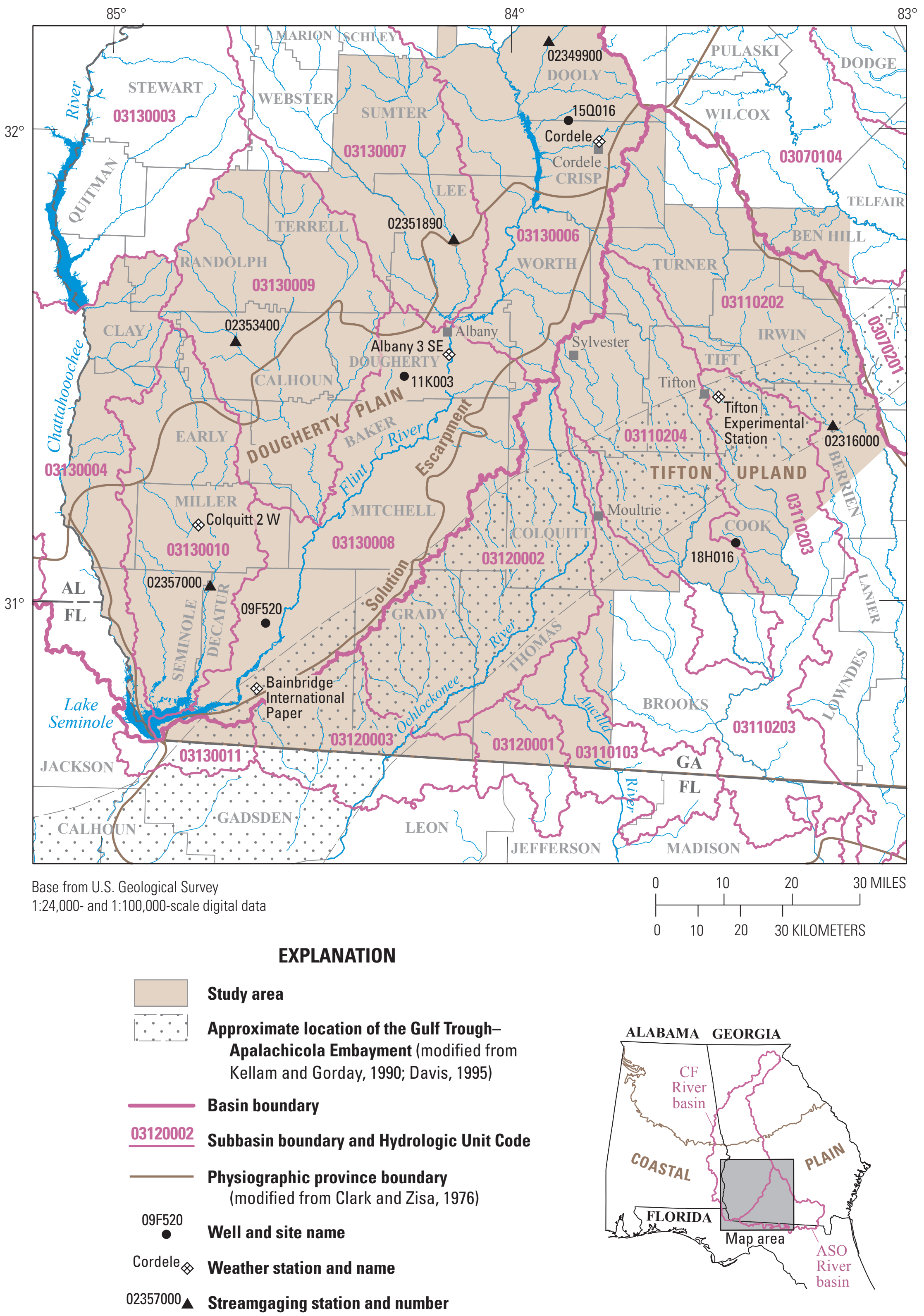


Figure 1. Location of the study area and selected wells, weather stations, and streamgaging stations in the lower Chattahoochee–Flint (CF) River basin and in western and central parts of the Aucilla–Suwannee–Ochlockonee (ASO) River basin, Georgia.

Hydrogeologic setting

The flow system and stream–aquifer connection in the study area are controlled by geology, hydrologic properties of the Upper Floridan aquifer and its confining units, precipitation, and pumping. Geologic units in the Flint River basin northwest and northeast of Lake Seminole and in the ASO River basin and hydrologic units in the study area are presented in figure 2.

Geologic units consist of Coastal Plain sediments of Eocene to Holocene age, including cross-bedded clayey sand, sand, gravel, clay, limestone, dolomite, and limestone residuum. Geologic units in the Flint River basin in ascending order are the Lisbon Formation, Clinchfield Sand, Ocala and Suwannee Limestones, undifferentiated overburden (residuum), and terrace and undifferentiated (surficial) deposits (Torak and Painter, 2006; fig. 2). Geologic units in the ASO River basin in ascending order are the Tallahatta Formation, Lisbon Formation, Ocala and Marianna Limestones, Byram Formation, Suwannee Limestone, Hawthorn Group, and terrace and undifferentiated (surficial) deposits (Torak and others, 2010; fig. 2).

Hydrologic units in descending order are the surficial aquifer system, the upper semiconfining unit, the Upper Floridan aquifer, and the lower confining unit (Torak and Painter, 2006; Torak and others, 2010; fig. 2). Weathering and dissolution of limestone in the Upper Floridan aquifer have created secondary permeability and interconnections with surface water. Direct recharge to or discharge from the aquifer occurs through karst or other erosional features. Many major streams in the area have eroded through the overburden and are in direct contact with the aquifer. Indirect recharge occurs by vertical leakage through the upper semiconfining unit or the surficial aquifer system. Groundwater discharges from the Upper Floridan aquifer where overlying residuum is thin or absent and where the groundwater level (hydraulic head) is higher than the stream or lake stage (Torak and Painter, 2006).

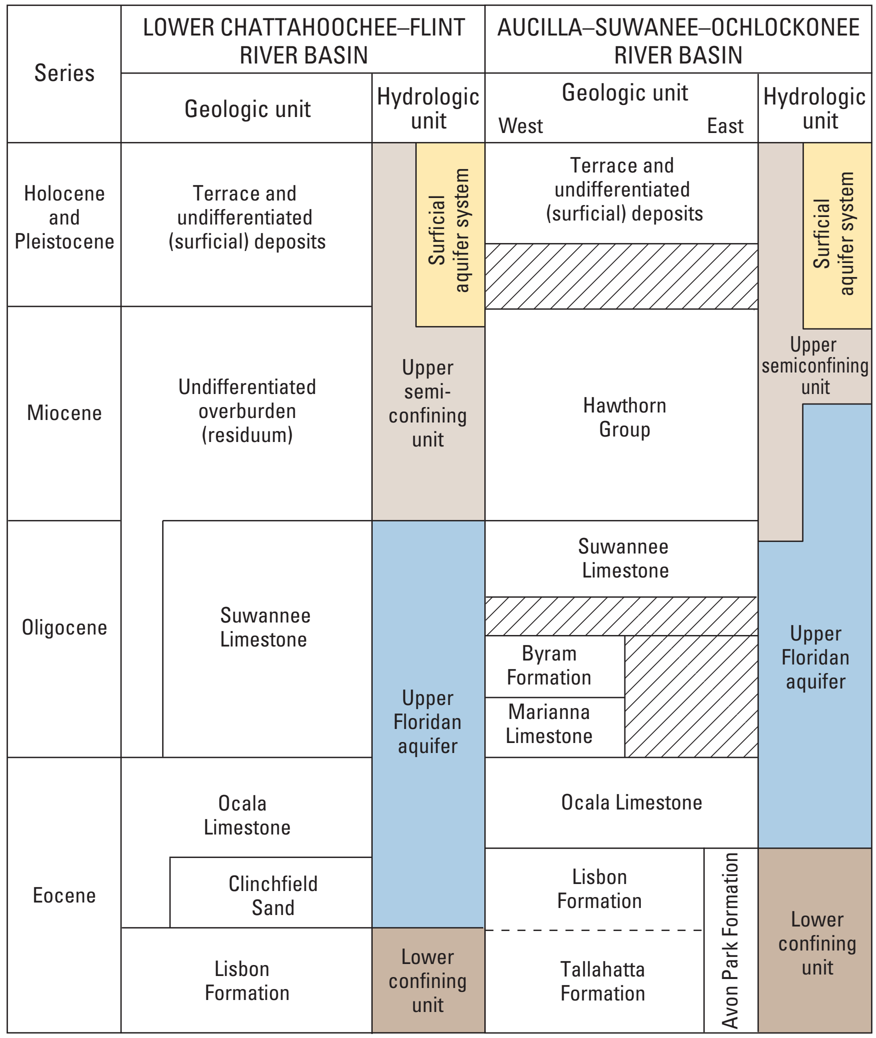


Figure 2. Geologic and hydrologic units of the Upper Floridan aquifer and hydraulically connected sediments in the lower Chattahoochee–Flint River basin and the Aucilla–Suwanee–Ochlockonee River basin (modified from Miller, 1986; Rupert, 1990; Torak and Painter, 2006).

