POTENTIOMETRIC SURFACE MAPS OF THE SOUTH CAROLINA COASTAL PLAIN AQUIFERS

NOVEMBER–DECEMBER 2016

STATE OF SOUTH CAROLINA
DEPARTMENT OF NATURAL RESOURCES

LAND, WATER AND
CONSERVATION DIVISION

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by

Andrew Wachob, Joseph A. Gellici, and Brooke Czwartacki

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WATER RESOURCES REPORT 60

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ABSTRACT

Water-level measurements of nearly 400 wells made primarliy during November and December 2016 were used to construct potentiometric surface maps of three Coastal Plain aquifers in South Carolina: one map of the Tertiary (Floridan and Gordon) aquifers; one of the Crouch Branch aquifer; and one of the McQueen Branch, Charleston, and Gramling aquifers. This report marks the first use by the South Carolina Department of Natural Resources of the aquifer nomenclature and hydrogeologic framework of Gellici and Lautier (2010), rather than that of Aucott and others (1987), for its potentiometric maps. In addition to providing well information, water-level data, and discussions about each potentiometric map, this report includes a brief description of this newer framework and its correlation to the older framework.

The 2016 Floridan-Gordon potentiometric surface map indicates a generally southeastward groundwater flow, with potentiometric elevations ranging from 282 ft (feet) in Barnwell County to -52 ft in southern Jasper County. Along the coast, water levels in the Gordon aquifer were slightly above sea level in northern Charleston County, but lower than -20 ft in most of southern Charleston County. No cones of depression are seen within South Carolina on this map, but the widespread potentiometric low caused by groundwater pumping in the Savannah, Georgia area continues to impact water levels and the groundwater flow direction in southern Beaufort and Jasper Counties.

The 2016 Crouch Branch potentiometric surface map shows a generally southeastward groundwater flow affected by potentiometric lows in the eastern half of the State. The most prominent feature on the 2016 map is a large cone of depression centered in Georgetown County, and water-level declines are also seen in the Myrtle Beach area of Horry County. Comparing the 2016 Crouch Branch potentiometric surface to the predevelopment water levels suggests that, in much of eastern South Carolina, water levels in this aquifer are about 50 to 100 ft below predevelopment levels, and in southern Georgetown County, the water level decline exceeds 200 ft.

The 2016 McQueen Branch-Charleston-Gramling potentiometric surface map shows a generally southeastward groundwater flow affected by potentiometric lows in Williamsburg, Charleston, and Georgetown Counties. Potentiometric levels range from more than 450 ft near the Fall Line to -136 ft in Georgetown County. A cone of depression centered at Mount Pleasant in Charleston County has not deepened since 2014, but appears to be expanding inland; water levels in two Mount Pleasant wells were more than 25 ft lower in 2016 than in 2014. Because the significant cone of depression in Georgetown County is defined by only one water-level measurement, its true magnitude and extent are largely unknown. Comparing the 2016 McQueen Branch potentiometric surface to predevelopment water levels suggests that, downdip from the recharge areas and outside of the western edge of the aquifer, water levels throughout much of this aquifer have declined 50 to 100 ft below predevelopment levels, and in parts of Charleston and Georgetown Counties, more than 200 ft.

INTRODUCTION

Background

The Coastal Plain province of South Carolina, which encompasses roughly the southeastern two-thirds of the State, is characterized by a wedge of sand, clay, silt, and limestone sediments overlying the metamorphic and igneous bedrock. The inward boundary of the Coastal Plain province, at the contact with the Piedmont province, is known as the Fall Line. The sediments thicken seaward from zero at the Fall Line to more than 1,500 ft (feet) in Horry County and more than 4,000 ft in southern Jasper and Beaufort Counties. These sediments tend to occur as distinct layers of sand, clay, or limestone, all of which are saturated with water. Permeable sand and limestone layers, from which water can be relatively easily extracted, form the State's largest and most important aquifers. These aquifers serve as an important source of water for many public, industrial, agricultural, and domestic uses throughout the Coastal Plain, and in some areas, are the only significant water source available.

Although there is a vast quantity of water stored in South Carolina's Coastal Plain aquifers, and although groundwater is continually replenished by rainwater infiltrating through soils and into shallow aquifers, it is possible to overuse the resource by pumping water from an aquifer faster than it can be replenished. Overpumping can lead to a variety of local or regional problems, such as lowered water levels in wells and decreased well productivity, saltwater intrusion into aquifers along the coast, and even aquifer compaction and land subsidence.

In an effort to identify and assess existing or potential problems related to groundwater withdrawals, the South Carolina Department of Natural Resources (DNR) routinely measures the static (nonpumping) water level in wells throughout the Coastal Plain. Changes in the water level, or potentiometric level, in a well completed in an aquifer indicate changes in groundwater storage within that aquifer. To examine hydrologic conditions in an entire aquifer, water levels are measured in wells located throughout the lateral extent of the aquifer; these potentiometric levels define the potentiometric surface of that aquifer. A potentiometric map is a contour map representing the elevation of the potentiometric surface of the aquifer at some point in time.

Potentiometric maps can help identify areas of overpumping (indicated by localized depressions in the potentiometric surface) and indicate the general direction of groundwater flow (from higher to lower potentiometric levels). Comparing recent potentiometric maps to earlier potentiometric maps can reveal long-term changes in aquifer storage that result from long-term groundwater withdrawals, changes in aquifer recharge rates, or varying climatic conditions.

DNR maintains a groundwater-level monitoring network—currently including 155 dedicated Coastal Plain monitoring wells—that provides water-level information for various aquifers at numerous locations across the State. Because the number and distribution of these monitoring wells are inadequate to properly define the potentiometric surface of any given aquifer, water levels in many additional public supply, industrial, irrigation, and domestic wells are measured as part of the data collection phase of the project. Dedicated monitoring wells are preferred over production wells, as they are always available for measuring, are less subject to pumping-related drawdowns, are usually constructed so as to be open to only one aquifer, and remain available for future mapping.

For the 2016 potentiometric project, water levels were measured in more than 400 wells, mostly in November and December 2016, and some in January 2017. In most years, DNR usually measures water levels necessary to produce a potentiometric map for only one aquifer, but in 2016, water levels were measured in all the major Coastal Plain aquifers in order to collect water-level data that could be used to help calibrate the Coastal Plain groundwater flow model currently being developed by the U.S. Geological Survey (USGS). As a result, enough water-level data were available to produce three potentiometric maps; one of the Tertiary aquifers, one of the Crouch Branch aquifer, and one of the McQueen Branch, Charleston, and Gramling aquifers.

Well locations were determined primarily using GPS measurements, and standardized to a decimal latitude and longitude coordinate system referenced to the NAD 83 geographic datum. Land surface elevations at each well site were determined primarily using lidar data, based on the latitude and longitude of the well, and reported in feet using the NAVD 88 datum. Water levels were manually measured using electric tapes, steel tapes, or pressure gages, with water levels reported in feet relative to land surface. Water-level measurements were converted into water-level elevations by subtracting the depth-to-water measurements from land surface elevation data. Potentiometric elevations were contoured using Golden Software's SURFER program, then manually adjusted as needed to produce the final maps.

Conversion to New Hydrogeologic Framework and Aquifer Nomenclature

A hydrogeologic framework describes the spatial distribution of the aquifers and confining units that control the occurrence and availability of groundwater throughout the South Carolina Coastal Plain. The hydrogeologic framework utilized in the DNR groundwater monitoring program has historically been that of Aucott and others (1987), who divided the Coastal Plain sedimentary sequence into six major aquifers, which in ascending order are the Cape Fear, Middendorf, Black Creek, Tertiary sand, Floridan, and surficial aquifers.

In 1995, Aadland and others presented a detailed hydrogeologic characterization of the Coastal Plain sequence at the Savannah River Site (SRS) and surrounding area, which resulted in a revised hydrogeologic framework and a new hydrostratigraphic nomenclature for west-central South Carolina (Aadland and others, 1995). Aquifers and confining units were named after local geographic features near type-well localities, and the previous aquifer names, which were based on geologic formations, were abandoned at SRS. This revised framework and new nomenclature were extended across the rest of the Coastal Plain in *Hydrogeologic Framework of the Atlantic Coastal Plain, North and South Carolina* (Gellici and Lautier, 2010), a chapter in the report *Groundwater Availability in the Atlantic Coastal Plain of North and South Carolina* (Campbell and Coes, 2010).

Since the mid-1990s, DNR has regularly produced potentiometric maps for the State's three largest and most heavily used aquifers—the Middendorf, Black Creek, and the combined Floridan and Tertiary sand aquifers—using the hydrogeologic framework of Aucott and others (1987). Beginning with this report, however, DNR is transitioning to the use of the newer aquifer nomenclature for its potentiometric mapping. Accordingly, potentiometric maps will now be produced for the McQueen Branch-Charleston-Gramling aquifers (rather than Middendorf aquifer); the Crouch Branch aquifer (rather than Black Creek aquifer); and the Tertiary (Gordon-Middle Floridan-Upper Floridan) aquifers.

Because this new hydrogeologic framework and aquifer nomenclature is relatively new and may be unfamiliar to some readers, this report includes a brief description of this newer framework and its correlation to the older framework. Well information, water-level data, and discussions about each potentiometric map are presented in the sections of this report specific to those potentiometric maps.

Acknowledgements

Water-level and well location data were collected by the South Carolina Department of Natural Resources, Savannah River National Laboratory, South Carolina Department of Health and Environmental Control, and U.S. Geological Survey. The authors are grateful for the participation of these cooperating agencies and for the cooperation of the many well owners who provided the access to their wells needed to obtain the water-level measurements used to produce these maps.

HYDROGEOLOGIC FRAMEWORK AND AQUIFER NOMENCLATURE

Correlation between Hydrogeologic Frameworks

The hydrogeologic framework and nomenclature used in this report (Fig. 1) was first developed at the Savannah River Site (SRS) by Aadland and others (1995) and later expanded upon by Gellici and Lautier (2010). The Gellici and Lautier (2010) framework generally correlates with that of Aucott and others (1987) (Fig. 2), which, prior to this report, has been the hydrogeologic framework used for most potentiometric mapping in South Carolina.

Although the two frameworks generally correlate with each other, there are some differences in how the upper and lower limits of the aquifers are defined. For example, although the Crouch Branch aquifer of Aadland generally correlates with the Black Creek aquifer of Aucott, the upper and lower boundaries typically are not exactly the same. In some cases, the differences in the boundaries are minor; for example, at the well ORG-108 in the Town of Bowman in Orangeburg County, which was used in the development both frameworks, the Black Creek aquifer occurs from -320 to -525 ft msl (feet, relative to mean sea level) whereas the Crouch Branch aquifer occurs from -188 to -513 ft msl. In other cases, fairly significant differences exist; for example, at the well DOR-211 in Dorchester County, the Black Creek occurs from -635 to -1,095 ft msl, whereas the Crouch Branch occurs from -444 to -812 ft msl. These differences can be attributed to many factors, such as data availability, geologic interpretation, and an author's knowledge of a particular area.

In addition to occasional differences in the upper and lower boundaries of the aquifers, there are sometimes significant structural differences between the two frameworks (Gellici and Lautier, 2010), several of which are described in the following sections.

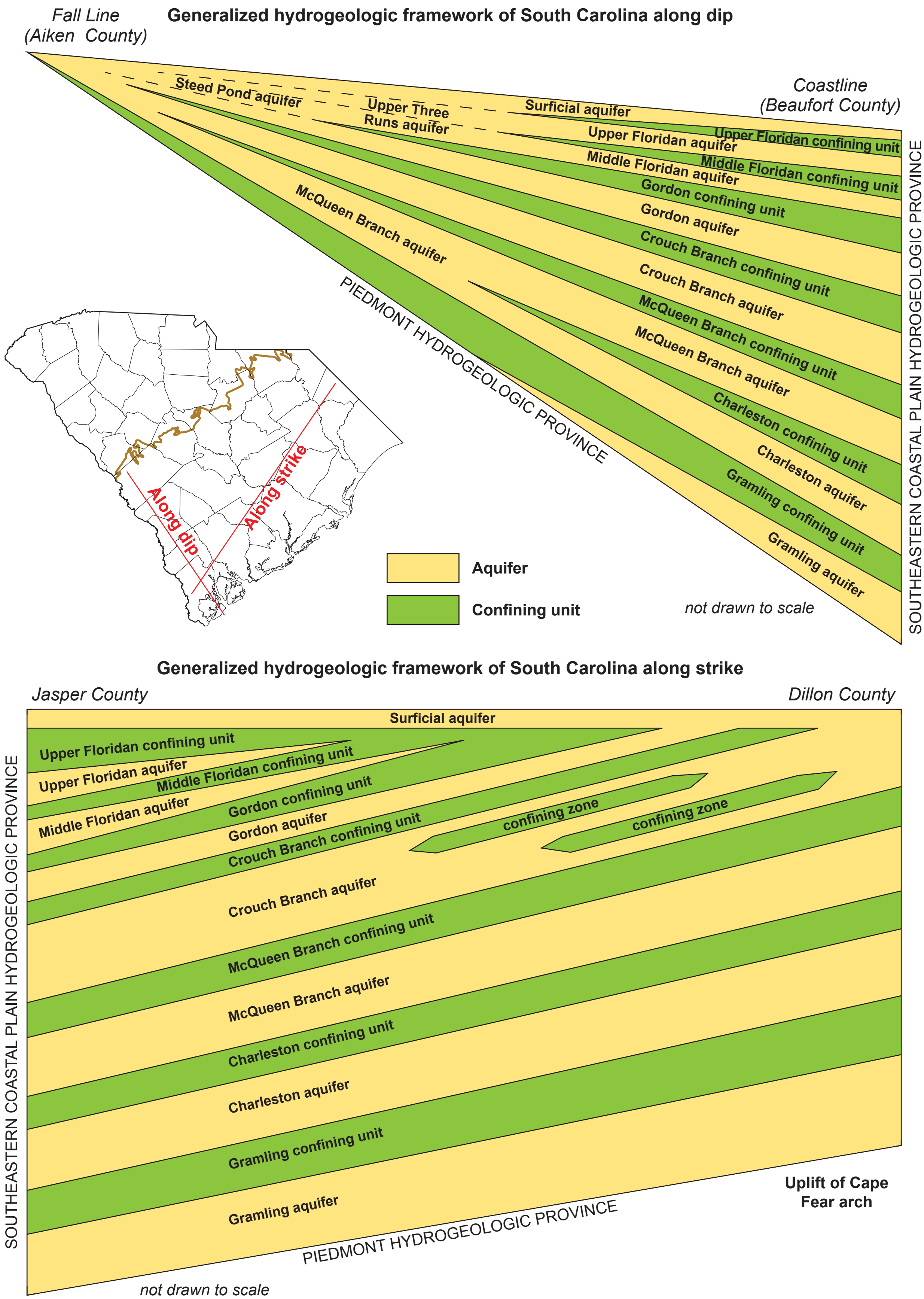


Figure 1. Generalized hydrogeologic framework of the South Carolina Coastal Plain (Gellici and Lautier, 2010).

