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Groundwater Conditions in Georgia, 2010–2011

Scientific Investigations Report 2013–5084

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

Preface

This report is published biennially to summarize groundwater conditions in Georgia. The report, presented in stop format, is the culmination of a concerted effort by U.S. Geological Survey Georgia Water Science Center personnel who collected, compiled, organized, analyzed, verified, edited, and assembled the report. In addition to the authors, who were primarily responsible for ensuring that the information contained herein is accurate and complete, the following individuals contributed substantially to the collection, processing, tabulation, and review of the data:

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Cover. Hydrologic technicians from the Groundwater Information and Project Support Unit installing a well into the surficial aquifer, Jekyll Island, Glynn County, Georgia.
Photo by John S. Clarke, USGS.

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By Michael F. Peck, Debbie W. Gordon, and Jaime A. Painter

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U.S. Department of the Interior
SALLY JEWELL, Secretary

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U.S. Geological Survey, Reston, Virginia: 2013

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Suggested citation:
Peck, M.F., Gordon, D.W., and Painter, J.A., 2013, Groundwater conditions in Georgia, 2010–2011: U.S. Geological Survey Scientific Investigations Report 2013–5084, 63 p., *http://pubs.usgs.gov/sir/2013/5084/*

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Conversion Factors and Datums

Inch/Pound to SI

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)
yard (yd)	0.9144	meter (m)
	Flow rate	
gallon per minute (gal/min)	0.06309	liter per second (L/s)
gallon per day (gal/d)	0.003785	cubic meter per day (m^3/d)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88). Historical data collected and stored as National Geodetic Vertical Datum of 1929 have been converted to NAVD 88 for use in this publication.

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83). Historical data collected and stored as North American Datum of 1927 (NAD 27) have been converted to NAD 83 for use in this publication.

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).

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By Michael F. Peck, Debbie W. Gordon, and Jaime A. Painter

Abstract

The U.S. Geological Survey collects groundwater data and conducts studies to monitor hydrologic conditions, better define groundwater resources, and address problems related to water supply, water use, and water quality. In Georgia, water levels were monitored continuously at 186 wells during calendar year 2010 and at 181 wells during calendar year 2011. Because of missing data or short periods of record (less than 3 years) for several of these wells, a total of 168 wells are discussed in this report. These wells include 17 in the surficial aquifer system, 19 in the Brunswick aquifer system and equivalent sediments, 70 in the Upper Floridan aquifer, 16 in the Lower Floridan aquifer and underlying units, 10 in the Claiborne aquifer, 1 in the Gordon aquifer, 11 in the Clayton aquifer, 14 in the Cretaceous aquifer system, 2 in Paleozoic-rock aquifers, and 8 in crystalline-rock aquifers. Data from the well network indicate that water levels generally declined during the 2010 through 2011 calendar-year period, with water levels declining in 158 wells and rising in 10. Water levels declined over the period of record at 106 wells, increased at 56 wells, and remained relatively constant at 6 wells.

In addition to continuous water-level data, periodic water-level measurements were collected and used to construct potentiometric-surface maps for the Upper Floridan aquifer in Camden, Charlton, and Ware Counties, Georgia, and adjacent counties in Florida during May–June 2010, and in the following areas in Georgia: the Brunswick area during August 2010 and August 2011, in the Albany–Dougherty County area during November 2010 and November 2011, and in the Augusta–Richmond County area during October 2010 and August 2011. In general, water levels in these areas were lower during 2011 than during 2010; however, the configuration of the potentiometric surfaces in each of the areas showed little change.

Groundwater quality in the Floridan aquifer system is monitored in the Albany, Savannah, and Brunswick areas of Georgia. In the Albany area, nitrate as nitrogen concentrations in the Upper Floridan aquifer during 2011 generally decreased from 2010; however, concentrations in two wells remained above the U.S. Environmental Protection Agency (USEPA) 10-milligrams-per-liter (mg/L) drinking-water standard. In the Savannah area, specific conductance and chloride concentrations were measured in water samples from discrete depths in two wells completed in the Upper Floridan aquifer. Data from the two wells indicate that chloride concentrations in the Upper Floridan aquifer showed little change during calendar years 2010 through 2011 and remained below the 250 mg/L USEPA secondary drinking-water standard. During calendar years 2010 through 2011, chloride concentrations in the Lower Floridan aquifer increased slightly at Tybee Island and Skidaway Island, remaining above the drinking-water standard. In the Brunswick area, maps showing the chloride concentration of water in the Upper Floridan aquifer constructed using data collected from 32 wells during August 2010 and from 30 wells during August 2011 indicate that chloride concentrations remained above the USEPA secondary drinking-water standard in an approximately 2-square-mile area. During calendar years 2010 through 2011, chloride concentrations generally decreased in over 70 percent of the wells sampled during 2011, with a maximum decrease of 200 mg/L in a well located in the north-central part of the Brunswick area.

Introduction

Reliable and impartial scientific information on the occurrence, quantity, quality, distribution, and movement of water is essential to resource managers, planners, and others throughout the Nation. The U.S. Geological Survey (USGS), in cooperation with numerous local, State, and Federal agencies, collects hydrologic data and conducts studies to monitor hydrologic conditions and better define the water resources of Georgia and other States and territories.

Groundwater-level and groundwater-quality data are essential for water-resources assessment and management. 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 measurement of water levels provides 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). Groundwater-quality data are necessary for the protection of groundwater resources because deterioration of groundwater quality may be virtually irreversible, and treatment of contaminated groundwater can be expensive (Alley, 1993). Reliable water-use data are important to many organizations and individuals in support of research and policy decisions and are essential in understanding the effects of humans on the hydrologic system (Hutson and others, 2004).

Purpose and Scope

This report presents an overview of groundwater levels, permitted water use, and groundwater quality throughout Georgia during calendar years 2010 through 2011 (hereafter referred to as “2010–2011”). In this report, the data collection period is based on a calendar year, for example, the phrase “during 2010” refers to the calendar year of January 1, 2010, through December 31, 2010. In Georgia, water levels were monitored continuously at 186 wells during 2010 and 181 wells during 2011. Because of missing data or short periods of record (less than 3 years) for several of these wells, a total of 168 wells are discussed in this report. Water-level data are summarized on graphs, maps, and tables. Ground-water levels in major aquifers are presented on hydrographs for selected wells. Estimated annual water-level change is reported for the period of record and for 2010–2011. Additional information on the wells included in this report can be obtained from the USGS National Water Information System (NWIS) at *http://waterdata.usgs.gov/ga/nwis/gw/*.

In addition to continuous water-level recording, periodic water-level measurements were collected to complete potentiometric surface maps for the Upper Floridan aquifer. In southwestern Georgia near Albany, measurements were collected from 62 wells during November 2010 and from 55 wells during November 2011. In the southern coastal area of Georgia, including Camden, Charlton, and Ware Counties, water-level measurements from 16 wells were collected during May–June 2010 (Kinnaman and Dixon, 2011). In the Brunswick–Glynn County area, water levels from 39 wells were collected during August 2010 and 43 wells during August 2011.

Because groundwater withdrawal can affect water levels, permitted water-use data compiled for 2005–2010 and reported herein are based on State-mandated reporting requirements for water users withdrawing more than 100,000 gallons per day (gal/d). State-mandated reporting includes data for public supply, industrial and commercial, and thermoelectric-power water use; however, reporting of information on irrigation water use is not mandated and, therefore, not discussed in this report.

The quality of groundwater in the Floridan aquifer system is being monitored in the Albany–Dougherty County area and in several areas along the Georgia coast. In the Albany area, nitrate as nitrogen concentrations in the Upper Floridan aquifer were determined in water from 16 wells during November 2010 and from 15 wells during November 2011. In the coastal area, groundwater quality of the Upper and Lower Floridan aquifers was determined in the Savannah and Brunswick areas. In the Savannah area, groundwater quality was assessed in four wells by using a combination of borehole fluid-resistivity logs and grab samples collected at discrete depths. Long-term chloride concentrations in the Brunswick area are presented by using composite-sample data from wells for the periods 1960–2011 (2 wells) and 1965–2011 (3 wells) together with maps showing chloride concentrations in the Brunswick area during August 2010 (28 wells) and August 2011 (26 wells). Also, data are presented from a network of five continuous, specific-conductance monitoring sites (used as surrogate data for chloride concentration) surrounding the chloride plume at Brunswick.

Methods of Analysis, Sources of Data, and Data Accuracy

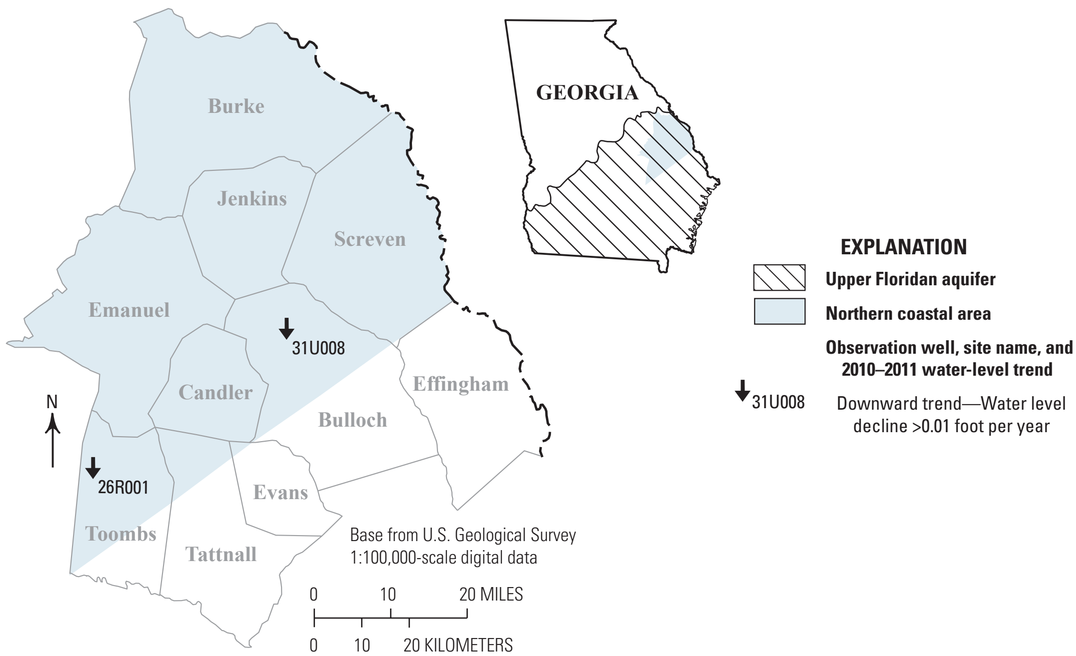
This report presents continuous water-level data from 168 wells throughout Georgia. Of these, 132 wells had electronic data recorders that recorded water levels at 60-minute intervals, and the data generally were retrieved bimonthly. Thirty-six wells had real-time satellite telemetry that recorded water levels at 60-minute intervals. Four of the real-time sites were equipped to monitor water levels and specific conductance, and at another site only specific conductance was monitored. Real-time satellite telemetry data are transmitted every 1 to 4 hours (based on equipment) available at *http://waterdata.usgs.gov/ga/nwis/current/?type=gw/*.

To illustrate long-term (period of record) and more recent (2010–2011) water-level changes, hydrographs showing monthly mean water levels are presented together with maps showing water-level trends during 2010–2011. To estimate water-level trends, the Levenberg–Marquardt (LMA) method for minimization of a weighted least-squares merit function (Janert, 2010) was used to determine a straight-line fit to both recent and period-of-record monthly mean groundwater levels (see example graph below). Estimated water levels from these straight-line fits were used to compute an annual rate of change (yearly slope) for the period of record and for 2010–2011. A more thorough discussion of the LMA method is presented at the end of this report along with associated summary statistics for each well and for straight-line fits (appendix).

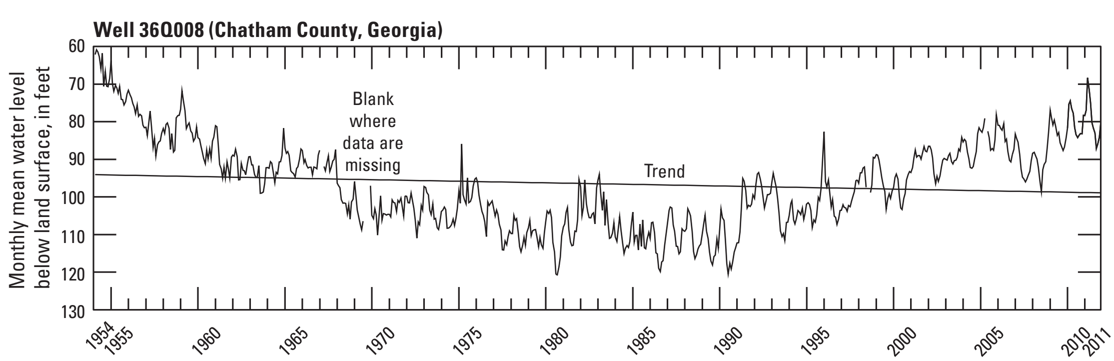
Water-level trends are presented on tables, hydrographs, and maps for each aquifer and sub-area in the groundwater level section of this report. Trends for 2010–2011 are presented on maps either by an upward arrow for a positive rate of change of 0.01 foot per year (ft/yr) or greater, or a downward arrow for a negative rate of change of 0.01 ft/yr or greater. A circle represents no water-level change on the map when the change was less than ± 0.01 ft/yr. Additional well information can be obtained from the USGS NWIS at *http://waterdata.usgs.gov/ga/nwis/gw/*.

Water samples were analyzed for nitrate as nitrogen at the USGS National Water Quality Laboratory (NWQL) in Denver, Colorado. Chloride analyses were conducted at TestAmerica Laboratory, Savannah, Georgia. Additional water-quality data for Georgia can be obtained from the USGS NWIS at *http://waterdata.usgs.gov/ga/nwis/qw/*.

Permitted water-use data for 2010 were compiled from the Georgia Water-Use Data System (GWUDS, Steven J. Lawrence, U.S. Geological Survey, written commun., August 17, 2012). The GWUDS contains permitted water-use information on public supplies, industrial and commercial supplies, and thermoelectric-power and hydroelectric-power uses for 1980–2011. These data are limited to permitted water withdrawals of 100,000 gal/d or greater, in compliance with Georgia water law that requires withdrawal permits for all public-supply, industrial, and other water users who withdraw more than 100,000 gal/d (*http://rules.sos.state.ga.us/docs/391/3/2/03.pdf*).



Water-level trends for 2010–2011 are presented on maps either by an upward arrow for a positive rate of change of 0.01 foot per year or greater, or a downward arrow for a negative rate of change of 0.01 foot per year or greater. A circle represents no water-level change.



Example hydrograph showing monthly mean water levels in well 36Q008 for the period 1954–2011, and period-of-record trend.

Previously published U.S. Geological Survey reports on groundwater conditions in Georgia.

[OFR, Open-File Report; WRIR, Water-Resources Investigations Report; SIR, Scientific Investigations Report]

Year of data collection	USGS report series and number	Author(s)	Year of publication
1977	OFR 79–213	U.S. Geological Survey	1978
1978	OFR 79–1290	Clarke, J.S., Hester, W.G., and O'Byrne, M.P.	1979
1979	OFR 80–501	Mathews, S.E., Hester, W.G., and O'Byrne, M.P.	1980
1980	OFR 81–1068	Mathews, S.E., Hester, W.G., and O'Byrne, M.P.	1981
1981	OFR 82–904	Mathews, S.E., Hester, W.G., and McFadden, K.W.	1982
1982	OFR 83–678	Stiles, H.R., and Mathews, S.E.	1983
1983	OFR 84–605	Clarke, J.S., Peck, M.F., Longsworth, S.A., and McFadden, K.W.	1984
1984	OFR 85–331	Clarke, J.S., Longsworth, S.A., McFadden, K.W., and Peck, M.F.	1985
1985	OFR 86–304	Clarke, J.S., Joiner, C.N., Longsworth, S.A., McFadden, K.W., and Peck, M.F.	1986
1986	OFR 87–376	Clarke, J.S., Longsworth, S.A., Joiner, C.N., Peck, M.F., McFadden, K.W., and Milby, B.J.	1987
1987	OFR 88–323	Joiner, C.N., Reynolds, M.S., Stayton, W.L., and Boucher, F.G.	1988
1988	OFR 89–408	Joiner, C.N., Peck, M.F., Reynolds, M.S., and Stayton, W.L.	1989
1989	OFR 90–706	Peck, M.F., Joiner, C.N., Clarke, J.S., and Cressler, A.M.	1990
1990	OFR 91–486	Milby, B.J., Joiner, C.N., Cressler, A.M., and West, C.T.	1991
1991	OFR 92–470	Peck, M.F., Joiner, C.N., and Cressler, A.M.	1992
1992	OFR 93–358	Peck, M.F., and Cressler, A.M.	1993
1993	OFR 94–118	Joiner, C.N., and Cressler, A.M.	1994
1994	OFR 95–302	Cressler, A.M., Jones, L.E., and Joiner, C.N.	1995
1995	OFR 96–200	Cressler, A.M.	1996
1996	OFR 97–192	Cressler, A.M.	1997
1997	OFR 98–172	Cressler, A.M.	1998
1998	OFR 99–204	Cressler, A.M.	1999
1999	OFR 00–151	Cressler, A.M.	2000
2000	OFR 01–220	Cressler, A.M., Blackburn, D.K., and McSwain, K.B.	2001
2001	WRIR 03–4032	Leeth, D.C., Clarke, J.S., and Craigg, S.D., and Wipperfurth, C.J.	2003
2002–2003	SIR 2005–5065	Leeth, D.C., Clarke, J.S., Wipperfurth, C.J., and Craigg, S.D.	2005
2004–2005	SIR 2007–5017	Leeth, D.C., Peck, M.F., and Painter, J.A.	2007
2006–2007	SIR 2009–5070	Peck, M.F., Painter, J.A., and Leeth, D.C.	2009
2008–2009	SIR 2011–5048	Peck, M.F., Leeth, D.C., and Painter, J.A.	2011

Georgia Well-Identification System

Wells described in this report are identified according to a system based on the index of USGS 7.5-minute topographic maps of Georgia. Each map in Georgia has been assigned a two- to three-digit number and letter designation (for example, 07H) beginning at the southwestern corner of the State. Numbers increase sequentially eastward and letters advance alphabetically northward. Quadrangles in the northern part of the State are designated by double letters: AA follows Z, and so forth. The letters I, O, II, and OO are not used in the well-identification system. Wells inventoried in each quadrangle are numbered consecutively, beginning with 001. Thus, the fourth well inventoried in the 11A quadrangle is designated 11A004. In the USGS NWIS database, this information is stored in the "Station Name" field; in NWIS Web, it is labeled "Site Name."

Cooperating Organizations and Agencies

Groundwater monitoring in Georgia is conducted in cooperation with numerous local organizations and State and Federal agencies. Cooperating organizations and agencies include:

- Albany Water, Gas, and Light Commission
- City of Lawrenceville
- City of Augusta/Richmond County
- City of Tybee Island
- Georgia Department of Natural Resources, Environmental Protection Division
- Glynn County Joint Water and Sewer Commission
- Miller Coors LLC
- Proctor and Gamble, Inc.

With the exception of the Federal agencies and private companies, all of these organizations participate in the USGS Cooperative Water Program, an ongoing partnership between the USGS and State and local agencies. The program enables joint planning and funding for groundwater monitoring and systematic studies of water quantity, quality, and use. Data obtained from these studies are used to guide water-resources management and planning activities and provide indications of emerging water problems. For a more complete description of the Cooperative Water Program, see Brooks (2001).

References

Alley, W.M., 1993, General design consideration, *in* Alley, W.M., ed., Regional groundwater quality: New York, N.Y., Van Nostrand Reinhold, 634 p.

Brooks, M.H., 2001, Cooperative Water Program—A partnership in the Nation's water-resources program: U.S. Geological Survey Fact Sheet 128–01, 2 p.

Hutson, S.S., Barber, N.L., Kenny, J.F., Linsey, K.S., Lumia, D.S., and Maupin, M.A., 2004, Estimated use of water in the United States in 2000: U.S. Geological Survey Circular 1268, 46 p.

Janert, P.K., 2010, Gnuplot in action—Understanding data with graphs: Greenwich, Conn., Manning Publications Co., 360 p.

Kinnaman, S.L., and Dixon, J.F., 2011, Potentiometric surface of the Upper Floridan aquifer in Florida and parts of Georgia, South Carolina, and Alabama, May–June 2010: U.S. Geological Survey Scientific Investigations Map 3182, 1 sheet.

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

Groundwater Resources

Contrasting geologic features and landforms of the physiographic provinces of Georgia (see map on p. 7 and table on p. 8–9) affect the quantity and quality of groundwater throughout the State. The surficial aquifer system is present in each of the physiographic provinces. In the Coastal Plain Physiographic Province, the surficial aquifer system consists of layered sand, clay, and limestone. The surficial aquifer system is usually under water-table (unconfined) conditions and provides water for domestic and livestock use. The surficial aquifer system is semiconfined to confined locally in the coastal area. In the Piedmont, Blue Ridge, and Valley and Ridge Physiographic Provinces, the surficial aquifer system consists of soil, saprolite, stream alluvium, colluvium, and other surficial deposits.

The most productive aquifers in Georgia are in the Coastal Plain Physiographic Province in the southern half of the State. The Coastal Plain is underlain by alternating layers of sand, clay, dolomite, and limestone that dip and thicken to the southeast. Coastal Plain aquifers generally are confined, except near their northern limits where they crop out or are near land surface. Aquifers in the Coastal Plain include the surficial aquifer system, Brunswick aquifer system, Upper and Lower Floridan aquifers, Gordon aquifer system, Claiborne aquifer, Clayton aquifer, and Cretaceous aquifer system.

In the Valley and Ridge Physiographic Province, groundwater is transmitted through primary and secondary openings in folded and faulted sedimentary and metasedimentary rocks of Paleozoic age, herein referred to as "Paleozoic-rock aquifers."

In the Piedmont and Blue Ridge Physiographic Provinces, the geology is complex and consists of structurally deformed metamorphic and igneous rocks. Groundwater is transmitted through secondary openings along fractures, foliation, joints, contacts, or other features in the crystalline bedrock. In these provinces, aquifers are referred to as "crystalline-rock aquifers." For a more complete discussion of the State's groundwater resources, see Clarke and Pierce (1985).

References

Clarke, J.S., 2003, The surficial and Brunswick aquifer systems—Alternative groundwater resources for coastal Georgia, *in* Hatcher, K.J., ed., Proceedings of the 2003 Georgia Water Resources Conference, April 23–24, 2003: Athens, Georgia, University of Georgia, CD–ROM.

Clarke, J.S., Brooks, Rebekah, and Faye, R.E., 1985, Hydrology of the Dublin and Midville aquifer system of east-central Georgia: Georgia Geologic Survey Information Circular 74, 62 p.

Clarke, J.S., Faye, R.E., and Brooks, Rebekah, 1983, Hydrogeology of the Providence aquifer of southwest Georgia: Georgia Geologic Survey Hydrologic Atlas 11, 5 sheets.

Clarke, J.S., Hacke, C.M., and Peck, M.F., 1990, Geology and groundwater resources of the coastal area of Georgia: Georgia Geologic Survey Bulletin 113, 106 p.

Clarke, J.S., and Pierce, R.R., 1985, Georgia groundwater resources, *in* U.S. Geological Survey, National Water Summary, 1984: U.S. Geological Survey Water-Supply Paper 2275, p. 179–184.

Cressler, C.W., 1964, Geology and groundwater resources of Walker County, Georgia: Georgia Geologic Survey Information Circular 29, 15 p.

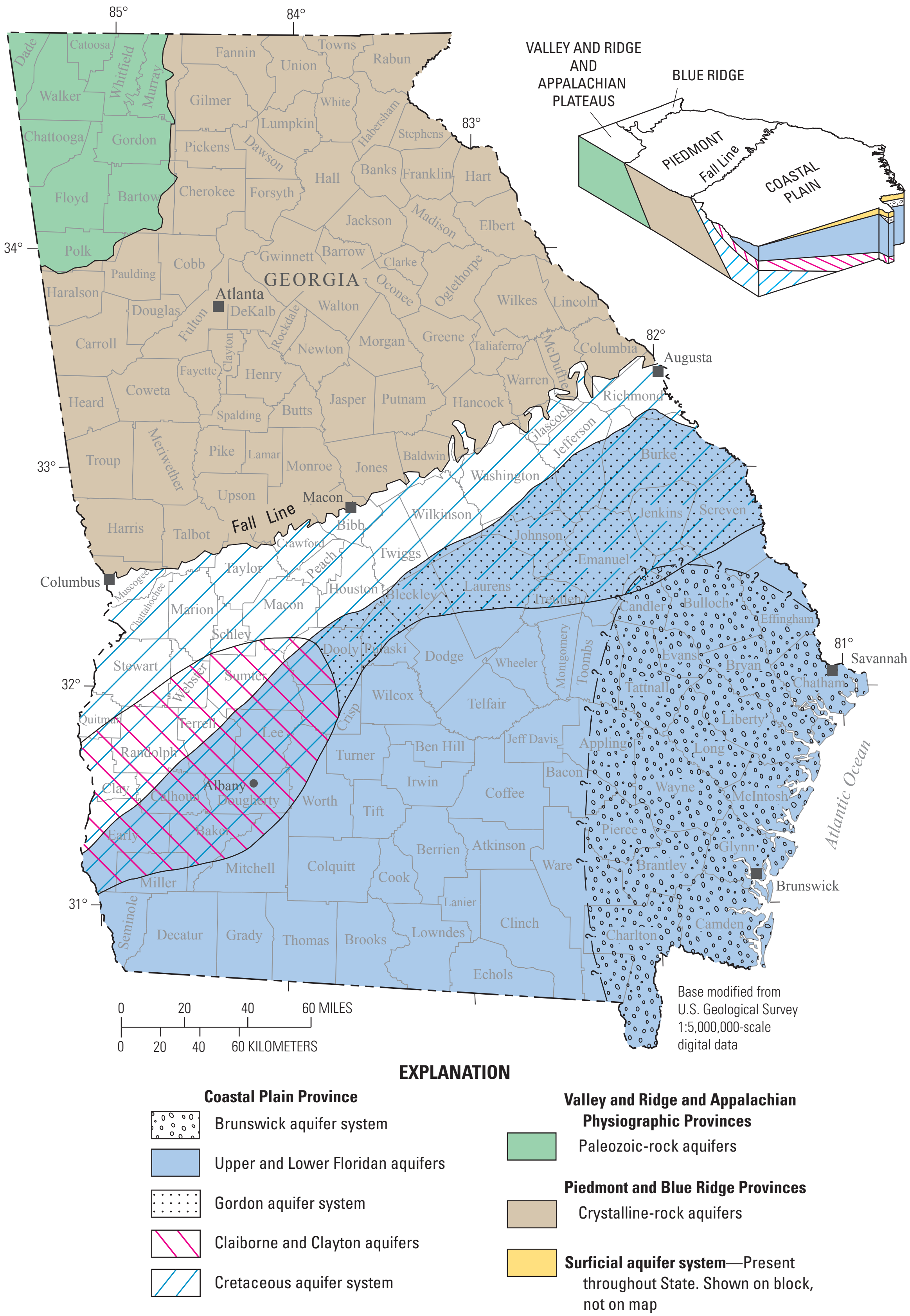
Cressler, C.W., Thurmond, C.J., and Hester, W.G., 1983, Groundwater in the greater Atlanta region, Georgia: Georgia Geologic Survey Information Circular 63, 144 p.

Hicks, D.W., Krause, R.E., and Clarke, J.S., 1981, Geohydrology of the Albany area, Georgia: Georgia Geologic Survey Information Circular 57, 31 p.

Jones, L.E., and Maslia, M.L., 1994, Selected groundwater data, and results of aquifer tests for the Upper Floridan aquifer, Brunswick, Glynn County, Georgia, area: U.S. Geological Survey Open-File Report 94–520, 107 p.

Krause, R.E., and Randolph, R.B., 1989, Hydrogeology of the Floridan aquifer system in southeast Georgia and adjacent parts of Florida and South Carolina: U.S. Geological Survey Professional Paper 1403–D, 65 p.

Peck, M.F., Joiner, C.N., and Cressler, A.M., 1992, Groundwater conditions in Georgia, 1991: U.S. Geological Survey Open-File Report 92–470, 137 p.



Areas of use of major aquifers in Georgia (modified from Clarke and Pierce, 1985).

Groundwater Resources

Aquifer and well characteristics in Georgia [modified from Clarke and Pierce, 1985; Peck and others, 1992; ft, foot; gal/min, gallon per minute]

Aquifer name	Aquifer description	Well characteristics		
		Depth (ft)	Yield (gal/min)	
		Typical range	Typical range	May exceed
Surficial aquifer system	Unconsolidated sediments and residuum; generally unconfined. However, in the coastal area of the Coastal Plain, at least two semiconfined aquifers have been identified	11–300	2–25	75
Brunswick aquifer system, including upper and lower Brunswick aquifers	Phosphatic and dolomitic quartz sand; generally confined	85–390	10–30	180
Upper and Lower Floridan aquifers	Limestone, dolomite, and calcareous sand; generally confined	40–900	1,000–5,000	11,000
Gordon aquifer system	Sand and sandy limestone; generally confined	270–530	87–1,200	1,800
Claiborne aquifer	Sand and sandy limestone; generally confined	20–450	150–600	1,500
Clayton aquifer	Limestone and sand; generally confined	40–800	250–600	2,150
Cretaceous aquifer system	Sand and gravel; generally confined	30–750	50–1,200	3,300
Paleozoic-rock aquifers	Sandstone, limestone and dolomite; generally confined	15–2,100	1–50	3,500
Crystalline-rock aquifers	Granite, gneiss, schist, and quartzite; confined and unconfined	40–600	1–25	500

Hydrologic response	Remarks
Water-level fluctuations are caused mainly by variations in precipitation, evapotranspiration, and natural drainage or discharge. In addition, water levels in the City of Brunswick area are influenced by nearby pumping, precipitation, and tidal fluctuations (Clarke and others, 1990). Water levels generally rise rapidly during wet periods and decline slowly during dry periods. Prolonged droughts may cause water levels to decline below pump intakes in shallow wells, particularly those located on hilltops and steep slopes, resulting in temporary well failures. Usually, well yields are restored by precipitation (Clarke, 2003).	Primary source of water for domestic and livestock supply in rural areas. Supplemental source of water for irrigation supply in coastal Georgia.
In the coastal area, the aquifers may respond to pumping from the Upper Floridan aquifer as a result of the hydraulic connection between the aquifers. Elsewhere, the water level mainly responds to seasonal variations in recharge and discharge. In Bulloch County, unnamed aquifers equivalent to the upper and lower Brunswick aquifers are unconfined to semiconfined and are influenced by variations in recharge from precipitation and by pumping from the Upper Floridan aquifer; in the Wayne and Glynn County area, the aquifers are confined and respond to nearby pumping (Clarke and others, 1990; Clarke, 2003).	Not a major source of water in coastal Georgia, but considered a supplemental water supply to the Upper Floridan aquifer.
In and near outcrop areas, the aquifers are semiconfined, and water levels in wells tapping the aquifers fluctuate seasonally in response to variations in recharge rate and pumping. Near the coast, where the aquifers are confined, water levels primarily respond to pumping, and fluctuations related to recharge are less pronounced (Clarke and others, 1990).	Supplies about 50 percent of groundwater in Georgia. The aquifer system is divided into the Upper and Lower Floridan aquifers. In the Brunswick area, the Upper Floridan aquifer includes two freshwater-bearing zones—the upper water-bearing zone and the lower water-bearing zone. In the Brunswick area and in southeastern Georgia, the Lower Floridan aquifer includes the brackish-water zone, the deep freshwater zone, and the Fernandina permeable zone (Krause and Randolph, 1989). The Lower Floridan aquifer extends to more than 2,700 ft in depth and yields high-chloride water below 2,300 ft (Jones and Maslia, 1994).
Water levels are influenced by seasonal fluctuations in recharge from precipitation, discharge to streams, and evapotranspiration (Clarke and others, 1985).	Major source of water for irrigation, industrial, and public-supply use in east-central Georgia.
Water levels are mainly affected by precipitation and by local and regional pumping (Hicks and others, 1981). The water level is generally highest following the winter and spring rainy seasons, and lowest in the fall following the summer irrigation season.	Major source of water for irrigation, industrial, and public-supply use in southwestern Georgia.
Water levels are affected by seasonal variations in local and regional pumping (Hicks and others, 1981).	Major source of water for irrigation, industrial, and public-supply use in southwestern Georgia.
Water levels are influenced by variations in precipitation and pumping (Clarke and others, 1983, 1985).	Major source of water in east-central Georgia. Supplies water for kaolin mining and processing; includes the Providence aquifer in southwestern Georgia, and the Dublin, Midville, and Dublin–Midville aquifer systems in east-central Georgia.
Water levels are affected mainly by precipitation and local pumping (Cressler, 1964).	Not laterally extensive. Limestone and dolomite aquifers are the most productive. Storage is in regolith, primary openings, and secondary fractures and solution openings in rock. Springs in limestone and dolomite aquifers discharge at rates of as much as 5,000 gal/min. Sinkholes may form in areas of intensive pumping.
Water levels are affected mainly by precipitation and evapotranspiration, and locally by pumping (Cressler and others, 1983). Precipitation can cause a rapid rise in water levels in wells tapping aquifers overlain by thin regolith.	Storage is in regolith and fractures in rock.

