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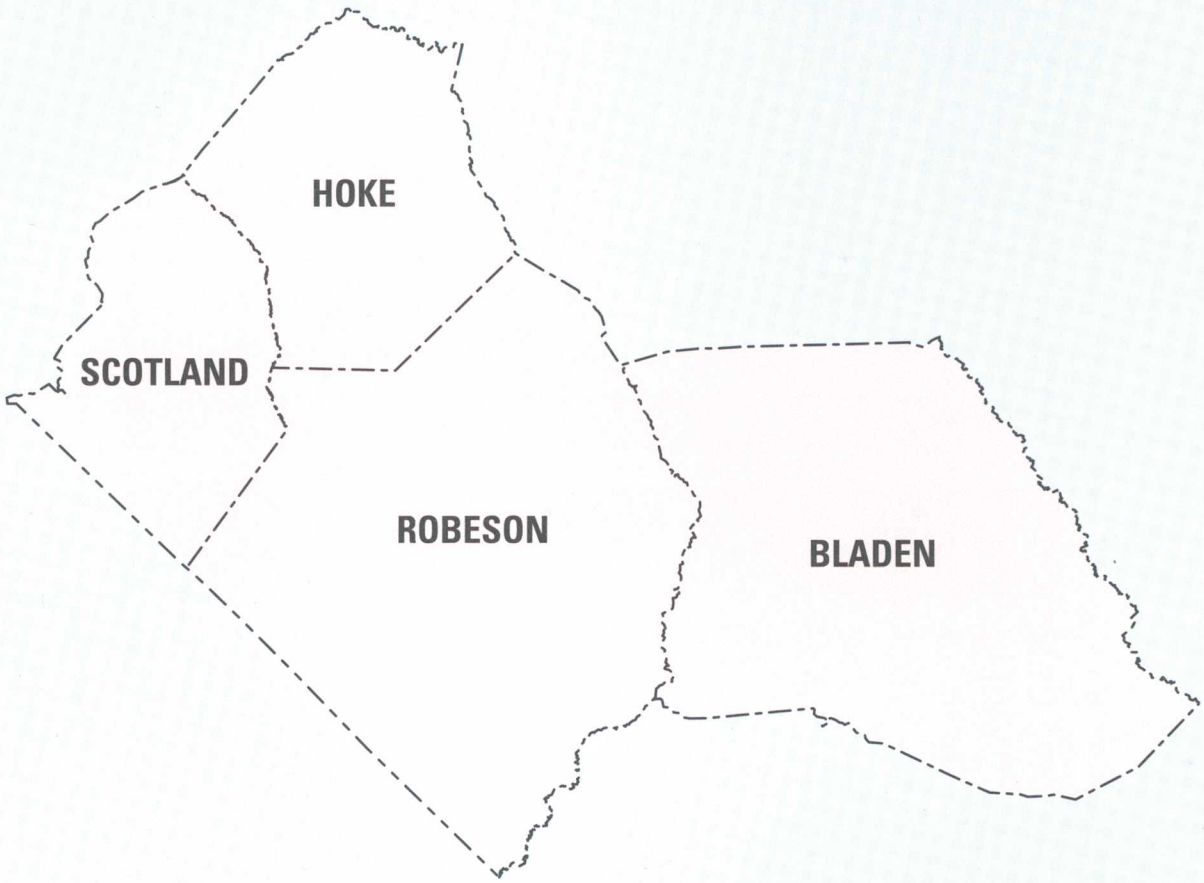
Water-Level Conditions in the Black Creek Aquifer, 1992–98, in Parts of Bladen, Hoke, Robeson, and Scotland Counties, North Carolina

Water-Resources Investigations Report 00–4138



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

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By A.G. Strickland

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 00–4138

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Lumber River Council of Governments

Raleigh, North Carolina
2000

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	by	To obtain
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer
million gallons per day (Mgal/d)	0.04381	cubic meter per second

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929), a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

Water-Level Conditions in the Black Creek Aquifer, 1992–98, in Parts of Bladen, Hoke, Robeson, and Scotland Counties, North Carolina

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ABSTRACT

Ground-water levels were monitored between September 1992 and December 1998 in 21 wells that are screened in the Black Creek aquifer throughout a 2,000-square-mile area in Bladen, Hoke, Robeson, and Scotland Counties, North Carolina. Observed water levels have changed little in the Black Creek aquifer throughout most of the area since 1992. Water levels have declined in some areas, however, as a result of pumping. The greatest decline was 30.8 feet near Laurinburg in Scotland County during 1993–98.

During the fall of 1998, water-level measurements made in 291 wells in or near Bladen, Hoke, Robeson, and Scotland Counties were used to map the potentiometric surface of the Black Creek aquifer. The map of the potentiometric surface can be used to infer the general direction of ground-water flow from recharge areas in the uplands to discharge areas at local streams and wells. Withdrawals from wells at pumping centers, such as areas around Elizabethtown in Bladen County and Lumberton in Robeson County, have caused ground water to flow toward the pumped wells, resulting in cones of depression in the potentiometric surface. In 1998, the major axes of the cones of depression were about 5 and 7 miles in length beneath the Elizabethtown and Lumberton areas, respectively. In southwestern Bladen County, where the Black Creek aquifer is overlain by the Peedee aquifer and the Black Creek confining unit, most ground water does not discharge to local streams but flows southeastward toward the coast or is discharged from pumped wells.

INTRODUCTION

In 1992, the U.S. Geological Survey (USGS) began a 3-year investigation of water levels in the major water-supply aquifers in the southern Coastal Plain Province of North Carolina. The study was extended in 1995 for an additional 4 years and is being conducted in cooperation with the Lumber River Council of Governments (LRCOG), which is composed of local governments in Bladen, Hoke, Robeson, and Scotland Counties (fig. 1). The objective of this investigation is to assess the effects of ground-water withdrawals on water levels in major aquifers in an approximately 2,000-square-mile study area within the LRCOG counties.

This report provides water-resources information to multiple parties for planning and operational purposes, which is one of the broad goals of the USGS. The report contains a description of water-level fluctuations in the Black Creek aquifer in parts of Bladen, Hoke, Robeson, and Scotland Counties, North Carolina. Selected hydrographs illustrate seasonal variations and the effects of ground-water withdrawals from 1992 through 1998. The report also includes an assessment of the effects of ground-water withdrawals on the potentiometric surface of the Black Creek aquifer during the fall of 1998.

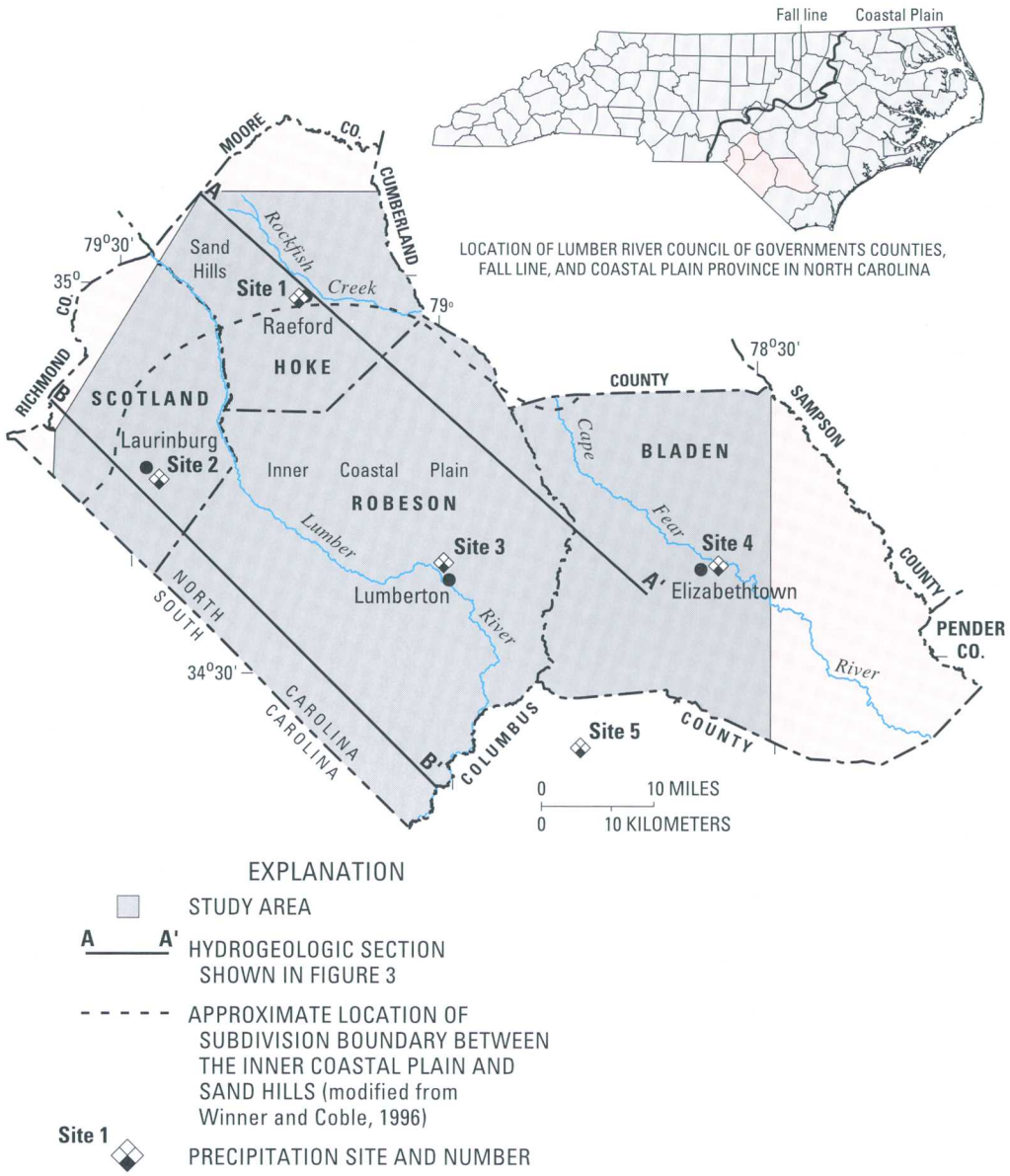

Figure 1. The study area and physiographic divisions within the Coastal Plain Province of North Carolina, including precipitation sites and lines of hydrogeologic sections A-A' and B-B'.

PHYSIOGRAPHIC SETTING

The study area is in the Coastal Plain Province of southeastern North Carolina. Stuckey (1965) recognized two physiographic subdivisions in the Coastal Plain in this area—the Inner Coastal Plain and the Sand Hills (fig. 1). The eastern part of the study area is in the Inner Coastal Plain, which includes most of Bladen and Robeson Counties and parts of Hoke and Scotland Counties. This area is characterized by broad, flat, commonly swampy uplands situated between major streams. Local topographic relief is generally 5 feet or less. However, areas near major rivers, such as the Cape Fear and its tributaries, are quite dissected. In some places, stream valleys are 50 feet deep or more.

The northwestern part of the study area is in the Sand Hills area, which includes the northern two-thirds of Hoke County and the northwestern half of Scotland County (Schipf, 1961). This area is characterized by rolling hills, deep sand, and sandy soils (Stuckey, 1965) upon which a dendritic drainage pattern has developed. Larger streams in the area flow eastward or southeastward across the Coastal Plain; stream valleys are

characterized by steep sides and well-developed flood plains.