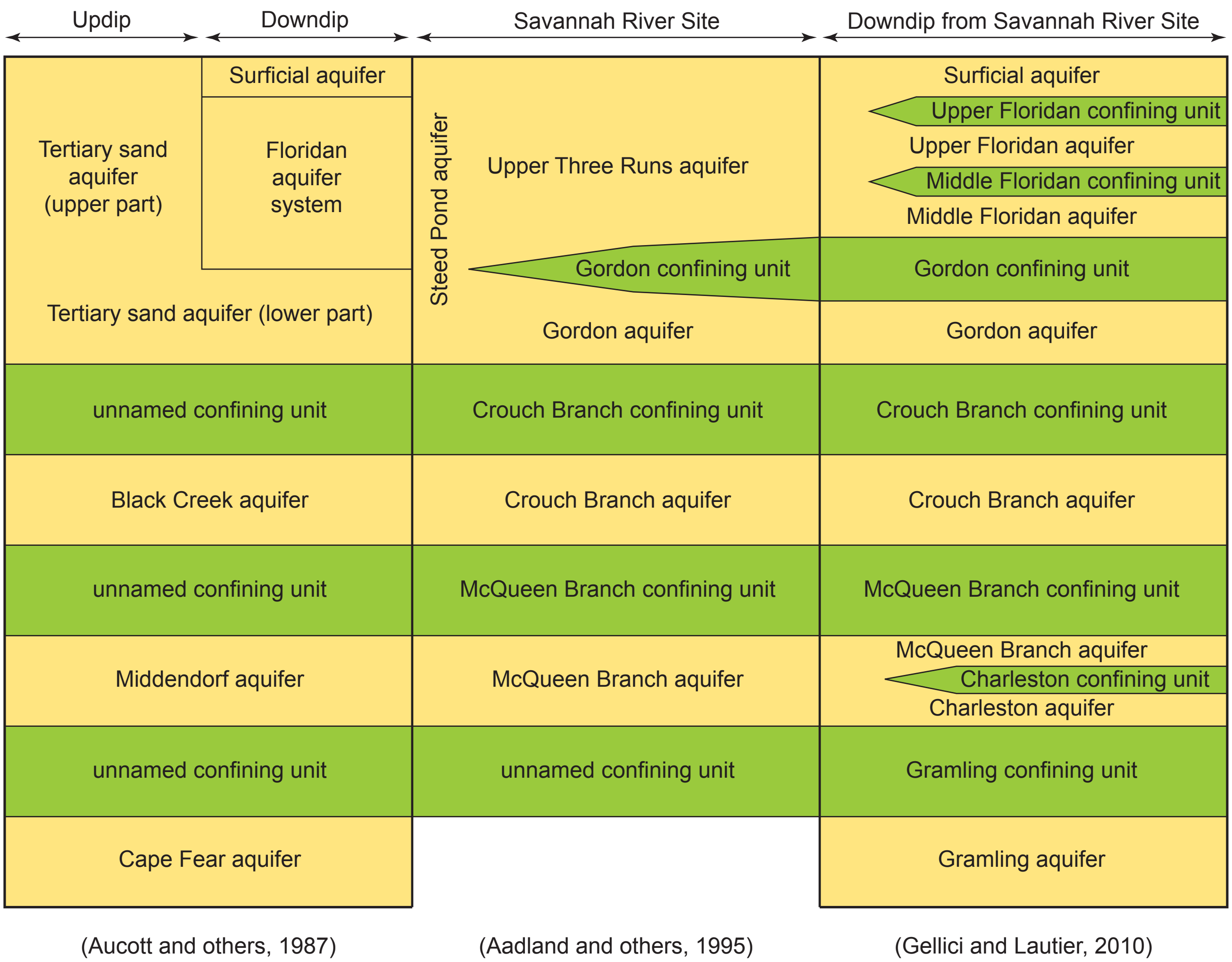


Figure 2. Comparison of hydrostratigraphic nomenclature systems in South Carolina.

Upper Floridan, Middle Floridan, and Gordon Aquifers

General stratigraphic relationships between the Tertiary aquifers and geologic formations, along with changes in lithology, are illustrated in Figure 3. It should be noted that the stratigraphy shown in Figure 3 is simplified and presents only the more significant formations composing the units, and that the lithologies indicated are highly generalized. The reader is referred to Gellici and Lautier (2010) for a more detailed description.

The Tertiary sand aquifer of Aucott is divided into the Steed Pond, Upper Three Runs, and Gordon aquifers, and the Floridan aquifer system of Aucott is divided into the Upper and Middle Floridan aquifers (Fig. 2).

The Upper Three Runs aquifer overlies the Gordon confining unit and consists of unconsolidated quartz sand and clay of the Upland unit (Miocene), Tobacco Road Fm (Formation) (late Eocene (?)), Dry Branch Fm (late Eocene), and quartz sand and sometimes calcareous sediments of the Tinker Fm (upper part of the middle Eocene) (Fig. 3). The Upper Three Runs aquifer splits downdip to form the Upper and Middle Floridan aquifers, both limestone aquifers. The Dry Branch Fm is age-equivalent to the Parkers Ferry Fm (or Ocala Limestone), which forms most of the Upper Floridan aquifer, and the Tinker Fm is age-equivalent to the Santee Fm, which forms most of the Middle Floridan aquifer (Fig. 3). Figures 4 and 5 show the extent of these aquifers and confining units in South Carolina.

The Gordon aquifer overlies the Crouch Branch confining unit and is overlain by the Gordon confining unit. The aquifer, which occurs throughout the western and central parts of the Coastal Plain, consists of several formations that are hydraulically connected. Updip, the aquifer consists mainly of the Congaree (early Eocene and early, middle Eocene) and Williamsburg Fms (late Paleocene) (Fig. 3). In some wells it includes beds of the Warley Hill Fm (middle, middle Eocene) and beds in the lower part of the Santee Fm (late, middle Eocene). South of Allendale County, the Congaree Fm is eroded by the overlying Santee Fm and the aquifer consists mainly of the Williamsburg Fm. In the northern part of SRS and updip of SRS, confining beds of the overlying Gordon confining unit thin, and the Gordon and Upper Three Runs aquifer coalesce to form the Steed Pond aquifer (Aadland and others, 1995). Figure 6 shows the extent of the Gordon aquifer and confining unit in South Carolina.

For the Tertiary aquifer potentiometric mapping work presented in this report, only the Upper Floridan, Middle Floridan, and Gordon aquifer names were used; in updip areas, such as Aiken County, where the Steed Pond and Upper Three Runs aquifers occur, wells open to those aquifers were considered to be part of the equivalent downdip aquifers. This was done primarily to simplify the incorporation of the water-level data into the USGS groundwater model currently under development, as that model does not include distinct Steed Pond and Upper Three Runs aquifers.

Crouch Branch Aquifer

General stratigraphic relationships between the Cretaceous-age Crouch Branch aquifer and geologic formations, along with changes in lithology, are illustrated in Figures 7 and 8. It should be noted that the stratigraphy shown in those figures is simplified and presents only the more significant formations composing the units, and that the lithologies indicated are highly generalized. The reader is referred to Gellici and Lautier (2010) for a more detailed description.

The Crouch Branch aquifer is correlated to the Black Creek aquifer. It consists of interbedded quartz sand and occurs over most of the Coastal Plain. In the western part of the Coastal Plain, the aquifer consists of the upper part of the Donoho Creek Fm (part of the Black Creek Group; late Campanian), the Peedee Fms (Maastrichtian) and, in some areas, the Sawdust Landing Fm (uppermost Maastrichtian).

In the eastern regions of the Coastal Plain, the lithology and texture of the various formations that compose the Crouch Branch aquifer change, both laterally and vertically, owing to different depositional settings that changed over time. The Peedee Fm, for example, which consists of mostly coarse-grained quartz sand in the western part of the Coastal Plain, transitions to fine-grained sand, clay, and marl in the east. A more striking difference occurs in the Bladen Fm—in the west, it consists of mainly clay and marl, and forms part of the McQueen Branch confining unit; in the east, it consists of clay and fine to medium-grained glauconitic sand, and forms part of the Crouch Branch aquifer (Fig. 8).

In general, clay beds in Cretaceous formations tend to be more prominent in the eastern part of the Coastal Plain, where they are sufficiently thick and continuous enough to divide the Crouch Branch aquifer into three aquifer zones, informally named the upper, middle, and lower zones (Fig. 8). Because of a lack of hydraulic head data available for each zone, it is unknown if the zones are hydraulically connected or isolated from each other; currently, they are grouped together and considered to be a continuation of the Crouch Branch aquifer. In addition, the zones are not always clearly delineated from geophysical logs, and the formations that compose the zones are

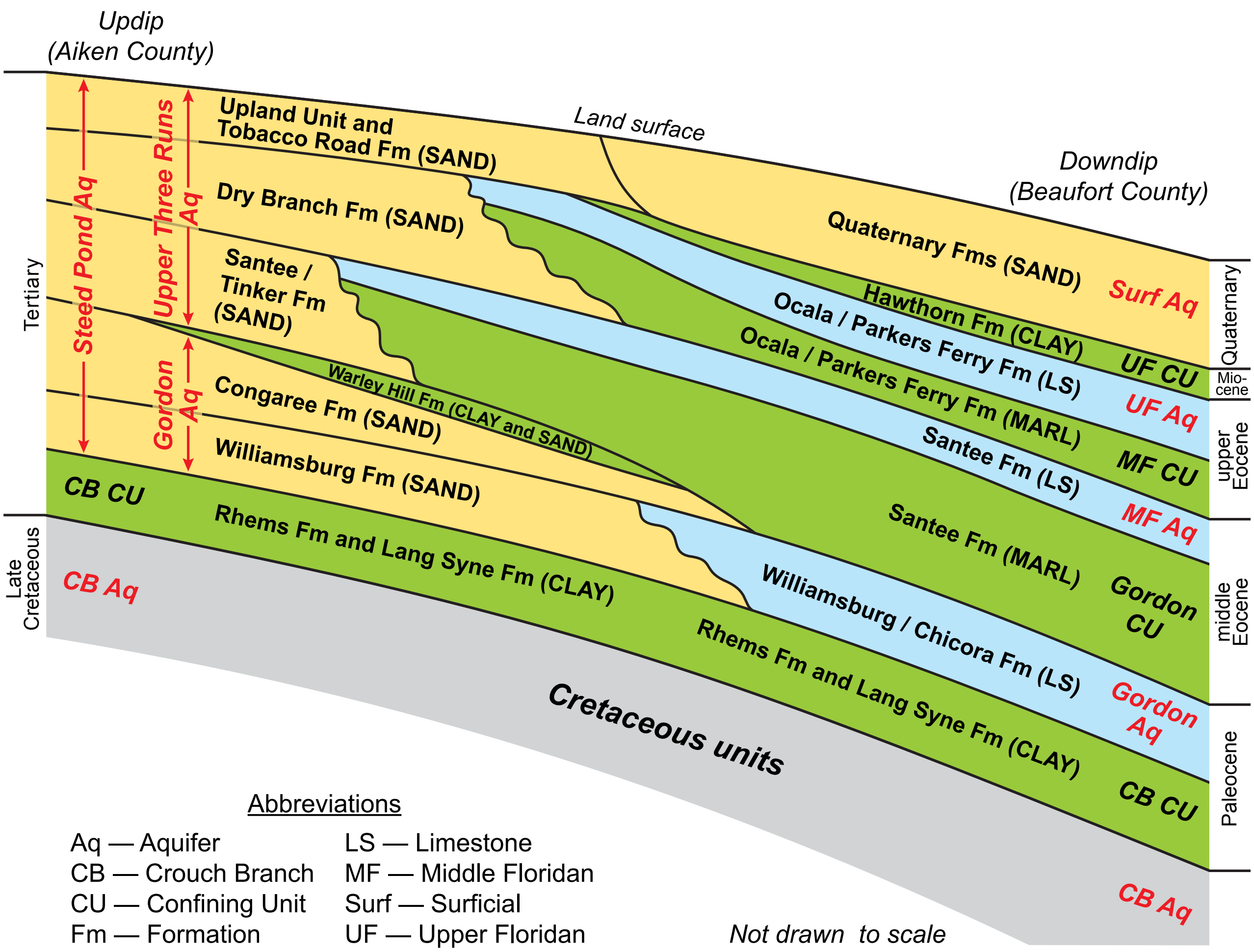


Figure 3. Generalized stratigraphic relationships between the aquifers and geologic formations of the Tertiary aquifers in South Carolina.

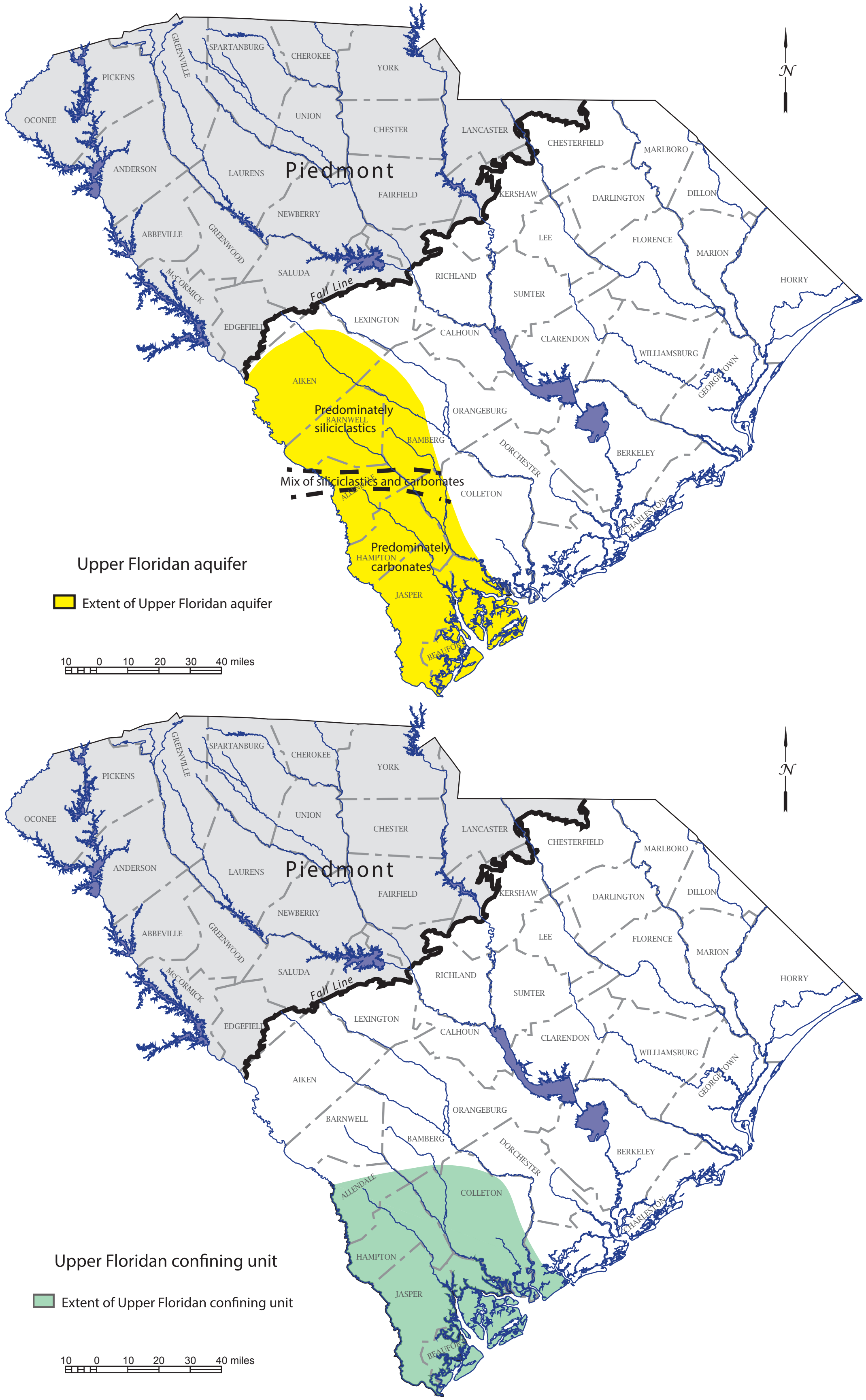
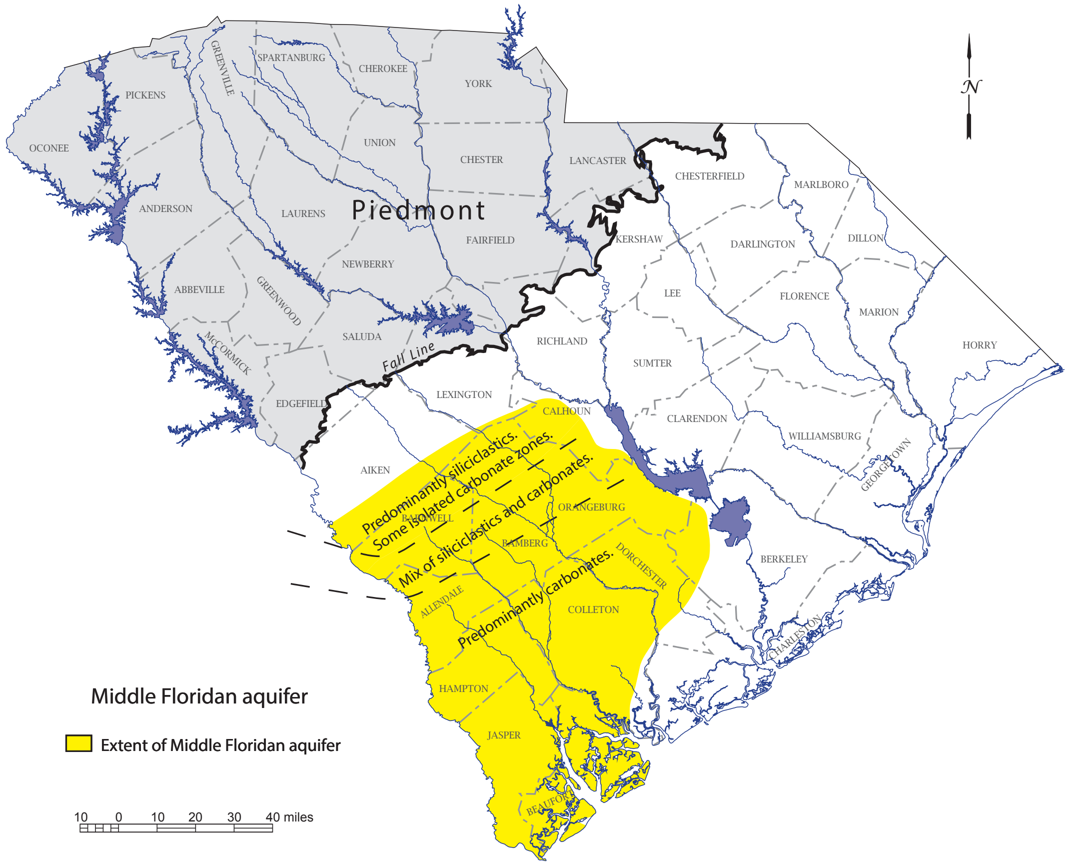


Figure 4. Approximate extent of the Upper Floridan aquifer and confining unit, as used in this report.