Climate

The study area is characterized by a humid subtropical climate, with temperatures and precipitation that vary seasonally and areally across the study area (fig. 1). Based on period-of-record (1971–2000) monthly normal temperature and precipitation, temperatures generally vary between

- 35.1 (January) and 92.5 (July) degrees Fahrenheit (ºF) at National Weather Service (NWS) station Albany 3 SE,
- 39.2 ºF (January) and 92.0 ºF (July) at NWS station Colquitt 2 W,
- 35.8 ºF (January) and 93.3 ºF (July) at NWS station Cordele, and
- 38.2 ºF (January) and 90.3 ºF (July) at the NWS Tifton Experimental Station (EXP STA).

Annual precipitation at these same weather stations averages 53.4, 53.2, 46.2, and 47.0 inches, respectively (table 2; National Oceanic and Atmospheric Administration, 2002).

Table 2. Period of record (1971–2000) monthly maximum, mean, and minimum values for temperature and precipitation at selected climatological stations in southwestern Georgia (National Oceanic and Atmospheric Administration, 2009).

Station name (fig. 1)	Statistic	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	Annual
						Temperature (degrees Fahrenheit)								
Albany 3 SE	Maximum	59.9	64.4	71.8	78.3	85.2	90.4	92.5	91.9	88.2	80.1	71.1	62.9	78.1
	Mean	47.5	51.1	58.2	64.1	72.2	78.6	81.4	80.9	76.7	66.3	57.6	50.3	65.4
	Minimum	35.1	37.8	44.6	49.9	59.1	66.7	70.2	69.9	65.1	52.5	44.0	37.7	52.7
						Precipitation (inches)								
		6.12	4.78	5.71	3.54	3.86	4.88	6.32	4.38	3.77	2.46	3.78	3.80	53.4
						Temperature (degrees Fahrenheit)								
Colquitt 2 W	Maximum	61.9	65.4	73.1	79.0	85.6	90.4	92.0	91.5	88.0	80.5	71.6	64.1	78.6
	Mean	50.6	53.5	60.7	65.8	73.3	79.2	81.3	80.8	76.9	67.5	59.2	52.8	66.8
	Minimum	39.2	41.6	48.3	52.5	60.9	67.9	70.6	70.1	65.7	54.5	46.7	41.4	55.0
						Precipitation (inches)								
		6.18	4.68	6.12	3.78	3.50	4.86	5.43	4.58	4.00	2.27	3.68	4.11	53.2
						Temperature (degrees Fahrenheit)								
Cordele	Maximum	57.9	62.4	70.1	77.9	85.3	91.1	93.3	92.1	87.3	78.3	69.0	60.5	77.1
	Mean	46.9	50.6	57.8	65.2	73.2	79.7	82.3	81.2	76.5	65.8	57.1	49.5	65.5
	Minimum	35.8	38.8	45.4	52.5	61.0	68.3	71.2	70.3	65.7	53.3	45.1	38.4	53.8
						Precipitation (inches)								
		5.11	4.40	4.98	3.27	3.16	4.15	4.64	3.47	3.69	2.07	3.41	3.81	46.2
						Temperature (degrees Fahrenheit)								
Tifton Experimental Station	Maximum	58.7	62.4	69.1	75.4	82.5	87.9	90.3	89.9	86.4	78.3	69.5	61.4	76.0
	Mean	48.5	51.4	58.1	64.1	71.9	78.0	80.6	80.1	76.2	66.6	58.3	50.7	65.4
	Minimum	38.2	40.3	47.1	52.8	61.2	68.1	70.9	70.2	65.9	54.8	47.0	40.0	54.7
						Precipitation (inches)								
		5.31	4.33	5.03	3.48	3.19	4.11	4.54	4.09	3.47	2.58	3.18	3.68	47.0

Previous Investigations

Since 1996, the USGS has conducted numerous investigations regarding the hydrogeology of the Apalachicola–Chattahoochee–Flint (ACF) and ASO River basins. Torak and McDowell (1996) updated the geohydrology of parts of the lower ACF River basin. Mosner (2002) described stream-aquifer relations and groundwater-level conditions in the lower ACF River basin during the drought years of 1999 and 2000 and computed aquifer contributions to streamflow for specific reaches. Jones and Torak (2004) described the geohydrology of the area surrounding Lake Seminole in southwestern Georgia and simulated the effects of impoundment on groundwater flow in the Upper Floridan aquifer. Torak and others (2006) cited physical and hydrochemical evidence of hydraulic connection between surface and groundwater beneath and around Lake Seminole and Jim Woodruff Lock and Dam and documented the complex exchange of surface and groundwater between the lake, streams, and aquifer. Torak and Painter (2006) described the geohydrology of the lower ACF basin in southwestern Georgia, northwestern Florida, and southeastern Alabama. Jones and Torak (2006) simulated hydrologic conditions and variations in the stream-aquifer flow system through a drought-period irrigation season. Torak and others (2010) investigated the geohydrology of the ASO basin in southwest Georgia and northern Florida. Torak (2009) reported that groundwater levels in the Upper Floridan aquifer throughout the ASO basin are affected by variations in climate, groundwater pumping, and withdrawal amounts. Williams (2009) described the insights gained by using flowmeter logging to identify permeable zones within the Suwannee, Marianna, and Ocala Limestones in south-central Georgia.

Several potentiometric-surface maps of the Upper Floridan aquifer in the study area and adjacent areas have been published. Maps include a potentiometric-surface map of Georgia and adjacent parts of Alabama, Florida, and South Carolina for May–June 1990 (Peck, 1991); a potentiometric-surface map for the same area for May 1998 (Peck and others, 1999); and potentiometric-surface maps of the Upper Floridan aquifer in the lower ACF basin for October 1999 and August 2000 (Mosner, 2002).

Well- and Stream-Numbering Systems

In this report, wells are identified by a numbering system based on USGS topographic maps. In Georgia, each 7.5-minute topographic quadrangle map has been given a number and letter designation beginning at the southwestern corner of the State. Numbers increase eastward through 39, and letters increase alphabetically northward through “Z” and then become double-letter designations “AA” through “PP.” The letters “I,” “O,” “II,” and “OO” are not used. Wells inventoried in each quadrangle are numbered sequentially beginning with “001.” Thus, the third well inventoried in the Chattahoochee quadrangle (map 06D) is designated 06D003. Surface-water stations are identified by a numbering system used for all USGS reports and publications since October 1, 1950. The station numbers are in downstream order along the main channel. All stations on a tributary entering upstream from each main channel are listed prior to the station on the main channel. Each surface-water station is assigned a unique 8 - to 14-digit number. Each station number, such as 02351890, begins with the 2-digit identifier “02,” which designates it as being a surface-water station, followed by the downstream-order number, “351890,” which can range from 6 to 12 digits.

Methods

Water-level measurements were made in wells open to the Upper Floridan aquifer. USGS personnel used steel or electric tapes to collect the water-level measurements to the nearest 0.01 ft. A pre-established measuring point was subtracted from the water level to obtain depth to water below land surface. The depth below land surface was then subtracted from the land-surface altitude to calculate the water-surface altitude. Most land-surface altitudes were estimated using topographic maps. As a result, calculated values for water-surface altitude are accurate to plus or minus (±) 10 ft. Water-level altitudes were contoured to produce a potentiometric surface for the Upper Floridan aquifer.

Stream-stage and flow measurements were made using traditional USGS methods (Rantz and others, 1982). Streamflow loss or gain was calculated by subtracting an upstream flow measurement from a downstream flow measurement. The difference is the amount of groundwater discharged to the stream along the stream reach. Estimated streamflow data typically are accurate to within 5 to 10 percent of actual flows (Hirsch and Costa, 2004).

Hydrologic and Climatic Conditions during November 2008

Although a moderate to severe drought persisted across southwestern Georgia during much of 2008, by November 2008 precipitation was in the normal range and only the northern parts of the study area remained abnormally dry (fig. 3; Drought Mitigation Center, 2009). From January through most of February 2008, the study area was in an extreme to moderate drought. Drought conditions receded northward, out of the study area at the end of February until June 2008, when the area was once again experiencing moderate to severe drought conditions. Most of the study area was abnormally dry from the end of August to the end of October 2008, when normal conditions returned (fig. 3; Drought Mitigation Center, 2009).