HYDROGEOLOGIC SETTING

The Coastal Plain Province of North Carolina consists of a southeastward dipping and thickening wedge of predominantly unconsolidated sedimentary deposits of sand and clay underlain by basement rocks. The western boundary of these deposits is the Fall Line (fig. 1; Winner and Coble, 1996). Based on their age and lithology, the Tertiary and Cretaceous sedimentary deposits are divided into geologic formations. These deposits are further classified according to hydraulic characteristics and grouped into either aquifers or confining units. The basement rocks underlying the sedimentary deposits consist of metamorphic and igneous crystalline rocks of pre-Cretaceous age. The correlation of geologic and hydrogeologic units that underlie the study area is shown in figure 2.

Aquifers can be composed of a single formation, parts of formations, or groups of formations that (1) contain ample saturated permeable material (sand or gravel in this study area), (2) allow the lateral movement of water within the material, and (3) yield substantial quantities of water to wells and springs. Confining units consist of distinctly less permeable material (beds of clay, silty clay, and(or) sandy clay) that restricts the movement of water between overlying and underlying aquifers.

Winner and Coble (1996) identified six aquifers in the study area—the surficial, Yorktown, Peedee, Black Creek, upper Cape Fear, and lower Cape Fear aquifers—separated by five confining units (figs. 2, 3). Each confining unit is informally named for the aquifer overlying it. The Yorktown aquifer is not present in most of the study area, except in Robeson County near the South Carolina State line.

The surficial aquifer is unconfined and primarily consists of thin hydrogeologic units in the shallow subsurface. The water table, which is the upper water surface in the surficial aquifer, is at atmospheric pressure. Where the Yorktown, Peedee, and Black Creek aquifers lie at shallow depths and where their respective confining units are missing, unconfined conditions can occur. In the highly dissected Sand Hills, where the confining unit is cut through in many places by streams, the Black Creek aquifer is confined only beneath hilltops (Winner and Coble, 1996).

Where present, the Black Creek confining unit overlies the Black Creek aquifer and consists of beds of clay, silty clay, and sandy clay (Winner and Coble, 1996). The confining unit ranges in thickness from zero to 50 feet.

The Black Creek aquifer, which is highlighted in this report, is the major source of water for public,

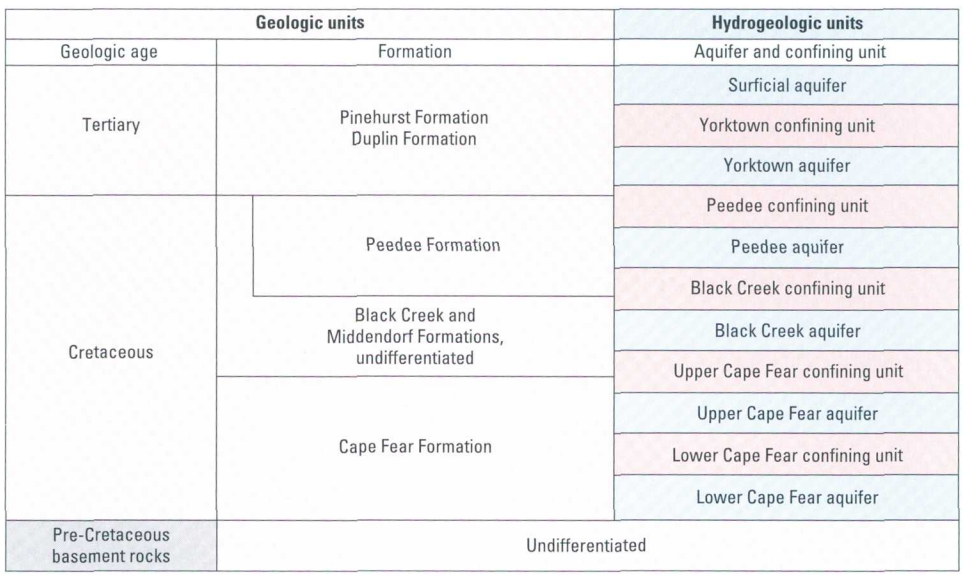

Figure 2. Generalized relation of geologic and hydrogeologic units in the study area (modified from North Carolina Department of Natural Resources and Community Development, 1985; Winner and Coble, 1996).

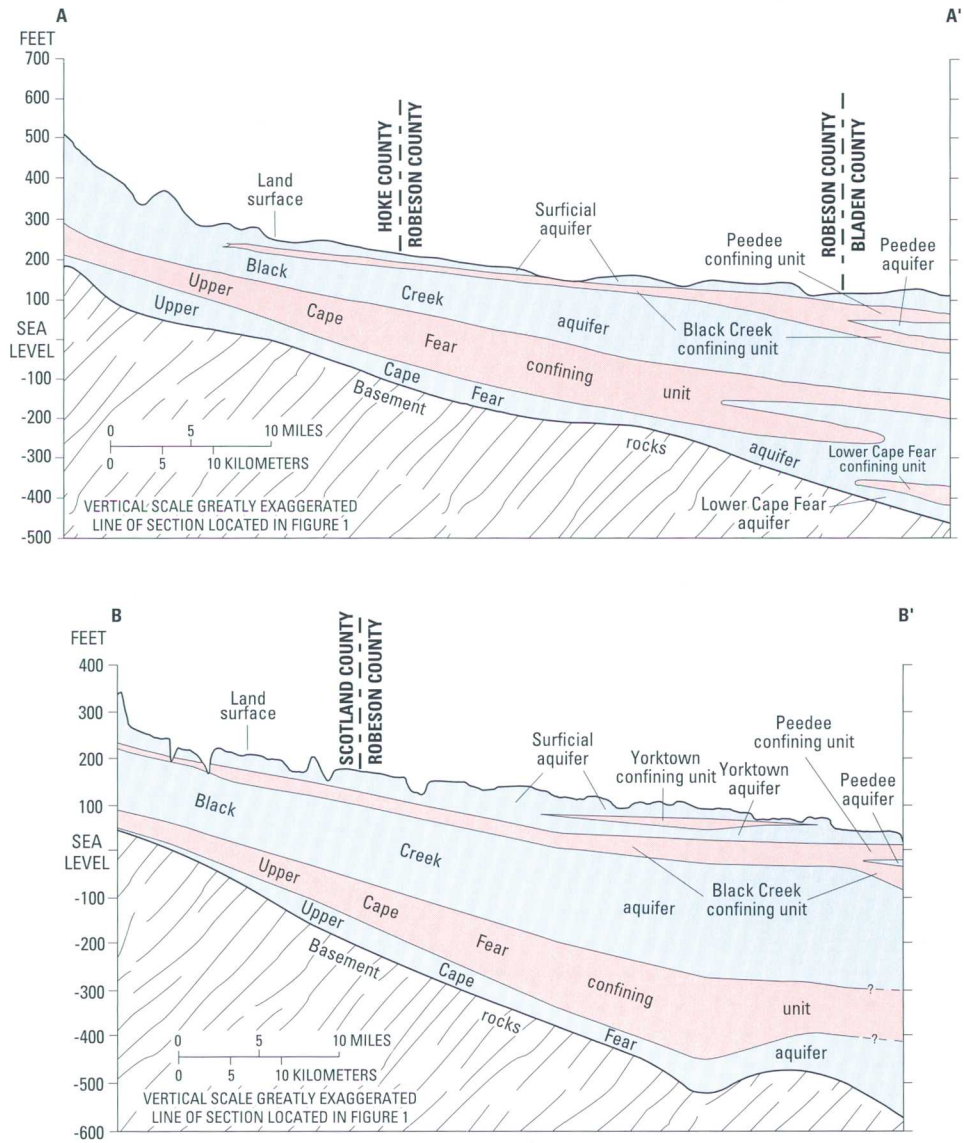

Figure 3. Generalized hydrogeologic sections A-A' and B-B' (modified from Winner and Coble, 1996).

industrial, and agricultural uses in the study area. The Black Creek aquifer primarily consists of sediments of the Black Creek and the underlying Middendorf Formations of Cretaceous age (Winner and Coble, 1996). The Black Creek Formation is composed of thinly laminated gray to black clay interlayered with gray to tan sand. The lagoonal or marine origin of the Black Creek Formation is reflected by the presence of shell and organic material, such as lignitized wood, which is common in these sediments. The Middendorf Formation, which crops out to the west of the Black Creek Formation in the Sand Hills section of the study area, is composed of fluvial sediments of nonmarine origin; these include a heterogeneous mix of fine to medium sand and silty clay beds, coarse channel sand, and thin laminated beds of sand and clay (Winner and Coble, 1996).

DATA COLLECTION AND ANALYSIS

Wells that were used during the study include North Carolina Department of Environment and Natural Resources (DENR) observation wells and industrial, municipal, county, State, Federal, and

private water-supply wells. Water levels in many of these wells have been measured periodically since fall 1988 (Strickland and others, 1992; Strickland, 1994, 1996; U.S. Geological Survey, 1997–99).

Water levels in observation and water-supply wells were measured by USGS personnel during periodic water-level-measurement site visits. To ensure that water levels in water-supply wells closely represented stable conditions in the wells, pumps were switched off at least 20 minutes prior to measuring the water levels. Water levels were measured until two consecutive measurements taken about 5 minutes apart differed by less than 0.1 foot. These water levels were considered representative of nonpumping (quasi-static) conditions.

Twenty-one wells open to the Black Creek aquifer and one well open to the upper Cape Fear aquifer were selected to monitor water-level fluctuations (figs. 4, 5). Most of these wells were selected to monitor the effects of pumping on the Black

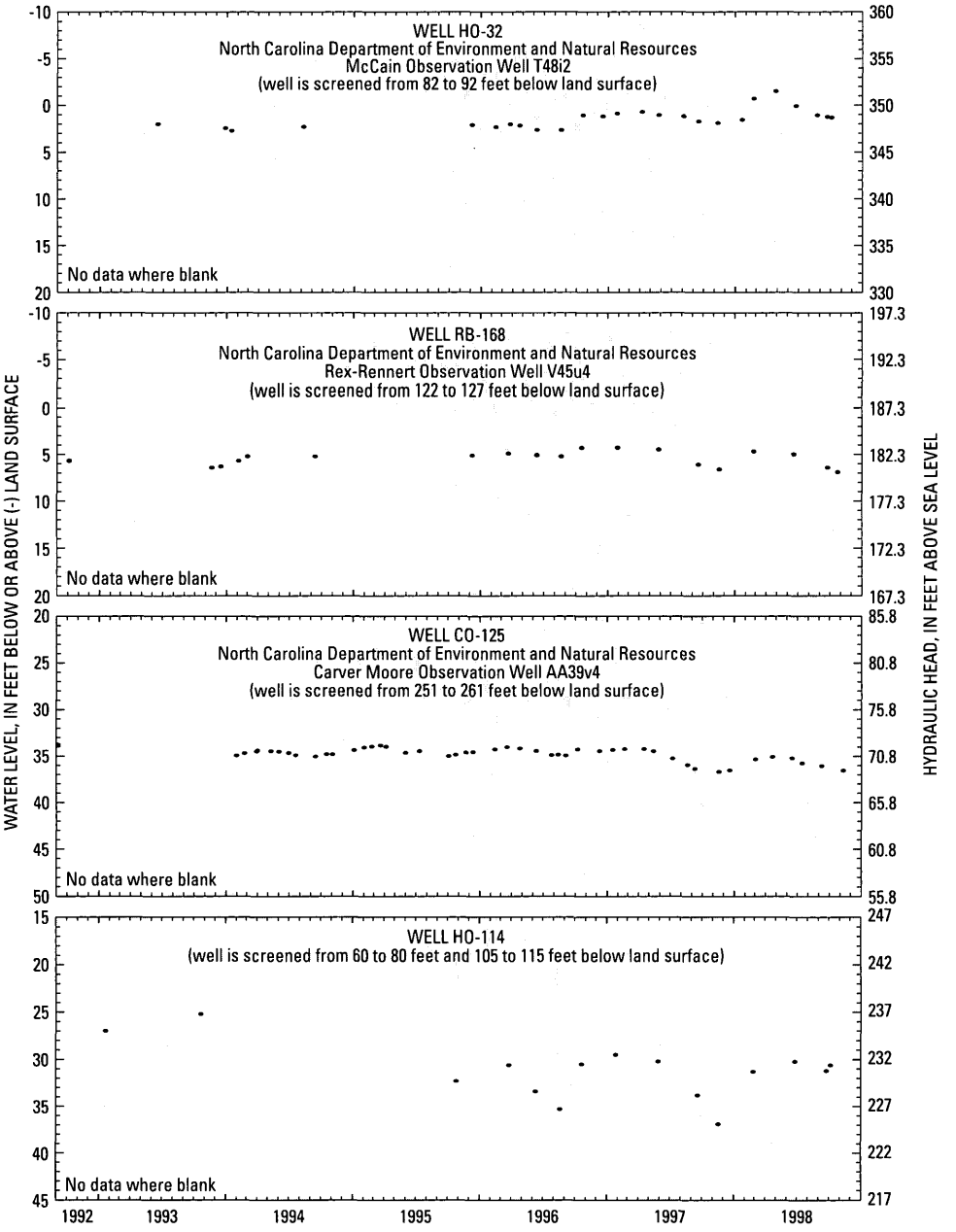

Figure 4. Water levels in selected wells in the Black Creek aquifer in Bladen, Columbus, Hoke, Robeson, and Scotland Counties, 1992–98.