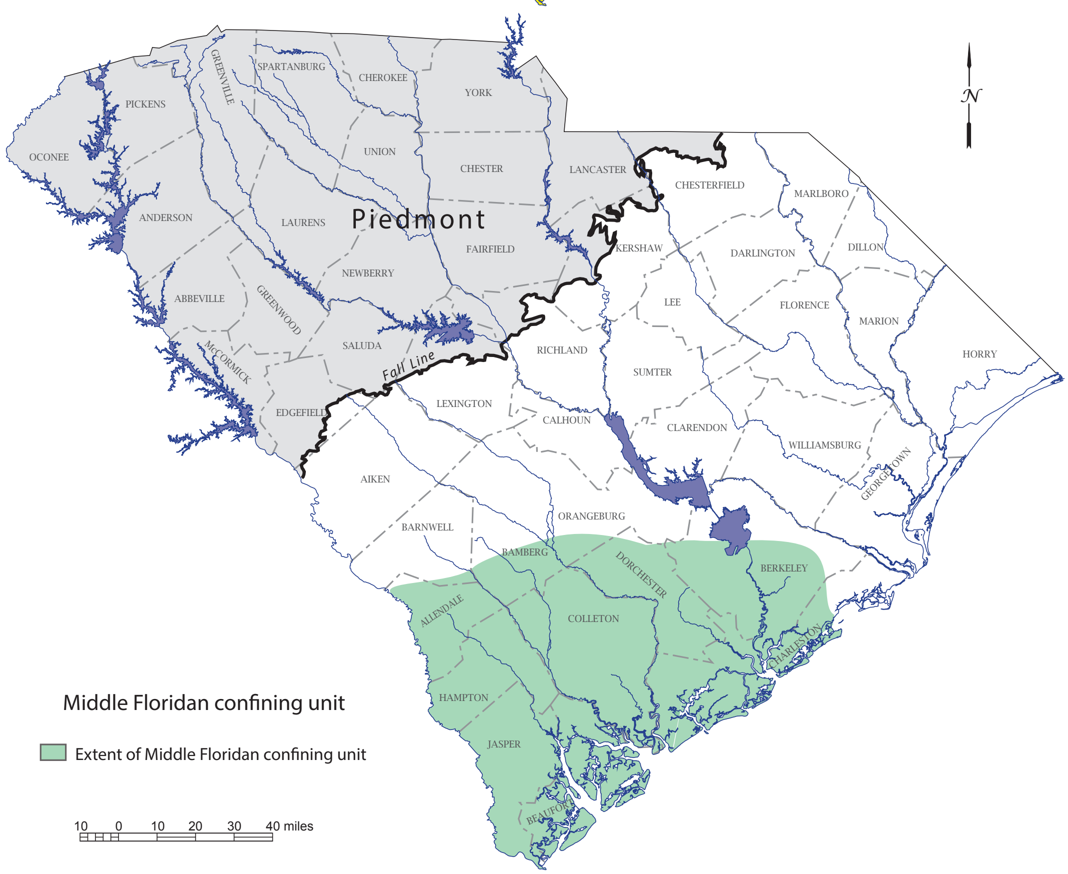
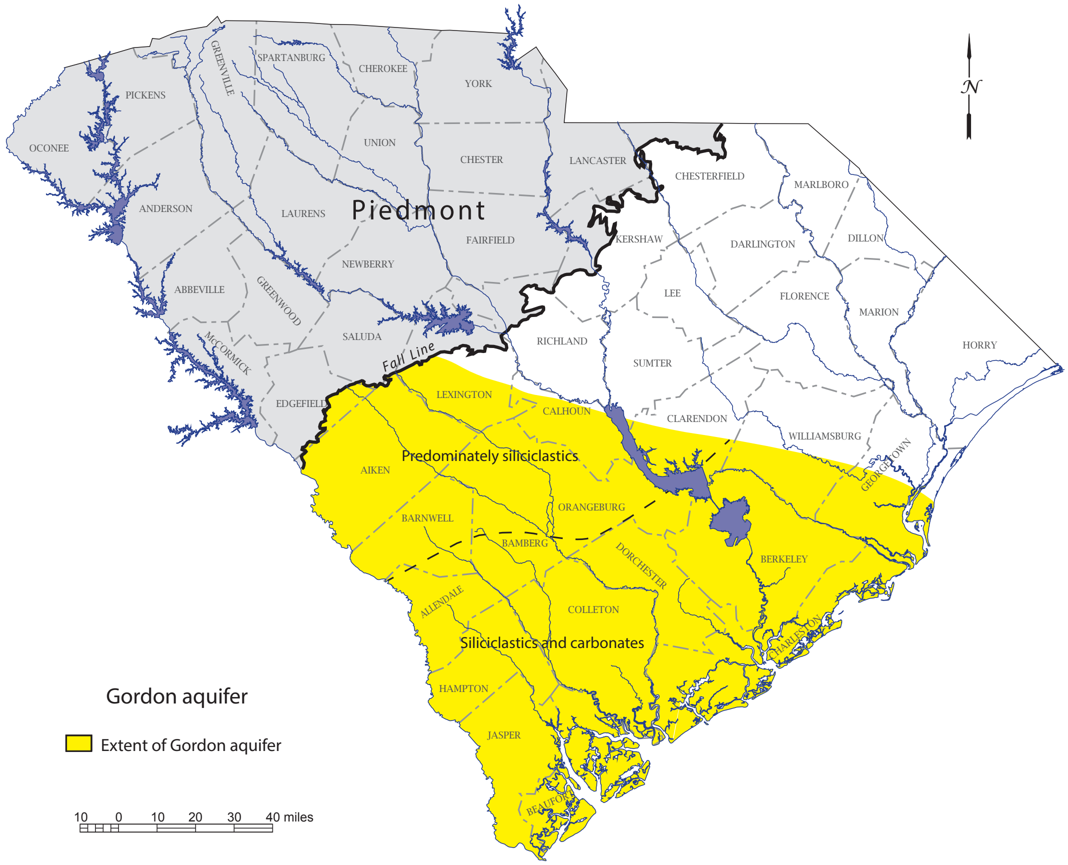


Figure 5. Approximate extent of the Middle Floridan aquifer and confining unit, as used in this report.



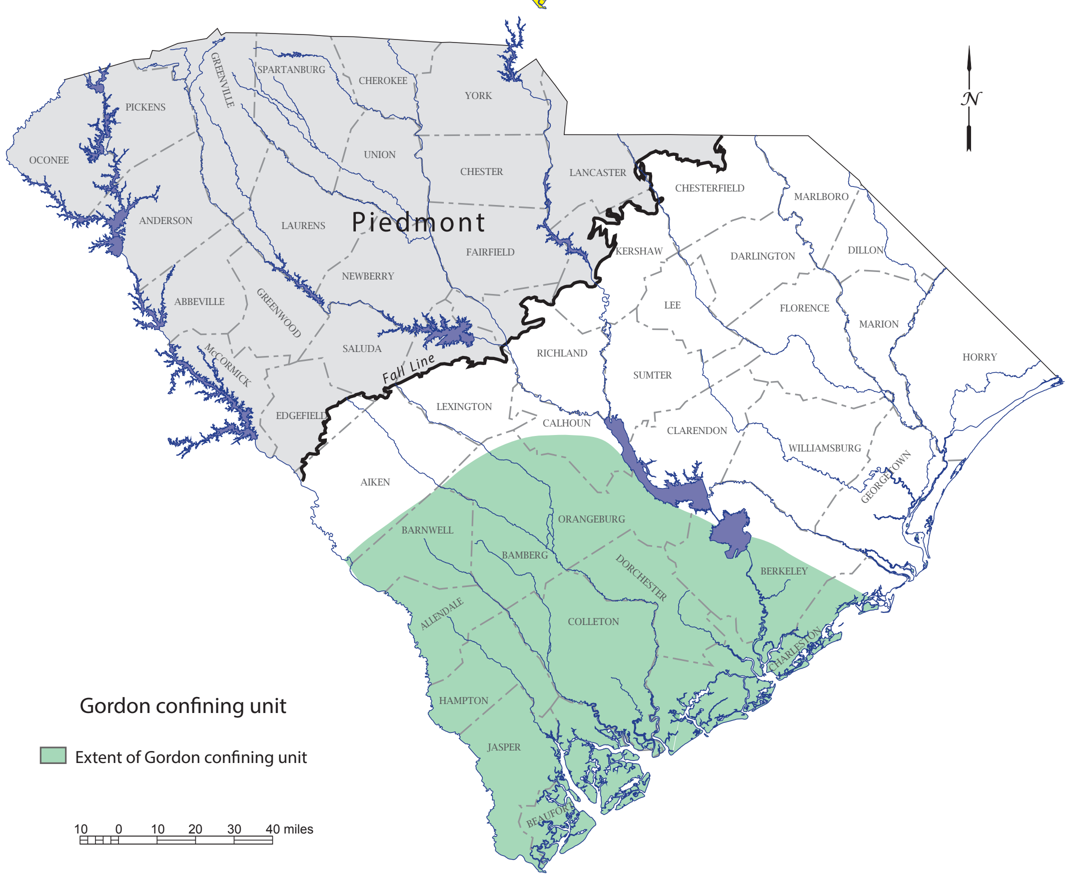


Figure 6. Approximate extent of the Gordon aquifer and confining unit, as used in this report.

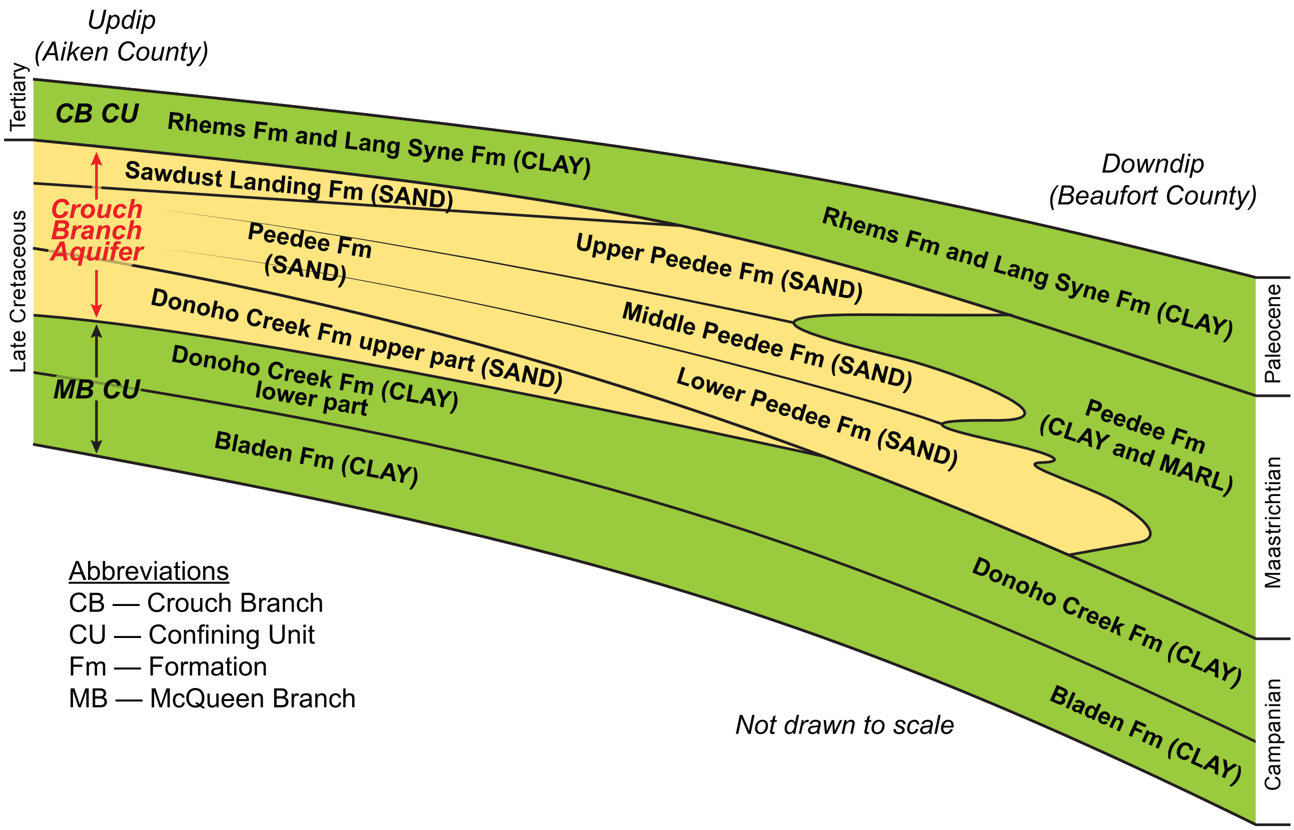


Figure 7. Generalized stratigraphic relationships of the Crouch Branch aquifer in western South Carolina.

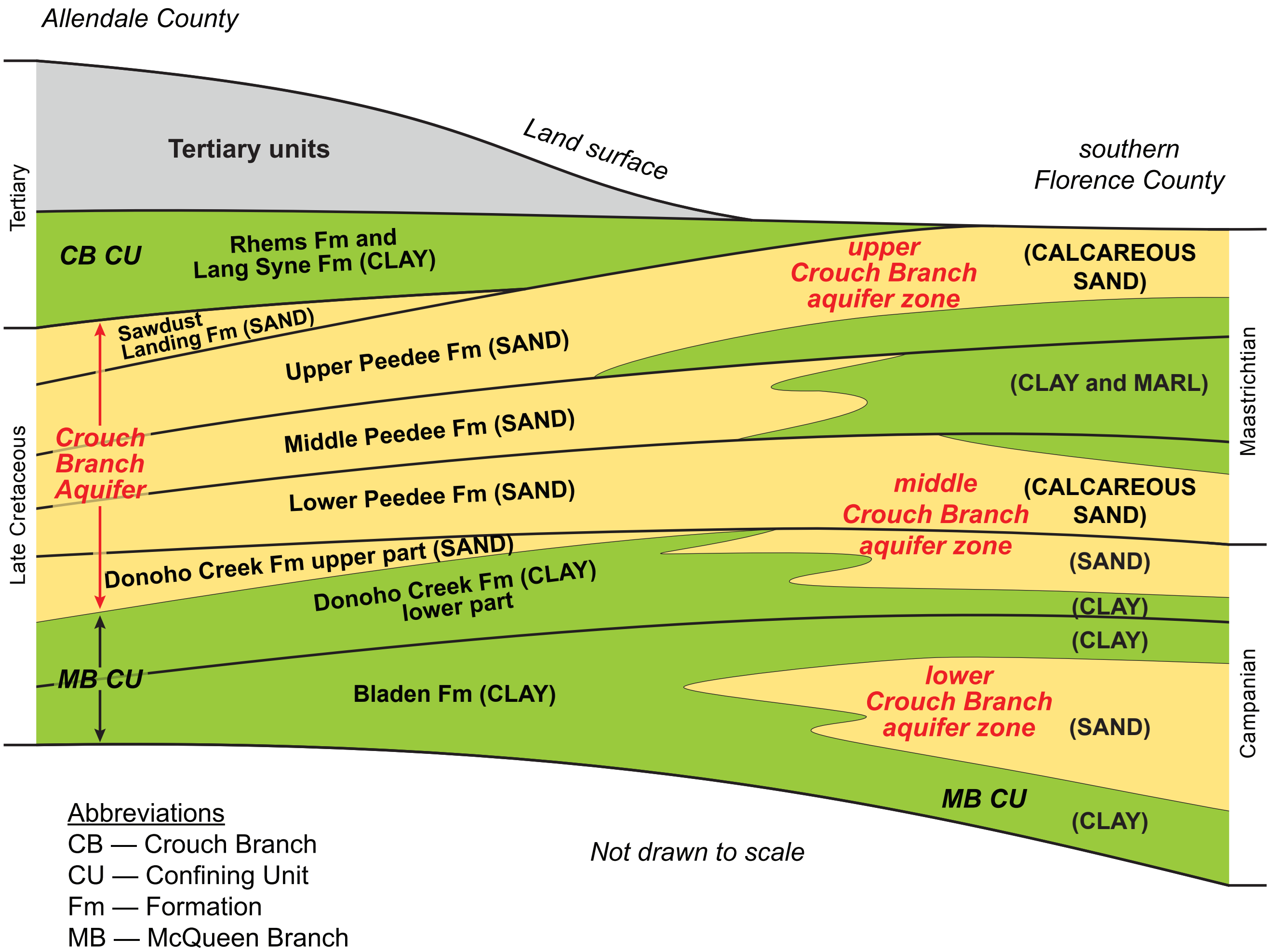


Figure 8. Generalized stratigraphic relationships of the Crouch Branch aquifer, from western South Carolina (Allendale County) to eastern South Carolina (Florence County).

not always consistent throughout the area, making mapping questionable. In some areas, the confining zones coalesce and pinch out the intervening aquifer zones—this is particularly true near the Town of Andrews in Georgetown County, where only the lower aquifer zone is present. In other areas, aquifer zones coalesce, pinching out the intervening confining zones. In the future, as more data become available, these zones may be considered and mapped as separate aquifers and may be formally classified and named.

