USGS
science for a changing world

Prepared in cooperation with the City of Lawrenceville

Hydrologic Conditions, Stream-Water Quality, and Selected Groundwater Studies Conducted in the Lawrenceville Area, Georgia, 2003–2008

Scientific Investigations Report 2010–5032

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

Cover. Clockwise from top left:

Flowing well 14FF59 near the Alcovy River near Lawrenceville, Georgia. Photo by Alan M. Cressler, USGS.

USGS surface-water station photos by Paul D. Ankcorn, USGS:

02208050, Alcovy River near Lawrenceville, Georgia.

02218565, Apalachee River at Fence Road near Dacula, Georgia.

02208130, Shoal Creek at Paper Mill Road near Lawrenceville, Georgia.

02205522, Pew Creek at Patterson Road near Lawrenceville, Georgia.

Hydrologic Conditions, Stream-Water Quality, and Selected Groundwater Studies Conducted in the Lawrenceville area, Georgia, 2003–2008

By John S. Clarke and Lester J. Williams

Prepared in cooperation with the City of Lawrenceville

Scientific Investigations Report 2010–5032

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

U.S. Department of the Interior
KEN SALAZAR, Secretary

U.S. Geological Survey
Marcia K. McNutt, Director

U.S. Geological Survey, Reston, Virginia: 2010

For more information on the USGS—the Federal source for science about the Earth, its natural and living resources, natural hazards, and the environment, visit *http://www.usgs.gov* or call 1-888-ASK-USGS

For an overview of USGS information products, including maps, imagery, and publications, visit *http://www.usgs.gov/pubprod*

To order this and other USGS information products, visit *http://store.usgs.gov*

Suggested citation:
Clarke, J.S., and Williams, L.J., 2010, Hydrologic conditions, stream-water quality, and selected groundwater studies conducted in the Lawrenceville area, Georgia, 2003–2008: U.S. Geological Survey Scientific Investigations Report 2010–5032, 55 p.

Contents

Figures

Appendix

Tables

Conversion Factors

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
gallon (gal)	3.785	liter (L)
gallon (gal)	0.003785	cubic meter (m^3)
gallon (gal)	3.785	cubic decimeter (dm^3)
million gallons (Mgal)	3,785	cubic meter (m^3)
	Flow rate	
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 (L/s)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)
	Radioactivity	
picocurie per liter (pCi/L)	0.037	becquerel per liter (Bq/L)
	Specific capacity	
gallon per minute per foot [(gal/min)/ft)]	0.2070	liter per second per meter [(L/s)/m]

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 North American Vertical Datum of 1988 (NAVD 88).

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

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

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C).

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L).

Concentrations of bacteria in water are reported in most probable number of colonies per 100 milliliters (MPN col/100 mL).

Hydrologic Conditions, Stream-Water Quality, and Selected Groundwater Studies Conducted in the Lawrenceville Area, Georgia, 2003–2008

By John S. Clarke and Lester J. Williams

Abstract

Hydrologic studies conducted during 2003–2008 as part of the U.S. Geological Survey Cooperative Water Program with the City of Lawrenceville, Georgia, provide important data for the management of water resources. The Cooperative Water Program includes (1) hydrologic monitoring (precipitation, streamflow, and groundwater levels) to quantify baseline conditions in anticipation of expanded groundwater development, (2) surface-water-quality monitoring to provide an understanding of how stream quality is affected by natural (such as precipitation) and anthropogenic factors (such as impervious area), and (3) geologic studies to better understand groundwater flow and hydrologic processes in a crystalline rock setting.

The hydrologic monitoring network includes each of the two watersheds projected for groundwater development—the Redland–Pew Creek and upper Alcovy River watersheds—and the upper Apalachee River watershed, which serves as a background or control watershed because of its similar hydrologic and geologic characteristics to the other two watersheds. In each watershed, precipitation was generally greater during 2003–2005 than during 2006–2008, and correspondingly streamflow and groundwater levels decreased. In the upper Alcovy River and Redland–Pew Creek watersheds, groundwater level declines during 2003–2008 were mostly between 2 and 7 feet, with maximum observed declines of as much as 28.5 feet in the upper Alcovy River watershed, and 49.1 feet in the Redland–Pew Creek watershed.

Synoptic base-flow measurements were used to locate and quantify gains or losses to streamflow resulting from groundwater interaction (groundwater seepage). In September 2006, seepage gains were measured at five of nine reaches evaluated in the upper Alcovy River watershed, with losses in the other four. The four losing reaches were near the confluence of the Alcovy River and Cedar Creek where the stream gradient is low and bedrock is at or near the land surface. In the Redland–Pew Creek watershed, groundwater seepage gains were observed at each of the 10 reaches measured during September 2008.

Continuous specific conductance, temperature, and turbidity data were collected at gage sites located on Pew and Shoal Creeks, which drain about 32 percent of the city area, and at a background site on the Apalachee River located outside the city boundary. Continuous surface-water monitoring data indicate that reduced precipitation during 2006–2008 resulted in lower turbidity and higher stream temperature and specific conductance than in 2003–2005. In comparison to the other two stream sites, water at the Apalachee River site had the lowest mean and median values for specific conductance, and the greatest mean and median values for turbidity during October 2005–December 2008.

In addition to continuous water-quality monitoring, samples were collected periodically to determine fecal-coliform bacteria concentrations. None of the individual samples at the three sites exceeded the Georgia Environmental Protection Division (GaEPD) limit of 4,000 most probable number of colonies per 100 milliliters (MPN col/100 mL) for November through April. In the Redland–Pew Creek and Shoal Creek watersheds, the GaEPD 30-day geometric mean standard of 200 MPN col/100 mL for May–October was exceeded twice during two sampling periods in May–October 2007 and twice during two sampling periods in May–October 2008.

Groundwater studies conducted during 2003–2007 include the collection of borehole geophysical logs from four test wells drilled in the upper Alcovy River watershed to provide insight into subsurface geologic characteristics. A flowmeter survey was conducted in a well south of Rhodes Jordan Park to help assess the interconnection of the well with surface water and the effectiveness of a liner-packer assembly installed to eliminate that interconnection. At that same well, hydraulic packer tests were conducted in the open-hole section of the well, and water samples were collected to assess the depth and concentration of gross-alpha radiation detected in the well before and after well modification.

Introduction

In the metropolitan Atlanta region, demand has increased for available surface-water resources as the population grows, and downstream users expect minimum streamflow requirements to be maintained. This demand has been exacerbated by droughts during 1998–2002 and 2006–2008. The City of Lawrenceville, Georgia, has a growing need for water supply (fig. 1). City population increased from 8,928 in 1980 to 22,397 in 2000 (Georgia Humanities Council, 2008) and by 2007 had risen to 28,969, an increase of 29 percent from 2000 (City-Data.com, 2009). These population increases resulted in a doubling of water use during 1985–2000 (Julia Fanning, U.S. Geological Survey, written commun., February 19, 2009).

To meet Lawrenceville's growing need for water, the city currently (2008) is expanding development of its existing groundwater supply. During 1995–2007, Lawrenceville obtained 4–7 percent of its drinking water from groundwater (from a single well), with the remainder from surface water (Chattahoochee River). In addition to an existing well near the center of town, the city plans to pump groundwater from two crystalline bedrock wells—one in the Redland–Pew Creek watershed and one in the upper Alcovy River watershed (fig. 1). Because the long-term effects of groundwater withdrawal in this area are largely unknown, the U.S. Geological Survey (USGS), in cooperation with the City of Lawrenceville, began a study in 2002 to investigate the sustainability of groundwater resources as additional municipal wells become operational. The study includes establishment of a groundwater level and streamflow monitoring network to (1) establish baseline conditions prior to the initiation of pumping, and (2) assess effects that groundwater development may have on ground- and surface-water resources. The data and information developed during the study can be used by local resource managers to help develop a sustainable groundwater supply that will minimize negative effects on surface-water resources.

In addition to understanding groundwater resources, successful watershed management requires an understanding of how stream-water quality is affected by watershed characteristics. Consistent, long-term, accurate monitoring can be used to describe the status and trends in stream-water quality and to assess how water quality is affected by natural factors (such as precipitation) and anthropogenic factors (such as impervious area), and to provide information that is essential for successful watershed management. To assist in these efforts, the USGS and the City of Lawrenceville established a surface-water-quality monitoring network in 2005. This network includes real-time streamflow and water-quality monitoring via satellite telemetry, automated water sampling during storm events, and periodic seasonal sampling during high- and low-flow conditions. These data provide information needed to meet regulatory requirements, while enhancing understanding of how urban stream quality is affected by natural and anthropogenic factors.

City of Lawrenceville Cooperative Water Program

A Cooperative Water Program (CWP) between the USGS and the City of Lawrenceville has been in existence since 1994. The studies under this program are conducted by the USGS and are supported by funding from the City of Lawrenceville and USGS Federal Cooperative Water Program. The initial purpose of the CWP was to provide a better understanding of the geologic controls on groundwater availability in fractured crystalline rock. In 2002, the program was modified to incorporate groundwater and stream monitoring to assess the effects of groundwater development. Stream-water-quality monitoring was added to the program in 2005.

Purpose and Scope

This report presents an overview of hydrologic conditions, stream-water quality, and groundwater studies based on groundwater, surface-water, and stream-water-quality data collected during 2003–2008 in and around Lawrenceville, Georgia (fig. 1). During 2008, 27 wells were used to monitor groundwater levels, of which 3 were continuously recorded, 21 were measured periodically, and 2 were continuously monitored during part of the year and measured periodically for the remainder of the year (table 1). Streamflow and precipitation were continuously recorded at four sites, of which three included continuous water-quality monitoring of water temperature, specific conductance, and turbidity (table 2). In addition to the 4 continuously monitored surface-water sites, the network included periodic streamflow measurements at 22 other sites (the number of locations measured in a given year varied over the reporting period).

Study Area

The 92-square-mile (mi^2) study area encompasses the 13.6-mi^2 City of Lawrenceville and adjacent areas in Gwinnett County (fig. 1), located approximately 26 miles (mi) northeast of Atlanta, Georgia, in the Piedmont Physiographic Province. In Georgia, the Piedmont lies between the Valley and Ridge and Blue Ridge Physiographic Provinces to the north and the Coastal Plain Physiographic Province to the south (fig. 1). Topography in the study area consists of low hills and moderately entrenched stream valleys that range in altitude from about 780 to 1,170 feet (ft). Lawrenceville is located on a drainage divide separating the Yellow River and Alcovy River. To the west, the area is drained by Redland Creek, Pew Creek, and unnamed tributaries of the Yellow River; to the east, the area is drained by Shoal Creek and unnamed tributaries of the Alcovy River (fig. 1).

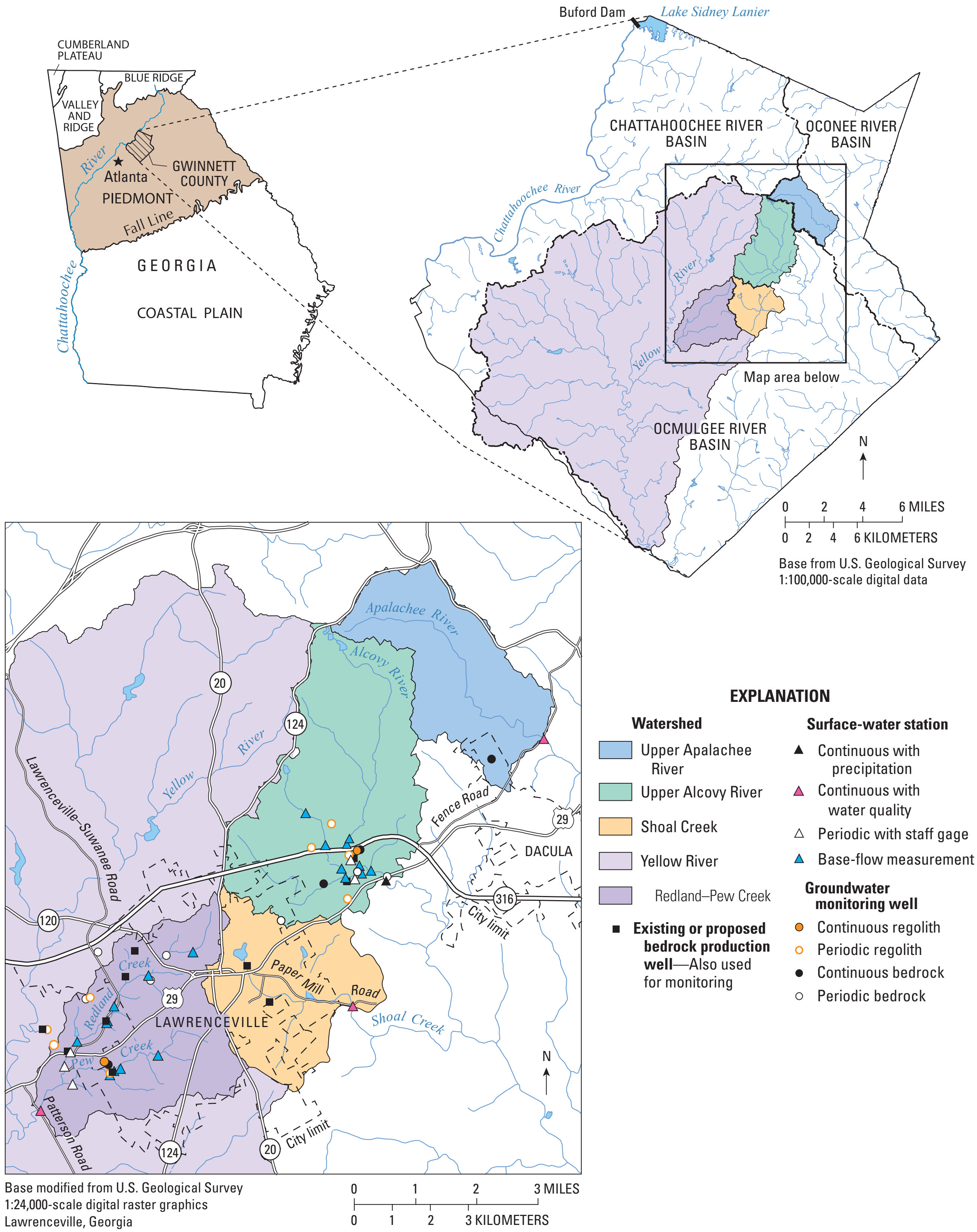


Figure 1. Location of study area and continuous groundwater-level monitoring network for the Lawrenceville area, Georgia.

Table 1. Construction and site information for selected wells in the Lawrenceville, Georgia, area.

[NAVD 88, North American Vertical Datum of 1988; Aquifer: 320CRSL—crystalline rock, 110SFCL—regolith; 2008 network: C—continuous water level, P—periodic water level; —, no data]

Basin	Well identifier	Site identification	Lattitude (decimal degrees)	Longitude (decimal degrees)	Altitude[1] (feet above NAVD 88)	Date drilled
Upper Apalachee River	14GG02	340049083551101	34.0137	−83.9198	1,120	—
Upper Alcovy River	14FF52	335806083581001	33.9684	−83.9698	1,082.25	06/1999
Upper Alcovy River	14FF59	335902083565901	33.9839	−83.9497	952.1	7/20/2001
Upper Alcovy River	14FF60	335902083565902	33.9839	−83.9497	952.8	8/16/2001
Upper Alcovy River	14FF62	335843083570101	33.9787	−83.9502	963	5/20/2003
Upper Alcovy River	14FF63	335851083564701	33.9809	−83.9465	939	5/22/2003
Upper Alcovy River	14FF64	335846083562401	33.9795	−83.9400	937	7/8/2003
Upper Alcovy River	14FF65	335905083565101	33.9847	−83.9475	985	7/23/2003
Upper Alcovy River	14FF66	335905083565102	33.9848	−83.9474	985	7/8/2003
Upper Alcovy River	14FF67	335908083573701	33.9856	−83.9603	985.17	7/8/2003
Upper Alcovy River	14FF68	335927083571701	33.9909	−83.9546	1,055	7/8/2003
Upper Alcovy River	14FF69	335827083565901	33.9741	−83.9500	1,090	7/8/2003
Yellow River	13FF20	335744084011601	33.9622	−84.0213	990.1	5/14/2001
Yellow River	13FF21	335641084021101	33.9447	−84.0364	889.4	5/16/2001
Yellow River	13FF24	335641084021102	33.9447	−84.0364	889.4	8/16/2001
Yellow River	13FF29	335628084020101	33.9410	−84.0337	1,005	7/9/2003
Redland–Pew Creek	13FF13	335721084002601	33.9559	−84.0069	972.3	—
Redland–Pew Creek	13FF14	335741084000801	33.9616	−84.0019	987.86	—
Redland–Pew Creek	13FF16	335743084003901	33.9625	−84.0109	1,004.68	06/1999
Redland–Pew Creek	13FF18	335721084004801	33.9559	−84.0134	953.8	5/9/2001
Redland–Pew Creek	13FF19	335602084010201	33.9341	−84.0178	921.8	5/10/2001
Redland–Pew Creek	13FF22	335646084010701	33.9461	−84.0187	929.7	5/17/2001
Redland–Pew Creek	13FF23	335623084014401	33.9396	−84.0289	906.2	5/30/2001
Redland–Pew Creek	13FF25	335602084010202	33.9341	−84.0178	921.6	8/16/2001
Redland–Pew Creek	13FF27	335705084012801	33.9515	−84.0244	1,009	7/15/2003
Redland–Pew Creek	13FF28	335705084012802	33.9515	−84.0244	1,009.46	7/9/2003
Redland–Pew Creek	13FF30	335614084010701	33.9372	−84.0186	1,000	7/23/2003
Redland–Pew Creek	13FF31	335614084010702	33.9371	−84.0185	1,000	7/9/2003
Redland–Pew Creek	13FF34	335653084010101	33.9480	−84.0170	940	6/25/2008
Shoal Creek	14FF16	335735083584502	33.9598	−83.9788	994.2	1949
Shoal Creek	14FF55	335707083582101	33.9519	−83.9726	969.6	4/16/2001

Table 1. Construction and site information for selected wells in the Lawrenceville, Georgia, area.—Continued

[NAVD 88, North American Vertical Datum of 1988; Aquifer: 320CRSL—crystalline rock, 110SFCL—regolith; 2008 network: C—continuous water level, P—periodic water level; —, no data???]

Well depth (feet)	Casing depth (feet)	Casing diameter (inches)	Measurement date	Depth to water below land surface[3] (feet)	Aquifer	Date monitoring began	2008 network
304	42	6	7/7/2003	81.85	320CRSL	7/11/2003	C
624	25	6	8/19/1999	18.80	320CRSL	8/19/1999	P
470	30	8	—	—	320CRSL	8/26/2001	—
[2]9	[2]4	2	1/23/2003	2.89	110SFCL	1/23/2003	P
600	25	8	6/5/2003	1.83	320CRSL	6/5/2003	P
600	25	8	6/5/2003	0.68	320CRSL	6/5/2003	P
600	26	6	7/24/2003	7.41	320CRSL	7/24/2003	P
465	25	6	7/23/2003	13.49	320CRSL	11/7/2003	C, P
[2]20	[2]15	2	7/23/2003	13.10	110SFCL	11/7/2003	C, P
[2]41	[2]36	2	7/23/2003	8.81	110SFCL	7/23/2003	P
[2]45	[2]39	2	7/23/2003	28.97	110SFCL	10/1/2001	P
[2]38	[2]33	2	7/23/2003	16.85	110SFCL	7/23/2003	P
455	72	6	8/2/2001	17.28	320CRSL	8/17/2001	P
505	40	8	8/2/2001	4.12	320CRSL	8/2/2001	P
[2]16	[2]12	2	10/31/2001	3.45	110SFCL	10/31/2001	P
26	21	2	7/23/2003	18.90	110SFCL	7/23/2003	P
430	22	6	11/17/1996	4.05	320CRSL	2/5/1998	P
280	23	10	10/6/1998	12.50	320CRSL	7/15/1998	—
627	25	6	8/19/1999	39.17	320CRSL	8/19/1999	P
550	55	8	1/23/2003	–6.47	320CRSL	8/2/2001	—
477	65	8	8/2/2001	8.50	320CRSL	8/2/2001	P
600	60	8	8/2/2001	0.15	320CRSL	8/2/2001	P
—	30	8	—	—	320CRSL	10/9/2001	—
[2]16	[2]10	2	10/31/2001	6.08	110SFCL	11/1/2001	P
305	34	6	7/23/2003	18.37	320CRSL	7/23/2003	P
[2]23	[2]18	2	7/23/2003	17.57	110SFCL	7/23/2003	P
345	36	6	7/23/2003	27.96	320CRSL	11/7/2003	C
[2]26	[2]21	2	7/23/2003	19.92	110SFCL	11/7/2003	C
605	21	6	6/26/2008	4.84	320CRSL	6/26/2008	P
302	6	12	12/6/1994	6.24	320CRSL	—	—
425	65	8	—	—	320CRSL	—	—

[1] Accuracy varies based on method of measurement. Values reported to tenths or hundredths of a foot represent measurement made by surveying or global positioning techniques.

[2] Values rounded to nearest foot.

[3] Values reported to hundredth of a foot

Table 2. Stream-site information, Lawrenceville, Georgia, surface-water monitoring network.

[Site type: S—streamflow, Q—water quality]

Basin	USGS site identification	Site name	Drainage area (square miles)	Site type	Date monitoring began
Upper Apalachee River	02218565	Apalachee River at Fence Road, near Dacula, GA	5.68	Continuous S/Q	7/13/2001
Upper Alcovy River	02208046	Alcovy River Hurricane Shoals Rd, near Dacula, GA	4.74	Base flow	8/28/2003
Upper Alcovy River	022080463	Alcovy River below Hurricane Sh Rd below confluence	4.90	Base flow	9/6/2006
Upper Alcovy River	02208047	Alcovy River at GA 316, near Lawrenceville, GA	5.01	Staff gage	4/23/2003
Upper Alcovy River	022080475	Alcovy River above Cedar Creek near Lawrenceville, GA	5.11	Base flow	8/28/2003
Upper Alcovy River	022080477	Cedar Creek above Progress Center Ave, Lawrenceville, GA	0.620	Base flow	9/6/2006
Upper Alcovy River	022080478	Cedar Creek below Hurricane Shoals Road, Lawrenceville, GA	1.50	Base flow	9/6/2006
Upper Alcovy River	022080479	Cedar Creek below GA 316, at Lawrenceville, GA	3.24	Base flow	8/28/2003
Upper Alcovy River	0220804795	Cedar Creek below airport near Lawrenceville, GA	0.630	Base flow	9/6/2006
Upper Alcovy River	02208048	Cedar Creek at Cedars Rd, near Lawrenceville, GA	4.08	Staff gage	7/19/2007
Upper Alcovy River	02208049	Cedar Creek above Alcovy River at Lawrenceville, GA	4.10	Base flow	8/28/2003
Upper Alcovy River	022080495	Alcovy River tributary at sewer cut near Lawrenceville, GA	0.630	Base flow	9/6/2006
Upper Alcovy River	02208050	Alcovy River near Lawrenceville, GA	10.0	Continuous S	4/23/2004
Redland–Pew Creek	02205450	Pew Creek at Sarah Lane, at Lawrenceville, GA	1.82	Base flow	8/29/2003
Redland–Pew Creek	02205500	Pew Creek near Lawrenceville, GA	2.23	Base flow	10/26/1953
Redland–Pew Creek	02205508	Pew Creek at Sugarloaf Pkwy, near Lawrenceville, GA	3.43	Staff gage	2/10/2003
Redland–Pew Creek	022055082	Redland Creek at Maltbie St near Lawrenceville, GA	0.470	Base flow	8/29/2003
Redland–Pew Creek	022055085	Redland Creek below GA 120 at Lawrenceville, GA	0.950	Base flow	8/29/2003
Redland–Pew Creek	02205520	Redland Creek at GA 29, near Lawrenceville, GA	3.11	Staff gage	9/10/1952
Redland–Pew Creek	02205522	Pew Creek at Patterson Rd, near Lawrenceville, GA	7.00	Continuous S/Q	3/28/2003
Redland–Pew Creek	335602084010401	Pew Creek tributary below Johnston Rd, Lawrenceville, GA	0.600	Base flow	9/6/2006
Redland–Pew Creek	335629084013801	Redland Creek tributary near Monfort Rd, Lawrenceville, GA	0.240	Base flow	9/5/2006
Redland–Pew Creek	335645084010701	Redland Creek at Lawrenceville Suwanee Rd, Lawrenceville, GA	2.57	Base flow	9/5/2006
Redland–Pew Creek	335646084010702	Redland Creek tributary at Lville Suwanee Rd, Lawrenceville, GA	0.090	Base flow	9/5/2006
Redland–Pew Creek	335658084010001	Redland Creek at Lawrenceville Suwanee Rd No 2, Lawrenceville, GA	2.38	Base flow	9/5/2006
Shoal Creek	USGS 02208130	Shoal Creek at Paper Mill Rd, near Lawrenceville, GA	3.90	Continuous S/Q	10/1/2005

The Lawrenceville area is underlain by igneous and metamorphic rocks (bedrock) of the Piedmont Physiographic Province that have very little primary porosity and permeability. The Redland–Pew Creek, upper Apalachee, and southern part of the upper Alcovy River watersheds are characterized by compositionally layered rocks, whereas the northern part of the upper Alcovy River watershed is underlain by granitic gneiss. Groundwater in igneous and metamorphic rock aquifers occurs in joints, fractures, and other secondary openings in the bedrock. The bedrock in most areas is overlain by a mantle of soil, saprolite, alluvium, and weathered rock, collectively referred to as regolith, that provide much of the recharge to the igneous and metamorphic rock aquifers in areas where the aquifers and regolith are hydraulically connected. Under natural, unstressed conditions, the amount of groundwater discharged to streams (base flow) and available to be withdrawn by wells is approximately equal to the amount of water recharging the aquifer.

Wells in the area have a wide range of yield and depth, and derive water mainly from the fractures and other discontinuities in the igneous and metamorphic bedrock that underlie the entire study area (Williams and others, 2004). The reported yield of wells ranges from about 1 to 600 gallons per minute (gal/min). Most of the bedrock wells range from about 100 to 600 ft in depth.

In a recent report on watersheds in Gwinnett County, Landers and others (2007) characterize the climate near Lawrenceville as humid subtropical with warm, humid summers and cool, wet winters. The average high monthly temperature of about 88 degrees Fahrenheit (°F) is in July, and the average low monthly temperature of about 32 °F is in January. Average annual precipitation in Gwinnett County during 1998–2003 was 53.6 inches, with most precipitation occurring December through April. Consequently, the greatest groundwater recharge and subsequent contribution to streamflow occurs during the cooler months when rainfall is highest and evapotranspiration is lowest. Summer precipitation is usually of short duration and unevenly distributed. Summer storms generally produce less cumulative rainfall than winter storms; however, they tend to have greater intensity and may result in more erosion and wash off of constituents (Landers and others, 2007).