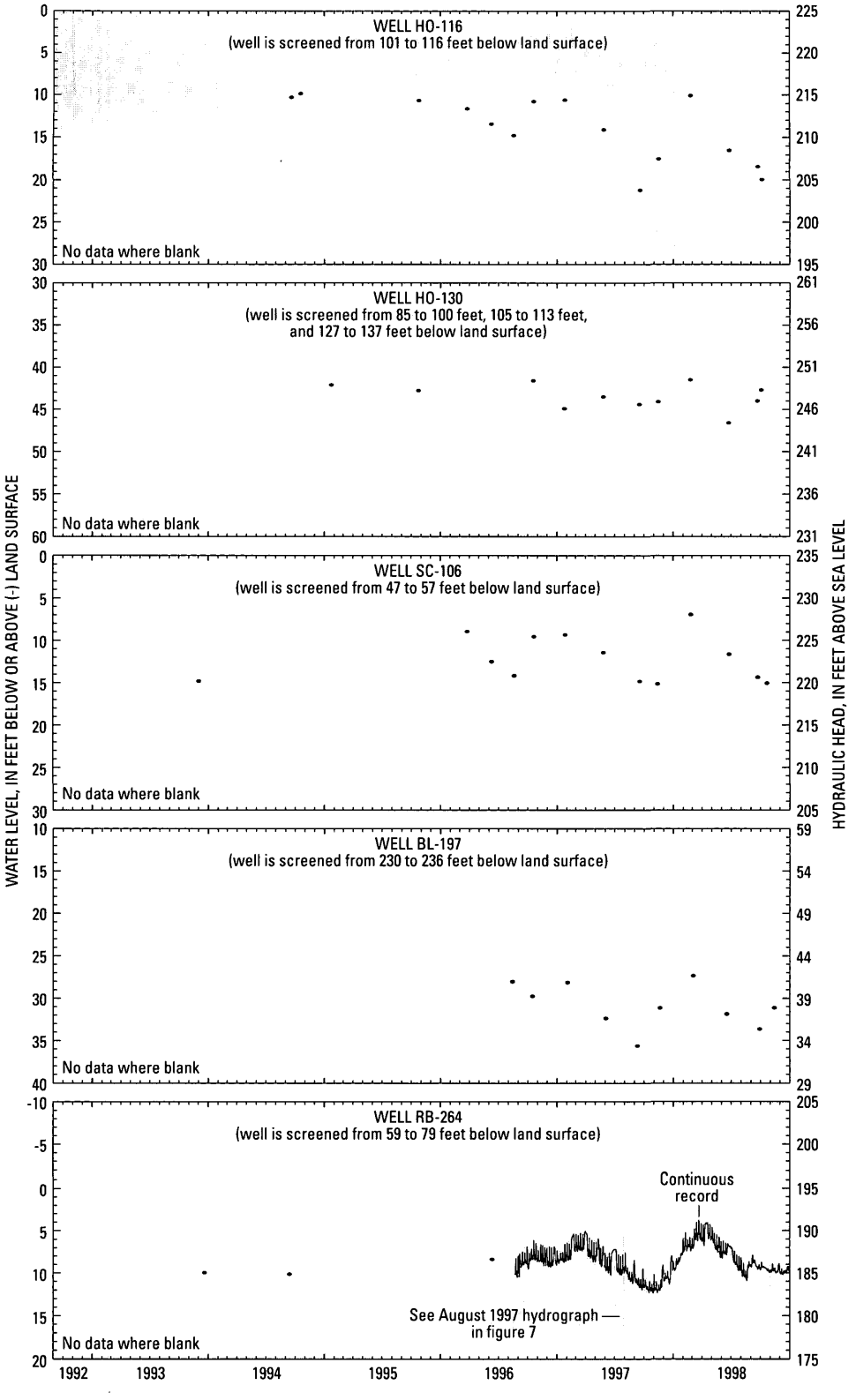

Figure 4. (Continued) Water levels in selected wells in the Black Creek aquifer in Bladen, Columbus, Hoke, Robeson, and Scotland Counties, 1992–98.

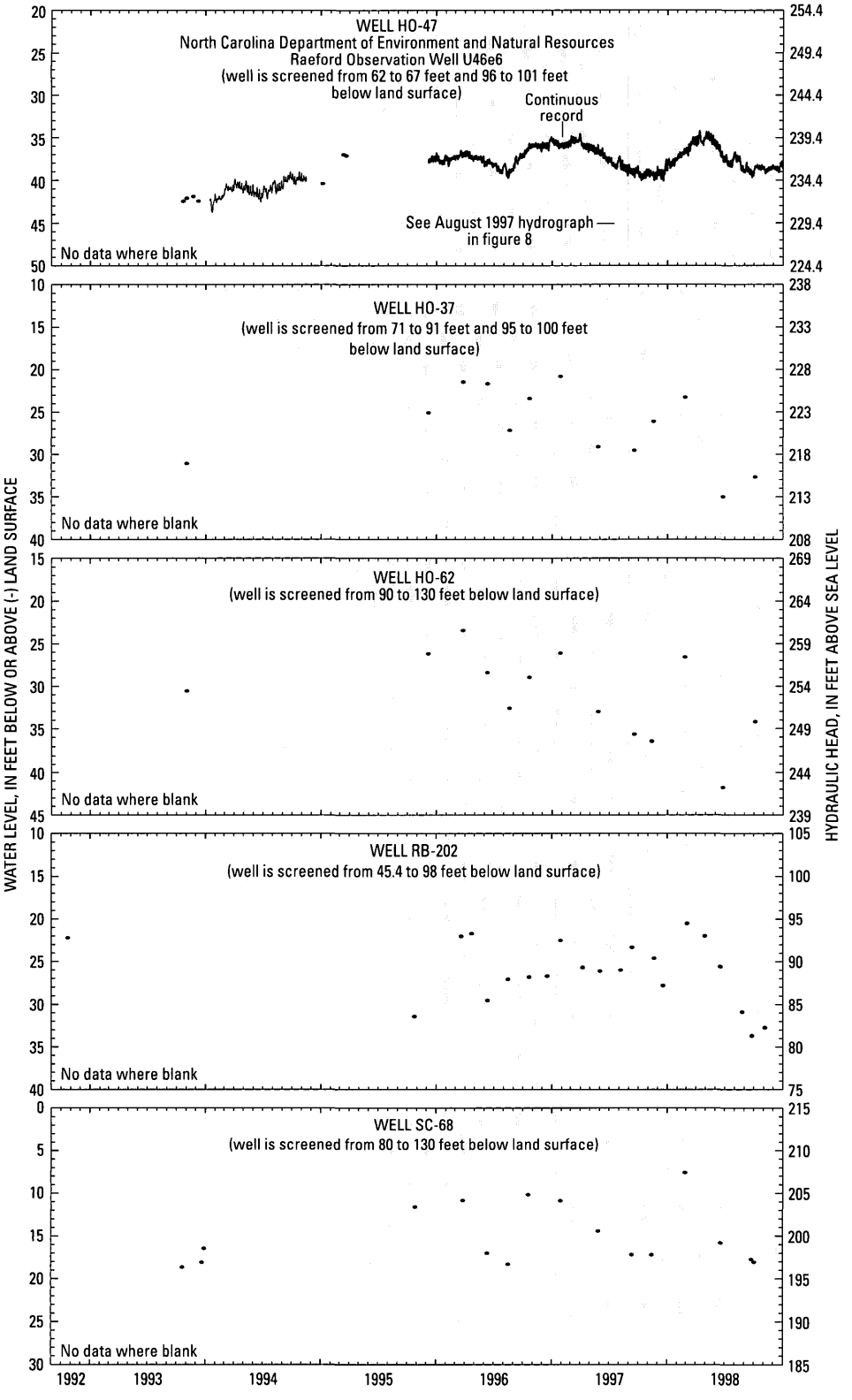

Figure 4. (Continued) Water levels in selected wells in the Black Creek aquifer in Bladen, Columbus, Hoke, Robeson, and Scotland Counties, 1992–98.

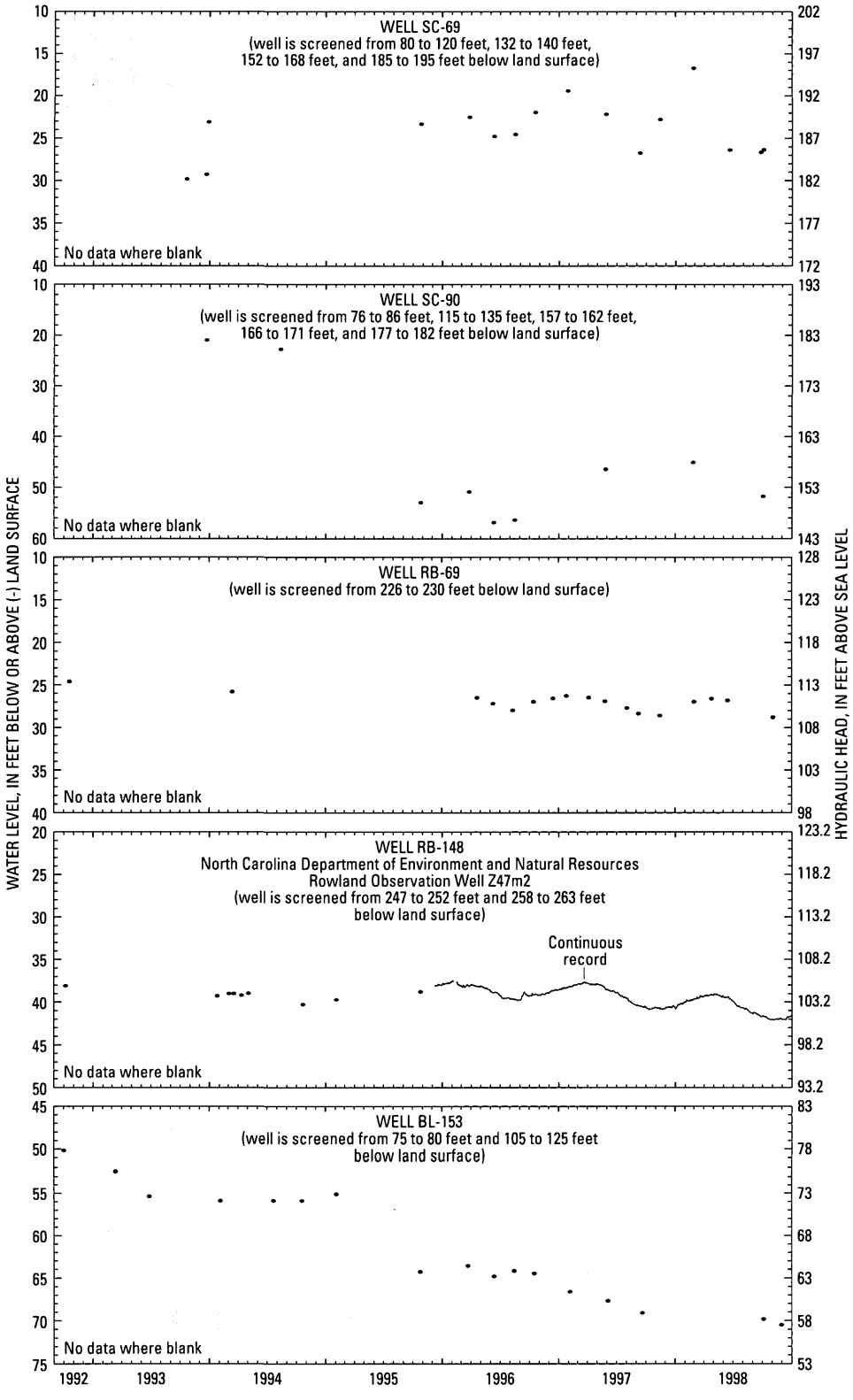

Figure 4. (Continued) Water levels in selected wells in the Black Creek aquifer in Bladen, Columbus, Hoke, Robeson, and Scotland Counties, 1992–98.