East of the Black River, as the result of either erosion or non-deposition caused by uplift of the Cape Fear Arch, the Paleocene section is generally missing. Consequently, the main body of the Crouch Branch confining unit is absent in this area (Figs. 8 and 9), and the upper part of the Crouch Branch aquifer (upper aquifer zone) outcrops and is unconfined. Clay beds in the underlying Cretaceous formations, however, locally confine the lower parts of the Crouch Branch aquifer (middle and lower aquifer zones). Farther updip, however, the middle and lower aquifer zones become increasingly shallow, eventually outcropping and becoming unconfined.

One notable difference between the frameworks is the inland extent of the Crouch Branch aquifer compared to that of the Black Creek aquifer. The Crouch Branch aquifer extends inland almost to the Fall Line throughout most of the Coastal Plain (Fig. 9), whereas the updip limit of the Black Creek aquifer is generally between 10 and 35 miles below the Fall Line (Aucott and others, 1987).

McQueen Branch, Charleston, and Gramling Aquifers

General stratigraphic relationships between the Cretaceous-age McQueen Branch, Charleston, and basal Gramling aquifers and geologic formations, along with changes in lithology, are illustrated in Figure 10. It should be noted that the stratigraphy shown in Figure 10 is simplified and presents only the more significant formations composing the units, and that the lithologies indicated are highly generalized. The reader is referred to Gellici and Lautier (2010) for a more detailed description.

The McQueen Branch aquifer is correlated to the updip Middendorf aquifer, and consists of interbedded quartz sand and clay. It occurs over most of the Coastal Plain but becomes very fine grained downdip. In updip regions of the Coastal Plain, the aquifer consists of several formations that include the upper part of the Cape Fear Fm (late Turonian to Coniacian), the Cane Acre Fm (middle Campanian), and the lower part of the Coachman Fm (middle Campanian). Most of the aquifer in updip regions, however, consists of the Cane Acre Fm.

The Charleston aquifer is correlated with the downdip Middendorf aquifer. It consists of unconsolidated quartz sand, clayey sand, and clay primarily of the Collins Creek Fm (middle to late Coniacian). In the central part of the Coastal Plain, the aquifer thins and coalesces with the overlying McQueen Branch. The differentiation of the McQueen Branch and Charleston aquifers stems from detailed paleontological analyses from core samples, which indicate the strata in downdip areas mapped by Aucott as the Middendorf aquifer are older than strata mapped as the Middendorf in updip areas. Gellici and Lautier (2010) mapped the downdip, older strata as a separate aquifer and named it the Charleston aquifer. In most regions, the two aquifers are separated by clay beds of the Shepherd Grove Fm (late Santonian); however, owing to the lack of hydraulic head data, it is not known if the two aquifers are hydraulically connected.

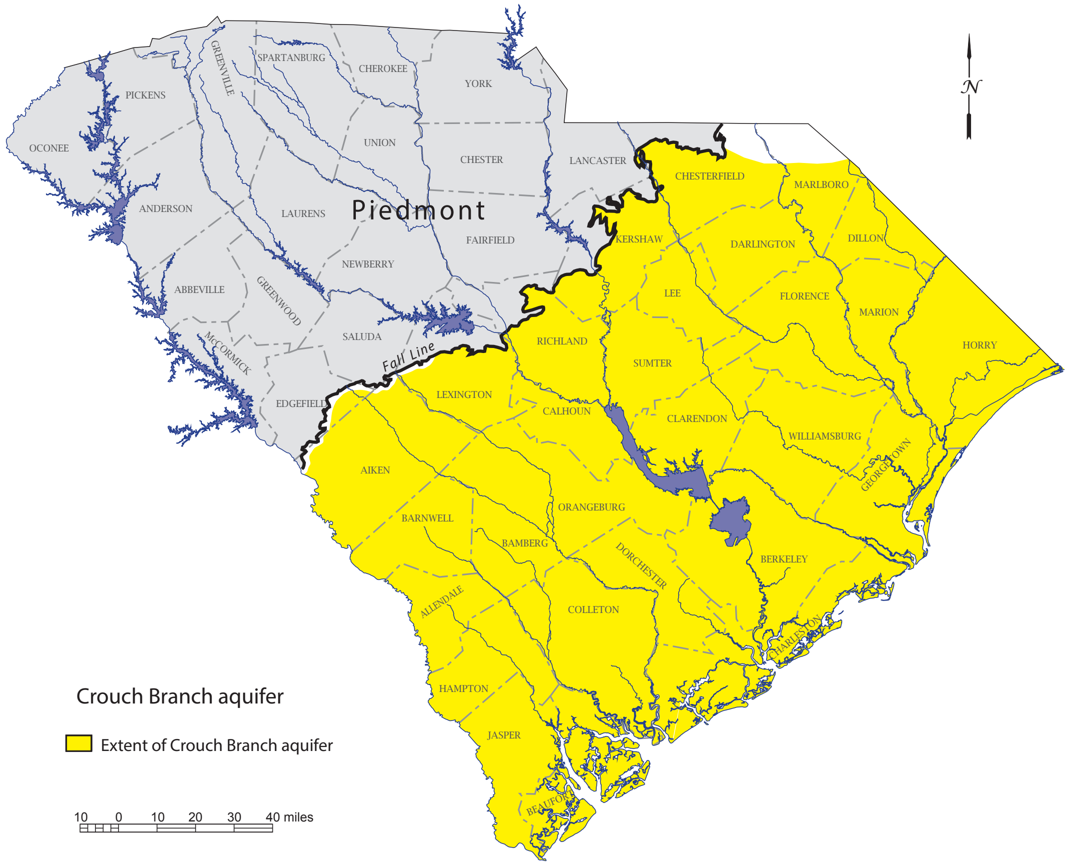
The Gramling aquifer is the basal aquifer of the Coastal Plain and correlates to the Cape Fear aquifer. It occurs primarily in the lower half of the Coastal Plain, where it sits on basement rocks. The aquifer consists of unconsolidated to semiconsolidated interbedded quartz sand, clayey sand, silt, and clay. It includes the Beech Hill (Cenomanian) and Clubhouse Fms (late Cenomanian (?) to early Turonian), and the lower part of the Cape Fear Fm (late Turonian to Coniacian).

The McQueen Branch aquifer occurs across most of the Coastal Plain (Fig. 11), whereas the Charleston and Gramling aquifers occur only in the lower half of the Coastal Plain (Figs. 12 and 13).

VERTICAL HYDRAULIC HEAD RELATIONSHIPS AMONG THE AQUIFERS

Hydraulic Head Differences within the Upper Three Runs Aquifer

Although no clay beds are continuous enough to form a mappable confining unit within the Upper Three Runs aquifer, head differences occur locally within the aquifer at the Savannah River Site (SRS). In the General Separations Area (GSA), near the center of SRS, clay beds near the base of the Dry Branch Fm form what is called the “tan clay confining zone” at SRS. This zone locally separates Upper Floridan-equivalent strata, called the “upper aquifer zone”, from Middle Floridan-equivalent strata, called the “lower aquifer zone”. There is a downward gradient between the two aquifer zones. Head differences as great as 25 ft occur in the area (between wells D and C at the P-27 site). At other locations in the GSA, head differences across the zone are only 2 to 3 ft (Aadland and others, 1995).



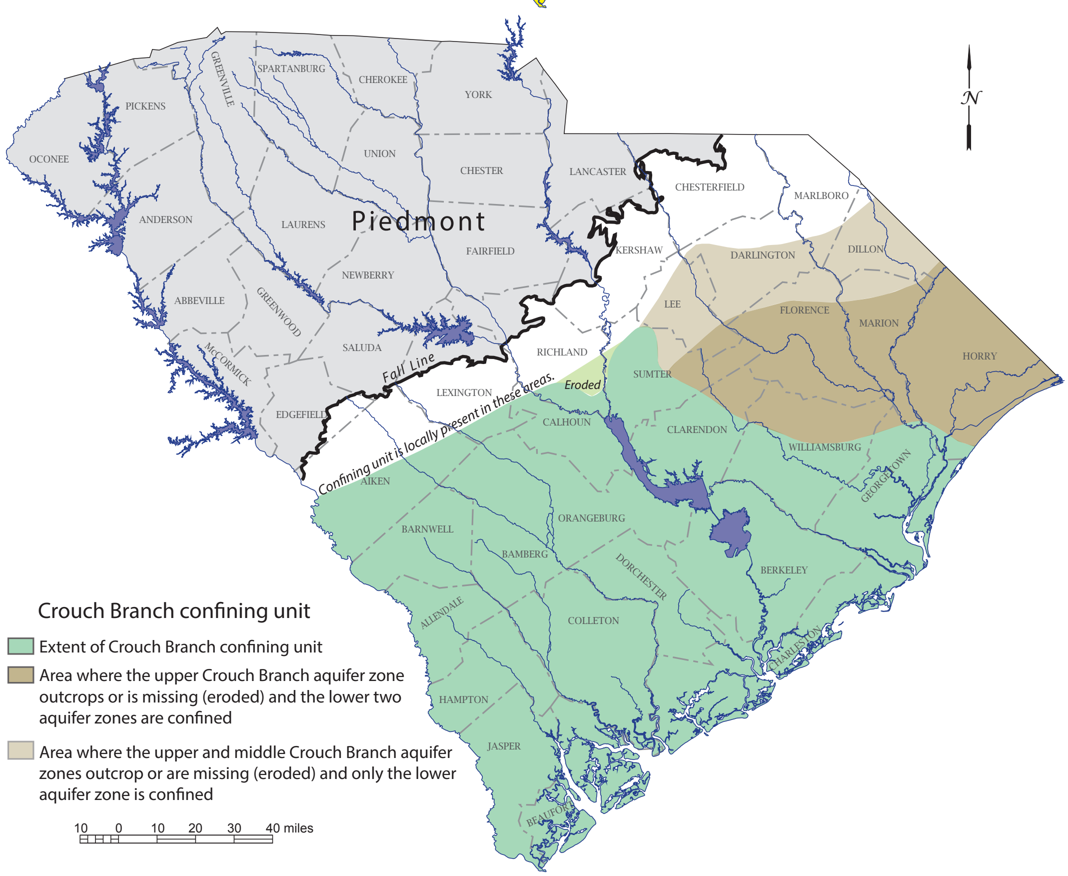


Figure 9. Approximate extent of the Crouch Branch aquifer and confining unit, as used in this report.

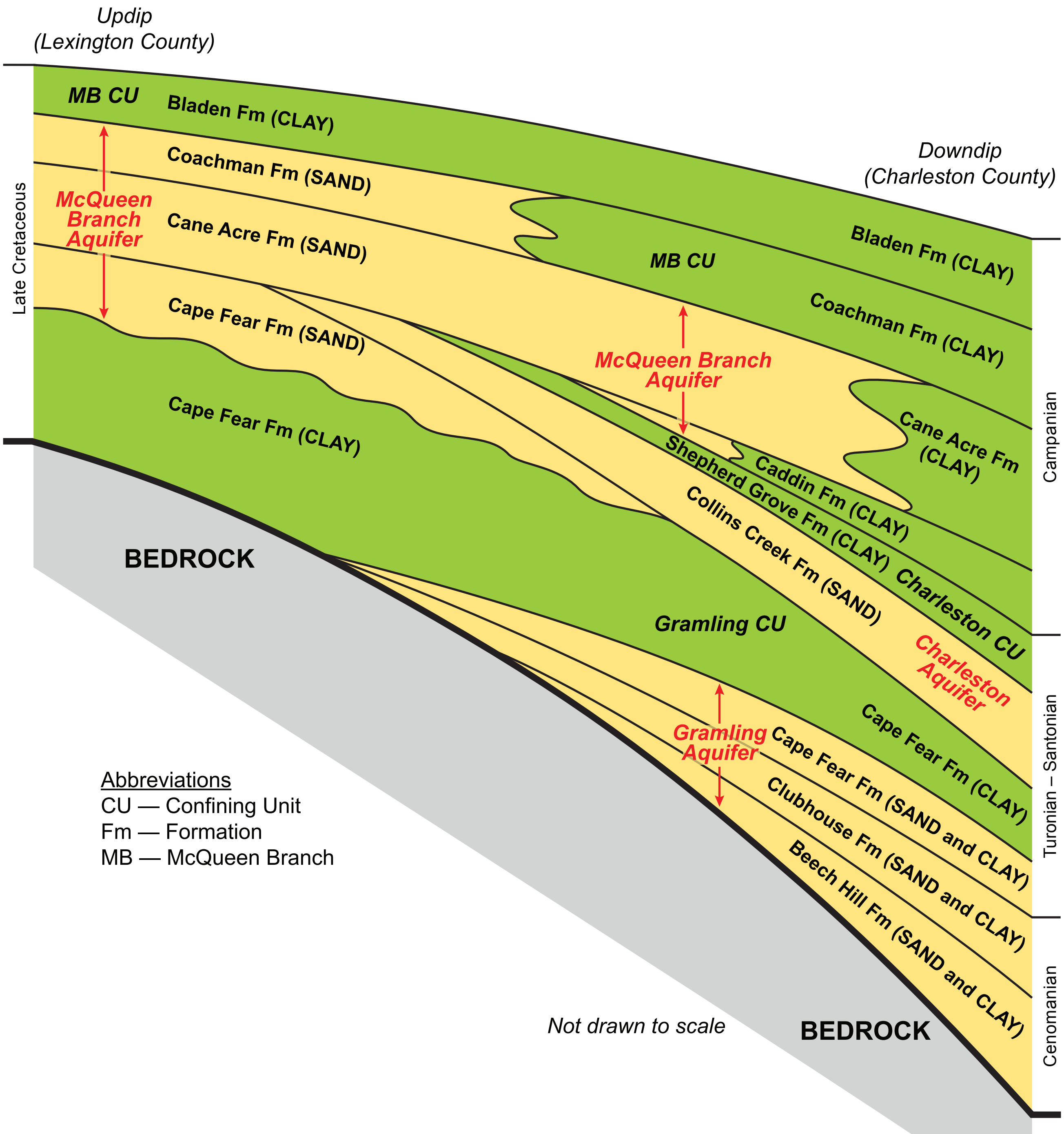


Figure 10. Generalized stratigraphic relationships of the McQueen Branch, Charleston, and Gramling aquifers in South Carolina.

