Hydrogeology, Hydraulic Properties, and Water Quality of the Surficial and Brunswick Aquifer Systems, McIntosh County, Georgia, May and November 2004

By Sherlyn Priest

INTRODUCTION

The Upper Floridan aquifer is the principal source of water in the coastal area of Georgia. Declining water levels and localized saltwater contamination have resulted in regulators restricting withdrawals from the aquifer in parts of the coastal area and have prompted interest in developing supplemental sources of ground-water supply. These supplemental sources of water include the surficial aquifer system, the Brunswick aquifer system, and the Lower Floridan aquifer. The U.S. Geological Survey (USGS)—in cooperation with State and local agencies—is studying these supplemental supplies.

The USGS—in cooperation with the McIntosh County Development Authority, Georgia—is evaluating the potential for alternative sources of ground water for the county and the city of Darien. The purpose of this study is to calculate the hydraulic properties and collect water-quality data for the lower confined zone of the surficial aquifer system (hereinafter referred to as lower confined zone) and the lower Brunswick aquifer of the Brunswick aquifer system. The scope of this study includes well drilling, geophysical logging, aquifer testing and subsequent analyses, and water-quality sampling and analyses. These data are essential for the successful development and management of the ground-water resources in the coastal area and within the county. Water managers may use this information to make informed decisions on further development of ground-water resources.

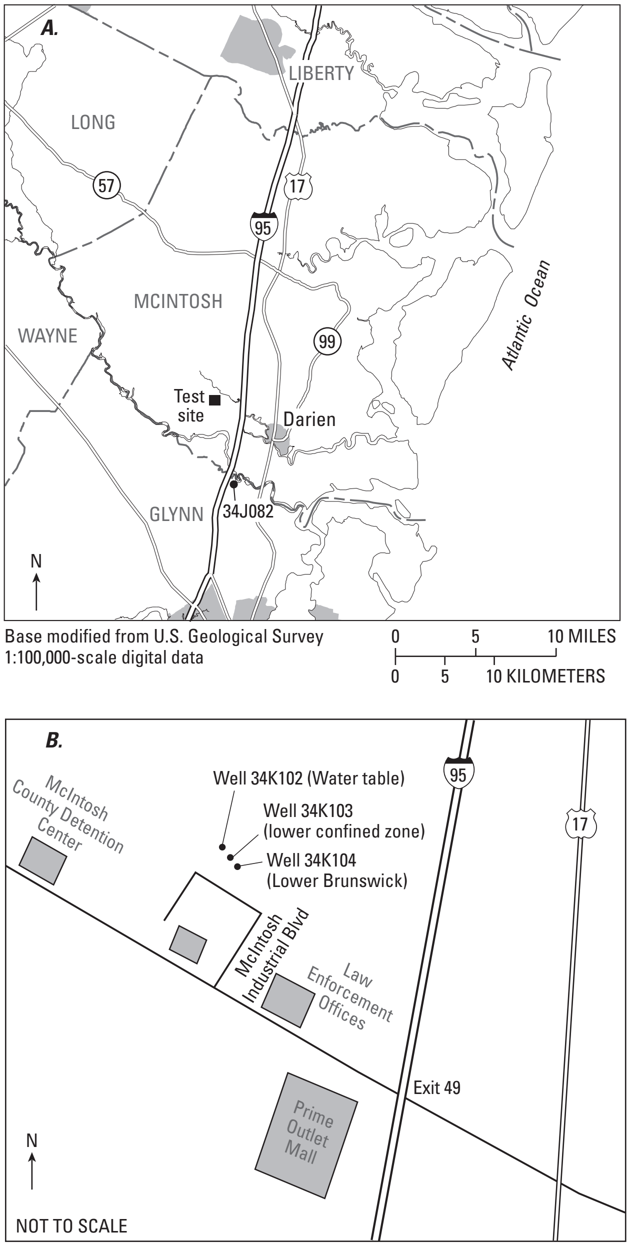
Darien test site, McIntosh County, Georgia, 2004.