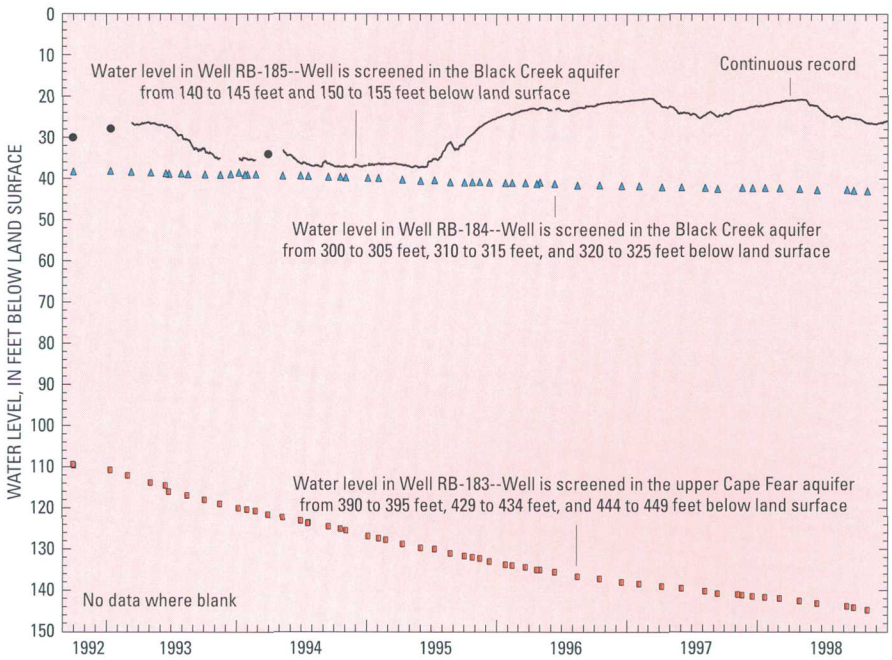

Figure 5. Water levels in wells RB-183, RB-184, and RB-185 in Robeson County, 1992–98 (North Carolina Department of Environment and Natural Resources Littlefield observation wells Y42f11, Y42f10, and Y42f9, respectively).

Creek aquifer in areas where major withdrawals previously were identified (Strickland, 1994, 1996) or in areas of planned ground-water development. A few wells were selected to monitor water-level fluctuations in areas away from pumping centers.

Water levels measured in these wells between September 1992 and December 1998 are included in this report (figs. 4, 5). During the first 3 years of the investigation, 1992–94, water levels in some wells were measured only once. During parts of 1994–95, although the monitoring of water levels in a few wells continued, water levels in most of the wells were not measured by USGS personnel. Water-level data for some wells were supplemented with water-level measurements made by DENR and well-drilling personnel.

At various times during 1992–98, four observation wells were equipped with water-level recorders set to automatically record water levels at 1-hour intervals, which is referred to as continuous record in this report. Once water-level monitoring resumed in late 1995, water levels in six wells, one of which was located outside of the study area in Columbus County, North Carolina, generally were measured at 2-month intervals. Water levels in the remaining 12 wells generally were measured quarterly.

In fall 1998, water levels were measured in 291 wells that tap the Black Creek aquifer (table 1, p. 17). Of these wells, six are located outside of the LRCOG area—three in Columbus County, North Carolina, and three in Dillon County, South Carolina (pl. 1).

The water level in a well represents the hydraulic head in the screened part of the aquifer. This water level is a function of the elevation of the screened part of the well and the pressure within the screened portion of the aquifer. The water level in a well that taps an unconfined aquifer indicates the altitude of the water table in the surrounding aquifer. Below the water table, the pressure is greater than atmospheric pressure and increases with increasing depth. In confined aquifers, the altitude of water in a tightly cased, nonpumped well stands above the top of the aquifer; this hydraulic head defines a point on the potentiometric surface of an aquifer. A map of the potentiometric surface depicts the areal distribution of hydraulic heads and can be used to infer the direction of ground-water movement in the aquifer. Lines of equal hydraulic head in the aquifer are represented on a map by potentiometric-surface contours. Ground water flows through an aquifer from areas of high hydraulic head to areas of low hydraulic head. The direction of flow is assumed to be perpendicular to the potentiometric-contour lines.

A map showing the potentiometric surface of the Black Creek aquifer was constructed by using water levels measured in wells during October and November 1998 (pl. 1). Hydraulic heads were computed by subtracting the water levels in these wells, in feet below land surface, from the land-surface altitudes at the wells, in feet above sea level. Hydraulic heads are reported to the nearest foot (table 1).

Most wells used in this study are screened in only one aquifer; however, six wells are screened in multiple aquifers (table 1). Although water levels measured in these six wells reflect a combination of hydraulic heads, the water levels are considered representative of the Black Creek, which is the primary source of ground water to the wells.

The locations of most wells used in this study were determined by using the Global Positioning System (GPS). Latitude and longitude coordinates are referenced to the North American Datum of 1927. Land-surface altitudes at well sites that have not been surveyed to the nearest 0.1 foot were estimated to the nearest foot from USGS 7.5-minute topographic quadrangle maps having 5- or 10-foot contour intervals. Latitude and longitude coordinates obtained by using GPS along with land-surface altitudes are listed in table 1 and may be different from those reported by Strickland (1994, 1996).

Ground-water flow in the Black Creek aquifer is from recharge areas, which include nearly all of the interstream areas, to discharge areas, which are the perennial streams and pumped wells. In areas away from pumping centers, the Black Creek aquifer discharges into streams. The Black Creek confining unit, which is present throughout much of the study area, somewhat restricts the flow of water into and out of the aquifer, but does not disrupt the regional flow pattern from the upland recharge areas to the discharge areas.

In areas where the natural pattern of ground-water flow is not disrupted by pumped wells, hydraulic heads in wells near streams are slightly to substantially higher than the stream stage. Therefore, to construct potentiometric contours, the hydraulic head in the aquifer along a stream was assumed to be slightly greater than the altitude of the stream.

WATER-LEVEL CONDITIONS IN THE BLACK CREEK AQUIFER

Water-level conditions in the Black Creek aquifer are presented in this report in two sections. The first section describes water-level fluctuations in the aquifer at selected wells in the study area from September 1992 through December 1998. Also included in this section are plots of total monthly precipitation measured at selected sites in and around the study area during this same period (figs. 1, 6). The second section discusses the potentiometric surface of the Black Creek aquifer during fall 1998.

Ground-Water Levels, 1992–98

Ground-water levels decline in response to periods when ground-water discharge from the aquifer exceeds recharge to the aquifer. Conversely, water levels rise during periods when recharge exceeds discharge. Water levels in the Black Creek aquifer respond to periodic recharge from precipitation. In much of the western half of the study area, where the Black Creek aquifer lies at shallow depths, water levels in wells generally are more sensitive to recharge. Figure 6 shows the total monthly precipitation measured at five sites located in and around the study area from 1992–98. These data were provided by the State Climate Office of North Carolina at North Carolina State University.

Hydrographs for three observation wells that are located away from pumping centers (wells HO-32, RB-168, and CO-125) are shown in figure 4. Well HO-32 is located in the Sand Hills area about 8 miles northwest of Raeford in Hoke County (pl. 1). From June 1993 through August 1996, water levels measured in well HO-32 remained fairly steady. Between August and October 1996, water levels in well HO-32 rose 1.5 feet. From October 1996 through October 1998, water levels remained above the level observed prior to August 1996. High water levels in well HO-32 since August 1996 indicate increased ground-water recharge to the Black Creek aquifer as a result of much higher than normal precipitation during late summer 1996 and again during winter and early spring 1998 (K. Chhak, State Climate Office, N.C. State University, written commun., 1999). The slight overall rise in water levels observed at well HO-32 between June 1993 and October 1998 indicates that recharge to the Black Creek aquifer exceeded discharge.