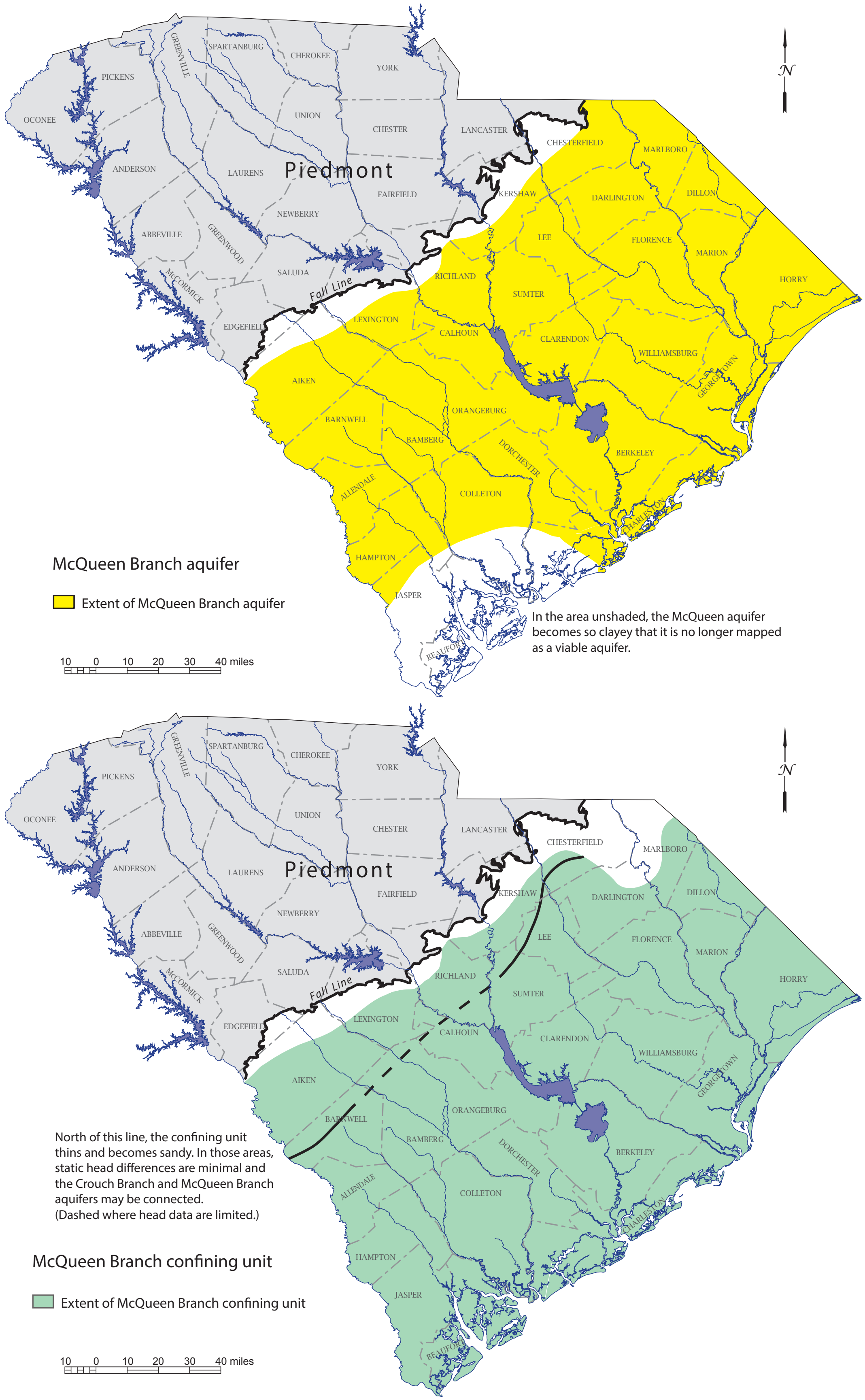


Figure 11. Approximate extent of the McQueen Branch aquifer and confining unit, as used in this report.

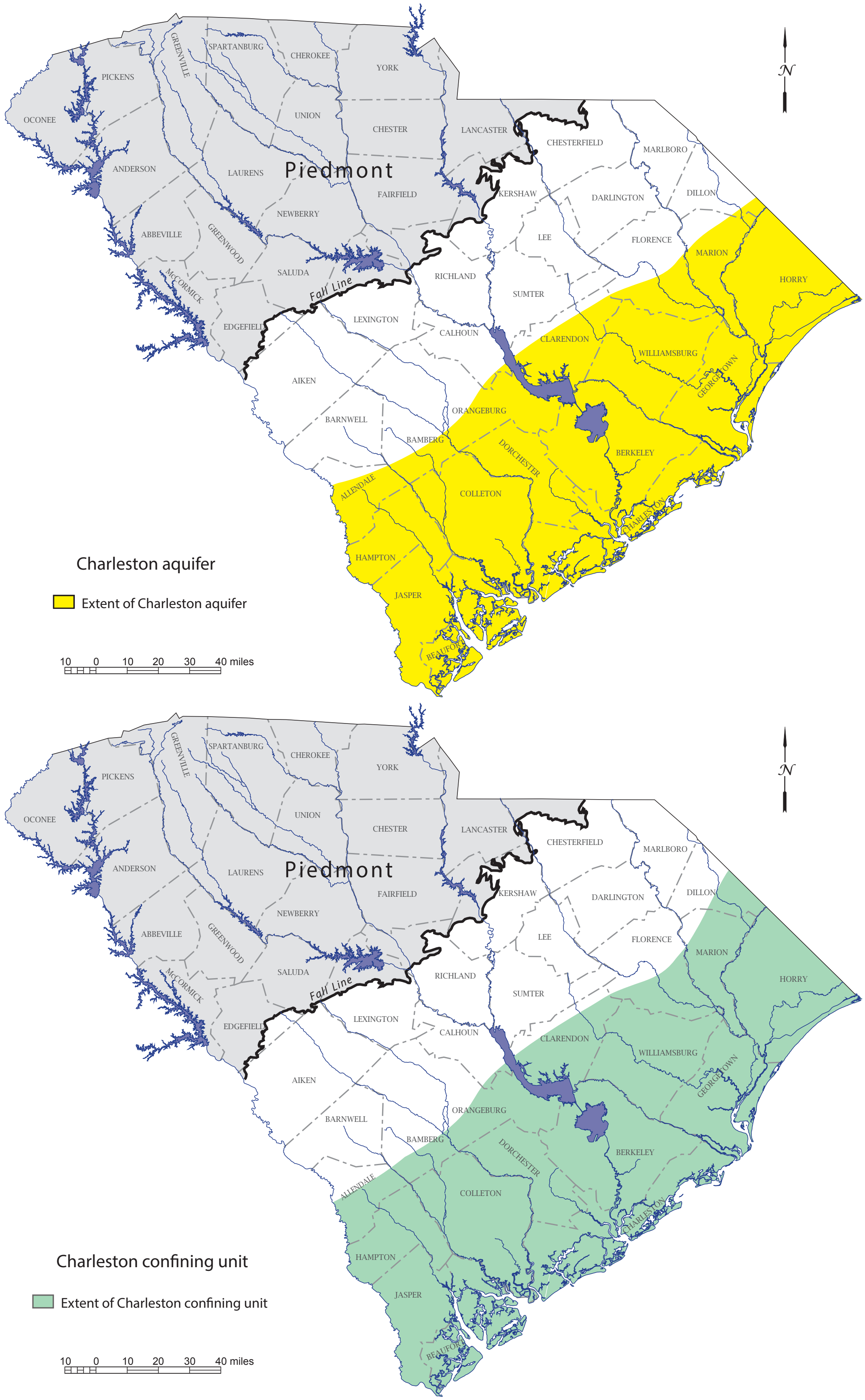


Figure 12. Approximate extent of the Charleston aquifer and confining unit, as used in this report.

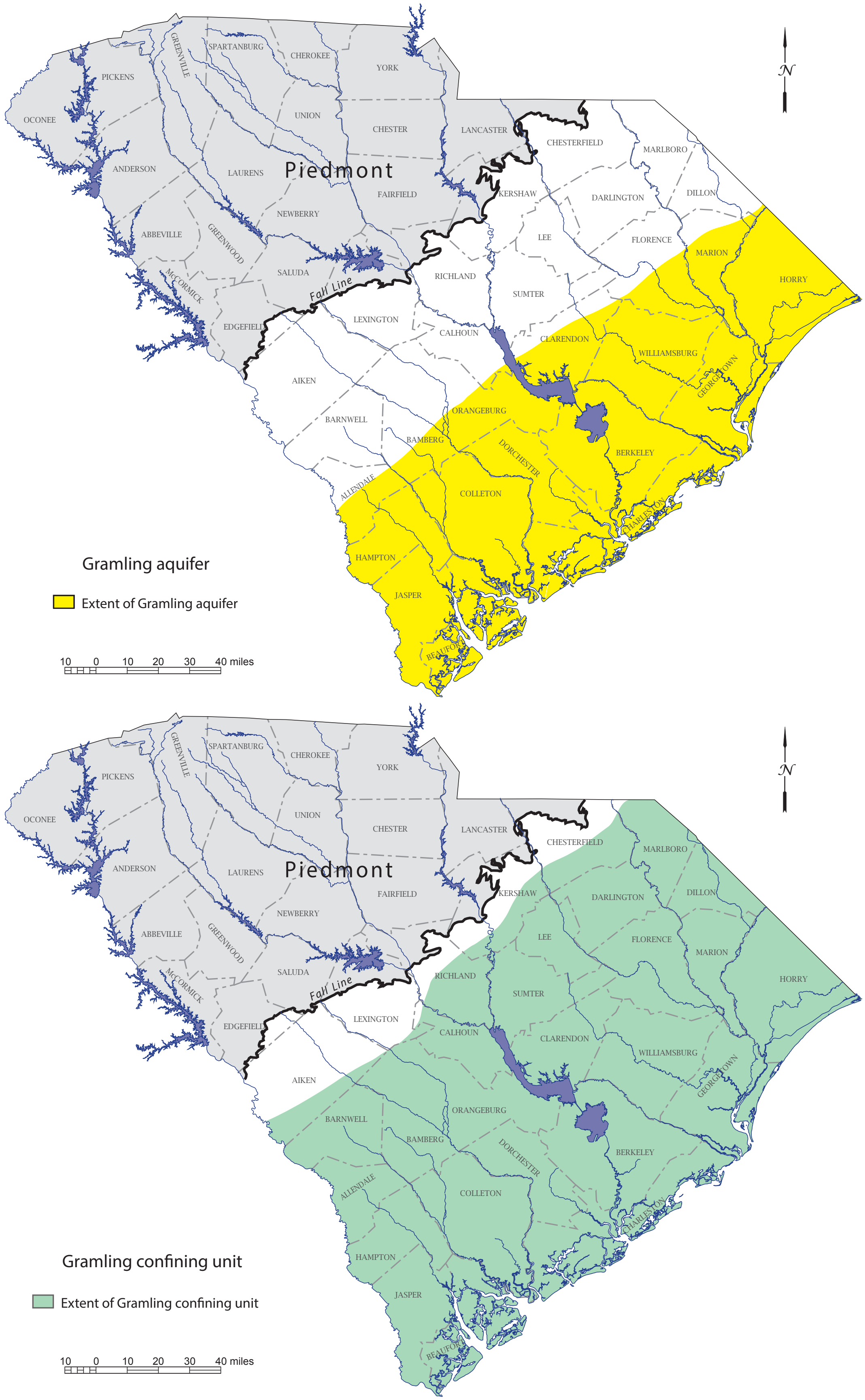


Figure 13. Approximate extent of the Gramling aquifer and confining unit, as used in this report.

Just outside of SRS, at DNR's C-well monitoring-well cluster sites, head differentials within the UTR aquifer vary slightly. At the C-6 site in southern Barnwell County (site of well BRN-350), for example, virtually no head differences occur within the aquifer; downdip, at the C-7 site in western Allendale County (site of well ALL-364), a head difference of only 2 ft is observed (downward gradient).

Hydraulic Head Differences across the Middle Floridan Confining Unit

At DNR's C-10 well-cluster site in central Allendale County (site of well ALL-373), the head difference between the Upper and Middle Floridan aquifers is 36 ft (downward gradient). This site is in an area that is transitional between the siliciclastic and carbonate phases of the aquifer and is in an updip area where the Upper Floridan is likely under water-table conditions. Farther downdip, however, in Hampton, Jasper, and Beaufort Counties, where both the Upper and Middle Floridan aquifers are confined and consist of indurated, moldic limestone, head differences between the two aquifers are nearly nonexistent. At the Lake Warren cluster site in Hampton County (site of well HAM-314), for example, head differences are less than 1 ft; at the C-15 and Blue Heron cluster sites in Jasper County (sites of wells JAS-425 and JAS-490, respectively), head differences are also less than 1 ft; and at the Indigo Run Plantation site at Hilton Head Island in Beaufort County, head differences are about 2 ft (all downward gradients).

Hydraulic Head Differences across the Gordon Confining Unit

All of the P-well cluster sites at SRS have observation wells that are completed in different parts of the Gordon and Upper Three Runs (UTR) aquifers (see Aadland and others, 1995). Water levels used in this report were selected mainly from those P-wells that were completed in the UTR aquifer, either in strata equivalent to the Upper Floridan aquifer (Dry Branch Fm) or to the Middle Floridan aquifer (Tinker/Santee Fm). Water levels from wells completed in the Gordon aquifer generally were not used. It is important to note, however, that there are significant vertical hydraulic head differences—up to 60 ft—that occur between the Gordon aquifer and the UTR aquifer at SRS (see Figure 22 in Aadland and others, 1995). Along the Savannah River floodplain and its major tributaries, a consistent upward gradient exists across the Gordon confining unit. Here, the river and tributaries have downcut into the UTR aquifer (the water-table aquifer at SRS) causing the aquifer to discharge water to adjacent streams, thereby lowering the hydraulic head of the UTR aquifer to below that of the underlying Gordon aquifer. Within interfluvial areas at SRS, however, higher heads occur in the UTR aquifer, and the gradient is reversed.

Just outside of SRS, at DNR's C-well cluster sites, head differentials between the Gordon and UTR aquifers also occur. At the C-5 and C-6 cluster sites in Barnwell County, for example, head differences of 29 and 14 ft occur across the Gordon confining unit, with higher heads in the UTR aquifer (downward gradient). Farther downdip, at the C-7 and C-10 cluster sites in Allendale County, there is a 34- and 22-ft head difference, respectively, between the Middle Floridan aquifer and the Gordon aquifer, with the higher heads occurring in the Middle Floridan (downward gradient). At a well-cluster site in the City of Orangeburg (at Clarke Middle School), there is a significant downward gradient between the Middle Floridan (unconfined) and the Gordon, with a head differential of about 60 ft.

No suitable monitoring wells exist in the southwestern part of the Coastal Plain (Hampton, Jasper, and Beaufort Counties) to determine if head differences occur between the Middle Floridan and Gordon aquifers in these areas. Few production wells are drilled into the Gordon in these counties because ample yields can usually be obtained from shallower aquifers such as the Upper Floridan and, locally, from the Middle Floridan.

Hydraulic Head Differences across the Crouch Branch Confining Unit

The Crouch Branch confining unit mainly consists of clay beds that occur in the middle and lower parts of the Paleocene section (Lang Syne and Rhems Fms). These beds extend updip at least as far as the C-3 well-cluster site in Aiken State Park, where there is separation and a hydraulic-head difference of about 15 ft between the Crouch Branch aquifer and the overlying Gordon aquifer. Water-level elevations are greater in the Crouch Branch than in the Gordon, indicating an upward hydraulic gradient. The C-3 site is located near the floodplain of the South Fork Edisto River, which down-cuts and drains the Gordon aquifer, resulting in relatively lower heads in the Gordon in this area.

Downdip of C-3, at SRS, head differences between the Gordon and Crouch Branch occur at most of the P-well cluster sites, with differences of up to 30 ft observed. At SRS, upward gradients occur in low-lying areas, such as along the Savannah River, and downward gradients in topographically high areas.

In Barnwell County, at the C-5 and C-6 well-cluster sites, head differences of about 10 ft occur with a downward gradient at C-5 and an upward gradient at C-6, which is located near the floodplain of the Salkehatchie River. Farther downdip, at the C-7 and C-10 well-cluster sites in Allendale County, head differences of 28 and 26 ft occur, respectively, with an upward gradient occurring at both sites. At a well-cluster site in the City of Orangeburg (Clarke Middle School), there is a downward gradient between the Gordon and the Crouch Branch aquifers, with a head differential of about 25 ft.

Updip of the C-3 site, in an area that extends from the Fall Line to about 20 miles south of the Fall Line, and from the Savannah River to the Black River (Fig. 9), clay beds that form the confining unit thin, become sandy, and are discontinuous. In these areas, the Crouch Branch and Gordon aquifers are thought to be hydraulically connected, although no relevant well-cluster sites exist in these areas to positively support this conclusion.