Permitted Water-Use Data for Georgia during 2010 and Groundwater-Use Trends for 2005–2010

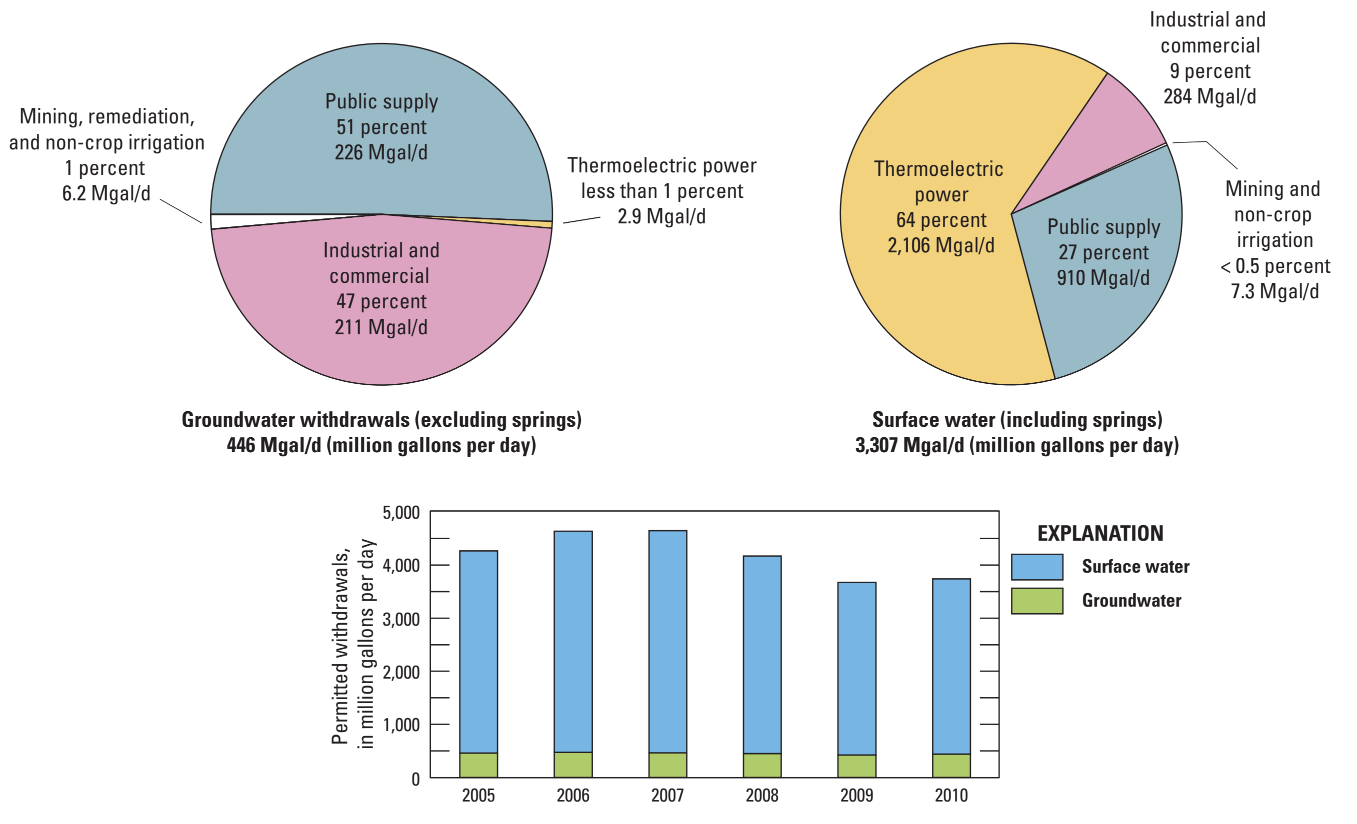
Permitted water-use data can be used to assess potential effects of groundwater withdrawal on groundwater systems. Only water-use data from permitted public supply, industrial and commercial, mining, non-crop irrigation (such as golf courses), and thermoelectric systems are included in this report. Estimates for crop irrigation, livestock, offstream hydroelectric, and domestic use are omitted.

During 2010, permitted water withdrawal in Georgia totaled 3,738 million gallons per day (Mgal/d) of which about 88 percent (3,307 Mgal/d) was from surface water and 12 percent (446 Mgal/d) was from groundwater sources (Steven J. Lawrence, U.S. Geological Survey, written commun., August 17, 2012). Thermoelectric facilities were the largest users of water in Georgia (excluding hydroelectric) during 2010, withdrawing about 2,106 Mgal/d mostly from surface-water sources.

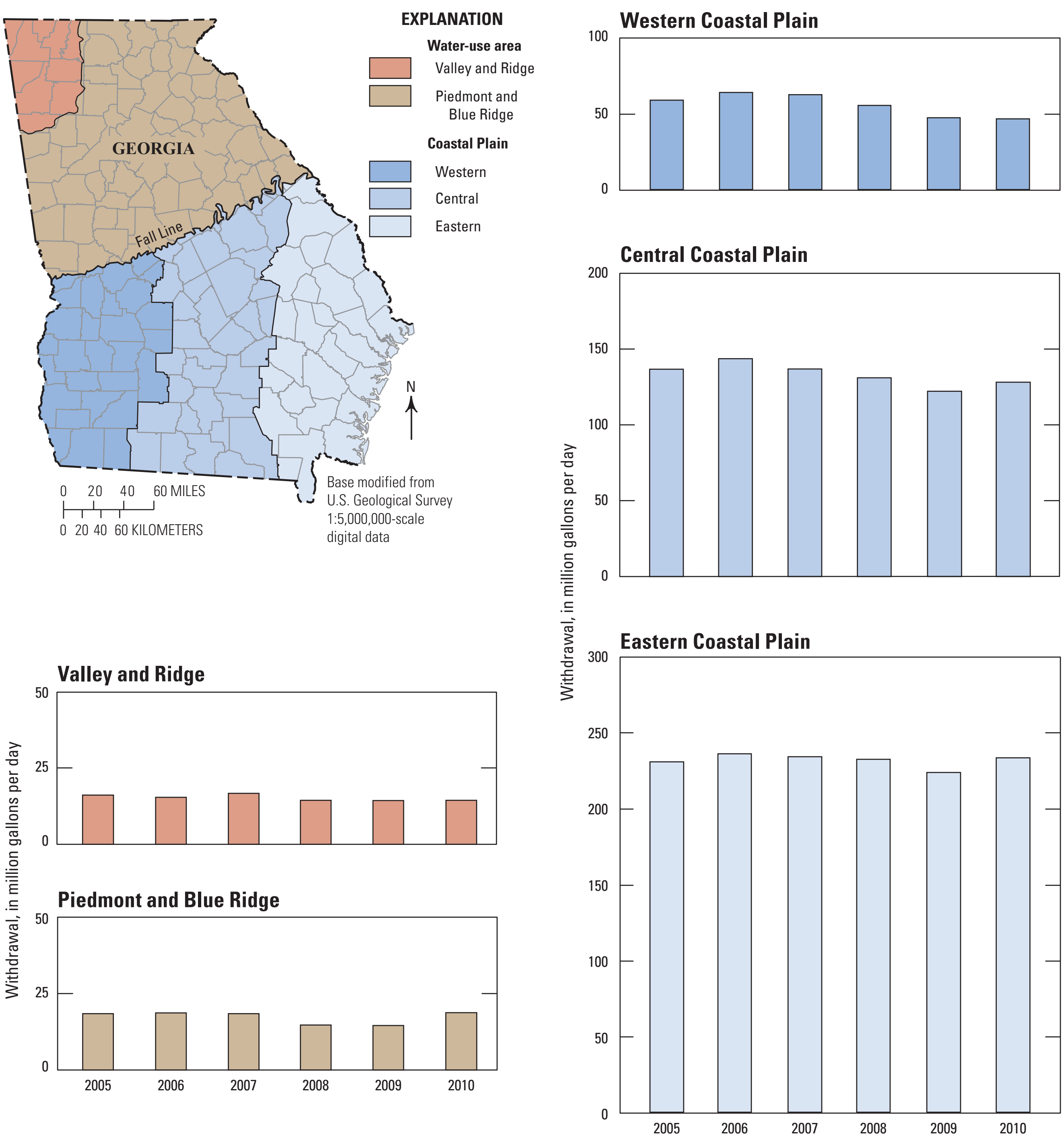
Permitted withdrawal by public-supply systems in 2010 totaled about 1,136 Mgal/d, about 80 percent of which was from surface-water sources and 20 percent was from ground-water sources (see pie charts below). Industrial and commercial users withdrew about 495 Mgal/d in 2010, with 43 percent from groundwater sources and 57 percent from surface water. The major industrial users in Georgia during 2010 were the pulp and paper, and chemical industries.

During 2005 to 2010, total withdrawals were highest in 2007 when 4,647 Mgal/d were withdrawn from all sources. Compared to 2007, total withdrawals for 2010 decreased by 909 Mgal/d (22 percent); however, the total withdrawals for 2010 were nearly 2 percent higher than in 2009. The largest decrease in groundwater withdrawals between 2007 and 2010 (13 percent) occurred among industrial and commercial users; total groundwater withdrawals were similar in 2009 and 2010.

Permitted groundwater withdrawals from 2005 to 2010 were grouped into five areas as depicted in the map and graphs (facing page). During this period, groundwater withdrawals decreased by 6 to 23 percent in the central Coastal Plain, Valley and Ridge, and western Coastal Plain areas, while withdrawals increased by 1 to 2 percent in the Piedmont/Blue Ridge and eastern Coastal Plain areas. Withdrawals from the Piedmont/Blue Ridge area in 2010 were 25 percent higher than 2009, while the eastern and central Coastal Plain areas increased 4 to 5 percent from 2009. Withdrawals in 2010 from the Valley and Ridge area were nearly 2 percent lower than in 2009. Withdrawals in 2010 from the western Coastal Plain were similar to 2009 withdrawals.



Percentages of permitted water withdrawals in Georgia by category and source, 2010.



Permitted groundwater withdrawals in Georgia by water-use area, 2005–2010.

Groundwater Conditions

Groundwater Levels

Maps and tables in this section provide an overview of groundwater levels in major aquifers in Georgia during 2010–2011. Hydrographs of selected wells are presented to demonstrate period-of-record and 2010–2011 water-level trends. Discussion of each aquifer is subdivided into areas where wells likely would have similar water-level fluctuations and trends. The map on the facing page shows the locations of 181 wells that were continuously monitored by the U.S. Geological Survey during the 2011 calendar year, including 40 wells that were monitored in real time. Of the 181 wells 168 are presented in this report.

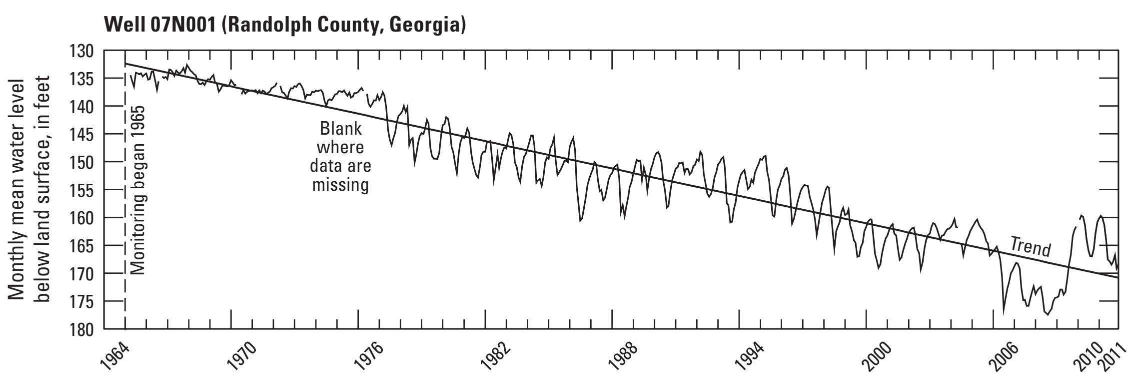
Changes in aquifer storage cause changes in groundwater levels in wells. Taylor and Alley (2001) described many factors that affect groundwater storage; these factors are discussed briefly here. When recharge to an aquifer exceeds discharge, groundwater levels rise; when discharge from an aquifer exceeds recharge, groundwater levels decline. Recharge varies in response to precipitation and surface-water infiltration to an aquifer. Discharge occurs as natural flow from an aquifer to streams and springs, as evapotranspiration, and as withdrawal from wells. Hydrologic responses and controls on groundwater levels in major aquifers in Georgia are summarized on pages 8–9.

Water levels in aquifers in Georgia typically follow a cyclical pattern of seasonal fluctuation. Water levels rise during winter and spring because of increased recharge from precipitation and decline during summer and fall because of decreased recharge, greater evapotranspiration, and increased pumping. The magnitude of fluctuations can vary greatly from season to season and from year to year in response to changing climatic conditions. During the period 2010–2011, drought conditions were first recorded in mid-2010 in southwest Georgia and progressed from moderate to severe drought throughout most of the State by the end of 2010. The drought continued during 2011 and went from severe and extreme conditions to exceptional throughout most areas of the State (*http://droughtmonitor.unl.edu/archive.html*; *http://www.griffin.uga.edu/aemn/Drought/MapPrecip.php?ID=2010*; *http://www.griffin.uga.edu/aemn/Drought/MapPrecip.php?ID=2011*).

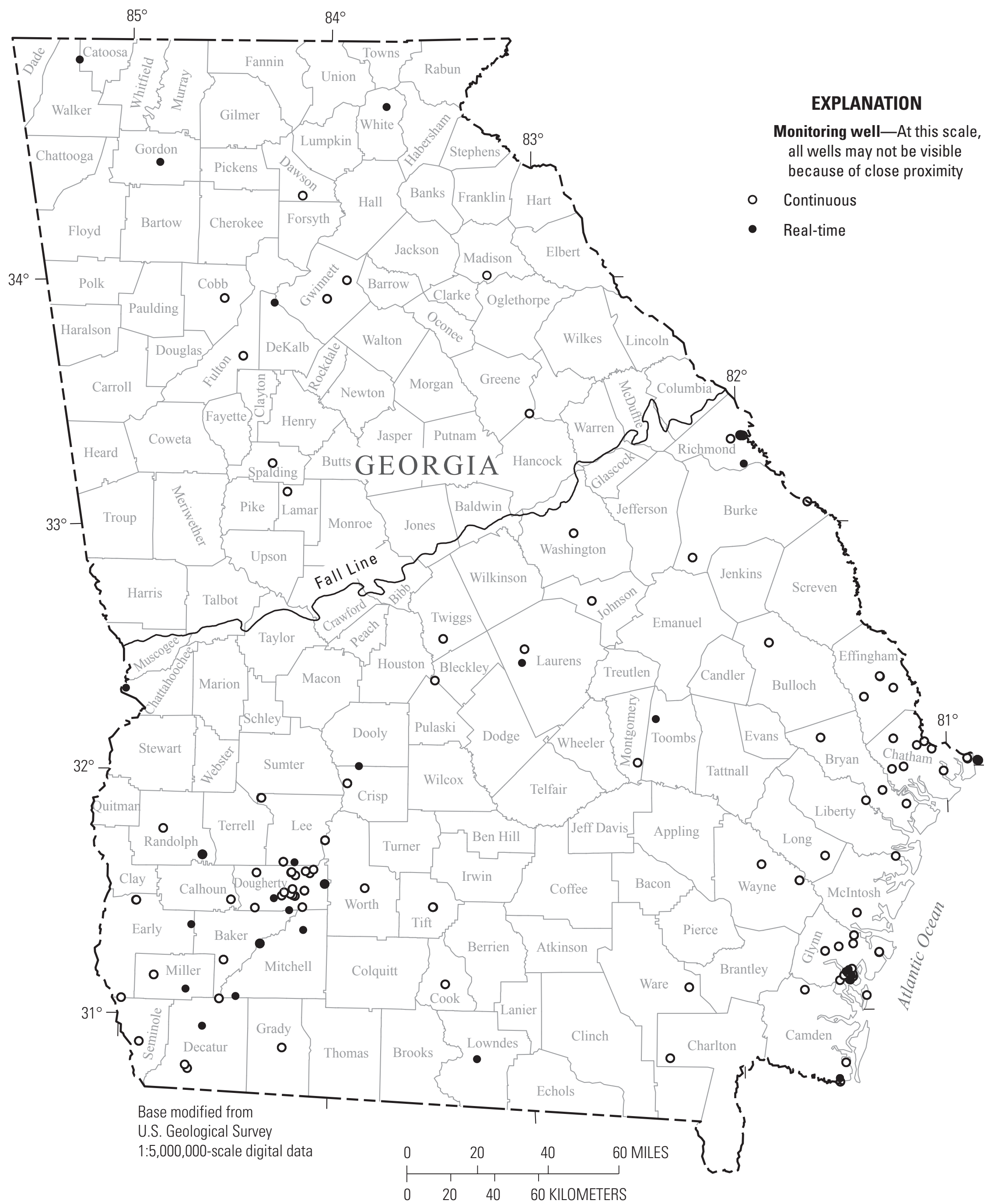
Groundwater pumping is the most important human activity that affects the amount of groundwater in storage and the rate of discharge from an aquifer (Taylor and Alley, 2001). As groundwater storage is depleted within the radius of influence of pumping, water levels in the aquifer decline forming a cone of depression around the well. In areas having a high density of pumped wells, multiple cones of depression can form and combine to produce water-level declines across a large area. These declines may alter groundwater-flow directions, reduce flow to streams, capture water from a stream or adjacent aquifer, or alter groundwater quality. The effects of sustained pumping can be seen in the hydrograph of well 07N001 completed in the Clayton aquifer in Randolph County (below).

Reference

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.



Example hydrograph showing monthly mean water levels and trend line for well 07N001 for the period 1965–2011, Randolph County, Georgia.



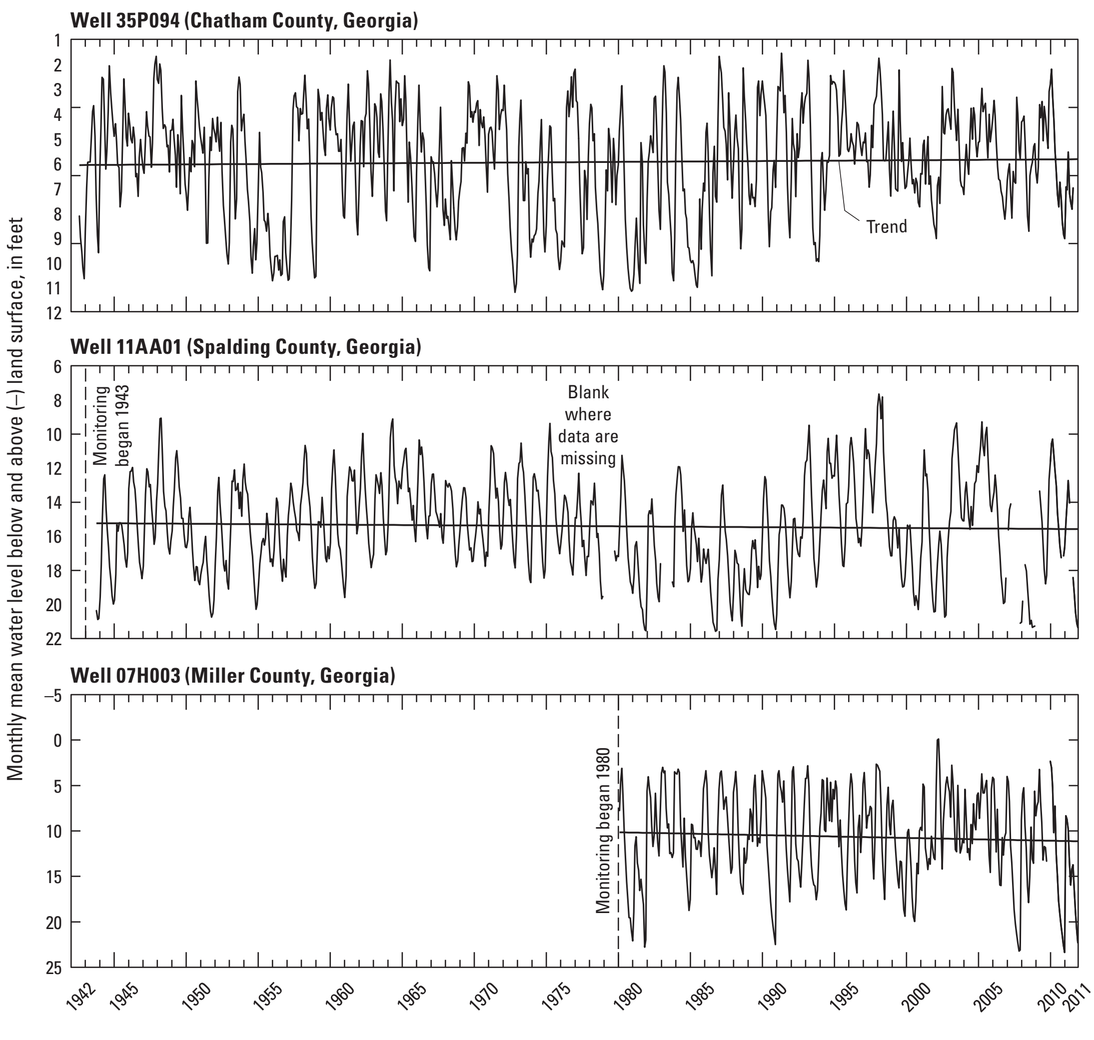
Locations of monitoring wells used to collect long-term water-level data in Georgia during 2011.

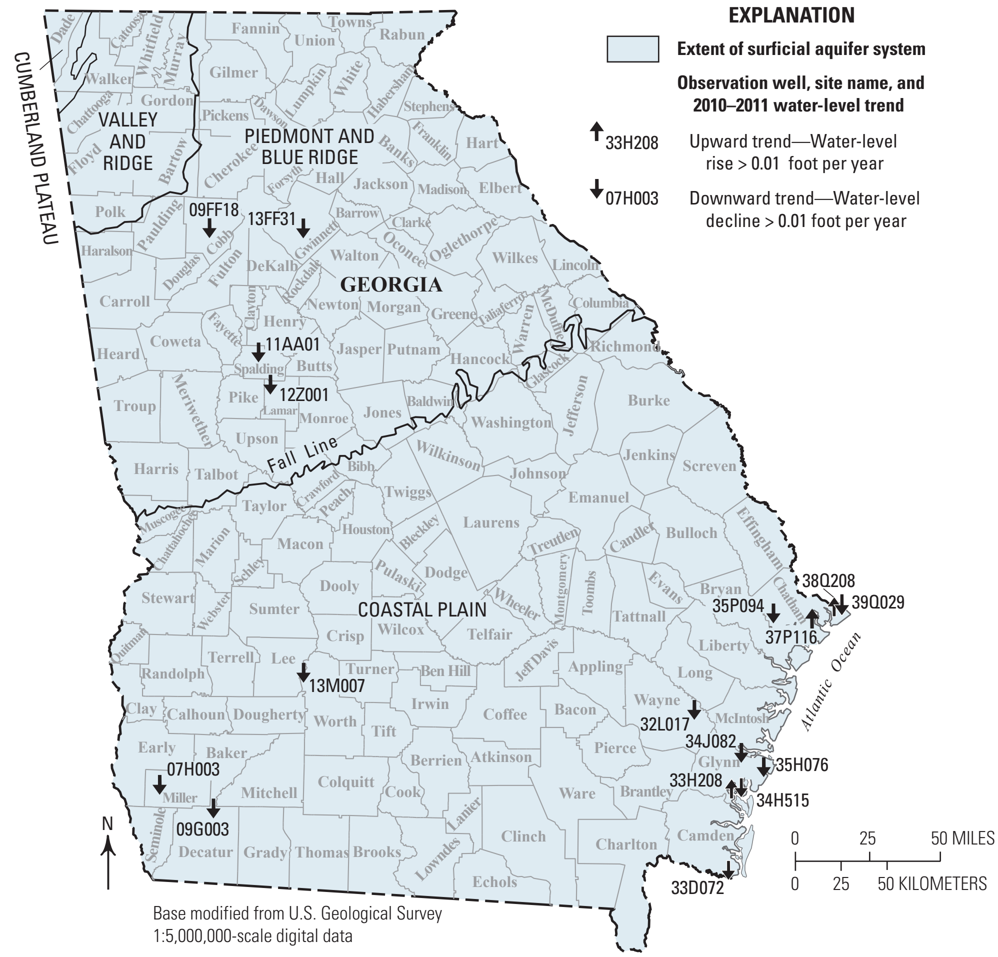
Groundwater Levels

Surficial Aquifer System

Water levels measured in 17 wells were used to define conditions in the surficial aquifer system during 2010–2011 (map and table, facing page). Groundwater in the surficial aquifer system typically is in contact with the atmosphere (referred to as an unconfined or water-table aquifer), but locally (especially in coastal Georgia) may be under pressure exerted by overlying sediments or rocks (referred to as a confined aquifer). Where unconfined, water levels change quickly in response to recharge and discharge. Consequently, hydrographs from these wells show a strong relation to climatic fluctuations. In parts of coastal Georgia the surficial aquifer system is used as a source of irrigation supply and shows a response to local pumping. Water-level hydrographs for selected wells (below) illustrate monthly mean water levels for the period of record. The hydrographs show mostly seasonal variations, with periodic upward or downward trends that respectively reflect surplus or deficits in rainfall. These periodic trends tend to be level over the long term.

Water levels in the surficial aquifer have shown little change in long-term trend during the period of record with rates of change less than ±0.01 foot per year (ft/yr) in five of the wells, declines of 0.01 to 0.18 ft/yr in nine wells, and rises of 0.03 to 0.30 ft/yr in three wells. During 2010–2011, water levels in all but three of the wells declined from 0.36 to 5.87 ft/yr corresponding to a decrease in precipitation because of drought conditions that began in mid-2010 and continued through 2011. Water levels in two wells in Chatham County rose 0.11 to 0.52 foot (ft) during 2010–2011. Well 33H208 in Glynn County rose 8.6 ft during 2010–2011, and may reflect reductions in local pumping.





Site name	County	Year monitoring began	Water-level change, in feet, per year[1]	
			Period of record	From 2010 to 2011
33D072	Camden	1998	0.30	–0.98
35P094	Chatham	1942	<0.01	–1.78
37P116	Chatham	1984	<0.01	0.11
38Q208	Chatham	1998	<0.01	0.52
39Q029	Chatham	1998	0.03	–1.08
09FF18	Cobb	2001	–0.15	–0.66
09G003	Decatur	1980	–0.01	–5.43
35H076	Glynn	2005	–0.18	–0.36
33H208	Glynn	1983	0.14	8.60
34H515	Glynn	2005	–0.06	–0.52
34J082	Glynn	2002	–0.09	–1.24
13FF31	Gwinnett	2003	<0.01	–1.60
12Z001	Lamar	1967	–0.07	–4.52
07H003	Miller	1980	–0.03	–5.87
11AA01	Spalding	1943	<0.01	–4.77
32L017	Wayne	1983	–0.16	–3.10
13M007	Worth	1980	–0.02	–4.56

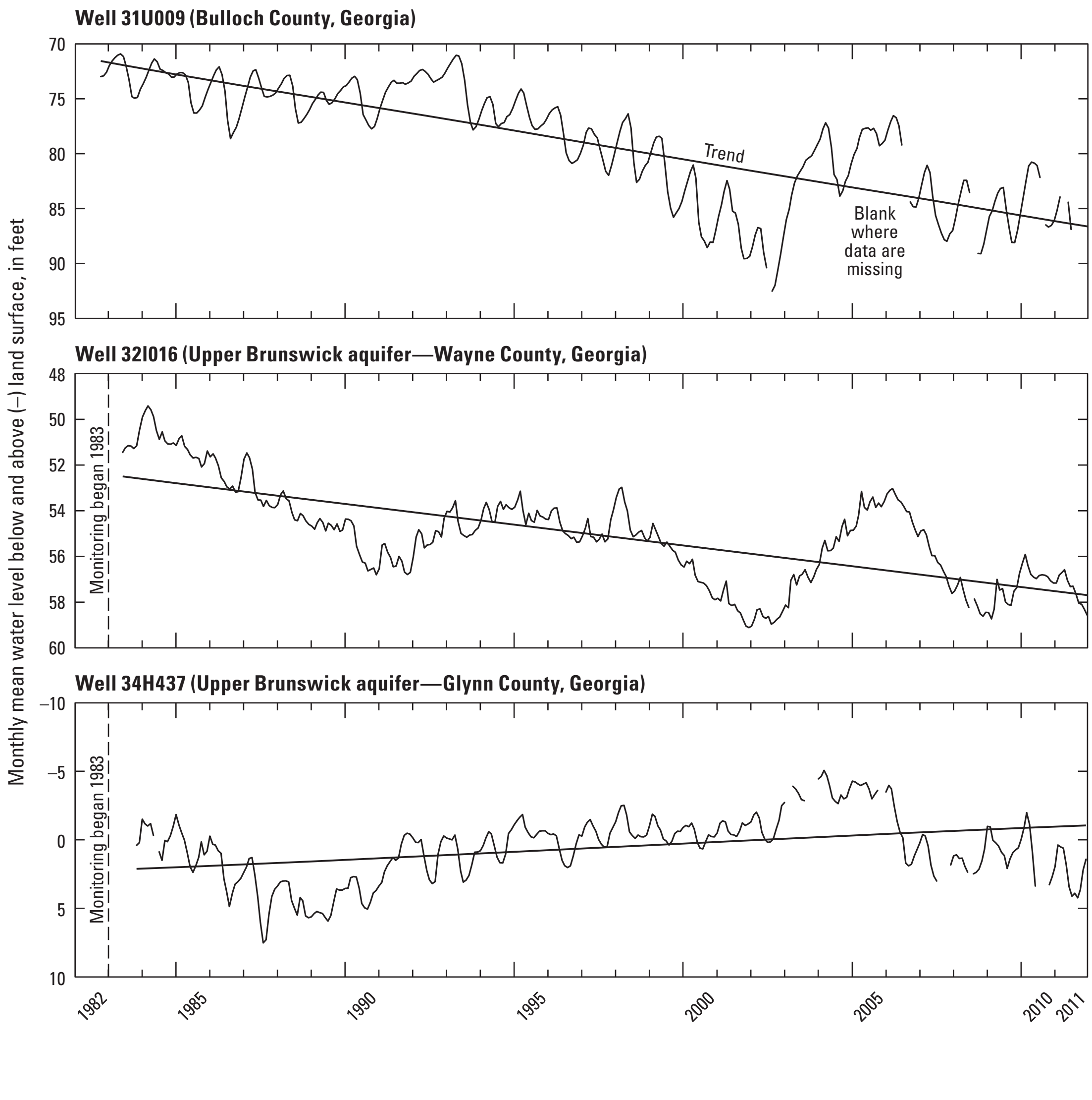
[1]See appendix for summary statistics.

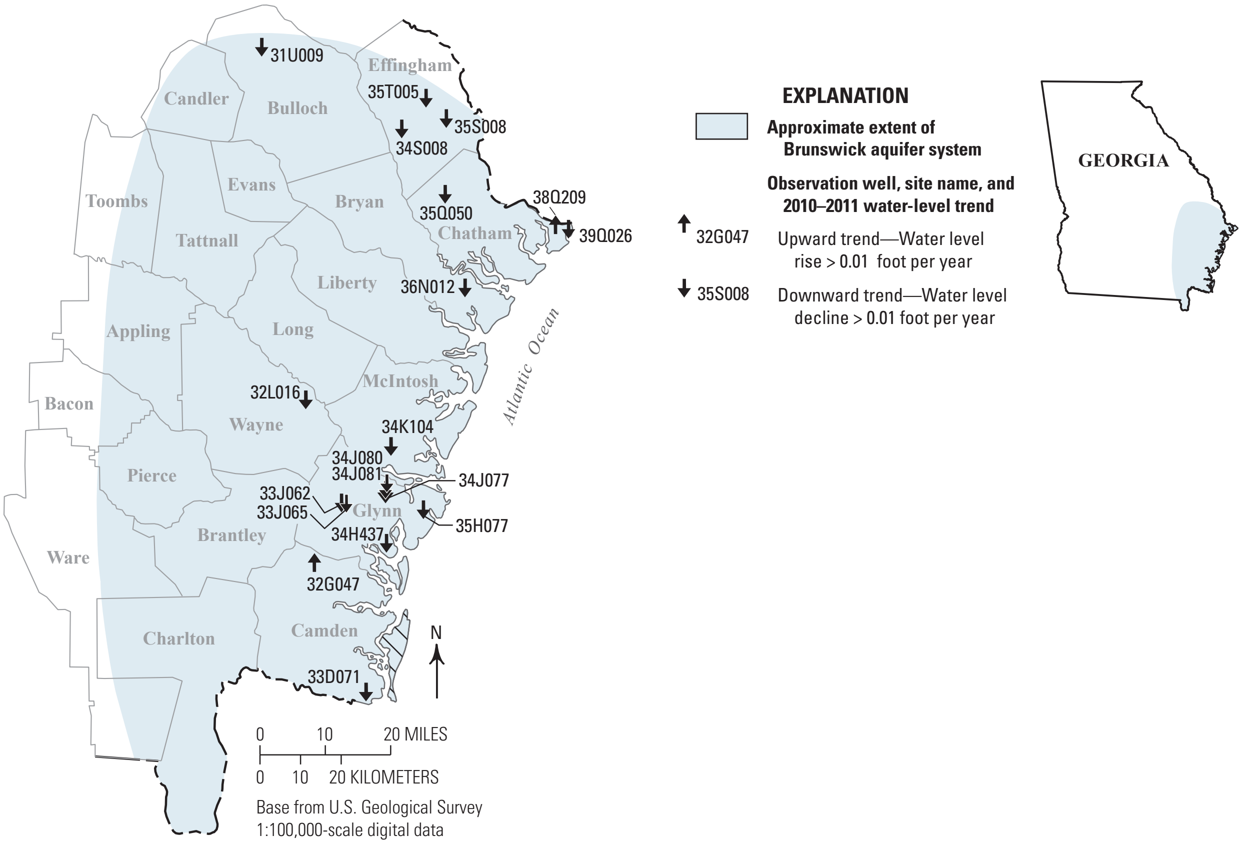
Groundwater Levels

Brunswick Aquifer System

Water levels in 19 wells were used to define conditions during 2010–2011 in the Brunswick aquifer system. The aquifer system consists of the confined upper and lower Brunswick aquifers and equivalent low-permeability sediments to the north and west in southeastern Georgia (map and table, facing page). Water-level fluctuations reflect changes in local pumping, interaquifer-leakage effects, and recharge. Water-level hydrographs for selected wells (below) illustrate monthly mean water levels for the period of record. The hydrographs show periodic upward or downward trends that reflect surplus or deficits in rainfall, respectively, and changes in pumping.

During the period of record, water levels in 10 of the 19 wells declined at rates of 0.05 to 1.06 feet per year (ft/yr). Water levels in nine wells rose at rates of 0.01 to 1.78 ft/yr during the period of record. During 2010–2011, water levels in 17 wells declined at rates of 0.26 to 10.88 ft/yr, which reflect the drought conditions that began in mid-2010 and continued throughout this period. Water levels in two wells rose from 0.06 to 0.16 ft/yr.