Description of Study Area

The Darien test site is located about 2 miles northwest of the city of Darien, McIntosh County, Georgia, in the Coastal Plain physiographic province (Clark and Zisa, 1976). The site is about 16 miles northeast of the city of Brunswick and about 31 miles southeast of the city of Jesup (maps at right and following page). Land use in the area primarily is forest. Topographic relief across the area is low, with approximate land-surface altitude of 30 feet (ft) above National American Vertical Datum 1988 (NAVD 88). The climate in the area is mild, with a mean-annual temperature of 76 degrees Fahrenheit at the Brunswick National Weather Station (National Oceanic Atmospheric Administration [NOAA], 2002). Average monthly precipitation ranges from about 2.1 inches per month during November to 7.6 inches per month during September. Annual precipitation averaged 49.4 inches per year for the 30-year period 1971–2000 (National Oceanic Atmospheric Administration, 2002).

Methods of Study

To better identify the water-bearing capability and lithology of the study area, the investigation included drilling three wells, collecting drill cuttings and geophysical logging of the deepest well, pre-aquifer test background water-level monitoring and pre-aquifer test pumping, aquifer testing, and collecting water-quality samples from the tested intervals. Three wells were completed—one in the water-table zone (34K102), one in the lower confined zone (34K103), and one in the lower Brunswick aquifer (34K104)—during June and July 2003. Wells completed in the lower confined zone and the lower Brunswick aquifer are open to the entire thickness of the aquifer. Separate aquifer tests were performed in the lower confined zone using well 34K103 and in the lower Brunswick aquifer using well 34K104. Data from these aquifer tests were analyzed to



(A) Location of test site and(B) detail showing relative position of wells, Darien, McIntosh County, Georgia.

calculate transmissivity, storage coefficient, and hydraulic conductivity for the aforementioned water-bearing units.

All wells were constructed using standard mud-rotary techniques. Each well consists of 12-inch-diameter polyvinyl-chloride surface casing, 6-inch-diameter steel casing, and 4-inch-diameter stainless steel screen in the aquifer material. The screened interval was gravel packed, and the casing was grouted with cement. The table below presents the well construction information.

Upon completion of the deepest boring for well 34K104, borehole geophysical logs were collected that included natural-gamma radiation, spontaneous potential, lateral resistivity, short-normal resistivity, long-normal resistivity, and caliper. The borehole geophysical logs and well cuttings were used as a basis for stratigraphic correlation and to select casing depth and screened intervals for each well constructed. Natural-gamma logs were used to identify the location of the A-marker, B-marker, and C-marker horizons, which are identified by a sharp increase in radiation (Clarke and others, 1990). These markers were used to help identify the upper Brunswick, lower Brunswick, and Upper Floridan aquifers. Lithologic and hydrogeologic descriptions for well 34K104 are derived from the borehole cuttings recovered during well drilling and subsequent geophysical logging of well 34K104.

Background ground-water levels were monitored prior to the start of each aquifer test using pressure transducers and data loggers to document water-level trends and possible tidal effects within selected intervals being studied. Water levels in well 34J082, located in Ebenezer Bend about 10 miles south of the test site, were monitored prior to the aquifer test in the lower confined zone and in wells 34K103 and 34K104 prior to the aquifer test in the lower Brunswick aquifer.

Pretest pumping was undertaken to verify that wells 34K103 and 34K104 were fully developed and to determine the optimum pumping rate prior to the 24-hour pumping phase of the aquifer tests. This pumping also ensured that the drawdown in the wells would not exceed the depth of the pressure transducer or induce cavitation (bubbling) in the wells. For the lower Brunswick aquifer test, water levels

Well location and construction for aquifer test at the Darien test site, McIntosh County, Georgia.

[NAVD 88, North American Vertical Datum of 1988; –, negative; NI, not installed; do., ditto]