Hydraulic Head Differences across the McQueen Branch Confining Unit

In the western part of the Coastal Plain, the McQueen Branch confining unit consists of clay beds in the Donoho Creek, Bladen, and Coachman Fms. These beds extend into the upper reaches of the Coastal Plain, pinching out within about 10 miles of the Fall Line (Fig. 11). Although the beds extend this far updip, they thin, become somewhat sandy, and are discontinuous in Aiken, Lexington, Richland, Kershaw, and Chesterfield Counties. In this area, hydraulic head differences between the McQueen Branch aquifer and the overlying Crouch Branch aquifer are minimal. At the C-3 well-cluster site in Aiken State Park, head differences are less than 1 ft; at the C-2 well-cluster site near New Ellenton in Aiken County, differences are less than 2 ft; and at the C-1 well-cluster site near the town of Jackson in western Aiken County, differences are less than 4 ft. Even in central SRS, just south of the Aiken-Barnwell county line, head differences at cluster sites P-18 and P-27 are less than 1 ft. In a long-duration pumping test at the P-29 cluster site in the northern part of SRS in Aiken County (Aadland and others, 1995), water-level declines were observed in the Crouch Branch aquifer during pumping of the McQueen Branch aquifer, indicating a hydraulic connection in this area.

Farther to the south (see Fig. 11), head differences between the aquifers become more pronounced. At the C-6 well-cluster site in southern Barnwell County, where the confining unit is more than 150 ft thick, a head difference of 24 ft is observed, with an upward gradient occurring at the site (higher heads in the McQueen Branch). At the C-7 and C-10 cluster sites in Allendale County, head differences are 25 and 39 ft, respectively, with an upward gradient at both sites. In Lee County, at the Lee State Park cluster site, there is a head difference of 10 ft with an upward gradient; in Sumter County, at the Municipal Airport well-cluster site, there is a head difference of 12 ft with a downward gradient; and in southern Chesterfield County, at the McBee well-cluster site, there is a head difference of 15 ft with a downward gradient.

The Bladen Fm, which is a clay and forms much of the McQueen Branch confining unit in the western part of the Coastal Plain, transitions to a glauconitic sand facies to the east, where it is included as part of the overlying Crouch Branch aquifer (Fig. 8). As such, the McQueen Branch confining unit thins to the east because it no longer includes all of the Bladen Fm or beds in the overlying Donoho Creek Fm. In the east, it generally consists only of clay beds in the lower part of the Bladen Fm and in the underlying Coachman Fm. The Bladen's transition from a predominantly clay lithofacies to a glauconitic sand facies starts at about the middle of the Coastal Plain in eastern Calhoun County and western Sumter County. At the Sumter airport site, where the Bladen is a sand unit and is included with the Crouch Branch aquifer, there is separation and a head difference of 12 ft between the Crouch Branch and McQueen Branch aquifers. The same is true at Lee State Park. Downdip, however, very little data exists. At Myrtle Beach State Park, where the confining unit is only about 50 ft thick, there is about a 7-ft head difference between the aquifers. It is unclear at the present time if the Crouch Branch and McQueen Branch aquifers are connected in these downdip areas in the eastern part of the state.

Hydraulic Head Differences across the Charleston and Gramling Confining Units

No well-cluster sites in South Carolina have wells completed in the Charleston and Gramling aquifers, so it is unclear what the head relationships are across these aquifers' confining units. There is, however, one well-cluster site near the coast in Calabash, North Carolina, which is just across the state line from Horry County. Correlations between aquifers at Myrtle Beach, SC and Calabash, NC were made by Gellici and Lautier (2010; see Figure B41 in Campbell and Coes, 2010). At the Calabash site, there is about a 45-ft head difference between the Lower Cape Fear aquifer (which is equivalent to the Gramling aquifer) and the Upper Cape Fear aquifer (equivalent to the Charleston aquifer) with the higher head in the Lower Cape Fear aquifer. Also at Calabash, there is a 50-ft head difference between the Upper Cape Fear aquifer and the Black Creek aquifer (equivalent to the McQueen Branch aquifer), with the higher head in the Upper Cape Fear aquifer.

The hydraulic head differences noted at the Calabash site are significant and suggest that there is separation between the McQueen Branch, Charleston, and Gramling aquifers. The data, however, are limited to one site. Additional data from well-cluster sites and from individual monitoring wells are needed in many areas of South Carolina. If these relationships hold, then individual potentiometric maps should be made for each of these aquifers. For this report, water levels from all three aquifers are combined and used to produce a single map.

FLORIDAN-GORDON POTENTIOMETRIC MAP – NOVEMBER–DECEMBER 2016

Previous Work

Although 2016 is the first year for which DNR has produced a potentiometric map of the Upper Floridan-Middle Floridan-Gordon aquifers in South Carolina, previously, similar maps have been produced as Floridan/Tertiary sand aquifer potentiometric maps. Almost all of the wells used to develop the 2016 Floridan-Gordon aquifers potentiometric map would also have been used to develop a 2016 Floridan/Tertiary sand aquifer potentiometric map, had such a map been produced. The similarity between the two aquifer systems allows for a fairly straightforward comparison of this 2016 map with earlier Floridan/Tertiary sand aquifer potentiometric maps.

Maps have been produced by DNR for the Floridan and Tertiary sand aquifers describing its potentiometric surface in 2013 (Wachob and others, 2014), 2010 (Hockensmith and others, 2013a), 2004 (Hockensmith, 2009), 1998 (Hockensmith, 2001), and 1986 (Crouch and others, 1987). Earlier work by the USGS includes a potentiometric map for the Floridan aquifer for 1982 (Aucott and Speiran, 1985a), and a predevelopment potentiometric surface map (Aucott and Speiran, 1985b).

Potentiometric Mapping of Multiple Tertiary Aquifers

The use of water-level data from the Upper Floridan, Middle Floridan, and Gordon aquifers to produce one potentiometric map is a simplification required, to some extent, by limited data available for each aquifer, but combining these aquifers on one potentiometric map is not unreasonable. In some updip areas, such as Aiken and Barnwell Counties, the confining unit above the Middle Floridan aquifer, and to a lesser extent, above the Gordon aquifer, can be discontinuous and somewhat ineffective; and in downdip areas such as Beaufort County, little difference is seen in the potentiometric levels of the Upper Floridan and Middle Floridan aquifers. In other areas, more significant differences in hydraulic head exist across these confining units, and these differences should be kept in mind when using the Tertiary aquifer potentiometric map produced for this report.

The hydraulic head differences discussed previously, especially across the Gordon confining unit, may warrant mapping the potentiometric surface of the Gordon aquifer separately from that of the Floridan aquifers and their updip clastic equivalents in the Upper Three Runs aquifer. Few Gordon wells exist in the Low Country, however, and it is believed that many of the wells in Orangeburg, Dorchester, and Colleton Counties that are constructed as open-hole wells are open to both the Middle Floridan and Gordon aquifers. Producing separate potentiometric maps of each Tertiary aquifer would be preferable and may be feasible in the future if more monitoring wells become available. Currently, however, water levels of the three aquifers are combined to produce a single map.

2016 Floridan-Gordon Potentiometric Map

The November–December 2016 Upper Floridan-Middle Floridan-Gordon potentiometric surface map presented in this report (Plate 1) was constructed using water levels measurements from 169 wells (Table 1) located throughout the southwestern part of the State. Of those 169 wells, 74 are screened in or open to the Upper Floridan aquifer, 30 are screened in or open to the Middle Floridan aquifer, and 44 are screened in or open to the Gordon aquifer. Fifteen wells are open to both the Middle Floridan and Gordon aquifers, 5 are open to both the Upper and Middle Floridan aquifers, and one is open to all three aquifers.

Although the Tertiary-age hydrostratigraphic framework includes the Upper Three Runs and Steed Pond aquifer designations in updip areas such as Aiken County, this report uses only the downdip equivalent aquifer names (Upper Floridan, Middle Floridan, and Gordon). This was done so that the aquifer designations are consistent with the aquifers being included in the new USGS groundwater flow model currently under development.

For this map, water-level data in Beaufort and Jasper Counties and most of Hampton County were from Upper Floridan wells; most of the water-level data in the northern extent of this map were from Middle Floridan wells; and most of the data in the eastern portion of the map area were from Gordon aquifer wells.

In wells located near the ocean coastline, the static water level can fluctuate in response to tides in nearby oceans and estuaries. In the most severe cases, tidal effects can temporarily raise or lower the water level by as much as 3 ft from the true static level. For this 2016 map,

Table 1. Wells used for the 2016 Tertiary aquifers potentiometric map

SCDNR Well ID	Latitude (NAD 83)	Longitude (NAD 83)	2016 WL Elevation (ft NAVD 88)	Aquifer *
AIK-867	33.37749	-81.64069	213	MF/UF
AIK-877	33.21445	-81.75885	115	MF/UF
AIK-889	33.28694	-81.72201	162	G
AIK-894	33.33804	-81.70858	201	G
ALL-330	33.02611	-81.28639	149	MF
ALL-364	33.11333	-81.50639	158	MF
ALL-373	33.02472	-81.38444	157	MF
ALL-393	33.09744	-81.20885	143	G/MF
ALL-408	32.97200	-81.45447	119	MF/UF
ALL-442	32.86528	-81.30833	121	UF
BAM-11	33.18221	-81.18524	185	MF
BAM-22	33.31574	-81.13865	182	G/MF/UF
BAM-26	33.10306	-81.01270	134	MF
BAM-68	33.05583	-81.09833	104	G
BAM-81	33.17611	-80.91667	127	MF
BFT-101	32.16874	-80.74070	-8	UF
BFT-118	32.42219	-80.75033	1	UF
BFT-133	32.52247	-80.71739	1	UF
BFT-145	32.55089	-80.74100	-3	UF
BFT-301	32.34569	-80.89750	-13	UF
BFT-374	32.23324	-80.81756	-6	UF
BFT-441	32.24945	-80.72857	-2	UF
BFT-452	32.40064	-80.43903	3	UF
BFT-455	32.32894	-80.46839	1	UF
BFT-459	32.31445	-80.67950	2	UF
BFT-461	32.68055	-80.84197	3	UF
BFT-559	32.43119	-80.67350	2	UF
BFT-563	32.37444	-80.54722	6	UF
BFT-564	32.33519	-80.62342	2	UF
BFT-565	32.32166	-80.67352	2	UF
BFT-566	32.35238	-80.69311	2	UF
BFT-697	32.24361	-80.72278	-1	UF
BFT-704	32.15379	-80.76499	-10	UF
BFT-709	32.13199	-80.79421	-12	UF
BFT-744	32.16617	-80.77805	-8	UF
BFT-787	32.24827	-80.69841	-2	UF
BFT-844	32.34006	-80.85538	-9	UF
BFT-976	32.34022	-80.58725	2	UF
BFT-982	32.36461	-80.65981	2	UF
BFT-1306	32.46294	-80.75986	5	UF
BFT-1540	32.43317	-80.53297	2	UF
BFT-1548	32.38119	-80.57278	4	UF
BFT-1583	32.44611	-80.65433	6	UF
BFT-1592	32.35958	-80.59522	2	UF
BFT-1599	32.47589	-80.63283	16	UF
BFT-1609	32.46336	-80.56136	3	UF
BFT-1736	32.40558	-80.76933	-2	UF
BFT-1810	32.26750	-80.72278	-4	UF
BFT-1840	32.30547	-80.68996	1	MF
BFT-1841	32.30541	-80.68963	1	UF
BFT-1845	32.28043	-80.82156	-5	MF
BFT-1846	32.28056	-80.82167	-4	UF
BFT-1925	32.46999	-80.74112	24	UF
BFT-1970	32.37517	-80.69303	0	UF
BFT-2198	32.25986	-80.71118	-2	UF
BFT-2200	32.25680	-80.70735	-1	UF
BFT-2245	32.14631	-80.82817	-12	UF
BFT-2247	32.08854	-80.87239	-17	UF
BFT-2301	32.29528	-80.79917	-2	UF
BFT-2303	32.23833	-80.80861	-6	UF
BFT-2305	32.23872	-80.85585	-9	UF
BFT-2308	32.22092	-80.67174	-3	UF
BFT-2309	32.17611	-80.76806	-7	UF
BFT-2314	32.22158	-80.77812	-5	UF
BFT-2401	32.27141	-80.85861	-8	UF
BFT-2405	32.23698	-80.73241	-2	UF
BRK-35	33.13870	-79.79765	23	G
BRK-174	33.03105	-79.96768	-3	G
BRK-177	33.44867	-80.06841	56	G
BRK-595	32.97542	-79.77228	12	G
BRK-644	33.40417	-79.93389	60	G
BRK-647	33.26167	-79.65750	42	G
BRN-295	33.12830	-81.23110	156	MF
BRN-341	33.20253	-81.57787	214	MF
BRN-343	33.31077	-81.60605	236	MF
BRN-345	33.21431	-81.62371	214	MF
BRN-350	33.17917	-81.31500	179	MF
BRN-360	33.32083	-81.40750	250	MF
BRN-362	33.34474	-81.50011	282	MF
BRN-390	33.25310	-81.67233	223	UF
BRN-396	33.24625	-81.61597	262	MF
BRN-399	33.27522	-81.57328	235	MF
BRN-405	33.14692	-81.60735	160	UF
BRN-409	33.19141	-81.51316	170	MF
BRN-416	33.18273	-81.67852	144	UF
BRN-420	33.22990	-81.57516	220	MF
BRN-427	33.21101	-81.65743	177	G
BRN-434	33.28603	-81.63483	240	MF
CHN-44	32.79659	-80.07018	-27	G
CHN-101	33.04604	-79.56674	10	G
CHN-363	32.81010	-80.40067	-12	G
CHN-422	33.16842	-79.47085	16	G

Table 1 (continued). Wells used for the 2016 Tertiary aquifers potentiometric map

SCDNR Well ID	Latitude (NAD 83)	Longitude (NAD 83)	2016 WL Elevation (ft NAVD 88)	Aquifer *
CHN-460	32.88049	-79.98766	-25	G
CHN-484	32.58194	-80.30611	-28	G
CHN-802	32.94110	-79.65721	3	G
CHN-803	33.15574	-79.36390	2	G
CHN-811	32.77597	-79.94002	-5	G
CHN-989	32.73733	-80.17771	-33	G
CHN-990	32.94072	-79.65685	1	G
COL-51	32.53803	-80.42147	-22	G
COL-92	32.66158	-80.65731	-17	G
COL-96	32.73586	-80.45211	-22	G
COL-97	33.04769	-80.59764	28	G/MF
COL-170	32.61072	-80.55358	-21	G
COL-232	33.06725	-80.95378	81	G
COL-243	32.61889	-80.61175	-13	G
COL-253	32.80261	-80.47019	-12	G
COL-269	32.86386	-80.65325	-15	G/MF
COL-273	32.87739	-80.77836	4	G/MF
COL-274	32.87361	-80.68881	-12	G/MF
COL-275	32.82294	-80.69903	-10	G/MF
COL-284	33.12847	-80.81192	101	MF
COL-294	32.88383	-80.40436	-5	G
COL-301	32.51159	-80.29922	-25	G
COL-782	32.59306	-80.46436	-23	G
COL-785	32.73697	-80.81725	8	MF
COL-787	32.63308	-80.49786	-25	G
COL-788	32.96700	-80.69514	0	G/MF
COL-789	32.73522	-80.59100	-19	G
COL-790	32.80353	-80.77689	6	G/MF
COL-791	33.04508	-80.44636	27	G
COL-792	32.82972	-80.56664	-13	G
COL-793	33.11347	-80.70336	89	MF
COL-794	32.98094	-80.85317	36	G/MF
COL-795	32.74881	-80.69547	-10	G
COL-796	32.85261	-80.84550	10	G/MF
COL-797	32.99261	-80.55650	19	G/MF
COL-798	33.04775	-80.52167	28	G/MF
DOR-49	32.96443	-80.27619	-14	G
DOR-58	33.11086	-80.28265	36	G
DOR-68	33.21359	-80.44922	39	G
DOR-155	33.14905	-80.42551	51	G/MF
DOR-168	33.20768	-80.64124	100	MF
DOR-240	33.03075	-80.20543	3	G
DOR-402	33.21194	-80.70389	113	MF
HAM-51	32.55756	-81.28461	23	UF
HAM-72	32.97810	-81.11280	100	G/MF
HAM-73	32.89919	-81.00489	56	MF/UF

SCDNR Well ID	Latitude (NAD 83)	Longitude (NAD 83)	2016 WL Elevation (ft NAVD 88)	Aquifer *
HAM-74	32.87830	-81.04000	72	UF
HAM-76	32.80550	-80.90842	28	MF/UF
HAM-79	32.78528	-81.05806	34	UF
HAM-83	32.69722	-80.85083	5	UF
HAM-174	32.82278	-81.28389	113	UF
HAM-175	32.92472	-81.04806	70	UF
HAM-180	32.76194	-81.25944	86	UF
HAM-181	32.73417	-81.36083	60	UF
HAM-261	32.68256	-81.25336	61	UF
HAM-314	32.83017	-81.16594	80	UF
JAS-298	32.45917	-80.89667	-14	UF
JAS-351	32.51997	-81.15392	16	UF
JAS-402	32.46361	-81.10750	9	UF
JAS-403	32.60522	-81.16261	19	UF
JAS-420	32.29778	-81.12028	-13	UF
JAS-421	32.13139	-81.05667	-52	UF
JAS-425	32.61806	-80.99528	4	UF
JAS-442	32.52083	-80.93750	-1	UF
JAS-474	32.54261	-81.25483	25	UF
JAS-490	32.48161	-80.97231	-5	UF
JAS-499	32.17303	-81.07631	-39	UF
ORG-48	33.46806	-80.85611	169	MF
ORG-431	33.50833	-80.86500	228	MF
ORG-635	33.45683	-80.59503	126	G
ORG-636	33.39383	-80.54247	83	G
ORG-637	33.58206	-80.81642	254	MF
ORG-638	33.43267	-80.42869	84	G
ORG-639	33.30931	-80.27931	77	MF
ORG-640	33.33219	-80.60556	105	G/MF
ORG-641	33.28556	-80.71875	131	MF
ORG-642	33.45194	-81.13694	194	G

* UF: *Upper Floridan aquifer;* MF: *Middle Floridan aquifer;* G: *Gordon aquifer*

water-level elevations were not compensated to account for these effects. Although tidal effects could influence water levels by as much as a few feet in some wells, it is unlikely that the use of uncorrected water levels would noticeably change the contouring on this map, given the use of a 20-foot contour interval. However, SCDNR's future potentiometric mapping work for the Floridan aquifer will likely include tidal corrections for some wells.