Water Use

Water supply in the Lawrenceville area is provided mostly by surface water (Chattahoochee River) purchased from Gwinnett County, with a smaller amount derived from city-owned supply wells (fig. 2). During 1985–2000, total water use more than doubled from 1.37 million gallons per day (Mgal/d) in 1985 to 2.81 Mgal/d in 2000 (Julia Fanning, U.S. Geological Survey, written commun., February 19, 2009). Since 2000, water use decreased as the result of water conservation, leak detection, and improvements in metering equipment (Mike Bouie, City of Lawrenceville, oral commun., February 2009).

During 1985–95, supply was exclusively provided by surface water. In 1995, groundwater from a single well located near the center of the city in the Shoal Creek watershed began to supply a small percentage of the total withdrawal (well 14FF16, table 1). Between 1995 and 2007, groundwater from this well contributed 4–7 percent of the water supply, with a maximum annual production of 0.19 Mgal/d in 2000. Additional production wells are planned for the Redland–Pew Creek and upper Alcovy River watersheds. An additional production well in the Redland–Pew Creek watershed was brought online during the fall of 2008. The city would like to develop a groundwater system capable of delivering 2 Mgal/d (Mike Bowie, City of Lawrenceville, oral commun., February 2009).

Related Studies

The USGS, in cooperation with the Gwinnett County Department of Water Resources, established a water-quality monitoring program during late 1996 to collect streamflow and stream-water-quality data (Landers and others, 2007). The overall purpose of the monitoring program is to provide a long-term record of hydrologic and water-quality data that can be used by county and State watershed managers to protect and enhance the streams in the county. This water-quality monitoring program provides comprehensive measurements of stream hydrology and constituent concentrations and loads. The program includes:

- Monitoring water-quantity and water-quality status,
- Monitoring long-term and seasonal water-quantity and water-quality trends,
- Providing flood warning data for emergency managers,
- Providing data to water managers to evaluate and meet regulatory monitoring requirements of permits for water-supply withdrawals, wastewater discharges, stormwater, source-water watersheds, and total maximum daily load studies, and
- Providing data for computation of constituent loads.

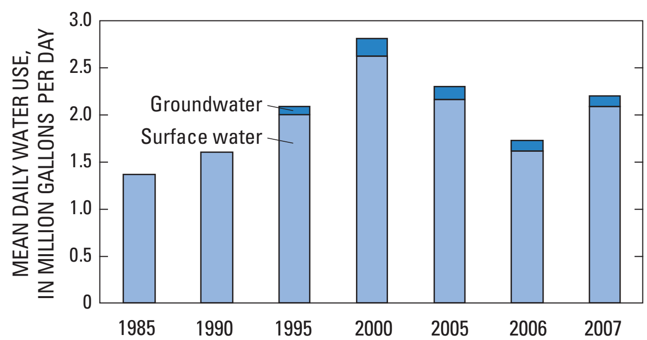


Figure 2. Mean daily water use by the City of Lawrenceville, Georgia, 1985–2007.

The scope of data-collection activities for the surface-water-quality component of the Lawrenceville CWP is similar to the Gwinnett County study, including continuous monitoring of temperature, specific conductance, and turbidity, and periodic sampling for bacteria and water quality.

Landers and Ankcorn (2008) conducted a reconnaissance-level investigation in cooperation with the Georgia Environmental Protection Division and the Gwinnett County Department of Water Resources to compare stream base flow in watersheds with low and high densities of onsite septic wastewater-treatment systems (OWTS). Base flow was measured during October 2007 in 24 watersheds in an area of consistent geologic setting (massive granitic rocks) in southeastern Gwinnett County that included watersheds in the southwestern and southeastern parts of the City of Lawrenceville. The resulting report provides a description of the method used to evaluate groundwater recharge and base flow from OWTS, and to determine if OWTS density can be used to explain changes in base-flow quantity.

Acknowledgments

This study was conducted in cooperation with the City of Lawrenceville, and we wish to thank the continued support of the City Council members and Mayor Rex Millsaps. Mike Bowie, City of Lawrenceville Water Department Superintendent, has provided enormous support to this program and provided day-to-day assistance when needed. Robert Paul and Steve Stubblefield, Water-Treatment Plant Operators, helped with logistical support, clearing roads to drilling sites, and assisting with the packer tests.

Many U.S. Geological Survey employees assisted with this project. Phil Albertson and Michael Hamrick maintained the groundwater level monitoring network and assisted in collection of stream base flow synoptic events. Alan Cressler also assisted by helping with the 2006 base-flow measurement event. Paul Ankcorn and Mark Landers provided all of the support for maintaining and interpreting the surface-water component of this study. Chris Leeth provided quality assurance and data verification of much of the data presented in this report.

Methods

A variety of methods have been used to monitor the hydrologic conditions in the Lawrenceville area, including groundwater monitoring, surface-water monitoring, and water-quality sampling. Groundwater data consist of continuous and intermittent water-level measurements in wells. Surface-water data consist of continuous precipitation, continuous and intermittent stage and discharge, and continuous and intermittent water quality. Information about well data-collection sites is listed in table 1; information about stream sites is listed in table 2.

A crucial element of the study was to determine baseline conditions for groundwater levels and streamflow before increasing groundwater withdrawal for public supply. The baseline data collected as part of this study can be compared with new data collected after the initiation of pumping to determine the amount of drawdown in the aquifer and reductions in base flow that may be attributed to pumping. Data were evaluated using linear regression to establish trends during the study period. The following sections describe the various data-collection components.

Groundwater Levels

Water-level measurements from observation wells are the principal source of information about the hydrologic stresses on aquifers and how these stresses affect groundwater recharge, storage, and discharge. Long-term, systematic measurements of water levels provide essential data needed to evaluate changes in the resource over time, develop groundwater models and forecast trends, and design, implement, and monitor the effectiveness of groundwater management and protection programs (Taylor and Alley, 2001).

In the Lawrenceville area, continuous and intermittent water-level measurements are collected according to USGS standard procedures (Brunett and others, 1997). Continuous water-level measurements were recorded hourly in selected wells using a pressure transducer and data logger. These data were manually retrieved, typically at 6-week intervals, from the data loggers and uploaded to the USGS National Water Information System (NWIS; available at *http://waterdata.usgs.gov/ga/nwis/gw*). Intermittent water levels typically are measured using a graduated steel tape or electric tape following procedures described in Garber and Koopman (1968).

Stream Stage and Discharge

Stage represents water height above an arbitrary datum and is used to compute streamflow—the total volume of water that flows past a specific point on a river during a period of time. Stream stage (or gage height) is continually measured at selected sites in the Lawrenceville area. Values are recorded to the nearest 0.01 foot using an air bubbler system. Discharge measurements are routinely made to define and verify a stage-to-discharge relation at each site, so that both stage and discharge are known. A bubbler gage also is verified against an outside reference gage routinely (at least every 6 weeks), and levels are run periodically from established reference points to verify gage datums. These sites continuously record data at 15-minute intervals and transmit the data via satellite to be incorporated into the USGS National Water Information System database. These data are automatically posted to the USGS Web site for public dissemination (*http://waterdata.usgs.gov/ga/nwis/nwis*). Discharge for periods of missing or unreliable stage data were estimated using hydrographic comparisons with nearby watersheds having similar characteristics (Rantz, 1982b).

Stage also is measured at several non-recording staff gages during site visits. Staff gages are installed and maintained in accordance with the methods of monitoring stream stage and computing streamflow further described in Rantz (1982a, b) and in the Surface-Water Quality-Assurance Plan of the USGS Georgia Water Science Center (Gotvald and Stamey, 2005).

Stream Base Flow

Synoptic base-flow measurement events are used to locate and quantify gains or losses to streamflow resulting from groundwater interaction (groundwater seepage). Gain or loss in streamflow is calculated by subtracting an upstream streamflow measurement from a downstream measurement. In Lawrenceville, base-flow discharge was periodically measured along selected stream reaches using (1) current meter (Pygmy-type) measurements (Rantz, 1982b), (2) acoustic Doppler velocity meter (ADVM) measurements (Laenen, 1985), or (3) volumetric measurements (Rantz, 1982b) based on the time for the flow to fill a container of known volume. Streamflow measurements have an error which may affect reported values for seepage and whether a stream reach is characterized as gaining or losing. Of the three methods, volumetric measurements are most accurate; ADVM measurements have been shown to have an uncertainty of 4.5 percent or less (Oberg and Mueller, 2007), and current meters have standard errors ranging from 3 to 6 percent (Sauer and Meyer, 1992). Sources of error include error contributed by the current meter, measurement of depth, the pulsation of flow, the vertical distribution of velocities, the measurement of horizontal angles, and computations involving the horizontal distribution of velocity and depth (insufficient number of or inadequate measuring subsections). Poor measuring conditions (such as very slow water velocities or shallow depths similar to those in the Lawrenceville study area) or improper procedures of meter use, however, can result in much larger errors. For this reason, stream seepage estimates are conservatively reported with a ±25-percent error bracket to account for errors in streamflow measurements. Improved accuracy of streamflow measurements using volumetric or acoustic Doppler current meters could provide more accurate seepage estimates.

Precipitation

Precipitation data are collected at real-time stream-gaging stations operated by USGS following procedures described in Gotvald and Stamey (2005). In general, precipitation is measured using a calibrated tipping bucket rain gage that records and transmits data via satellite to the USGS NWIS database every 15 minutes. Periodic inspection of the rain gage occurs every 6 weeks, and calibration occurs yearly using a constant-head bottle.

Stream-Water Quality

Stream-water quality is monitored at streamgage sites in the Apalachee River, Pew Creek, and Shoal Creek. At each site, water-quality meters are deployed to continuously measure and record streamwater temperature, specific conductance, and turbidity every 15 minutes. Specific conductance is directly related to the total dissolved solids in water. Turbidity provides an indicator of the total suspended solids in water. Turbidity to suspended solids concentration relations, however, may be unreliable because turbidity readings vary with suspended solids size, gradation, and color, as well as concentration (Gray and Glysson, 2003). Water-quality meters are cleaned and calibrations are checked at least every 4 weeks following the quality-assurance procedures described in Wagner and others (2000).

In addition to continuous stream-water quality monitoring, discrete water-quality samples were collected during storms to characterize nonpoint-source pollution in storm flow. To improve the ability to collect discrete samples during rainfall runoff, pumping point samplers were installed at all water-quality monitoring stations. These data can be used to characterize stream-water quality and develop relations between continuously-monitored parameters and laboratory-analyzed concentrations. Eight samples are collected annually from each of these water-quality sampling sites, four samples per site collected during each of the two sampling seasons (November–April, May–October). During each season, samples were collected during three storm events and one dry event.

Storm composite water-quality samples are collected with in situ “automatic” point samplers, which are cleaned and prepared prior to each sampled storm. The sampler is programmed to begin sampling based on precipitation and (or) stream-stage thresholds and to collect subsamples each time a specified volume of water flows by the station at variable time intervals. This method of sampling provides a composite sample of the storm that is discharge-weighted, and accounts for pollutant concentration differences throughout the storm hydrograph. All storm samples were collected in accordance with the applicable standards for stormwater monitoring (Metropolitan North Georgia Water Planning District, 2007) which require that wet-weather samples follow a minimum precipitation event of 0.3 inch Additionally, a minimum time of 72 hours is required between each wet-weather event to ensure that the events are discrete and that the measured water-quality properties are associated with the sampled event. The samples are refrigerated at about 4 degrees Celsius until the sample is removed and processed. Sampler cleaning and maintenance procedures are followed as described in the USGS Georgia Water Science Center, water-quality-assurance plan (Steven J. Lawrence, U.S. Geological Survey, written commun., 2009).

Base-flow samples were collected with a USGS DH-81 manual sampler, or open bottle method as hydrologic conditions permit, using depth and width integrating techniques as outlined in Wilde and others (1998). Base-flow samples were collected after no more than 0.1 inch of precipitation had fallen during the previous 72 hours. Base-flow and stormflow samples were processed and preserved following USGS field methods (Wilde and others, 1998), and analyzed in USGS-approved laboratories.

Hydrologic Conditions

The collection of groundwater-level, streamflow, base flow, and precipitation data are necessary to provide the City of Lawrenceville a means to estimate the sustainability of the hydrologic system under normal or anticipated pumping conditions. A monitoring network was established in two areas projected for groundwater development—the Redland–Pew Creek and upper Alcovy River watersheds, and the upper Apalachee River watershed, which serves as a background or control watershed because of its similar hydrologic characteristics to the pumped watersheds (fig. 1). In addition, sites in the Yellow River watershed are monitored to provide an indication of changes along the northern boundary of the Redland–Pew Creek watershed.

In the 4 watersheds, 26 wells were monitored during 2008, of which 10 are completed in the regolith, and 16 are completed in bedrock (table 1). Twelve of these wells are located at cluster sites, with each including a bedrock well and a regolith well. At the beginning of 2008, five wells were equipped with continuous recorders; however, a funding shortage required conversion of two of these sites (wells 14FF65 and 14FF66; table 1) to periodic measurements in February 2008, leaving three continuously recorded wells at the end of the year.

In addition to an existing real-time continuous stream stage recorder at the outlet of the upper Apalachee River control watershed, new installations were established at the outlet of the upper Alcovy River, Redland–Pew Creek, and Shoal Creek watersheds during 2004–2005 (table 2). Each of the four sites includes a precipitation gage. Additional periodic streamflow measurements were made at 22 locations during the study period.

Upper Apalachee River Watershed

The upper Apalachee River watershed covers a 5.68-mi^2 area in the northeastern part of the study area (fig. 3) and is similar in size and has similar geology and topography as the upper Alcovy River and Redland–Pew Creek watersheds, located to the southwest. Examination of land use maps reported by Landers and others (2007) indicate the upper Apalachee River has less transportation land use and high and low density development than the other two watersheds. Because this watershed has no known major groundwater withdrawal wells and because of its proximity to the pumped watersheds, it was selected as the most suitable background or control site for comparison to data from the other watersheds in the study area.

Monitoring Networks

To assess hydrologic conditions and trends in the upper Apalachee River watershed, streamflow and precipitation data have been recorded at surface-water station 02218565 since July 2001, and groundwater levels have been recorded at observation well 14GG02 since July 2003 (fig. 3; tables 1 and 2). In addition to streamflow and precipitation data, specific conductance, temperature, turbidity, and precipitation data are collected; intermittent water-quality samples also are collected for quality assurance and for characterization of storm events. Water-quality information for this site is described in the "Stream-Water Quality" section of this report.

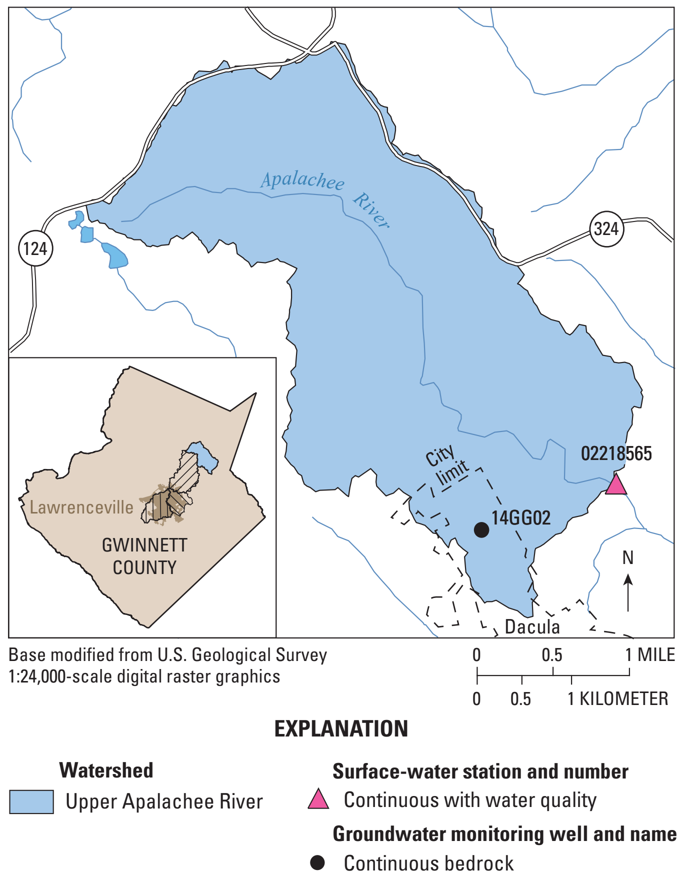


Figure 3. Surface-water and groundwater monitoring networks, upper Apalachee River watershed near Lawrenceville, Georgia, 2008.

Hydrologic and Precipitation Trends

Precipitation is the main control on streamflow and groundwater levels in the Apalachee River watershed. Increased precipitation generally results in increasing streamflow and groundwater levels; decreased precipitation results in decreased streamflow and groundwater levels (fig. 4). Although there are gaps in the record, precipitation was generally greater during 2003–2005, than in 2006–2008, with an average monthly rainfall of 5 inches and 3.3 inches, respectively. Lower precipitation during 2006–2008 resulted in a corresponding decrease in streamflow and groundwater levels. At surface-water station 02218565, the lowest mean monthly streamflow during 2003–2008, was 1.03 cubic feet per second (ft^3/s) in September 2008 (fig. 4). The lowest groundwater level of 88.9 ft below land surface was measured in October 2008.

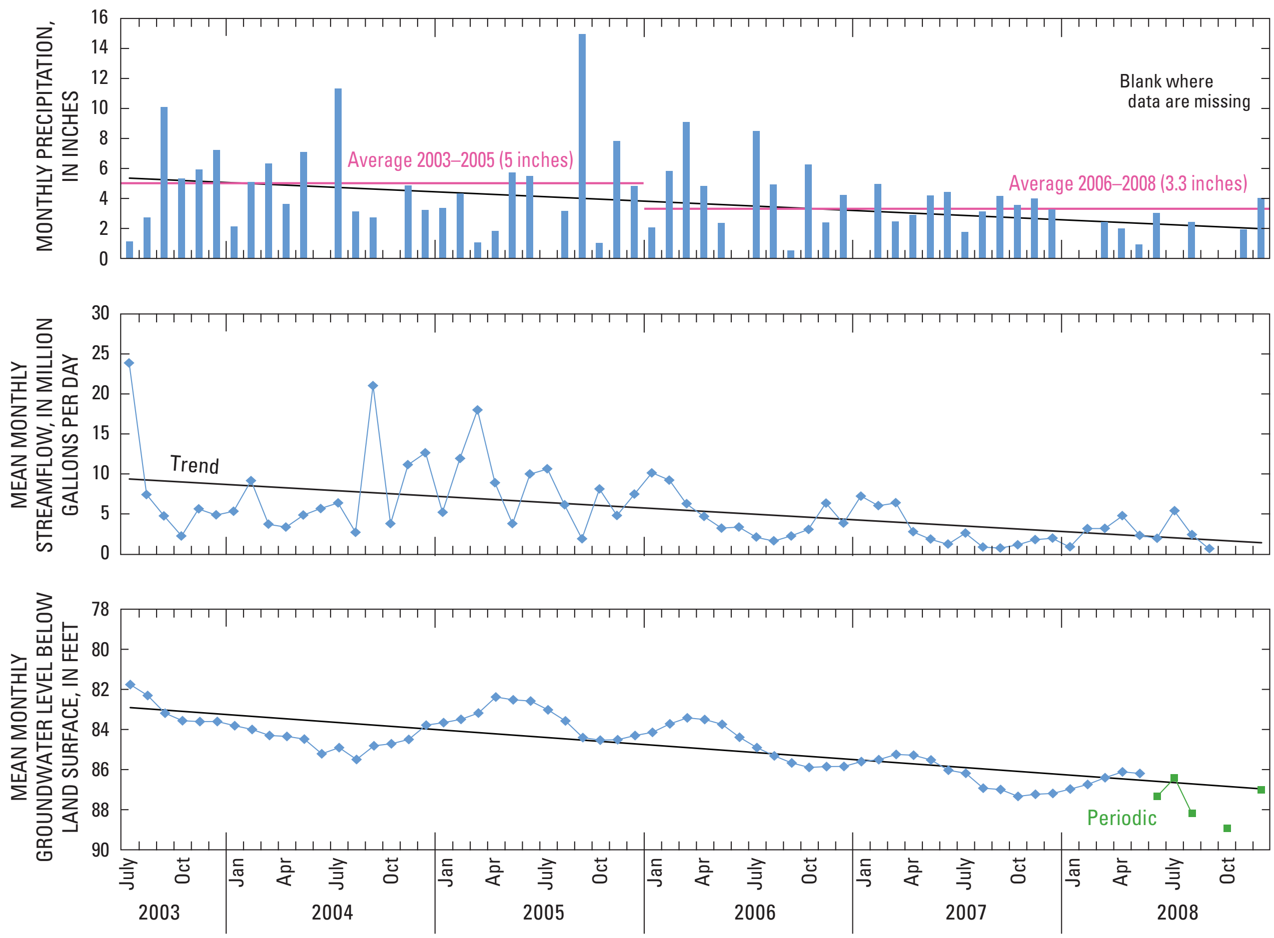


Figure 4. Total monthly precipitation and mean monthly streamflow at surface-water station 02218565, and mean monthly and periodic water levels in well 14GG02, upper Apalachee River watershed near Lawrenceville, Georgia, 2003–2008. (See fig. 3 for location.)

Upper Alcovy Watershed

The upper Alcovy River watershed covers a 9.97-mi^2 area in the north-central portion of the study area (fig. 5). Examination of land use maps reported by Landers and others (2007) indicate the watershed has a greater amount of high density land use than the upper Apalachee River watershed to the northeast. Currently (2008) there are no known groundwater withdrawal sites in the upper Alcovy River watershed; however, two production wells have been identified by the city for possible future use. One of these wells (14FF59) is a flowing artesian well and discharges 40 to 50 gallons per minute (gal/min) into the upper Alcovy River. The current (2008) main production well for the city (14FF16) is located in the adjacent Shoal Creek watershed, about 1-mi southwest of the watershed boundary.

Monitoring Networks

To assess hydrologic conditions and trends in the upper Alcovy River watershed, streamflow and precipitation data have been continuously recorded at surface-water station (02208050) since April 2004 (table 2; fig. 5). Eleven additional surface-water sites were visited periodically during 2004–2006 for measurement of base-flow conditions. The periodic streamflow measurement program for this area was discontinued after September 2006 to enable the shifting of resources to the Redland–Pew Creek watershed where groundwater development is anticipated in the near future.

In addition to streamflow and precipitation data, specific conductance, temperature, turbidity, and precipitation data are continuously monitored at surface-water station 02208050 with intermittent water-quality samples collected for quality assurance and for characterization of storm events. Water-quality information for this site is described in the "Stream-Water Quality" section of this report.

During 2008, groundwater levels were monitored in 11 wells in the upper Alcovy River watershed, of which 6 are completed in the bedrock and 5 are completed in the regolith (table 1, fig. 5). At the beginning of 2008, water levels were continuously recorded in three observation wells; however, this number was reduced to one well by the end of the year. Wells 14FF65 (bedrock) and 14FF66 (regolith) were continuously monitored from November 2003 until March 2008, when the recorders were removed due to a shortage of funding.

Hydrologic and Precipitation Trends

During 2003–2008, streamflow and precipitation in the upper Alcovy River watershed showed a general downward trend (fig. 6). Although there are gaps in the record, precipitation was generally greater during 2003–2005 than in 2006–2008, with average monthly rainfall of 5.4 inches and 3.3 inches, respectively. Lower precipitation during 2006–2008 resulted in a corresponding decrease in streamflow and groundwater levels. At surface-water station 02208050, the lowest mean monthly flow during 2003–2008, was 0.7 Mgal/d in September 2008 (fig. 6).

During 2003–2008, water levels declined in each of the 10 wells monitored in the upper Alcovy River watershed, with the exception of well 14FF63, which showed little change (figs. 7 and 8). The declining water levels corresponded to decreased precipitation and changes in pumping. The magnitude of decline was similar in regolith and bedrock wells, ranging mostly between 2.4 and 6.9 ft, with a considerably greater decline of 28.5 ft in bedrock well 14FF52, located near the basin divide between the upper Alcovy River and Shoal Creek. During January 2003–December 2007, water levels in well 14FF52 showed little change until a pronounced water-level decline of 23.7 ft beginning in December 2007 through September 2008. This accelerated rate of decline may be related to the initiation of periodic pumping from well 14FF55, located about 1.2 mi southwest, near the center of the city in the Shoal Creek watershed.

To assess changes in base-flow conditions in selected stream reaches in the Alcovy River watershed, periodic streamflow measurements were made during periods of low rainfall in August 2003, August 2004, September 2005, and September 2006 (table 3, figs. 6 and 9). Net gain or loss of streamflow (seepage) during these dry or base-flow periods is representative of the interaction between surface and groundwater—when positive, there is a net gain in groundwater inflow; when negative, there is a net loss of streamflow to the groundwater system. Seepage was calculated for the following stream reaches:

- Reach AL-1: intermediate area between sites 02208046 and 02208047;
- Reach AL-2: intermediate area between sites 02208047 and 022080475;
- Reach AL-3: area above site 022080477;
- Reach AL-4: intermediate area between sites 022080477 and 022080478;
- Reach AL-5: intermediate area between sites 022080478 and 022080479;
- Reach AL-6: intermediate area between sites 022080479 and 02208048;
- Reach AL-7: intermediate area between sites 02208048 and 02208049;
- Reach AL-8: intermediate area between site 02208050 and combined flow at sites 022080475, 02208049, and 022080495; and
- Reach AL-9: area above site 022080495.