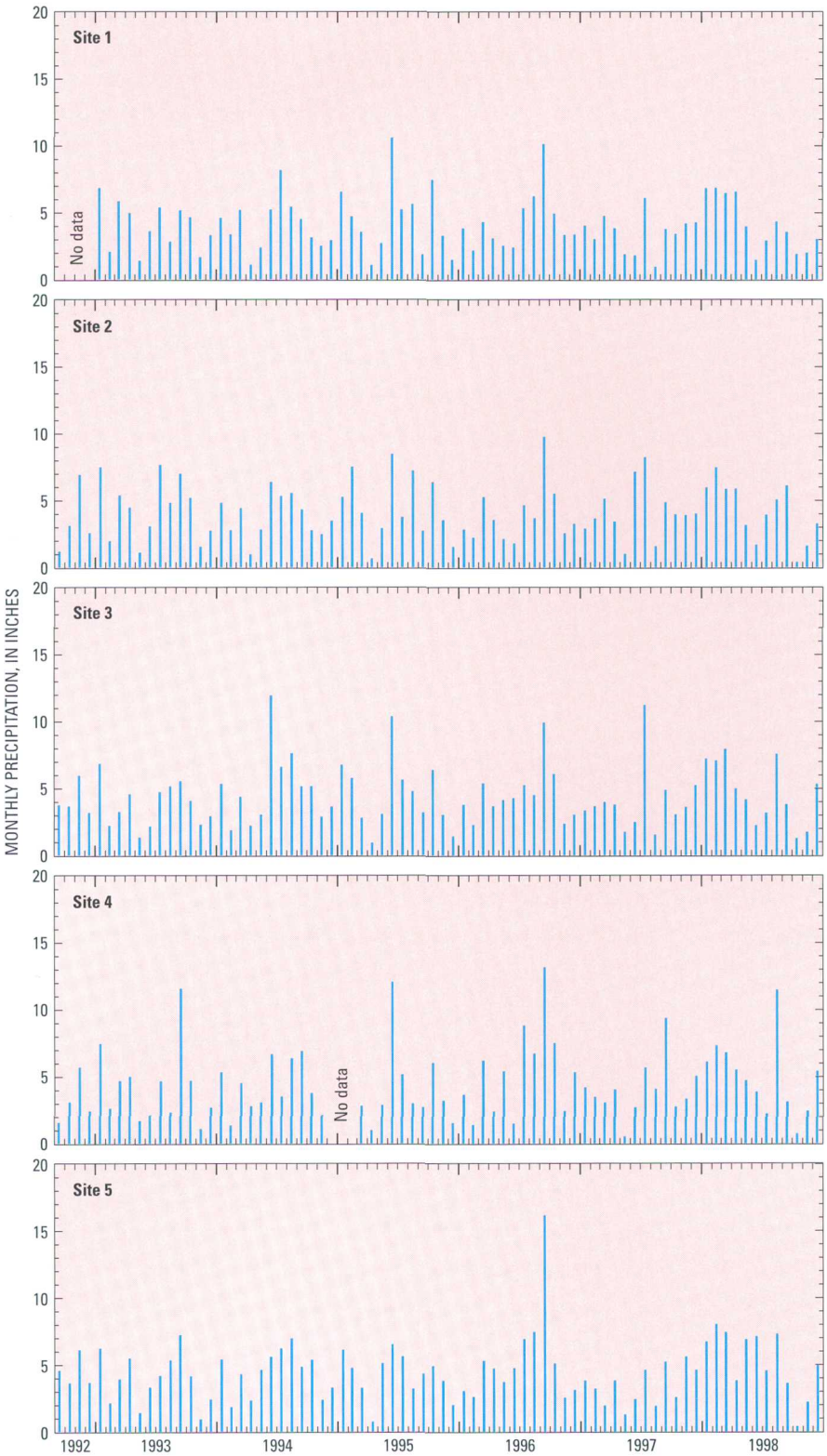

Figure 6. Monthly precipitation at selected sites in Bladen, Columbus, Hoke, Robeson, and Scotland Counties, 1992–98. (Site locations shown in fig. 1.)

Observation well RB-168 is located about 2 miles north of Rennert in Robeson County (pl. 1). From October 1992 through October 1998, water levels observed in well RB-168 fluctuated from a high of 4.3 feet below land surface in October 1996 and January 1997 to a low of 6.9 feet below land surface in October 1998 (fig. 4). From February 1994 through August 1996, water levels observed in well RB-168 were fairly steady. Between August and October 1996, water levels measured in well RB-168 rose about 1 foot and remained fairly steady through May 1997. From mid-1997 through 1998, water levels were higher during winter and spring than those measured during late summer and fall. From October 1992 through October 1998, water levels in well RB-168 were relatively stable with the exception of seasonal fluctuations.

Observation well CO-125 is located in Columbus County near the Bladen-Columbus County line and about 5.5 miles southeast of Clarkton in Bladen County (pl. 1). From January 1994 through May 1997, water levels measured in well CO-125 generally reflect uniform seasonal fluctuations (fig. 4). Between May and November 1997, the water level declined 2.2 feet. Since November 1997, water levels have not recovered to levels above those observed prior to May 1997. The overall decline in water levels observed at well CO-125 between September 1992 and November 1998 indicates that discharge from the Black Creek aquifer exceeded recharge.

Water levels were observed in wells that are located in areas where pumping occurs. Water-level fluctuations in these wells likely were in response to withdrawals and seasonal fluctuations.

Public water-supply wells HO-114, HO-116, and HO-130 are located 6.4 miles northeast, 4.4 miles southeast, and 3.4 miles north-northeast of Raeford in Hoke County, respectively (pl. 1). Withdrawals from the Black Creek aquifer at well HO-114 began after October 1993. Water levels observed in well HO-114 were 7.1 feet lower in October 1995 than in October 1993 (fig. 4). Between October 1995 and October 1998, observed water levels in well HO-114 fluctuated from a high of 29.5 feet below land surface in January 1997 to a low of 36.9 feet below land surface in November 1997. Between October 1995 and October 1998, an upward or downward trend in water levels in well HO-114 was not apparent.

Withdrawals from the Black Creek aquifer at wells HO-116 and HO-130 began after October 1994 and January 1995, respectfully. Observed water levels in water-supply well HO-116 were less than 1 foot lower in October 1995 than in October 1994 (fig. 4). Water levels measured in water-supply well HO-130 were less than 1 foot lower between January 1995 and October 1995 (fig. 4). From October 1995 through October 1998, water levels observed in well HO-116 fluctuated from a low of 21.2 feet below land surface in September 1997 to a high of 10.1 feet below land surface in February 1998. During this same period, water levels measured in well HO-130 fluctuated between a high of 41.4 feet below land surface in February 1998 and a low of 46.5 feet below land surface in June 1998. Between October 1995 and October 1998, no rising or falling trend in water levels in wells HO-116 and HO-130 was apparent.

Well SC-106 is located near a public water-supply well in Wagram in Scotland County (pl. 1). Between December 1993 and October 1998, water levels measured in well SC-106, which is rarely pumped, fluctuated from a low of 15.1 feet below land surface in November 1997 to a high of 6.9 feet below land surface in February 1998 (fig. 4). No apparent trend in water-level rise or decline in well SC-106 was evident during this period of record.

Well BL-197, which is rarely pumped, is located near a public water-supply well at the western edge of White Lake in Bladen County (pl. 1). Between August 1996 and November 1998, water levels measured in well BL-197 fluctuated between a low of 35.6 feet below land surface in September 1997 and a high of 27.3 feet below land surface in March 1998 (fig. 4). Water-level fluctuations in well BL-197 seem to reflect the effects of seasonal pumping from the Black Creek aquifer in order to meet the increased demand for water in the White Lake area during the summer months.

Hydrographs for two observation wells that are located near pumping centers (wells RB-264 and HO-47) are shown in figure 4. Observation well RB-264 is located near the southern edge of a well field 3 miles north of Maxton in western Robeson County (area A, pl. 1). Withdrawals from the Black Creek aquifer, such as occurred in August 1997 (fig. 7; Myron Neville, written commun., 1999), caused water levels in well RB-264 to fluctuate from more than 1 to 2 feet over time intervals of about 1 week. The approximate 2- to 5-foot changes in water levels recorded over 6 to 8 months are seasonal fluctuations (fig. 4).

Observation well HO-47 is located near water-supply wells in and around the northwestern part of

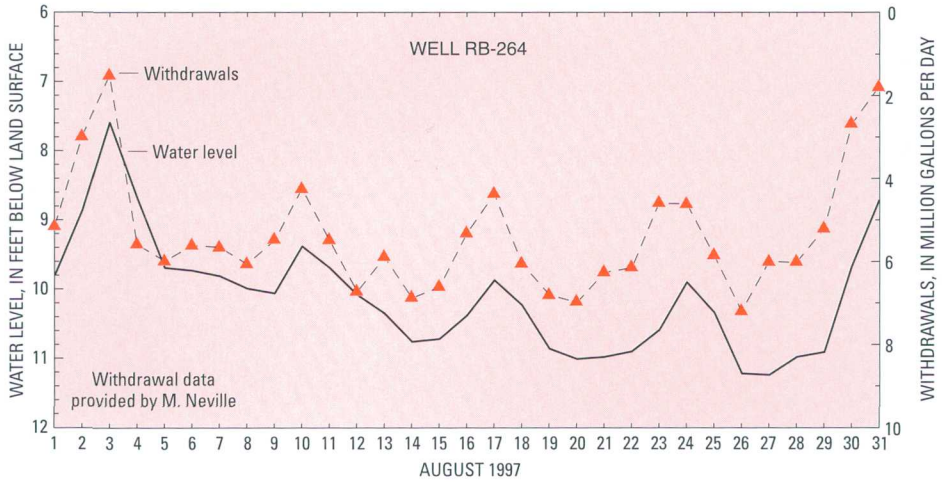

Figure 7. Water level in well RB-264 and withdrawals from the Black Creek aquifer near Maxton, Robeson County, August 1997.

Raeford in Hoke County (pl. 1). Water-level fluctuations in well HO-47 (fig. 4) have a pattern similar to that of well RB-264. The steep water-level declines and rises of about 1 to 2 feet that occurred in 4- to 5-day intervals, such as in August 1997 (fig. 8), probably were caused by pumping at nearby wells. The approximate 2- to 5-foot changes in water levels recorded over 5 to 9 months are seasonal fluctuations (fig. 4). The overall rise in water levels at observation well HO-47 from October 1993 through December 1998 indicates that recharge to the Black Creek aquifer exceeded discharge.

Hydrographs for other wells located at major pumping centers are shown in figure 4. This includes public water-supply wells HO-37 and HO-62 in the Raeford area, observation well RB-202 at Lumberton in Robeson County, and public water-supply wells SC-68, SC-69, and SC-90 in Laurinburg in Scotland County.

Well HO-37 is located in the southern part of Raeford (pl. 1). From November 1993 through October 1998, water levels measured in well HO-37 fluctuated from a high of 20.8 feet below land surface in January 1997 to a low of 35 feet below land surface in June 1998 (fig. 4). The water level measured in well HO-37 was 6 feet higher in December 1995 than in November 1993. From December 1995 through February 1998, water levels observed in well HO-37 exceeded the level

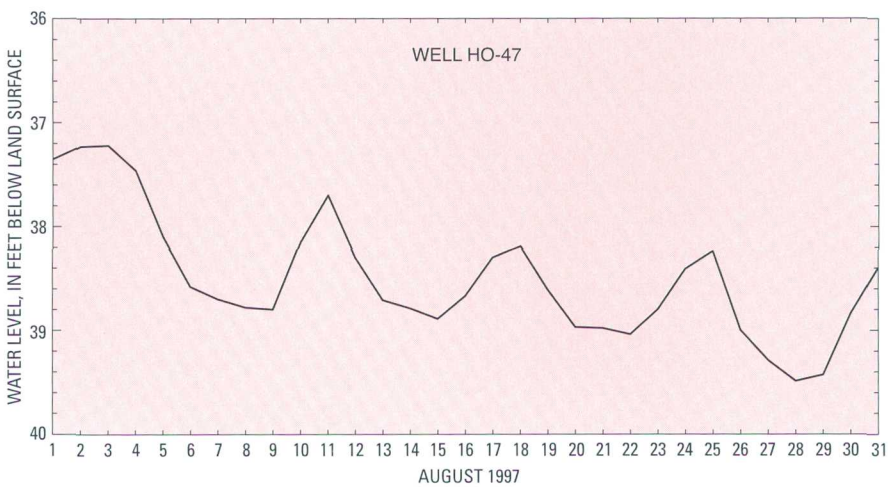

Figure 8. Water level in well HO-47 in Raeford, Hoke County, August 1997.

measured in November 1993. However, water levels measured in this public water-supply well in June and October 1998 were lower than the level measured in November 1993 and were the two lowest levels measured during the period of record. Insufficient data are available to determine water-level trends in well HO-37 prior to 1995, but from January 1997 through October 1998, a downward trend in water level occurred.

Well HO-62 is located on the western edge of the pumping center in the Raeford area (pl. 1). Water-level fluctuations in public water-supply well HO-62 have a pattern similar to that of well HO-37 (fig. 4). From November 1993 through October 1998, water levels measured in well HO-62 fluctuated from a high of 23.4 feet below land surface in March 1996 to a low of 41.8 feet below land surface in June 1998. The water level observed in well HO-62 was 4.4 feet higher in December 1995 than in November 1993. From March 1996 through October 1998, however, a general downward trend in water levels has been observed in well HO-62.

Observation well RB-202 is located near several pumped public water-supply wells in Lumberton (pl. 1). From October 1992 through November 1998, water levels measured in well RB-202 fluctuated from a high of 20.5 feet below land surface in March 1998 to a low of 33.7 feet below land surface in September 1998 (fig. 4). Although water levels observed in September and November 1998 were the two lowest measured between October 1992 and November 1998, a definite upward or downward trend in water levels in well RB-202 was not apparent.