Site name	Water-bearing unit[1]	County	Year monitoring began	Water-level trend, in feet, per year[2]	
				Period of record	From 2010 to 2011
36N012	L	Bryan	1999	0.16	–3.17
31U009	UX	Bulloch	1982	–0.52	–5.56
32G047	U	Camden	2004	–0.25	0.16
33D071	U	Camden	1998	1.78	–1.53
35Q050	U	Chatham	2001	0.19	–1.82
38Q209	B	Chatham	1998	0.03	0.06
39Q026	UX	Chatham	1996	0.01	–0.26
34S008	LX	Effingham	2001	0.40	–2.06
35S008	LX	Effingham	2000	0.33	–0.45
35T005	UX	Effingham	2000	0.03	–3.05
33J062	L	Glynn	2001	–0.17	–2.59
33J065	U	Glynn	2001	–0.05	–0.83
34H437	U	Glynn	1983	0.11	–1.95
34J077	U	Glynn	1998	–0.68	–4.32
34J080	L	Glynn	2002	–0.41	–2.64
34J081	U	Glynn	2002	–0.09	–3.10
35H077	L	Glynn	2005	–1.06	–10.88
34K104	L	McIntosh	2005	–0.16	–2.20
32L016	U	Wayne	1983	–0.18	–0.91

[1]L, lower Brunswick aquifer; UX, undifferentiated, low-permeability equivalent to the upper Brunswick aquifer; U, upper Brunswick aquifer; B, Brunswick aquifer system; LX, undifferentiated, low-permeability equivalent to the lower Brunswick aquifer.

[2]See appendix for summary statistics.

Groundwater Levels

Upper Floridan Aquifer

The Upper Floridan aquifer underlies most of the Coastal Plain of Georgia, southern South Carolina, extreme southeastern Alabama, and all of Florida (Miller, 1986). The aquifer is one of the most productive in the United States and a major source of water in the region. During 2005, about 658 million gallons per day (Mgal/d) were withdrawn from the Upper and Lower Floridan aquifers in Georgia, primarily for industrial and irrigation uses (Fanning and Trent, 2009).

The Upper Floridan aquifer predominately consists of Eocene to Oligocene limestone, dolomite, and calcareous sand. The aquifer is thinnest along its northern limit (map, facing page) and thickens to the southeast, where the maximum thickness is about 1,700 feet (ft) in Ware County, Georgia (Miller, 1986). The aquifer is confined throughout most of its extent, except where it crops out or is near land surface along the northern limit, and in karst areas in parts of southwestern and south-central Georgia.

The Coastal Plain of Georgia has been divided informally into four hydrologic areas for discussion of water levels (map, facing page)—the southwestern, south-central, east-central, and coastal areas. This subdivision is a modification of that used by Peck and others (1999) and is similar to that used by Clarke (1987).

Southwestern area. All or parts of 16 counties constitute the southwestern area. In this area, the Upper Floridan aquifer ranges in thickness from about 50 ft in the northwest to about 475 ft in the southeast (Hicks and others, 1987). The aquifer is overlain by sandy clay residuum, which is hydraulically connected to streams. Since the introduction of center-pivot irrigation systems around 1975, the Upper Floridan aquifer has been widely used as the primary water source for irrigation in southwestern Georgia (Hicks and others, 1987). About 314 Mgal/d of water was withdrawn from the Upper Floridan aquifer in the southwestern area during 2005, and 80 percent of this amount was used for irrigation (Fanning and Trent, 2009).

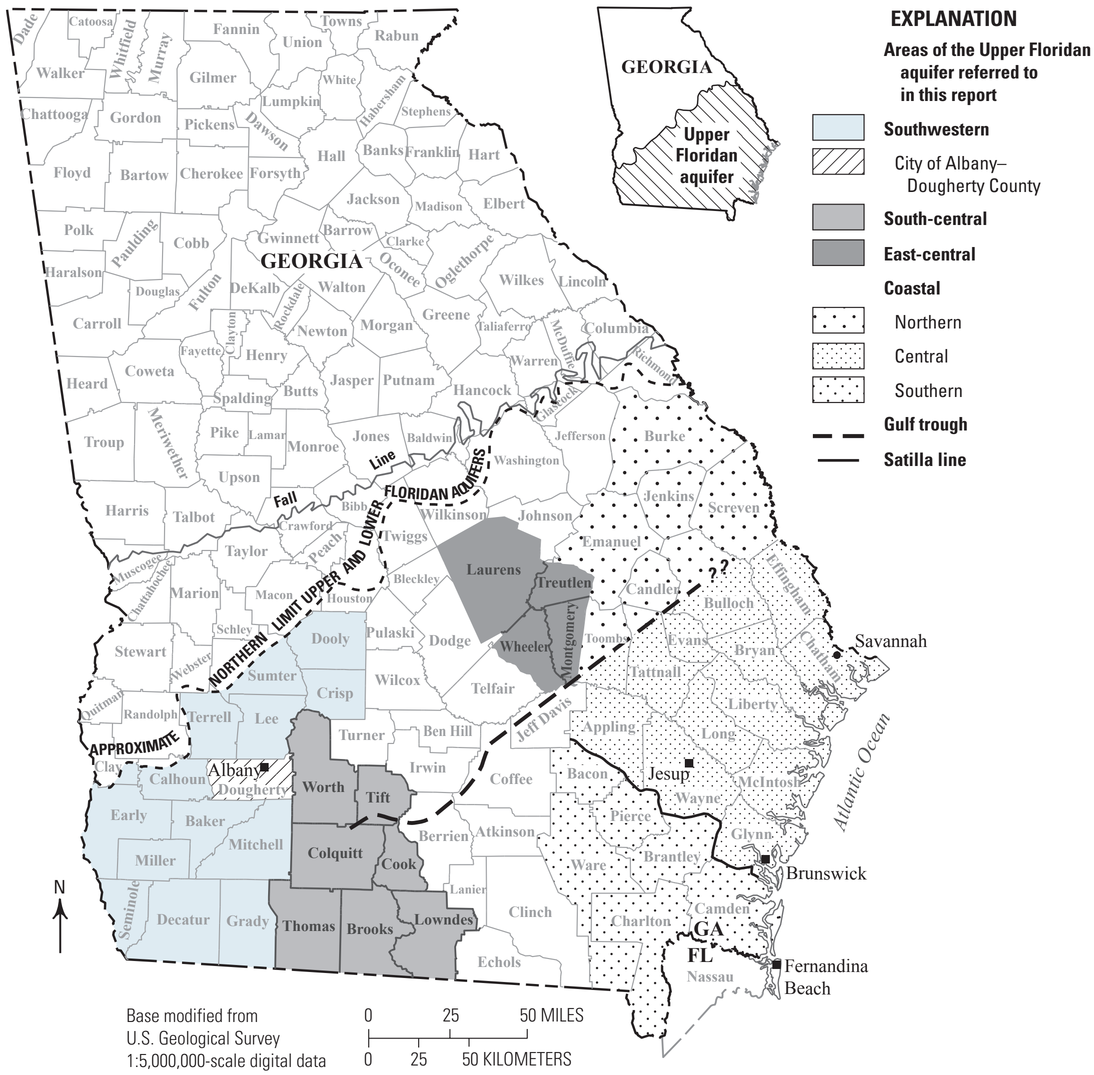
The city of Albany–Dougherty County lies in the southwestern area of Georgia. During 2005, most of the water withdrawn from the Upper Floridan aquifer in this area was used for public supply (about 14 Mgal/d) and industry (14 Mgal/d; Fanning and Trent, 2009).

South-central area. Six counties constitute the south-central area. In this area, the Upper Floridan aquifer ranges in thickness from about 300 to 700 ft (Miller, 1986). Lowndes County is a karst region with abundant sinkholes and sinkhole lakes that have formed where the aquifer crops out and the overlying confining unit has been removed by erosion (Krause, 1979). Direct recharge from rivers to the Upper Floridan aquifer occurs through these sinkholes at a rate of about 70 Mgal/d (Krause, 1979). In the south-central area, groundwater use totaled about 91 Mgal/d in 2005, and most of this withdrawal was used for irrigation (Fanning and Trent, 2009).

East-central area. Four counties constitute the east-central area. In this area, the Upper Floridan aquifer can be as thick as 650 ft in the southeast or absent in the north. In the east-central area, groundwater withdrawal totaled about 15 Mgal/d during 2005 and was used predominantly for irrigation (Fanning and Trent, 2009).

Coastal area. The Georgia Environmental Protection Division (GaEPD) defines the coastal area of Georgia as a 24-county area that includes 6 coastal counties and the adjacent 18 counties—an area of about 12,240 square miles. In the coastal area, the Upper Floridan aquifer may be thin or absent in the north (Burke County) and about 1,700 ft thick in the south (Ware County; Miller, 1986). Excluding withdrawals for thermoelectric-power generation, nearly 70 percent of all withdrawals in the area is from groundwater, primarily for industrial purposes. During 2005, about 308 Mgal/d of water was withdrawn from the Upper Floridan aquifer in the coastal area (Fanning and Trent, 2009).

The coastal area of Georgia has been subdivided by GaEPD into three subareas—northern, central, and southern—to facilitate implementation of the State's water-management policies. The central subarea includes the largest concentration of pumpage in the coastal area of the Savannah, Brunswick, and Jesup pumping centers. The northern subarea is northwest of the Gulf Trough (Herrick and Vorhis, 1963), a prominent geologic feature that is characterized by a zone of low permeability in the Upper Floridan aquifer that inhibits flow between the central and northern subareas. In the northern subarea, pumping from the aquifer primarily is for agricultural use, and no large pumping centers are located in the area. The southern subarea is separated from the central subarea by the Satilla line, a postulated hydrologic boundary (W.H. McLemore, Georgia Environmental Protection Division, Geologic Survey Branch, oral commun., 2000). In the southern subarea, the largest pumping center is located immediately south of the area at Fernandina Beach, Nassau County, Florida.



Areas of the Upper Floridan aquifer referred to in this report.

References

Clarke, J.S., 1987, Potentiometric surface of the Upper Floridan aquifer in Georgia, May 1985, and water-level trends, 1980–85: Georgia Geologic Survey Hydrologic Atlas 16, scale 1:1,000,000, 1 sheet.

Fanning, J.L., and Trent, V.P., 2009, Water use in Georgia by county for 2005; and water-use trends, 1980–2005: U.S. Geological Survey Scientific Investigations Report 2009–5002, 186 p.; available online at *http://pubs.usgs.gov/sir/2009/5002/*.

Herrick, S.M., and Vorhis, R.C., 1963, Subsurface geology of the Georgia Coastal Plain: Georgia Department of Natural Resources, Division of Mines, Mining, and Geology, Information Circular 25, 80 p.

Hicks, D.W., Gill, H.E., and Longsworth, S.A., 1987, Hydrogeology, chemical quality, and availability of ground water in the Upper Floridan aquifer, Albany area, Georgia: U.S. Geological Survey Water-Resources Investigations Report 87–4145, 52 p.; available online at *http://pubs.usgs.gov/wri/wri87-4145/*.

Krause, R.E., 1979, Geohydrology of Brooks, Lowndes, and western Echols Counties, Georgia: U.S. Geological Survey Water-Resources Investigations Report 78–117, 48 p.

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

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

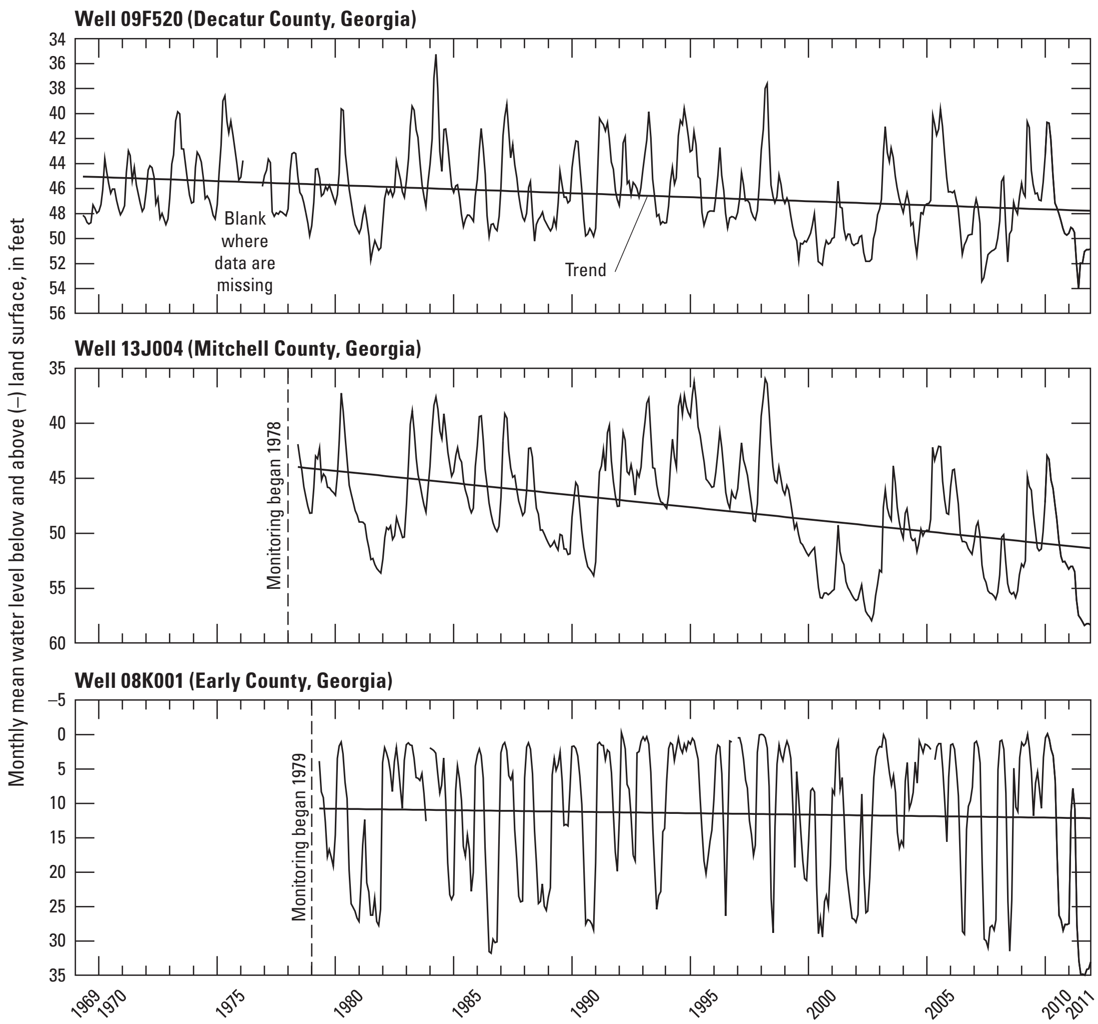
Groundwater Levels

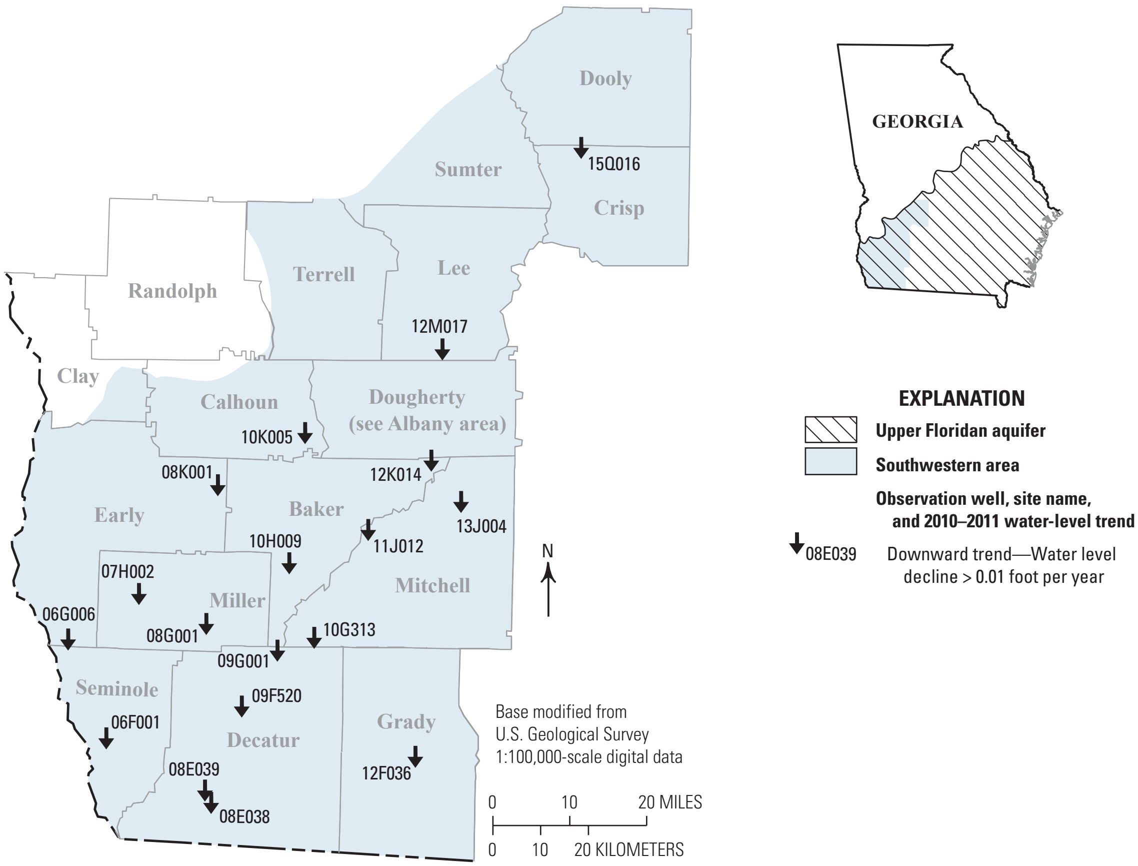
Upper Floridan Aquifer

Southwestern Area

Water levels in 18 wells were used to define groundwater conditions in the Upper Floridan aquifer in southwestern Georgia during 2010–2011 (map and table, facing page). In this area, water in the Upper Floridan aquifer typically is confined; however, in areas where no sediments overlie the aquifer (typically to the north and west), water is unconfined. Water levels in this area are affected by changes in precipitation and pumping. Hydrographs for selected wells (below) illustrate monthly mean water levels for the period of record. The hydrographs show periodic upward or downward trends that reflect surplus or deficits in rainfall, respectively, and changes in pumping.

During the period of record, water levels in 14 wells had declining trends of 0.01 to 1.12 foot per year (ft/yr), and 4 wells had rising trends of 0.05 to 0.30 ft/yr. During 2010–2011, water levels in all 18 of the wells declined at rates of 1.16 to 17.77 ft/yr, with declines exceeding 10 feet in Baker, Crisp, Early, Miller, and Seminole Counties. These declines correspond to decreased precipitation and increased pumping resulting from the drought that began in mid-2010 and continued through 2011.





Site name	County	Year monitoring began	Water-level trend, in feet, per year[1]	
			Period of record	From 2010 to 2011
10H009	Baker	1998	0.10	–11.14
12K014	Baker	1982	–0.09	–7.06
10K005	Calhoun	1983	–0.11	–4.17
15Q016	Crisp	2002	–1.12	–15.71
08E038	Decatur	2001	0.05	–1.19
08E039	Decatur	2002	–0.06	–1.16
09F520	Decatur	1972	–0.06	–5.27
09G001	Decatur	1980	–0.07	–6.11
06G006	Early	1982	–0.08	–12.76
08K001	Early	1982	–0.04	–17.77
12F036	Grady	1971	0.24	–3.88
12M017	Lee	1982	–0.01	–8.65
07H002	Miller	1980	0.30	–6.21
08G001	Miller	1977	–0.15	–13.78
10G313	Mitchell	1976	–0.09	–9.42
11J012	Mitchell	1981	–0.06	–5.62
13J004	Mitchell	1978	–0.22	–8.12
06F001	Seminole	1979	–0.13	–10.82

[1]See appendix for summary statistics.

Groundwater Levels

Upper Floridan Aquifer

City of Albany–Dougherty County Area

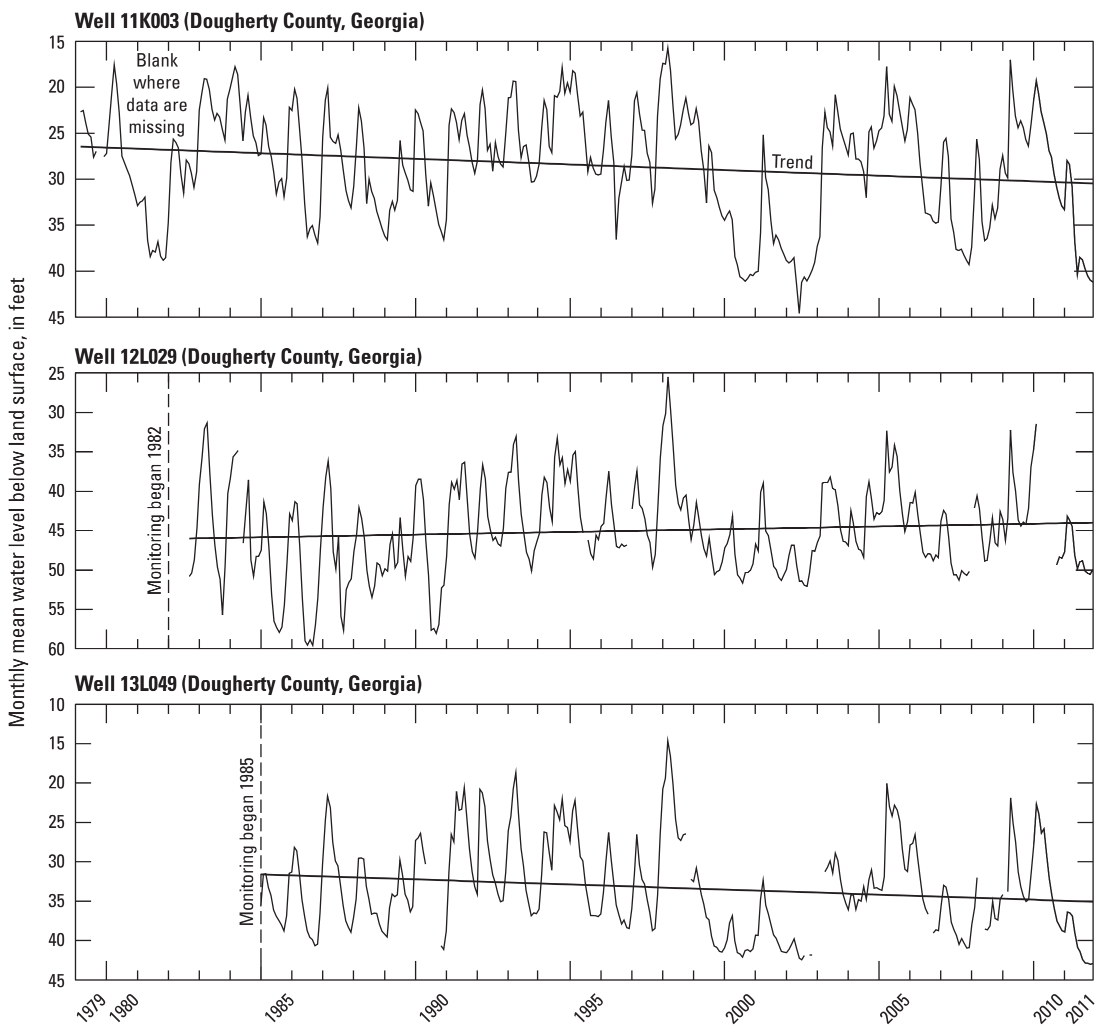
Water levels in 12 wells were used to define groundwater conditions in the Upper Floridan aquifer near Albany, Georgia, during 2010–2011 (Dougherty County map and table, facing page). Water levels in this area are affected by changes in precipitation and pumping (Gordon and others, 2012). Hydrographs for selected wells (below) illustrate monthly mean water levels for the period of record. The hydrographs show periodic upward or downward trends that reflect surplus or deficits in rainfall, respectively, and changes in pumping.

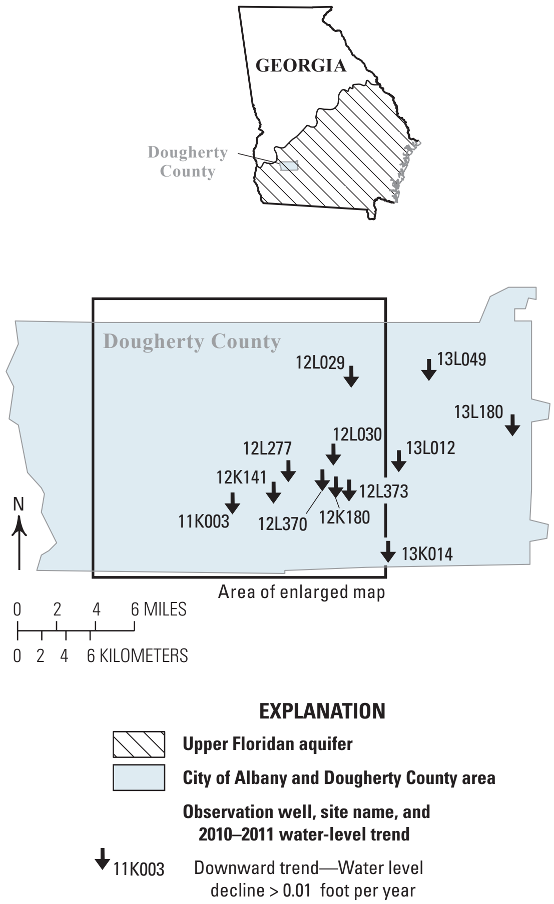
During the period of record, water levels in 10 of the 12 wells had declining trends ranging from 0.05 to 0.31 per year (ft/yr); of the remaining 2 wells one had a rate of change less than ± 0.01 ft/yr and the other a rising trend of 0.07 ft/yr. During 2010–2011, water levels in all of the wells declined from 6.10 to 12.28 ft/yr, which reflect drought conditions that began in mid-2010 and continued through 2011.

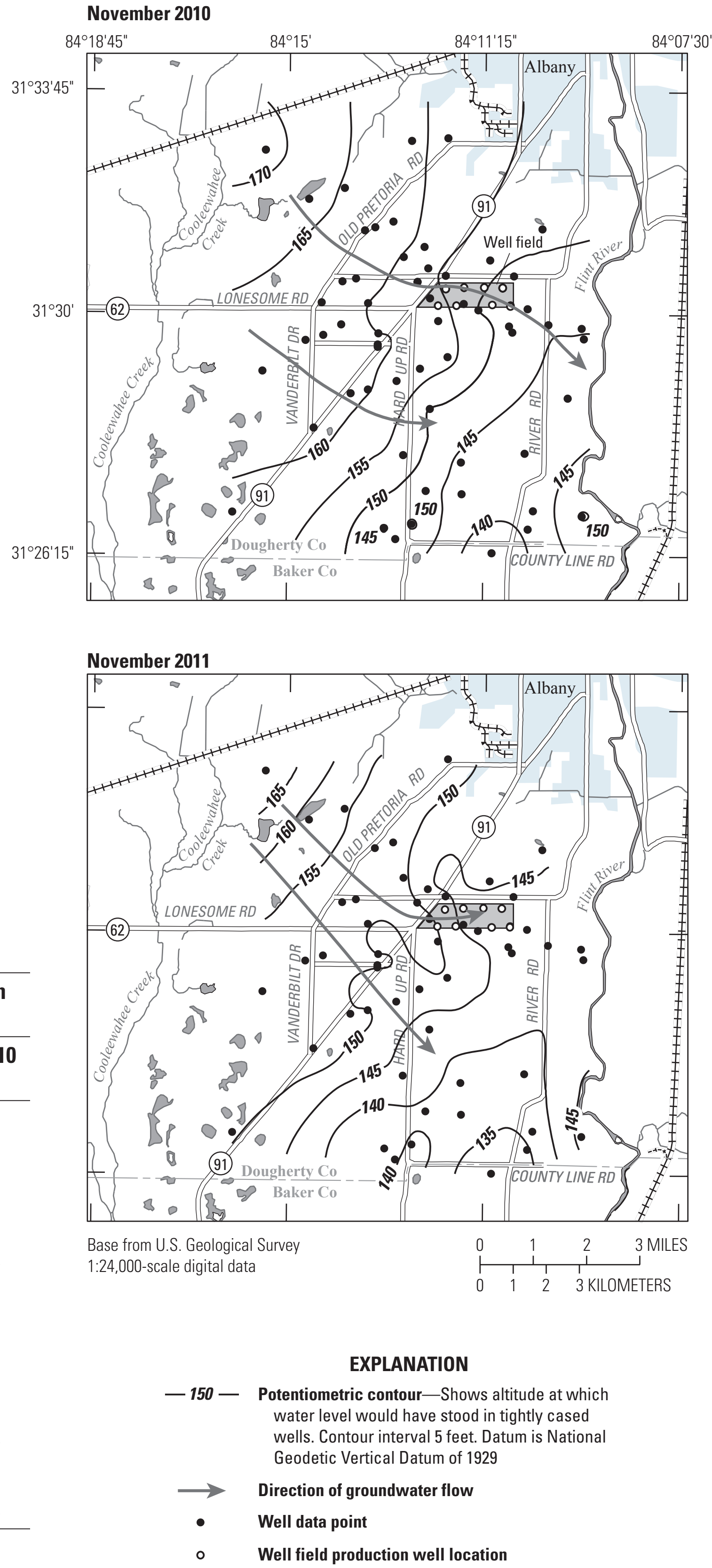
In addition to continuous water-level monitoring, synoptic water-level measurements are made periodically in wells southwest of Albany. Water-level measurements from 62 wells during November 2010 and 55 wells during November 2011 were used to construct maps showing the potentiometric surface of the Upper Floridan aquifer. Although water levels in 2010 generally were higher than in 2011, the configuration of the potentiometric surface maps (facing page) was similar. The potentiometric-surface maps show that water generally flows from northwest to southeast toward the Flint River. In the southeastern part of the mapped area, flow was away from the river toward the southwest.

Reference

Gordon, D.W., Painter, J.A., and McCranie, J.M., 2012, Hydrologic conditions, groundwater quality, and analysis of sinkhole formation in the Albany area of Dougherty County, Georgia, 2009: U.S. Geological Survey Scientific Investigations Report 2012–5018, 60 p.; available online at *http://pubs.usgs.gov/sir/2012/5018/*.







Site name	County	Year monitoring began	Water-level trend, in feet, per year[1]	
			Period of record	From 2010 to 2011
11K003	Dougherty	1982	–0.12	–11.41
12K141	Dougherty	1996	–0.31	–12.28
12K180	Dougherty	2002	–0.25	–6.68
12L029	Dougherty	1982	0.07	–8.26
12L030	Dougherty	1985	–0.06	–8.94
12L277	Dougherty	2000	<0.01	–10.47
12L370	Dougherty	2000	–0.11	–10.49
12L373	Dougherty	2002	–0.24	–7.97
13K014	Dougherty	1982	–0.13	–6.10
13L012	Dougherty	1978	–0.05	–6.74
13L049	Dougherty	1985	–0.13	–10.21
13L180	Dougherty	1996	–0.07	–9.64

[1]See appendix for summary statistics.

Groundwater Levels

Upper Floridan Aquifer

South-Central Area

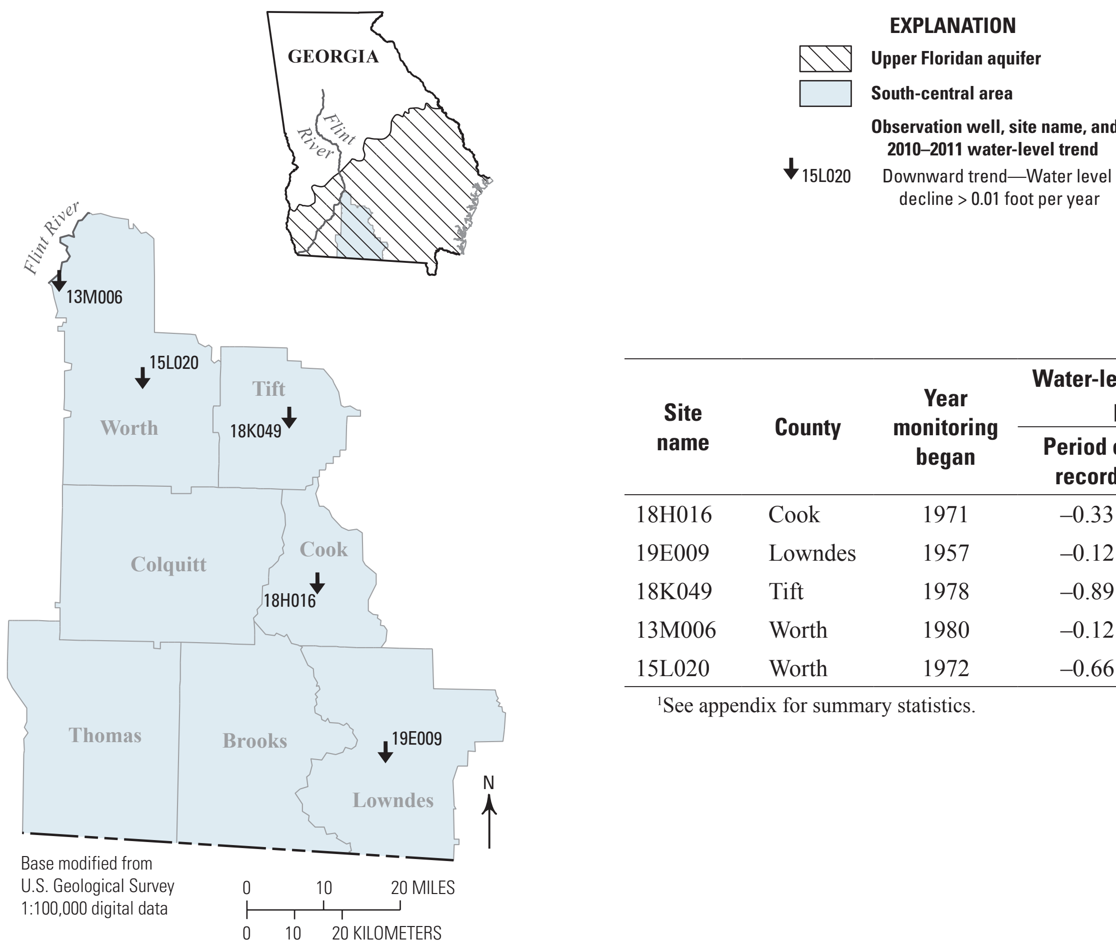
Water levels in five wells were used to define groundwater conditions in the Upper Floridan aquifer in south-central Georgia during 2010–2011 (map and table below). In this area, water in the Upper Floridan aquifer generally is confined but locally is unconfined in karst areas in Lowndes County. Water levels in this area are affected by changes in pumping and by precipitation, with climatic effects more pronounced in areas where the aquifer is close to land surface, such as the karst area in Lowndes County and near the Flint River in the northwestern part of Worth County.

Hydrographs for selected wells (facing page) illustrate monthly mean water levels for the period of record. In Lowndes County, water-level fluctuations in well 19E009 show a pronounced response to climatic effects because the well is in a karst area. Climatic effects are less pronounced in the other four wells, and water levels primarily are influenced by pumping. The hydrographs show periodic upward or downward trends that reflect surplus or deficits in rainfall, respectively, and changes in pumping.