Well name	Other identifier	Aquifer	Well depth (feet)	Casing depth (feet)	Casing diameter (inches)	Altitude (feet NAVD 88)			Type of opening	Sump at bottom of screen (feet)
						Land surface	Top of screen interval	Bottom of screen interval		
34K102	MCDA TW-1	Water-table zone of surficial	40	20	6	30	10	–10	Screened	NI
34K103	MCDA TW-2	Lower confined zone of surficial	265	160	6	do.	–130	–230	do.	5
34K104	MCDA TW-3	Lower Brunswick	583	488	6	do.	–458	–548	do.	5

were measured using an electric tape in pumping well 34K104 and using an electronic recorder in observation wells 34K103 and 34K102. For the lower confined zone test, water levels were monitored using an In-Situ, Inc. Hermit 3000™ data logger with a 100-pound per square inch (psi) pressure transducer in pumping well 34K103 and using an electric tape in observation wells 34K102 and 34K104. During the lower confined zone test, atmospheric pressure was measured with an internal pressure sensor in the data logger. Starting at time equals 0, a sampling interval was programmed into the data logger to facilitate the rapid collection of early time data, using a logarithmic scale that was decreased to a 1-minute interval later in the test.

To provide constant pumping rates, a 25-horsepower submersible pump was used for well 34K103 and a 5-horsepower submersible pump was used for well 34K104. To transport water away from the wells, about 80 ft of 6-inch-diameter hose was used for well 34K103 and 60 ft of 4-inch-diameter hose was used for well 34K104. Well discharge was measured using a Model 2300078 Butler Brass Meter for well 34K103 and a Model FL-30005 Closed Pipe System Water Measurement Flowmeter for well 34K104. An appropriate discharge was determined during pretest pumping and was constantly maintained throughout the duration of the aquifer tests.

During each aquifer test, the magnitude of water-level fluctuation produced by changes in atmospheric pressure, local pumping, or tidal oscillations was minor in comparison to the amount of drawdown induced by the pump. Therefore, the data used in the analysis of the aquifer test were not corrected for atmospheric pressure, local pumping, or tidal effects.

Using the drawdown and recovery data, the aquifer-test data were analyzed using the Cooper and Jacob (1946) modified nonequilibrium analytical method, the Theis method (1935) for confined aquifers and fully penetrating wells, and the Hantush and Jacob method (1955) analytical model for nonsteady radial flow in an infinite leaky aquifer. The Hantush and Jacob method (1955) accounts for leakage, but does not differentiate between leakage above or below the aquifer. Leakage may be indicated by the change in slope of the graphs near the end of the aquifer test. According to the boundaries for the models, the slope of the graphs would continue to follow a straight path unless a source of additional ground water or an impermeable boundary is encountered.

Water samples were collected from wells 34K103 and 34K104 and analyzed for major ions, nutrients, metals, and radionuclides. Based on major ionic composition, results from the chemical analyses were used to describe and differentiate the water quality between the water-bearing units. Water samples were collected after several hours of pumping when field properties (specific conductance and pH) were stable.

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Field properties were measured in a flow-through chamber using DataSonde® Hydrolab® 4 water-quality multiprobe following USGS protocols (Wilde and Radtke, 1999). Whole-water samples were preserved and stored in polyethylene or acid-rinsed bottles and sent by overnight carrier to the USGS National Water Quality Laboratory, Denver, Colorado (NWQL). Equipment blanks and duplicate water-quality samples were not collected.

Previous Investigations

Clarke and others (1990) defined the surficial and upper and lower Brunswick aquifers and described their water-bearing characteristics. Steele and McDowell (1998) mapped the permeable thickness and areal distribution of the upper and lower Brunswick aquifers. Sharpe and others (1998) described results of the lower Brunswick aquifer test in Chatham County, Georgia. Leeth (1999) described the hydrogeology of the surficial aquifer at Naval Submarine Base Kings Bay in Camden County, Georgia. Hodges (1998, 1999) described results of aquifer tests in Toombs and Evans Counties in Georgia. More recent investigations include Gill (2001), who described the development potential of the upper and lower Brunswick aquifers in Glynn and Bryan Counties, Georgia; Radtke and others (2001) who described the results of an engineering assessment of the "Miocene" aquifer system in coastal Georgia; Weems and Edwards (2001) who described the geology of Oligocene and younger deposits in Coastal Georgia; and Clarke (2003), who described the surficial and Brunswick aquifer systems as alternative sources of ground water.