Well SC-68 is located in Laurinburg at the northeastern end of a line of public water-supply wells that trend from the southwest to the northeast (pl. 1). From October 1993 through October 1998, water levels measured in this public water-supply well fluctuated between a low of 18.7 feet below land surface in October 1993 and a high of 7.6 feet below land surface in February 1998 (fig. 4). Between October 1993 and October 1998, no apparent trend in rising or falling water levels in well SC-68 was observed.

Well SC-69 is located in Laurinburg near the northeastern end of the line of wells (pl. 1). Between October 1993 and October 1998, water levels measured in public water-supply well SC-69 fluctuated between a low of 29.8 feet below land surface in October 1993 and a high of 16.8 feet below land surface in February 1998 (fig. 4). Between October 1993 and October 1998, water levels observed in well SC-69 indicate a slightly upward trend.

Public water-supply well SC-90 is located at the southwestern end of the line of water-supply wells in Laurinburg (pl. 1). Water levels measured in well SC-90 declined 30.8 feet between December 1993 and October 1998 (fig. 4). Withdrawals from the Black Creek aquifer at well SC-90 began in March 1995. Observed water levels were 30.3 feet lower in October 1995 than in August 1994. During this period, much of the water-level decline was likely the result of this pumping. Between October 1995 and October 1998, observed water levels fluctuated from a low of 56.9 feet below land surface in June 1996 to a high of 45.1 feet below land surface in February 1998.

Pumping also has resulted in water-level declines in other areas. Well RB-69, which is an unused water-supply well, is located 1.6 miles east of McDonald and 5.4 miles southwest of Lumberton in Robeson County (pl. 1). Water levels observed in well RB-69 declined 4.2 feet between October 1992 and November 1998 (fig. 4). Water-level decline in well RB-69 seems to be the result of regional pumping, possibly in the Lumberton area.

At Rowland in southwestern Robeson County (pl. 1), water levels in the Black Creek aquifer declined 4 feet in observation well RB-148 between October 1992 and November 1998 (fig. 4). Local pumping, as well as withdrawals by several users in South Carolina, likely have resulted in the water-level decline observed in well RB-148.

Near Tar Heel in Bladen County, water levels measured in well BL-153, which is screened in the Black Creek aquifer, declined 20.3 feet between September 1992 and November 1998 (fig. 4; pl. 1). The greatest decline, 9.2 feet, occurred between February and October 1995. Well BL-153 is located near the center of a well field where major withdrawals began from the upper Cape Fear aquifer, which is below the Black Creek aquifer, in mid-October 1992. Initially, the water-level decline in well BL-153 likely was in response to ground-water leakage from the Black Creek aquifer through the confining unit and into the heavily pumped upper Cape Fear aquifer (Strickland, 1996). From February 1995 through November 1998, however, increased pumping from the Black Creek aquifer near and at well BL-153 contributed substantially to the water-level decline observed in well BL-153. Additional detailed study is needed to determine the extent that pumping from the Black

Creek and upper Cape Fear aquifers has on water-level declines in the Black Creek aquifer in the Tar Heel area.

Three observation wells located about 4 miles east of Lumberton in Robeson County (fig. 5; pl. 1) tap different zones of the Black Creek and upper Cape Fear aquifers. Two of the wells, RB-184 and RB-185, are screened in different zones of the Black Creek aquifer, and the third well, RB-183, is screened near the top of the upper Cape Fear aquifer. Observation well RB-185 is completed in the upper zone of the Black Creek aquifer, which is the same zone in which most surrounding water-supply wells also are completed. Observation well RB-184 is screened in the lower zone of the aquifer. Winner and Coble (1996) determined the thickness of the Black Creek aquifer to be about 250 feet at these wells.

From September 1992 through December 1998, water-level fluctuations in well RB-185, which taps the upper part of the Black Creek aquifer, seem to be the result of nearby pumping and seasonal variations (fig. 5). Between May 1993 and May 1995, water levels in well RB-185 declined about 11 feet, which was attributed to increased local pumping from the aquifer. Between June 1995 and March 1997, however, water levels in well RB-185 rose 17 feet, which was in response to a reduction in nearby pumping that began in late May 1995. From March 1997 through December 1998, water-level fluctuations of about 6 feet may have been a seasonal response with little influence from local pumping.

Water levels fluctuated differently in the lower zone of the Black Creek aquifer compared to water levels in the upper zone. The hydrograph for well RB-184 illustrates a slightly downward trend in water levels between September 1992 and November 1998. During this period, water levels measured in well RB-184 declined 4.7 feet (fig. 5). Correspondingly during this period, water levels in well RB-183 declined 35.4 feet, which was caused by major withdrawals from the upper Cape Fear aquifer (fig. 5; Strickland, 1995, 1999). The data suggest that ground-water leakage is occurring from the lower part of the Black Creek aquifer through the confining unit and into the upper Cape Fear aquifer.

Potentiometric-Surface Map, Fall 1998

The potentiometric surface of the Black Creek aquifer throughout the mapped area in Hoke, Robeson, and Scotland Counties and in parts of Bladen County is shown in plate 1. Ground water flows from areas of high hydraulic head to areas of low hydraulic head. The bending of potentiometric contours upstream indicates that ground water is discharging from the Black Creek aquifer to the streams.

In the highly dissected Sand Hills area, the aquifer is unconfined in valleys where streams have cut through the Black Creek confining unit (Winner and Coble, 1996). The orientation of the potentiometric contours, which are closely spaced in the valleys, is strongly influenced by topography. The natural ground-water flow system has changed little in the Sand Hills area since measurements were made in the fall of 1993 (Strickland, 1996), or in most areas away from pumping centers in Bladen, Hoke, Robeson, and Scotland Counties (Strickland, 1994, 1996).

In Bladen County, between the Cumberland-Bladen County line and Elizabethtown, the Cape Fear River channel cuts through the Black Creek confining unit, which provides direct hydraulic connection between the river and the Black Creek aquifer (Winner and Coble, 1996). The closely spaced potentiometric contours along the Cape Fear River indicate a steep horizontal gradient and ground-water discharge to the river.

In the Tar Heel area of Bladen County, the natural ground-water flow system has been altered by increased withdrawals from the Black Creek aquifer from 1995 through 1998. These withdrawals have lowered the potentiometric surface, resulting in a shift of the potentiometric contours since 1992 to the southwest toward the pumped wells (Strickland, 1994, 1996).

The natural ground-water flow also has been altered around pumping centers in the Elizabethtown and Lumberton areas. Withdrawals from wells in these areas have resulted in substantial cones of depression in the potentiometric surface of the Black Creek aquifer.

Most wells at pumping centers in the Elizabethtown area tap the Black Creek, upper Cape Fear, and lower Cape Fear aquifers. During 1998, withdrawals from these aquifers averaged about 2.8 million gallons per day in the Elizabethtown area (Earl Phillips, John Hester, and Dan Boone, oral commun., 1999). The elongated cone of depression in the potentiometric surface of the Black Creek aquifer, which is a major contributing zone to production wells in the Elizabethtown area, was about 5 miles long in fall 1998.

Ground-water withdrawals have resulted in a cone of depression beneath the Lumberton area. The cone of depression extended about 7 miles along its major axis and covered over 30 square miles in fall 1998. Two major pumping centers account for much of the water withdrawn from the Black Creek aquifer in the Lumberton area. The combined withdrawals averaged about 4.3 million gallons per day during 1998 (Jeff Musselwhite and Johnny Strickland, oral commun., 1999).

The natural ground-water flow also has been disrupted near Rowland in southwestern Robeson County. Withdrawals by several users in South Carolina have caused a regional cone of depression to develop, which has extended into North Carolina near Rowland.

At Laurinburg in Scotland County, withdrawals from the Black Creek aquifer averaged 3 million gallons per day during 1998 (Robert Ellis, written commun., 1999). The effects of these withdrawals on the potentiometric surface were not substantial enough to be mapped at the 10- or 20-foot contour interval for most of the Laurinburg area. Near the southwestern edge of Laurinburg, however, withdrawals from the aquifer at well SC-90 since March 1995 have resulted in a small cone of depression.

The effects of pumping on the potentiometric surface at other major pumping centers also were not substantial enough to be mapped at the 10- or 20-foot contour interval. These included pumping centers in Raeford in Hoke County, in western Robeson County (area A, pl. 1), and east of Laurinburg in Scotland County (area B, pl. 1). Withdrawals at these pumping centers averaged 1.76 million gallons per day (David Carroll, oral commun., 1998), 5.2 million gallons per day (Myron Neville, written commun., 1999), and 1.45 million gallons per day (Larry Barnett, oral commun., 1999), respectively, during 1998.

In the mapped part of southwestern Bladen County, the Black Creek aquifer is overlain by the Peedee aquifer and the Black Creek confining unit. Most water in this part of the Black Creek aquifer does not discharge to local streams, but rather flows southeastward toward the coast or is discharged from pumped wells, such as those in Clarkton.

REFERENCES CITED

North Carolina Department of Natural Resources and Community Development, 1985, Geologic map of North Carolina, 1985: Raleigh, North Carolina Department of Natural Resources and Community Development, 1 sheet, Scale 1:500,000.

Schipf, R.G., 1961, Geology and ground-water resources of the Fayetteville area: Raleigh, North Carolina Department of Water Resources, Division of Ground Water, Ground-Water Bulletin Number 3, 99 p.

Strickland, A.G., 1994, Water-level conditions in the Black Creek and upper Cape Fear aquifers, 1992, in parts of Bladen and Robeson Counties, North Carolina: U.S. Geological Survey Water-Resources Investigations Report 94-4016, 1 sheet.

———1995, Water-level conditions in the upper Cape Fear aquifer, 1992–94, in parts of Bladen and Robeson Counties, North Carolina: U.S. Geological Survey Water-Resources Investigations Report 95-4129, 1 sheet.

———1996,Water-level conditions in the Black Creek aquifer, 1992–94, in parts of Bladen, Hoke, Robeson, and Scotland Counties, North Carolina: U.S. Geological Survey Water-Resources Investigations Report 95-4283, 2 sheets.

———1999,Water-level conditions in the upper Cape Fear aquifer, 1994–98, in parts of Bladen and Robeson Counties, North Carolina: U.S. Geological Survey Water-Resources Investigations Report 99-4127, 1 sheet.

Strickland, A.G., Coble, R.W., Edwards, L.A., and Pope, B.F., 1992, Ground-water level data for North Carolina, 1988–90: U.S. Geological Survey Open-File Report 92-57, 167 p.

Stuckey, J.L., 1965, North Carolina—Its geology and mineral resources: Raleigh, North Carolina Department of Conservation and Development, 50 p.

U.S. Geological Survey, 1997–99 (published annually), Water resources data, North Carolina, water years 1996–98, v. 2, Ground-water records: U.S. Geological Survey Water-Data Report NC-___-2 [variously paged].

Winner, M.D., Jr., and Coble, R.W., 1996, Hydrogeologic framework of the North Carolina Coastal Plain: U.S. Geological Survey Professional Paper 1404-I, 106 p., 24 pls.