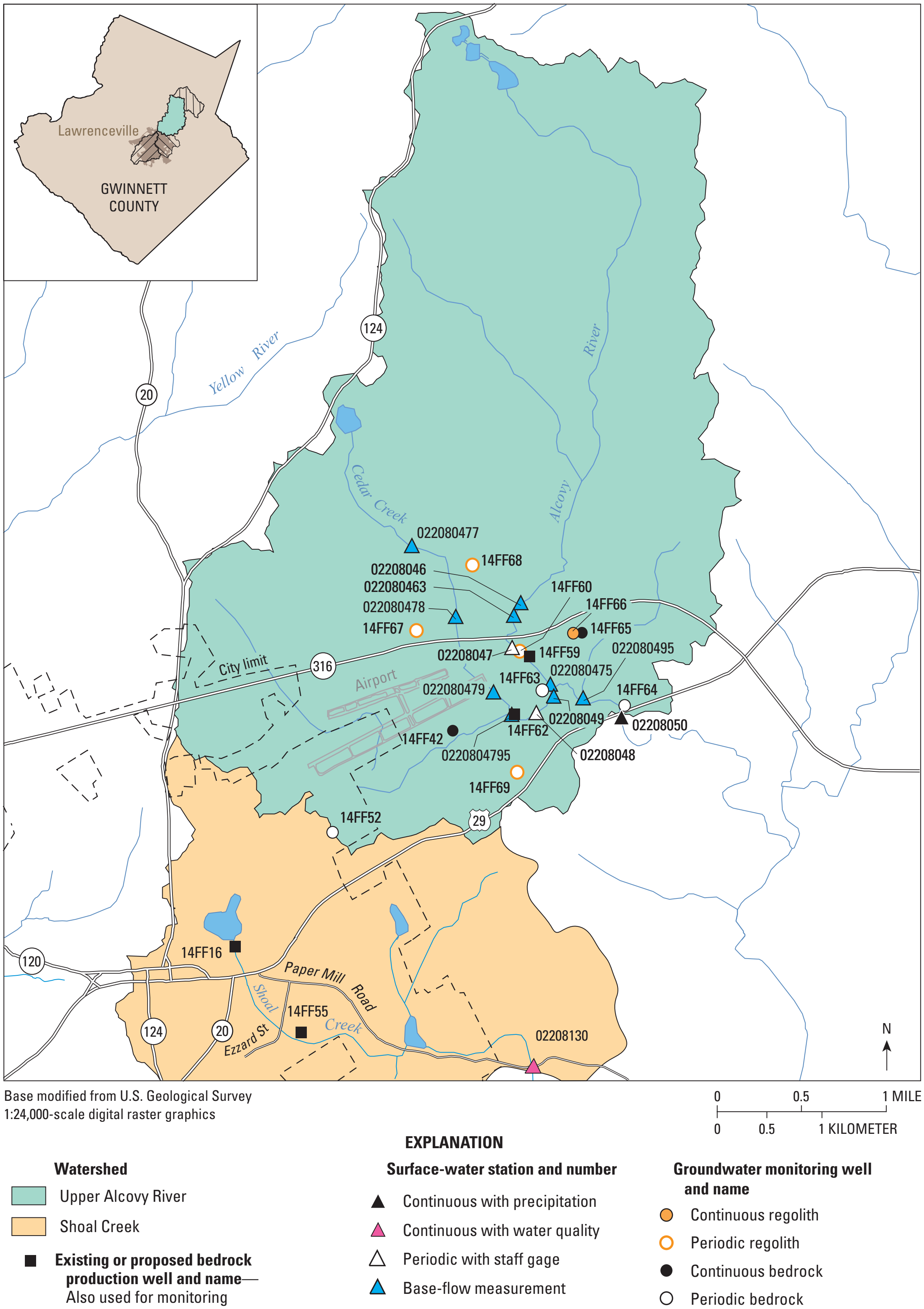


Figure 5. Surface-water and groundwater monitoring networks, upper Alcovy River watershed near Lawrenceville, Georgia, 2008.

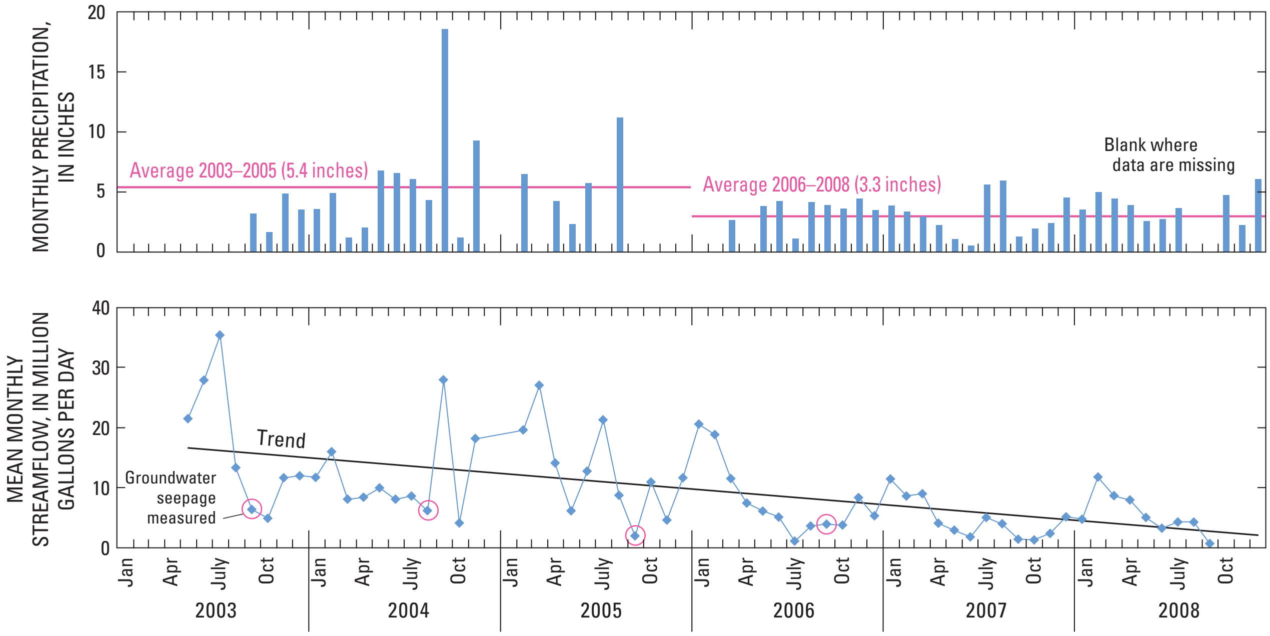


Figure 6. Total monthly precipitation and mean monthly streamflow at surface-water station 02208050, upper Alcovy River watershed near Lawrenceville, Georgia, 2003–2008. (See fig. 5 for location.)

Table 3. Base-flow measurements along selected stream reaches, upper Alcovy River watershed in the Lawrenceville area, Georgia, 2003–2006.

[mi², square miles; see figure 9 for reach locations; shaded cells represent reaches evaluated for groundwater seepage; —, no data]

Site identification	Station name	Intermediate drainage area (mi²)	Drainage area (mi²)	Base flow, in million gallons per day, and date measured			
				8/28/2003	8/31/2004	9/12/05–9/13/05	9/5/06–9/6/06
02208046	Alcovy River Hurricane Shoals Rd, near Dacula, GA		4.74	2.19	1.49	1.53	0.790
Reach AL-1	Intermediate area between sites 02208046 and 02208047	0.270	—	0.680	–0.370	–0.260	–0.090
02208047	Alcovy River at GA 316, near Lawrenceville, GA		5.01	2.87	1.11	1.27	0.700
Reach AL-2	Intermediate area between sites 00208047 and 022080475	0.100	—	0.170	0.060	0.220	–0.110
022080475	Alcovy River above Cedar Creek near Lawrenceville, GA		5.11	3.04	1.17	1.49	0.590
Reach AL-3	Area above site 022080477	0.624	—	—	—	—	0.070
022080477	Cedar Creek above Progress Center Ave, Lawrenceville, GA		0.624	—	—	—	0.070
Reach AL-4	Intermediate area between sites 022080477 and 022080478	0.880	—	—	—	—	0.350
022080478	Cedar Creek below Hurricane Shoals Road, Lawrenceville, GA		1.50	—	—	—	0.430
Reach AL-5	Intermediate area between sites 022080478 and 022080479	1.74	—	—	—	—	0.34
022080479	Cedar Creek below GA 316 at Lawrenceville, GA		3.24	1.73	1.02	0.710	0.760
Reach AL-6	Intermediate area between sites 022080479 and 02208048	0.840	—	0.120	0.210	0.050	0.070
02208048	Cedar Creek at Cedars Rd, near Lawrenceville, GA		4.08	1.85	1.23	0.760	0.830
Reach AL-7	Intermediate area between sites 02208048 and 02208049	0.020	—	0.160	–0.010	0.180	–0.180
02208049	Cedar Creek above Alcovy River at Lawrenceville, GA		4.10	2.01	1.23	0.940	0.650
Combined flow at sites 022080475, 02208049, and 022080495 compared to flow at site 02208050							
022080475	Alcovy River above Cedar Creek near Lawrenceville, GA		5.11	3.04	1.17	1.49	0.590
02208049	Cedar Creek above Alcovy River at Lawrenceville, GA		4.10	2.01	1.23	0.940	0.650
022080495	Alcovy River tributary at sewer cut near Lawrenceville, GA		0.630	—	—	—	0.060
Combined			9.22	—	—	—	1.31
Reach AL-8	Intermediate area between site 02208050 and combined flow at sites 022080475, 02208049, and 022080495	0.760	—	—	—	—	–0.210
02208050	Alcovy River near Lawrenceville, GA		10.0	5.36	3.43	1.62	1.10
Reach AL-9	Area above site 022080495		0.630	—	—	—	0.060
022080495	Alcovy River tributary at sewer cut near Lawrenceville, GA		0.630	—	—	—	0.060
			Minimum	**0.120**	**–0.370**	**–0.260**	**–0.210**
			Maximum	**0.680**	**0.210**	**0.220**	**0.350**
			Median	**0.160**	**0.030**	**0.120**	**0.060**

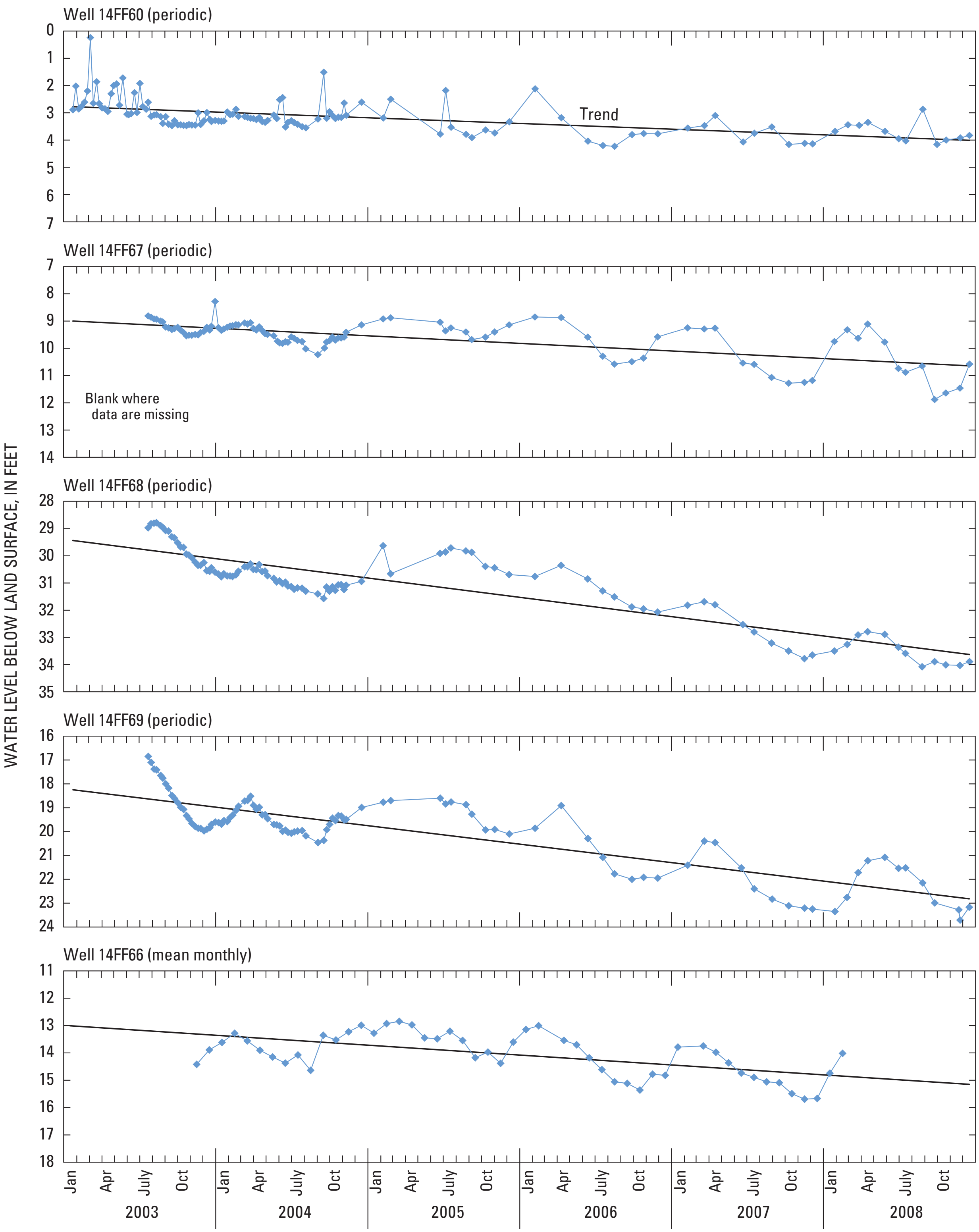


Figure 7. Groundwater levels in the regolith in the upper Alcovy River watershed near Lawrenceville, Georgia, 2003–2008. (See fig. 5 for location.)

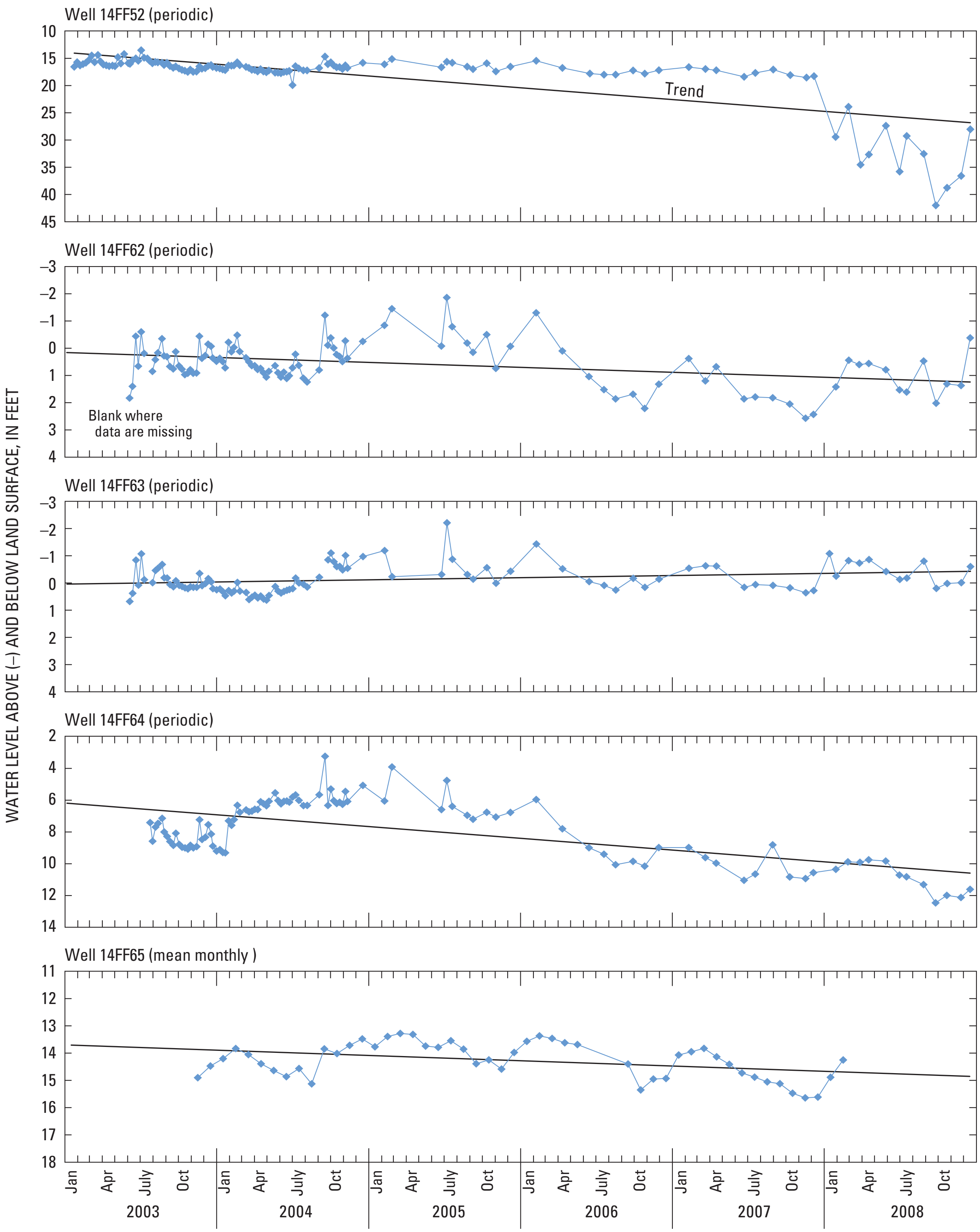


Figure 8. Groundwater levels in the bedrock in the upper Alcovy River watershed near Lawrenceville, Georgia, 2003–2008. (See fig. 5 for location.)

Seepage values in this report are in million gallons per day, rather than in the more commonly used cubic feet per second, to facilitate comparison to groundwater pumping rates.

Multiple-year records of seepage data are available for reaches AL-1, AL-2, AL-6, and AL-7 (fig. 9). During August 2003—a period of relatively high precipitation (fig. 6)—each of the four reaches showed seepage gains (fig. 9). In September 2006, three of the four reaches showed seepage loss corresponding to a period of reduced precipitation as effects of the drought began to take effect. During the summers of 2004–2006 reach AL-6 remained gaining, with seepage ranging from 0.05 to 0.21 Mgal/d. The largest change in seepage during 2003–2006 occurred at reach AL-1, where a seepage gain of 0.68 Mgal/d in 2003 changed to seepage losses ranging from 0.09 to 0.37 Mgal/d during 2004–2006. The reason for this large change is unclear but may be related to decreased precipitation and changes in drainage patterns or impervious area that reduce recharge and (or) runoff.

The most extensive monitoring effort was conducted in September 2006, when seepage in all nine reaches was measured, as shown on the map in figure 9. During this period, seepage gains were measured at five of the nine reaches evaluated, with losses measured at the other four reaches. The four losing reaches were near the confluence of the Alcovy River and Cedar Creek where the stream gradient is low, regolith is thin, and bedrock is at or near land surface, limiting the amount of storage available to replenish streamflow. September 2006 was a period of low precipitation resulting in low streamflow and groundwater levels.

In losing reaches, it is likely the water table fell near or beneath stream stage, resulting in a decrease or reversal of the hydraulic gradient between groundwater and the stream. A decreased gradient would result in a decrease in groundwater discharge to the stream; a gradient reversal would result in movement of water from the stream into the aquifer. Head relations between Alcovy River stage and groundwater are shown with hydrographs for surface-water station 02208047 and regolith well 14FF60 during 2003–2008 (fig. 10). Altitudes of stream stage and groundwater levels are similar, with groundwater levels slightly higher than stream levels, indicating a gradient from the aquifer into the stream. Because altitudes are similar, a slight change in stage or head could change the magnitude and direction of flow, as were apparent during dry conditions in the summer and fall of 2006–2008 when stream stage and groundwater levels were nearly coincident. Lowering of the water table can sometimes be caused by nearby groundwater pumping; however, the nearest groundwater pumping is in the Shoal Creek watershed, greater than 2.5 mi to the southwest.

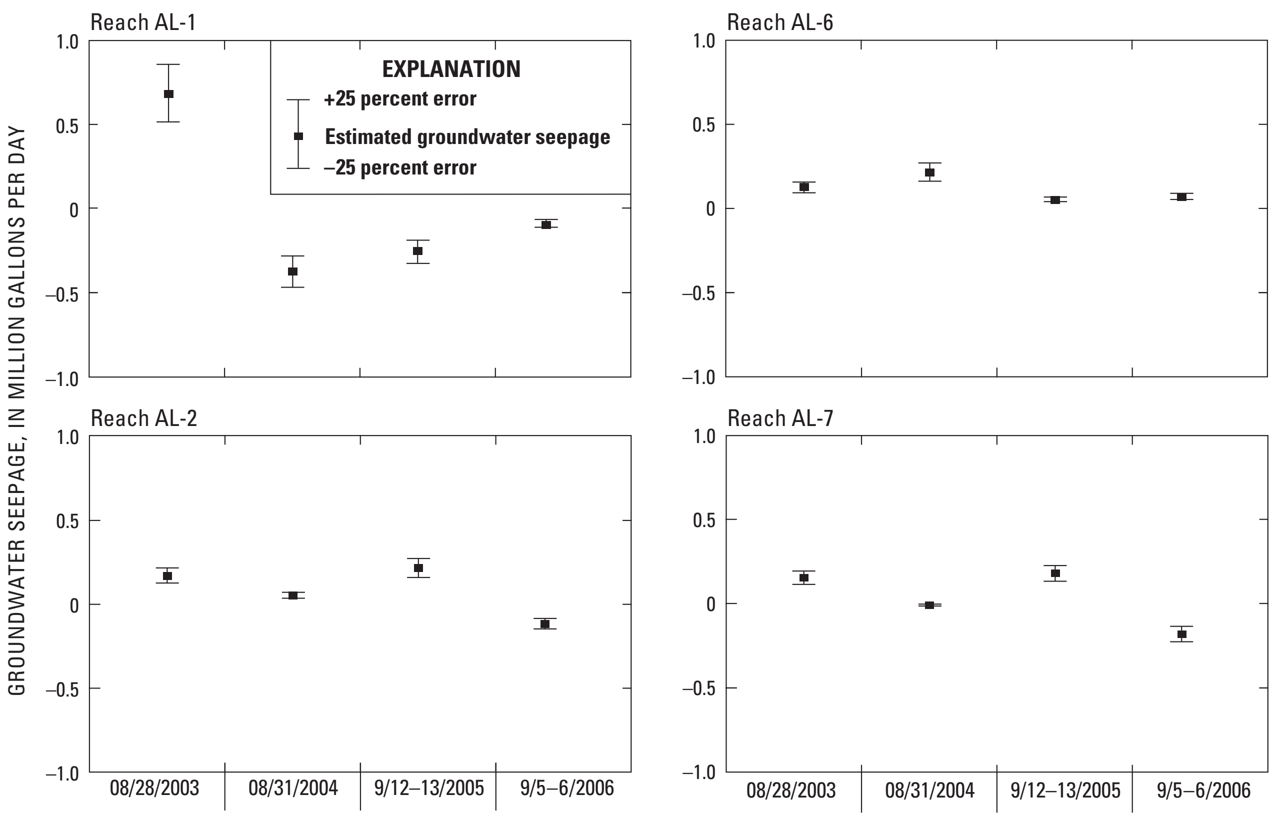
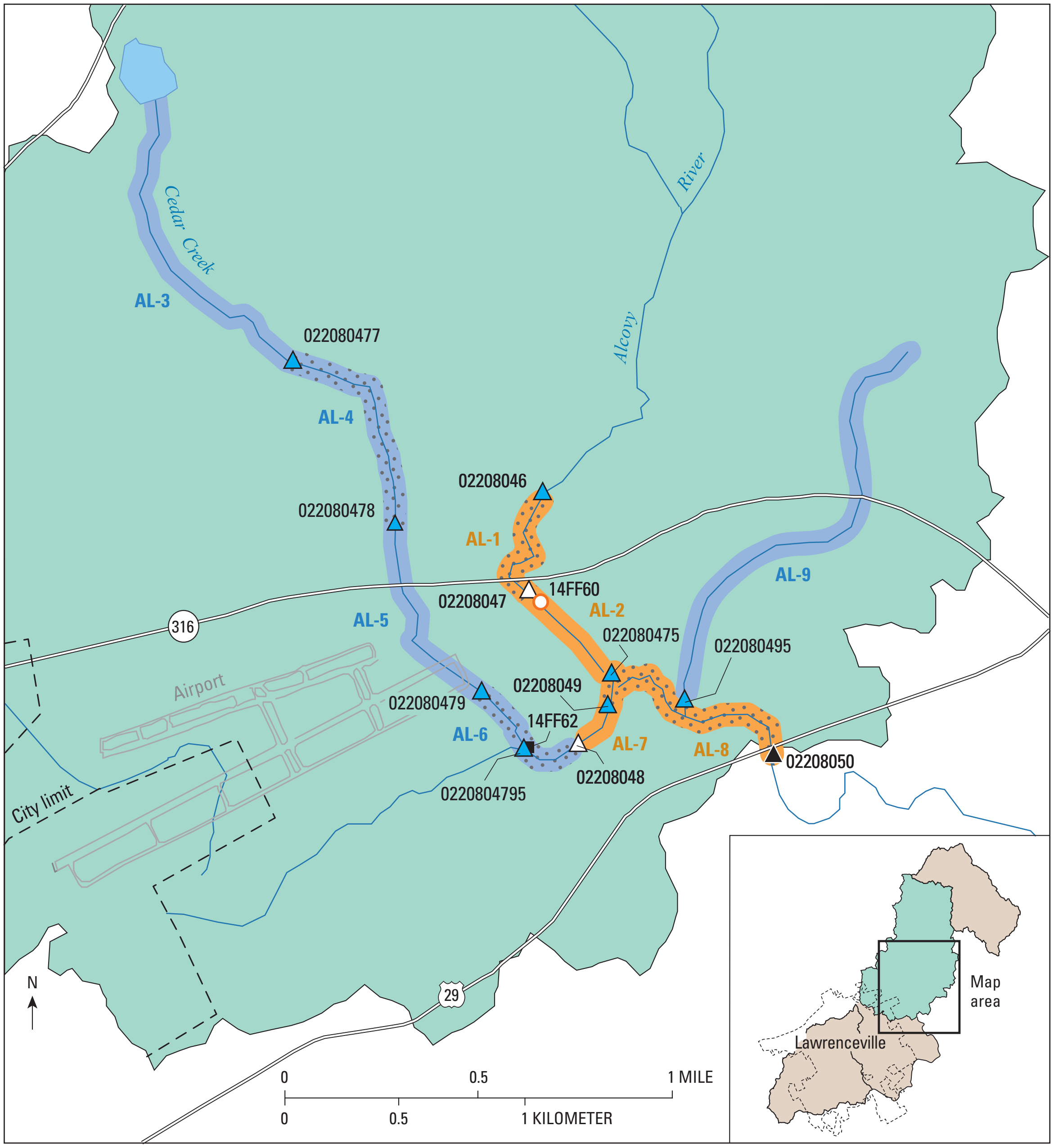


Figure 9. Groundwater seepage along selected reaches in the upper Alcovy River watershed near Lawrenceville, Georgia, 2003–2006.