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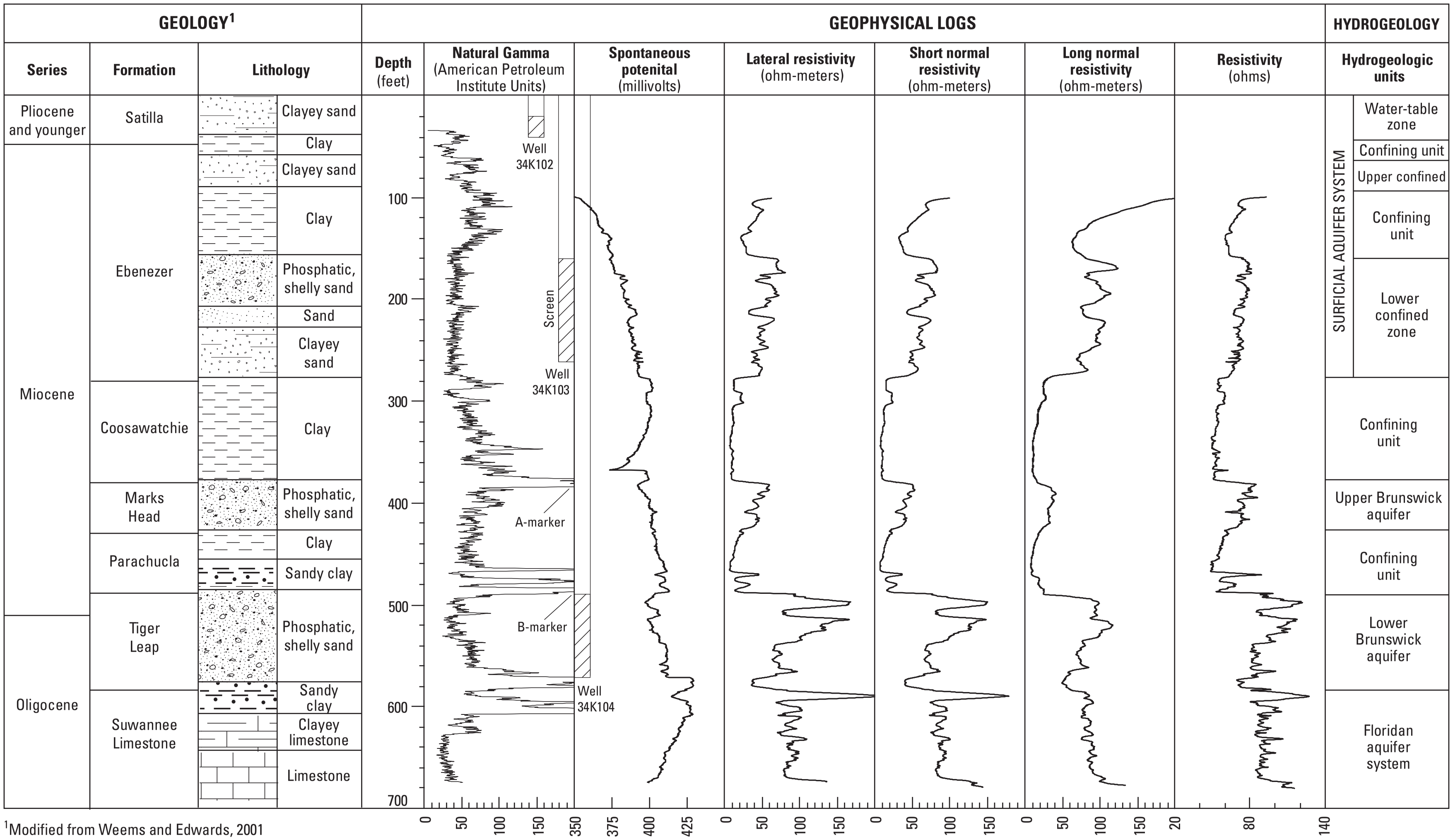
HYDROGEOLOGY AND LITHOLOGY

Hydrologic units in the Coastal Plain of Georgia include, but are not limited to, in descending order, the water table and lower confined zones of the surficial aquifer system (Miller, 1986; Krause and Randolph, 1989; Clarke and others, 1990; Clarke, 2003); the upper and lower Brunswick aquifers of the Brunswick aquifer system (Clarke and others, 1990); and the Upper and Lower Floridan aquifers of the Floridan aquifer system (Miller, 1986). The lower confined zone and lower Brunswick aquifer are the focus of this study. The lithology and description of well 34K104 is derived from borehole cuttings recovered during drilling (hydrogeologic chart, following page). The lithology of the surficial aquifer system typically consists of sand and clay; these sediments overlie sandy limestone of the Brunswick aquifer system.