Table 1. Selected records for wells in the Black Creek aquifer in Bladen, Columbus, Hoke, Robeson, and Scotland Counties, North Carolina, and Dillon County, South Carolina, October and November 1998

[BL, Bladen County; CO, Columbus County; HO, Hoke County; SC, Scotland County; RB, Robeson County; DIL, Dillon County; latitude and longitude coordinates are referenced to the North American Datum of 1927]

Well number (pl. 1)	Latitude	Longitude	Altitude of land surface (feet above sea level)	Water level (feet below land surface)	Hydraulic head (reported to nearest foot above or below (-) sea level)
		North Carolina			
BL-23	34°29'38"	78°39'19"	90	29.9	60
[a]BL-27	34°31'46"	78°47'57"	117	12.2	105
BL-56	34°40'45"	78°35'44"	72	20.4	52
[a]BL-79	34°29'11"	78°39'39"	92	20.1	72
BL-98	34°43'33"	78°47'29"	125	33.3	92
[b]BL-106	34°39'17"	78°31'02"	70	38.9	31
BL-132	34°45'24"	78°48'24"	130	65.8	64
BL-143	34°45'05"	78°44'03"	85	18.2	67
BL-146	34°38'23"	78°44'22"	139.8	26.3	114
BL-151	34°45'39"	78°48'12"	142	83.0	59
BL-153	34°44'30"	78°48'18"	128	70.4	58
BL-154	34°48'57"	78°50'34"	125	21.5	104
BL-160	34°41'12"	78°47'49"	130	25.9	104
BL-162	34°49'11"	78°48'11"	75	26.7	48
BL-167	34°37'22"	78°43'06"	126	18.0	108
BL-168	34°38'51"	78°47'37"	125	17.1	108
BL-169	34°42'32"	78°49'14"	131	16.2	115
BL-171	34°43'06"	78°45'06"	150	108.2	42
BL-173	34°31'33"	78°44'45"	121	24.7	96
BL-174	34°35'49"	78°44'02"	125	18.3	107
BL-178	34°31'20"	78°37'00"	116	36.6	79
BL-181	34°35'21"	78°40'29"	125	22.6	102
BL-183	34°28'56"	78°42'46"	125	43.6	81
BL-184	34°32'38"	78°51'02"	106	10.0	96
BL-185	34°29'03"	78°49'57"	106	6.9	99
BL-186	34°36'03"	78°48'27"	120	10.4	110
BL-195	34°44'14"	78°47'46"	132	53.4	79
BL-196	34°36'33"	78°36'16"	117	83.7	33
BL-197	34°39'15"	78°31'13"	69	31.1	38
BL-198	34°37'33"	78°34'37"	35	18.2	17
[b]BL-199	34°50'05"	78°44'00"	113	42.5	70
BL-202	34°36'02"	78°37'23"	123	38.9	84
BL-203	34°47'57"	78°49'04"	136	83.5	52
BL-205	34°47'19"	78°43'37"	80	11.3	69
BL-206	34°38'00"	78°42'09"	130	31.3	99
BL-207	34°39'42"	78°44'53"	140	23.8	116
BL-208	34°45'23"	78°46'47"	67	18.2	49
BL-209	34°48'02"	78°48'40"	52	6.0	46
BL-210	34°38'36"	78°38'07"	111	132.5	-22
BL-211	34°38'42"	78°35'45"	50	30.2	20
BL-212	34°36'52"	78°36'22"	85	57.3	28
BL-213	34°44'10"	78°49'51"	140	29.2	111

Table 1. Selected records for wells in the Black Creek aquifer in Bladen, Columbus, Hoke, Robeson, and Scotland Counties, North Carolina, and Dillon County, South Carolina, October and November 1998—Continued

[BL, Bladen County; CO, Columbus County; HO, Hoke County; SC, Scotland County; RB, Robeson County; DIL, Dillon County; latitude and longitude coordinates are referenced to the North American Datum of 1927]

Well number (pl. 1)	Latitude	Longitude	Altitude of land surface (feet above sea level)	Water level (feet below land surface)	Hydraulic head (reported to nearest foot above or below (-) sea level)
		North Carolina (Continued)			
BL-214	34°42'04"	78°40'29"	63	13.7	49
BL-215	34°41'17"	78°43'04"	145	57.8	87
BL-216	34°37'42"	78°37'21"	124	67.7	56
BL-217	34°36'06"	78°34'11"	127	85.1	42
BL-218	34°37'03"	78°36'09"	108	79.6	28
BL-219	34°38'53"	78°41'45"	125	35.8	89
BL-220	34°44'58"	78°48'03"	129	70.6	58
BL-222	34°32'41"	78°48'15"	118	14.8	103
CO-88	34°18'41"	79°01'47"	64	9.4	55
CO-125	34°25'07"	78°36'10"	105.8	36.5	69
CO-148	34°28'25"	78°51'15"	104	7.2	97
HO-32	35°03'17"	79°21'35"	350	1.3	349
HO-35	34°58'20"	79°14'12"	251	25.7	225
HO-36	34°59'00"	79°14'16"	276	46.7	229
HO-37	34°58'07"	79°13'42"	248	32.7	215
HO-38	34°58'15"	79°13'48"	248	29.5	218
HO-40	34°59'15"	79°14'43"	290	61.3	229
HO-47	34°59'34"	79°14'42"	274.4	38.4	236
HO-48	34°56'52"	79°07'40"	225	15.1	210
HO-51	34°59'03"	79°16'08"	295.2	26.6	269
HO-52	34°58'41"	79°15'35"	277.3	43.2	234
HO-53	34°58'40"	79°16'07"	286.3	48.5	238
HO-54	34°52'39"	79°17'10"	241	13.0	228
HO-55	34°57'27"	79°02'24"	175	32.2	143
HO-60	34°58'58"	79°14'33"	270	43.1	227
HO-61	34°59'08"	79°16'49"	296.2	28.4	268
HO-62	34°58'46"	79°16'55"	284	34.2	250
HO-64	34°58'18"	79°15'26"	268	22.8	245
HO-65	34°59'11"	79°14'21"	281	47.1	234
HO-66	34°58'39"	79°11'45"	190	19.4	171
HO-70	34°59'40"	79°19'29"	354	62.4	292
HO-72	34°52'33"	79°13'19"	225	16.9	208
HO-75	34°54'03"	79°14'55"	233	15.9	217
HO-76	34°56'09"	79°20'43"	265	28.8	236
HO-77	34°58'33"	79°19'49"	341	51.1	290
HO-78	34°59'19"	79°11'44"	223	33.6	189
HO-79	34°53'26"	79°10'42"	218	14.6	203
HO-80	34°59'33"	79°12'14"	234	42.7	191
HO-81	34°59'28"	79°11'56"	237	44.5	192
HO-82	34°56'37"	79°15'17"	232	3.5	228
HO-83	34°57'22"	79°02'57"	190	43.1	147

Table 1. Selected records for wells in the Black Creek aquifer in Bladen, Columbus, Hoke, Robeson, and Scotland Counties, North Carolina, and Dillon County, South Carolina, October and November 1998—Continued

[BL, Bladen County; CO, Columbus County; HO, Hoke County; SC, Scotland County; RB, Robeson County; DIL, Dillon County; latitude and longitude coordinates are referenced to the North American Datum of 1927]

Well number (pl. 1)	Latitude	Longitude	Altitude of land surface (feet above sea level)	Water level (feet below land surface)	Hydraulic head (reported to nearest foot above or below (-) sea level)
		North Carolina (Continued)			
HO-84	34°57'57"	79°22'04"	254	22.4	232
HO-85	34°57'54"	79°21'56"	240	9.2	231
HO-86	34°59'14"	79°21'30"	316	29.9	286
HO-87	34°59'52"	79°08'39"	224	38.6	185
HO-88	35°00'00"	79°08'31"	210	23.8	186
HO-90	35°01'11"	79°07'50"	175	4.3	171
HO-92	35°01'16"	79°09'19"	250	19.2	231
HO-93	35°01'09"	79°08'11"	242	27.8	214
HO-95	35°01'12"	79°06'54"	250	35.6	214
HO-96	35°00'04"	79°06'33"	242	47.3	195
HO-97	35°02'44"	79°06'48"	271	42.8	228
HO-100	35°02'49"	79°07'10"	274	38.4	236
HO-101	34°59'22"	79°04'10"	220	31.7	188
HO-102	34°59'23"	79°04'02"	200	14.9	185
HO-103	35°03'33"	79°22'55"	391	51.6	339
HO-104	35°01'26"	79°22'02"	342	34.7	307
HO-107	35°02'12"	79°18'03"	347	52.5	294
HO-108	35°01'43"	79°22'16"	291	13.2	278
HO-109	34°59'41"	79°05'49"	224	27.2	197
HO-111	34°52'53"	79°12'30"	233	25.4	208
HO-113	35°00'55"	79°11'16"	283	40.9	242
HO-114	35°02'10"	79°06'45"	262	30.6	231
HO-115	35°02'19"	79°06'56"	273	49.0	224
HO-116	34°56'49"	79°07'49"	225	20.0	205
HO-117	34°57'18"	79°02'23"	130	6.2	124
HO-118	34°59'46"	79°14'43"	276	42.8	233
HO-119	34°59'58"	79°15'00"	272	53.3	219
HO-121	34°59'36"	79°11'01"	259	28.3	231
HO-122	34°59'02"	79°10'48"	236	32.8	203
HO-123	34°59'11"	79°10'13"	245	37.9	207
HO-125	35°02'40"	79°08'20"	251	33.7	217
HO-126	34°58'33"	79°07'06"	173	16.7	156
HO-128	34°58'37"	79°07'10"	200	45.5	154
HO-129	34°57'00"	79°02'33"	136	7.4	129
HO-130	35°01'40"	79°10'16"	291	42.6	248
HO-132	35°01'38"	79°07'46"	241	31.9	209
HO-133	34°59'06"	79°15'44"	302	50.5	252
HO-134	34°55'32"	79°09'06"	228	16.5	212
HO-135	34°57'59"	79°12'28"	248	25.7	222
HO-136	34°55'18"	79°07'14"	220	17.9	202
RB-29	34°38'07"	79°14'49"	163	16.7	146
RB-69	34°33'23"	79°08'36"	138	28.8	109

Table 1. Selected records for wells in the Black Creek aquifer in Bladen, Columbus, Hoke, Robeson, and Scotland Counties, North Carolina, and Dillon County, South Carolina, October and November 1998—Continued

[BL, Bladen County; CO, Columbus County; HO, Hoke County; SC, Scotland County; RB, Robeson County; DIL, Dillon County; latitude and longitude coordinates are referenced to the North American Datum of 1927]

Well number (pl. 1)	Latitude	Longitude	Altitude of land surface (feet above sea level)	Water level (feet below land surface)	Hydraulic head (reported to nearest foot above or below (-) sea level)
		North Carolina (Continued)			
RB-83	34°29'50"	79°06'38"	118	38.8	79
RB-84	34°32'32"	79°17'38"	150	41.6	108
RB-87	34°40'52"	79°11'42"	172	14.2	158
[b]RB-90	34°48'17"	78°58'20"	165	18.7	146
[b]RB-92	34°48'29"	78°59'07"	175	24.1	151
RB-97	34°35'31"	79°00'13"	108	67.2	41
RB-100	34°35'27"	79°00'03"	108	68.6	39
RB-106	34°39'08"	79°25'24"	166	18.2	148
RB-108	34°46'23"	79°19'45"	190	11.6	178
RB-115	34°33'56"	78°59'39"	114	48.0	66
RB-116	34°52'33"	78°58'40"	180	22.8	157
RB-117	34°47'55"	78°56'18"	158	17.6	140
RB-119	34°35'53"	79°12'15"	150	25.7	124
RB-121	34°40'46"	79°10'56"	167	12.5	154
RB-122	34°29'19"	79°02'52"	126	32.5	94
RB-123	34°30'40"	79°08'16"	130	33.5	96
RB-124	34°26'38"	79°04'44"	129	38.4	91
RB-127	34°35'35"	78°55'29"	135	49.1	86
RB-130	34°36'08"	79°05'51"	129.6	20.5	109
RB-134	34°48'45"	79°12'38"	205	13.8	191
RB-139	34°22'23"	79°07'39"	90.6	15.9	75
RB-148	34°31'55"	79°17'47"	143.2	42.1	101
RB-157	34°42'35"	79°00'07"	149.4	6.8	143
RB-161	34°30'31"	79°07'08"	129	38.5	90
RB-162	34°40'46"	79°14'13"	158	-0.3	158
RB-165	34°52'18"	79°05'52"	201	16.2	185
RB-168	34°50'35"	79°05'16"	187.3	6.9	180
RB-174	34°54'29"	79°00'24"	184	10.2	174
RB-185	34°38'40"	78°54'58"	142	26.5	116
RB-195	34°37'50"	79°01'41"	110	37.8	72
RB-197	34°37'49"	79°01'54"	107	39.5	68
RB-199	34°37'55"	79°02'01"	117	34.7	82
RB-202	34°37'57"	79°01'57"	115	32.7	82
RB-205	34°46'52"	79°18'23"	212	23.0	189
RB-206	34°46'28"	79°18'01"	203	11.0	192
RB-207	34°39'28"	79°04'14"	122	1.7	120
RB-208	34°39'50"	79°05'53"	148	14.1	134
RB-209	34°39'32"	79°06'31"	152	17.9	134
RB-210	34°39'22"	79°05'50"	150	17.8	132
RB-213	34°41'19"	79°03'54"	147	18.5	128
RB-215	34°39'22"	79°03'43"	124	7.4	117
RB-216	34°40'44"	79°07'27"	158	10.3	148