During the period of record, water levels in all five of the wells monitored in the south-central area declined 0.12 to 0.89 foot per year (ft/yr). The greatest declines were in Tift, Cook, and Worth Counties in the northern and eastern part of the area, where recharge is limited by low-permeability overburden and irrigation pumping is high (Torak and others, 2010). The period of record decline was lower in wells located near areas of recharge in Lowndes County (well 19E009) and near the Flint River in northwestern Worth County (well 13M006). During 2010–2011, water levels in all of the wells declined at rates ranging from 1.41 to 11.97 ft/yr, which reflect the drought conditions that existed during 2010–2011. The largest decline of 11.97 ft/yr was at well 19E009, reflecting decreased recharge during the drought period.

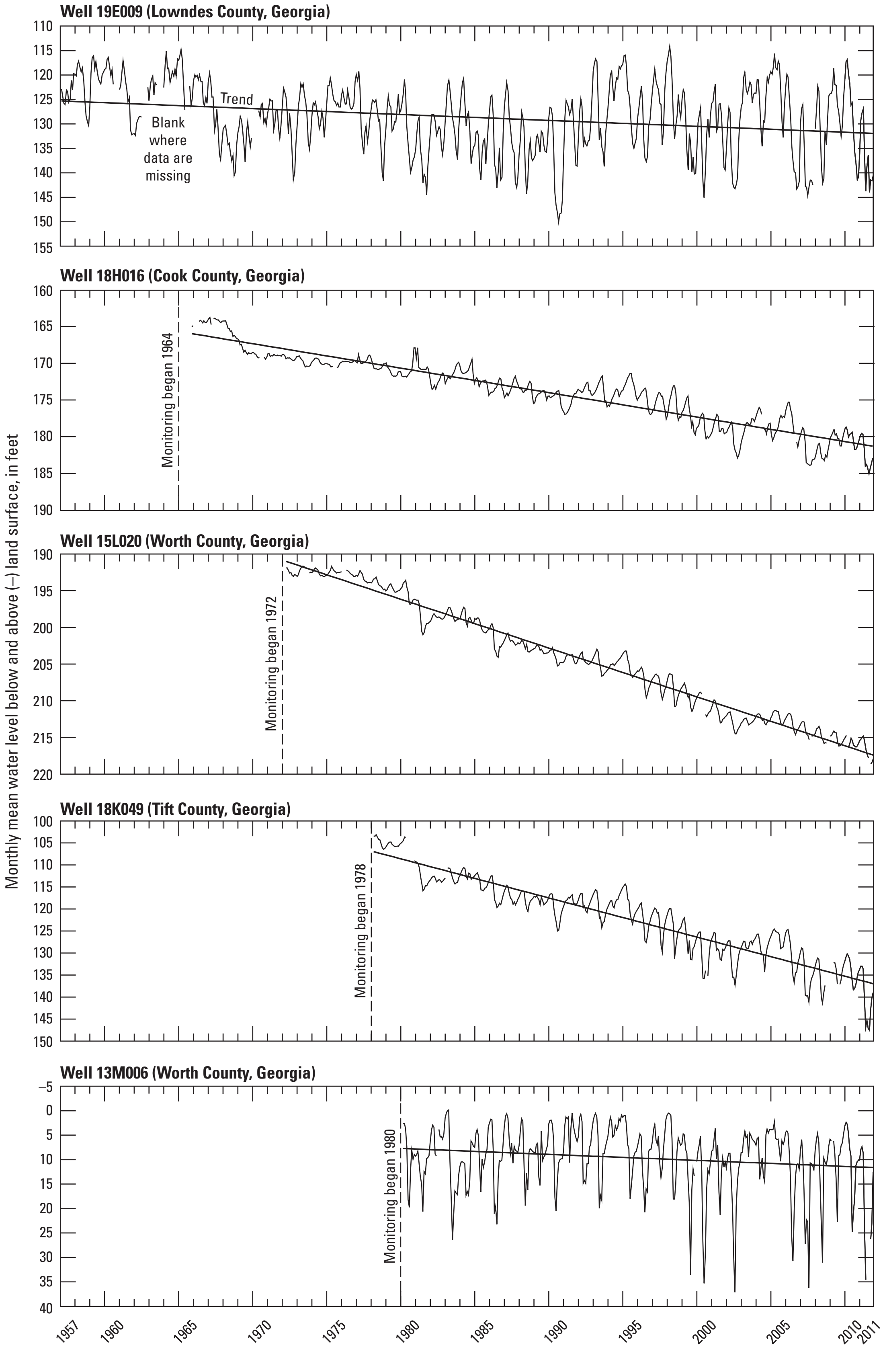
Reference

Torak, L.J., Painter, J.A., and Peck, M.F., 2010, Geohydrology of the Aucilla–Suwannee–Ochlockonee River Basin, south-central Georgia and adjacent parts of Florida: U.S. Geological Survey Scientific Investigations Report 2010–5072; available online at *http://pubs.usgs.gov/sir/2010/5072/*.



Site name	County	Year monitoring began	Water-level trend, in feet, per year[1]	
			Period of record	From 2010 to 2011
18H016	Cook	1971	–0.33	–2.81
19E009	Lowndes	1957	–0.12	–11.97
18K049	Tift	1978	–0.89	–7.05
13M006	Worth	1980	–0.12	–8.91
15L020	Worth	1972	–0.66	–1.41

[1]See appendix for summary statistics.


Well 19E009 (Lowndes County, Georgia)
110
115
120
125
130
135
140
145
150
155
Trend
Blank where data are missing
Well 18H016 (Cook County, Georgia)
160
165
170
175
180
185
190
Monitoring began 1964
Well 15L020 (Worth County, Georgia)
190
195
200
205
210
215
220
Monitoring began 1972
Well 18K049 (Tift County, Georgia)
100
105
110
115
120
125
130
135
140
145
150
Monitoring began 1978
Well 13M006 (Worth County, Georgia)
−5
0
5
10
15
20
25
30
35
40
Monitoring began 1980
Monthly mean water level below and above (−) land surface, in feet
1957
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2011

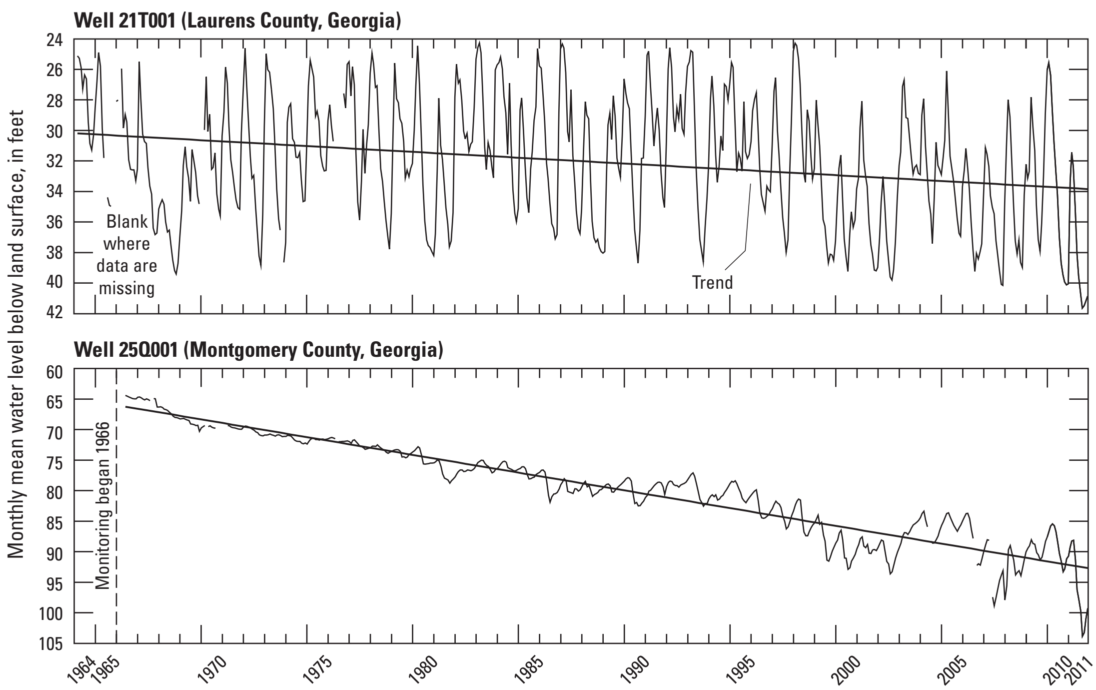
Groundwater Levels

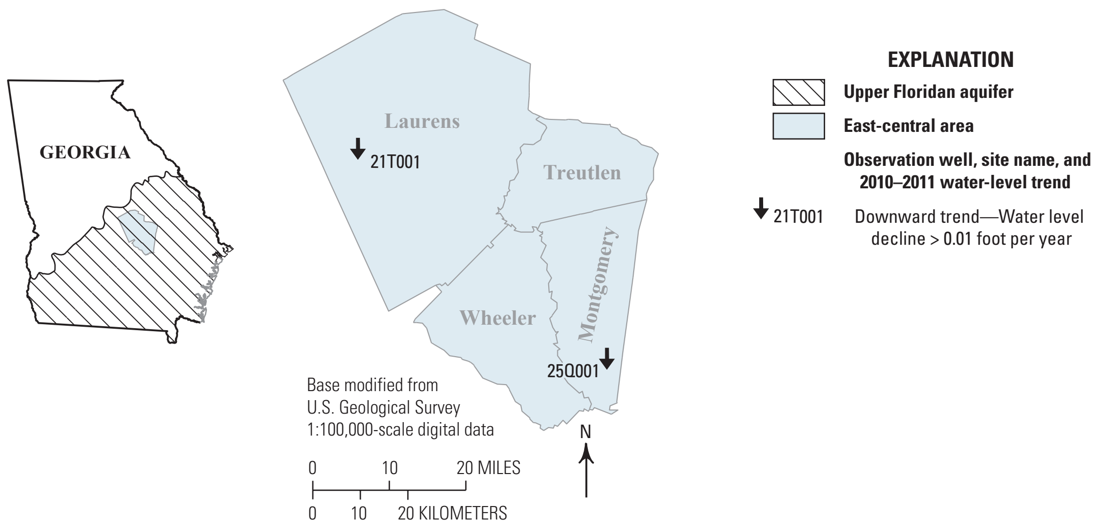
Upper Floridan Aquifer

East-Central Area

Water levels in two wells were used to define groundwater conditions in the Upper Floridan aquifer in east-central Georgia during 2010–2011 (map and table, facing page). In this area, water in the Upper Floridan aquifer is confined in the southeast and is semiconfined in the northwest, and water levels are influenced by climatic effects and agricultural pumping in these areas. Hydrographs for the two wells (below) illustrate monthly mean water levels for the period of record. The hydrographs show periodic upward or downward trends that reflect surplus or deficits in rainfall, respectively, and changes in pumping.

During the period of record, water levels in both wells showed a long-term decline, ranging from 0.08 foot per year (ft/yr) in well 21T001 to 0.58 ft/yr in well 25Q001. During 2010–2011, water levels in both wells declined, ranging from 6.95 to 8.31 ft/yr, respectively. These variations in water-level response may be related to differences in proximity to available recharge and to local pumping changes. Well 21T001 in Laurens County is in the northwestern part of the area where the aquifer is semiconfined and close to the area of recharge. Well 25Q001 in Montgomery County is in an area where the aquifer is deeply buried and confined and is more isolated from recharge sources.





Site name	County	Year monitoring began	Water-level trend, in feet, per year[1]	
			Period of record	From 2010 to 2011
21T001	Laurens	1964	–0.08	–6.95
25Q001	Montgomery	1966	–0.58	–8.31

[1]See appendix for summary statistics.

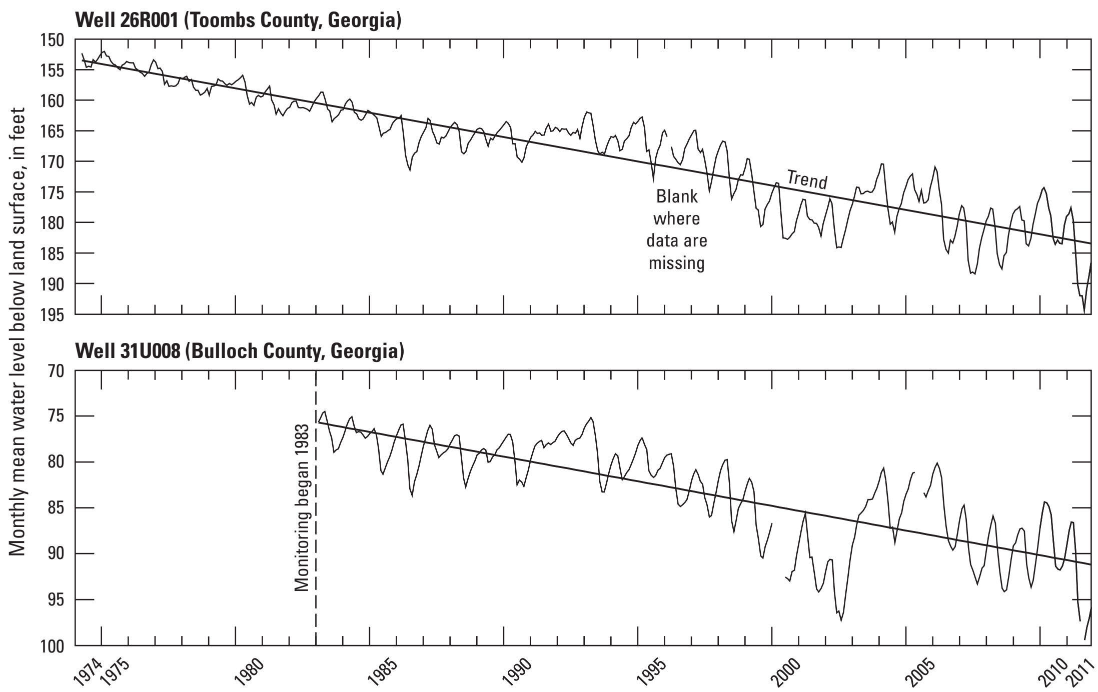
Groundwater Levels

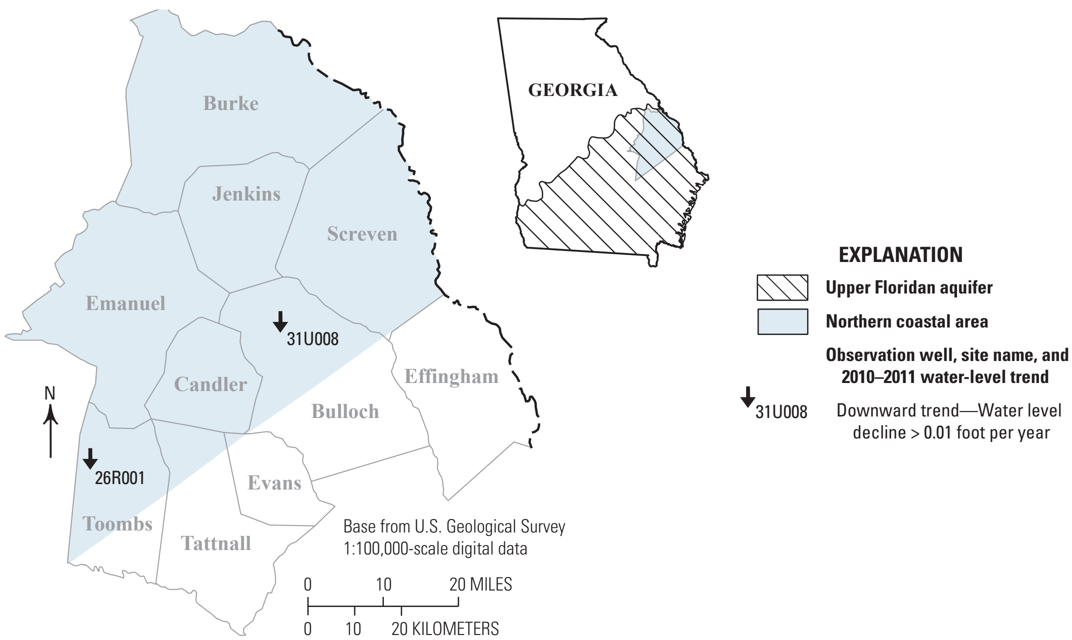
Upper Floridan Aquifer

Northern Coastal Area

Water levels in two wells were used to define groundwater conditions in the Upper Floridan aquifer in the northern coastal area during 2010–2011 (map and table, facing page). In this area, water in the Upper Floridan aquifer is confined to the southeast and is semiconfined to the northwest, and water levels are influenced by climatic effects and agricultural pumping in these areas. Hydrographs for the two wells (below) illustrate monthly mean water levels for the period of record. The hydrographs show periodic upward or downward trends that reflect surplus or deficits in rainfall, respectively, and changes in pumping.

During the period of record, water levels declined at rates of 0.54 foot per year (ft/yr) in well 31U008 and 0.79 ft/yr in well 26R001. During 2010–2011, water levels declined at an accelerated rate of 6.45 ft/yr in well 31U008 and 8.28 ft/yr in well 26R001 and likely resulted from the drought conditions during this period.





Site name	County	Year monitoring began	Water-level trend, in feet, per year[1]	
			Period of record	From 2010 to 2011
31U008	Bulloch	1983	–0.54	–6.45
26R001	Toombs	1974	–0.79	–8.28

[1]See appendix for summary statistics.

Groundwater Levels

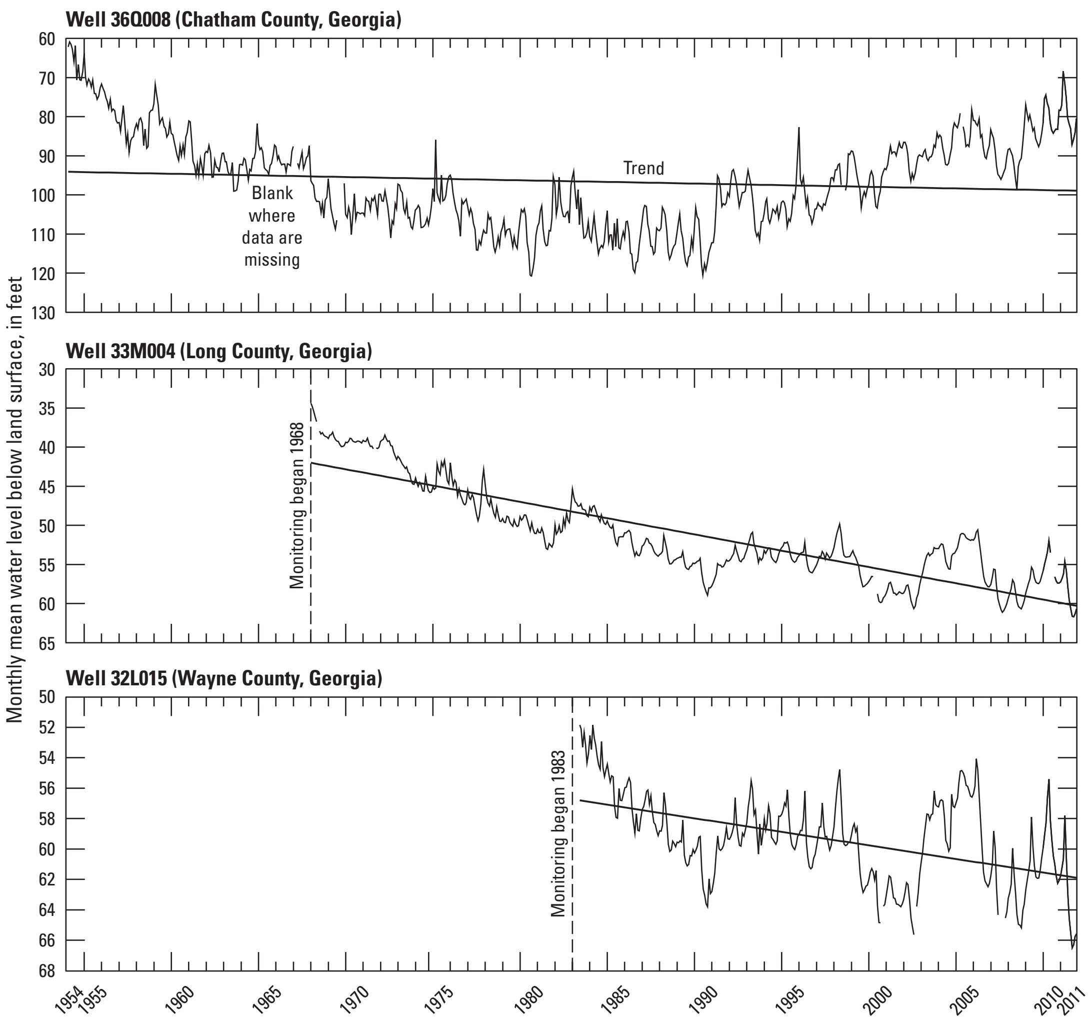
Upper Floridan Aquifer

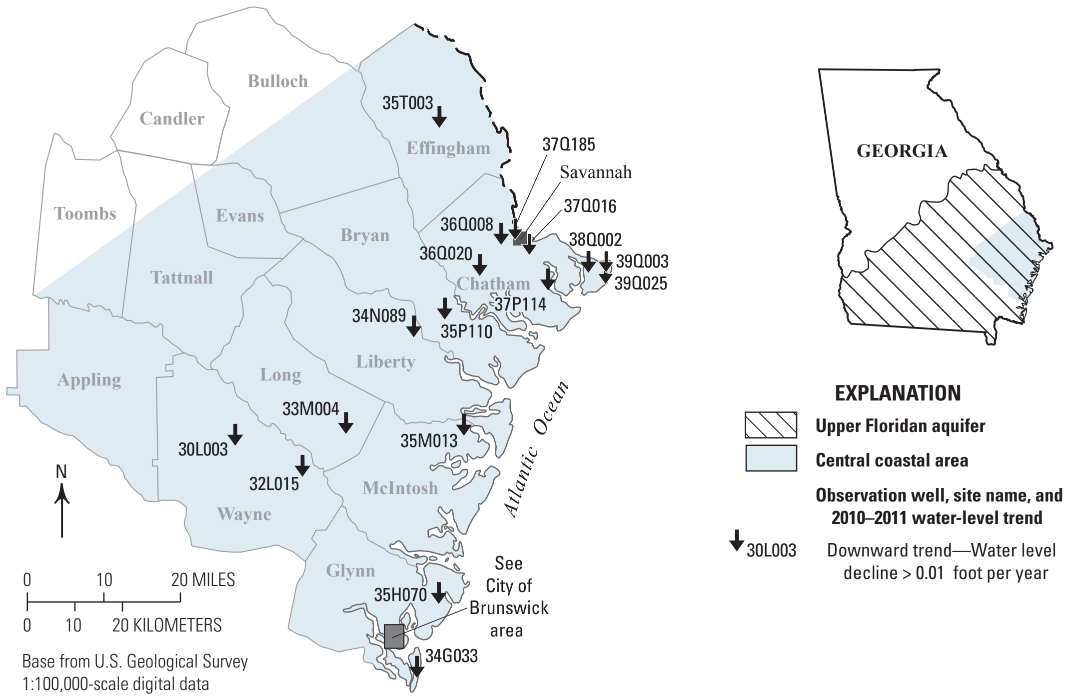
Central Coastal Area

Water levels in 17 wells were used to define groundwater conditions in the Upper Floridan aquifer in the central coastal area of Georgia (excluding the Brunswick area of Glynn County) during 2010–2011 (map and table, facing page). In this area, water in the Upper Floridan aquifer is confined and primarily influenced by pumping. Hydrographs for selected wells (below) illustrate monthly mean water levels for the period of record. The hydrographs show periodic upward or downward trends that reflect changes primarily in pumping.

During the period of record, water levels in 10 of the 17 wells declined 0.08 to 0.49 feet per year (ft/yr). Water levels in the remaining seven wells rose at rates of 0.03 to 1.53 ft/yr. During 2010–2011, water levels in all 17 wells declined at rates ranging from 1.1 to 5.58 ft/yr, which reflect the drought conditions during the period.

The hydrograph for well 36Q008 near Savannah in Chatham County shows an overall downward trend of 0.08 ft/yr in water levels for the period of record. Since 1991, however, water levels have been rising in the well, largely as the result of decreased water use due to conservation practices in the area (J.L. Fanning, U.S. Geological Survey, oral commun., 2008). Water levels during 2010–2011 declined slightly at a rate of 1.80 ft/yr because of decreased precipitation and increased water demand. Despite this decline, water levels in well 36Q008 have recovered to what they were during the mid- to late-1950s (John S. Clarke, U.S. Geological Survey, written commun., August 17, 2012).





Site name	County	Year monitoring began	Water-level trend, in feet, per year[1]	
			Period of record	From 2010 to 2011
35P110	Bryan	2000	0.05	–3.85
36Q008	Chatham	1954	–0.08	–1.80
36Q020	Chatham	1958	–0.49	–3.69
37P114	Chatham	1984	0.26	–3.04
37Q016	Chatham	1955	0.03	–3.11
37Q185	Chatham	1985	1.53	–2.09
38Q002	Chatham	1956	–0.25	–1.78
39Q003	Chatham	1962	–0.24	–1.26
39Q025	Chatham	1996	0.21	–1.10
35H070	Glynn	2005	0.30	–2.45
34G033	Glynn	2004	–0.47	–2.02
35T003	Effingham	2000	0.16	–4.66
34N089	Liberty	1967	–0.47	–3.71
33M004	Long	1968	–0.42	–3.90
35M013	McIntosh	1966	–0.40	–2.78
30L003	Wayne	1964	–0.44	–5.58
32L015	Wayne	1983	–0.18	–4.35

[1]See appendix for summary statistics.

Groundwater Levels

Upper Floridan Aquifer

City of Brunswick Area

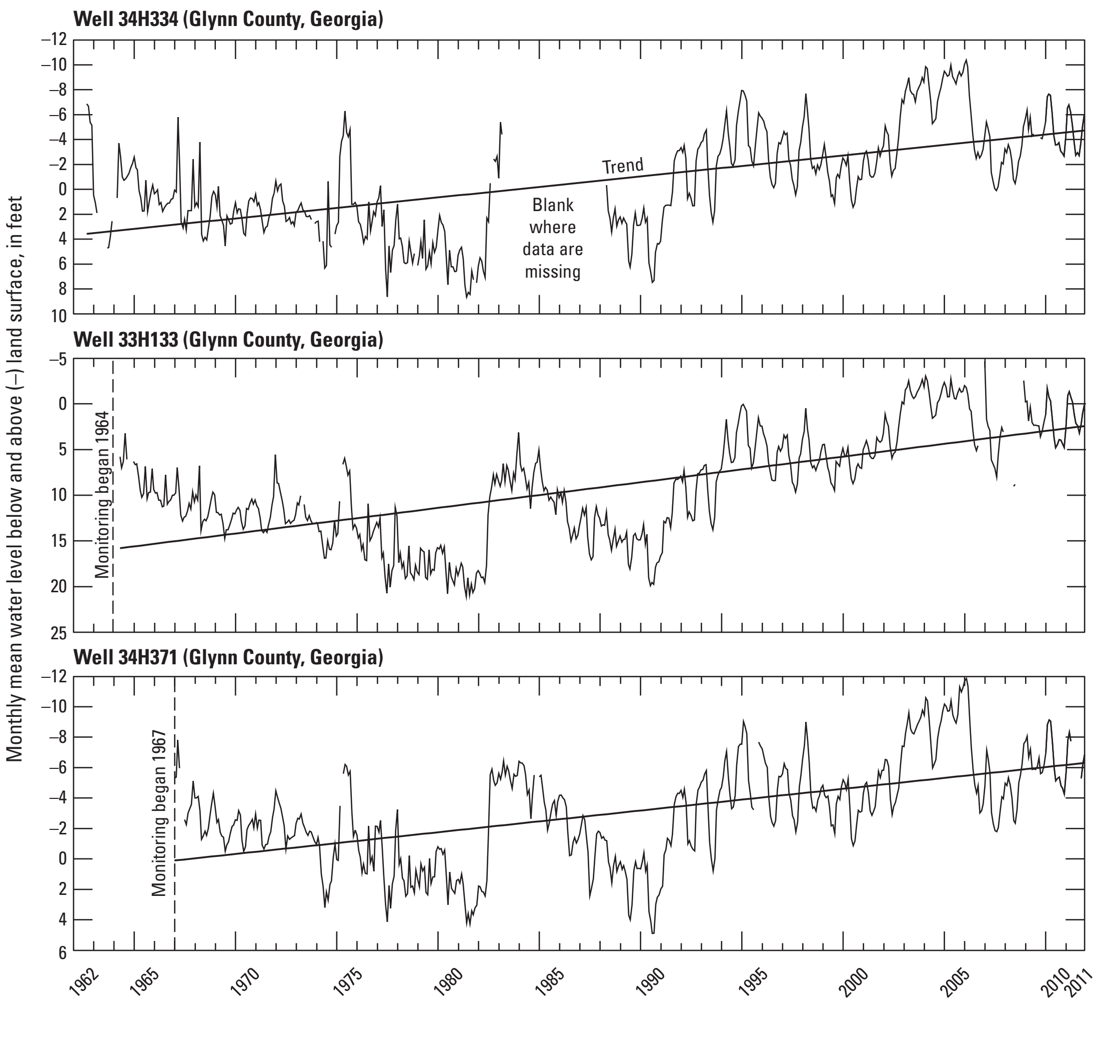
Water levels in 10 wells were used to define groundwater conditions in the Upper Floridan aquifer near the city of Brunswick in the central coastal area of Georgia during 2010–2011 (maps and table, facing page). In this area, water in the Upper Floridan aquifer is confined, and groundwater flow paths are influenced primarily by pumping for industrial and public supply (Cherry and others, 2011).

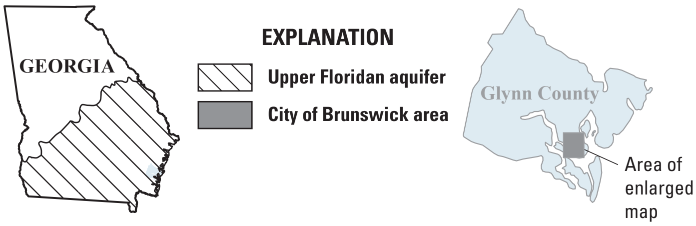
During the period of record, water levels in all of the wells had rising trends with rates of change that ranged from 0.06 to 6.81 feet per year (ft/yr). Hydrographs for three wells in the Upper Floridan aquifer in the Brunswick area (below) illustrate monthly mean water levels for the period of record. During 2010–2011, water levels in six wells declined at rates ranging from 0.24 to 1.58 ft/yr and rose in four wells at rates ranging from 0.11 to 16.94 ft/yr. The largest rise during 2010–2011 was at well 33H325 located in an area of industrial pumping. Although well 33H324 is located adjacent to well 33H325, it showed a rise of only 1.24 ft during the same period. The two wells are completed in different water-bearing zones of the Upper Floridan aquifer—the deeper zone in well 33H325 provides water to a nearby industrial user and therefore shows a greater response to changes in pumping at the industrial site (John S. Clarke, U.S. Geological Survey, written commun., August 17, 2012).

In addition to continuous water-level monitoring, synoptic water-level measurements are made periodically in wells in the Brunswick area. Water-level measurements from 39 wells during August 2010 and 43 wells during August 2011 were used to construct potentiometric-surface maps of the Upper Floridan aquifer. The maps on the facing page show that groundwater generally flows from the south, where water-level altitudes are greater than 15 ft, toward industrial pumping centers in northern Brunswick, where water-level altitude is less than 0 ft.

Reference

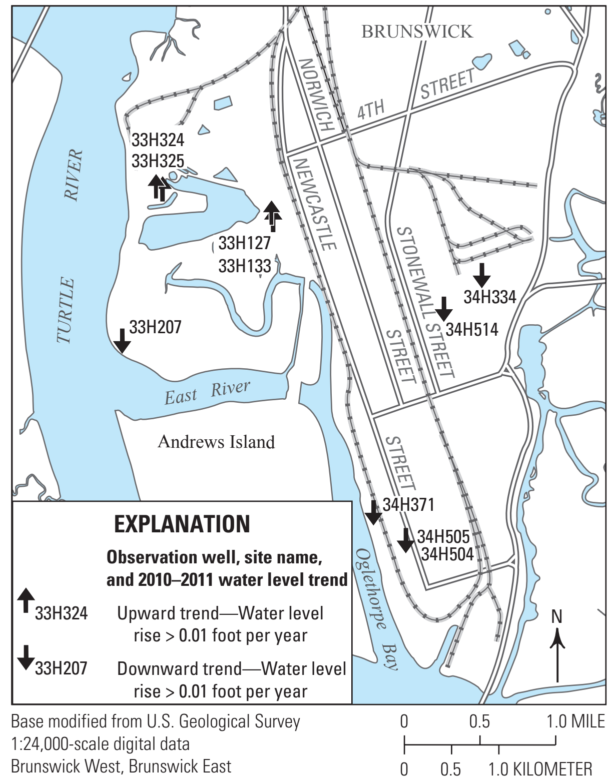
Cherry, G.S., Peck, M.F., Painter, J.A., and Stayton, W.L., 2011, Groundwater conditions in the Brunswick–Glynn County area, Georgia, 2009: U.S. Geological Survey Scientific Investigations Report 2011–5087, 58 p.; available online at *http://pubs.usgs.gov/sir/2011/5087/*.