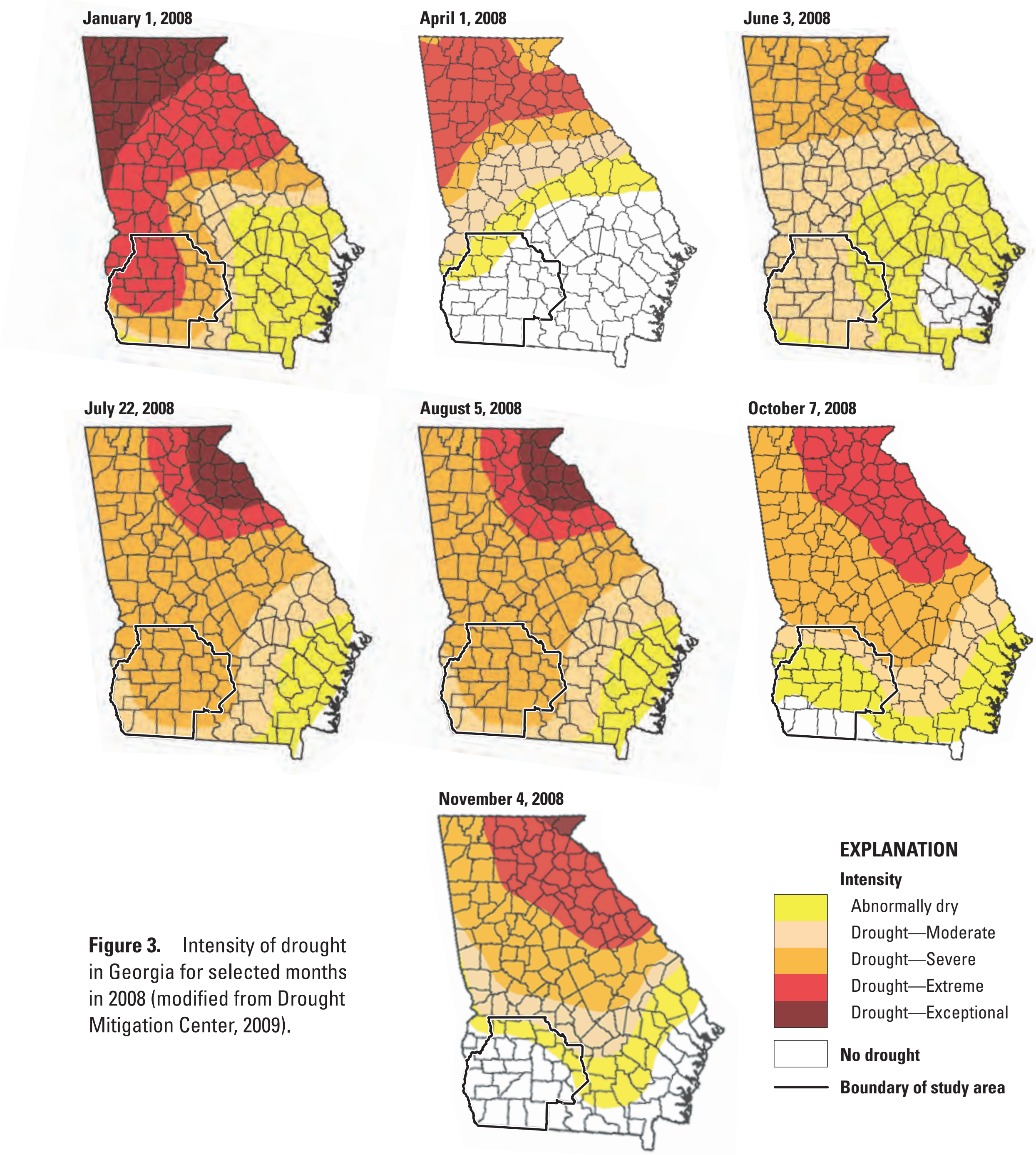


Figure 3. Intensity of drought in Georgia for selected months in 2008 (modified from Drought Mitigation Center, 2009).

Data that represent cumulative departures of rainfall from normal rainfall can be used to evaluate trends in rainfall and define the long-term rainfall surplus or deficit during a specific period. Graphs are derived by adding successive daily values for departures from normal daily rainfall. A positive slope indicates above-normal rainfall, and a negative slope indicates below-normal rainfall. Graphs of cumulative departures from normal rainfall for 2003–2008 at three National Oceanic and Atmospheric Administraion (NOAA) weather stations in the area—Albany 3 SE (GA090140), Bainbridge International Paper (GA090586), and Tifton Experimental Station (GA098703) (fig. 1)—show long-term rainfall declines since the beginning of 2006 (fig. 4). By summer 2008, the deficit reached a maximum, with departures of 19 inches in July at Albany, 37 inches in August at Bainbridge, and 7.7 inches in June at Tifton. Rainfall in August was above normal, which decreased the cumulative deficit at the three sites. By November 2008, the cumulative deficit was 10 inches at Albany, 27 inches at Bainbridge, and 2.2 inches at Tifton.

Daily mean groundwater levels throughout most of the study area were below long-term median daily levels for most of 2008, as shown on hydrographs for wells 09F520 at Bainbridge in Decatur County, 11K003 south of Albany in Dougherty County, and 18H016 at Adel in Cook County (fig. 5). At well 15Q016 near Cordele in Crisp County, groundwater levels were near long-term median daily levels until November 2008 when levels rose slightly above the long-term median daily levels. Daily mean groundwater levels rose to or above long-term median daily levels by November at many locations in the area. The water level in well 09F520 in Bainbridge, for example, rose to the long-term median daily levels in September, remained near the median levels until December, and then rose above the long-term median daily levels. Conversely, the water level in well 18H016 at Adel has been declining since 1967 and has been below the long-term median daily levels since the late 1990s.

Discharge in most of the streams in the area was within the normal range by November 2008. Discharge was normal from December 2007 until about May 2008; then, discharge in many streams in the area dropped below the 10th percentile during summer 2008. The 7-day average stream discharge for 2007 and 2008 compared to historical data for each streamgaging site is shown in the hydrographs in figure 6. Data are categorized in ranges from “much above normal” (90th percentile) to much below normal (10th percentile; Knaak and Joiner, 2008). Discharge in most of the streams was in the normal range by fall 2008, including at streamgages 02351890 on Muckalee Creek near Leesburg, 02353400 on Pachitla Creek near Edison, 02316000 on the Alapaha River near Alapaha, and 02357000 on Spring Creek near Iron City. At a few locations, such as streamgage 02349900 on Turkey Creek at Byromville in the northern part of the study area, record-low discharge measurements were recorded during 2007 and 2008, and discharge was below normal when measurements were made in November 2008.

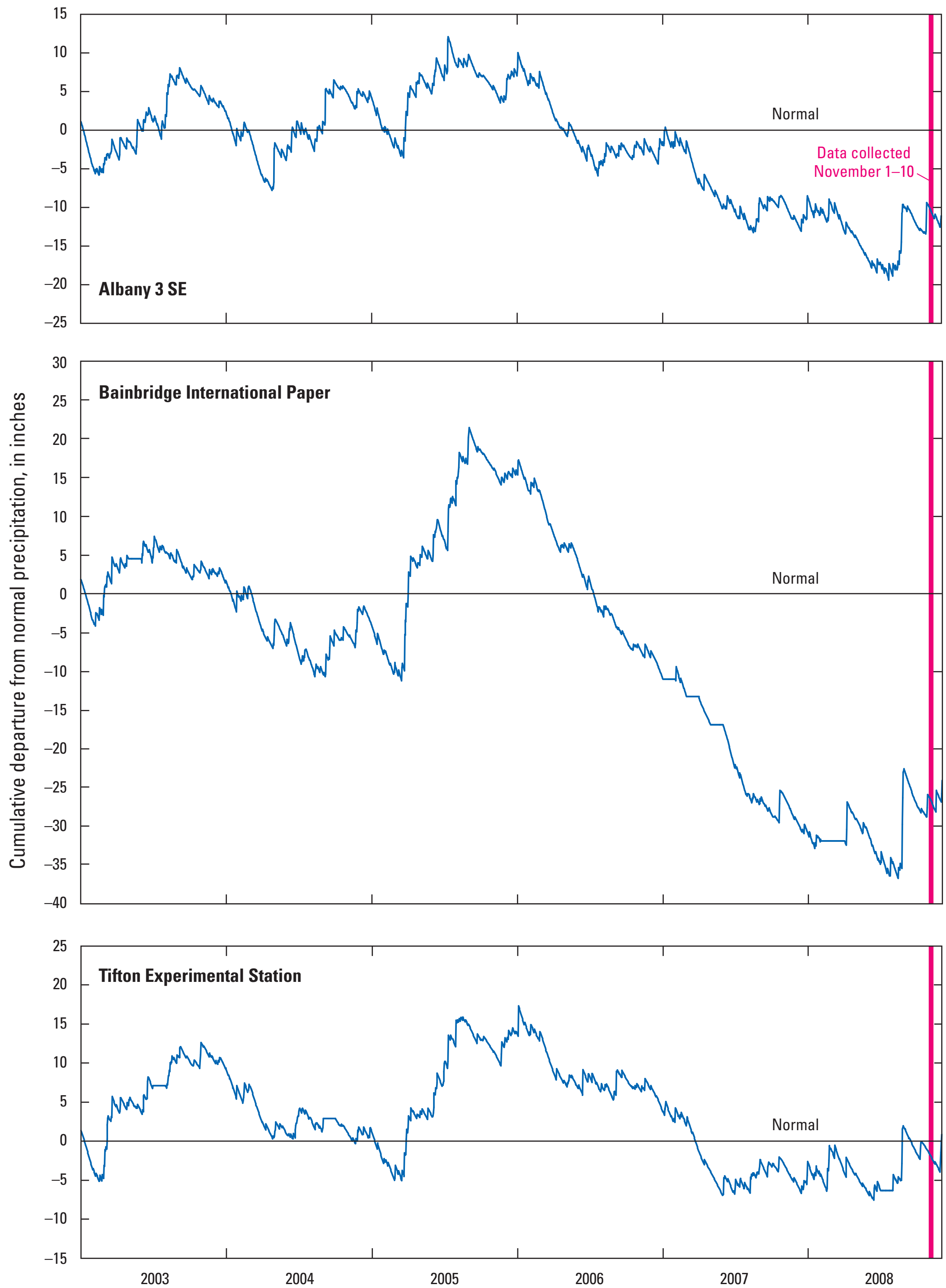


Figure 4. Cumulative departure from normal (1971–2001) precipitation at National Oceanic and Atmospheric Administration Georgia weather stations Albany 3 SE (GA090140), Bainbridge International Paper (GA090586), and Tifton Experimental Station (GA098703), 2003–2008. (See figure 1 for locations.)