Base modified from U.S. Geological Survey
1:24,000-scale digital raster graphics

EXPLANATION

Groundwater seepage, September 2006— Pattern shown to differentiate between stream reaches. Number is stream-reach identifier listed in table 3

AL-5 Stream reach with net gain in seepage

AL-2 Stream reach with net loss in seepage

Upper Alcovy River watershed

Existing or proposed bedrock production well and name— Also used for monitoring

Groundwater monitoring well and name

Periodic regolith

Surface-water station and number

Continuous with precipitation

Periodic with staff gage

Base-flow measurement

Figure 9. Groundwater seepage along selected reaches in the upper Alcovy River watershed near Lawrenceville, Georgia, 2003–2006.—Continued

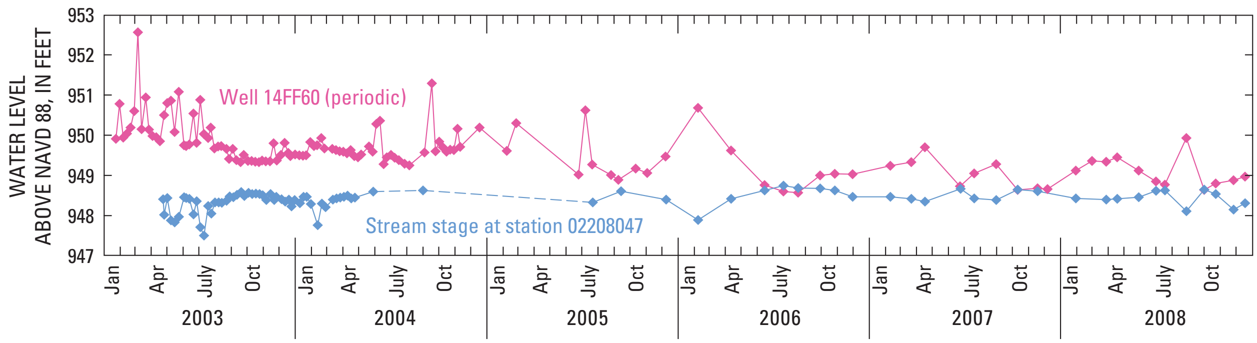


Figure 10. Stream stage at surface-water station 02208047 and groundwater levels in regolith well 14FF60, upper Alcovy River watershed near Lawrenceville, Georgia, 2003–2008. (See fig. 9 for location.)

Redland–Pew Creek Watershed

The Redland–Pew Creek watershed covers a 7.49-mi^2 area in the southwestern part of the study area (fig. 11). The watershed is part of the larger Yellow River watershed, and is the most urbanized of the watersheds included in this study, with a greater proportion of high density land use according to maps presented by Landers and others (2007). Several well sites in this area have been identified for development of groundwater supplies for the city, including well 13FF18, which was brought online in the fall of 2008.

Monitoring Networks

To assess hydrologic conditions and trends in the Redland–Pew Creek watershed, streamflow and precipitation data have been continuously recorded at Pew Creek at Patterson Road (02205522) since March 2003 (table 2, fig. 11). Eleven additional surface-water sites were visited periodically during 2003–2008 for measurement of base-flow conditions.

Streamflow, precipitation, specific conductance, temperature, and turbidity data are continuously monitored at surface-water station 02205522. Intermittent water-quality samples are collected for quality assurance and for characterization of storm events. Water-quality information for this site is described in the “Stream-Water Quality” section of this report.

During 2008, groundwater levels in the Redland–Pew Creek watershed were continuously monitored in wells 13FF30 (bedrock) and well 13FF31 (regolith) at a multi-well cluster to provide insight into vertical head relations between the bedrock and overlying regolith (table 1, fig. 11). In addition to continuously recording wells, periodic water-level measurements were made in 7 wells in the Redland–Pew Creek watershed, and 4 wells in the adjacent Yellow River watershed, for a total of 11 wells. Of the 11 wells with periodic measurements, 7 are completed in bedrock, and 4 are completed in regolith.

Hydrologic and Precipitation Trends

During 2003–2008, streamflow and precipitation in the Redland–Pew Creek watershed showed a general downward trend (fig. 12). Although there are gaps in the record, precipitation was generally greater during 2003–2005 than in 2006–2008, with average monthly totals of 4.42 inches and 3.25 inches, respectively. Lower precipitation during 2006–2008 resulted in a corresponding decrease in streamflow and groundwater levels. At surface-water station 02205522, the lowest mean monthly flow during 2003–2008, was 1.09 Mgal/d in September 2008 (fig. 12).

During 2003–2008, water levels declined in 12 of the 13 wells monitored in the Redland–Pew Creek and Yellow River watersheds, corresponding to decreased precipitation and changes in pumping (figs. 13 and 14). The magnitude of decline was similar in regolith and bedrock wells, ranging mostly between 2.8 and 6.5 ft, with considerably greater declines in bedrock wells 13FF16 (40.4 ft) and 13FF13 (49.1 ft). The water-level change in well 13FF16 represented a temporary decline during a water-sampling event in September 2008. In well 13FF13, water levels showed little decline (0.34 ft) during January 2003–July 2008; however, a pronounced water-level decline of 36.8 ft was observed beginning in August through December 2008. This accelerated decline corresponded to the initiation of pumping in well 13FF18, located about 0.3 mi west of well 13FF13 (fig. 11). This decline is due to the pumping drawdown that extends out in an east-west direction along the trend of foliation-parallel partings identified in well logs collected in these wells (Williams and others, 2004). The amount of drawdown observed at well 13FF13 is similar to the drawdown observed during an aquifer test conducted at well 13FF18 (Williams and others, 2005).

Not all of the wells in the area showed a decreasing trend. Water levels in bedrock well 13FF20 generally rose during 2003–2008 (fig. 14). The well is located in an upland area of the adjacent Yellow River watershed. The reason for rising

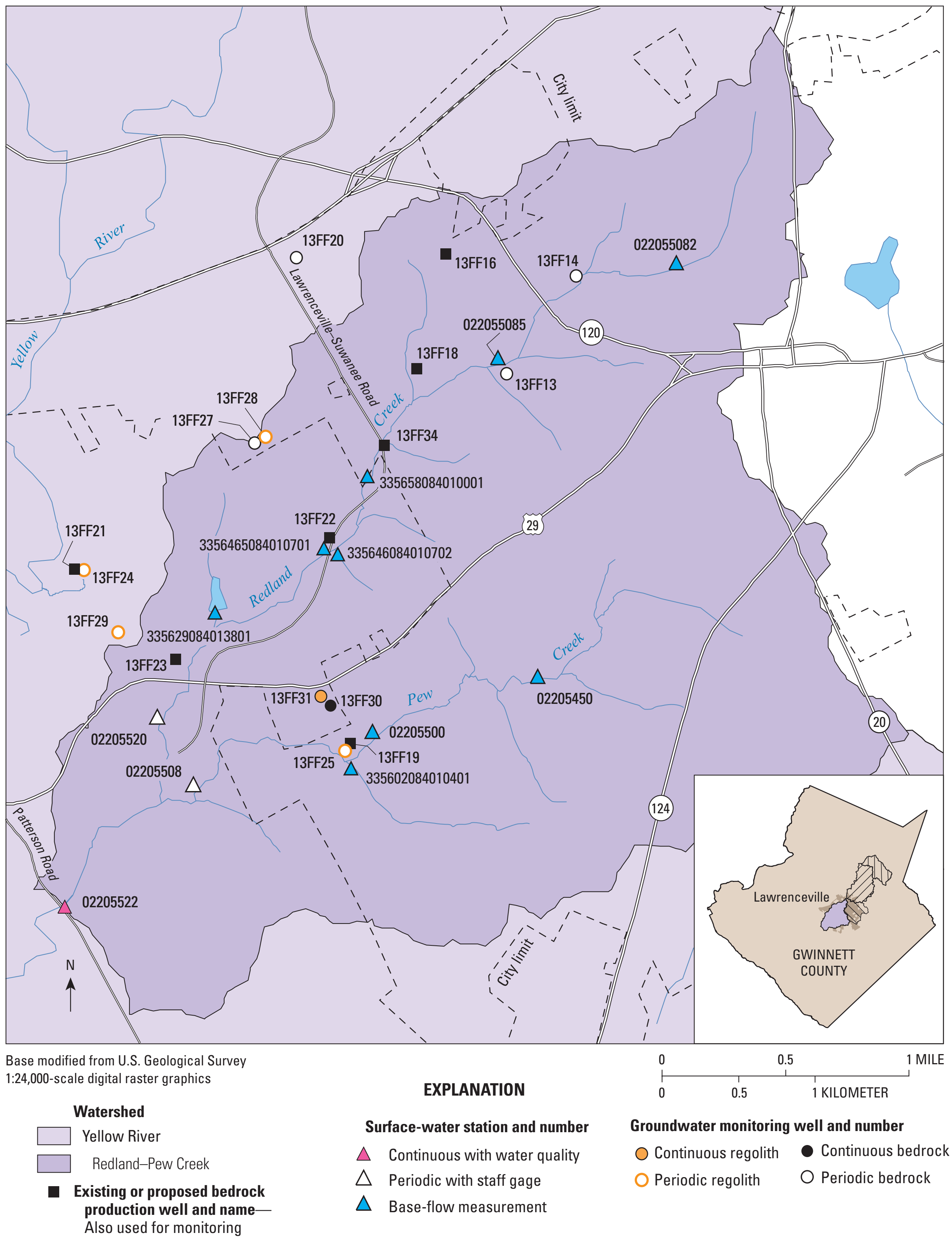


Figure 11. Surface-water and groundwater monitoring networks, Redland–Pew Creek and Yellow River watersheds near Lawrenceville, Georgia, 2008.

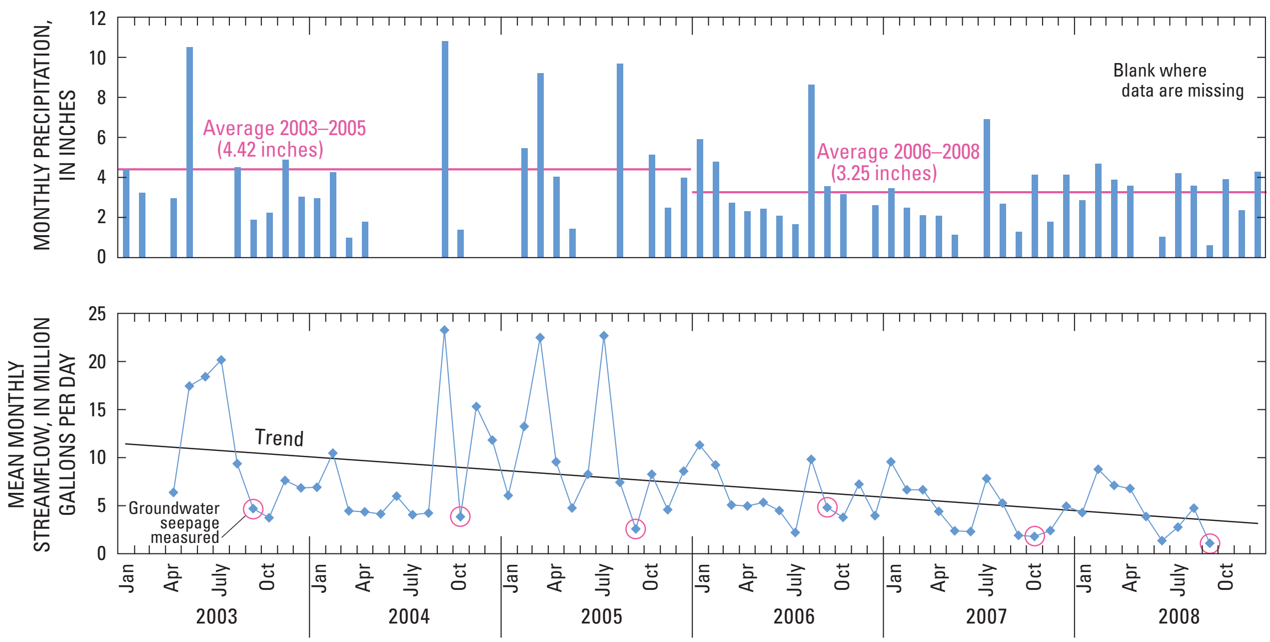


Figure 12. Total monthly precipitation and mean monthly streamflow at surface-water station 02205522, Redland–Pew Creek watershed near Lawrenceville, Georgia, 2003–2008.

water levels in this well is not clear at this time, although it may be related to new landscaping and runoff controls that may have affected recharge to the bedrock.

To evaluate changes in base-flow conditions in selected stream reaches in the Redland–Pew Creek watershed, periodic streamflow measurements were made during periods of low rainfall in September 2003, October 2004, September 2005, September 2006, October 2007, and September 2008 (table 4; figs. 12 and 15). Net gain or loss of streamflow (seepage) during these dry or base-flow periods is representative of the interaction between surface and groundwater—when positive, there is a net gain in groundwater inflow; when negative, there is a net loss of streamflow to the groundwater system. Seepage was evaluated for the following stream reaches:

- Reach RP-1: area above site 02205450;
- Reach RP-2: intermediate area between sites 02205450 and 02205500;
- Reach RP-3: area above site 335602084010401;
- Reach RP-4: area above site 022055082;
- Reach RP-5: intermediate area between sites 022055082 and 022055085;
- Reach RP-6: intermediate area between sites 022055085 and 335658084010001;
- Reach RP-7: intermediate area between sites 335658084010001 and 335646084010701;
- Reach RP-8: area above site 335629084013801;
- Reach RP-9: area above site 335646084010702;
- Reach RP-10: intermediate area between 02205522 and combined flow at 02205520 and 02205508;
- Reach RP-11: intermediate area between 02205508 and combined flow at 02205500 and 335602084010401; and
- Reach RP-12: intermediate area between 02205520 & combined flow at 335646084010701, 335646084010702, and 335629084013801.

Seepage measurements collected during 2003–2008 indicate that with the exception of reach RP-10, most stream reaches were gaining throughout the period (fig. 15). Multiple-year records of seepage data are available for all reaches except for RP-6, RP-7, and RP-8. For sites with multiple-year records, net seepage was positive during each of the measurement periods, with the exceptions of reach RP-10, which was negative during 2003–2005 and in 2007, and reach RP-9, which was zero during 2007 and near zero during 2006 and 2008. Maximum seepage gains during 2003–2008 were observed in reaches RP-1, RP-2 and RP-10, ranged from 0.23 to 1.17 Mgal/d.

During September 2008, seepage measurements were made at 10 of the 12 reaches. Although each of the 10 sites was gaining water, median seepage was 0.03 Mgal/d, the lowest observed during 2003–2008 (table 4). September 2008 was a period of low precipitation (fig. 12) that resulted in low streamflow and groundwater levels.

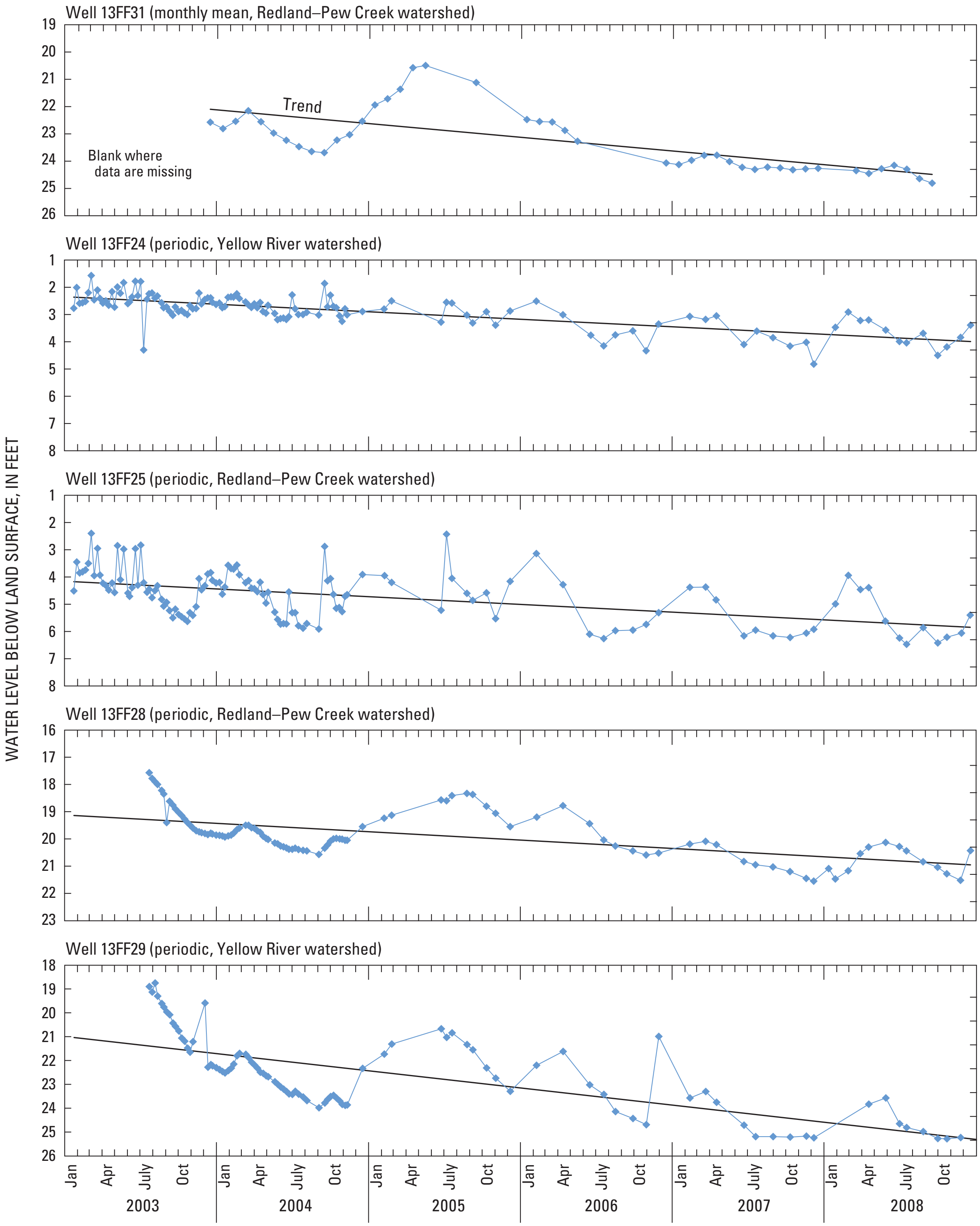


Figure 13. Groundwater levels in the regolith in the Redland–Pew Creek and Yellow River watersheds near Lawrenceville, Georgia, 2003–2008. (See fig. 11 for location.)

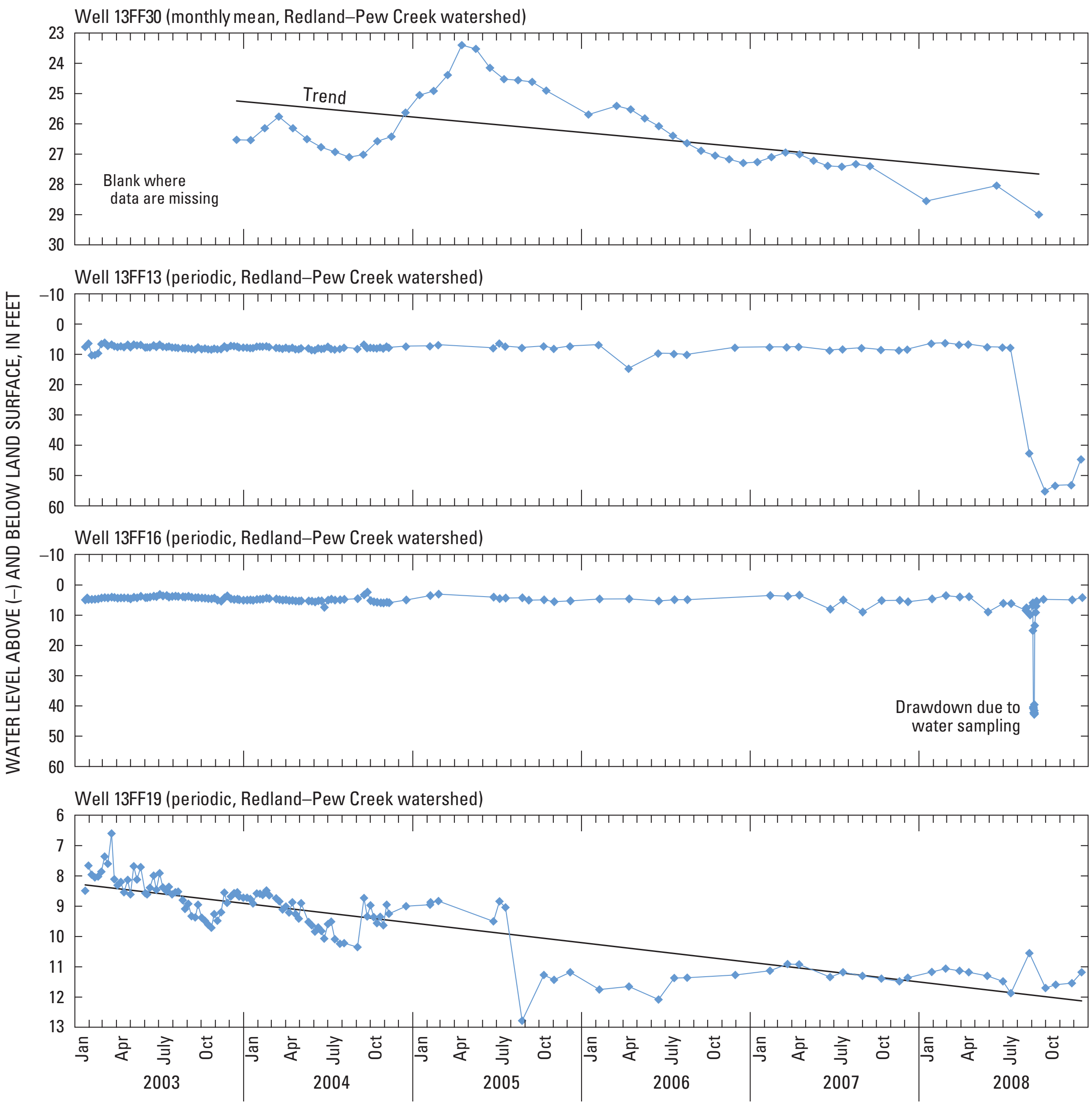


Figure 14. Groundwater levels in the bedrock in the Redland–Pew Creek and Yellow River watersheds near Lawrenceville, Georgia, 2003–2008. (See fig. 11 for location.)

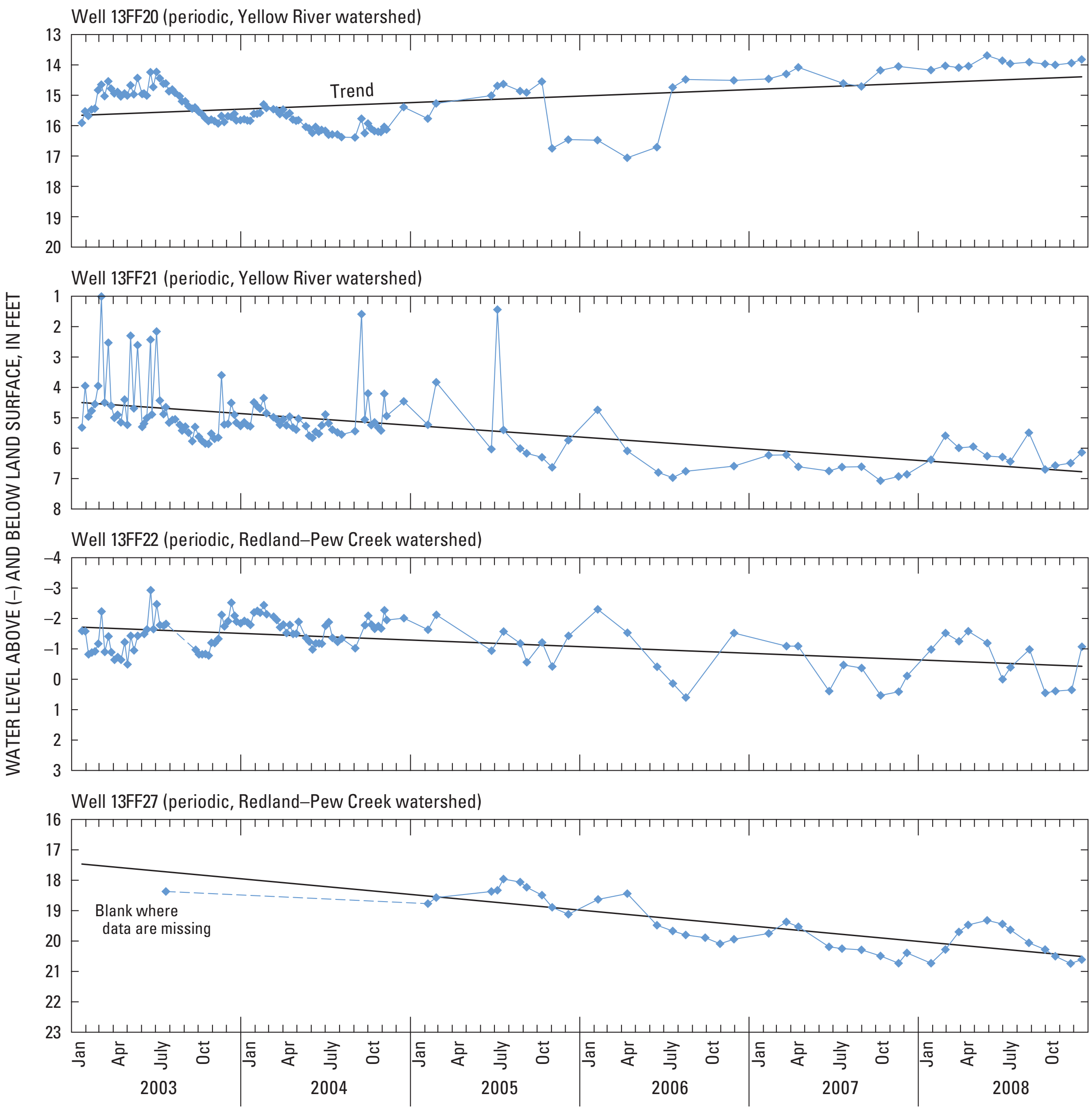


Figure 14. Groundwater levels in the bedrock in the Redland–Pew Creek and Yellow River watersheds near Lawrenceville, Georgia, 2003–2008. (See fig. 11 for location.)—Continued

Table 4. Base-flow measurements along selected stream reaches, Redland–Pew Creek watershed, Lawrenceville, Georgia area, 2003–2006.