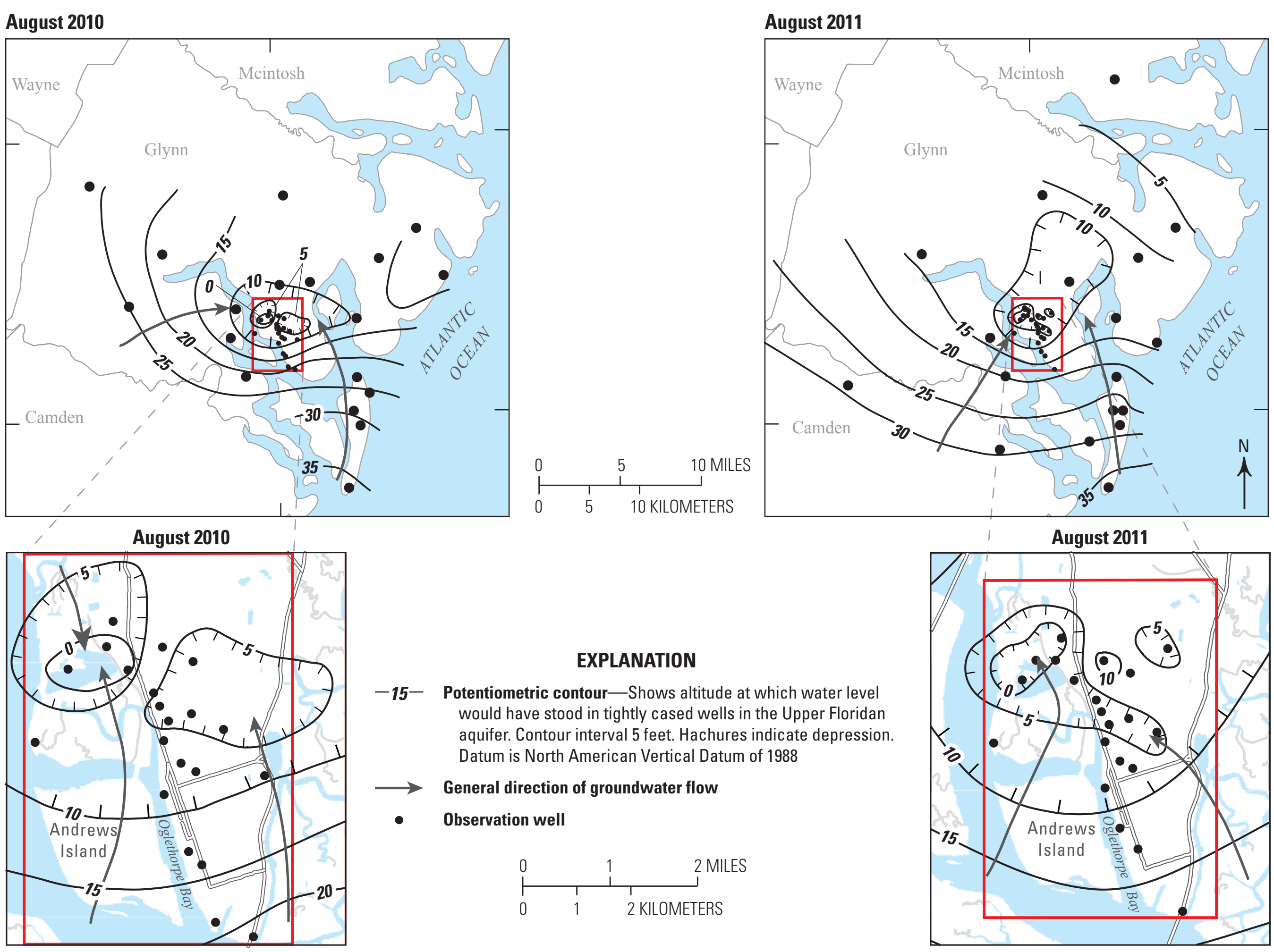




Site name	County	Year monitoring began	Water-level trend, in feet, per year[1]	
			Period of record	From 2010 to 2011
33H127	Glynn	1962	0.06	0.22
33H133	Glynn	1964	0.28	0.11
34H504	Glynn	2007	0.53	–1.16
34H505	Glynn	2007	0.27	–1.58
34H514	Glynn	2007	0.55	–0.98
33H207	Glynn	1983	0.43	–0.24
33H324	Glynn	2007	1.41	1.04
33H325	Glynn	2007	6.81	16.94
34H334	Glynn	1988	0.17	–1.02
34H371	Glynn	1967	0.14	–0.75

[1]See appendix for summary statistics.





Groundwater Levels

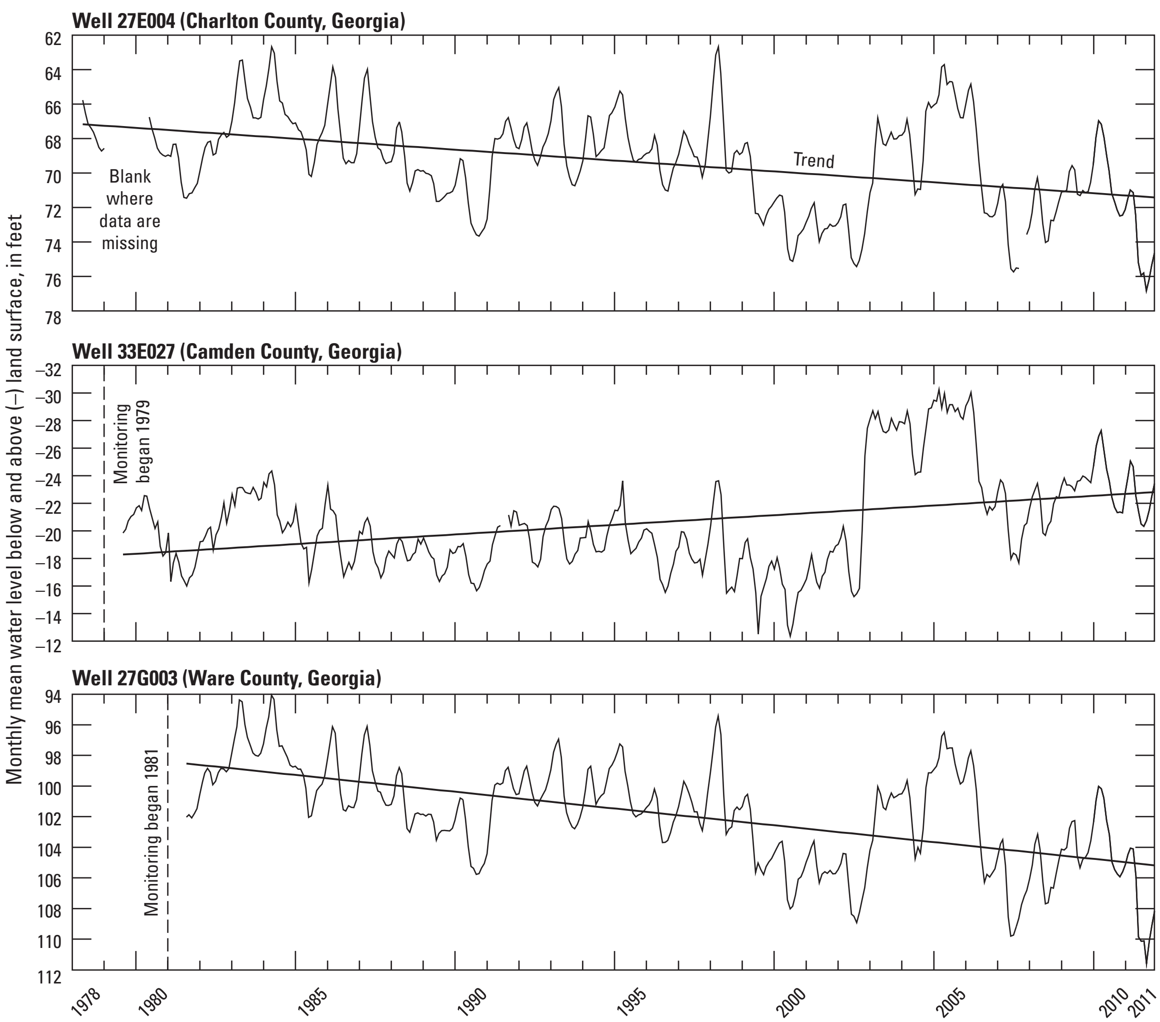
Upper Floridan Aquifer

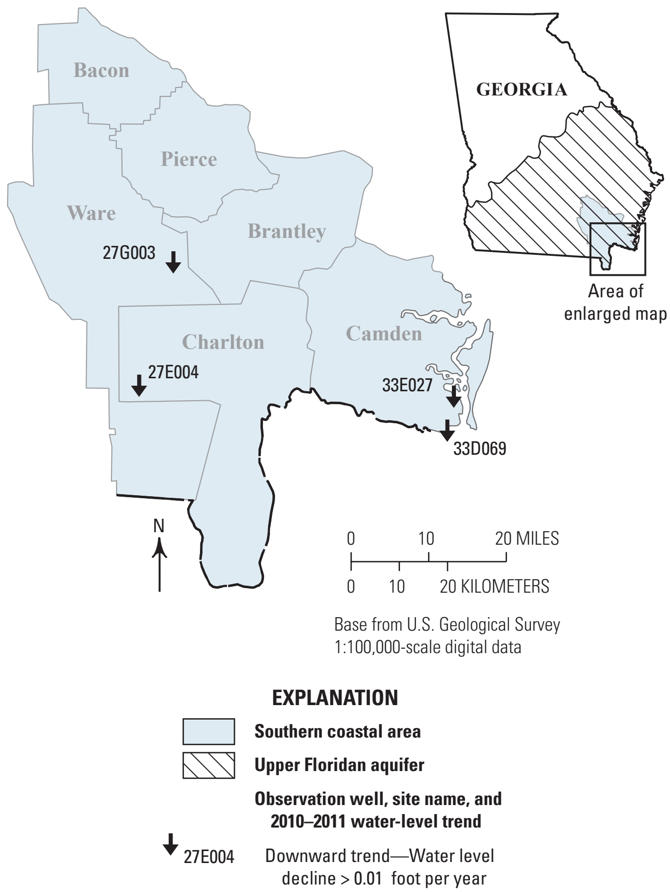
Southern Coastal Area

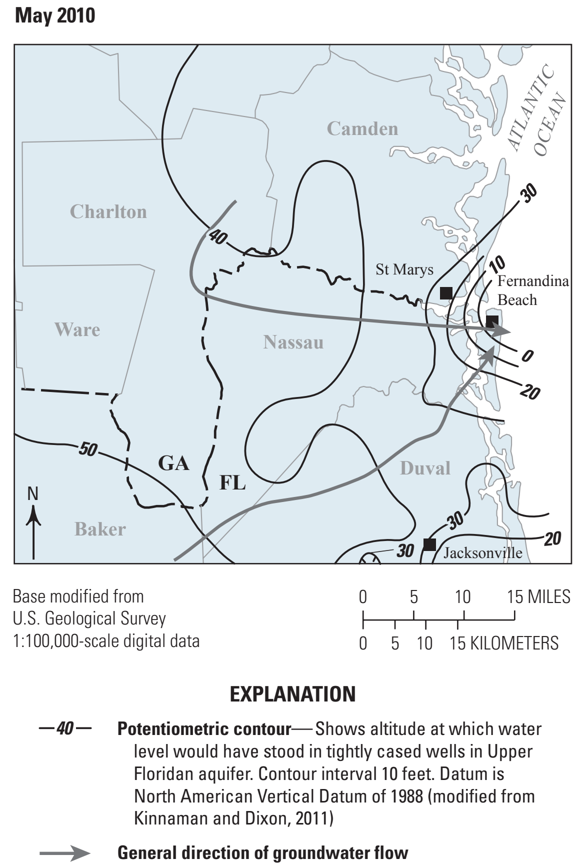
Water levels in four wells were used to define groundwater conditions in the Upper Floridan aquifer in the southern coastal area of Georgia during 2010–2011 (map and table, facing page). In this area, water in the Upper Floridan aquifer is confined and influenced mostly by pumping to the south in the Fernandina Beach area, Florida, and by climatic effects and pumping to the west. Hydrographs for selected wells (below) illustrate monthly mean water levels for the period of record. The hydrographs show periodic upward or downward trends that primarily reflect changes in pumping. The sharp rise in water levels in late 2002 on each of the hydrographs is the result of a decrease in pumpage of 35 million gallons per day at a nearby industry in St. Marys (Peck and others, 2005).

Water-level changes during the period of record varied across the southern coastal area. In the western part of the area, water levels declined at rates of 0.13 to 0.22 foot per year (ft/yr). In the eastern part of the area, water levels rose at rates of 0.14 to 1.52 ft/yr. The larger water-level rises in the eastern part of the area result from the discontinuation of pumping at nearby St. Marys in 2002 (see hydrograph for well 33E027). During 2010–2011, water levels in all of the wells declined at rates ranging from 2.23 to 5.17 ft/yr, which correspond to the drought conditions that began in mid-2010 and continued through 2011.

In addition to continuous water-level monitoring, synoptic water-level measurements are made periodically in wells in and around the southern coastal area of Georgia and adjacent parts of Florida. During May to June 2010, water levels in 16 wells measured in Camden, Ware, and Charlton Counties were used to construct a potentiometric-surface map of the Upper Floridan aquifer (Kinnaman and Dixon, 2011). The map for 2010 (inset, facing page) shows that water generally flowed from west to east toward the Atlantic Ocean and toward pumping centers at Fernandina Beach and Jacksonville, Florida.







Site name	County	Year monitoring began	Water-level trend, in feet, per year[1]	
			Period of record	From 2010 to 2011
33D069	Camden	1994	1.52	–3.28
33E027	Camden	1979	0.14	–2.23
27E004	Charlton	1986	–0.13	–4.57
27G003	Ware	1984	–0.22	–5.17

[1]See appendix for summary statistics.

References

Kinnaman, S.L., and Dixon, J.F., 2011, Potentiometric surface of the Upper Floridan aquifer in Florida and parts of Georgia, South Carolina, and Alabama, May–June 2010: U.S. Geological Survey Scientific Investigations Map 3182, 1 sheet.

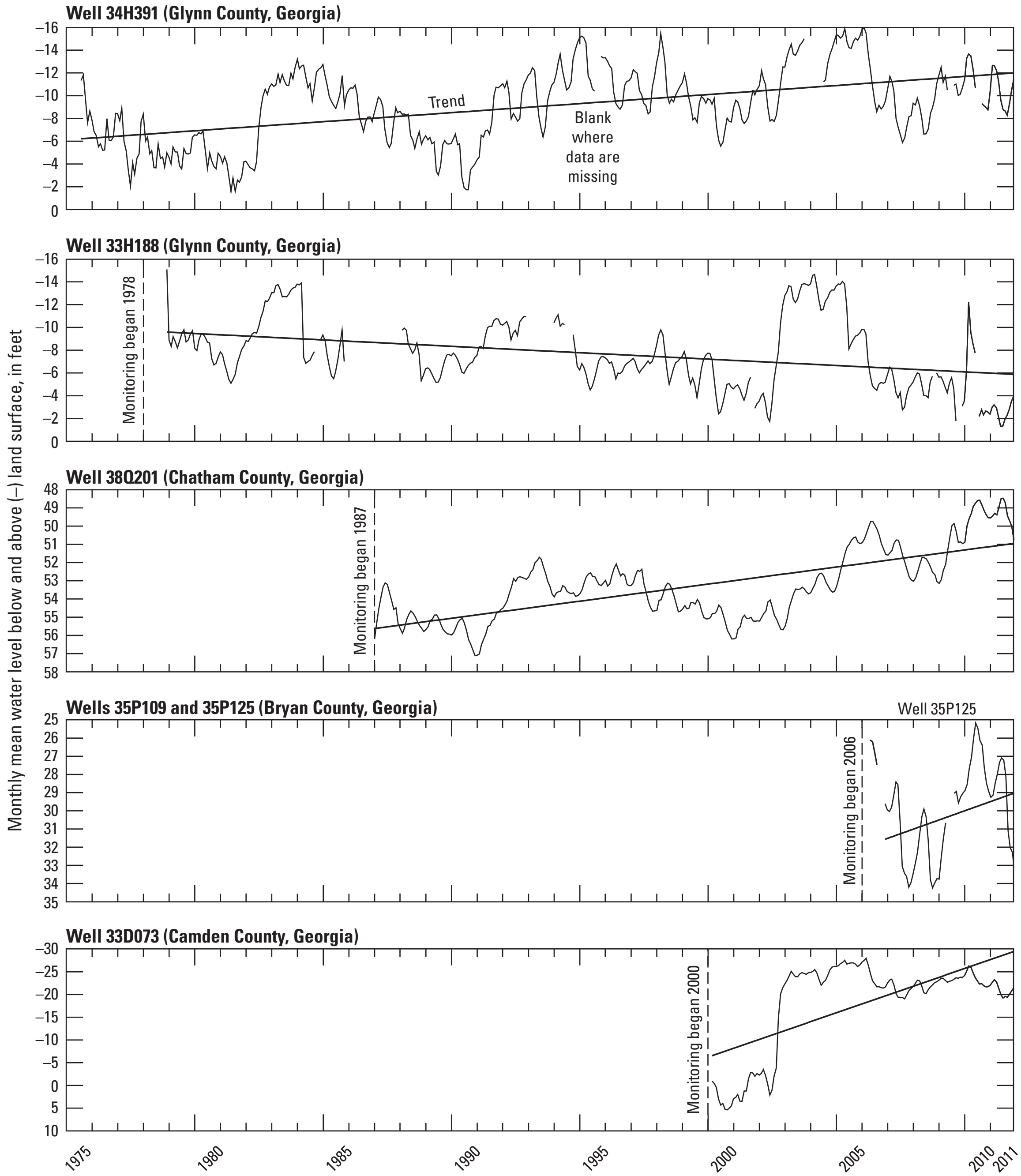
Peck, M.F., McFadden, K.W., and Leeth, D.C., 2005, Effects of decreased ground-water withdrawal on ground-water levels and chloride concentrations in Camden County, Georgia, and ground-water levels in Nassau County, Florida, from September 2001 to May 2003: U.S. Geological Survey Scientific Investigations Report 2004–5295, 36 p.; available online at *http://pubs.usgs.gov/sir/2004/5295/*.

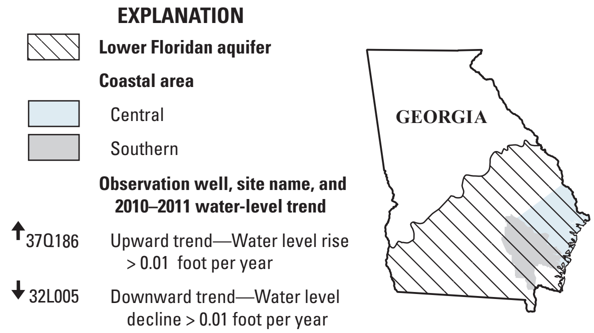
Groundwater Levels

Lower Floridan Aquifer and Underlying Units in Coastal Georgia

Water levels in 16 wells in central and southern coastal Georgia were used to define groundwater conditions in the Lower Floridan aquifer and underlying units during 2010–2011 (map and table, facing page). In this area, water in the Lower Floridan aquifer is confined and influenced mostly by pumping. Hydrographs for selected wells (below) illustrate monthly mean water levels for the period of record. The hydrographs show periodic upward or downward trends that primarily reflect changes in pumping.

During the period of record, water levels in 11 of the wells rose 0.08 to 1.95 feet per year (ft/yr) and declined in 5 wells from 0.11 to 0.38 ft/yr. The largest rise occurred in well 33D073 near St. Marys, Camden County, in response to the shutdown of a local industrial site in 2002 (Peck and others, 2005). During 2010–2011, water levels in 15 of the 16 wells declined at rates ranging from 0.01 to 4.65 ft/yr, corresponding to decreased precipitation and increased water demand due to drought. During the same period, water levels rose 1.62 ft/yr in well 37Q186, reflecting variations in local pumping conditions.





Reference

Peck, M.F., McFadden, K.W., and Leeth, D.C., 2005, Effects of decreased ground-water withdrawal on ground-water levels and chloride concentrations in Camden County, Georgia, and ground-water levels in Nassau County, Florida, from September 2001 to May 2003: U.S. Geological Survey Scientific Investigations Report 2004–5295, 36 p.; available online at *http://pubs.usgs.gov/sir/2004/5295/*.

Site name	Water-bearing unit[1]	County	Year monitoring began	Water-level trend, in feet, per year[2]	
				Period of record	From 2010 to 2011
33R045	LF	Bryan	2002	–0.38	–4.65
35P125	LF	Bryan	2006	0.51	–3.66
33D073	LF	Camden	2000	1.95	–2.87
33D074	LF	Camden	2003	–0.31	–2.05
37Q186	P	Chatham	1985	0.72	1.62
38Q201	P	Chatham	1987	0.19	–0.01
39Q024	LF	Chatham	1996	0.21	–1.17
34S011	LF	Effingham	2002	–0.25	–4.06
33H188	F	Glynn	1978	–0.11	–2.98
33H206	LF	Glynn	1983	0.23	–1.21
33J044	LF	Glynn	1979	0.09	–1.81
34H391	LF	Glynn	1975	0.16	–1.47
34H436	LF	Glynn	1983	0.17	–0.94
34H495	LF	Glynn	2001	0.87	–1.92
34H500	LF	Glynn	2001	0.08	–0.58
32L005	LF	Wayne	1980	–0.32	–1.31

[1]LF, Lower Floridan aquifer; P, Paleocene unit of low permeability; F, Fernandina permeable zone.

[2]See appendix for summary statistics.

Groundwater Levels

Claiborne and Gordon Aquifers

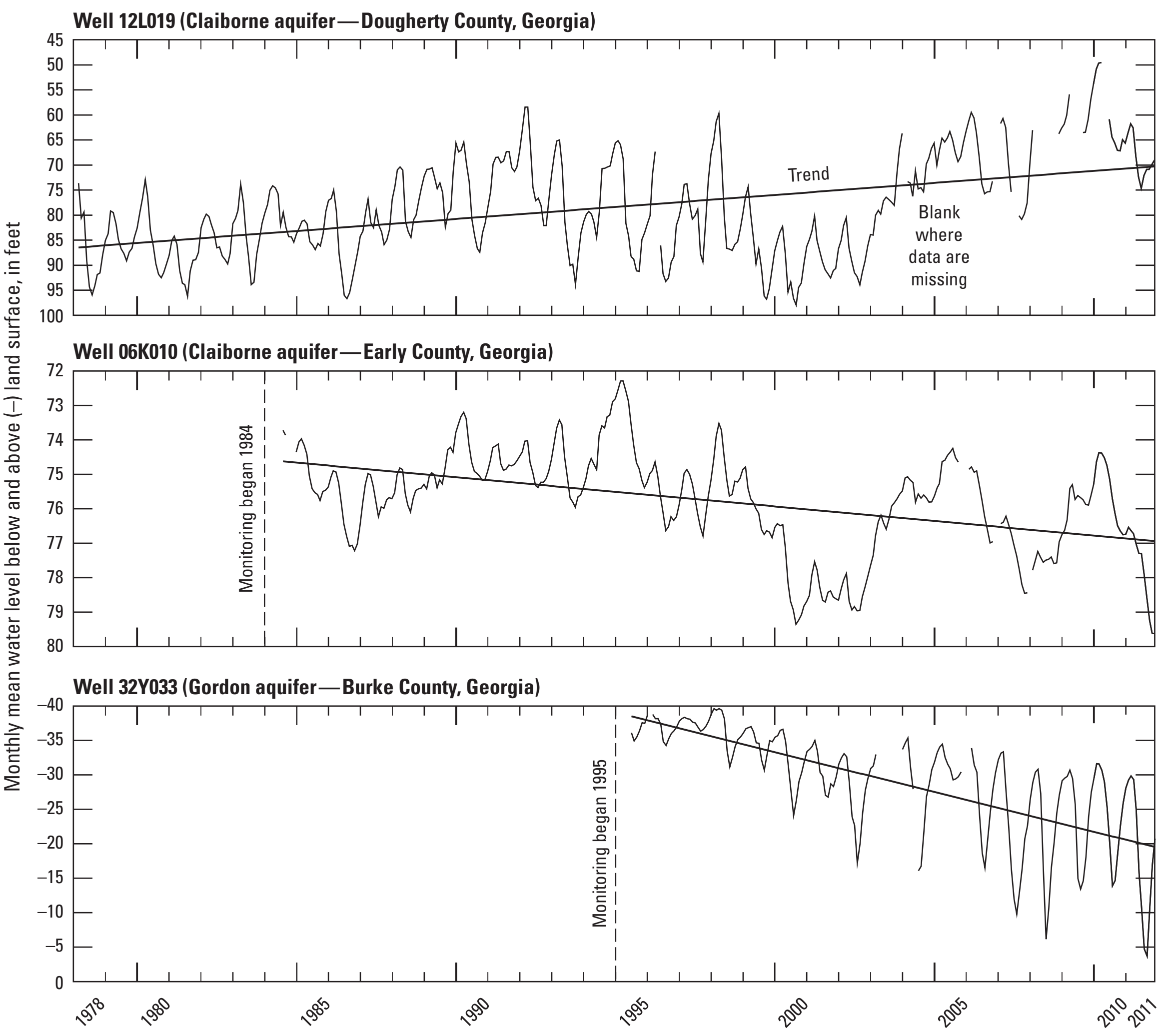
Water levels in 10 Claiborne aquifer wells and 1 Gordon aquifer well were used to define groundwater conditions in southwestern and east-central Georgia during 2010–2011 (map and table, facing page). Water in the Claiborne and Gordon aquifers can be confined or unconfined. Hydrographs showing water levels in two wells in the Claiborne aquifer and one well in the Gordon aquifer (below) illustrate monthly mean water levels for the period of record. The hydrographs show periodic upward or downward trends that reflect changes in precipitation and pumping.

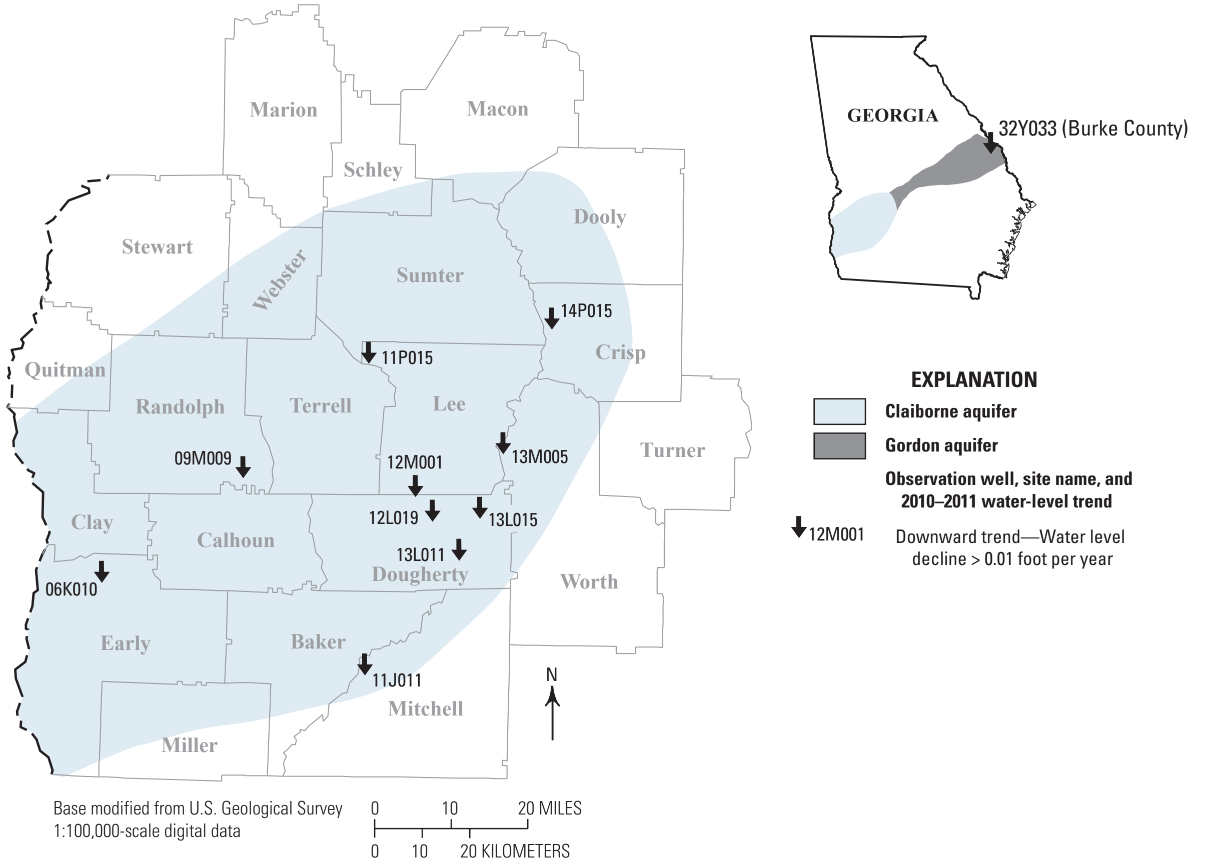
During the period of record, water levels in the Claiborne aquifer declined at rates of 0.05 to 1.02 feet per year (ft/yr) in 7 of the 10 wells monitored. The water levels rose in three wells at a rate of 0.01 to 0.48 ft/yr. During 2010–2011, water levels in all 10 of the Claiborne aquifer wells declined from 2.57 to 21.55 ft/yr, which correspond to drought conditions that began in mid-2010 and continued through 2011. The greatest declines for both the period of record and 2010–2011 were in well 12M001 in southern Lee County and are probably related to increases in local pumping.

In the Gordon aquifer, water levels in well 32Y033 declined at a rate of 1.15 ft/yr for the period of record. During 2010–2011, water-levels continued to decline at a rate of 8.84 ft/yr. These declines correspond to increased agricultural use in east-central Georgia (Cherry, 2006).

Reference

Cherry, G.S., 2006, Simulation and particle-tracking analysis of ground-water flow near the Savannah River Site, Georgia and South Carolina, 2002, and for selected water-management scenarios, 2002 and 2020: U.S. Geological Survey Scientific Investigations Report 2006–5195, 156 p.; available online at *http://pubs.usgs.gov/sir/2006/5195/*.





Site name	Water-bearing unit[1]	County	Year monitoring began	Water-level trend, in feet, per year[2]	
				Period of record	From 2010 to 2011
14P015	C	Crisp	1984	–0.38	–12.74
12L019	C	Dougherty	1978	0.48	–10.74
13L011	C	Dougherty	1977	0.15	–7.78
13L015	C	Dougherty	1979	–0.50	–10.04
06K010	C	Early	1986	–0.08	–2.57
11P015	C	Lee	1984	–0.05	–3.38
12M001	C	Lee	1978	–1.02	–21.55
11J011	C	Mitchell	1981	–0.16	–7.55
09M009	C	Randolph	1984	0.01	–2.98
13M005	C	Worth	1980	–0.24	–9.91
32Y033	G	Burke	1995	–1.15	–8.84

[1]C, Claiborne aquifer; G, Gordon aquifer.

[2]See appendix for summary statistics.

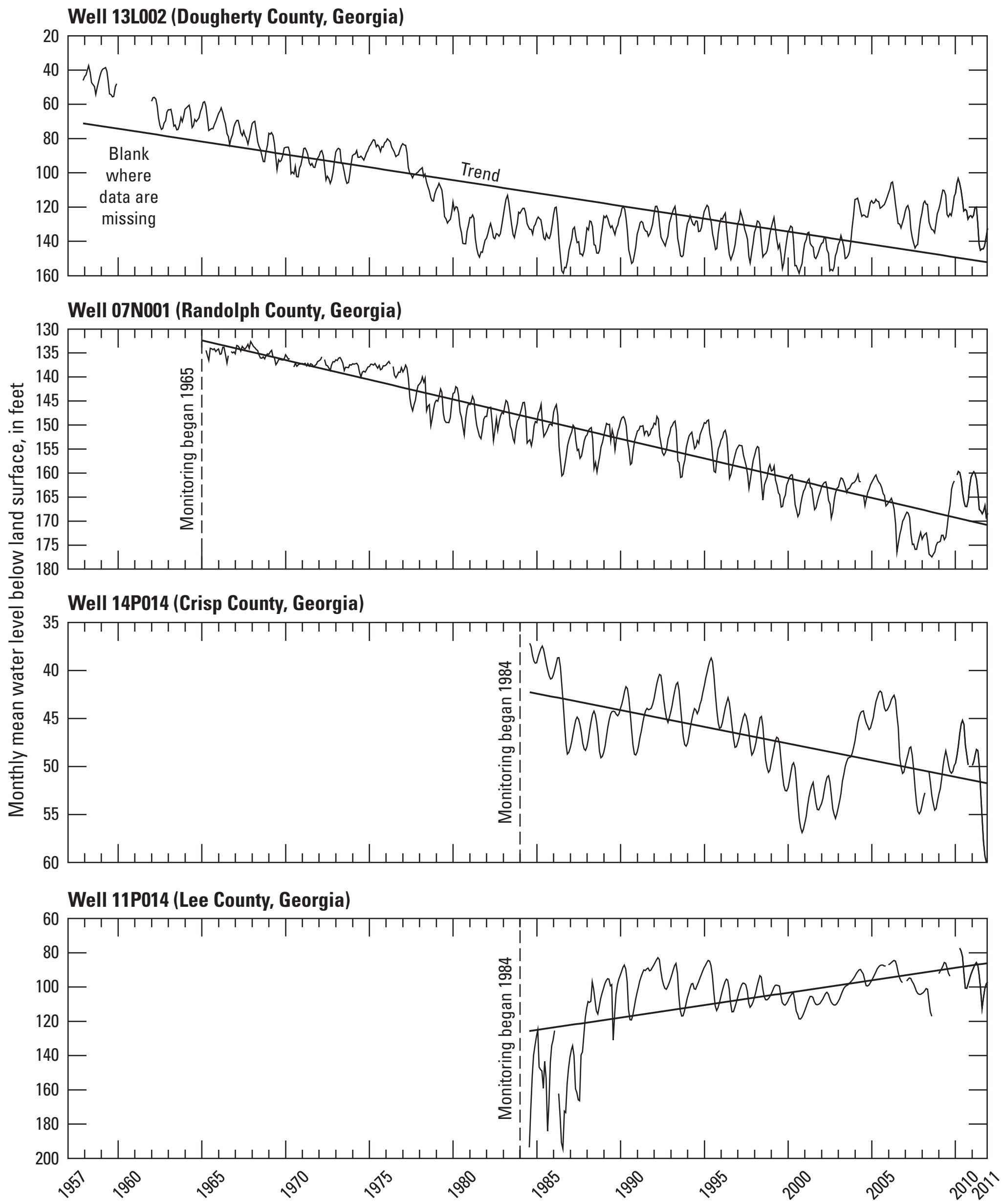
Groundwater Levels

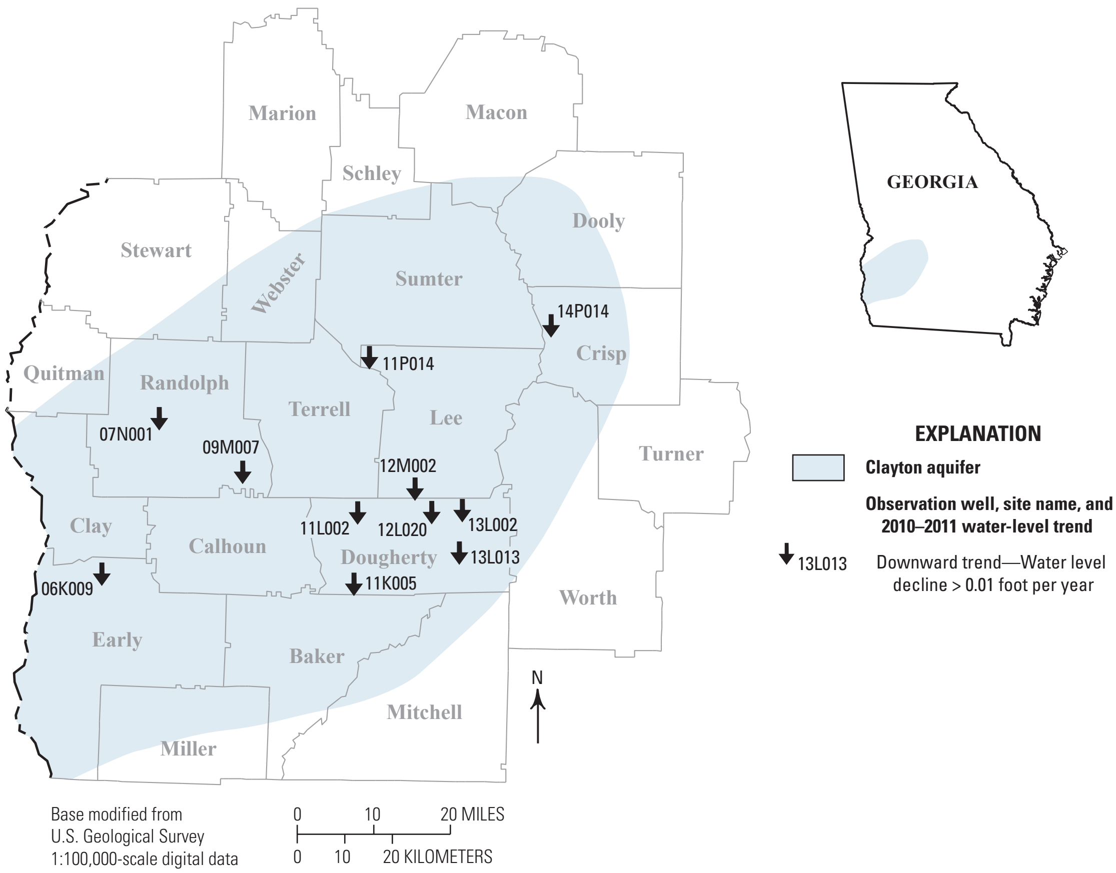
Clayton Aquifer

Water levels in 11 wells were used to define groundwater conditions in the Clayton aquifer in southwestern Georgia during 2010–2011 (map and table, facing page). In this area, water in the Clayton aquifer is confined and influenced mostly by pumping. Hydrographs for selected wells (below) illustrate monthly mean water levels for the period of record. The hydrographs show periodic upward or downward trends that reflect changes in pumping.