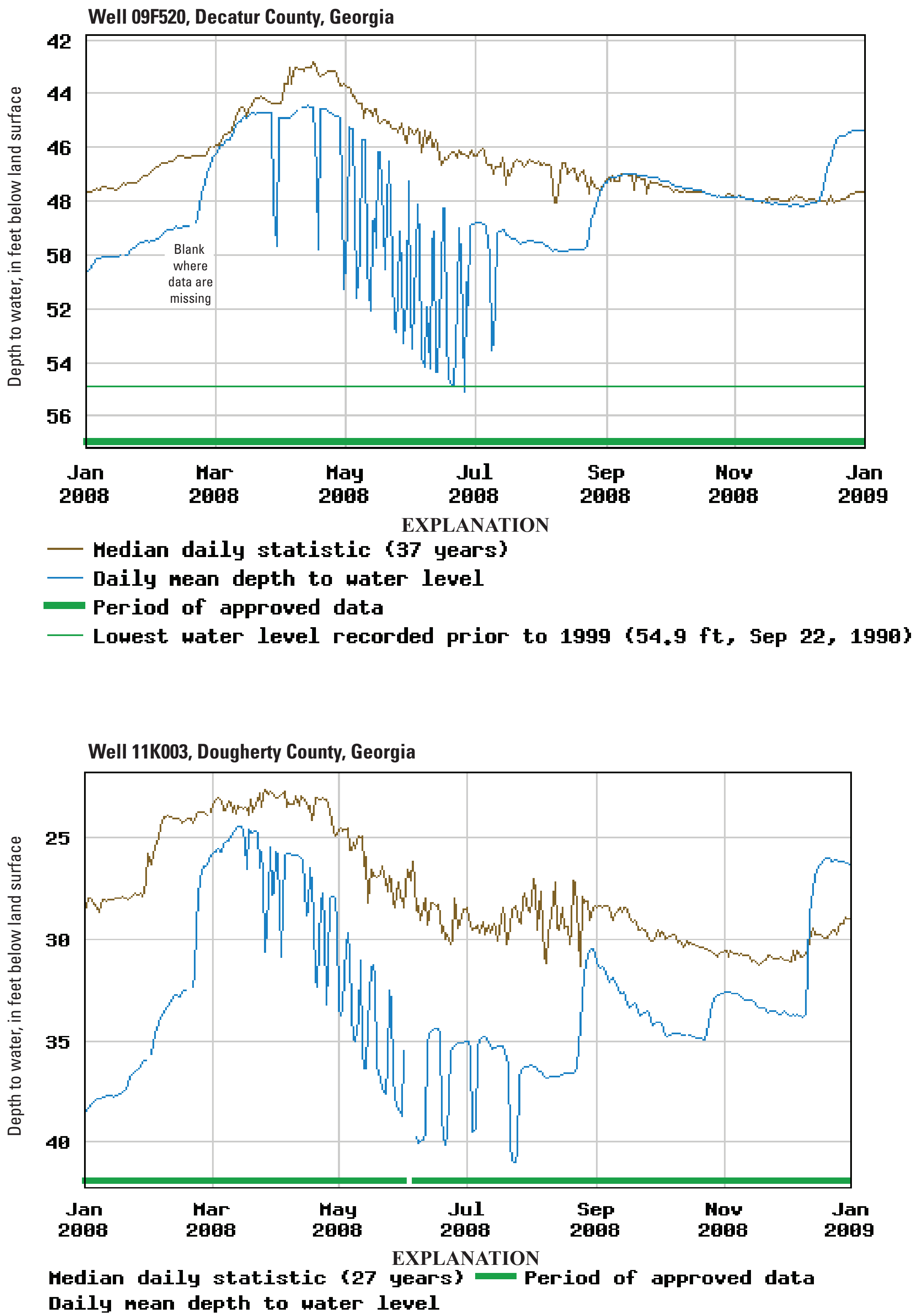
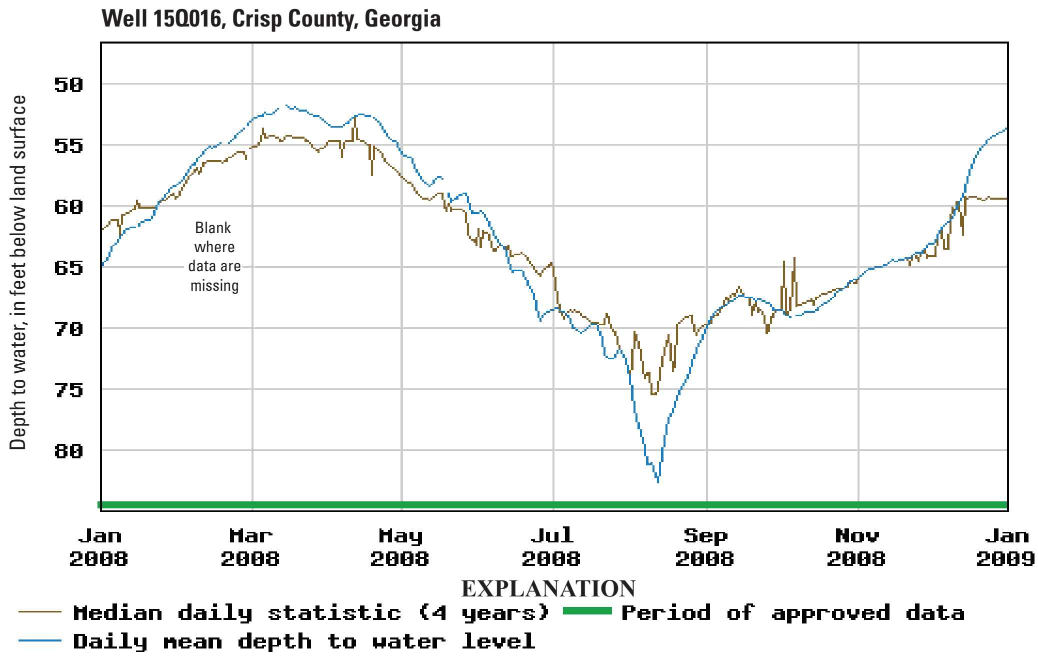


Figure 5. Water levels and long-term daily median statistics for wells 09F520, 11K003, 15Q016, and 18H016, 2008. (See figure 1 for locations.)



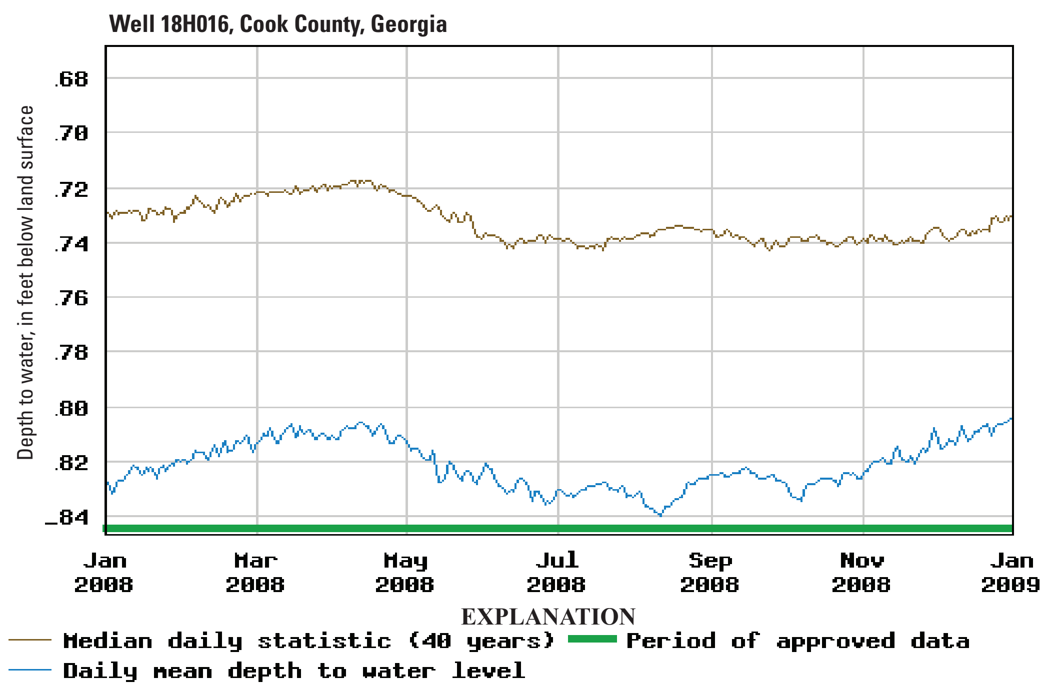


Figure 5. Water levels and long-term daily median statistics for wells 09F520, 11K003, 15Q016, and 18H016, 2008. (See figure 1 for locations.)—Continued