[mi², square miles; see figure 15 for reach locations; shaded cells represent reaches evaluated for groundwater seepage; <, less than; —, no data]

Site identification	Station name	Intermediate drainage area (mi²)	Drainage area (mi²)	Base flow, in million gallons per day, and date measured					
				9/8/2003	10/28/2004	9/12/2005	9/5/2006	10/17/2007	9/8/2008
Reach RP-1	Area above site 02205450	1.82	—	0.58	0.83	—	0.32	0.23	0.25
02205450	Pew Creek at Sarah Lane, at Lawrenceville, Ga		1.82	0.58	0.83	—	0.32	0.23	0.25
Reach RP-2	Intermediate area between sites 02205450 and 02205500	0.410	—	—	—	—	0.37	0.11	0.03
02205500	Pew Creek near Lawrenceville, GA		2.23	—	—	—	0.69	0.34	0.28
Reach RP-3	Area above site 335602084010401	0.599	—	—	—	—	0.17	0.12	0.10
335602084010401	Pew Creek tributary below Johnston Rd, Lawrenceville, GA		0.599	—	—	—	0.17	0.12	0.10
Reach RP-4	Area above site 022055082	0.471	—	0.22	0.21	0.10	0.06	0.06	0.08
022055082	Redland Creek at Maltble St near Lawrenceville, GA		0.471	0.22	0.21	0.10	0.06	0.06	0.08
Reach RP-5	Intermediate area between sites 022055082 and 022055085	0.480	—	0.33	0.29	0.35	0.12	0.02	0.01
022055085	Redland Creek below GA 120 at Lawrence- ville, GA		0.954	0.56	0.49	0.45	0.19	0.08	0.10
Reach RP-6	Intermediate area between sites 335658084010001 and 022055085	1.43	—	—	—	—	0.30	—	—
335658084010001	Redland Creek at Lville Suwanee Rd No 2, Lawrenceville, GA		2.38	—	—	—	0.49	—	—
Reach RP-7	Intermediate area between sites 335658084010001, 335645084010701	0.190	—	—	—	—	0.09	—	—
335645084010701	Redland Creek at Lville Suwanee Rd, Lawrenceville, GA		2.57	—	—	—	0.57	0.30	0.32
Reach RP-8	Area above site 335629084013801	0.241	—	—	—	—	0.06	—	0.03
335629084013801	Redland Creek tributary near Monfort Rd, Lawrenceville, GA		0.241	—	—	—	0.06	—	0.03
Reach RP-9	Area above site 335646084010702	0.093	—	—	—	—	0.02	dry	< 0.01
335646084010702	Redland Creek tributary at Lville Suwanee Rd, Lawrenceville, GA		0.093	—	—	—	0.02	dry	< 0.01

Table 4. Base-flow measurements along selected stream reaches, Redland–Pew Creek watershed, Lawrenceville, Georgia area, 2003–2006.—Continued

[mi², square miles; see figure 15 for reach locations; shaded cells represent reaches evaluated for groundwater seepage; <, less than]

Site identification	Station name	Intermediate drainage area (mi²)	Drainage area (mi²)	Base flow, in million gallons per day, and date measured					
				9/8/2003	10/28/2004	9/12/2005	9/5/2006	10/17/2007	9/8/2008
	Combined flow at sites 02205520 and 02205508								
02205520	Redland Creek at GA 29, near Lawrenceville, GA		3.11	1.25	1.36	0.96	0.80	0.41	0.37
02205508	Pew Creek at Sugarloaf Pkwy, near Lawrence-ville, GA		3.43	3.10	2.04	1.74	1.17	0.49	0.45
Combined			6.54	4.35	3.39	2.70	1.97	0.90	0.83
Reach RP-10	Intermediate area between site 02205522 and combined flow at sites 02205520 and 02205508	0.950	—	–1.03	–0.61	–0.50	0.29	–0.13	1.17
	Combined flow at sites 02205522, 02205500, and 335602084010401								
02205522	Pew Creek at Patterson Rd, near Lawrenceville, GA		7.49	3.32	2.78	2.20	2.26	0.78	2.00
02205500	Pew Creek near Lawrenceville, GA		2.23	—	—	—	0.69	0.34	0.28
335602084010401	Pew Creek tributary below Johnston Rd, Lawrenceville, GA		0.60	—	—	—	0.17	0.12	0.10
Combined			2.83	—	—	—	0.86	0.46	0.38
Reach RP-11	Intermediate area between site 02205508 and combined flow at sites 02205500 and 335602084010401	0.601	—	—	—	—	0.31	0.03	0.08
	Combined flow at sites 02205508, 335629084013801, 335645084010701, and 335646084010702								
02205508	Pew Creek at Sugarloaf Pkwy, near Lawrence-ville, GA		3.43	2.13	2.04	1.74	1.17	0.49	0.45
335629084013801	Redland Creek tributary near Monfort Rd, Lawrenceville, GA		0.24	—	—	—	0.06	0.00	0.03
335645084010701	Redland Creek at Lville Suwanee Rd, Lawrenceville, GA		2.57	—	—	—	0.57	0.30	0.32
335646084010702	Redland Creek tributary at Lville Suwanee Rd, Lawrenceville, GA		0.09	—	—	—	0.02	dry	0.00
Combined			2.90	—	—	—	0.65	—	0.35
Reach RP-12	Intermediate area between site 02205520 and combined flow at sites 335645084010701, 335646084010702, 335629084013801	0.207	—	—	—	—	0.15	—	0.03
02205520	Redland Creek at GA 29, near Lawrenceville, GA		3.11	1.25	1.36	0.96	0.80	0.41	0.37
			Minimum	**–1.03**	**–0.61**	**–0.50**	**0.02**	**–0.13**	**0.00**
			Maximum	**0.58**	**0.83**	**0.35**	**0.37**	**0.23**	**1.17**
			Median	**0.28**	**0.25**	**0.10**	**0.16**	**0.06**	**0.05**

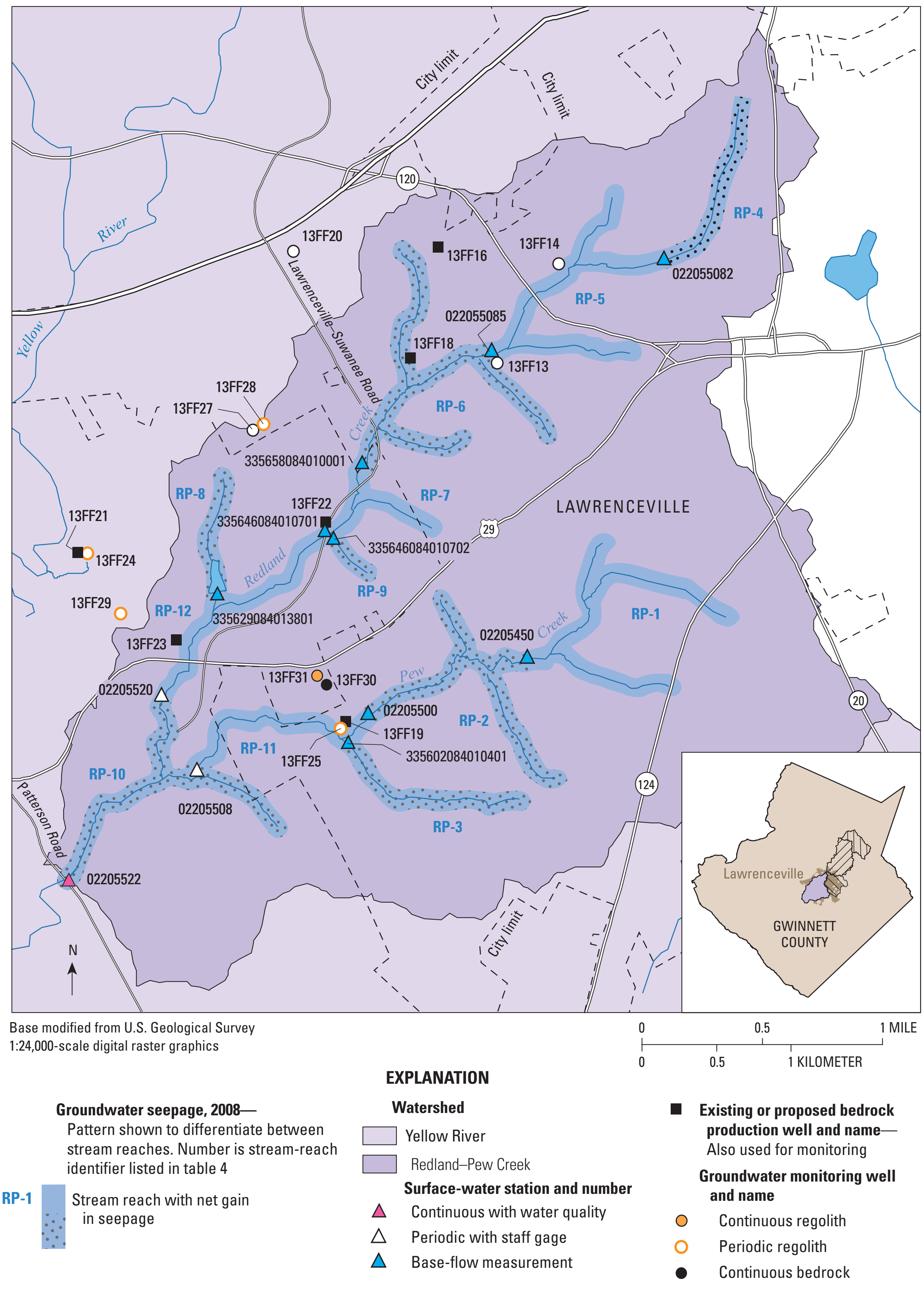


Figure 15. Groundwater seepage along selected reaches in the Redland–Pew Creek watershed near Lawrenceville, Georgia, 2003–2008.

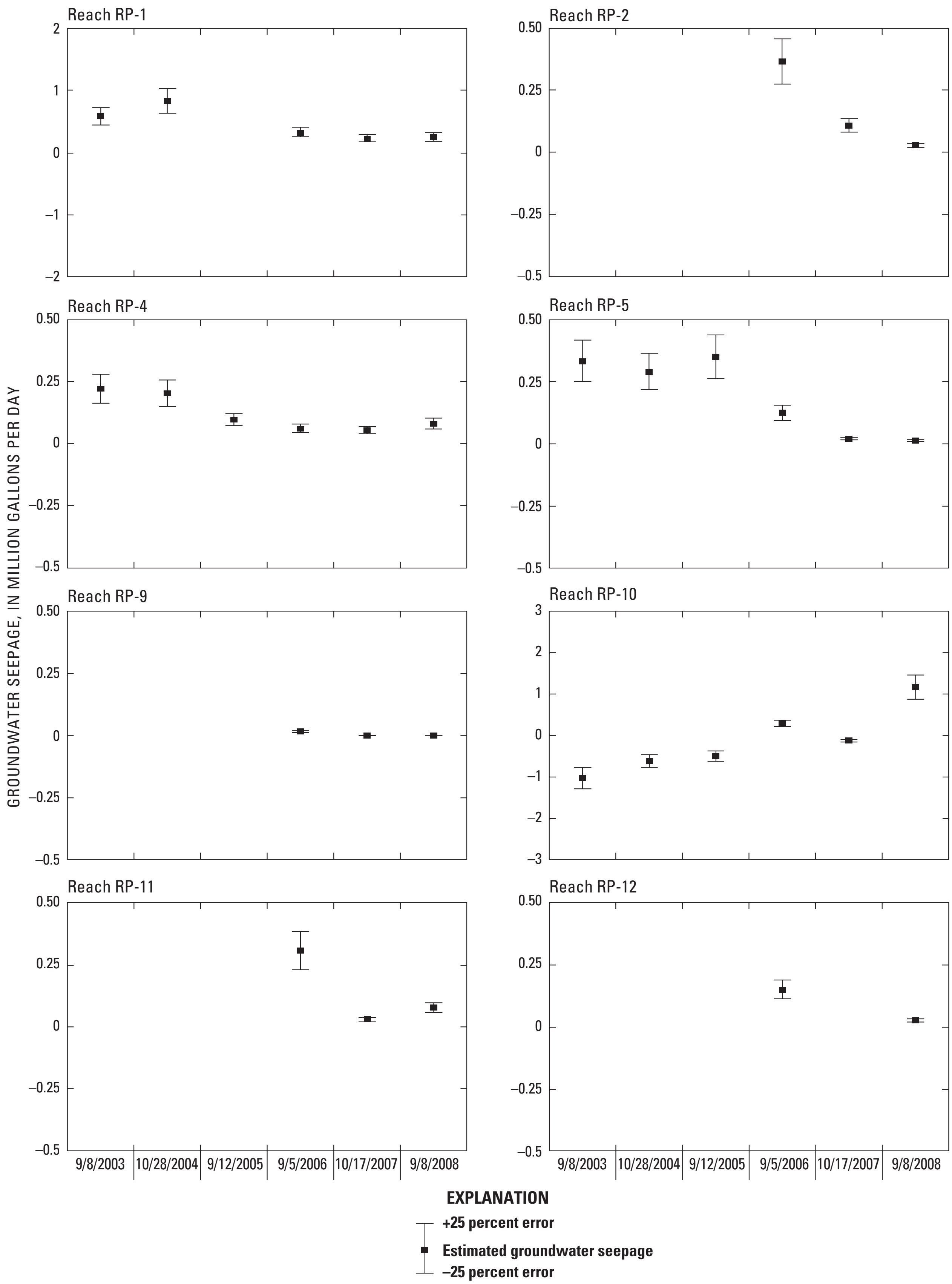


Figure 15. Groundwater seepage along selected reaches in the Redland–Pew Creek watershed near Lawrenceville, Georgia, 2003–2008.—Continued

Stream-Water Quality

Continuous water-quality data are collected at gage sites located on Pew Creek and Shoal Creek inside the city limits and at a background site on the Apalachee River located outside the city boundary (fig. 1). These sites provide long-term data for various water-quality properties to help better characterize stormwater runoff. These sites are used to continuously monitor precipitation, water temperature, specific conductance, and turbidity. In addition, water samples are collected at the sites to monitor fecal bacteria at Pew and Shoal Creeks, using the geometric mean method for comparison with State water-quality regulations. Because streamflow characteristics are a primary control of nonpoint-source-associated water quality (Hirsch and others, 2006), continuous stream stage and discharge are continuously monitored at the stream-water-quality sites. The sites are

- 02218565—Apalachee River at Fence Road near Dacula (fig. 3),
- 02205522—Pew Creek at Patterson Road, about 0.8 mi southwest of Lawrenceville (fig. 11), and
- 02208130—Shoal Creek at Paper Mill Road, about 0.3 mi east of Lawrenceville (fig. 5).

Monitoring at the Pew and Shoal Creek sites is funded through the Lawrenceville CWP, and monitoring at the Apalachee River site is funded by the Gwinnett County CWP.

A statistical summary of mean and median daily streamflow, precipitation, water temperature, specific conductance, and turbidity is listed in table 5. Additional data are summarized for each site in the USGS Annual Water Data Reports for Georgia (*http://wdr.water.usgs.gov/*). These archival products supplement direct access to current and historical water data provided by the USGS National Water Information System (*http://waterdata.usgs.gov/ga/nwis/*). Beginning with water year 2006 (defined as the period from October 1, 2005 through September 30, 2006), Annual Water Data Reports are available as individual electronic Site Data Sheets for retrieval, download, and localized printing on demand.

Apalachee River

Based on comparison of land-use maps presented in Landers and others (2007), the 5.68-mi^2 upper Apalachee River watershed in the northeastern part of the study area (fig. 3) has less transportation land use and less high and low density development than the upper Alcovy River and Redland–Pew Creek watersheds located to the southwest. Water-quality monitoring at the Upper Apalachee station (02218565) began in July 2001, and includes real-time monitoring of discharge, specific conductance, water temperature, turbidity, and precipitation, and collection of intermittent water-quality samples for quality assurance and to characterize water quality during storm events.

In comparison to the water quality at the other two stream sites, water at the Apalachee River site had the lowest mean and median values for specific conductance and water temperature and the greatest mean and median values for turbidity during October 2005–December 2008 (table 5). Continuous surface-water monitoring data indicate that changes in stream water-quality properties may be related to decreased streamflow during the 2006–2008 drought (fig. 16). During this drought period, streamflow and values of turbidity were generally lower than during 2003–2005, whereas water temperature and specific conductance were generally higher. Water temperature varies seasonally in response to air temperature, with highest values in the summer months.

In addition to water-quality monitoring, 29 fecal coliform samples were collected at the Apalachee River site during October 2005 through July 2008 (fig. 17). Bacteria counts ranged from a low of 44 most probable number of colonies per 100 MPN col/100 mL in December 2006, to a high of 31,000 MPN col/100 mL in October 2005. Fecal coliform standards for drinking-water supply, fishing, and recreation are listed in table 6. None of the samples at the Apalachee River site during November–April were above the Georgia Environmental Protection Division (GaEPD) single sample limit of 4,000 MPN col/100 mL for November–April.

Table 5. Statistical summary of mean and median daily streamflow, precipitation, stream temperature, specific conductance, and turbidity data for surface-water sites in the Lawrenceville area, Georgia, October 1, 2005, through December 31, 2008.

Statistic	Pew Creek at Patterson Road (02205522)	Apalachee River at Fence Road (02218565)	Shoal Creek at Paper Mill Road (02208130)
Streamflow, in cubic feet per second			
Minimum	0.650	0.300	0.410
Maximum	161	99.0	247
Mean	8.01	5.78	5.74
Median	4.10	3.35	2.70
Precipitation, in inches			
Minimum	0.00	0.000	0.000
Maximum	3.50	4.18	2.97
Mean	0.110	0.110	0.110
Median	0.000	0.000	0.000
Stream temperature, in degrees Celsius			
Minimum	2.70	2.60	3.10
Maximum	25.6	25.6	26.3
Mean	15.5	15.2	15.8
Median	15.7	15.1	15.8
Specific conductance, in microsiemens per centimeter at 25 degrees Celsius			
Minimum	45.0	44.0	44.0
Maximum	152	196	157
Mean	103	67.9	81.6
Median	107	69.0	82.0
Turbidity, in formazin nephelometric units			
Minimum	2.00	2.00	2.00
Maximum	100	182	90.0
Mean	8.05	11.6	9.04
Median	4.20	6.20	6.00

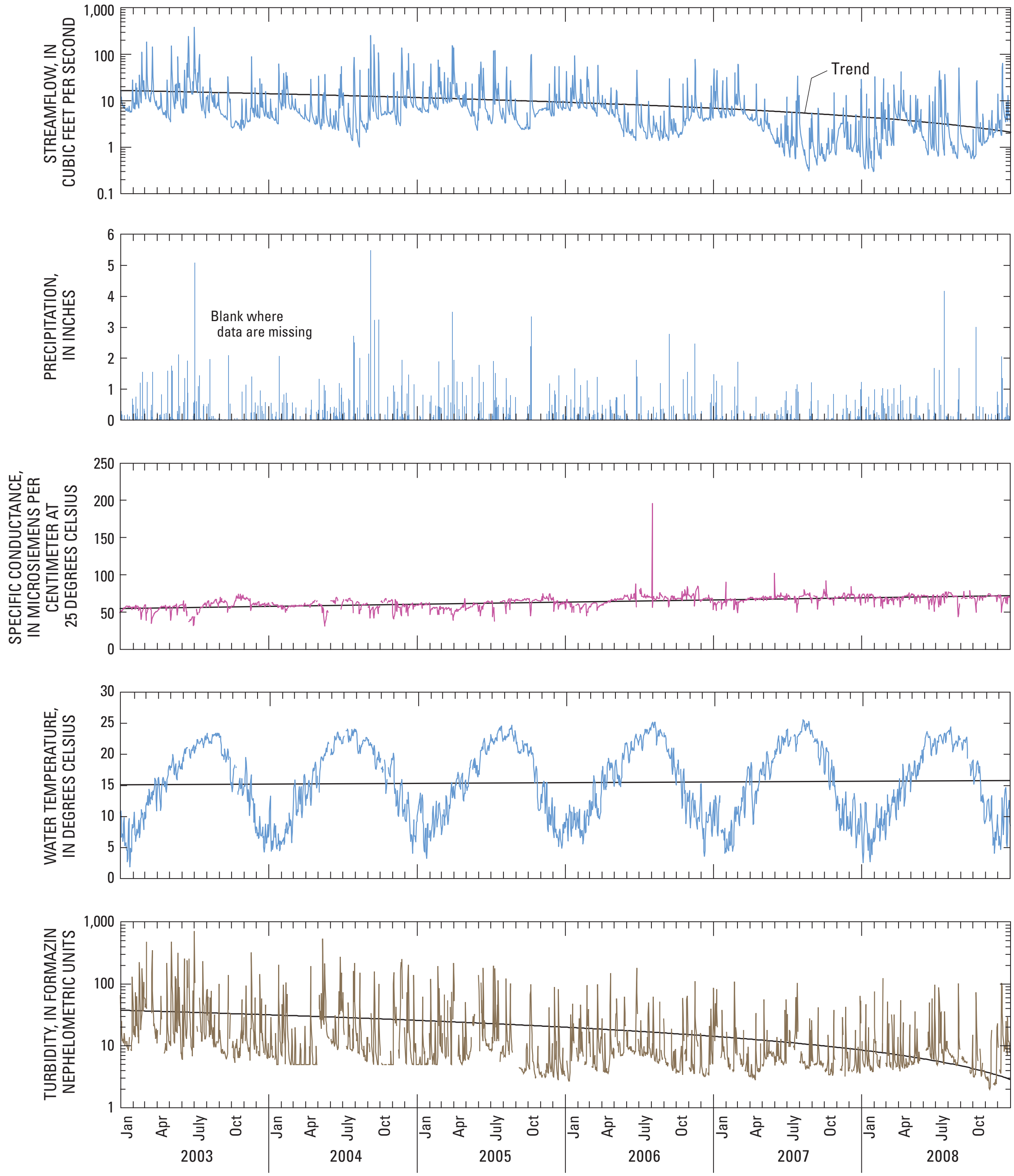


Figure 16. Mean daily streamflow, precipitation, specific conductance, and water temperature, and median daily turbidity at surface-water station 02218565, Apalachee River at Fence Road near Dacula, Georgia, 2003–2008. (See fig. 3 for location.)

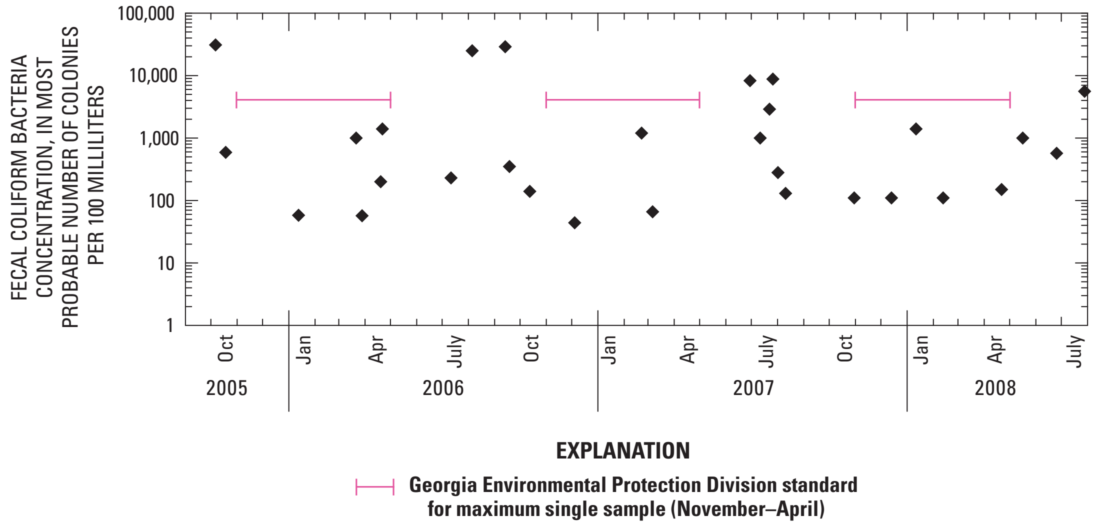


Figure 17. Fecal coliform sampling results for surface-water station 02218565, Apalachee River at Fence Road near Dacula, Georgia, 2005–2008. (See fig. 3 for location.)

Table 6. Georgia Environmental Protection Division fecal coliform bacteria standards (modified from Georgia Department of Natural Resources, 1994; Gregory and Frick, 2000).

[All standards and criterion are in most probable number of colonies per 100 milliliters (MPN col/100 mL); —, no standard or criterion]

Designated use	Time of year that standards apply	30-day geometric mean[1]	Maximum single sample
Drinking-water supply and fishing	May–October	200	—
	November–April	1,000	4,000
Recreation	Year round	200	—

[1]Geometric mean based on at least four samples collected from a given site over a 30-day period at an interval not less than 24 hours. The geometric mean of a series of N terms is the Nth root of their product. For example, the geometric mean of 2 and 18 is 6—the square root of 36.

Redland–Pew Creek

The Pew Creek site at Patterson Road (02205522; fig. 11; table 2) serves as a primary monitoring point for drainages in the western part of the city. The primary drainages include Pew and Redland Creeks, which together drain about 5.5 mi^2, or 41 percent, of the area covered by the city. Water-quality monitoring at the site began in September 2005.