During the period of record, water levels in 8 of the 11 wells declined at rates of 0.35 to 2.06 feet per year (ft/yr). Water levels rose in three wells at rates from 0.10 to 1.45 ft/yr during the period of record. These changes reflect variations in local and regional pumping.

During 2010–2011, water levels in all 11 of the wells declined from 2.93 to 33.29 ft/yr, which correspond to the drought conditions that began in mid-2010 and continued through 2011. Declines exceeding 19 ft/yr occur in a band extending from northern Dougherty County northwestward into southern parts of Lee, Terrell, Randolph, and Clay Counties, and northern Early County, reflecting an increase in pumping due to the drought.





Site name	County	Year monitoring began	Water-level trend, in feet, per year[1]	
			Period of record	From 2010 to 2011
14P014	Crisp	1986	–0.35	–6.05
11K005	Dougherty	1979	–1.57	–2.93
11L002	Dougherty	1973	–1.73	–29.68
12L020	Dougherty	1980	0.42	–19.08
13L002	Dougherty	1957	–1.50	–19.06
13L013	Dougherty	1978	0.10	–3.02
06K009	Early	1986	–1.48	–20.13
11P014	Lee	1984	1.45	–8.34
12M002	Lee	1978	–0.66	–28.83
07N001	Randolph	1965	–0.82	–3.68
09M007	Randolph	1984	–2.06	–33.29

[1]See appendix for summary statistics.

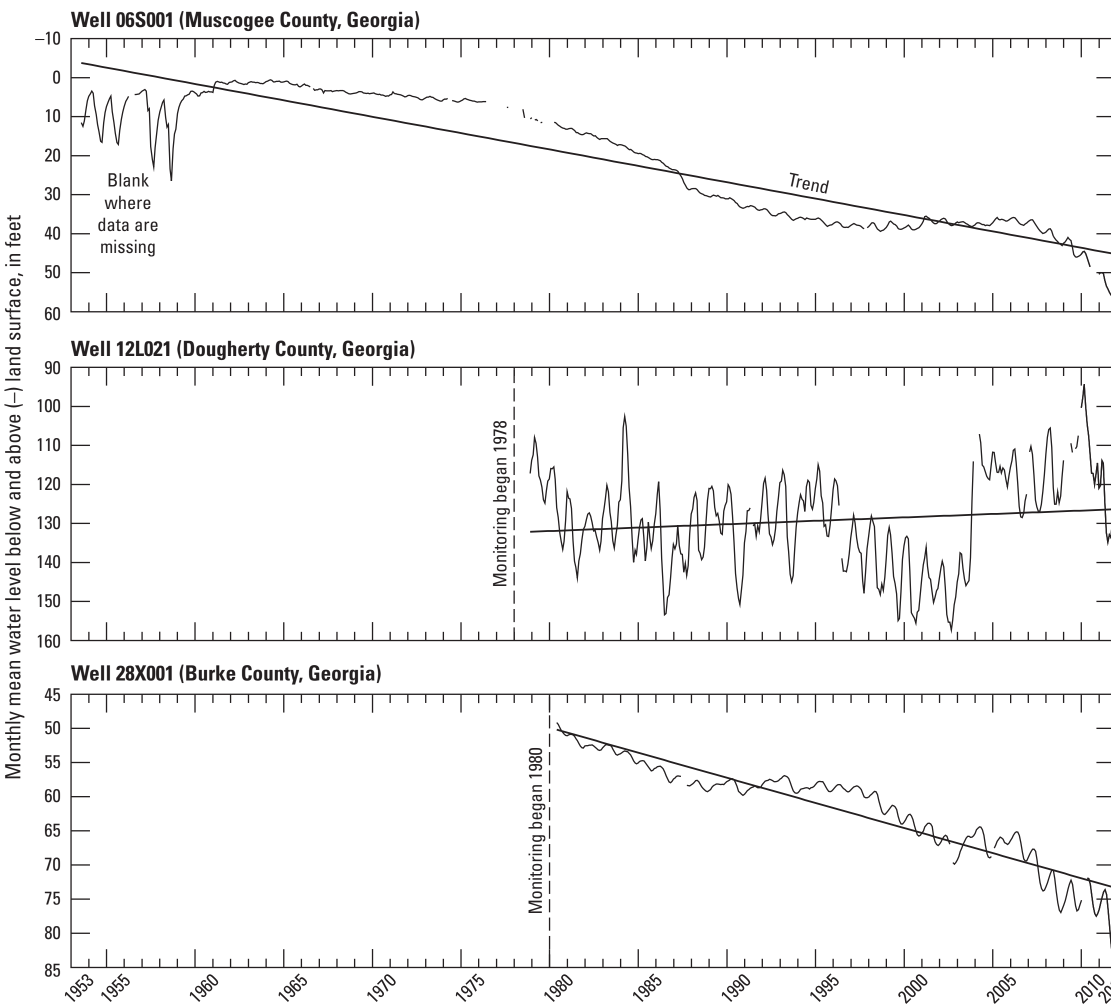
Groundwater Levels

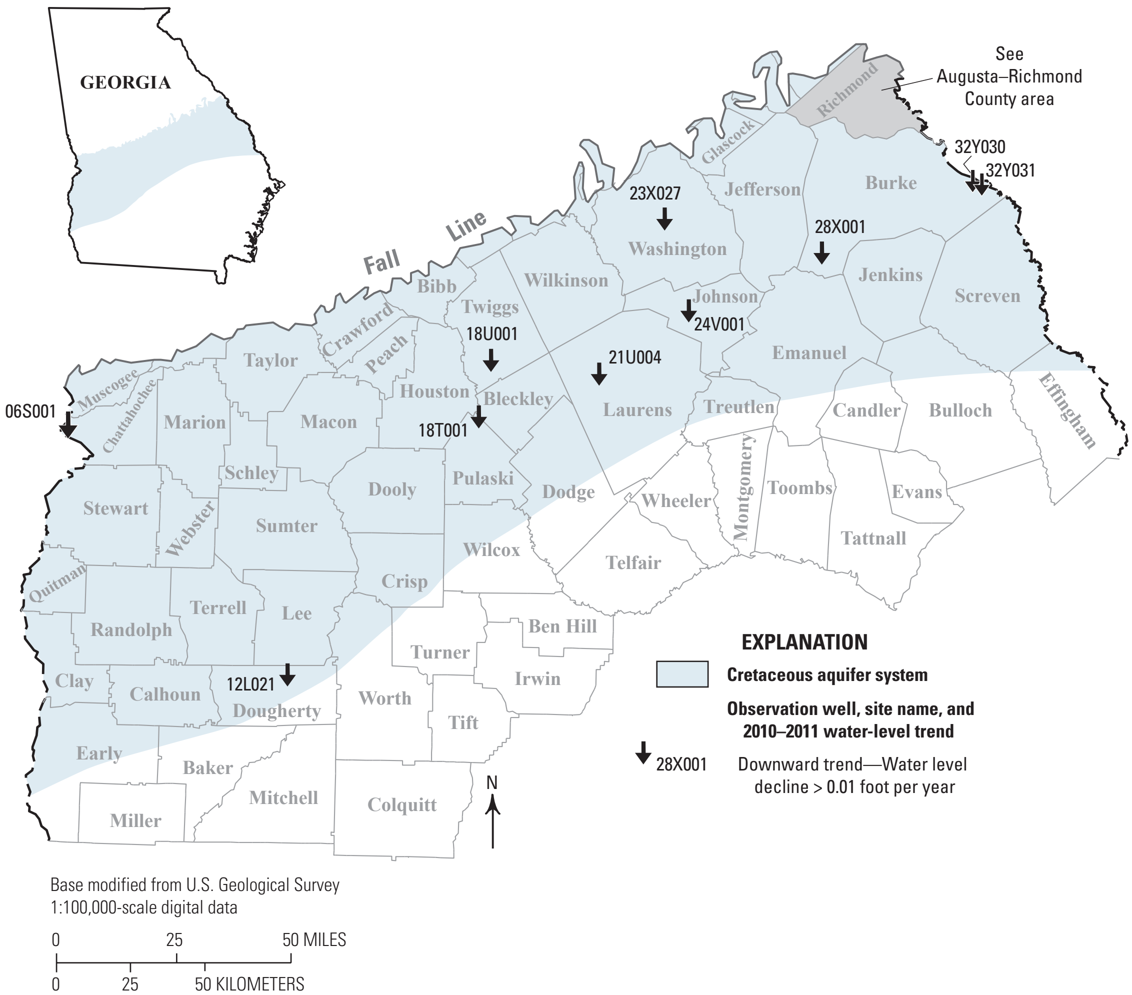
Cretaceous Aquifer System

Water levels in 10 wells in the Cretaceous aquifer system were used to define groundwater conditions throughout central and southwestern Georgia during 2010–2011 (map and table, facing page). In this area, water in the Cretaceous aquifer system mostly is confined but can be unconfined in stream valleys. Hydrographs for selected wells (below) illustrate monthly mean water levels for the period of record. The hydrographs show periodic upward or downward trends that largely reflect changes in pumping. Water levels in wells 06S001 and 28X001 both show a long-term downward trend related to groundwater pumping. The hydrograph for well 12L021 shows a sharp water-level rise in 2003 when pumping was discontinued from a nearby public-supply well.

During the period of record, water levels in 9 of the 10 wells declined from 0.13 to 0.84 foot per year (ft/yr). The only well showing a water-level rise (0.17 ft/yr) during the period of record was well 12L021 at Albany because of decreased pumping for public supply.

During 2010–2011, water levels in all 10 of the wells declined at rates of 1.55 to 17.05 ft/yr, reflecting decreased precipitation and increased water demand due to drought. The largest decline occurred in well 12L021 in Dougherty County, reflecting changes in local pumping.





Site name	Water-bearing unit[1]	County	Year monitoring began	Water-level trend, in feet, per year[2]	
				Period of record	From 2010 to 2011
28X001	M	Burke	1980	–0.73	–5.03
32Y030	LM	Burke	1995	–0.45	–1.75
32Y031	LD	Burke	1995	–0.53	–2.78
12L021	P	Dougherty	1978	0.17	–17.05
24V001	M	Johnson	1980	–0.58	–2.55
21U004	M	Laurens	1982	–0.33	–1.55
06S001	T	Muscogee	1953	–0.84	–5.85
18T001	M	Pulaski	1981	–0.25	–1.76
18U001	D	Twiggs	1975	–0.13	–1.77
23X027	DM	Washington	1985	–0.68	–2.26

[1]M, Midville aquifer system; LM, lower Midville aquifer; LD, lower Dublin aquifer; T, Tuscaloosa Formation; P, Providence aquifer; UM, upper Midville aquifer; DM, Dublin-Midville aquifer system; D, Dublin aquifer system.

[2]See appendix for summary statistics.

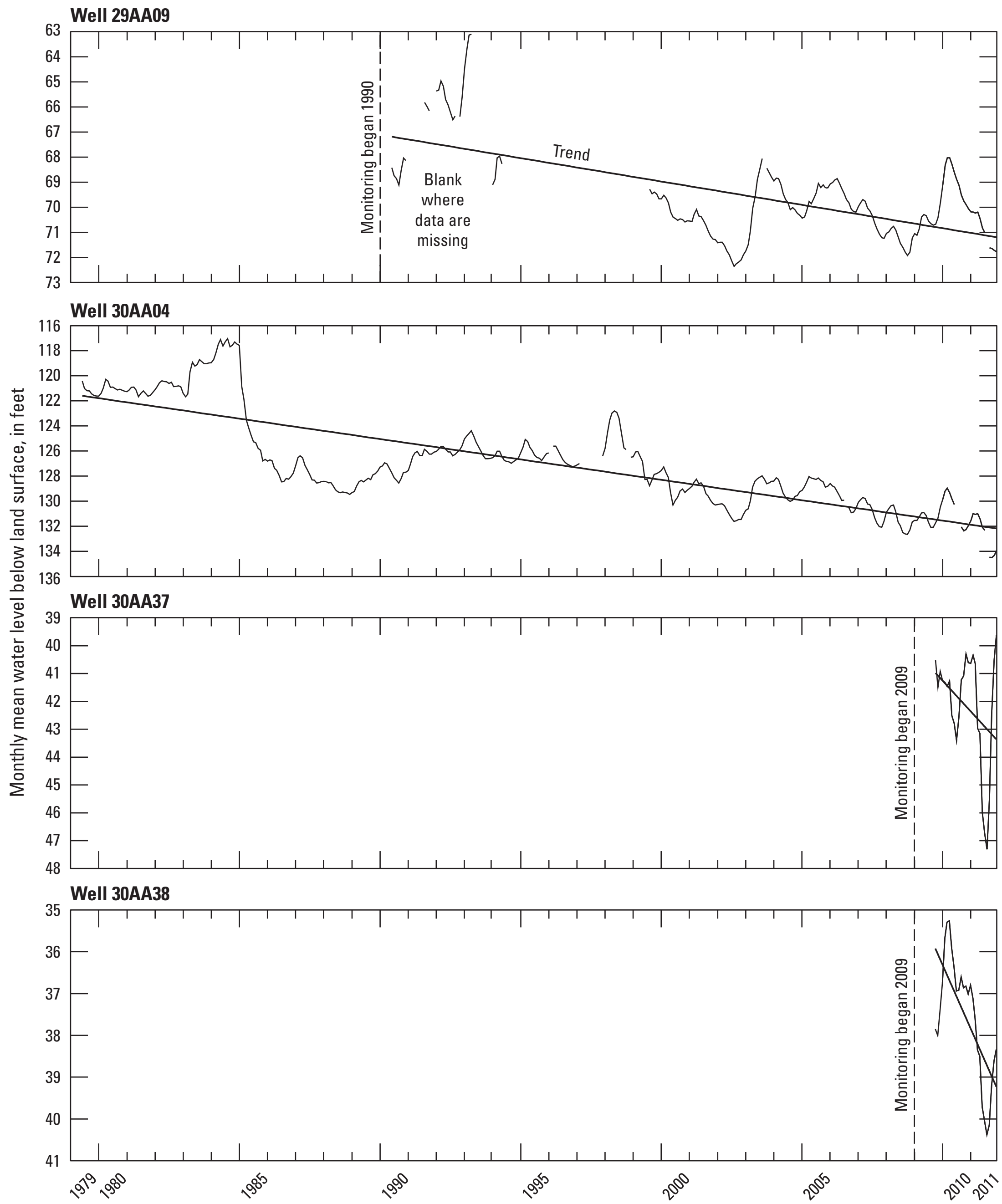
Groundwater Levels

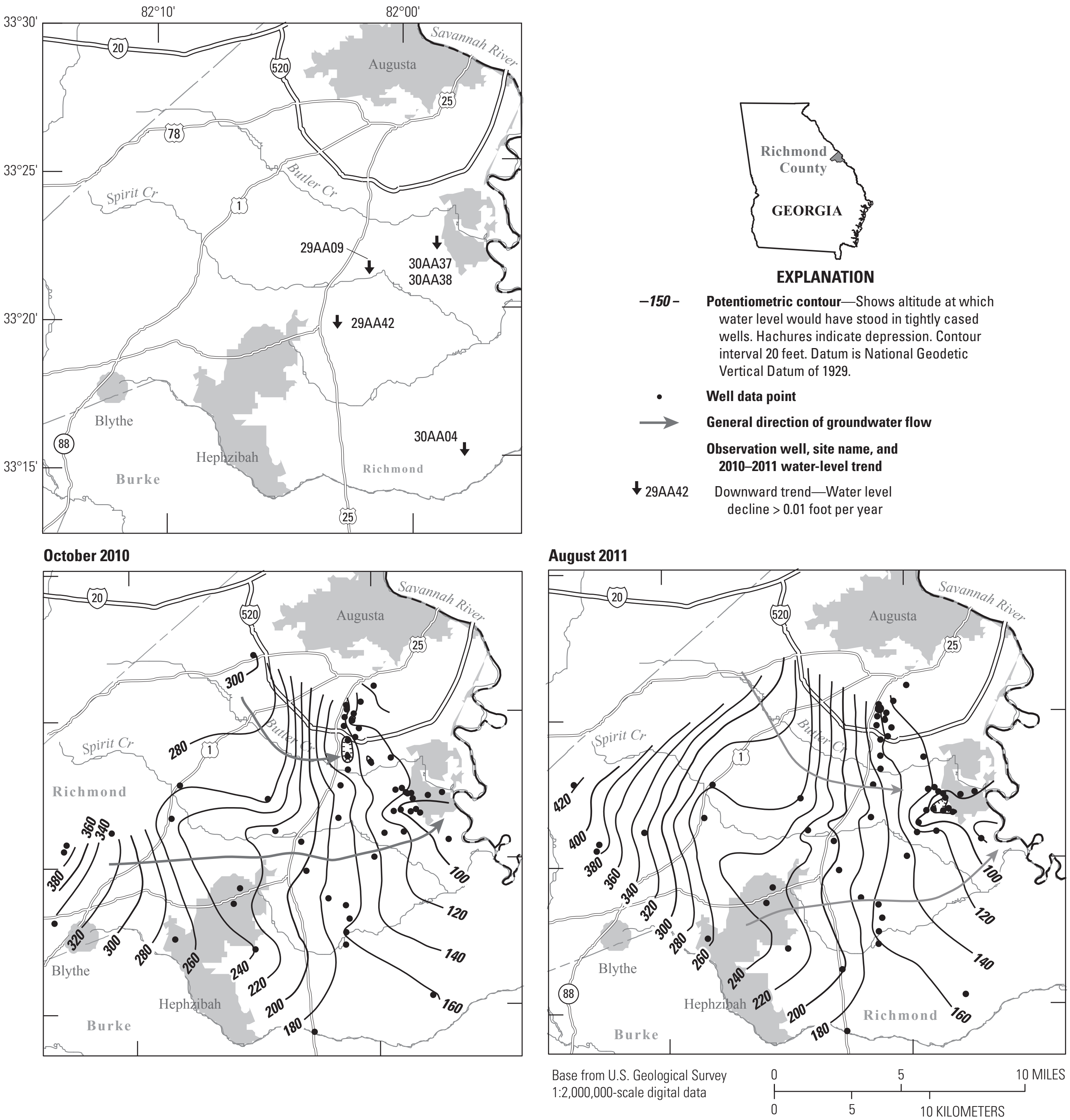
Cretaceous Aquifer System

Augusta–Richmond County Area

Water levels were continuously monitored in six wells in the Cretaceous aquifer system in the Augusta–Richmond County area; however, only four wells with periods of record greater than 3 years are presented here. During the period of record, water levels declined in all four wells at rates of 0.19 to 1.52 ft/yr. Water levels continued to decline in all four wells at rates of 1.06 to 2.49 ft/yr during 2010–2011. These declines are probably related to changes in local pumping and the drought conditions throughout the period.

In addition to continuous water-level monitoring, synoptic water-level measurements were made in 56 wells during October 2010 and 57 wells during August 2011 to map the potentiometric surface of the Dublin-Midville aquifer system (Cretaceous) in Augusta–Richmond County. During both years, the general direction of groundwater flow is eastward toward the Savannah River. During 2010, the potentiometric surface shows a cone of depression that illustrates the effect of pumping at one of Augusta–Richmond County's well fields located in the northeastern part of the county. The effects of pumping at another Augusta–Richmond County well field is indicated on the 2011 map by a cone of depression in the eastern part of the county.





Site name	Water-bearing unit[1]	County	Year monitoring began	Water-level trend, in feet, per year[2]	
				Period of record	From 2010 to 2011
29AA09	UM	Richmond	1990	–0.19	–1.97
30AA04	DM	Richmond	1979	–0.32	–2.49
30AA37	LM	Richmond	2009	–1.10	–1.06
30AA38	DM	Richmond	2009	–1.52	–2.25

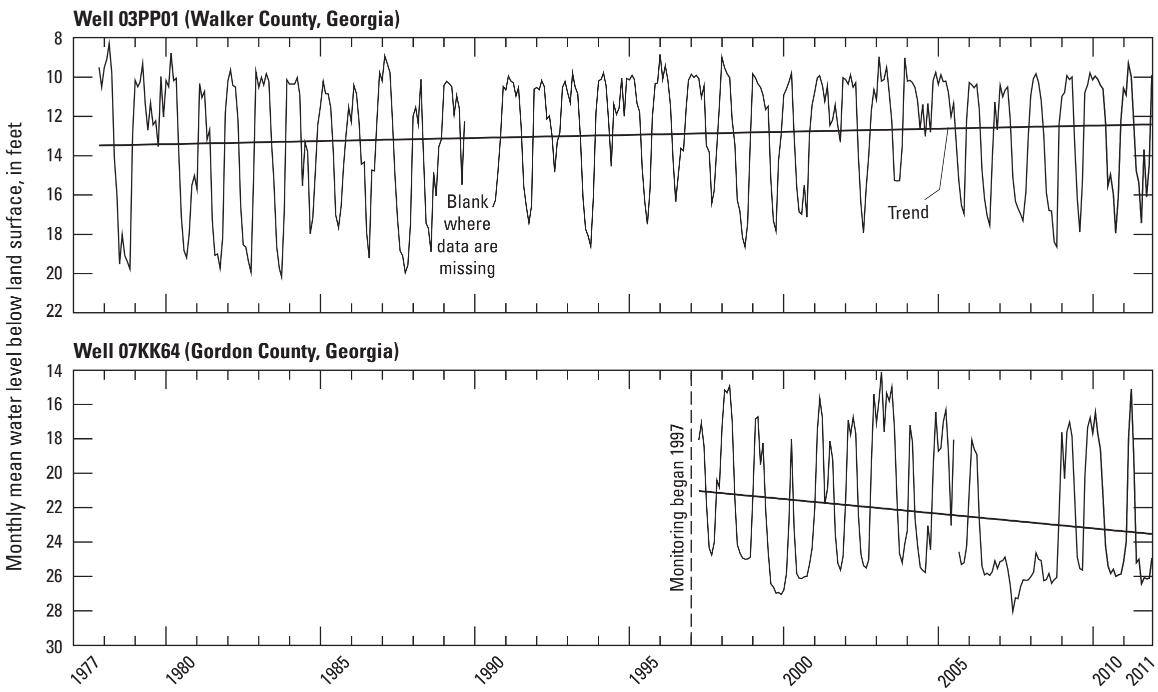
[1]UM, upper Midville aquifer; DM, Dublin-Midville aquifer system; LM, lower Midville aquifer.

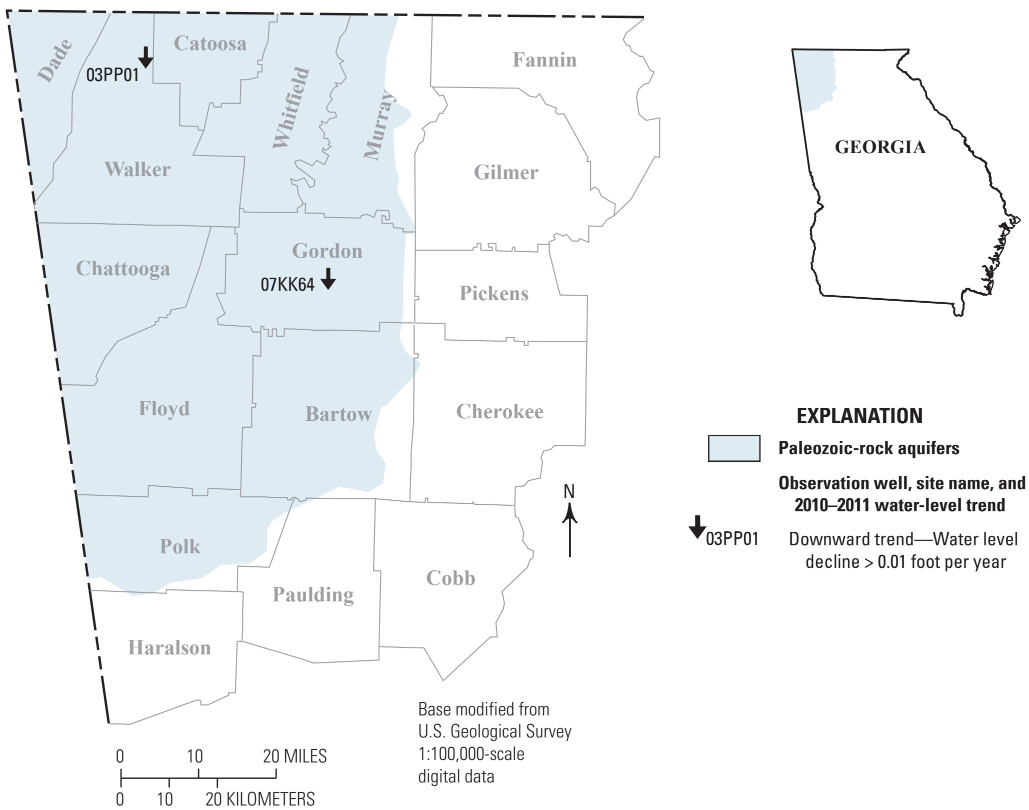
[2]See appendix for summary statistics.

Groundwater Levels

Paleozoic-Rock Aquifers

Water levels were measured in two wells in the Paleozoic-rock aquifers of northwestern Georgia during 2010–2011 (map and table, facing page). In this area, the Paleozoic-rock aquifers are unconfined and show a pronounced response to precipitation. Hydrographs for selected wells (below) illustrate monthly mean water levels for the period of record. The hydrographs show periodic upward or downward trends that reflect changes in precipitation and pumping. During the period of record, the water level in well 07KK64 declined 0.17 foot per year (ft/yr) due to pumping from a nearby public-supply well. Conversely, the water level in well 03PP01 showed little change during the period of record (rose 0.03 ft/yr). During 2010–2011, the water level in both wells declined, reflecting effects of decreased precipitation and increased water demand due to drought.





Site name	County	Year monitoring began	Water-level trend, in feet, per year[1]	
			Period of record	From 2010 to 2011
07KK64	Gordon	1997	–0.17	–2.92
03PP01	Walker	1977	0.03	–1.38

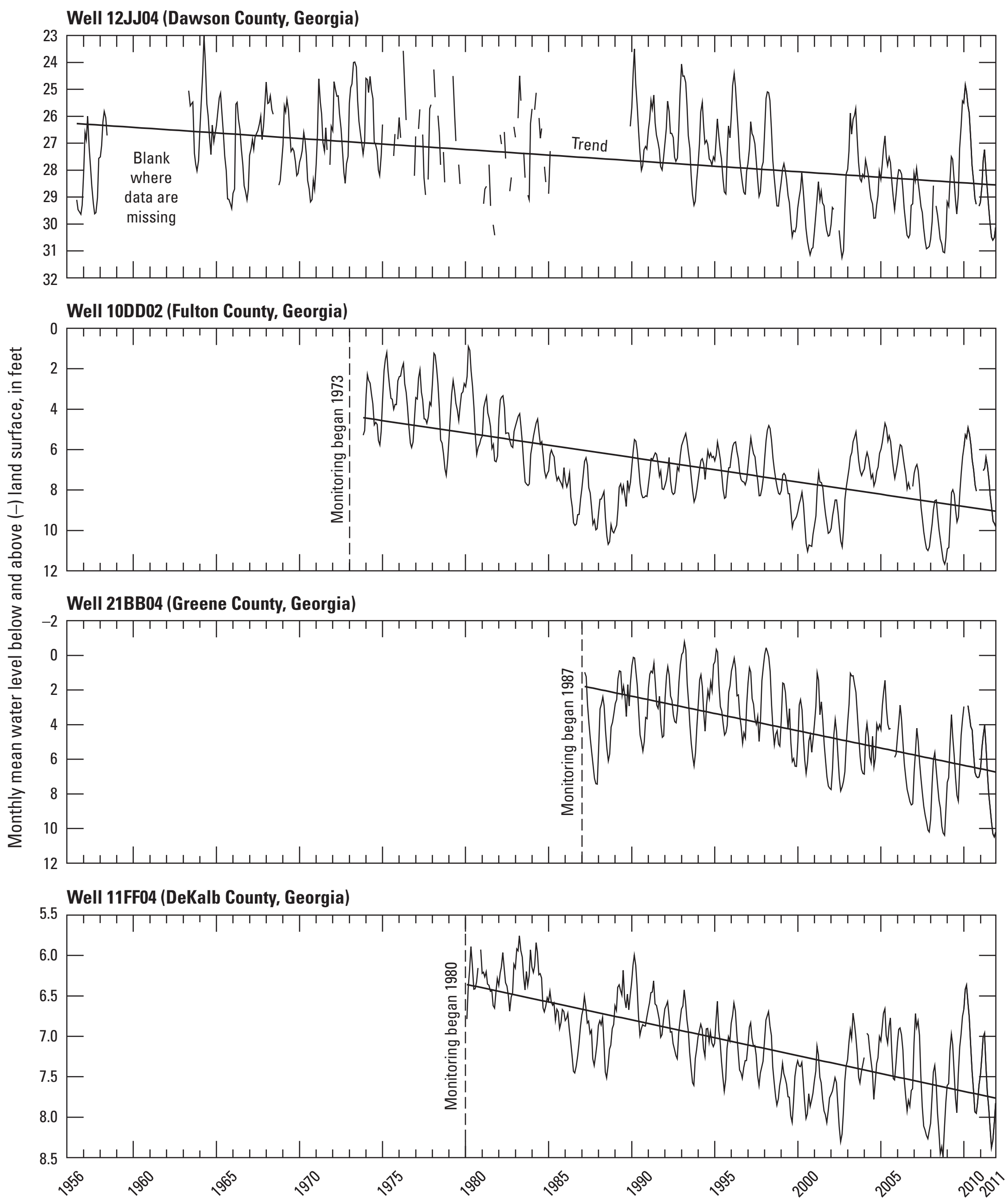
[1]See appendix for summary statistics.

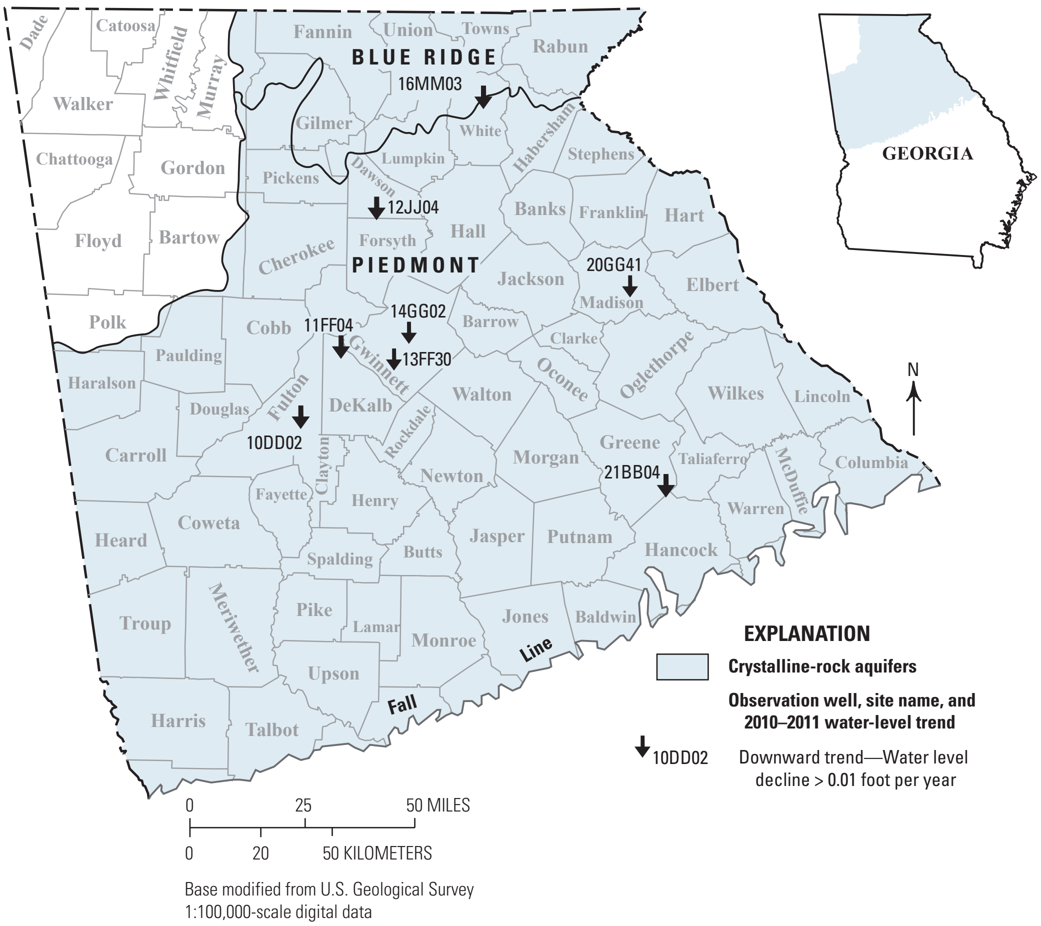
Groundwater Levels

Crystalline-Rock Aquifers

Water levels in eight wells were measured in crystalline-rock aquifers in the Piedmont and Blue Ridge Physiographic Provinces of Georgia during 2010–2011 (map and table, facing page). In this area, water is present in discontinuous joints and fractures and may be confined or unconfined. In general, crystalline-rock aquifers have local extent and can be greatly affected by localized water use and climate. Hydrographs for selected wells (below) illustrate monthly mean water levels for the period of record. The hydrographs show periodic upward or downward trends that reflect changes in precipitation and pumping.