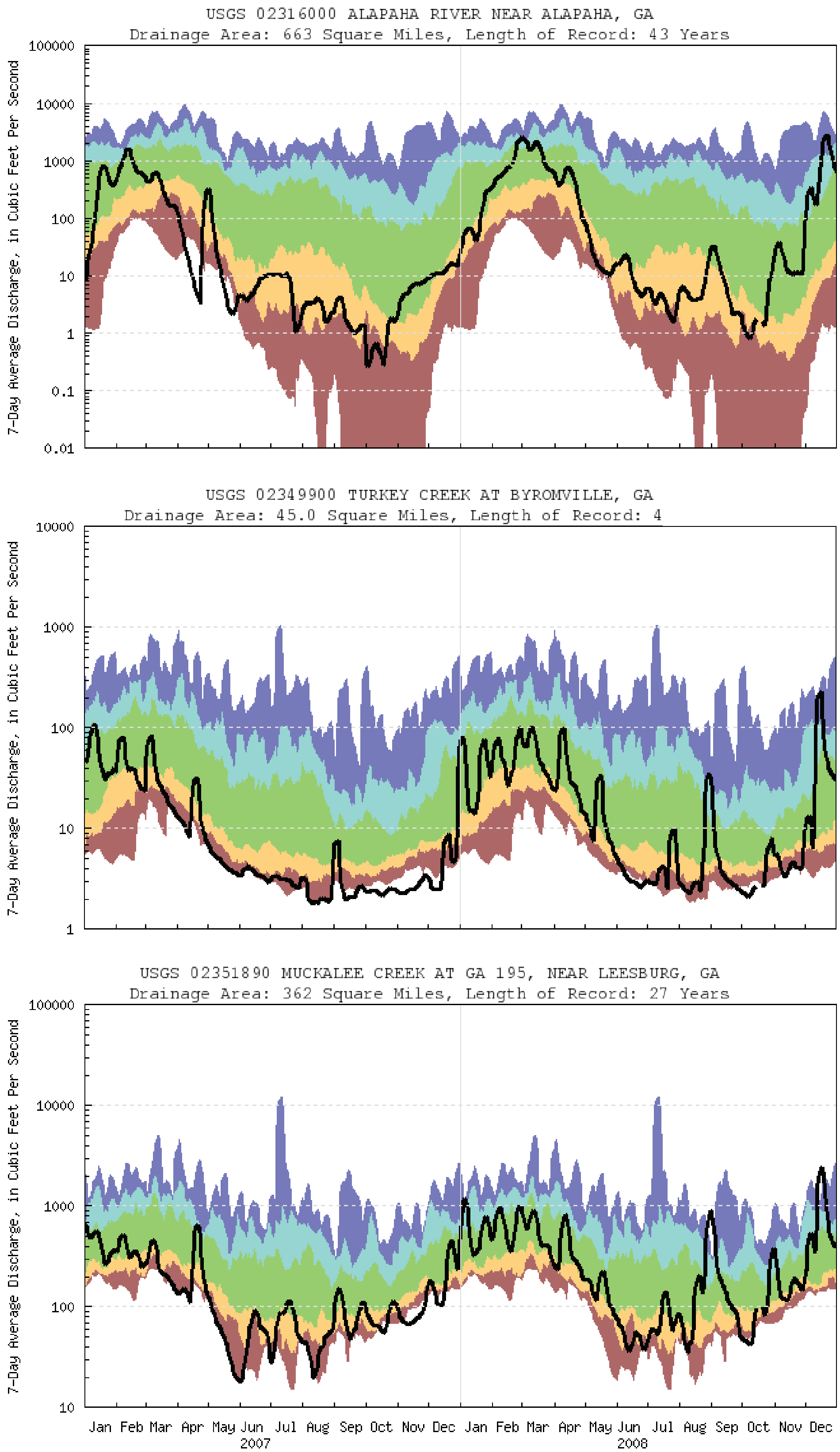


Figure 6. Seven-day average discharge for U.S. Geological Survey streamgages 02316000, 02349900, 02351890, 02353400, and 02357000, 2007–2008. (See figure 1 for locations.)