[1]Modified from Weems and Edwards, 2001

Generalized lithologic, geologic, and hydrologic description of Darien test site, McIntosh County, Georgia.

At the Darien test site, the surficial aquifer system is present from land surface to a depth of about 280 ft. For this study, it is informally divided into three water-bearing zones: water-table zone, upper confined zone, and lower confined zone. These water-bearing zones are separated by clay and sandy clay confining units. The lower confined zone is the focus of this investigation and is present from 160 to 280 ft. The lower confined zone consists of fine to medium sand with few shell fragments and clay layers, with a total thickness of about 120 ft. The base of the confining unit underlying the surficial aquifer system (top of the upper Brunswick aquifer) is identified on natural gamma radiation logs by the A-marker horizon (Clarke and others, 1990). Well 34K103 is screened in the lower confined zone.

At the Darien test site, the lower Brunswick aquifer extends from a depth of 490 to 580 ft and consists mostly of phosphatic sand. The total thickness of the lower Brunswick aquifer is about 90ft. The top of the aquifer is identified by the B-marker horizon, a zone of high natural gamma radiation (Clarke and others, 1990). Well 34K104 is screened in the lower Brunswick aquifer.

HYDRAULIC PROPERTIES

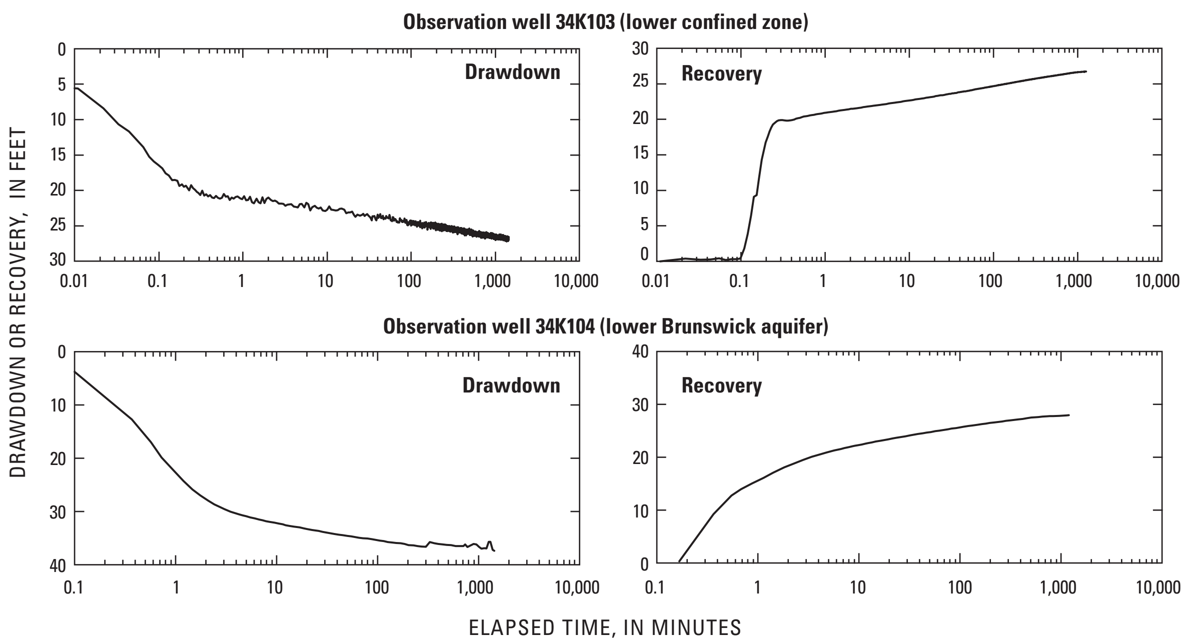
Each single-well aquifer test was designed to provide ground-water-level and well-discharge data to calculate hydraulic properties. The two aquifer tests included a pretest step drawdown test and background ground-water-level monitoring, constant discharge aquifer test followed by post-test recovery monitoring.