The Floridan aquifer potentiometric surface for late 2016 indicates a generally southeastward groundwater flow. Potentiometric elevations range from 282 ft in Barnwell County to -52 ft in southern Jasper County. Along the coast, water levels in the Gordon aquifer were slightly above sea level in northern Charleston County, but lower than -20 ft in most of southern Charleston County. In Beaufort County, water levels in the Upper Floridan aquifer north of the Broad River were generally slightly above sea level, while south of the Broad River water levels were below sea level, decreasing steadily toward the southwest. No cones of depression are seen within South Carolina on this map, but the widespread potentiometric low caused by groundwater pumping in the Savannah, Georgia area continues to impact water levels and the groundwater flow direction in southern Beaufort and Jasper Counties. Although water levels in much of Charleston and southern Colleton and Dorchester Counties were below sea level, the lack of any specific cones of depression suggests regional rather than localized lowering of the potentiometric surface, along with water-level recoveries in some areas where groundwater pumping has been reduced in recent years.

A comparison of the 2016 map with the predevelopment potentiometric map (Aucott and Speiran, 1985b) suggests that water levels in the updip extents of the aquifer have not significantly declined over time, but that elsewhere, water levels have been lowered regionally and locally in response to many years of groundwater pumping. Declines from predevelopment of about 20 ft are seen in southern Orangeburg and Bamberg Counties, and declines in Colleton County range from 20 ft in the northern end of the county to as much as 50 ft near the coast. In Berkeley and northern Charleston Counties, declines are less than 25 ft, while in southern Charleston County, water levels may be as much as 50 ft lower. Declines in Hampton County range from less than 10 ft in the north to about 30 ft near the Jasper County border. In the northeastern half of Beaufort County, water levels are within 25 ft of predevelopment levels. The largest departure from predevelopment conditions in this aquifer occurs in southwestern Beaufort and Jasper Counties, where water levels declines may be 50 to 80 ft, respectively.

Considerations for Future Work

The distribution and number of wells available for this potentiometric map is generally very good. More Upper Floridan wells could be helpful in southern Jasper and western Beaufort Counties to help better monitor the Savannah cone of depression, and more Gordon aquifer wells in Charleston and Berkeley Counties would be beneficial, as that area has relatively few data points. Also, more water-level data for the Gordon aquifer in Beaufort, Hampton, and Jasper Counties would help quantify the hydraulic head difference across the Gordon confining unit in that region and determine if mapping the potentiometric surface of the Gordon aquifer separately from that of the Floridan aquifers if warranted.

DNR is developing tidal corrections for numerous coastal wells that can be used to compensate for tidal distortion of true static water levels. It is expected that for future potentiometric mapping work for the Floridan aquifer will include tidal corrections for some wells.

CROUCH BRANCH POTENTIOMETRIC MAP – NOVEMBER–DECEMBER 2016

Previous Work

Because almost all of the wells used to develop the 2016 Crouch Branch aquifer potentiometric map would also have been used to develop a 2016 Black Creek aquifer potentiometric map, had such a map been produced, the Crouch Branch map is likely to closely resemble the 2016 Black Creek map. Some wells in the eastern part of the state that would have been included in a Black Creek map were determined to be screened in the McQueen Branch or Charleston aquifers, and used for the potentiometric map of those aquifers. Although the removal of those wells from the Crouch Branch map did reduce the number of data points in that area, it did not significantly change the potentiometric contouring. The similarity between the Crouch Branch and Black Creek aquifers allows for a fairly direct comparison of the 2016 Crouch Branch map with earlier Black Creek potentiometric maps.

Although 2016 is the first year for which the potentiometric map has been made for the Crouch Branch aquifer in South Carolina, similar maps have been produced by DNR showing the potentiometric surface of the Black Creek aquifer in 2015 (Wachob and Czwartacki, 2016), 2012 (Hockensmith and others, 2013b), 2009 (Hockensmith, 2012a), 2004 (Hockensmith, 2008a), 2001 (Hockensmith, 2003a), and 1995 (Hockensmith, 1997). Earlier work by the USGS produced potentiometric maps for the Black Creek aquifer for 1989 (Stringfield and Campbell, 1993) and 1982 (Aucott and Speiran, 1985a),

Table 2. Wells used for the 2016 Crouch Branch aquifer potentiometric map

SCDNR Well ID	Latitude (NAD 83)	Longitude (NAD 83)	2016 WL Elevation (ft NAVD 88)	Aquifer *
AIK-344	33.51682	-81.57552	291	CB
AIK-497	33.55092	-81.65740	325	CB
AIK-824	33.43784	-81.77030	234	CB
AIK-846	33.54234	-81.48559	269	CB
AIK-847	33.54245	-81.48553	269	CB
AIK-859	33.37739	-81.64070	216	CB
AIK-863	33.21461	-81.75885	143	CB
AIK-874	33.21457	-81.75883	150	CB
AIK-888	33.28689	-81.72198	157	CB
AIK-2378	33.35329	-81.80902	163	CB
AIK-2379	33.35339	-81.80895	164	CB
AIK-2450	33.52488	-81.70878	301	MB/CB
AIK-2468	33.66051	-81.36985	332	CB
AIK-2721	33.49497	-81.65766	294	CB
ALL-367	33.11339	-81.50602	149	CB
ALL-368	33.11351	-81.50600	150	CB
ALL-369	33.11313	-81.50609	150	CB
ALL-376	33.02489	-81.38481	137	CB
BAM-27	33.28836	-81.04081	145	CB
BRK-89	33.28494	-79.69440	-33	MB/CB
BRN-324	33.31085	-81.60611	186	CB
BRN-325	33.31081	-81.60605	186	CB
BRN-328	33.20253	-81.57787	165	CB
BRN-331	33.21436	-81.62369	170	CB
BRN-353	33.17887	-81.31431	159	CB
BRN-355	33.17896	-81.31437	160	CB
BRN-363	33.40298	-81.43940	227	CB
BRN-365	33.32163	-81.40678	202	CB
BRN-368	33.32148	-81.40682	202	CB
BRN-375	33.27521	-81.57346	185	CB
BRN-377	33.18274	-81.67868	159	CB
BRN-380	33.28614	-81.63492	178	CB
BRN-389	33.34480	-81.50013	209	CB
BRN-393	33.24621	-81.61608	175	CB
BRN-402	33.14697	-81.60733	156	CB
BRN-406	33.19135	-81.51319	166	CB
BRN-418	33.22987	-81.57519	175	CB
BRN-424	33.21103	-81.65739	165	CB
BRN-432	33.28612	-81.63488	178	CB
BRN-437	33.25322	-81.67243	169	CB
CAL-2	33.55700	-80.71671	107	CB
CAL-195	33.59858	-80.64786	95	CB
CHN-182	33.20098	-79.43516	-48	CB
CLA-30	33.88542	-80.01019	47	CB
CLA-33	33.65142	-80.27992	95	CB
CLA-61	33.82599	-79.94917	21	CB
CLA-63	33.89226	-80.07793	57	CB
CLA-148	33.73825	-80.35829	143	CB
CLA-213	33.58871	-80.20605	66	CB
COL-30	32.89593	-80.67781	48	CB
COL-150	33.09148	-80.81211	76	CB
DIL-169	34.36335	-79.53416	109	CB
DIL-172	34.33028	-79.28690	37	CB
FLO-207	34.03692	-79.78519	30	CB
FLO-276	33.85582	-79.76658	-13	CB
FLO-298	34.17020	-79.78815	59	CB
FLO-317	33.99389	-79.60157	72	CB
GEO-95	33.34015	-79.36215	-198	CB
GEO-153	33.36303	-79.22768	-109	CB
GEO-232	33.23595	-79.39252	-143	CB
GEO-249	33.66252	-79.24560	-62	MB/CB
GEO-296	33.22504	-79.20454	-53	CB
GEO-379	33.69803	-79.35318	-54	MB/CB
GEO-382	33.33580	-79.24458	-105	CB
GEO-383	33.33580	-79.24453	-100	CB
HOR-225	33.99861	-79.20389	-3	CB
HOR-290	33.67079	-78.93916	-78	CB
HOR-304	33.69361	-78.89763	-82	MB/CB
HOR-309	33.76762	-78.96631	-80	CB
HOR-548	33.68128	-78.99569	-85	CB
HOR-666	33.68800	-79.11840	-64	MB/CB
HOR-1327	33.65709	-78.92686	-82	CB
LEX-823	33.73578	-81.10539	287	CB
LEE-180	34.20221	-80.17448	173	CB
MRN-77	33.86178	-79.33055	-22	CB
ORG-385	33.36904	-81.03065	134	CB
ORG-388	33.36232	-81.03298	136	CB
ORG-393	33.50826	-80.86494	136	CB
ORG-509	33.55011	-80.95374	171	CB
ORG-548	33.70342	-81.03570	224	CB
RIC-776	33.83714	-80.62544	88	CB
SUM-288	33.98583	-80.21333	122	CB
SUM-297	33.71022	-80.53203	57	CB
SUM-497	33.87416	-80.43776	156	CB
WIL-12	33.67307	-79.82708	-3	CB
WIL-16	33.72701	-79.57423	-31	CB
WIL-51	33.78720	-79.80723	8	CB
WIL-177	33.52482	-79.89203	25	CB

* CB: *Crouch Branch aquifer;* MB: *McQueen Branch aquifer*

and Aucott and Speiran (1985b) also mapped the Black Creek aquifer's predevelopment potentiometric surface.

2016 Crouch Branch Potentiometric Map

The November–December 2016 Crouch Branch potentiometric surface map presented in this report (Plate 2) was constructed using water-level measurements from 88 wells (Table 2). Of those 88 wells, 82 are screened only in the Crouch Branch aquifer, and 6 are screened in both the Crouch Branch and McQueen Branch aquifers.

The 2016 potentiometric surface of the Crouch Branch aquifer shows a generally southeastward groundwater flow affected by potentiometric lows in the eastern half of the State. The most prominent feature on the 2016 map is the large cone of depression centered in Georgetown County, and water-level declines are also seen in the Myrtle Beach area of Horry County (Fig. 14). The potentiometric lows in coastal Georgetown and Horry Counties, which are the result of groundwater pumping, may lead to saltwater intrusion into the aquifer in this area.

Comparison to Previous Black Creek Potentiometric Maps

Compared to previous Black Creek potentiometric maps, the 2016 map shows little change in water levels in the western half of the Coastal Plain and in most of the inland regions of the eastern part of the State. Overall, the 2016 Crouch Branch potentiometric surface is very similar to the 2015 Black Creek potentiometric surface. The lowest water-level elevation measured in 2016 was -198 ft (corresponding to a water level depth of 218 ft below land surface) in the well GEO-95; the water level in this same well was 3 ft lower when measured for the November 2015 map. On both the 2016 and 2015 maps, GEO-95 defined the center of the Georgetown County cone of depression. The potentiometric depression centered in Georgetown County appears deeper and more widespread than on the potentiometric maps made for 2012 and all years before that. Note that direct comparisons to previous maps can be difficult because the same wells are often not used for different maps, and each map's contours are based on the data available for that year.

Comparing the 2016 Crouch Branch potentiometric surface to the predevelopment Black Creek potentiometric surface of Aucott and Speiran (1985b) suggests that, downdip from the recharge areas and outside of the western edge of the aquifer, water levels throughout much of this aquifer have generally declined about 50 to 100 ft below estimated predevelopment levels. In southern Georgetown County, the water level decline is more than 200 ft.

Considerations for Future Work

The most significant feature of the 2016 Crouch Branch potentiometric surface—the deep and widespread cone of depression centered in Georgetown County—is defined by only six water level measurements. Currently, DNR has only two Crouch Branch monitoring wells in Georgetown County (GEO-382 and GEO-383), both of which are located at the same site east of the center of the cone of depression. Because no wells near the Town of Andrews in western Georgetown County were available for measurement in 2016, the potentiometric low centered in that area that is seen on earlier potentiometric maps (for example, in 2001 and 2004) is absent from this map; had wells in the Andrews area been measured, the 2016 map may have shown the potentiometric depression in Georgetown County extending across most of the southern half of that county. For future potentiometric mapping, the inclusion of additional Crouch Branch wells located throughout Georgetown County and eastern Williamsburg County could significantly improve the definition of aquifer conditions in this area.

In the southern part of the state (Berkeley, Charleston, Colleton, Dorchester, Hampton, and Jasper Counties), very few Crouch Branch wells were available for measurement, so the contouring of the potentiometric surface in that area is somewhat speculative. Even a small number of additional data points in these counties would improve confidence in the potentiometric surface contours in this region.

Because of the large number of monitoring wells at the Savannah River Site and surrounding area, the northwestern corner of the Coastal Plain (primarily Aiken and Barnwell Counties) is adequately covered by the existing well network.

On this 2016 Crouch Branch map, limited water-level data were available throughout much of the updip and recharge areas near the Fall Line, most notably in the upper Pee Dee region of Darlington and Marlboro Counties, which limits potentiometric contouring of the Crouch Branch aquifer near the Fall Line. There may be limited value in attempting to extend the potentiometric contours to the Fall Line, however, as in this area the aquifer becomes unconfined, and the shape of the water table is dominated by local topography. Thinning aquifer beds also limit the extent to which water levels can fluctuate. On top of all that, as the land surface elevation rises to over 400 ft above sea level near the Fall Line, so too does the water table, and contours of the water table begin to resemble contours of the topography.