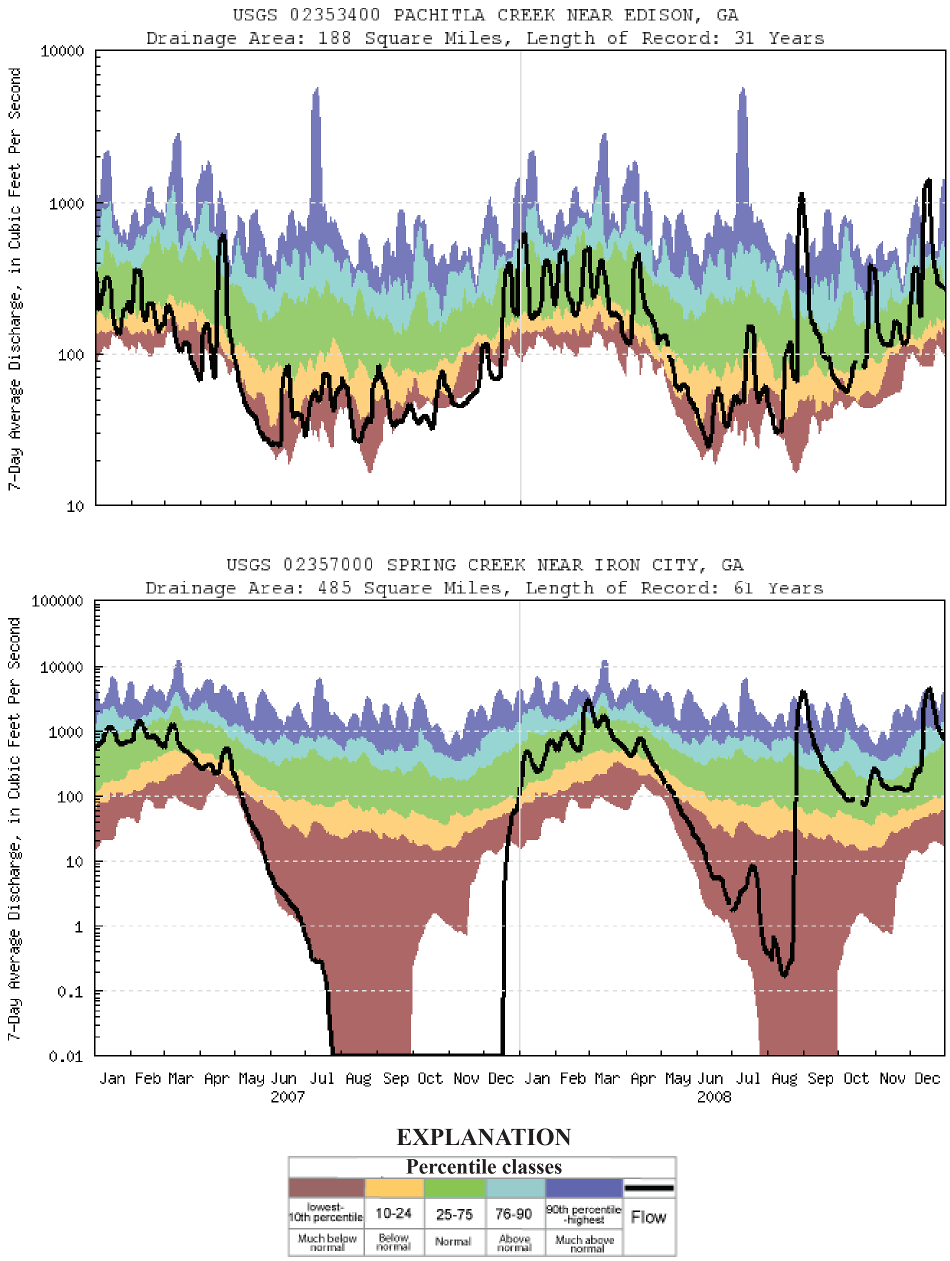


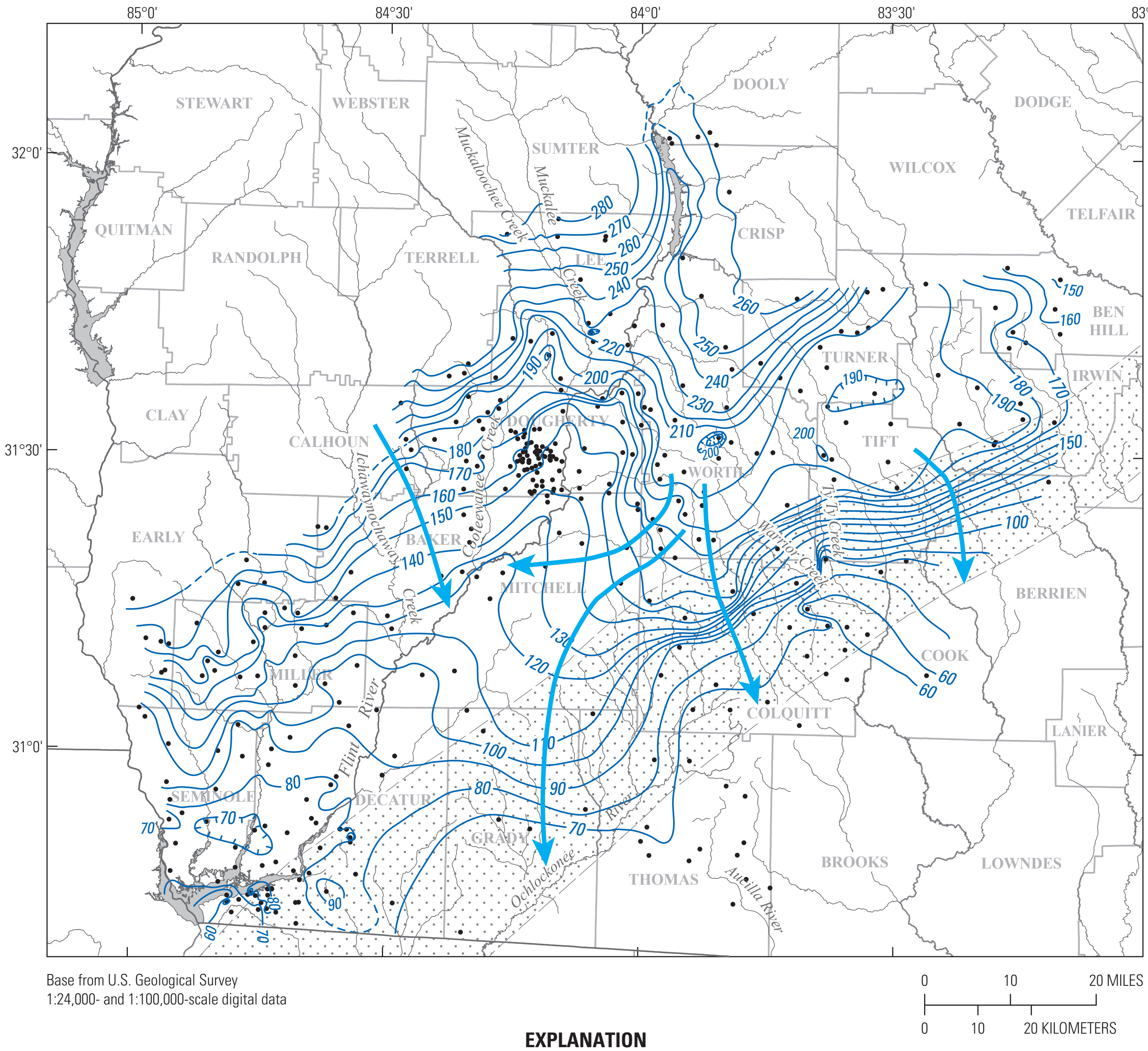
Figure 6. Seven-day average discharge for U.S. Geological Survey streamgages 02316000, 02349900, 02351890, 02353400, and 02357000, 2007–2008. (See figure 1 for locations.)—Continued

Potentiometric Surface

The potentiometric surface represents the altitude at which water would have stood in tightly cased wells if open to the Upper Floridan aquifer. The November 2008 potentiometric-surface map is more detailed than previous maps by Peck (1991) and Peck and others (1999) in the southwestern and northeastern parts of the study area. Increased detail is due to the addition of wells inventoried during studies conducted by Torak and Painter (2006) and Williams (2009).

The potentiometric-surface map is used to better understand groundwater flow in the Upper Floridan aquifer. The configuration of a potentiometric surface indicates general direction of groundwater flow and areas of recharge and discharge. Groundwater generally flows southeastward on the west side of the Flint River, southwestward on the east side of the Flint River, and southward in the eastern part of the study area (fig. 7). One of the more prominent features of the potentiometric surface is the Gulf Trough, a subsurface feature where the hydraulic gradient abruptly steepens. This trough feature is indicated by tightly spaced potentiometric contours, particularly the 80- to 190-ft contours in the east-central part of the map area.

According to Hicks and others (1987) and Torak and Painter (2006), many of the major streams in the Albany–Dougherty County area are incised through the overburden into the Upper Floridan aquifer providing a direct connection between the streams and the Upper Floridan aquifer. Water is discharged from the aquifer through springs that are present along or in the streams when the head in the aquifer is greater than the altitude of the stream stage, or water from the stream recharges the aquifer when the head in the aquifer is less than the altitude of the stream stage. The degree of connection between the Upper Floridan aquifer and streams decreases to the east of the Flint River where the overburden is thicker. The decreased connection is evident as stream-stage altitudes measured east of the Flint River during November 3–6, 2008, are not similar to adjacent groundwater-level altitudes. Of the streams that were flowing (not dry), the stream stages were up to about 160 ft higher than the groundwater altitudes. To the west of the Flint River, the stream stages are coincident with the altitudes of the potentiometric surface of the aquifer, which indicate a direct connection between the aquifer and the streams. The Upper Floridan aquifer discharges to streams in most of the area west of the Flint River. This discharge is evident on the potentiometric map by the contours that "bend" upstream where the contours cross the Flint River in Dougherty County near Albany. Several stream reaches in the area were losing water at the time when measurements were collected. These reaches are on Warrior Creek, Ty Ty Creek, Ichawaynochaway Creek, Cooleewahee Creek, Muckaloochee Creek, and Muckalee Creek (fig. 7). The potentiometric contours "bend" downstream where the contours cross the losing reaches that are connected to the Upper Floridan aquifer (west of the Flint River) or show no deflection where there is no interaction between the stream and the aquifer.



Base from U.S. Geological Survey
1:24,000- and 1:100,000-scale digital data

EXPLANATION

Approximate location of the Gulf Trough–Apalachicola Embayment (modified from Kellam and Gorday, 1990; Davis, 1995)

80 — **Potentiometric contour**—Shows altitude at which water level would have stood in tightly cased wells, November 1–10, 2008. Dashed where approximately located. Hachures indicate depression. Contour interval 10 feet. Datum is NGVD 29

General direction of groundwater flow

Well location

Figure 7. Potentiometric surface of the Upper Floridan aquifer in the lower Chattahoochee–Flint River basin and western and central parts of the Aucilla–Suwanee–Ochlockonee River basin, Georgia, November 1–10, 2008.

Stream Base Flow

Streamflow is composed of surface runoff and base flow. Stream base flow is the portion of streamflow contributed by groundwater discharge. During periods of low precipitation, all or most of streamflow is from base flow. Even though streamflow in most of the study area was above historic lows during November 2008, base-flow conditions were believed to prevail, because little to no rainfall occurred within at least 7 days prior to the measurement period. The hydrograph in figure 8 from USGS streamgage 02353400 at Pachitla Creek near Edison, Georgia, shows the discharge increasing in Pachitla Creek on October 23, peaking on October 26, and then decreasing until November 13. Streamflow during the period when discharge was nearly level between the two rainfall events (November 1–14, 2008) is considered to be at or near base flow conditions.

Streamflow measurements were made at 87 stream sites in the lower CF and upper ASO River basins during November 3–6, 2008 (fig. 9 and Appendix). Base flow was calculated by subtracting an upstream streamflow measurement from the downstream streamflow measurements along the rest of that reach. The difference is an estimate of base flow or the amount of groundwater that discharges to the stream along a specific stream reach. Negative values represent losing stream reaches, where water from the stream is recharging the aquifer. During November 3–6, 2008, the estimated base flow contributed to stream reaches ranged from losing 10 cubic feet per second (ft^3/s) to gaining 4,559 ft^3/s. There were five losing stream reaches in the study area during this period—the reach between streamgages 02317900 and 02317920 on Ty Ty Creek lost 8 ft^3/s; the reaches between streamgages 02317856 on Town Creek, 02317866 on Horse Creek, and 02317874 on Warrior Creek lost 2 ft^3/s; the reach between streamgages 02353460 and 02353500 on Ichawaynochaway Creek lost 9 ft^3/s; the reach between streamgages 02352970 and 02352980 on Cooleewahee Creek lost 4 ft^3/s; and the reach between streamgages 02351800 on Muckaloochee Creek, 02351700 on Muckalee Creek, and 02351890 on Muckalee Creek lost 10 ft^3/s. Stream-reach losses ranged from 2 ft^3/s to 10 ft^3/s, which in a few cases may be within the accuracy of the streamflow measurement. Streamflow measurements typically have errors between 5 and 10 percent (Hirsch and Costa, 2004). Of the 87 stream reaches measured, 24 were dry. All but two of the dry reaches are east of the Flint River where little or no direct connection occurs between streams and the Upper Floridan aquifer. Most of the dry stream reaches are headwater reaches, except in the Alapaha River subbasin in the northeastern part of the study area where the majority of reaches were dry. Mosner (2002) reported seven losing reaches in seven streams during October 1999—a period when southwestern Georgia had severe drought conditions, and record-low streamflow and groundwater levels were measured (Barber and Stamey, 2000; Drought Mitigation Center, 2009). The seven losing streams were the Flint River, Muckalee Creek, Kinchafoonee Creek, Chickasawhatchee Creek, Ichawaynochaway Creek, Carter Creek, and Spring Creek. Even though all seven stream reaches were measured during both October 1999 and November 2008, four of the seven losing reaches had returned to gaining reaches by November 2008.