As was the case in the Apalachee River watershed, continuous surface-water monitoring data indicate that changes in stream-water-quality properties may be related to decreased streamflow during the 2006–2008 drought (fig. 18). During

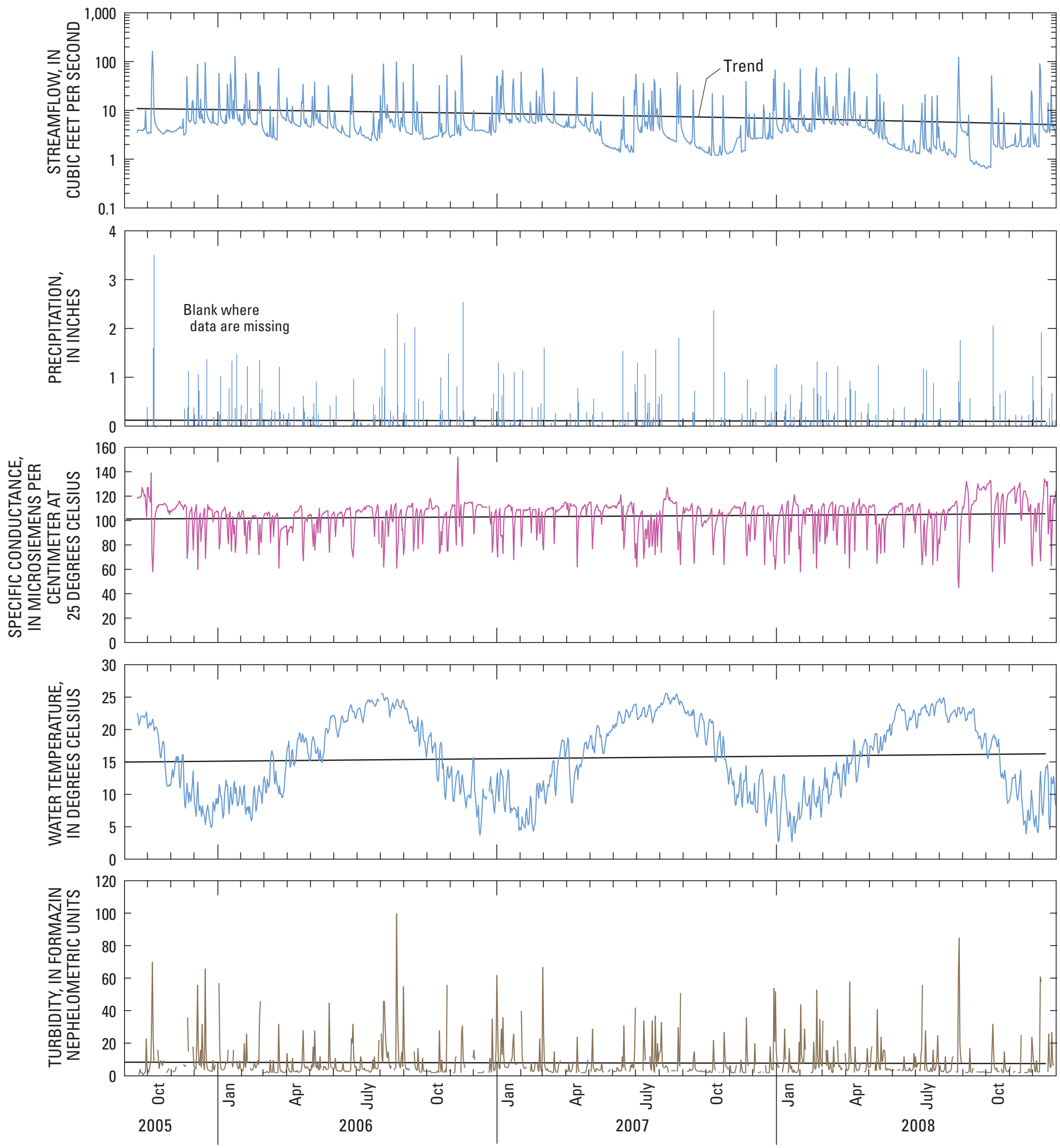


Figure 18. Mean daily streamflow, precipitation, specific conductance, and water temperature, and median daily turbidity at surface-water station 02205522, Pew Creek at Patterson Road near Lawrenceville, Georgia, 2005–2008. (See fig. 11 for location.)

this drought period, values of streamflow and turbidity were generally lower than during 2005, whereas stream temperature and specific conductance were generally higher. Water temperature data show a seasonal fluctuation in response to air temperature, with highest values in the summer months.

Fecal coliform sampling began at the Pew Creek site in late 2005. During the period November 2005 through August 2008, 36 samples were collected and analyzed for fecal coliform (fig. 19). In 2007, a sampling strategy was adopted for comparison with the State water-quality regulations that are based on a geometric mean of four samples taken within a 30-day period. Data collected during 2007–2008 were combined into seven geometric means of at least four samples per mean, all of which met GaEPD water-quality standards for fecal coliform. None of the individual samples collected during November–April in 2005–2008 exceeded the GaEPD criterion of 4,000 MPN col/100 mL. During 2007 and 2008, the GaEPD 30-day geometric mean standard of 200 MPN col/100 mL for May–October was exceeded twice during May–October 2007 and twice during May–August 2008.

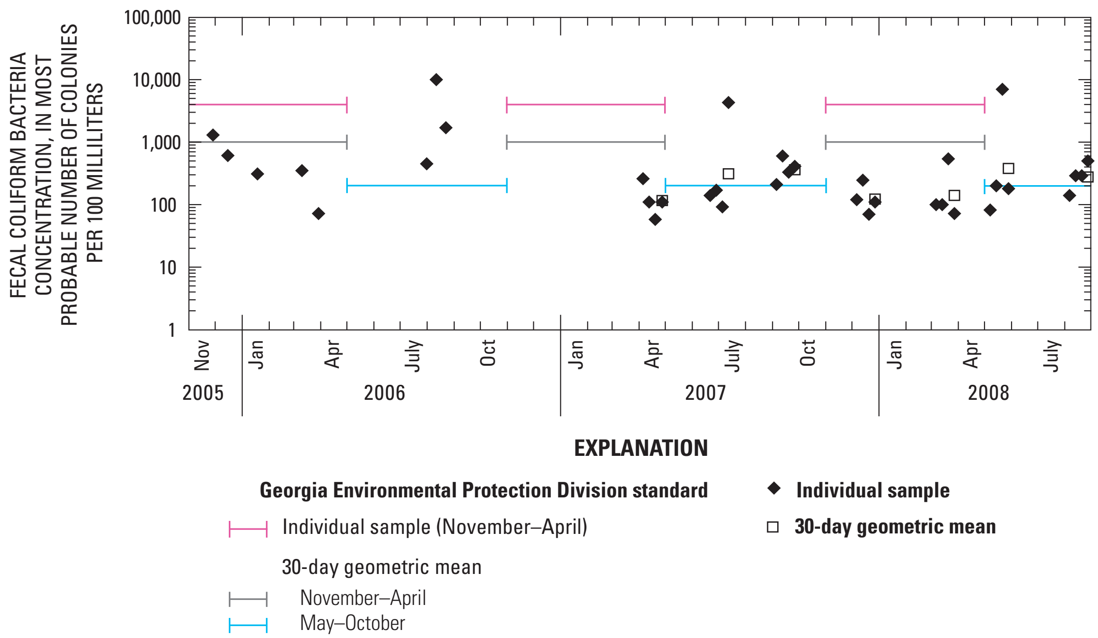


Figure 19. Fecal coliform sampling results for surface-water station 02205522, Pew Creek at Patterson Road near Lawrenceville, Georgia, 2005–2008. (See fig. 11 for location.)

Shoal Creek

The Shoal Creek site at Paper Mill Road (02208130; fig. 20; table 2) serves as a primary monitoring point for drainages in the eastern part of the city. Shoal Creek drains about 3.6 mi^2, or 26 percent, of the area covered by the city. According to maps presented by Landers and others (2007), urban development in this area is comparable to that of the Redland–Pew Creek watershed to the southwest (fig. 1). Continuous and periodic water-quality sampling at this site began in October 2005, continuous stage and discharge monitoring began in October 2006 (fig. 21).

Fecal coliform sampling began at the Shoal Creek site in October 2006. A geometric mean sampling strategy was used for comparison with State water-quality regulations. During October 2006 through August 2008, 36 samples were collected and analyzed for fecal coliform (fig. 22). Data collected during 2006–2008 were combined into nine geometric means of at least four samples per mean. None of the individual samples collected during November–April in 2006–2008 exceeded the GaEPD criterion of 4,000 MPN col/100 mL. During 2007 and 2008, the GaEPD 30-day geometric mean standard of 200 MPN col/100 mL for May–October was exceeded twice in May–October 2007 and twice in May–October 2008.

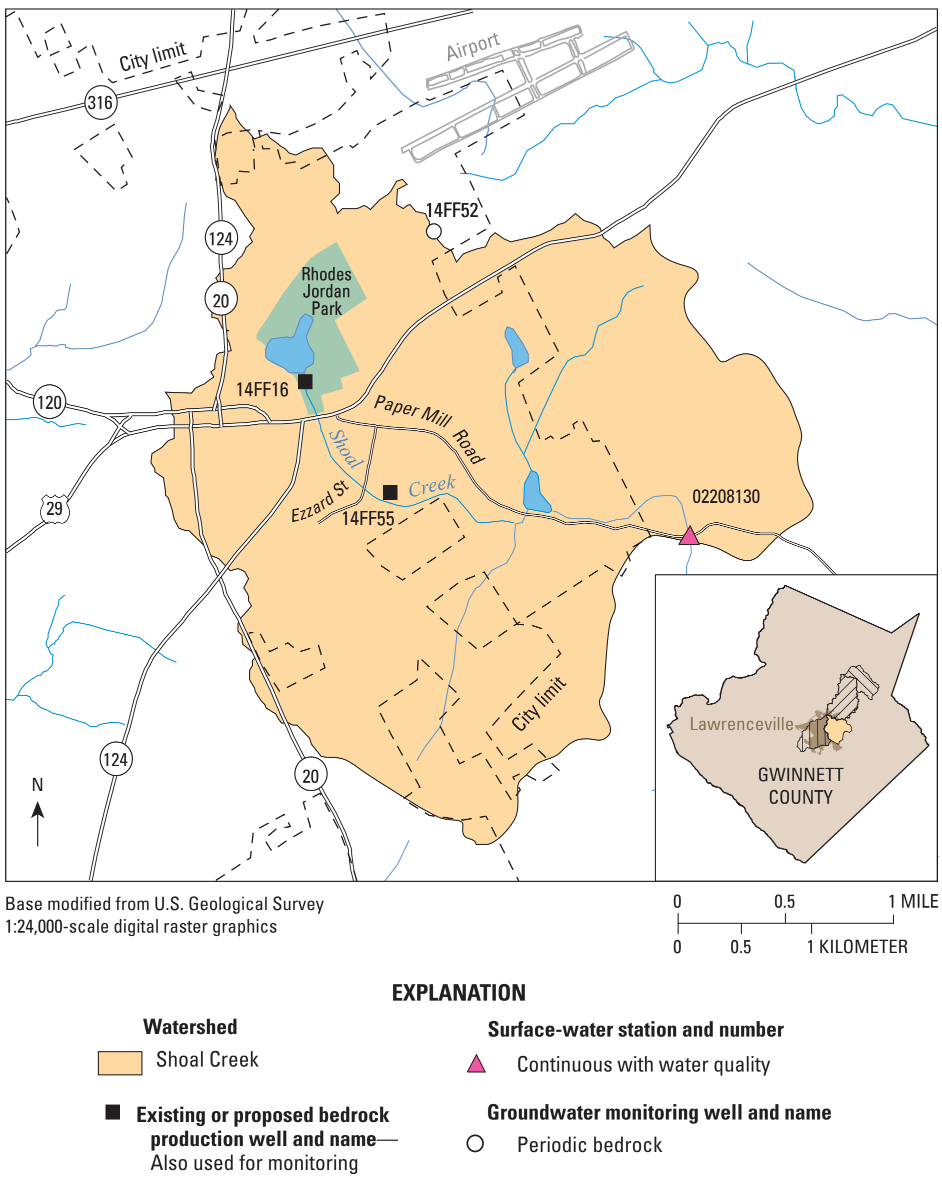


Figure 20. Surface-water and groundwater monitoring networks, Shoal Creek watershed near Lawrenceville, Georgia, 2008.

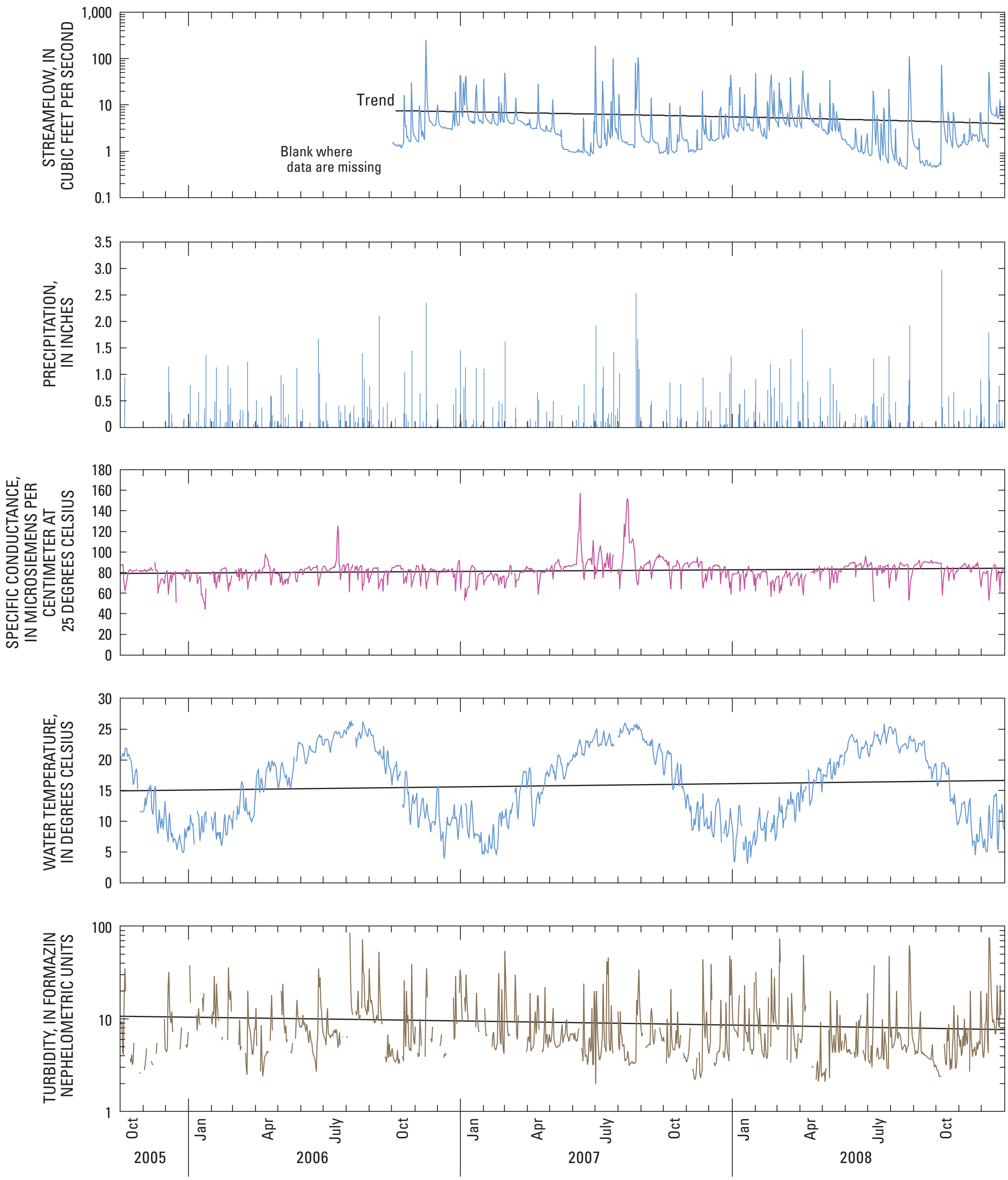


Figure 21. Mean daily streamflow, precipitation, specific conductance, and water temperature, and median daily turbidity at surface-water station 02208130, Shoal Creek at Paper Mill Road near Lawrenceville, Georgia, 2005–2008. (See fig. 20 for location.)

Real-time continuous monitoring of discharge, specific conductance, and turbidity during June 1–20, 2007, helped to identify a sewage overflow, which began on or about June 7 and continued through June 12. In general, these stream-water-quality properties show little variation under base-flow conditions, with most changes occurring during storm events. For example, during base-flow conditions of June 1–6, there was little variation in streamflow and specific conductance, and only minor variation in turbidity (fig. 23). Conversely, during June 15th, there was a large increase in turbidity and decrease in specific conductance in response to a storm event. Increased specific conductance during June 7–12—a period of base-flow conditions—indicated a point source of contamination into the creek. This finding prompted a site inspection where algae growth was observed in the creek. Gwinnett County authorities determined that the source of the spill was from a clogged sewer line resulting in overflow of a nearby manhole (Jonathan B. Evans, U.S. Geological Survey, oral commun., June 2007). The sewer line was repaired, and water quality returned to normal conditions after June 12.

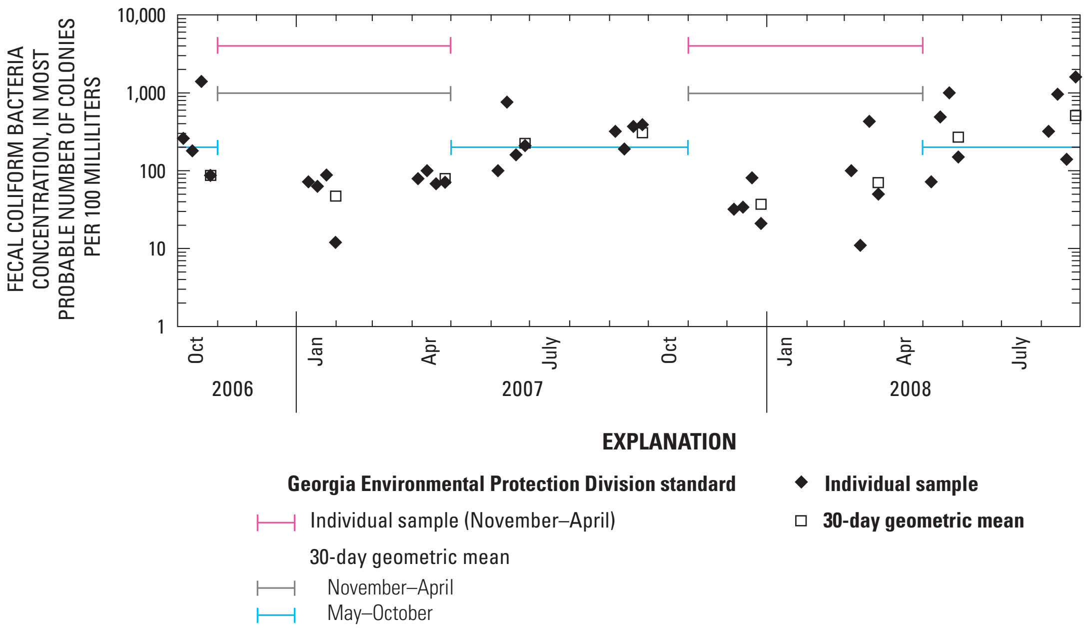


Figure 22. Fecal coliform sampling results at surface-water station 02208130, Shoal Creek at Paper Mill Road near Lawrenceville, Georgia, 2006–2008. (See fig. 20 for location.)

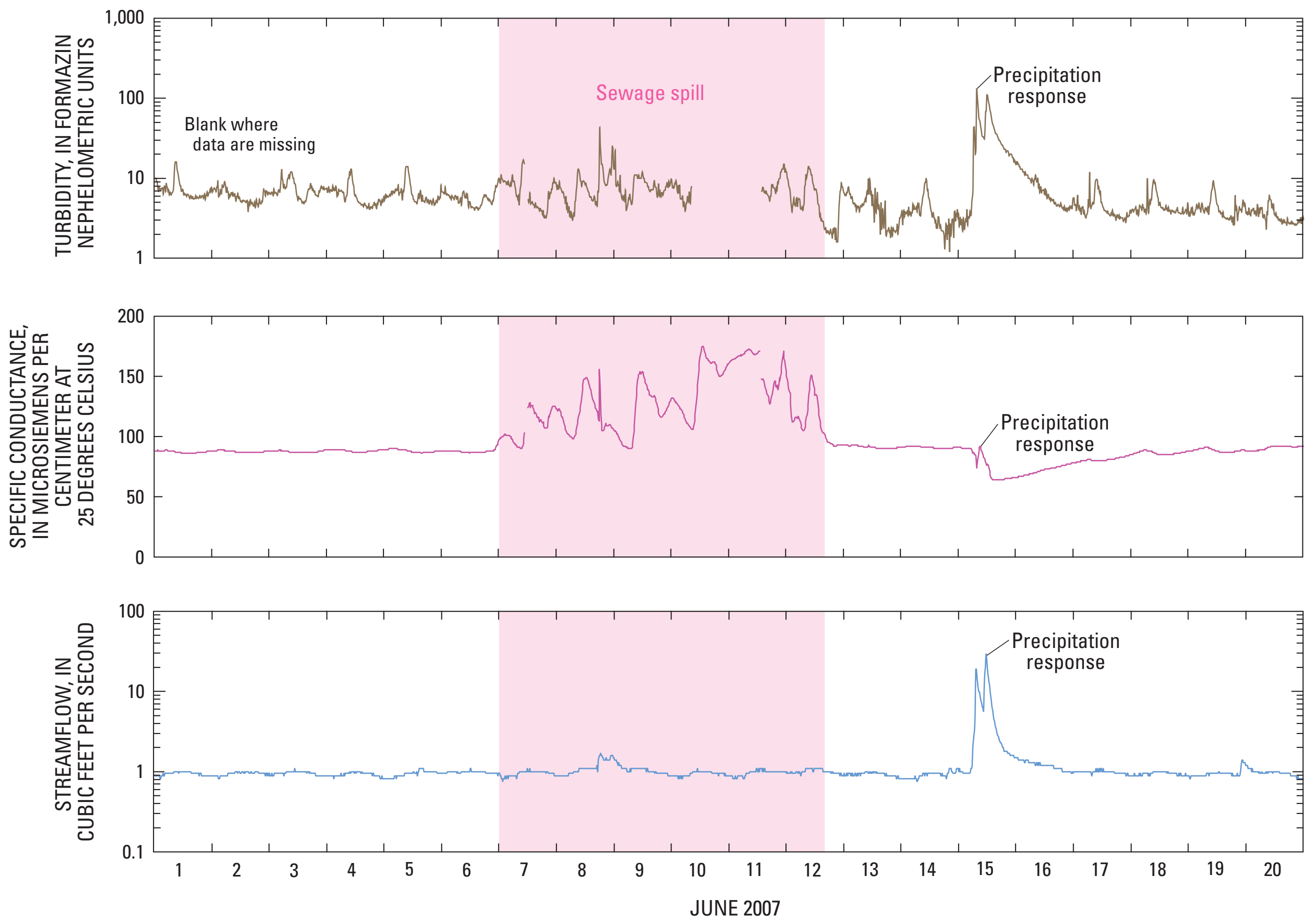


Figure 23. Streamflow, specific conductance, and turbidity at surface-water station 02208130, Shoal Creek at Paper Mill Road near Lawrenceville, Georgia, June 1–20, 2007. (See fig. 20 for location.)

Groundwater Studies

Groundwater studies were completed during 2003 to 2008 in support of the city's continued development and management of groundwater resources. These ongoing studies provide additional data to help support water-management decisions and to continue increasing the understanding of hydrologic processes.

Well-Field Expansion in the Upper Alcovy River Watershed

In 2001, the City of Lawrenceville drilled its first test well in the upper Alcovy River watershed. This test well was later converted into production well 14FF59, which is capable of producing 350 gal/min (Williams and others, 2004). Because of the success of this well, the City of Lawrenceville drilled three additional test wells in an attempt to fully develop the available groundwater resources in that area. Wells 14FF62 and 14FF63 were drilled in May 2003, and well 14FF64 was drilled in July 2003 (table 1). In addition to the three test wells, a new bedrock-monitoring well (14FF65) was drilled in July 2003. The locations of the test wells in relation to the geology are shown in figure 24, and borehole geophysical logs are included in Appendix 1.

The results of the test drilling indicated that well 14FF62 is capable of yielding 85 gal/min whereas the other two test wells had well yields below 10 gal/min. The two low-yielding test wells, in addition to the new monitoring well, were incorporated into the existing groundwater monitoring network.

Hydrogeologic Investigation of Ezzard Street Well, Shoal Creek Watershed

Well 14FF55 is a new production well located approximately 25 ft south of Shoal Creek and 3,500 ft south of the existing production well (14FF16) at Rhodes Jordan Park in Lawrenceville (table 1, fig. 20). The rocks penetrated by this well include a biotite gneiss unit and an amphibolite unit (fig. 25; Williams and others, 2004). Borehole geophysical logs and flowmeter surveys conducted by the USGS indicated several water-bearing zones, including the following:

- 14–17 ft: 15 gal/min (cavernous zone mostly along foliation);
- 100.5–101.5 ft: 5 gal/min (foliation parting);
- 181–182 ft: 20 gal/min (major opening along foliation/layering);
- 251–252 ft: 110 gal/min (major opening along foliation/layering); and
- 416–417 ft: 100 gal/min (major opening along foliation/layering).

Hydrogeologic investigations conducted by the USGS at this well involved investigation of water-bearing zones connected with surface water and containing elevated radionuclide levels.

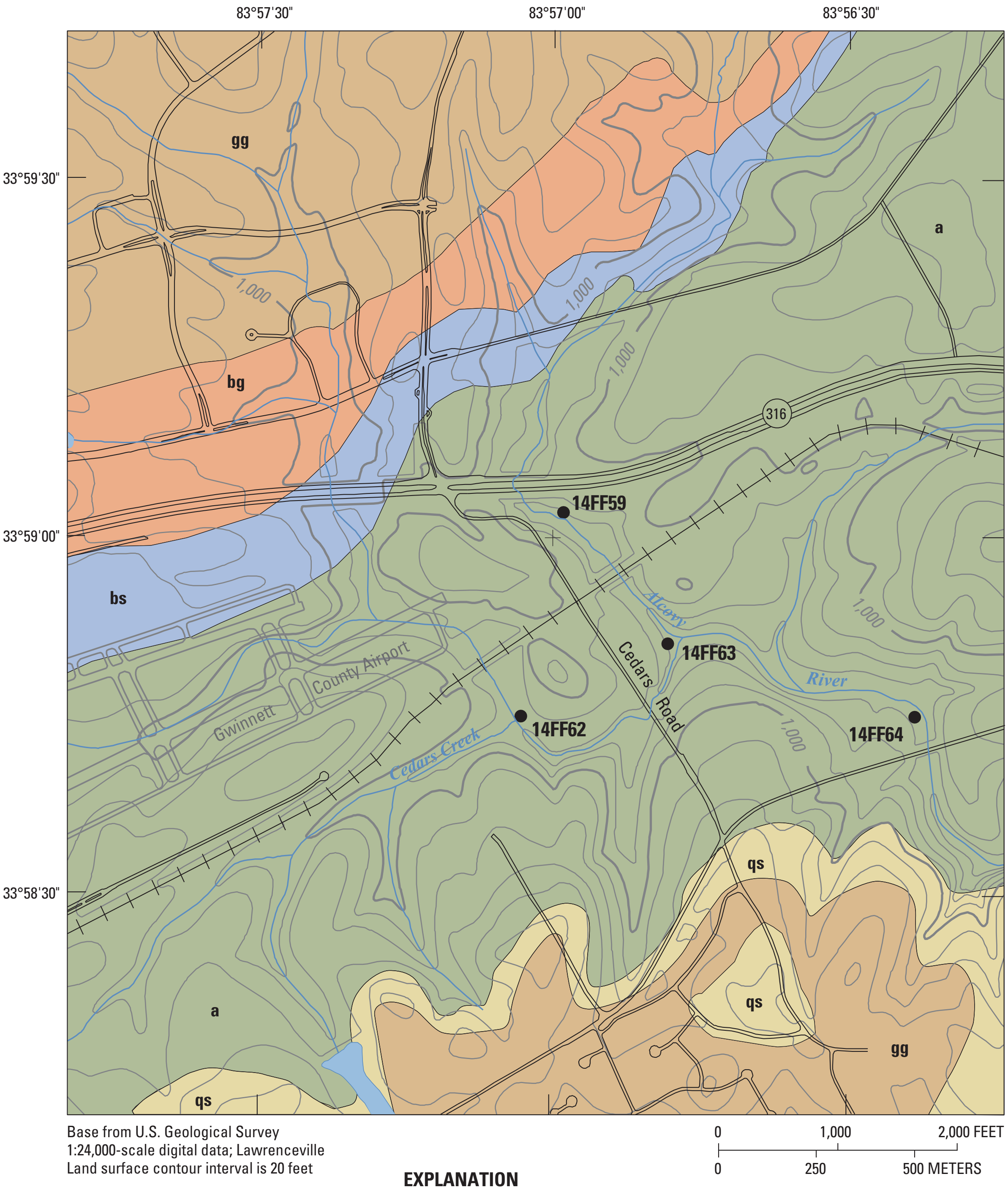
Surface-Water Interconnection

In February 2005, during the well permitting phase, the GaEPD conducted a microscopic particulate analysis (MPA) test on well 14FF55 and determined that this well was under the influence of surface water. An ambient flowmeter survey of the well conducted by the USGS in 2001 (Williams and others, 2004) identified a shallow fracture about 1 to 2 ft deeper than the base of the casing (63 ft), which was losing about 10 gal/min and was the likely pathway for interconnection with surface water. To eliminate the surface-water influence, the fracture at 64–65 ft and another fracture at about 100 ft were sealed off by installing a 6-inch PVC liner and K-packer into the well to a depth of 120 ft in March 2005 (fig. 26).