During the period of record, water levels in seven of the wells declined from 0.04 to 0.26 foot per year (ft/yr) and rose in one well 1.03 ft/yr. During 2010–2011, water levels in all eight of the wells declined at rates of change ranging from 0.76 to 3.58 ft/yr, which correspond to the drought conditions during the period.





Site name	County	Year monitoring began	Water-level trend, in feet, per year[1]	
			Period of record	From 2010 to 2011
12JJ04	Dawson	1956	–0.04	–2.57
11FF04	DeKalb	1980	–0.04	–0.76
20GG41	Madison	2007	1.03	–2.35
10DD02	Fulton	1973	–0.12	–2.01
21BB04	Green	1987	–0.20	–3.58
13FF30	Gwinnett	2003	–0.21	–1.72
14GG02	Gwinnett	2003	–0.26	–2.22
16MM03	White	1988	–0.03	–0.76

[1]See appendix for summary statistics.

Groundwater Quality in the Upper and Lower Floridan Aquifers

City of Albany Area

The Upper Floridan aquifer is shallow in southwestern Georgia where agricultural land use is prevalent, which increases the susceptibility of groundwater to contamination from nitrates and other chemicals. Nitrate as nitrogen (N) levels greater than 10 milligrams per liter (mg/L), the maximum contaminant level (MCL) for nitrate as N set by the U.S. Environmental Protection Agency (2000), have been measured in wells southwest of Albany.

Nitrate plus nitrite as N concentrations have been measured in the southwestern Albany area at least annually since September 1998. Because nitrite typically represents a small fraction of the total concentration, the reported values are presented and discussed as nitrate. During November 2010 and November 2011, samples were collected from selected wells and at one site on the Flint River and analyzed for major cations and anions and selected nutrients. The graph below shows the nitrate trend in selected wells and the Flint River.

Sixteen wells were sampled for nitrate concentration in the vicinity of the Albany area well field during November 2010 and November 2011. During 2010, samples from wells 12L061 and 12L277, completed in the Upper Floridan aquifer, and 12L376, completed in the surficial aquifer, had a nitrate concentration greater than the 10-mg/L MCL. Concentrations in most wells showed an increase during 2007–2009, followed by a decrease during 2010–2011. In 2011, nitrate concentrations remained above the MCL at wells 12L061 and 12L376 but decreased to a level below the MCL in well 12L277 (Gordon, 2009).

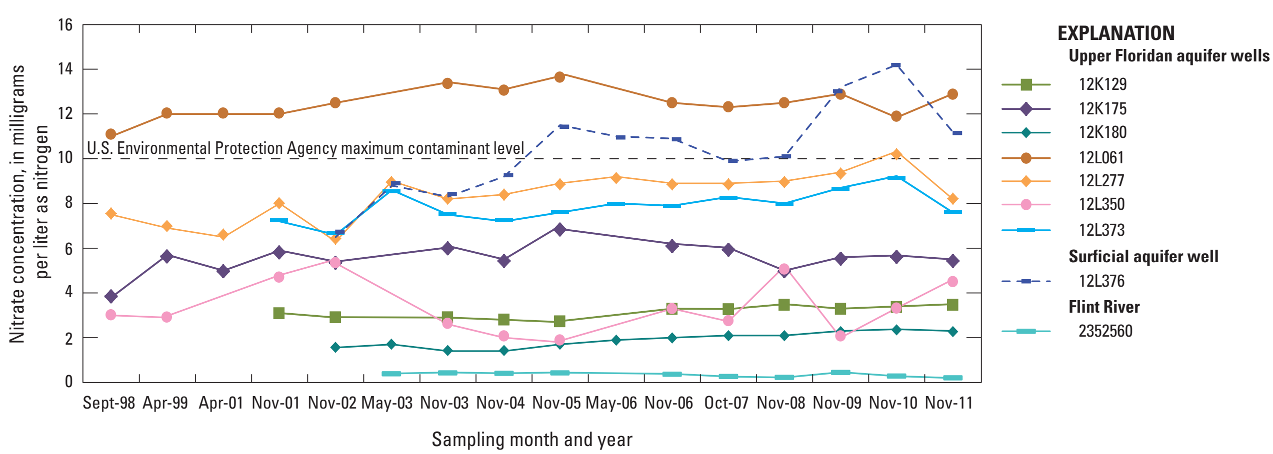
Samples from wells near the well field and the Flint River collected during November 2010 and November 2011 were plotted on trilinear diagrams (facing page). The difference in percentage contribution of major cations and anions between groundwater and surface water indicates that groundwater remains chemically distinct from the surface-water sample. The groundwater samples had lower sodium, potassium, and magnesium content and higher carbonate and bicarbonate content than the surface-water sample.

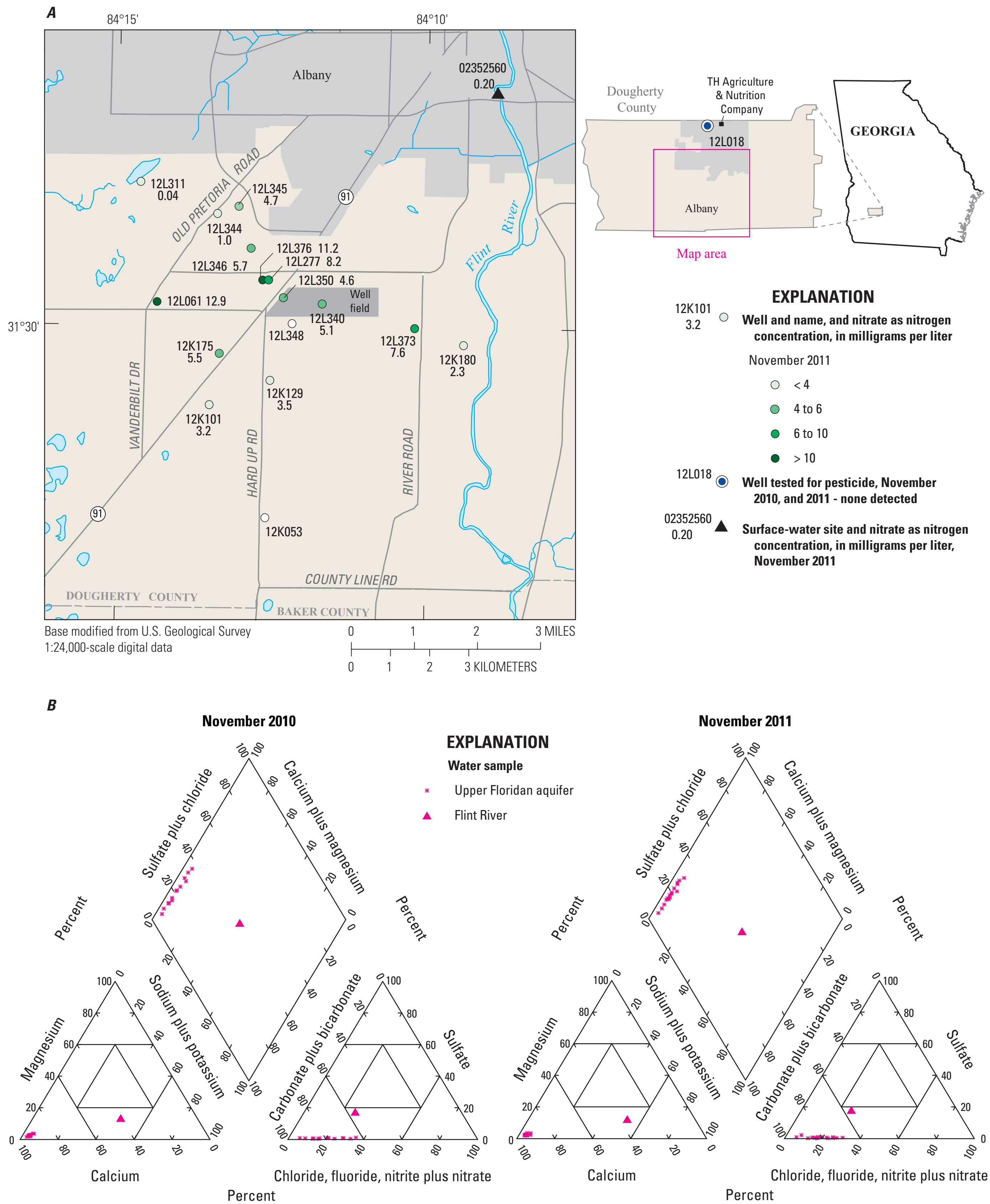
In the northern part of Albany, samples were collected from well 12L018 to monitor water quality and ensure that pesticide contamination from the T.H. Agriculture & Nutrition (THAN) Company Superfund Site (*http://www.clu-in.org/products/costperf/THRMDESP/Thagr.htm*, accessed January 31, 2011) does not affect water quality of the well. Contaminants were not detected in any samples collected from the well during 2010–2011.

References

Gordon, D.W., 2009, Groundwater conditions and studies in the Albany area of Dougherty County, Georgia, 2008: U.S. Geological Survey Open-File Report 2009–1244, 54 p.; available online at *http://pubs.usgs.gov/of/2009/1244/*.

U.S. Environmental Protection Agency, 2000, Maximum contaminant levels (Part 143, National Secondary Drinking Water Regulations): U.S. Code of Federal Regulations, Title 40, Parts 100–149, rev. as of July 1, 2000, p. 612–614.





Trilinear diagrams of major cation and anion compositions of water samples from the Upper Floridan aquifer and the Flint River, November 2010 and November 2011.

Groundwater Quality in the Upper and Lower Floridan Aquifers

City of Savannah Area

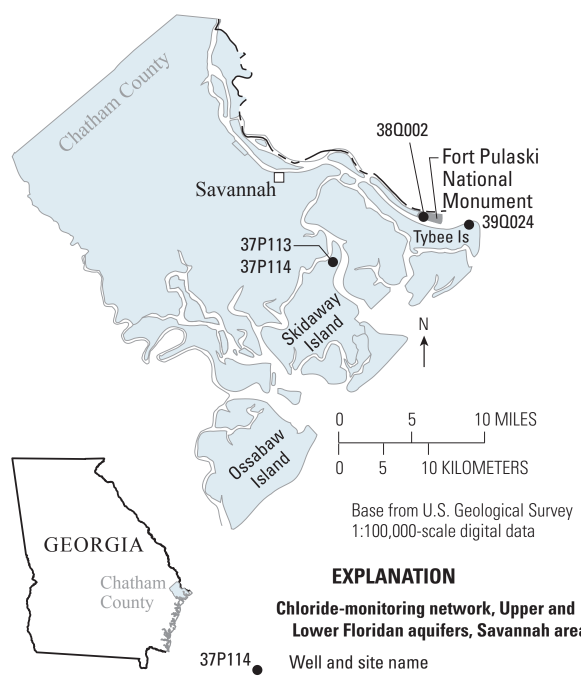
During December 2010 and November–December 2011, borehole geophysical logs and discrete water samples were collected from open intervals in wells completed in the Upper and Lower Floridan aquifers to assess changes in chloride concentration in the Savannah area—a continuation of a program that began in 2003. Wells east of Savannah at Fort Pulaski, Tybee Island, and Skidaway Island were evaluated. Borehole geophysical logs include fluid resistivity—an indicator of dissolved-solids concentration—and fluid temperature—an indicator of possible breaches in the well casing that might compromise the reliability of water-quality measurements. Water samples were collected at specific depth intervals in each well to reflect the range of fluid resistivity observed in the well during logging. The chloride concentrations in water samples are summarized in a table and shown graphically on the facing page.

At Fort Pulaski, geophysical logs and water samples were collected from well 38Q002 completed in the Upper Floridan aquifer (graphs and table, facing page). The geophysical logs collected during 2010–2011 indicated no changes or breaches in the well casing. During 2010 and 2011, chloride concentrations in all samples collected at depths of 200 and 320 feet (ft) were below 12 milligrams per liter (mg/L).

At Skidaway Island, geophysical logs and water samples were collected from well 37P114 completed in the Upper Floridan aquifer and from well 37P113 completed in the Lower Floridan aquifer. Water in the Upper Floridan aquifer is fresh (chloride concentrations less than 7 mg/L) at the Skidaway Island site, and chloride concentrations of samples from well 37P114 did not appreciably change during 2010–2011. The geophysical logs collected indicated no changes or breaches in the well casing. During 2010–2011, chloride concentrations in samples collected at depths of 300 and 360 ft were less than 7 mg/L.

Water from the Lower Floridan aquifer at Skidaway Island remained above the 250 mg/L secondary drinking water standard during 2010–2011 (Georgia Environmental Protection Division, 1997; U.S. Environmental Protection Agency, 2000). In well 37P113, the geophysical logs collected during 2010–2011 indicated no changes or breaches in the well casing. The chloride concentrations were higher in samples collected at a depth of 1,070 ft and had greater variability than in the samples collected from the 900-ft interval. Chloride concentrations in samples collected from a depth of 1,070 ft varied from 4,330 mg/L in 2010 to 4,720 mg/L in 2011. Concentrations in samples collected from a depth of 900 ft during the same period ranged from 1,270 to 1,310 mg/L.

At Tybee Island, chloride concentrations in the Lower Floridan aquifer also remained above the 250 mg/L drinking water standard during 2010–2011. Fluid-resistivity logs and water samples were collected from well 39Q024 completed in the Lower Floridan aquifer. The geophysical logs collected during 2010–2011 indicated no changes or breaches in the well casing. Chloride concentrations in samples collected at two depths in well 39Q024 decreased during 2009–2010 and then increased during 2011 (graphs and table, facing page). Concentrations in samples from the 845-ft interval decreased from 3,200 in 2009 to 2,650 mg/L during 2010 and increased to 2,980 mg/L during 2011. Similarly, concentrations in samples from the 860-ft interval decreased from 3,200 mg/L during 2009 (Peck and others, 2011) to 2,720 mg/L during 2010 and increased to 3,030 mg/L during 2011.

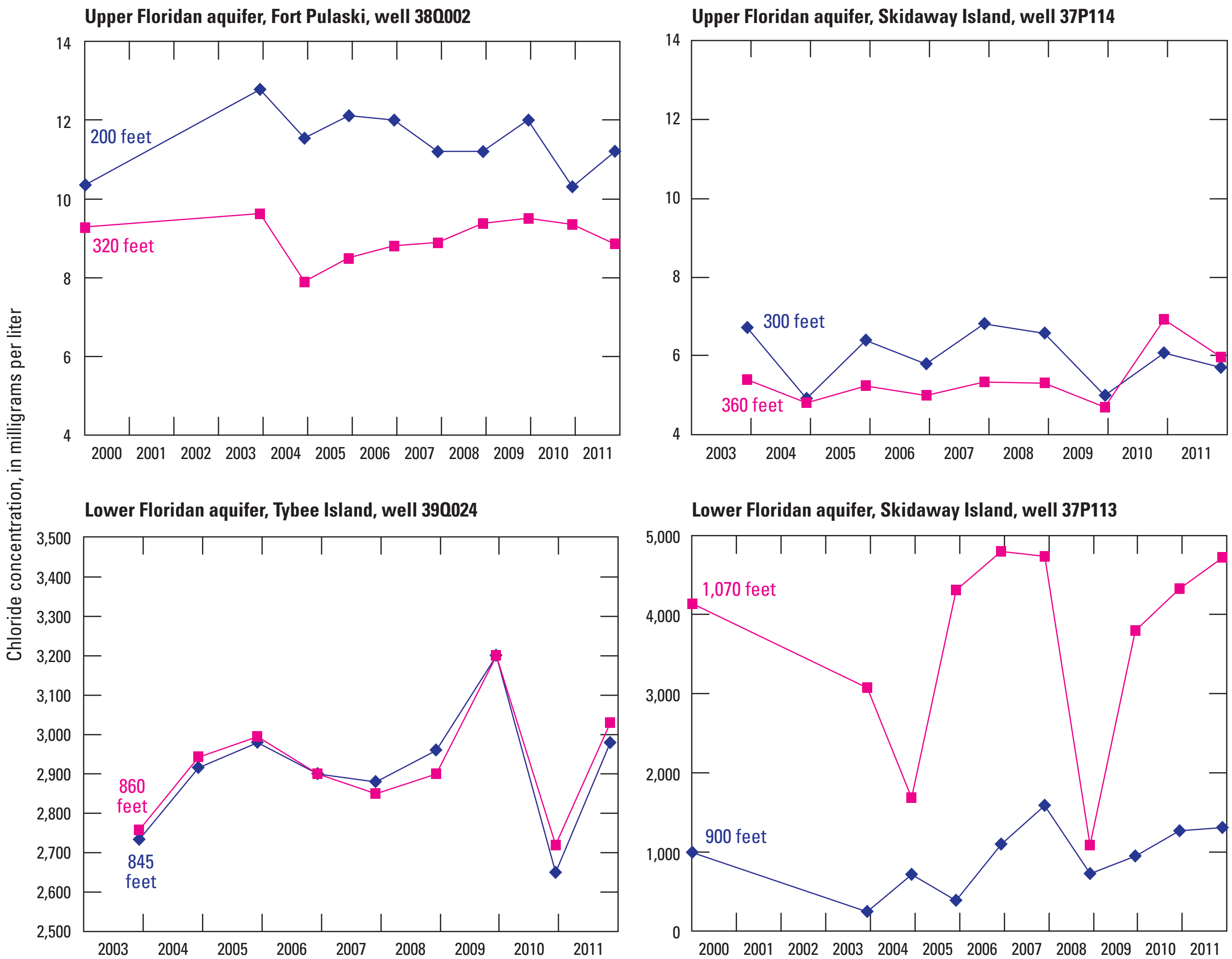


References

Georgia Environmental Protection Division, 1997, Secondary maximum contaminant levels for drinking water: Environmental Rule 391-3-5-19, revised October 1997: Official Code of Georgia Annotated Statutes, Statute 12-5-170 (Georgia Safe Drinking Water Act), variously paginated.

Peck, M.F., Leeth, D.C., and Painter, J.A., 2011, Groundwater conditions and studies in Georgia, 2008–2009: U.S. Geological Survey Scientific Investigations Report 2011–5048, 83 p.; available online at *http://pubs.usgs.gov/sir/2011/5048/*.

U.S. Environmental Protection Agency, 2000, Maximum contaminant levels (Part 143, National Secondary Drinking Water Regulations): U.S. Code of Federal Regulations, Title 40, Parts 100–149, rev. as of July 1, 2000, p. 612–614.



Site name	Other identifier	Open interval (feet below land surface)	Water-bearing unit[1]	Water sample depth (feet below land surface)	Chloride concentration (milligrams per liter)	Water sample depth (feet below land surface)	Chloride concentration (milligrams per liter)
				December 2010		December 2011	
38Q002	U.S. National Park Service, Fort Pulaski Pilot House	110–348	U	200	10.3	200	11.2
				320	9.34	320	8.84
37P113	Skidaway Institute test well 1	700–1,100	L	900	1,270	900	1,310
				1,070	4,330	1,070	4,720
37P114	Skidaway Institute test well 2	262–400	U	300	6.08	300	5.71
				360	6.93	360	5.98
39Q024	Georgia Geologic Survey, Tybee Island, test well 1	840–880	L	845	2,650	845	2,980
				860	2,720	860	3,030

[1] L, Lower Floridan aquifer; U, Upper Floridan aquifer.

Groundwater Quality in the Upper and Lower Floridan Aquifers

City of Brunswick Area

Chloride concentrations have been monitored in the Brunswick area since the late 1950s when saltwater was first detected in wells completed in the Upper Floridan aquifer at the southern part of the area (Wait, 1965; Cherry and others, 2011). By the 1960s, a plume of saltwater had migrated northward toward two major industrial pumping centers. Since 1965, chloride concentrations have increased markedly in wells completed in the Upper Floridan aquifer in the northern Brunswick area. During 2010 and 2011, the chloride concentration was above the 250 milligrams per liter (mg/L) State and Federal secondary drinking-water standards (Georgia Environmental Protection Division, 1997; U.S. Environmental Protection Agency, 2000) in a 2-square-mile area and exceeded 2,250 mg/L in part of the area. More information on monitoring groundwater quality in the Brunswick area is available at *http://ga.water.usgs.gov/projects/brunswick/*.

Dissolved chloride concentrations in the upper water-bearing zone of the Upper Floridan aquifer at Brunswick were mapped for August 2010 using data from 28 wells, and for August 2011 using data from 26 wells (facing page). The 2010 and 2011 maps are similar to previously published maps for 2008 and 2009 (Peck and others, 2011) and show that areas of highest chloride concentrations are near the two industrial pumping centers in the northern part of the city and the original area of contamination in the southern part of the city.

Changes in chloride concentration during 1960–2011 are illustrated on graphs from selected wells in the southern and northern Brunswick areas, and on a map showing changes during 2010–2011. Chloride concentrations within the plume area decreased in 21 of 29 wells sampled during 2010–2011. The greatest decrease in concentration was 200 mg/L at well 34H401 in the north-central part of the plume. Chloride concentrations in seven wells increased from 0.3 to 50 mg/L during 2010–2011; the largest increase occurred in well 34H424 in the northern part of the plume, and concentrations remained the same in one well. These changes probably reflect shifts in local pumping patterns.

References

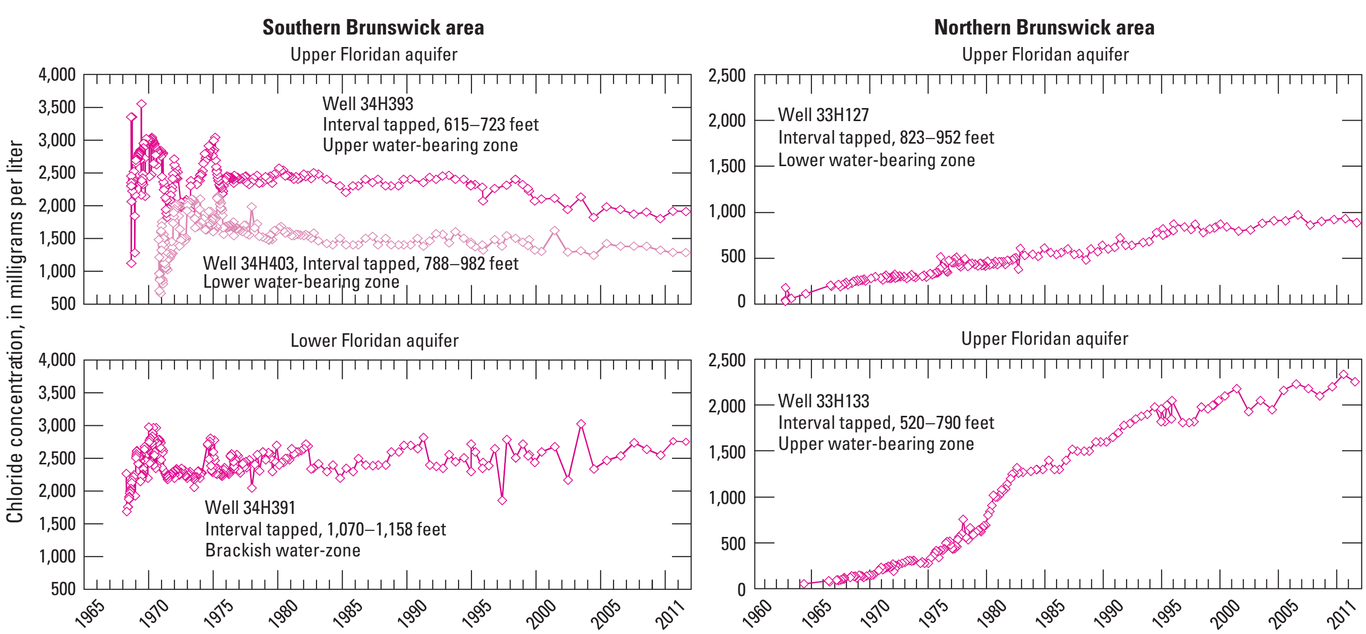
Cherry, G.S., Peck, M.F., Painter, J.A., and Stayton, W.L., 2011, Groundwater conditions in the Brunswick–Glynn County area, Georgia, 2009: U.S. Geological Survey Scientific Investigations Report 2011–5087, 58 p.; available online at *http://pubs.usgs.gov/sir/2011/5087/*.

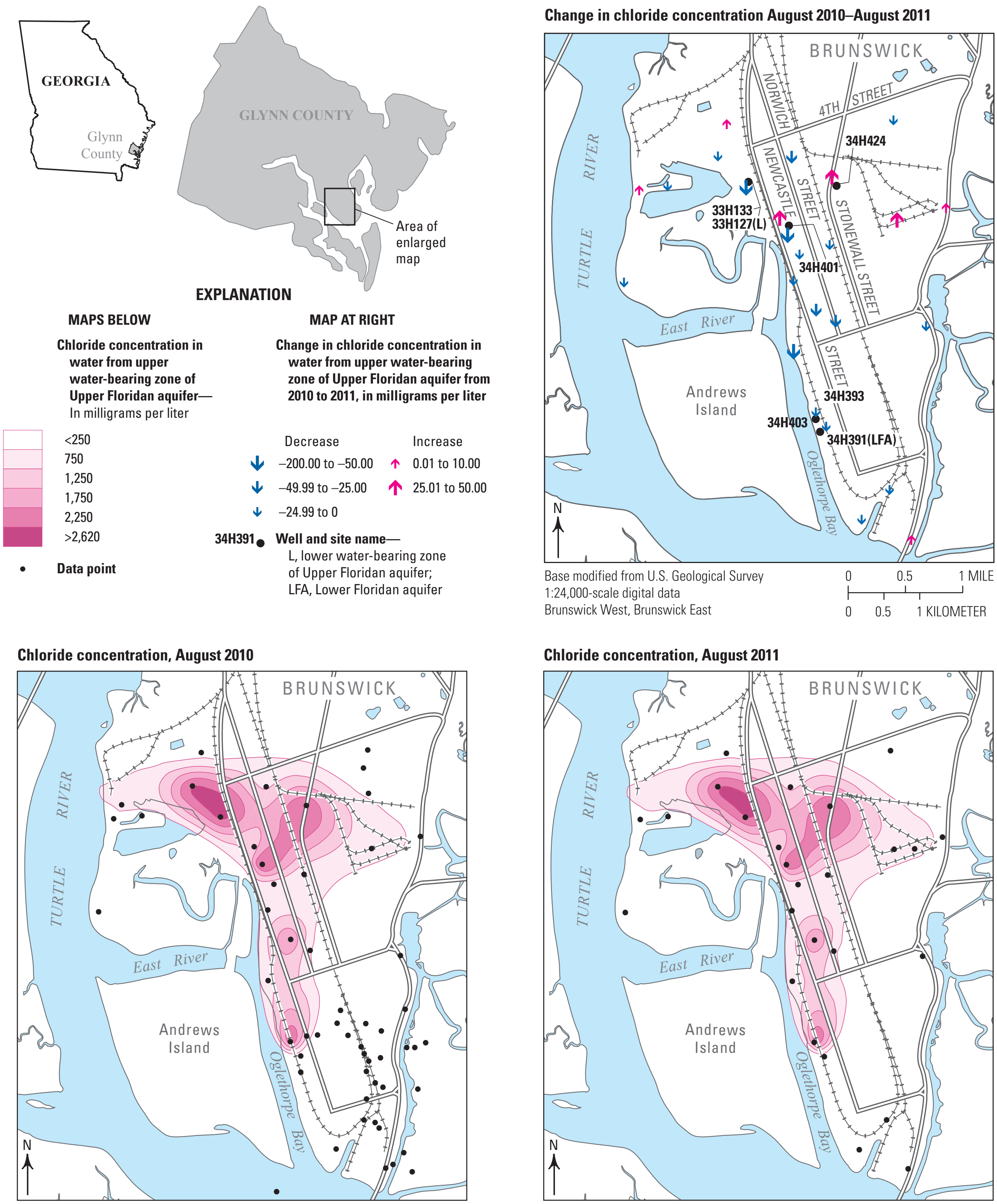
Georgia Environmental Protection Division, 1997, Secondary maximum contaminant levels for drinking water: Environmental Rule 391-3-5-19, revised October 1997: Official Code of Georgia Annotated Statutes, Statute 12-5-170 (Georgia Safe Drinking Water Act), variously paginated.

Peck, M.F., Leeth, D.C., and Painter, J.A., 2011, Groundwater conditions and studies in Georgia, 2008–2009: U.S. Geological Survey Scientific Investigations Report 2011–5048, 83 p.; available online at *http://pubs.usgs.gov/sir/2011/5048/*.

U.S. Environmental Protection Agency, 2000, Maximum contaminant levels (Part 143, National Secondary Drinking Water Regulations): U.S. Code of Federal Regulations, Title 40, Parts 100–149, rev. July 1, 2000, p. 612–614.

Wait, R.L., 1965, Geology and occurrence of fresh and brackish ground water in Glynn County, Georgia: U.S. Geological Survey Water-Supply Paper 1613–E , 94 p.




GEORGIA
Glynn County
GLYNN COUNTY
Area of enlarged map
Change in chloride concentration August 2010–August 2011
BRUNSWICK
4TH STREET
NORWICH
NEWCASTLE STREET
STONEWALL STREET
STREET
TURTLE RIVER
East River
Andrews Island
Oglethorpe Bay
34H424
33H133
33H127(L)
34H401
34H393
34H403
34H391(LFA)
N
Base modified from U.S. Geological Survey 1:24,000-scale digital data Brunswick West, Brunswick East
0 0.5 1 MILE
0 0.5 1 KILOMETER
EXPLANATION
MAPS BELOW
Chloride concentration in water from upper water-bearing zone of Upper Floridan aquifer—In milligrams per liter
<250
750
1,250
1,750
2,250
>2,620
Data point
MAP AT RIGHT
Change in chloride concentration in water from upper water-bearing zone of Upper Floridan aquifer from 2010 to 2011, in milligrams per liter
Decrease
–200.00 to –50.00
–49.99 to –25.00
–24.99 to 0
Increase
0.01 to 10.00
25.01 to 50.00
34H391 Well and site name—L, lower water-bearing zone of Upper Floridan aquifer; LFA, Lower Floridan aquifer
Chloride concentration, August 2010
Chloride concentration, August 2011

Groundwater Quality in the Upper and Lower Floridan Aquifers

Real-Time Specific Conductance Monitoring in Brunswick Area

Beginning in 2007, a network of wells with real-time satellite telemetry was established at Brunswick to monitor changes in specific conductance in the upper and lower water-bearing zones of the Upper Floridan aquifer (specific conductance is a surrogate for changes in chloride concentration). Four of the five wells are located immediately outside of the chloride plume, and one is located inside the plume area (see map, facing page). Of these five wells currently monitored in real time, four are monitored for daily specific conductance and hourly water levels, and one is monitored for specific conductance only. Specific conductance is monitored in wells 33H325, 34H505, and 34H514 by pumping once a day from rigid, small-diameter tubing installed at predetermined depths (see table, below) in the water-bearing zone of interest (Walls and others, 2009). In supply wells 34H134 and 34H552, specific conductance is recorded directly in the well-discharge pipe as the well is pumped every 15 minutes. Data are transmitted every 1 to 4 hours, based on equipment, and can be viewed on the Web at *http://water.usgs.gov/ga/nwis/current/?type=gw/*.

Ranges of chloride concentrations in the five wells monitored for specific conductance were estimated based on a correlation of specific conductance to chloride concentration (Cherry and others, 2011; see table, below). Specific conductance monitoring indicates estimated chloride concentration in the upper water-bearing zone in well 34H552 was at or below the 250 mg/L secondary drinking water standard and in well 34H514 ranged above the standard (Georgia Environmental Protection Division, 1997; U.S. Environmental Protection Agency, 2000). The estimated chloride concentration in lower water-bearing zone wells 34H505 and 33H325 exceeded the secondary drinking water standard during 2010–2011. In well 34H134, completed in the upper and lower water-bearing zones, the estimated chloride concentration was below the secondary drinking water standard during 2010–2011.

References

Cherry, G.S., Peck, M.F., Painter, J.A., and Stayton, W.L., 2011, Groundwater condition in the Brunswick–Glynn County area, Georgia, 2009: U.S. Geological Survey Scientific Investigations Report 2011–5087, 58 p.; available online at *http://pubs.usgs.gov/sir/2011/5087/*.

Georgia Environmental Protection Division, 1997, Secondary maximum contaminant levels for drinking water: Environmental Rule 391-3-5-19, revised October 1997: Official Code of Georgia Annotated Statutes, Statute 12-5-170 (Georgia Safe Drinking Water Act), variously paginated.