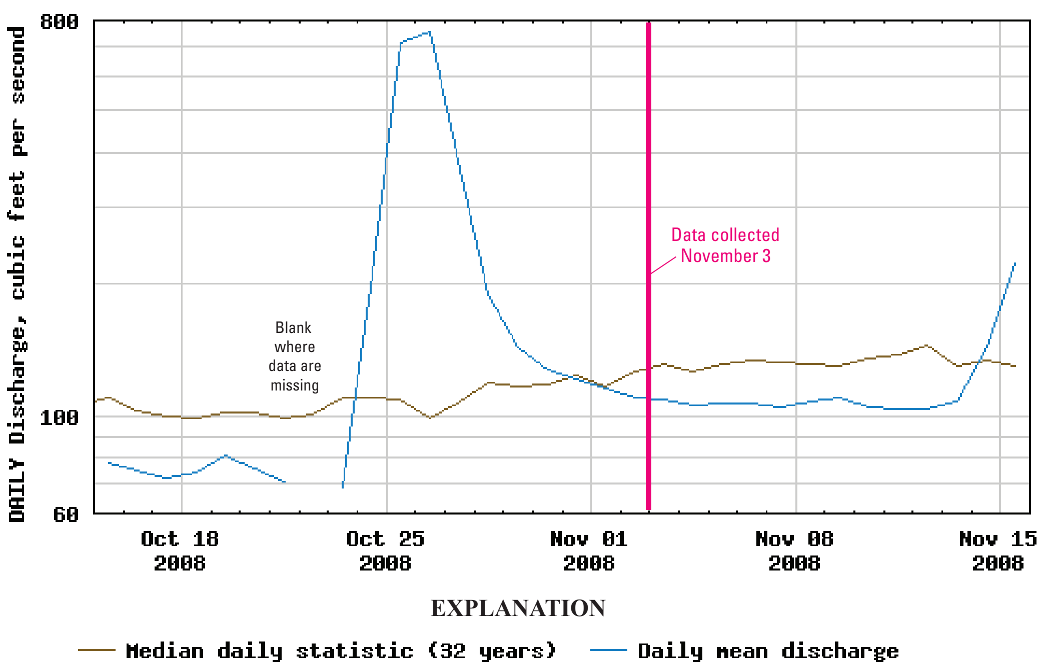


Figure 8. Daily mean discharge for U.S. Geological Survey streamgage 02353400 on Pachitla Creek near Edison, Georgia, October 15 to November 15, 2008. (See figure 1 for location.)

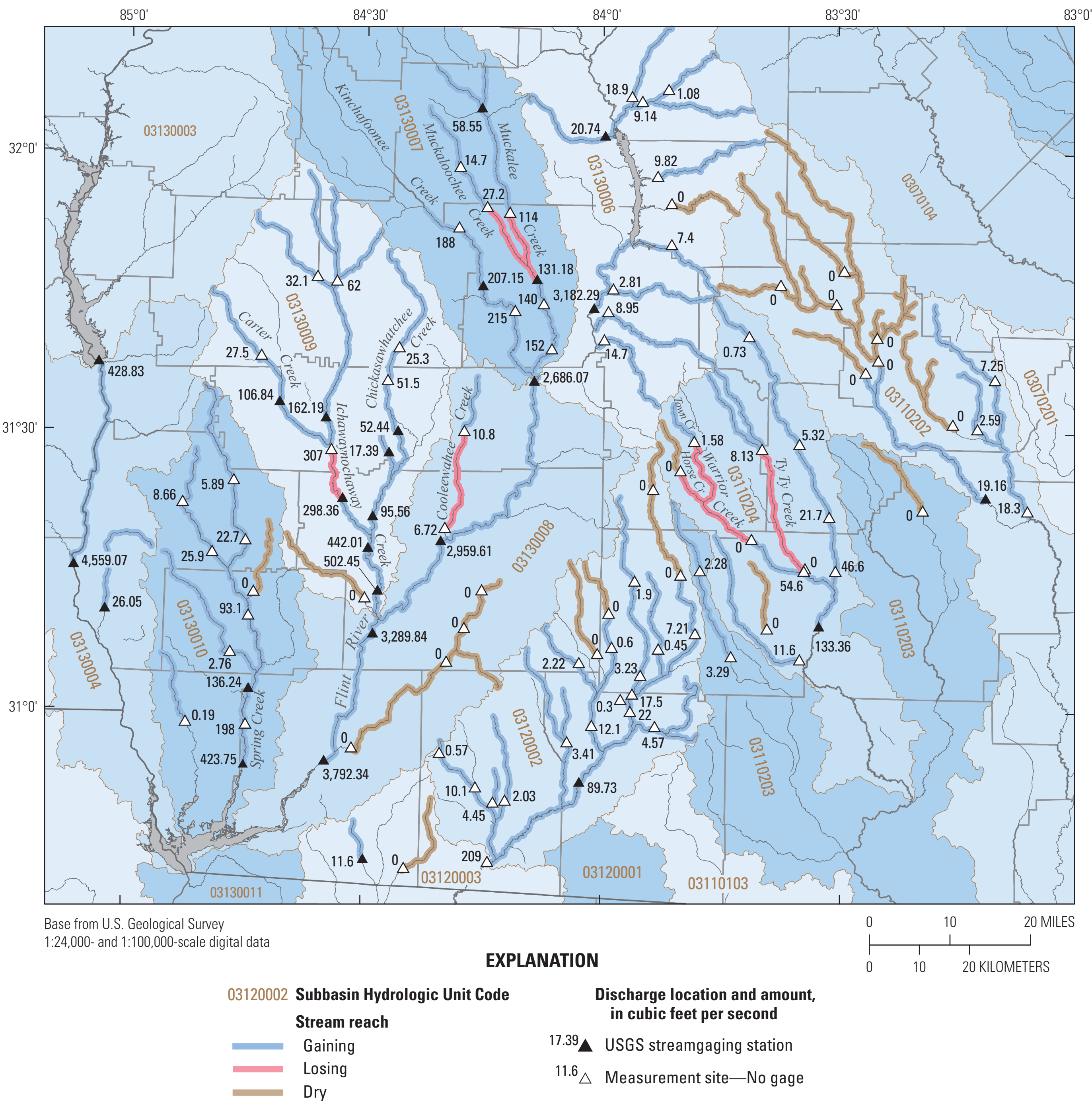


Figure 9. Discharge measurements made in the lower Chattahoochee–Flint River basin and western and central parts of the Aucilla–Suwanee–Ochlockonee River basin, Georgia, showing gaining, losing, and dry stream reaches during November 3–6, 2008.

Summary

During most of 2008, southwestern Georgia had moderate to severe drought conditions. Graphs of cumulative departure from normal rainfall during 2003–2008 show a long-term rainfall deficit from the beginning of 2006. Groundwater levels were below normal throughout most of 2008 and, in some cases, until December 2008 (for example, well 11K003 south of Albany). At some locations, however, groundwater levels rose to median daily levels by November. Flow in most of the streams in the area also had risen into the normal range by November. Streamflow was normal from December 2007 until about May 2008, after which flow in many area streams dropped below the 10th percentile. Flow in most of the streams was back in the normal range by September 2008. At a few locations, record-low streamflow measurements were recorded during 2007 and 2008, and were below normal when measurements were made in November 2008.

The potentiometric surface of the Upper Floridan aquifer was constructed using water-level measurements collected in 21 counties from 376 wells during November 1–10, 2008. The potentiometric surface indicates that groundwater in the study area generally flows to the south and toward the streams except where stream reaches discharge to the Upper Floridan aquifer. One of the more prominent features of the potentiometric surface is the Gulf Trough, an area where the hydraulic gradient abruptly steepens. The degree of direct connection between the Upper Floridan aquifer and the streams decreases east of the Flint River where the overburden is thicker. The decreased connection is evident from the stream-stage altitudes measured in November 2008 east of the Flint River, which were not equivalent to water-level altitudes in the Upper Floridan aquifer.

Streamflow was used to estimate base flow in November 2008, because little to no rainfall occurred prior to when measurements were made. The measurements indicate that the estimated base flow contributed to stream reaches ranged from losing 10 cubic feet per second (ft^3/s) to gaining 4,559 ft^3/s. Stream-reach losses ranged from 2 ft^3/s to 10 ft^3/s. Most of the stream reaches in the Alapaha River subbasin were dry when measured in November 2008.

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Selected References

Barber, N.L., and Stamey, T.C., 2000, Droughts in Georgia: U.S. Geological Survey Open-File Report 00–380, 2 p.

Clark, W.Z., and Zisa, A.C., 1976, Physiographic map of Georgia: Georgia Geological Survey SM–4, reprinted 1988, scale 1:2,000,000.

Davis, Hal, 1996, Hydrogeologic investigation and simulation of ground-water flow in the Upper Floridan aquifer of north-central Florida and southwestern Georgia and delineation of contributing areas for selected City of Tallahassee, Florida, water-supply wells: U.S. Geological Survey Water-Resources Investigations Report 95–4296, 55 p.

Drought Mitigation Center, 2009, Drought monitor archives: accessed July 7, 2009, at *http://drought.unl.edu/dm/archive.html*.

Georgia Automated Environmental Monitoring Network, 2009, Drought table, 2008, accessed February 10, 2009, at *http://www.griffin.uga.edu/aemn/d2008/prec.php*.

Hicks, D.W., Gill, H.E., and Longsworth, S.A., 1987, Hydrogeology, chemical quality, and availability of ground water in the Upper Floridan aquifer, Albany area, Georgia: U.S. Geological Survey Water-Resources Investigations Report 87–4145, 52 p.

Hirsch, R.M., and Costa, J.E., 2004, U.S. stream flow measurement and data dissemination improve: EOS, Transactions, American Geophysical Union, v. 85, no. 20, p. 197–203.

Jones, L.E., and Torak, L.J., 2004, Simulated effects of impoundment of Lake Seminole on ground-water flow in the Upper Floridan aquifer in southwestern Georgia and adjacent parts of Alabama and Florida: U.S. Geological Survey Scientific Investigations Report 2004–5077, 18 p.

Jones, L.E., and, Torak, L.J., 2006, Simulated effects of seasonal ground-water pumpage for irrigation on hydrologic conditions in the lower Apalachicola–Chattahoochee–Flint River Basin, southwestern Georgia and parts of Alabama and Florida, 1999–2002: U.S. Geological Survey Scientific Investigations Report 2006–5234, 83 p., online only at *http://pubs.usgs.gov/sir/2006/5234/*.