Table 1. Selected records for wells in the Black Creek aquifer in Bladen, Columbus, Hoke, Robeson, and Scotland Counties, North Carolina, and Dillon County, South Carolina, October and November 1998—Continued

[BL, Bladen County; CO, Columbus County; HO, Hoke County; SC, Scotland County; RB, Robeson County; DIL, Dillon County; latitude and longitude coordinates are referenced to the North American Datum of 1927]

Well number (pl. 1)	Latitude	Longitude	Altitude of land surface (feet above sea level)	Water level (feet below land surface)	Hydraulic head (reported to nearest foot above or below (-) sea level)
North Carolina (Continued)					
RB-217	34°46'10"	78°55'05"	160	19.3	141
RB-222	34°44'45"	78°57'29"	150	12.8	137
RB-226	34°35'16"	78°58'26"	132	68.6	63
RB-228	34°35'21"	78°58'38"	140	82.0	58
RB-232	34°38'01"	79°02'13"	116	32.2	84
RB-235	34°37'36"	79°01'17"	112	47.3	65
RB-236	34°37'25"	79°01'03"	110	47.5	62
RB-237	34°37'24"	79°00'57"	110	45.0	65
RB-238	34°36'23"	79°05'45"	127	20.9	106
RB-240	34°39'27"	78°55'11"	152	42.5	110
RB-241	34°48'03"	78°54'06"	139	13.3	125
RB-242	34°48'09"	78°53'44"	133	19.1	114
RB-243	34°48'22"	78°53'49"	136	15.3	121
RB-244	34°48'12"	78°53'55"	132	11.6	120
RB-245	34°36'46"	79°00'03"	114	54.6	59
RB-246	34°46'41"	79°19'50"	190	12.4	178
RB-247	34°46'44"	79°19'37"	194	13.1	181
RB-248	34°46'57"	79°19'39"	193	13.8	179
RB-249	34°47'08"	79°19'48"	194	16.8	177
RB-250	34°28'03"	79°12'14"	152	61.6	90
RB-251	34°52'39"	79°05'22"	200	19.5	180
RB-253	34°53'13"	79°00'54"	178	11.8	166
RB-255	34°48'22"	79°11'36"	204	16.2	188
RB-256	34°48'24"	79°11'48"	203	15.7	187
RB-257	34°37'42"	79°22'15"	150	17.9	132
RB-258	34°37'29"	79°23'11"	160	27.5	132
RB-264	34°46'21"	79°19'24"	195	9.0	186
RB-265	34°56'50"	79°02'33"	144	9.5	134
RB-266	34°30'19"	79°18'19"	131	40.9	90
RB-267	34°34'49"	79°09'34"	148	26.9	121
RB-269	34°35'14"	79°19'13"	136	12.0	124
RB-270	34°33'27"	79°01'52"	123	41.2	82
RB-273	34°33'28"	79°15'03"	115	2.0	113
RB-275	34°23'32"	79°02'22"	114	36.4	78
RB-278	34°35'34"	79°07'40"	142	23.8	118
RB-279	34°28'42"	79°05'40"	115	23.1	92
RB-280	34°27'55"	79°00'40"	106	17.6	88
RB-282	34°23'29"	79°00'23"	115	38.4	77
RB-285	34°34'10"	78°53'25"	106	10.3	96
RB-286	34°27'46"	79°05'49"	95	-0.6	96
RB-288	34°26'34"	79°10'11"	106	23.8	82
RB-290	34°32'19"	79°14'07"	125	18.8	106

Table 1. Selected records for wells in the Black Creek aquifer in Bladen, Columbus, Hoke, Robeson, and Scotland Counties, North Carolina, and Dillon County, South Carolina, October and November 1998—Continued

[BL, Bladen County; CO, Columbus County; HO, Hoke County; SC, Scotland County; RB, Robeson County; DIL, Dillon County; latitude and longitude coordinates are referenced to the North American Datum of 1927]

Well number (pl. 1)	Latitude	Longitude	Altitude of land surface (feet above sea level)	Water level (feet below land surface)	Hydraulic head (reported to nearest foot above or below (-) sea level)
North Carolina (Continued)					
RB-291	34°25'48"	79°11'48"	124	36.4	88
RB-293	34°30'07"	79°12'47"	125	27.0	98
RB-294	34°28'44"	79°10'49"	118	23.1	95
RB-296	34°21'40"	79°05'00"	85	22.5	62
RB-299	34°36'54"	79°21'48"	159	28.8	130
RB-301	34°32'03"	78°59'12"	120	30.2	90
RB-302	34°35'07"	79°14'27"	146	23.4	123
RB-303	34°44'21"	79°21'05"	196	18.0	178
RB-305	34°37'34"	79°04'29"	130	24.5	106
RB-306	34°33'31"	79°21'09"	146	36.9	109
RB-307	34°43'34"	79°18'45"	176	7.0	169
RB-308	34°41'28"	79°23'29"	180	15.2	165
RB-310	34°42'33"	79°04'28"	135	-2.0	137
RB-311	34°46'09"	79°07'01"	185	19.3	166
RB-312	34°38'39"	79°00'22"	126	18.8	107
RB-313	34°45'00"	79°02'34"	166	9.5	156
RB-314	34°48'25"	79°20'51"	202	10.0	192
RB-315	34°28'15"	79°12'57"	150	57.0	93
RB-316	34°31'32"	78°52'39"	96	6.4	90
RB-317	34°25'57"	79°12'57"	121	37.8	83
RB-318	34°36'37"	78°59'43"	115	56.5	58
RB-319	34°46'55"	79°18'35"	210	21.9	188
RB-320	34°47'31"	79°20'00"	200	16.2	184
RB-322	34°49'52"	79°01'11"	176	13.0	163
RB-323	34°35'12"	79°03'03"	125	51.4	74
RB-324	34°35'13"	79°00'08"	108	68.9	39
SC-40	34°45'17"	79°28'03"	210	16.6	193
SC-63	34°53'32"	79°26'45"	275	29.6	245
SC-64	34°54'30"	79°25'01"	276	9.2	267
SC-65	34°44'27"	79°30'41"	190	8.8	181
SC-68	34°45'21"	79°27'37"	215	18.1	197
SC-69	34°44'59"	79°28'03"	212	26.4	186
SC-70	34°42'37"	79°24'52"	190	18.9	171
SC-73	34°45'39"	79°35'53"	252	30.3	222
SC-74	34°46'41"	79°25'10"	210	8.7	201
SC-77	34°43'02"	79°23'46"	187	12.3	175
SC-84	34°45'51"	79°36'31"	251	29.4	222
SC-85	34°44'49"	79°28'16"	206	20.2	186
SC-86	34°44'33"	79°28'32"	205	23.1	182
SC-87	34°44'18"	79°28'47"	211	23.0	188
SC-88	34°44'08"	79°29'12"	207	18.2	189
SC-89	34°44'51"	79°28'39"	205	17.2	188

Table 1. Selected records for wells in the Black Creek aquifer in Bladen, Columbus, Hoke, Robeson, and Scotland Counties, North Carolina, and Dillon County, South Carolina, October and November 1998—Continued

[BL, Bladen County; CO, Columbus County; HO, Hoke County; SC, Scotland County; RB, Robeson County; DIL, Dillon County; latitude and longitude coordinates are referenced to the North American Datum of 1927]

Well number (pl. 1)	Latitude	Longitude	Altitude of land surface (feet above sea level)	Water level (feet below land surface)	Hydraulic head (reported to nearest foot above or below (-) sea level)
North Carolina (Continued)					
SC-90	34°43'43"	79°29'17"	203	51.8	151
SC-92	34°50'14"	79°30'27"	251	21.6	229
SC-94	34°49'20"	79°31'29"	250	36.0	214
SC-96	34°41'22"	79°31'43"	204	34.3	170
SC-97	34°49'13"	79°31'49"	200	4.6	195
SC-98	34°41'50"	79°29'08"	195	16.0	179
SC-99	34°49'13"	79°25'08"	197	3.6	193
SC-100	34°52'06"	79°24'27"	230	5.1	225
SC-101	34°52'30"	79°25'17"	250	18.2	232
SC-103	34°57'13"	79°26'47"	360	41.3	319
SC-104	34°57'23"	79°26'11"	365	50.6	314
SC-106	34°53'13"	79°22'09"	235	15.0	220
SC-107	34°53'12"	79°22'21"	235	15.6	219
SC-108	34°46'43"	79°29'12"	230	14.2	216
SC-110	34°48'19"	79°23'10"	220	25.7	194
SC-111	34°47'51"	79°24'42"	230	30.3	200
SC-112	34°52'29"	79°20'47"	220	12.2	208
SC-113	34°52'08"	79°21'06"	221	8.5	212
SC-114	34°44'27"	79°30'08"	224	22.9	201
SC-115	34°42'36"	79°33'09"	210	18.1	192
SC-116	34°48'35"	79°31'31"	227	18.2	209
SC-117	34°48'44"	79°32'42"	241	27.0	214
SC-118	34°48'20"	79°32'43"	255	42.7	212
SC-119	34°47'17"	79°21'47"	211	14.2	197
SC-121	34°46'00"	79°22'12"	212	35.2	177
SC-123	34°46'03"	79°22'25"	198	19.3	179
SC-126	34°46'14"	79°22'29"	186	18.3	168
SC-127	34°48'03"	79°22'20"	199	17.2	182
SC-128	34°45'04"	79°27'28"	212	17.1	195
SC-129	34°47'37"	79°33'44"	232	20.0	212
SC-130	34°41'36"	79°31'42"	192	14.6	177
SC-131	34°55'18"	79°27'04"	351	56.0	295
SC-132	34°50'17"	79°24'07"	239	12.4	227
SC-134	34°43'03"	79°29'29"	197	31.4	166
SC-135	34°51'11"	79°21'31"	220	8.3	212
SC-136	34°45'26"	79°23'21"	169	2.3	167
SC-137	34°45'56"	79°22'25"	210	35.2	175
South Carolina					
DIL-116	34°30'07"	79°20'38"	134	46.8	87
DIL-117	34°29'42"	79°18'30"	128	40.7	87
DIL-118	34°29'44"	79°18'16"	131	42.6	88

[a]Well screened in the Peedee and the Black Creek aquifers.

[b]Well screened in the Black Creek and the upper Cape Fear aquifers.

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