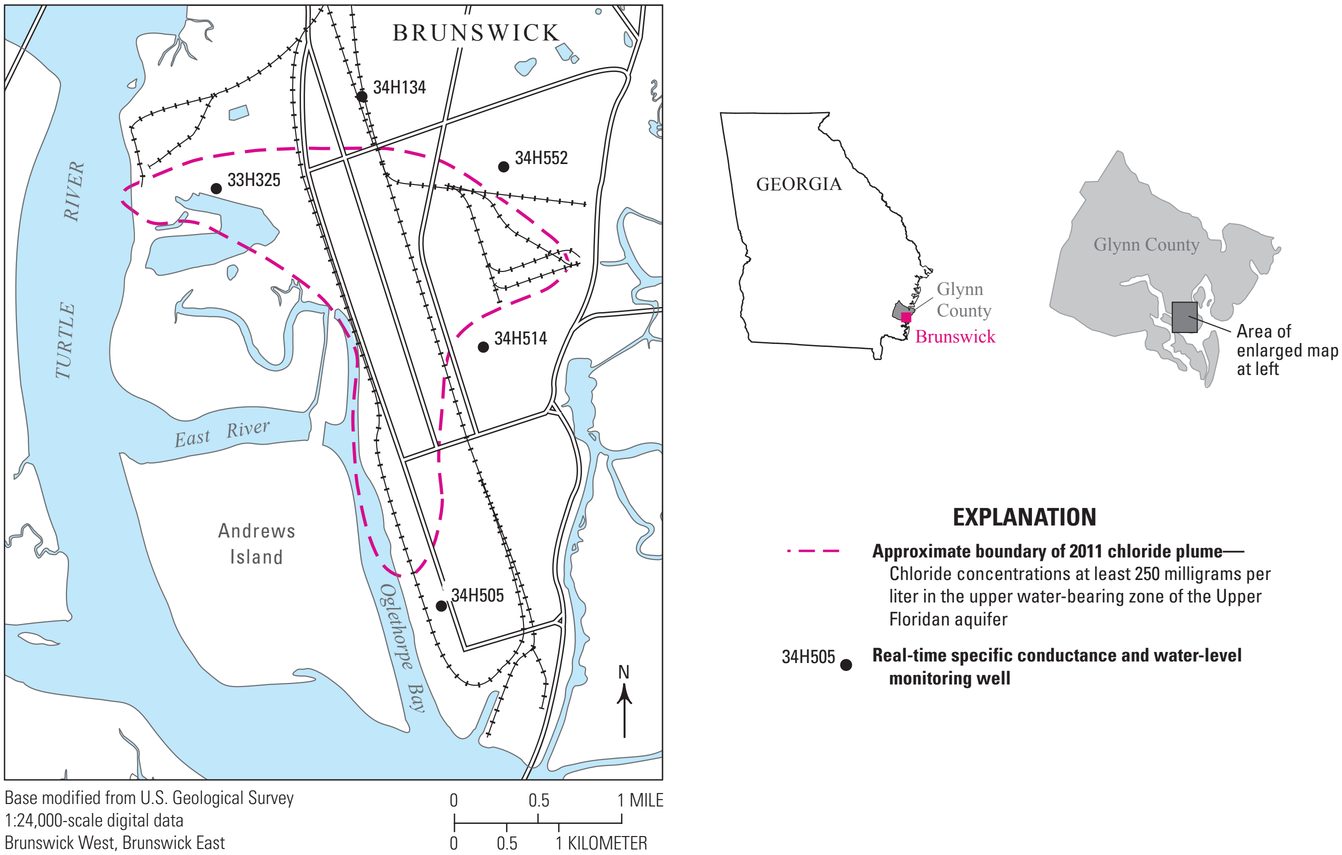
U.S. Environmental Protection Agency, 2000, Maximum contaminant levels (Part 143, National Secondary Drinking Water Regulations): U.S. Code of Federal Regulations, Title 40, Parts 100–149, rev. July 1, 2000, p. 612–614.

Walls, C.B., Cressler, A.M., and Stayton, W.L., 2009, Real-time water-level and specific conductance monitoring of saltwater contamination in the Upper Floridan aquifer, Brunswick, Georgia, *in* Rasmussen, Todd, Carroll, D.G., and Georgakakos, Aris, eds., Proceedings of the 2009 Georgia Water Resources Conference, held April 27–29, 2009, at the University of Georgia, Athens, Institute of Ecology, The University of Georgia, accessed July 2, 2009, at *http://www.gwri.gatech.edu/node/3851*.

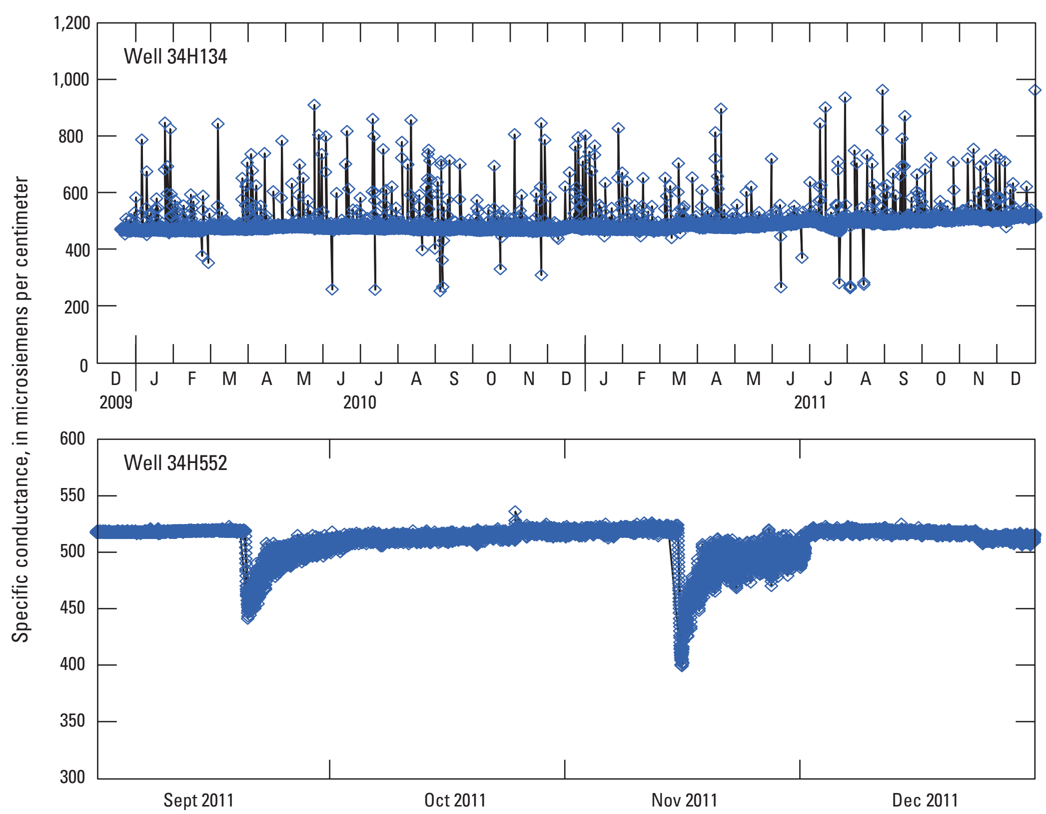
Period of Record Specific Conductance, Upper Floridan aquifer

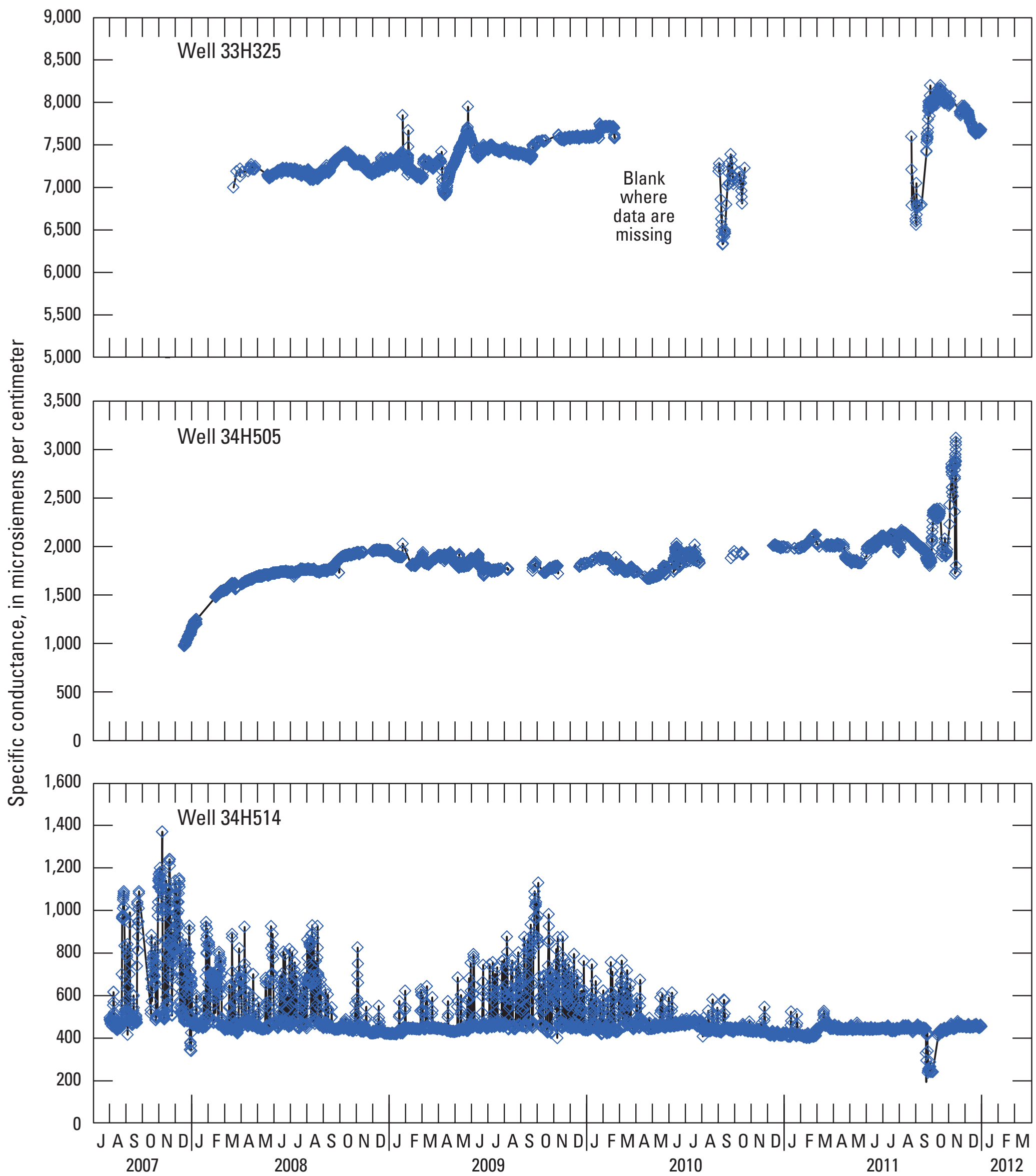
[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligram per liter; >, greater than; LWBZ, lower water-bearing zone; UWBZ, upper water-bearing zone; ULWBZ, upper and lower water-bearing zones; estimates based on correlation between specific conductance and chloride concentration reported by Cherry and others, 2011]

Site name	Water-bearing zone	Sampling interval (feet)	Specific conductance (µS/cm)	Estimated chloride concentration (mg/L)
34H514	UWBZ	605	194–1,370	>1–283
34H134	ULWBZ	518–942	251–962	>1–167
33H325	LWBZ	900	6,330–8,200	1,686–2,214
34H505	LWBZ	960	973–3,120	171–778
34H552	UWBZ	565–750	399–536	8–47



Location of real-time specific conductance monitoring network and estimated chloride concentration in the upper and lower water-bearing zone of the Upper Floridan aquifer in the Brunswick–Glynn County area, Georgia.




Specific conductance, in microsiemens per centimeter
Well 33H325
9,000
8,500
8,000
7,500
7,000
6,500
6,000
5,500
5,000
Blank where data are missing
Well 34H505
3,500
3,000
2,500
2,000
1,500
1,000
500
0
Well 34H514
1,600
1,400
1,200
1,000
800
600
400
200
0
J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M
2007
2008
2009
2010
2011
2012

Appendix. Regression Statistics

Water-level trends in this report were estimated by applying the Levenberg-Marquardt Algorithm (LMA; Moré, 1978) to monthly mean water-level data for the period of record and during 2010–2011. Although the LMA typically is used for nonlinear fitting, it also can be used for deriving linear fits that are very near values derived using ordinary least squares fitting. In concept, LMA works by optimizing a mathematical function (called a merit function by statisticians) that measures how well the function represents the data. In this report, the merit function is the weighted sum of the squares of the differences (informally known as chi-squared and represented in equations and tables as χ^2).

In this report, the steps involved in minimizing this merit function are as follows:

1. Estimate a value for the slope and intercept, and calculate a line based on this estimate.
2. Calculate how far this line lies from the data (using the χ^2). Adjust the line so that it lies closer to the center of the data.
3. Repeat this until adjustments no longer affect the χ^2 value.

Each step is completed through manipulations of algebraic matrices that are beyond the scope of this report but are fully explained in Moré (1978).

Summary statistics for the straight line (linear) fits of water-level trends described in the main body of the report are provided here as an indicator of goodness of fit (Janert, 2010), and so that readers can make decisions based on their tolerance for risk. These include:

- The degrees of freedom representing the number of data points minus the variables used. For this evaluation, two variables are used—slope (m) and intercept (b). A general rule of thumb is that the residuals and the χ^2 should be in the same order of magnitude for the fit to be reasonable (with some exceptions).
- The root mean square error (RMSE) of the residuals is the square root of the average squared distance of a data point from the fitted line. RMSE units are in the same units as the quantity being estimated (in this report, feet).
- The chi-squared is the sum of squared residuals (differences) between the monthly mean water level and the values computed by the algorithm after the final iteration. Thus, the term "least-squares" fitting. The χ^2 from the fit along with χ^2 distribution tables may be used to estimate confidence intervals.
- The standard error (SE) of a variable (m or b in this report), expressed as a percentage, is a measure of how well m or b has been estimated and affects the location of the regression line. The greater the standard error, the greater the scatter around the regression line. In other words, standard error is a measure of dispersion.

References

Janert, P.K., 2010, Gnuplot in action—Understanding data with graphs: Greenwich, Connecticut, Manning Publications Co., 360 p.

Moré, J., 1978, The Levenberg-Marquardt Algorithm—Implementation and theory, *in* Watson, G.A., ed., Numerical analysis, v. 630: Berlin, Springer-Verlag, p. 105.

Table A–1. Regression statistics.

[%, percent]

	Period of record summary statistics					2010–2011 summary statistics				
Well name	Degrees of freedom	Root mean square error of residuals (RMSE)	Variance of residuals (χ^2)	Standard error of slope (SE_m %)	Standard error of intercept (SE_b %)	Degrees of freedom	Root mean square error of residuals (RMSE)	Variance of residuals (χ^2)	Standard error of slope (SE_m %)	Standard error of intercept (SE_b %)
06K010	318	1.319	1.739	–11.11%	–0.10%	22	0.510	0.260	–7.01%	–4.09%
06S001	660	6.116	37.404	–1.66%	–0.96%	17	1.014	1.029	–6.26%	–28.32%
07H002	370	7.734	59.816	–14.81%	–3.22%	22	6.294	39.613	–35.79%	–46.21%
07H003	379	5.087	25.874	–91.82%	–2.65%	22	5.402	29.176	–32.49%	–41.78%
07KK64	174	3.796	14.412	–39.31%	–1.95%	22	3.451	11.907	–41.67%	–146.80%
07N001	553	3.666	13.442	–1.41%	–0.13%	21	2.803	7.857	–28.72%	–9.42%
08E038	113	0.809	0.654	–49.71%	–0.80%	22	0.360	0.130	–10.73%	–14.22%
08E039	115	1.209	1.462	–69.09%	–2.24%	22	0.609	0.371	–18.47%	–154.80%
08G001	417	8.566	73.378	–28.37%	–1.49%	22	5.227	27.324	–13.40%	–17.73%
08K001	386	9.879	97.590	–123.80%	–4.75%	22	8.261	68.247	–16.42%	–18.37%
09F520	501	3.030	9.182	–17.07%	–0.36%	22	1.880	3.533	–12.60%	–77.39%
09FF18	109	0.558	0.311	–10.76%	–0.58%	18	0.300	0.090	–17.07%	–8.44%
09G001	374	3.465	12.009	–26.53%	–0.38%	21	2.184	4.771	–13.17%	–58.97%
09G003	355	2.495	6.223	–128.20%	–0.39%	17	2.966	8.796	–20.63%	–51.44%
09M007	319	24.301	590.539	–8.33%	–0.79%	22	30.977	959.554	–32.87%	–75.81%
09M009	324	1.524	2.324	–78.36%	–0.31%	22	0.932	0.868	–11.05%	–69.38%
10DD02	452	1.731	2.998	–6.11%	–1.28%	19	0.824	0.679	–14.54%	–21.59%
10G313	487	5.382	28.969	–19.96%	–0.56%	22	1.942	3.772	–7.28%	–15.62%
10H009	160	6.043	36.521	–122.20%	–2.03%	22	3.610	13.031	–11.44%	–16.93%
10K005	330	2.063	4.255	–12.21%	–0.52%	22	3.188	10.162	–26.99%	–59.91%
11AA01	784	2.818	7.940	–101.30%	–0.99%	19	1.881	3.537	–14.43%	–20.50%
11FF04	379	0.404	0.163	–5.09%	–0.31%	22	0.399	0.160	–18.60%	–174.30%
11J011	369	3.747	14.038	–13.83%	–0.51%	22	1.438	2.067	–6.73%	–13.96%
11J012	366	3.640	13.251	–32.92%	–0.44%	22	2.461	6.059	–15.48%	–66.29%
11K003	390	6.024	36.285	–26.35%	–1.16%	22	2.242	5.025	–6.94%	–9.26%
11K005	386	4.452	19.819	–1.52%	–0.37%	22	1.563	2.443	–18.85%	–13.15%
11L002	448	16.033	257.068	–3.97%	–0.75%	21	15.863	251.618	–20.12%	–34.18%
11P014	312	17.191	295.529	–8.64%	–0.97%	19	7.542	56.876	–39%	–3,637%
11P015	320	1.720	2.958	–22.23%	–0.26%	22	0.686	0.470	–7.16%	–149.10%
12F036	541	5.828	33.967	–7.72%	–0.24%	19	1.304	1.701	–13.18%	–5.77%
12JJ04	487	1.535	2.355	–10.37%	–0.32%	21	0.968	0.938	–13.30%	–3,411%
12K014	354	4.004	16.032	–26.48%	–0.52%	22	2.533	6.414	–12.67%	–29.42%
12K141	184	6.823	46.548	–34.94%	–2.03%	21	1.624	2.637	–4.98%	–6.74%
12K180	108	4.097	16.784	–56.02%	–4.82%	22	2.719	7.392	–14.38%	–21.95%
12L019	384	8.803	77.498	–9.79%	–0.68%	20	3.965	15.720	–13.70%	–30.03%
12L020	377	14.600	213.167	–18.53%	–0.64%	18	9.575	91.672	–19.77%	–47.70%
12L021	383	12.038	144.916	–37.02%	–0.54%	22	6.068	36.825	–12.57%	–33.47%
12L029	340	5.843	34.144	–55.09%	–0.75%	16	3.177	10.095	–16.29%	–32.51%
12L030	310	4.566	20.851	–58.57%	–1.15%	21	1.876	3.518	–7.67%	–10.09%
12L277	154	6.083	37.007	–1398%	–2.63%	22	2.149	4.616	–7.25%	–10.02%
12L370	131	4.762	22.679	–111.60%	–2.26%	22	2.702	7.300	–9.10%	–13.98%
12L373	112	4.462	19.909	–63.17%	–3.29%	22	2.765	7.647	–12.26%	–21.74%

Table A–1. Regression statistics.—Continued

[%, percent]

	Period of record summary statistics					2010–2011 summary statistics				
Well name	Degrees of freedom	Root mean square error of residuals (RMSE)	Variance of residuals (χ^2)	Standard error of slope (SE_m%)	Standard error of intercept (SE_b%)	Degrees of freedom	Root mean square error of residuals (RMSE)	Variance of residuals (χ^2)	Standard error of slope (SE_m%)	Standard error of intercept (SE_b%)
12M001	353	12.173	148.192	–6.58%	–0.65%	10	13.687	187.339	–28.69%	–53.83%
12M002	366	14.381	206.806	–11.65%	–0.56%	19	11.550	133.406	–14.71%	–28.38%
12M017	350	5.208	27.128	–328.20%	–0.93%	22	6.881	47.344	–28.11%	–44.76%
12Z001	505	2.125	4.517	–11.28%	–1.03%	20	1.495	2.234	–11.69%	–15.61%
13FF30	76	1.309	1.714	–33.93%	–2.14%	7	0.802	0.643	–50.46%	–130.60%
13FF31	90	1.299	1.688	–1,816%	–2.05%	22	0.554	0.307	–12.23%	–48.41%
13J004	401	4.522	20.449	–10.55%	–0.52%	22	1.464	2.144	–6.37%	–15.46%
13K014	346	4.626	21.404	–22.99%	–0.80%	21	2.846	8.102	–17.55%	–37.08%
13L002	623	17.857	318.857	–3.14%	–0.73%	22	6.049	36.585	–11.21%	–27.92%
13L011	406	6.494	42.169	–20.94%	–0.49%	22	2.177	4.740	–9.89%	–56.25%
13L012	412	3.758	14.123	–39.19%	–0.49%	22	2.800	7.841	–14.67%	–35.64%
13L013	383	8.756	76.669	–45.59%	–0.48%	14	0.366	0.134	–7.43%	–3.69%
13L015	379	9.052	81.931	–9.87%	–0.55%	19	3.790	14.367	–14.99%	–142.50%
13L049	308	5.889	34.686	–33.13%	–1.02%	22	2.469	6.096	–8.54%	–12.55%
13L180	161	5.205	27.095	–132.60%	–1.16%	22	1.490	2.219	–5.46%	–11.02%
13M005	373	5.32	28.302	–12.42%	–2.08%	19	6.472	41.890	–26.07%	–31.26%
13M006	374	6.670	44.494	–30.78%	–3.71%	19	7.558	57.131	–32.88%	–38.17%
13M007	375	2.168	4.699	–74.54%	–1.45%	22	1.296	1.679	–10.03%	–12.31%
14GG02	88	1.355	1.836	–23.10%	–0.56%	16	1.490	2.222	–36.54%	–14.30%
14P014	324	3.657	13.377	–7.41%	–0.44%	20	2.899	8.407	–16.96%	–71.61%
14P015	323	9.850	97.026	–18.35%	–2.38%	22	13.593	184.773	–37.69%	–48.27%
15L020	464	1.188	1.411	–0.73%	–0.03%	20	0.849	0.722	–22.94%	–1.78%
15Q016	100	8.951	80.128	–32.10%	–5.41%	22	7.895	62.331	–17.75%	–28.85%
16MM03	282	0.642	0.412	–18.81%	–0.89%	22	0.441	0.194	–20.54%	–43.34%
18H016	551	1.576	2.484	–1.53%	–0.05%	22	1.177	1.386	–14.79%	–3.04%
18K049	391	3.374	11.381	–1.99%	–0.15%	22	3.708	13.748	–18.58%	–24.13%
18T001	359	1.374	1.888	–3.28%	–0.13%	22	0.953	0.908	–19.13%	–8.28%
18U001	430	1.140	1.299	–4.16%	–0.04%	22	0.918	0.842	–18.33%	–2.40%
19E009	637	6.907	47.712	–14.41%	–0.29%	22	5.370	28.838	–15.85%	–2,088%
20GG41	43	1.944	3.780	–24.81%	–10.56%	21	1.198	1.436	–18.03%	–35.73%
21BB04	292	2.089	4.362	–8.55%	–2.81%	20	1.364	1.861	–14.94%	–17.85%
21T001	560	3.971	15.765	–15.99%	–0.67%	22	3.483	12.129	–17.70%	–33.23%
21U004	356	0.721	0.519	–1.35%	–0.10%	21	0.656	0.431	–15.02%	–9.09%
23X027	313	5.267	27.740	–5.68%	–0.12%	20	1.637	2.678	–26.51%	–2.95%
24V001	362	1.069	1.144	–1.07%	–0.04%	22	1.029	1.059	–14.26%	–3.36%
25Q001	534	2.401	5.764	–1.37%	–0.16%	22	3.054	9.327	–12.98%	–1,187%
26R001	450	3.362	11.305	–1.83%	–0.11%	22	3.609	13.026	–15.39%	–15.27%
27E004	385	2.545	6.476	–10.89%	–0.20%	22	1.283	1.647	–9.91%	–22.98%
27G003	363	2.681	7.190	–7.30%	–0.15%	22	1.635	2.673	–11.17%	–13.06%
28X001	369	2.416	5.837	–1.88%	–0.21%	19	2.608	6.803	–21.45%	–57.36%
29AA09	175	1.410	1.987	–9.46%	–0.18%	21	0.322	0.104	–5.91%	–2.65%

Table A–1. Regression statistics.—Continued

[%, percent]

Well name	Period of record summary statistics: Degrees of freedom	Root mean square error of residuals (RMSE)	Variance of residuals (χ^2)	Standard error of slope (SE_m %	Standard error of intercept (SE_b %)	2010–2011 summary statistics: Degrees of freedom	Root mean square error of residuals (RMSE)	Variance of residuals (χ^2)	Standard error of slope (SE_m %)	Standard error of intercept (SE_b %)
30AA04	374	2.222	4.936	–3.72%	–0.10%	19	0.842	0.709	–12.54%	–3.30%
30AA37	25	1.958	3.833	–52.78%	–20.84%	22	2.082	4.334	–69.59%	–26.33%
30AA38	25	1.054	1.110	–20.49%	–16.13%	22	0.781	0.610	–12.28%	–23.59%
30L003	449	3.473	12.061	–3.08%	–0.23%	22	2.095	4.388	–14.38%	–25.35%
31U008	336	3.466	12.011	–4.19%	–0.23%	21	2.890	8.352	–16.26%	–58%
31U009	338	3.208	10.289	–4.06%	–0.23%	16	2.040	4.161	–14.60%	–35.36%
32G047	89	1.835	3.369	–33.73%	–10.93%	22	1.117	1.247	–252.40%	–126%
32L005	156	1.008	1.016	–2.52%	–0.15%	21	0.362	0.131	–10.29%	–2.27%
32L015	336	2.568	6.594	–9.50%	–0.24%	22	1.801	3.243	–14.61%	–51.50%
32L016	340	1.499	2.247	–5.41%	–0.15%	22	0.346	0.120	–13.38%	–2.86%
32L017	333	1.562	2.440	–6.33%	–0.21%	22	0.589	0.347	–6.72%	–21.87%
32Y030	172	0.979	0.959	–3.47%	–0.10%	22	0.541	0.293	–10.94%	–1.95%
32Y031	186	1.438	2.068	–4.11%	–0.18%	20	0.788	0.620	–10.08%	–3.10%
32Y033	182	5.546	30.756	–7.23%	–1.54%	22	6.984	48.782	–27.90%	–22.86%
33D069	207	6.409	41.071	–5.60%	–9.31%	22	1.465	2.146	–15.79%	–10.50%
33D071	158	5.065	25.656	–5.59%	–9.11%	22	0.347	0.120	–8.02%	–5.42%
33D072	160	1.527	2.332	–9.99%	–3.48%	20	1.124	1.264	–42.20%	–60.59%
33D073	140	7.762	60.248	–9.77%	–21.31%	22	1.083	1.173	–13.32%	–7.81%
33D074	101	1.594	2.542	–20.16%	–1.40%	22	0.797	0.636	–13.72%	–5.54%
33E027	385	3.334	11.117	–12.92%	–0.88%	22	1.624	2.636	–25.72%	–13.23%
33H127	560	4.299	18.479	–20.92%	–37.99%	21	1.859	3.456	–293.60%	–4,995%
33H133	552	4.465	19.934	–5.00%	–4.41%	22	2.154	4.640	–709.90%	–287.40%
33H188	348	2.923	8.543	–14.29%	–2.34%	21	2.312	5.348	–27.77%	–24.82%
33H206	326	3.240	10.495	–9.44%	–3.46%	18	1.722	2.966	–53.38%	–35.22%
33H207	327	3.761	14.143	–5.75%	–27.24%	22	2.053	4.214	–300.30%	–174.30%
33H208	327	1.361	1.853	–6.29%	–2.05%	22	0.623	0.389	–25.57%	–36.37%
33H324	51	1.960	3.843	–12.98%	–7.21%	16	2.054	4.220	–87.42%	–50.24%
33H325	51	7.438	55.321	–10.23%	–6.03%	16	5.258	27.646	–13.68%	–11.62%
33J044	387	2.580	6.657	–15.55%	–23.66%	22	1.009	1.019	–19.69%	–19.31%
33J062	123	2.771	7.677	–46.60%	–4.75%	20	1.162	1.350	–16.24%	–12.17%
33J065	119	1.096	1.200	–61.16%	–67.34%	20	0.252	0.063	–11.22%	–11.83%
33M004	520	2.979	8.875	–2.48%	–0.30%	20	1.613	2.602	–14.99%	–45.57%
33R045	113	3.349	11.219	–29.70%	–1.38%	21	1.668	2.782	–13.11%	–45.36%
34G033	83	2.688	7.223	–29.25%	–5.25%	22	1.151	1.325	–20.08%	–10.77%
34H334	516	3.371	11.367	–5.94%	–7.07%	22	1.608	2.585	–55.69%	–39.15%
34H371	526	2.834	8.033	–6.72%	–3.48%	17	1.570	2.466	–84.37%	–46.84%
34H391	421	2.787	7.768	–8.14%	–2.63%	20	1.560	2.433	–38.47%	–27.18%
34H436	334	2.862	8.191	–11.25%	–1.83%	22	1.613	2.600	–60.71%	–30.93%
34H437	318	2.220	4.927	–13.69%	–44.12%	18	1.460	2.133	–27.45%	–29.88%
34H495	112	2.888	8.342	–9.36%	–5.47%	22	0.779	0.607	–14.34%	–7.59%
34H500	126	3.252	10.574	–111.10%	–5.60%	22	1.249	1.560	–76.76%	–24.55%

Table A–1. Regression statistics.—Continued

[%, percent]

	Period of record summary statistics					2010–2011 summary statistics				
Well name	Degrees of freedom	Root mean square error of residuals (RMSE)	Variance of residuals (χ^2)	Standard error of slope (SE_m %)	Standard error of intercept (SE_b %)	Degrees of freedom	Root mean square error of residuals (RMSE)	Variance of residuals (χ^2)	Standard error of slope (SE_m %)	Standard error of intercept (SE_b %)
34H504	57	1.651	2.727	–28.53%	–145.80%	22	1.585	2.511	–48.16%	–35.13%
34H505	57	1.688	2.850	–57.75%	–55.46%	22	1.582	2.503	–35.35%	–26.69%
34H514	57	1.945	3.783	–32.59%	–18.49%	22	1.790	3.205	–64.88%	–94.95%
34H515	71	0.520	0.270	–48.40%	–11.75%	21	0.427	0.182	–29.33%	–65.06%
34J077	160	3.930	15.445	–11.58%	–2.87%	22	2.380	5.665	–19.45%	–37.31%
34J080	114	2.243	5.031	–18.20%	–44.61%	22	1.188	1.410	–15.88%	–19.38%
34J081	112	1.719	2.956	–66.93%	–3.21%	22	1.053	1.110	–12.20%	–21.41%
34J082	114	0.864	0.747	–31.20%	–3.32%	22	0.345	0.119	–9.88%	–22.48%
34K104	74	2.251	5.067	–80.94%	–3.88%	20	0.884	0.781	–14.72%	–57.16%
34N089	532	3.119	9.729	–2.24%	–0.68%	22	1.344	1.806	–12.78%	–37.35%
34S008	122	1.480	2.189	–11.01%	–1.04%	22	0.724	0.525	–12.45%	–78.74%
34S011	113	3.046	9.278	–41.61%	–1.08%	21	1.204	1.449	–10.69%	–16.12%
35H070	56	2.011	4.045	–57.91%	–11.24%	21	1.811	3.280	–26.21%	–46.22%
35H076	51	0.423	0.179	–20.30%	–2.11%	22	0.310	0.096	–30.61%	–8.03%
35H077	76	6.549	42.886	–36.97%	–31.40%	22	7.869	61.921	–25.55%	–31.69%
35M013	526	2.600	6.759	–2.18%	–0.63%	18	0.953	0.909	–14.21%	–74.10%
35P094	830	2.220	4.928	–114.10%	–1.98%	21	1.556	2.421	–32.03%	–48.16%
35P110	135	3.027	9.163	–151.90%	–1.85%	22	1.477	2.183	–13.56%	–43.30%
35P125	59	2.404	5.778	–38.36%	–5.27%	22	1.373	1.886	–13.24%	–46.75%
35Q050	119	1.278	1.633	–21.01%	–1.60%	22	0.340	0.115	–6.60%	–38.04%
35S008	139	1.321	1.744	–9.73%	–0.43%	22	0.489	0.239	–38.32%	–4.33%
35T003	135	3.359	11.286	–52.75%	–1.48%	21	1.911	3.654	–15.44%	–65.09%
35T005	130	2.216	4.909	–218.60%	–1.50%	21	1.217	1.482	–15.05%	–97.06%
36N012	142	2.395	5.738	–34.48%	–0.85%	19	1.343	1.804	–15.34%	–95.54%
36Q008	684	11.757	138.216	–32.22%	–0.65%	22	4.641	21.535	–91.26%	–29.99%
36Q020	627	4.811	23.146	–2.52%	–0.53%	22	2.047	4.190	–19.57%	–138.40%
37P114	331	3.026	9.154	–7.90%	–0.34%	22	2.485	6.176	–28.84%	–78.32%
37P116	328	0.313	0.098	–97.40%	–0.21%	22	0.235	0.055	–74.49%	–9.22%
37Q016	671	8.734	76.276	–75.84%	–0.58%	22	3.340	11.156	–37.98%	–40.72%
37Q185	269	5.446	29.661	–2.89%	–0.33%	20	4.128	17.036	–73.37%	–27.26%
37Q186	277	2.225	4.952	–2.40%	–0.19%	22	0.720	0.519	–15.74%	–3.59%
38Q002	665	3.231	10.442	–3.12%	–0.52%	22	1.553	2.412	–30.75%	–55.81%
38Q201	298	1.408	1.982	–6.01%	–0.15%	22	0.662	0.438	–1,652%	–5.23%
38Q208	161	0.418	0.175	–338.20%	–0.85%	22	0.366	0.134	–24.90%	–12.16%
38Q209	161	0.338	0.114	–20.10%	–0.47%	18	0.228	0.052	–136.90%	–9.44%
39Q003	567	2.704	7.311	–3.49%	–0.50%	22	1.423	2.025	–39.87%	–40.16%
39Q024	181	1.314	1.726	–10.28%	–0.34%	20	0.899	0.808	–27.49%	–15.40%
39Q025	180	1.631	2.660	–12.47%	–0.46%	20	1.482	2.196	–49.90%	–28.58%
39Q026	176	0.496	0.246	–75.56%	–0.45%	22	0.461	0.213	–63.21%	–20.23%
39Q029	157	1.086	1.180	–87.37%	–1.38%	16	0.980	0.961	–37.44%	–157.50%

Manuscript approved for publication, April 9, 2013

Edited by John M. Watson
Illustrations and layout by Kimberly Swidarski
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Peck and others—**Groundwater Conditions in Georgia, 2010–2011**—Scientific Investigations Report 2013–5084