Knaak, A.E., and Joiner, J.K., 2008, Hydrologic streamflow conditions for Georgia, 2007: U.S. Geological Survey Fact Sheet 2008–3099, 6 p.

Miller, J.A., 1986, Hydrogeologic framework of the Floridan aquifer system in Florida and parts of Georgia, Alabama, and South Carolina: U.S. Geological Survey Professional Paper 1403–B, 91 p.

Mosner, M.S., 2002, Stream-aquifer relations and the potentiometric surface of the Upper Floridan aquifer in the lower Apalachicola–Chattahoochee–Flint River basin in parts of Georgia, Florida, and Alabama, 1999–2000: U.S. Geological Survey Water-Resources Investigations Report 02–4244, 45 p., accessed September 13, 2005, at *http://ga.water.usgs.gov/pubs/wrir/wrir02-4244/*.

National Oceanic and Atmospheric Administration, 2002, Monthly station normals of temperature, precipitation, and heating and cooling degree days, 1971–2000: National Oceanic and Atmospheric Administration, Climatography of the United States no. 81–09 Georgia, 28 p., accessed June 2, 2009, at *http://cdo.ncdc.noaa.gov/climatenormals/clim81/GAnorm.pdf*.

Peck, M.F., 1991, Potentiometric surface of the Upper Floridan aquifer in Georgia and adjacent parts of Alabama, Florida, and South Carolina, May–June 1990: U.S. Geological Survey Open-File Report 91–206, 3 p.

Peck, M.F., Clarke, J.S., Ransom, Camille, III, and Richards, C.J., 1999, Potentiometric surface of the Upper Floridan Aquifer in Georgia and adjacent parts of Alabama, Florida, and South Carolina, May 1998, and water level trends in Georgia, 1990–98: Georgia Geologic Survey Hydrologic Atlas 22, 1 sheet.

Rantz, S.E. and others, 1982, Measurement and computation of streamflow: Volume 1. Measurement of stage discharge: U.S. Geological Survey Water-Supply Paper 2175, 313 p.

Rupert, F.R., 1990, Geology of Gadsden County, Florida: Florida Geological Survey Bulletin 62, 61 p.

Seaber, P.R., Kapinos, F.P., and Knapp, G.L., 1987, Hydrologic unit maps: U.S. Geological Survey Water-Supply Paper 2294, 63 p.

Torak, L.J., 2009, Effects of climate and pumpage on the ground-water levels of the Upper Floridan aquifer in the Aucilla–Suwannee–Ochlockonee River basin in south-central Georgia, 2009; *in* Proceeding of 2009 Georgia Water Resources Conference, April 27–29, 2009, Athens: Georgia Water Resources Institute, 49 p., accessed June 2009 at *http://www.gwri.gatech.edu/conferences/previous-gwrc-conferences/gwrc-2009/.*

Torak, L.J., Crilley, D.M., and Painter, J.A., 2006, Physical and hydrochemical evidence of lake leakage near Jim Woodruff Lock and Dam and of ground-water inflow to Lake Seminole, and an assessment of karst features in and near the lake, southwestern Georgia and northwestern Florida: U.S. Geological Survey Scientific Investigations Report 2005–5084, 90 p.

Torak, L.J., Davis, G.S., Strain, G.A., and Herndon, J.G., 1996, Geohydrology and evaluation of stream-aquifer relations in the Apalachicola–Chattahoochee–Flint River basin, southeastern Alabama, northwestern Florida, and southwestern Georgia: U.S. Geological Survey Water-Supply Paper 2460, 94 p.

Torak, L.J., and McDowell, R.J., 1996, Ground-water resources of the lower Apalachicola–Chattahoochee–Flint River basin in parts of Alabama, Florida, and Georgia—Subarea 4 of the Apalachicola–Chattahoochee–Flint and Alabama–Coosa–Tallapoosa River basins: U.S. Geological Survey Open File Report 95–321, 145 p.

Torak, L.J., and Painter, J.A., 2006, Geohydrology of the Lower Apalachicola–Chattahoochee–Flint River basin, southwestern Georgia, northwestern Florida, and south-eastern Alabama: U.S. Geological Survey Scientific Investigations Report 2006–5070, 73 p.

Torak, L.J., Painter, J.A., and Peck, M.F., 2010, Geohydrology and water resources of the Aucilla–Suwannee–Ochlockonee River basin, southwestern Georgia and adjacent parts of Florida: U.S. Geological Survey Scientific Investigations Report 2010–5072, in press.

U.S. Geological Survey, 2006, Benefits of USGS stream-gaging program: U.S. Geological Survey report prepared for the National Hydrologic Warning Council, 20 p., accessed August 10, 2009, at *http://water.usgs.gov/osw/pubs/nhwc_report.pdf*.

Williams, L.J., Revised hydrostratigraphy of the Upper Floridan aquifer in south-central Georgia—Insights gained through flowmeter logging, 2009, in Proceeding of the 2009 Georgia Water Resources Conference, April 27–29, 2009, Athens: Georgia Water Resources Institute, 49 p., accessed June 2009 at *http://www.gwri.gatech.edu/conferences/previous-gwrc-conferences/gwrc-2009/*.

Zimmerman, E.A., 1977, Ground-water resources of Colquitt County, Georgia: U.S. Geological Survey Open-File Report 77–56, 41 p.

Appendix

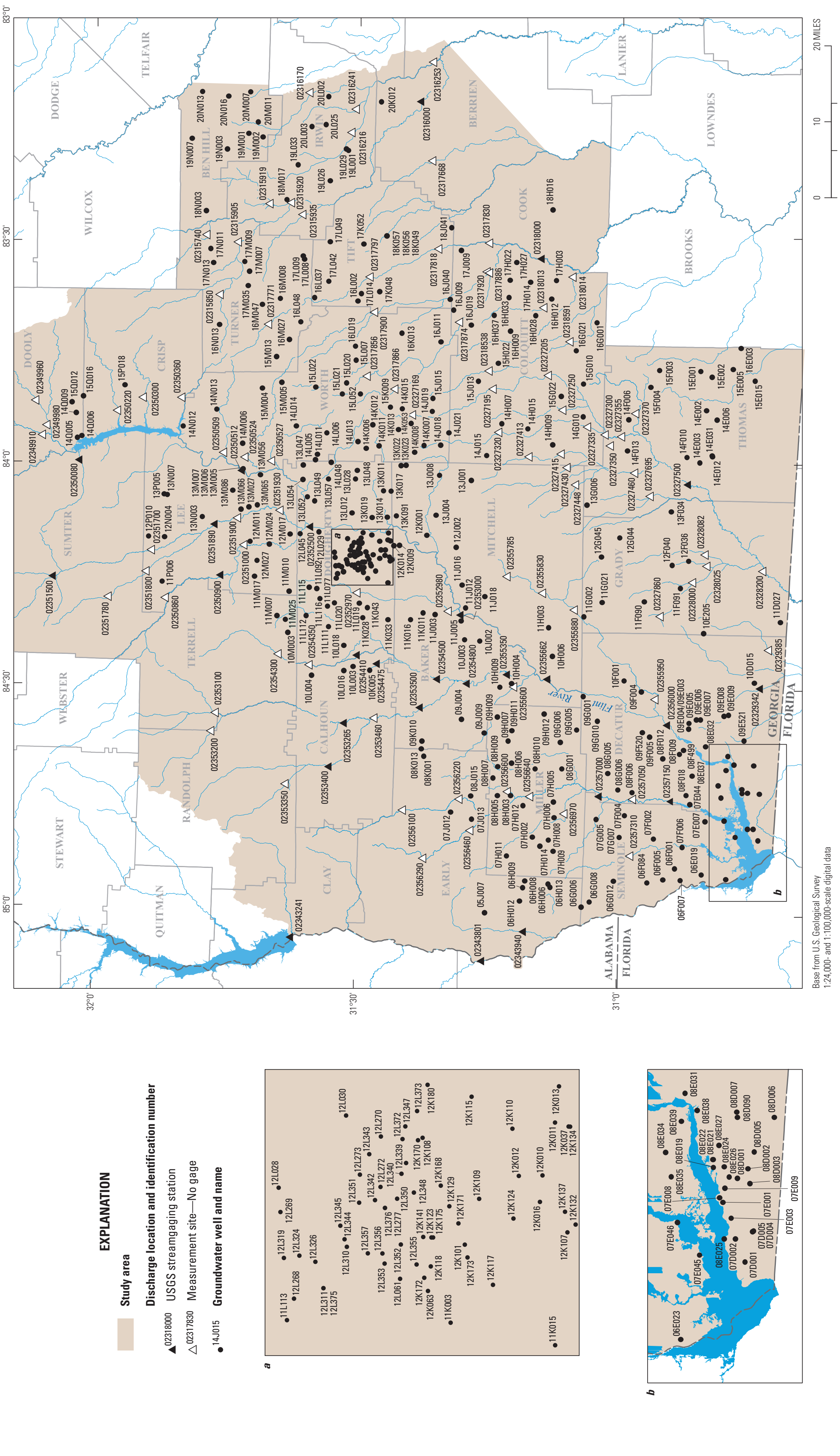

Figure A–1. Location of all measurements sites used to create a potentiometric surface of the Upper Floridan aquifer in south-central and southwestern Georgia during November 2008.

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