Lower Confined Zone, Surficial Aquifer System

The lower confined zone single-well test consisted of pumping and monitoring well 34K103. During November 1–4, 2004, the lower confined zone aquifer test consisted of about 1.5 hours of pretest pumping, 24 hours of constant-discharge pumping, and 24-hours monitoring ground-water-level recovery. Ten days of background water-level data were collected from another well completed in the lower confined zone (well 34J082, about 10 miles south of the Darien test site) to note any trends in the water level prior to pumping. During October 22–31, 2004, water levels in well 34J082 varied from 6.23 to 6.53 ft. Background data indicate there was a downward trend prior to the start of the test, which continued after completion of the test; however, the trend was not substantial enough to affect the aquifer test.

The pretest pumping of well 34K103 was performed on November 2, 2004. The static water level was 25.31 ft. Discharge during the pretest pumping averaged 311 gallons per minute (gal/min) for 1.5 hours. The maximum drawdown was 26.7 ft.

During November 2–3, 2004, a 24-hour aquifer test was conducted in well 34K103 with an average discharge of 310 gal/min. The total amount of ground water withdrawn from the lower confined zone during the test was about 446,400 gallons. The total drawdown from 24 hours of pumping was about 27 ft (lower confined zone drawdown graph, below). During November 3–4, water-level recovery was monitored for 24 hours.



Drawdown and recovery in observed wells during aquifer test of the lower confined zone and the lower Brunswick aquifer, Darien test site, McIntosh County, Georgia, May and November, 2004.

Hydraulic properties of wells 34K103 and 34K104, Darien test site, McIntosh County, Georgia.

[ft^2/d, feet squared per day; ft/d, feet per day; do., ditto]

Well identification	Transmissivity (ft^2/d)	Hydraulic conductivity (ft/d)	Condition	Method used
		Lower confined zone		
34K103	6,000	60	Drawdown	Hantush and Jacob (1955)
do.	6,000	60	Recovery	Cooper and Jacob (1946)
		Lower Brunswick aquifer		
34K104	700	7	Drawdown	Cooper and Jacob (1946)
do.	700	7	Recovery	Cooper and Jacob (1946)
do.	700	7	Drawdown	Hantush and Jacob (1955)

Results from the drawdown analysis using the Hantush and Jacob (1955) method and recovery analysis using the Cooper and Jacob (1946) method provided a reasonable estimate of the hydraulic properties for the lower confined zone. The two methods using drawdown and recovery data estimated the transmissivity of the lower confined zone to be about 6,000 feet squared per day (ft^2/d) with a hydraulic conductivity of about 60 feet per day (ft/d) (hydraulic properties table, above).

Lower Brunswick Aquifer

The lower Brunswick aquifer test consisted of pumping and monitoring well 34K104, open to the lower Brunswick aquifer, and monitoring well 34K103, open to the lower confined zone. There was no change in ground-water level in the lower confined zone resulting from pumping the lower Brunswick aquifer. During April 29–May 6, 2004, the lower Brunswick aquifer test consisted of 5 days of background ground-water level monitoring, 4 hours pretest pumping, 24 hours constant-discharge pumping, and 24 hours monitoring ground-water-level recovery.

From April 29 to May 3, 2004, background ground-water-level data were collected in well 34K104. The water level varied from 23.04 ft to 27.14 ft, increasing during the period. The pretest pumping of well 34K104, open to the lower Brunswick aquifer, was performed on May 3, 2004. The static water level was 27.23 ft. Discharge during the pretest pumping averaged 61 gal/min for 4 hours. Total drawdown was 37.38 ft.

During May 4 –5, 2004, a 24-hour aquifer test was conducted in well 34K104 with an average discharge of 58gal/min. The total amount of ground water withdrawn from the lower Brunswick aquifer was about 83,520 gallons. Total drawdown after about 24hours of pumping was about 37 ft (lower Brunswick drawdown graph, previous page). During May 5– 6, 2004, water-level recovery was monitored for 24 hours.