Following liner installation, flowmeter measurements were collected above and below the liner under ambient conditions on March 15, 2005, to check for any potential leakage behind the newly installed liner. The flowmeter measurements indicated less than 0.02 gal/min of upward flow (near the detection limit of 0.01 gal/min of the flowmeter) near the base of the casing. This result provided a good indication that the liner-packer assembly had effectively sealed off the shallow fractures.

In addition to the geophysical logs, water-level measurements taken by city personnel also gave an indication of an effective seal and hydraulic separation of shallow water-bearing zones from the deeper zones (Robert Paul, City of Lawrenceville Water Department, written commun., 2005). The water level before the liner installation was 1.8 ft below land surface (March 14, 2005), and the water level after the liner installation was 2.4 ft above land surface (March 15, 2005).

The water-level change from below land surface to above land surface indicates that shallower, lower head fractures are effectively being sealed and that the liner-packer assembly has had a measurable effect on the hydraulic condition in the well. The second MPA test conducted by the GaEPD on March 28, 2005, indicated the well was no longer under the influence of surface water and that the corrective measure was successful.



EXPLANATION

Lithologic unit

gg	Granite gneiss
bg	Biotite gneiss
bs	Button schist
a	Amphibolite
qs	Quartzite/schist

● **Well and site name**
14FF64

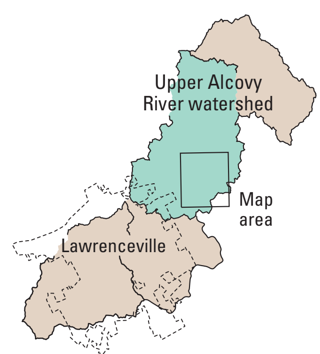


Figure 24. Geologic map of the upper Alcovy River watershed showing locations of test wells drilled in May and July 2003 near Lawrenceville, Georgia (modified from Williams and others, 2005).

Elevated Levels of Radionuclides

As described in the previous section, although modification of well 14FF55 effectively eliminated the connection to surface water, it also had an unexpected effect on water quality. Prior to retrofitting the well with a casing liner in March 2005, water samples collected from this well had gross-alpha particle activity radiation generally less than 11 picocuries per liter (pCi/L; table 7). Following well modification, the levels increased to 173 pCi/L, indicating a large contribution from deeper water-bearing zones containing high gross-alpha levels.

The source of the elevated radiation in well 14FF55 is unknown, but may be associated with a pegmatitic zone in the biotite gneiss unit (upper interval). Natural gamma logs show elevated levels in parts of the upper interval (fig. 25) that may indicate the location of radioactive zones. Additional geophysical, flowmeter, and geochemical investigations would be required to identify the specific zone(s) contributing radioactive water to the well. Laboratory tests indicated the radioactivity associated with the sample collected on August 5, 2005 resulted from the presence of uranium with an activity of 179 pCi/L.

In February 2006, the well was sampled following a 10–14-day period of continuous pumping at a rate of 138 to 150 gal/min. That sample contained 64 pCi/L of gross-alpha particle activity and 58 pCi/L of uranium. The large reduction in radioactivity was attributed to the continuous pumping of the well prior to collecting the sample. Concentrations in samples collected later that month ranged from 56.6 to 70.6 pCi/L of gross-alpha particle activity and from 58 to 68.2 pCi/L of uranium (table 7). One of these samples was submitted for analysis of uranium mass for the purpose of converting picocuries per liter to micrograms per liter, which was needed for comparison to the U.S. Environmental Protection Agency maximum contaminant level (MCL) of 30 micrograms per liter (µg/L) (U.S. Environmental Protection Agency, 2009). That sample had a uranium activity of 68.2 pCi/L with a computed concentration of 61.1 µg/L, which is almost double the MCL.

To investigate the source of the elevated radionuclides, several packer tests were conducted by the USGS between May and August 2005 to isolate and sample the upper and lower parts of well 14FF55 (fig. 26). The first test was conducted on May 10, 2005, which isolated the upper portion of the borehole for sampling. During this test,

- The top of the packer was set at 310–314 ft with an inline submersible pump positioned just above the packer.
- The packer was inflated to approximately 200 pounds per square inch (psi) and held at that pressure for the 1.5-hour test duration.
- While inflated, the well was pumped at a rate of 27 gal/min; the water level in the upper part of the borehole was monitored until it stabilized at about 25 ft below land surface (fig. 27).
- A water sample was collected, and the packer assembly was removed from the borehole.

Table 7. Summary of radiological testing results for water samples collected from Well 14FF55.

[Lab: GaEPD—Georgia Environmental Protection Division, RadSafe—Radiation Safety Engineering, Chandler, Arizona; MCL, U.S. Environmental Protection Agency Maximum Contaminant Level (*http://www.epa.gov/safewater/contaminants/index.html#listmcl*, accessed August 19, 2009); —, no data; <, less than]

Lab	Date tested	Picocuries per liter										
		Gross alpha			Radium 226			Radium 228			Total uranium	
		Value	Error	MCL	Value	Error	MCL	Value	Error	MCL	Value	Error
GaEPD	8/28/2001	10	—	15	0.7	—	5	—	—	5	—	—
GaEPD	7/14/2004	5	—	15	2	—	5	3	—	5	—	—
GaEPD	8/5/2005	173	8	15	<1	—	5	<1	—	5	179	20
GaEPD	2/2/2006	64	5	15	1	1	5	<1	—	5	58	4
RadSafe[1]	2/2/2006	70.6	5.6	15	2	0.2	5	<0.4	0.4	5	63.8	2.1
RadSafe[2]	2/20/2006	56.6	4.7	15	1.8	0.2	5	<0.4	0.4	5	68.2	2
GaEPD	3/17/2006	62	5	15	2	1	5	1	1	5	70	3
RadSafe	7/26/2007	83.1	6.4	15	2.4	0.3	5	0.4	0.5	5	87.2	2.5

[1] Samples taken on February 2, 2006, were after 10–14 days of continuous pumping at a rate of 138–150 gallons per minute.

[2] Sample taken on February 20, 2006, also included analysis for isotopic uranium (uranium sass). The result was 61.1 ± 3.4 micrograms per liter.

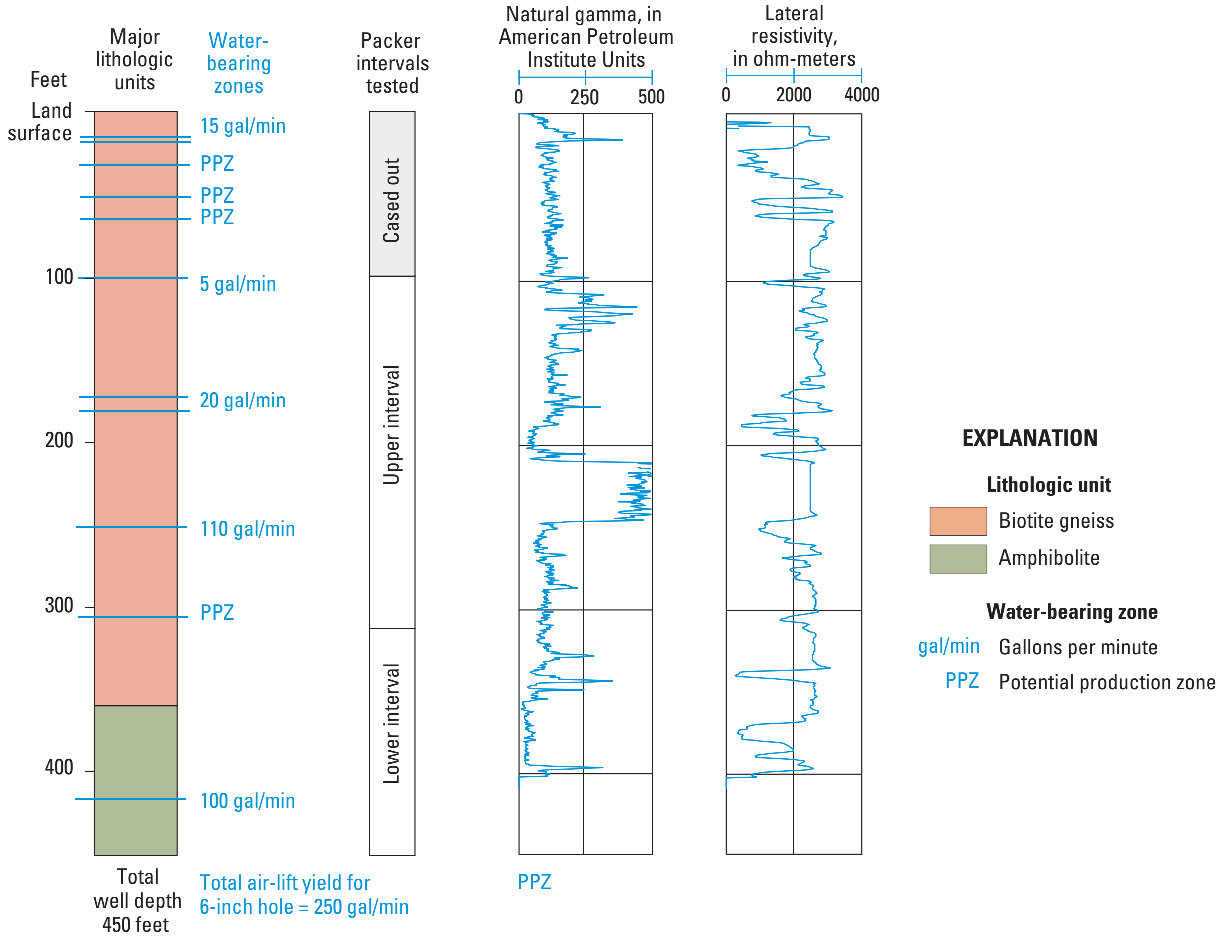


Figure 25. Upper and lower packer intervals in relation to water-bearing zones in well 14FF55 near Lawrenceville, Georgia, 2005. (See fig. 20 for well location.)

Figure 26. K-packer system used to modify well 14FF55 to eliminate the influence of surface water, March 2005. (Photo by Robert Paul, City of Lawrenceville.)

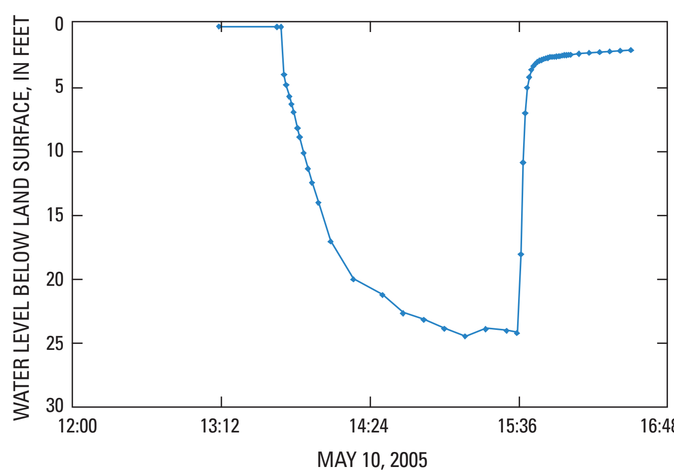


Figure 27. Hydrograph showing water level in the upper portion of well 14FF55 near Lawrenceville, Georgia, during the packer test, May 10, 2005. (See fig. 20 for well location.)

The results of the upper-zone packer test yielded a gross-alpha concentration of 1,054 pCi/L , which is more than an order of magnitude greater than the previous “whole-well” samples collected earlier that year (table 8). Although this result appeared to indicate that the radioactivity was originating from the upper portion of the borehole, a second packer test was planned to determine the concentrations and yield in the lower portion of the borehole. This information could help determine whether the lower part of the well could produce an adequate yield for production purposes. If the lower part of the borehole could yield an adequate amount of good-quality water, then the well could be modified by extending the liner pipe to a greater depth to isolate the poorer quality water.

During the second packer test conducted in August 2005,

- The top of packer was set at 310–314 ft with an inline submersible pump positioned just below the packer.
- The packer was inflated to about 200 psi and held at that pressure for the duration of the 2-hour test.
- While inflated, the lower (314–450 ft) portion of the borehole was pumped at a rate of 37.5 gal/min; no water levels were obtained from the pumped zone because it was isolated beneath the packer assembly and there was no pass-through access for installation of a transducer.
- The water level in the borehole above the packer (120–310 ft) slowly declined 1.5 ft during the test, apparently in response to pumping. This finding indicated that although the packer was not leaking, the upper and lower zones were hydraulically connected through fractures intersecting both zones.
- A water sample was collected after 2 hours of pumping, and the packer assembly was removed from the borehole.

The results of the lower-zone packer test yielded a gross-alpha concentration of 448 pCi/L, which was approximately half the value for the upper zone, but still an order of magnitude greater than the previous whole-well samples collected earlier that year (table 8). The disparity between the whole-well samples and the packer interval samples was thought to be related to the shorter period of time the well was pumped, the lower pumping rate, or a combination of these two factors. The lower pumping rate could cause water to be derived from a smaller network of fractures, whereas a larger pumping rate could cause water to be derived from a larger network of fractures.

Because high gross-alpha activity was detected in the water samples collected through the packer assembly, it was determined that a longer-term test should be run to obtain more representative samples from the packer intervals. The lower interval was selected for testing because the results from this zone had about half of the gross-alpha activity as the upper interval.

The third and final packer test was designed with the following considerations:

- Prior to installing the packer assembly, the well should be pumped using the existing production pump for 1 to 2 weeks to stabilize radionuclide concentrations surrounding the well, and a water sample should be collected at the end of the period to establish pre-packer conditions.
- The packer installation should be similar to that of the previous test to isolate the lower portion of the borehole from 314 to 450 ft.
- Following packer inflation and pump startup, samples should be collected at various time intervals during continuous pumping for analysis of gross-alpha particle activity. The packer should be kept fully inflated throughout the duration of the test.

Table 8. Summary of radiological testing for water samples collected from discrete packer intervals in well 14FF55.

[Analysis by Radiation Safety Engineering, Chandler, AZ; gal/min, gallon per minute]

Date tested	Zone tested	Gross alpha, in picocuries per liter	Notes
5/10/2007	Upper (120–310 ft)	1,054±67.0	Sample taken after the packer interval was pumped at 27 gal/min for 2 hours
5/30/2009	Lower (314–450 ft)	448±29.0	Sample taken after the packer interval was pumped at 31 gal/min for 2.5 hours
8/6/2007	Lower (314–450 ft)	41.0±4.0	Sample taken after the packer interval was pumped at 60 gal/min for 5 days
8/11/2007	Lower (314–450 ft)	40.0±4.0	Sample taken after the packer interval was pumped at 60 gal/min for 10 days
8/20/2007	Lower (314–450 ft)	41.0±4.0	Sample taken after the packer interval was pumped at 60 gal/min for 19 days

On July, 30, 2007, after removing the production pump from well 14FF55, the packer assembly was set to a depth of 310–314 ft and inflated. Beneath the packer, a submersible pump capable of pumping 60 to 80 gal/min was installed, which is twice as large as the pump used for previous packer tests. At startup, a constant rate of 75 gal/min was initially established, but was shut off only 3 hours into the test because of a loss of pressure in the packer assembly. On August 1, 2007, the packers were re-inflated, and the pump was restarted at a rate of 60 gal/min. That rate was maintained for the next 19 days during which time water samples were collected from the lower zone on August 6, 11, and 20. Following pump shutdown, the upper and lower zones were monitored in a "shut-in" condition for an additional 2 weeks to monitor the recovery response in the two zones. The results of the packer test are shown in figure 28, listed in tables 8 and 9, and are briefly described here. Prior to pumping, water levels in the two zones were identical at 2.09 ft; after 1 day of pumping the water level in the upper zone declined to 19.22 ft, and the water level in the lower zone declined to 23.84 ft. Water levels in the upper and lower zones declined slightly during the remainder of the pumping period, and by the 19th day, were 22.96 and 29.42, respectively (table 9). Total drawdown during the test period was 20.87 ft in the upper zone and 27.33 ft in the lower zone. The hydraulic responses observed during the packer test indicate that the upper and lower zones are hydraulically connected to some degree as evidenced by drawdown response in both zones. Gross-alpha particle activity in water samples collected from the lower zone at 5, 10, and 19 days ranged from 40–41 pCi/L (table 8), indicating the radioactivity in water had reached equilibrium with stabilization of the pumping water levels.

Results of the packer tests indicate that sealing off the upper poor water-quality zone would result in a slight decrease in well yield and an improvement in groundwater quality.

Pumping the lower zone at 60 gal/min resulted in a specific capacity of 2.44 gallons per minute per foot [(gal/min)/ft], which is slightly less than the value of 2.6 (gal/min)/ft reported for a 36-hour test of the combined upper and lower intervals (Williams and others, 2004). Because a modified well sealing off the upper interval could be installed at a deeper depth, the slight loss in yield might be offset by the greater available drawdown in the well. Water sampling results indicate that well modification may help reduce the overall level of radionuclides by as much as 50 percent, although it is possible that pumping from the lower zone may eventually induce enough leakage between the zones to produce an increase the overall concentration of radionuclides.

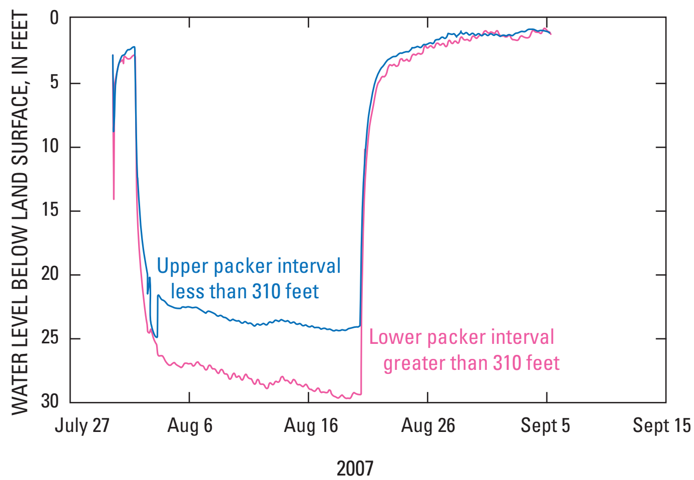


Figure 28. Hydrograph showing water level responses to pumping the lower zone of well 14FF55 near Lawrenceville, Georgia, during packer tests, August 2007. (See fig. 20 for well location.)

Table 9. Water levels in the upper and lower zones in well 14FF55 during packer test, August 1–19, 2007.

[Head separation: when positive, water level in lower zone is deeper than in upper zone]

Zone depth (feet below land surface)	Water level, in feet below land surface				
	Start test	1 day	5 days	10 days	19 days
Upper (120–310)	2.09	19.22	22.59	23.97	22.96
Lower (134–450)	2.09	23.84	27.11	28.46	29.42
Head separation	0.00	4.62	5.73	5.61	5.55

Lithology and Water-Bearing Characteristics at Lawrenceville–Suwanee No. 2 Test Well, Redland–Pew Creek Watershed

Well 13FF34 is a 605-ft-deep test well drilled by the City of Lawrenceville in June 2008 to explore additional water resources in the Redland–Pew Creek watershed (table 1). The well is located near the city boundary on the west side of Lawrenceville–Suwanee Road (fig. 11).

The rocks penetrated by this well include an upper and lower amphibolite unit, biotite gneiss and button schist unit, and a quartzite/schist unit. Borehole geophysical logs and examination of drill cuttings by the USGS indicated four water-bearing zones: (1) within the upper amphibolite unit, (2) near the contact of the upper amphibolite unit and the biotite gneiss and button schist unit, (3) within the quartzite/schist unit, and (4) near the basal contact of the lower amphibolite unit (fig. 29). The final air-lift yield was measured at about 22 gal/min.

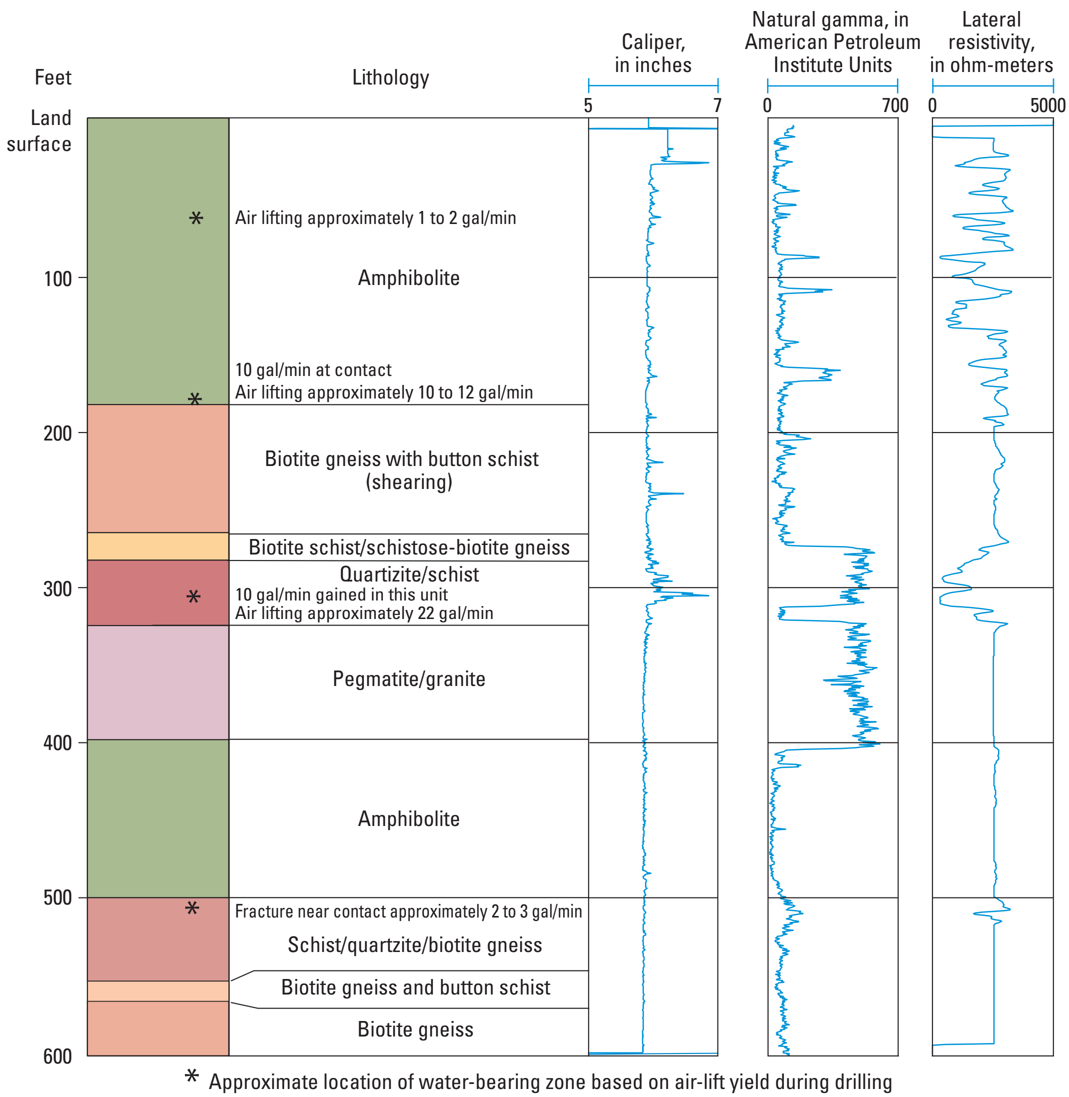


Figure 29. Lithology and borehole geophysical log characteristics for test well 13FF34 near Lawrenceville, Georgia. (See fig. 11 for well location; gal/min, gallons per minute)

Summary

Hydrologic studies conducted as part of the cooperative water program between the U.S. Geological Survey and the City of Lawrenceville provide important data for the management of water resources. Focus areas during 2003–2008 included hydrologic and surface-water-quality monitoring and geologic studies to better understand groundwater flow and hydrologic processes in a crystalline rock setting. Hydrologic monitoring data are being used by the City of Lawrenceville to quantify baseline hydrologic conditions in anticipation of expanded groundwater development. Surface-water-quality data are being used to provide an understanding of how stream quality is affected by natural factors (such as precipitation) and anthropogenic factors (such as impervious area) and to provide information that is essential for successful watershed management.

Groundwater-level, streamflow, base flow, and precipitation-monitoring networks were established in the Lawrenceville area during 2003–2008 to provide the City of Lawrenceville a means to estimate the sustainability of the hydrologic system under normal or anticipated pumping conditions. The network includes each of the two watersheds projected for groundwater development—the Redland–Pew Creek and the upper Alcovy River watersheds—and the upper Apalachee River watershed, which serves as a background or control watershed because of its similar geologic and hydrologic characteristics to the pumped watersheds.

The upper Apalachee River watershed covers a 5.68-square-mile (mi^2) area in the northeastern part of the study area. Precipitation is the main control on hydrologic conditions in the Apalachee River watershed. Increased precipitation generally results in increases in both streamflow and groundwater levels; decreased precipitation results in decreased streamflow and groundwater levels. Precipitation was generally greater during 2003–2005 than during 2006–2008, resulting in a corresponding decrease in streamflow and groundwater levels.