Results from the analyses of drawdown and recovery data from well 34K104 using Cooper and Jacob (1946) and Hantush and Jacob (1955) methods provided a reasonable estimate of the hydraulic properties for the lower Brunswick aquifer. The two methods estimated the transmissivity of the lower Brunswick aquifer to be about 700 ft^2/d with a hydraulic conductivity of about 7 ft/d (hydraulic properties table, above).

GROUND-WATER QUALITY

Results of the chemical analysis of ground-water samples obtained from wells completed in the lower confined zone and lower Brunswick aquifer were used to describe and compare the geochemical variability of ground water in the two aquifers. Water samples were analyzed for major ions, metals, total organic carbon, nutrients, and radionuclides (water-quality table, facing page). Field properties— including pH, specific conductance, and water temperature— were measured onsite prior to sample collection. Concentration of constituents from the two aquifers were compared and to the U.S. Environmental Protection Agency (USEPA) (2000a, b) maximum contaminant levels (formerly known as primary contaminant level) and secondary standards (formerly know as secondary contaminant level) for drinking water. Additionally, these data were compared to the Georgia Environmental Protection Division (GaEPD) regulations for drinking water (Georgia Environmental Protection Division, 1997a, b). The major ion data are presented graphically using a trilinear diagram (page 100) showing the percentage composition of selected major cations and anions, as well as total dissolved-solids concentrations.

Lower Confined Zone, Surficial Aquifer System

Constituent concentrations in water from the lower confined zone are generally within the USEPA and GaEPD regulations for drinking water. Water collected from the lower confined zone has a dissolved chloride concentration of 10.9 milligrams per liter (mg/L), specific conductance of 245 microsiemens per centimeter (µS/cm), total organic carbon of 3.7 mg/L, and pH of 7.3. The 1,290 µg/L concentration of iron and the 171 µg/L concentration of manganese exceed the GaEPD regulations for these constituents. An analysis of tritium in water from the lower confined zone was conducted to determine if water may be entering the aquifer from the surface recharge. Total tritium was 0.3 picocuries per liter (pCi/L), which is less then the reporting limit of 5.7 pCi/L (water-quality table, facing page).

Concentration of major ions and field properties in water samples collected from the lower confined zone (well 34K103) and the lower Brunswick aquifer (well 34K104), Darien test site, McIntosh County Georgia, May 3 and November 2, 2004

[MCL, primary maximum contaminant level; SMCL, secondary maximum contaminant level; mg/L, milligram perliter; —, no data; pH are in standard units; µS/cm, microsiemens per centimeter; $CaCO_3$ calcium carbonate; NTU, nephelometric turbidity unit; <, less than; µg/L, microgram per liter; pCi/L, picocurie per liter; E, estimated value]