The upper Alcovy River watershed covers a 10-mi^2 area in the north-central part of the study area. The current (2008) main production well for the city (14FF16) is located in the adjacent Shoal Creek watershed, about 1 mi southwest of the watershed boundary. During 2003–2008, precipitation, streamflow, and groundwater levels in the upper Alcovy River watershed showed a general downward trend. Most groundwater-level declines were from 2.4 to 6.9 feet (ft), with the greatest decline of 28.5 ft in bedrock well 14FF52 that corresponded to periodic pumping from well 14FF55. The most extensive streamflow measurement effort was conducted in September 2006, when seepage gains were measured at five of the nine reaches evaluated, with losses measured at the other four reaches.

The Redland–Pew Creek watershed covers a 7.5-mi^2 area in the southwestern part of the study area. Several well sites in this area have been identified for development of groundwater supplies for the city, including well 13FF18, which was brought online in the fall of 2008. During 2003–2008, precipitation, streamflow, and groundwater levels in the Redland–Pew Creek watershed showed a general downward trend. Groundwater-level declines were measured in 12 of the 13 wells monitored, ranging mostly between 2.8 and 6.5 ft, with considerably greater declines in bedrock wells 13FF16 (40.4 ft) and 13FF13 (49.1 ft). The water-level change in well 13FF16 represented a temporary decline during a water-sampling event in September 2008, whereas the decline in well 13FF13 corresponded to the initiation of pumping in well 13FF18, located westward along the trend of foliation-parallel partings that provide an interconnection between the wells. Seepage measurement data collected at 12 reaches during 2003–2008 indicate that most stream reaches were gaining throughout the period.

Continuous water-quality data were collected at gage sites located on Pew Creek and Shoal Creek inside the city limits, and at a background site on the Apalachee River located outside the city boundary. Continuous surface-water-monitoring data indicate that changes in stream-water-quality properties at all three sites may be related to decreased streamflow during the 2006–2008 drought. During this drought period, values of streamflow and turbidity were generally lower than during 2003–2005, whereas water temperature and specific conductance were generally higher. In comparison to the other two stream sites, water at the Apalachee River site had the lowest mean and median values for specific conductance and the greatest mean and median values for turbidity during October 2005–December 2008. In the Shoal Creek watershed, real-time continuous monitoring of discharge, specific conductance, and turbidity during June 1–20, 2007, helped to identify a sewage overflow, which began on or about June 7 and continued through June 12.

In addition to water-quality monitoring, samples were collected to determine fecal coliform bacteria concentrations. None of the individual samples from the three water-quality sites exceeded the Georgia Environmental Protection Division (GaEPD) limit of 4,000 MPN col/100 mL for November through April. In the Redland–Pew Creek and Shoal Creek watersheds, the GaEPD 30-day geometric mean standard of 200 most probable number of colonies per 100 milliliters for May–October was exceeded twice during May–October 2007 and twice during May–October 2008.

Selected groundwater studies were completed during 2003–2008 in support of the city's continued development and management of groundwater resources. These included flowmeter surveys and water sampling at well 14FF55 in the Shoal Creek watershed to evaluate the effectiveness of installing a casing liner to eliminate the influence of surface water and to identify the source of radionuclides, and test drilling and logging of four wells drilled in the upper Alcovy River watershed and one well in the Redland–Pew Creek watershed to determine subsurface geology and locations of water-bearing zones.

Selected References

Albertson, P.N., 2005, Establishment of a groundwater and surface-water monitoring network to assess the potential effects of groundwater development in an igneous and metamorphic rock aquifer, and preliminary data, Lawrenceville, Georgia, 2003–2004, *in* Hatcher, K.J., ed., Proceedings of the 2005 Georgia Water Resources Conference, held April 25–27, 2005, at the University of Georgia Institute of Ecology, The University of Georgia, Athens, Georgia, accessed November 22, 2009, at *http://ga.water.usgs.gov/pubs/other/gwrc2005/pdf/GWRC05_Albertson.pdf*.

Brunett, J.O., Barber, N.L., Burns, A.W., Fogelman, R.P., Gillies, D.C., Lidwin, R.A., and Mack, T.J., 1997, A quality-assurance plan for district groundwater activities of the U.S. Geological Survey: U.S. Geological Survey Open-File Report, 97–11, 19 p., accessed October 6, 2009, at *http://water.usgs.gov/ogw/pubs/OFR9711/gwqap.pdf*.

City-Data.com, 2009, Lawrenceville, Georgia, accessed February 4, 2009, at *http://www.city-data.com/city/Lawrenceville-Georgia.html*.

Clark, W.Z., and Zisa, A.C., 1976, Physiographic map of Georgia: Atlanta, Ga., Georgia Department of Natural Resources, Geologic and Water Resources Division, 1 pl., scale 1:2,000,000.

Garber, M.S., and Koopman, F.C., 1968, Methods of measuring water levels in deep wells: U.S. Geological Survey Techniques of Water-Resources Investigations, book 8, chap. A1, 23 p.

Georgia Humanities Council, 2008, The new Georgia encyclopedia, accessed February 4, 2009, at *http://74.125.47.132/search?q=cache:v5MHoiKuCK8J:www.georgiaencyclopedia.org/nge/Article.jsp%3Fid%3Dh-2233+population+lawrenceville+ga+1980&hl=en&ct=clnk&cd=6&gl=us*.

Gotvald, A.J., and Stamey, T.C., 2005, Surface-water quality-assurance plan for the USGS Georgia Water Science Center: U.S. Geological Survey Open-File Report 2005–1246, 45 p., accessed October 6, 2009, at *http://pubs.usgs.gov/of/2005/1246/*.

Gray, J.R., and Glysson, G.D., eds., 2003, Proceedings of the Federal Interagency Workshop on Turbidity and Other Sediment Surrogates, April 30–May 2, 2002, Reno, Nevada: U.S. Geological Survey Circular 1250, 56 p., accessed October 6, 2009, at *http://pubs.usgs.gov/circ/2003/circ1250/*.

Gregory, M.B., and Frick, E.A., 2000, Fecal-coliform bacteria concentrations in streams of the Chattahoochee River National Recreation Area, Metropolitan Atlanta, Georgia, May–October 1994 and 1995: U.S. Geological Survey Water-Resources Investigations Report 00–4139, 8 p., accessed October 6, 2009, at *http://pubs.usgs.gov/wri/wri004139/*.

Hirsch, R.M., Hamilton, P.A., and Miller, T.L., 2006, U.S. Geological Survey perspective on water-quality monitoring and assessment: Journal of Environmental Monitoring, v. 8, p. 512–518.

Laenen, T.A., 1985, Acoustic velocity meter systems: U.S. Geological Survey Techniques of Water-Resources Investigations, book 3, chap. A13, 38 p.

Landers, M.N., and Ankcorn, P.D., 2008, Methods to evaluate influence of onsite septic wastewater-treatment systems on base flow in selected watersheds in Gwinnett County, Georgia, October 2007: U.S. Geological Survey Scientific Investigations Report 2008–5220, 12 p., accessed October 6, 2009, at *http://pubs.usgs.gov/sir/2008/5220/*.

Landers, M.N., Ankcorn, P.D., and McFadden, K.W., 2007, Watershed effects on streamflow quantity and quality in six watersheds of Gwinnett County, Georgia: U.S. Geological Survey Scientific Investigations Report 2007–5132, 54 p., accessed October 6, 2009, at *http://pubs.usgs.gov/sir/2007/5132/*.

Metropolitan North Georgia Water Planning District, 2007, Standards and methodologies for surface water quality monitoring, March 2007, accessed November 22, 2009, at *http://www.northgeorgiawater.com/files/MNGWPD_StandardsMethodologies_March2007a.pdf*.

Oberg, K.A., and Mueller, D.S., 2007, Validation of streamflow measurements made with Acoustic Doppler Current Profilers: Journal of Hydraulic Engineering, v. 133, no. 12, p. 1421–1432.

Rantz, S.E., 1982a, Measurement and computation of streamflow—Volume 1, Measurement of stage and discharge: U.S. Geological Survey Water-Supply Paper 2175, accessed October 6, 2009, at *http://pubs.usgs.gov/wsp/wsp2175/html/WSP2175_vol1_pdf.html*.

Rantz, S.E., 1982b, Measurement and computation of streamflow—Volume 2, Computation of discharge: U.S. Geological Survey Water-Supply Paper 2175, accessed October 6, 2009, at *http://pubs.usgs.gov/wsp/wsp2175/html/wsp2175_vol2.html*.

Sauer, V.B., and Meyer, R.W., 1992, Determination of error in individual discharge measurements: U.S. Geological Survey Open-File Report 92–144, 21 p.

Taylor, C.J., and Alley, W.M., 2001, Ground-water-level monitoring and the importance of long-term water-level data: U.S. Geological Survey Circular 1217, 68 p.

U.S. Environmental Protection Agency, 1997, Guidelines for preparation of the comprehensive state water-quality assessments (305b reports and electronic updates): Washington, D.C., U.S. Environmental Protection Agency, Office of Water, EPA-841-B-97-002a, variously paginated.

U.S. Environmental Protection Agency, 2009, Drinking water contaminants, accessed August 19, 2009, at *http://www.epa.gov/safewater/contaminants/index.html#listmcl*.

Wagner, R.J., Mattraw, H.C., Ritz, G.F., and Smith, B.A., 2000, Guidelines and standard procedures for continuous water-quality monitors—Site selection, field operation, calibration, record computation, and reporting: U.S. Geological Survey Water-Resources Investigations Report 00–4252, 53 p., accessed October 6, 2009, at *http://pubs.usgs.gov/tm/2006/tm1D3/*.

Wilde, F.D., Radke, D.B., Gibs, Jacob, and Iwatsubo, R.T., 1998, National field manual for the collection of water-quality data—Handbooks for water-resources investigations: U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, accessed October 6, 2009, at *http://water.usgs.gov/owq/FieldManual/*.

Williams, L.J., Albertson, P.N., Tucker, D.D., and Painter, J.A., 2004, Methods and hydrogeologic data from test drilling and geophysical logging surveys in the Lawrenceville, Georgia, area: U.S. Geological Survey Open-File Report 2004–1366, 38 p., accessed October 6, 2009, at *http://pubs.usgs.gov/of/2004/1366/*.

Williams, L.J., Kath, R.L., Crawford, T.J., and Chapman, M.J., 2005, Influence of geologic setting on ground-water availability in the Lawrenceville area, Gwinnett County, Georgia: U.S. Geological Survey Scientific Investigations Report 2005–5136, 43 p., accessed October 6, 2009, at *http://pubs.usgs.gov/sir/2005/5136/*.

Appendix 1. Borehole Geophysical Logs For Wells 14FF62, 14FF63, 14FF64, and 14FF65, Lawrenceville Area, Georgia

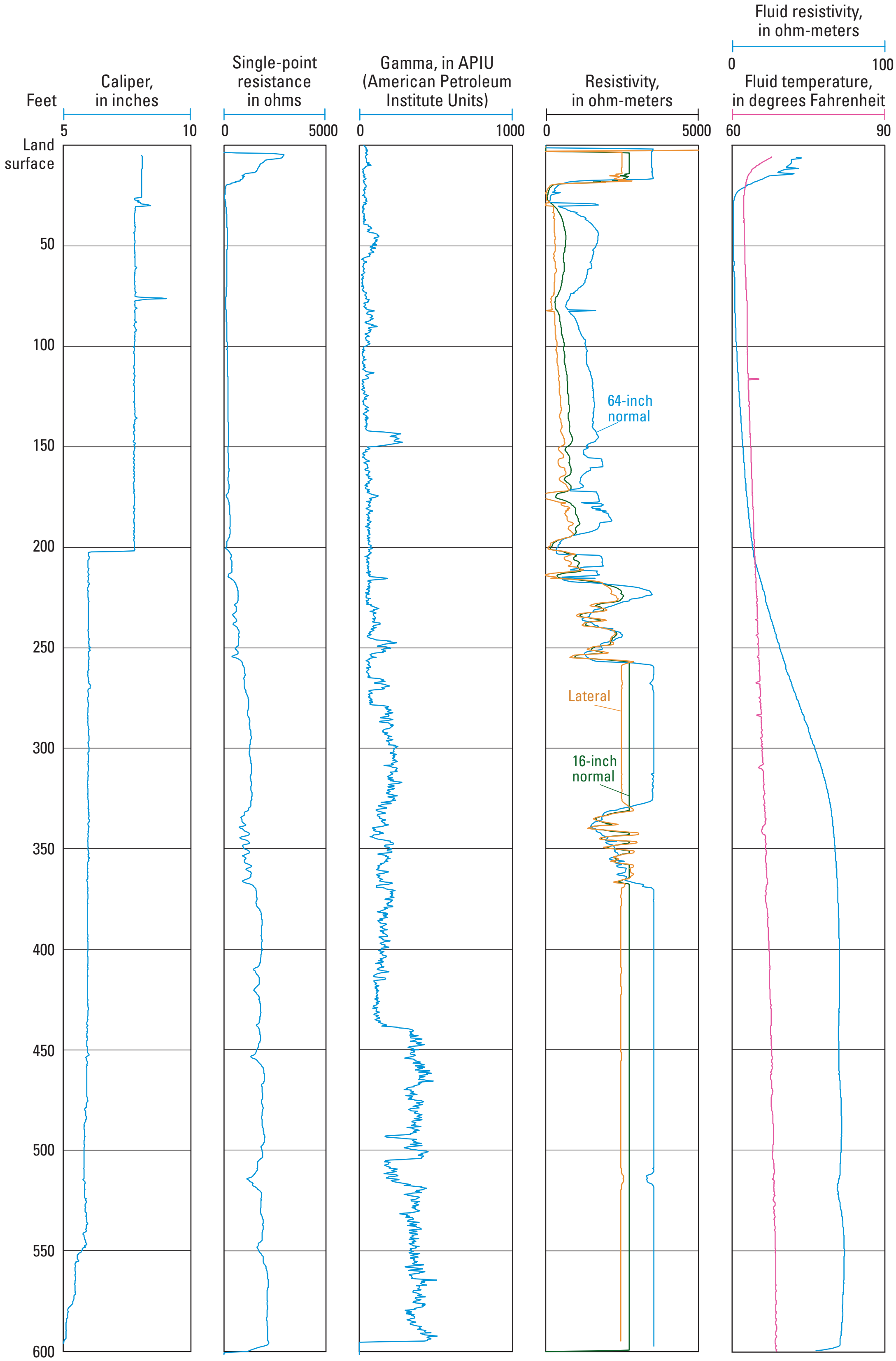


Figure 1–1. Borehole geophysical logs for well 14FF62, Lawrenceville area, Georgia.

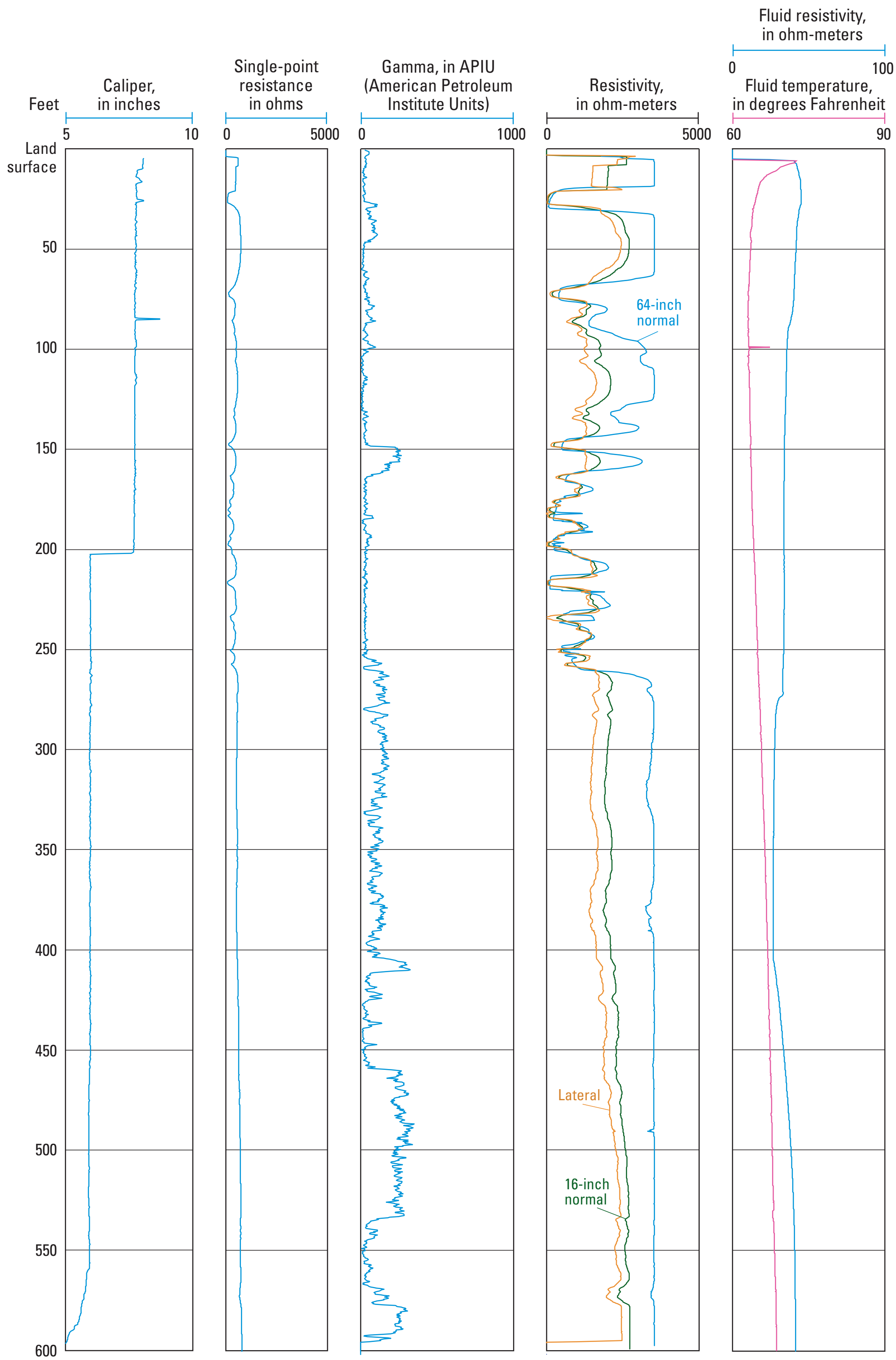


Figure 1–2. Borehole geophysical logs for well 14FF63, Lawrenceville area, Georgia.

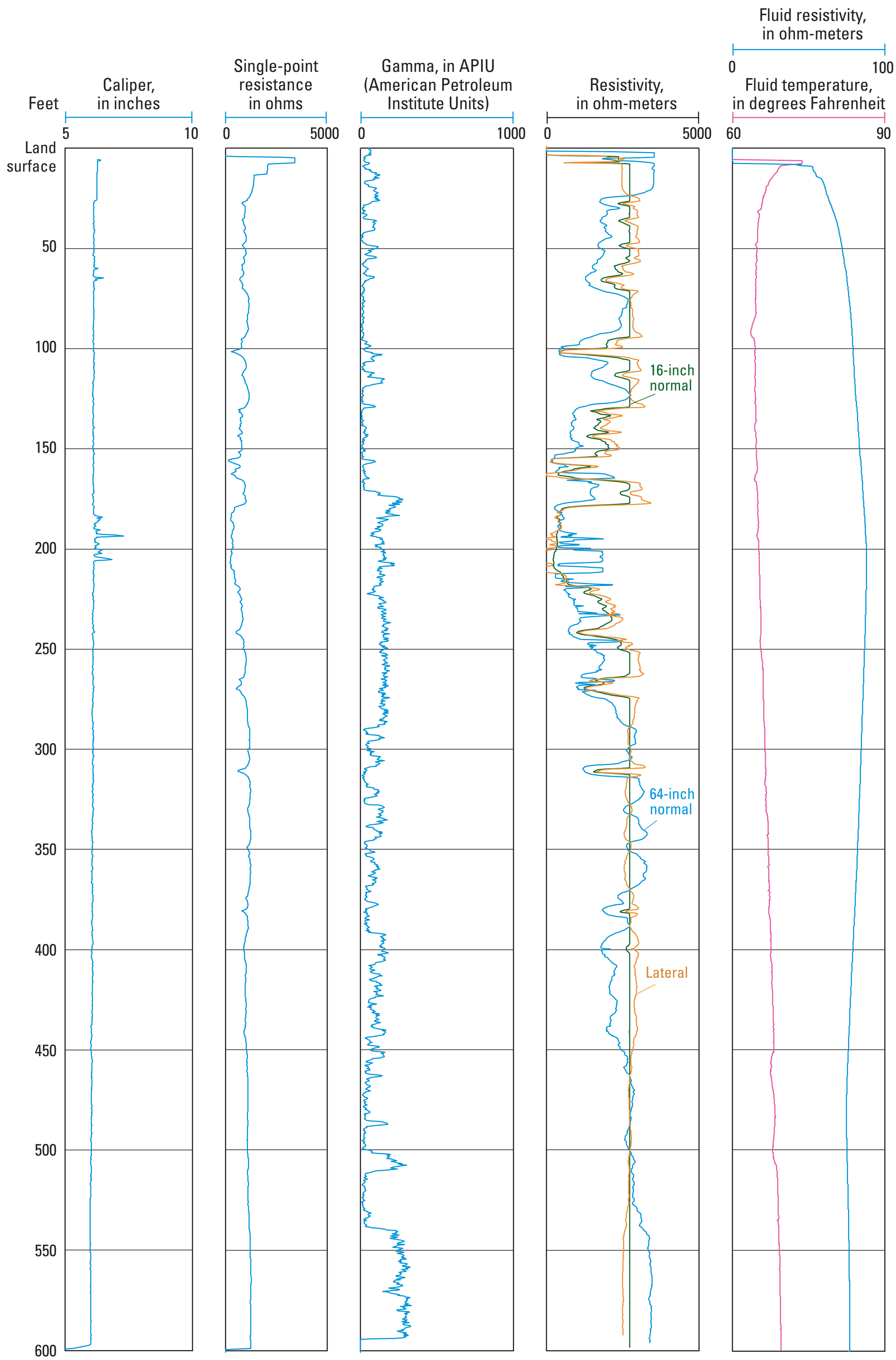


Figure 1–3. Borehole geophysical logs for well 14FF64, Lawrenceville area, Georgia.

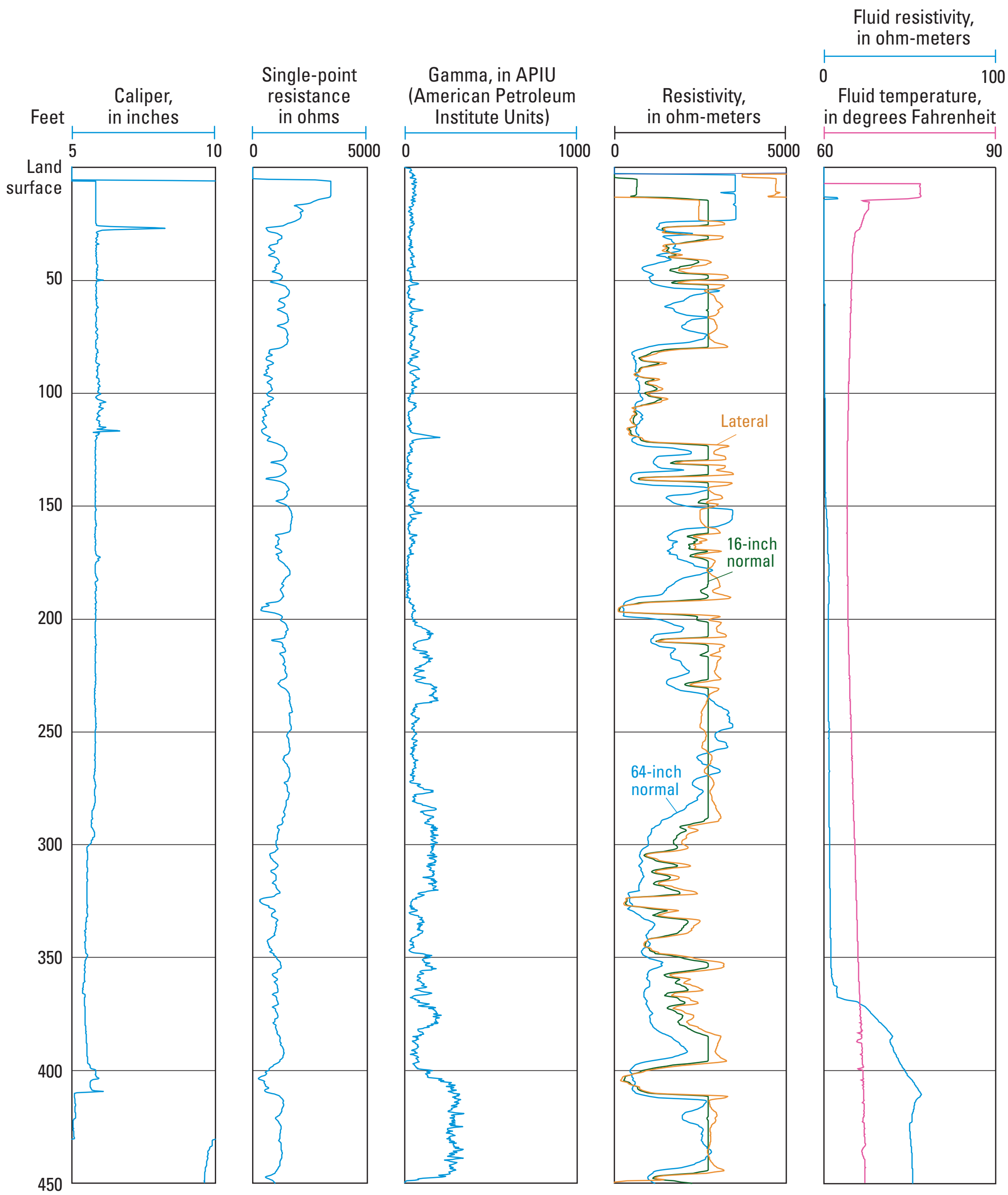


Figure 1–4. Borehole geophysical logs for well 14FF65, Lawrenceville area, Georgia.

Manuscript approved on February 16, 2010

Editing by Kimberly A. Waltenbaugh

Illustrations and layout by Bonnie J. Turcott

For more information about this publication, contact:
USGS Georgia Water Science Center
3039 Amwiler Road
Atlanta, GA 30360
telephone: 770-903-9100

http://ga.water.usgs.gov/

Clarke and Williams—**Hydrologic Conditions, Stream-Water Quality, and Selected Groundwater Studies, Lawrenceville, Georgia, 2003–2008**—Scientific Investigations Report 2010–5032