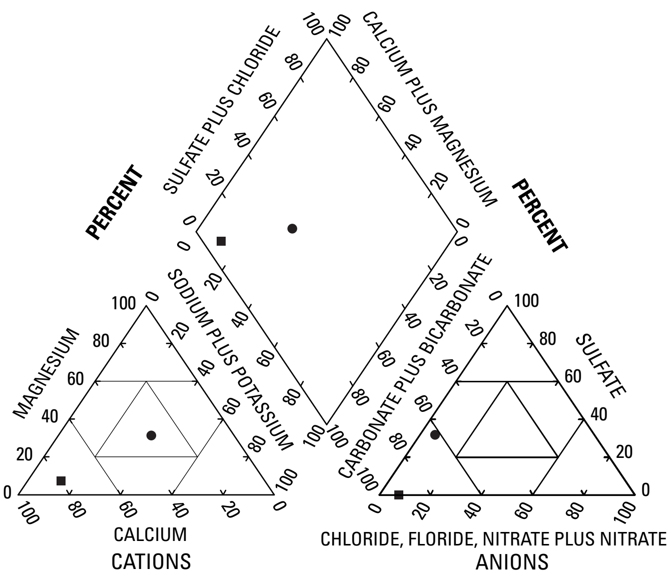
Constituents	Test well identification number and date		Drinking-water standards[1]	
	34K103 November 2, 2004	34K104 May 3, 2004	MCL	SMCL
Dissolved oxygen, in mg/L	6.4	0.3	—	—
Field pH, standard units	7.1	7.8	—	6.5–8.5
Lab pH, standard units	7.3	7.7	—	6.5–8.5
Field specific conductance, in µS/cm	355	412	—	—
Lab specific conductance, in µS/cm	245	443	—	—
Water temperature, in degrees Celsius	20.3	24.1	—	—
Hardness, as $CaCO_3$, in mg/L	188	152	—	—
Calcium, dissolved, in mg/L	68.8	31.1	—	—
Magnesium, dissolved, in mg/L	4.1	18.1	—	—
Potassium, dissolved, in mg/L	1.4	4.28	—	—
Sodium, dissolved, in mg/L	11.5	37.3	—	—
Alkalinity as $CaCO_3$, in mg/L	189	113	—	—
Turbidity, in NTU	10	—	—	—
Chloride, dissolved, in mg/L	10.9	10.2	—	250
Silica, dissolved, in mg/L	57.8	18.3	—	—
Sulfate, dissolved, in mg/L	<.2	75.2	—	250
Dissolved solids (sum of constituents), in mg/L	98	176	—	500
Ammonia, dissolved, in mg/L	0.2	0.1	—	—
Nitrite, nitrate, as N, dissolved, in mg/L	<.016	<.016	10	—
Phosphorus, dissolved, in mg/L	—	0.005	—	—
Phosphorus, total, in mg/L	—	<.004	—	—
Organic carbon, total, in mg/L	3.7	3.3	—	—
Aluminum, dissolved, in µg/L	<2	M	—	50–200
Antimony, dissolved, in µg/L	<.20	<.20	6	—
Barium, dissolved, in µg/L	8	5	2,000	—
Beryllium, dissolved, in µg/L	<.06	<.06	4	—
Cadmium, dissolved, in µg/L	<.04	<.04	5	—
Chromium, dissolved, in µg/L	<.8	<.8	100	—
Cobalt, dissolved, in µg/L	0.114	0.085	—	—
Copper, dissolved, in µg/L	E.2	0.6	—	1,000
Iron, dissolved, in µg/L	1,290	26	—	300
Lead, dissolved, in µg/L	0.27	E.05	—	—
Manganese, dissolved, in µg/L	171	<.8	—	50
Molybdenum, dissolved, in µg/L	<.4	E.2	—	—
Nickel, dissolved, in µg/L	<.06	0.52	100	—
Silver, dissolved, in µg/L	<.2		—	100
Strontium, dissolved, in µg/L	422	781	—	—
Zinc, dissolved, in µg/L	35	<3	—	5,000
Alpha radioactivity, Th-230, in pCi/L	—	0.2	—	—
Gross beta radioactivity, CS-137, in pCi/L	—	4.1	—	—
Tritium 2-sigma, in pCi/L	3.2	—	—	—
Tritium, total, in pCi/L	0.3	—	—	—
Uranium, dissolved, in µg/L	<.04	<.04	30	—

[1]U.S. Environmental Protection Agency, 2000a, b

Lower Brunswick Aquifer

Constituent concentrations in water from the lower Brunswick aquifer are generally within the USEPA and GaEPD regulations for drinking water. Water collected from the lower Brunswick aquifer has a dissolved chloride concentration of 10.2 mg/L, specific conductance of 443 µS/cm, total organic carbon of 3.3 mg/L, and pH of 7.7.

A trilinear diagram showing the percentage composition of selected major cations and anions, as well as dissolved solids concentrations of those constituents is shown below. The trilinear diagram shows that water from the lower Brunswick aquifer is a calcium-carbonate type, and water from the lower confined zone is a bicarbonate type. Water in the lower confined zone has a hardness of 188 mg/L as $CaCO_3$, and water in the lower Brunswick aquifer has a hardness of 152 mg/L as $CaCO_3$ (based on the sum of milliequivalent of calcium, magnesium, barium, and strontium). According to Durfor and Becker (1964), water from the lower confined zone is classified as very hard and from the lower Brunswick aquifer is classified as hard.



Percentage composition of major ionic constituents and total dissolved solids in water from the lower confined zone of the surficial aquifer system and the lower Brunswick aquifer, Darien test site, McIntosh County, Georgia, May and November 2004.

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