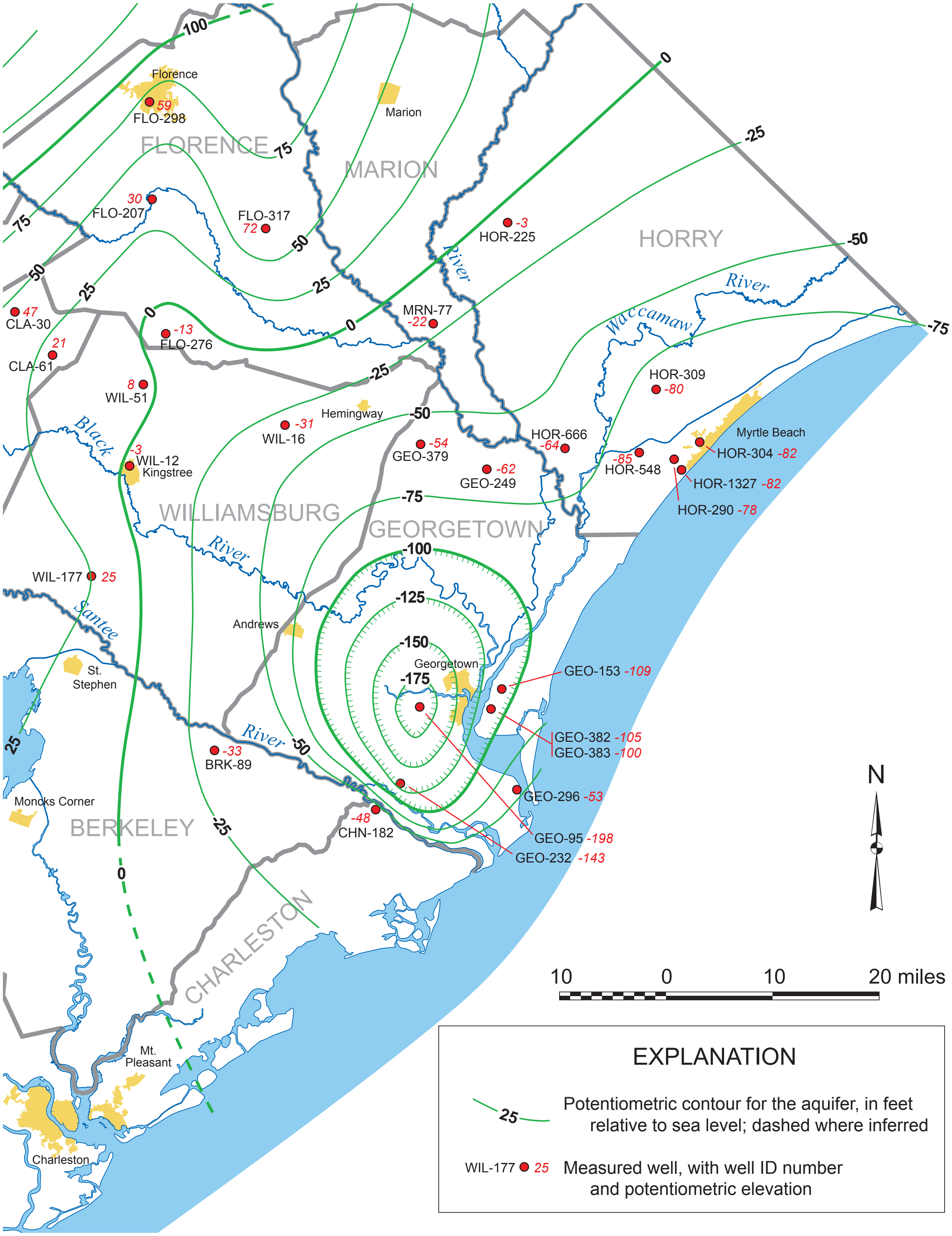


Figure 14. Contour map of the potentiometric surface of the Crouch Branch aquifer in November–December 2016 in eastern South Carolina (see Plate 2), showing the large cone of depression in Georgetown County.

McQUEEN BRANCH POTENTIOMETRIC MAP – NOVEMBER–DECEMBER 2016

Previous Work

2016 is the first year for which DNR mapped the potentiometric surface of the McQueen Branch-Charleston-Gramling aquifers in South Carolina. Because the McQueen Branch and Charleston aquifers of the newer aquifer nomenclature system are correlated with the Middendorf aquifer of the older nomenclature system, the new McQueen Branch-Charleston-Gramling potentiometric map is generally comparable to previously produced Middendorf potentiometric maps.

Maps have been produced by DNR describing the potentiometric surface of the Middendorf aquifer in 2014 (Wachob, 2015), 2011 (Hockensmith and others, 2013c), 2009 (Hockensmith, 2012b), 2004 (Hockensmith, 2008b), 2001 (Hockensmith, 2003b), and 1996 (Hockensmith and Waters, 1998). Earlier work by the USGS produced potentiometric maps for the Middendorf aquifer for 1989 (Stringfield and Campbell, 1993) and 1982 (Aucott and Speiran, 1985a), and Aucott and Speiran (1985b) mapped the Middendorf aquifer's predevelopment potentiometric surface.

2016 McQueen Branch Potentiometric Map

The November–December 2016 McQueen Branch-Charleston-Gramling potentiometric surface map presented in this report (Plate 3) was constructed using water-levels measurement from 120 wells (Table 3) located throughout the South Carolina Coastal Plain. Of those 120 wells, 87 are screened solely in the McQueen Branch aquifer. All 24 wells located in Berkeley, Charleston, Colleton, Dorchester, and Jasper Counties are open to the Charleston aquifer; the 3 wells in Beaufort County are open to the Gramling aquifer; and of the 7 wells measured in Williamsburg County, one is McQueen Branch, two are Charleston, and 4 are screened in both Charleston and McQueen Branch aquifers.

The 2016 potentiometric surface of the McQueen Branch aquifer shows a generally southeastward groundwater flow affected by several potentiometric lows in the eastern half of the Coastal Plain region. Potentiometric levels range from more than 450 ft near the Fall Line to -136 ft in Georgetown County. Cones of depression caused by groundwater pumping are seen in Williamsburg, Charleston, and Georgetown Counties.

On this map, the contouring of the cone of depression in Georgetown County is somewhat speculative, as it is defined by only one water-level measurement, from the well GEO-188. There is also some uncertainty that the water level measured in GEO-188 is truly representative of conditions in the McQueen Branch aquifer because that well was constructed with four screened zones, the highest of which is likely in the Crouch Branch aquifer. However, owing to pumping from the McQueen Branch aquifer and the overlying Crouch Branch aquifer, and probable leakage through the McQueen Branch confining unit, the authors believe that there likely exists some potentiometric low in this area, although its magnitude and extent are largely unknown.

Several production wells near the City of Florence that are usually included in the water-level data collection are absent from this 2016 map, owing to problems with accessing and measuring the water level in those wells. When included on previous Middendorf aquifer potentiometric maps, those wells defined a potentiometric depression in northern Florence County (see, for example, Wachob, 2015; Hockensmith and others, 2013c; Hockensmith, 2012b; and Hockensmith, 2008b). Because data from these wells were unavailable this year, the 2016 map gives no indication of a cone of depression near the City of Florence, although it is believed to still exist. For that reason, the contour lines in the Florence County area are dashed, indicating that they are inferred and may overestimate water levels in that area. Near the City of Florence, water levels may be as much as 100 ft lower than indicated on this map.

Comparison to Previous Middendorf Potentiometric Maps

Comparing recent potentiometric maps to earlier potentiometric maps can indicate changing hydrologic conditions within an aquifer. Care must be taken, however, that the maps being compared represent the essentially same aquifers. Because this is the first McQueen Branch map produced by DNR, only earlier Middendorf potentiometric maps are available for comparison.

In the western half of South Carolina, the comparison between the 2016 McQueen Branch map and earlier Middendorf maps is fairly straightforward, as most wells that appear on the McQueen Branch aquifer map would have also been used for a Middendorf aquifer map. A comparison of the 2016 McQueen Branch map to recent Middendorf potentiometric maps shows no significant changes in water levels in the aquifer in Aiken, Allendale, Barnwell, Bamberg, Calhoun, Orangeburg, and Lexington Counties.

A cone of depression centered at Mount Pleasant continues to dominate the potentiometric surface in Charleston County. Compared to water levels measured in 2014, the maximum depth of the cone has not deepened, but

Table 3. Wells used for the 2016 McQueen Branch-Charleston-Gramling aquifers potentiometric map

SCDNR Well ID	Latitude (NAD 83)	Longitude (NAD 83)	2016 WL Elevation (ft NAVD 88)	Aquifer *
AIK-430	33.32778	-81.74306	190	MB
AIK-643	33.37746	-81.64064	212	MB
AIK-817	33.43750	-81.77000	225	MB
AIK-818	33.43750	-81.77000	228	MB
AIK-826	33.54222	-81.48556	271	MB
AIK-845	33.54306	-81.48556	271	MB
AIK-865	33.28701	-81.72194	166	MB
AIK-871	33.37740	-81.64063	216	MB
AIK-872	33.21449	-81.75880	156	MB
AIK-892	33.33789	-81.70847	191	MB
AIK-902	33.35278	-81.80972	144	MB
AIK-2380	33.35333	-81.80917	151	MB
AIK-2449	33.53946	-81.85498	232	MB
AIK-2544	33.62531	-81.84964	411	MB
AIK-2711	33.51389	-81.92083	225	MB
AIK-2720	33.65386	-81.71552	355	MB
ALL-347	33.02472	-81.38444	178	MB
ALL-358	33.11306	-81.50639	169	MB
ALL-377	33.02472	-81.38444	178	MB
ALL-378	33.06139	-81.56389	164	MB
BAM-77	33.30636	-81.03567	173	MB
BFT-10	32.32976	-80.70774	123	Gramling
BFT-11	32.35294	-80.68974	108	Gramling
BFT-454	32.24828	-80.73262	142	Gramling
BRK-46	33.40542	-79.92556	6	Char.
BRK-431	33.17222	-80.03861	6	Char.
BRK-654	33.00655	-79.88091	-40	Char.
BRN-78	33.39989	-81.42186	227	MB
BRN-243	33.20253	-81.57787	173	MB
BRN-246	33.21432	-81.62378	173	MB
BRN-303	33.24616	-81.61598	176	MB
BRN-312	33.34473	-81.50018	208	MB
BRN-313	33.25313	-81.67242	169	MB
BRN-314	33.19139	-81.51310	179	MB
BRN-316	33.18269	-81.67853	164	MB
BRN-335	33.14695	-81.60737	171	MB
BRN-349	33.17833	-81.31444	183	MB
BRN-356	33.17889	-81.31444	182	MB
BRN-358	33.32111	-81.40667	207	MB
BRN-366	33.32056	-81.40778	206	MB
BRN-384	33.18270	-81.67857	163	MB
BRN-417	33.22981	-81.57512	178	MB
BRN-430	33.28604	-81.63476	178	MB
CAL-115	33.81091	-80.98310	149	MB
CAL-196	33.48578	-80.65986	104	MB
CHN-14	32.79139	-79.92861	-50	Char.
CHN-163	32.78823	-79.87189	-101	Char.
CHN-172	32.84723	-80.06480	-23	Char.
CHN-173	32.84363	-79.82681	-71	Char.
CHN-174	32.58059	-80.15977	-27	Char.
CHN-178	32.78481	-79.94786	-31	Char.
CHN-185	32.82043	-79.83715	-81	Char.
CHN-186	32.60084	-80.10587	-56	Char.
CHN-187	32.78731	-79.78814	24	Char.
CHN-219	32.80497	-79.73339	32	Char.
CHN-601	32.75967	-79.84875	-51	Char.
CHN-603	32.77686	-79.80981	8	Char.
CHN-604	32.80259	-79.75474	-27	Char.
CHN-635	32.76473	-79.83279	12	Char.
CHN-801	32.61449	-80.05243	-52	Char.
CHN-849	32.79175	-79.89866	-67	Char.
CLA-27	33.68827	-80.19344	52	MB
CLA-146	33.63456	-80.26667	60	MB
COL-49	32.95069	-80.63461	81	Char.
COL-50	32.91178	-80.64733	84	Char.
CTF-197	34.65194	-80.27889	451	MB
CTF-221	34.42881	-80.28201	243	MB
CTF-224	34.49156	-80.26497	327	MB
DAR-96	34.50583	-79.85611	73	MB
DAR-228	34.45889	-79.88000	132	MB
DIL-70	34.47312	-79.40152	65	MB
DIL-79	34.34554	-79.16781	58	MB
DIL-121	34.32860	-79.28390	41	MB
DIL-129	34.46853	-79.33158	65	MB
DIL-132	34.48263	-79.31456	76	MB
DIL-170	34.36335	-79.53422	50	MB
DIL-173	34.33029	-79.28698	37	MB
DIL-175	34.33032	-79.28702	35	MB
DOR-88	32.95979	-80.20158	11	Char.
DOR-228	32.98372	-80.21845	10	Char.
FLO-95	34.23724	-79.81236	104	MB
FLO-128	34.19556	-79.58056	59	MB
FLO-274	33.85556	-79.76639	2	MB
GEO-188	33.36216	-79.46130	-136	MB
HOR-409	33.68933	-78.98089	-83	MB
HOR-419	33.62994	-78.96492	-82	MB
HOR-1171	33.87538	-79.23406	-38	MB
HOR-1326	33.65721	-78.92680	-75	MB
JAS-426	32.61833	-80.99528	119	Char.
LEE-60	34.11006	-80.22586	170	MB
LEE-179	34.20225	-80.17436	179	MB
LEX-838	33.86816	-81.40758	455	MB
LEX-844	33.74611	-81.10750	296	MB
MLB-27	34.54722	-79.52083	107	MB

Table 3 (continued). Wells used for the 2016 McQueen Branch-Charleston-Gramling aquifers potentiometric map

SCDNR Well ID	Latitude (NAD 83)	Longitude (NAD 83)	2016 WL Elevation (ft NAVD 88)	Aquifer *
MLB-31	34.67381	-79.54164	164	MB
MLB-110	34.49306	-79.71944	60	MB
MLB-112	34.62600	-79.68917	128	MB
MRN-68	34.24679	-79.50017	28	MB
MRN-69	34.25113	-79.49738	29	MB
ORG-79	33.41319	-80.84757	150	MB
ORG-461	33.24736	-80.81933	150	MB
RIC-543	33.87500	-80.70250	132	MB
RIC-585	33.94889	-80.84083	203	MB
RIC-729	34.08308	-80.91708	268	MB
RIC-775	33.83744	-80.62550	102	MB
SUM-119	33.91750	-80.32111	78	MB
SUM-132	33.91833	-80.32333	77	MB
SUM-146	33.93608	-80.34513	99	MB

SCDNR Well ID	Latitude (NAD 83)	Longitude (NAD 83)	2016 WL Elevation (ft NAVD 88)	Aquifer *
SUM-153	33.86515	-80.37646	79	MB
SUM-332	33.84444	-80.37556	90	MB
SUM-364	33.93639	-80.34944	105	MB
SUM-488	33.87444	-80.43778	108	MB
SUM-492	33.94556	-79.98000	53	MB
WIL-203	33.70433	-79.81333	-47	MB/Char.
WIL-207	33.57653	-79.93653	-3	MB/Char.
WIL-208	33.58322	-79.87039	-11	MB/Char.
WIL-211	33.68156	-79.55717	-25	MB/Char.
WIL-212	33.65361	-79.50206	-27	Char.
WIL-213	33.77292	-79.44781	-42	Char.
WIL-355	33.40250	-79.77832	-9	MB

* MB: *McQueen Branch aquifer;* Char.: *Charleston aquifer*

it appears to be expanding inland; water levels in two Mount Pleasant wells were more than 25 ft lower in 2016 than in 2014.

In the eastern half of the state, however, the comparison between McQueen Branch and Middendorf maps becomes more problematic. In this area, the Black Creek aquifer of Aucott and others (1987), rather than the Middendorf aquifer, is equivalent to the McQueen Branch aquifer of Gellici and Lautier (2010). As a result, several wells measured for this mapping work that would have been used for a Black Creek potentiometric map (rather than a Middendorf map) appear on the McQueen Branch map. The inclusion of these wells, which are mostly in Horry and Georgetown Counties, results in significantly different potentiometric surfaces of the McQueen Branch aquifer compared to that of the Middendorf aquifer in eastern South Carolina (see Figs. 15 and 16). On the McQueen Brach map, water levels in Williamsburg and southern Marion Counties are generally 25 to 50 ft lower than on the Middendorf map, but the extensive cone of depression in Williamsburg County on the Middendorf map is much smaller and centered at the Town of Kingstree. Potentiometric levels in Horry and Georgetown Counties on the McQueen Branch map are generally 50 to 125 ft lower than on the Middendorf map, and the McQueen Branch map shows a deep cone of depression east of the City of Georgetown that is absent from the Middendorf map.

Comparing the 2016 McQueen Branch potentiometric surface to the predevelopment Middendorf potentiometric surface of Aucott and Speiran (1985b) suggests that, downdip from the recharge areas and outside of the western edge of the aquifer, water levels throughout much of this aquifer have generally declined 50 to 100 ft below estimated predevelopment levels, and in downdip areas where this aquifer has been used extensively, water level declines have been even larger. Water levels in areas of Charleston and Georgetown Counties are more than 200 ft lower than estimated predevelopment levels.

Considerations for Future Work

The most significant need for additional McQueen Branch water-level data occurs in eastern South Carolina. More data points in Horry, Georgetown, Marion, and Williamsburg Counties would serve to better define the potentiometric surface in that area and confirm the presence and extent of the cones of depression in Georgetown and Williamsburg Counties, as each of those features is presently defined by only one well. Improved hydrogeologic understanding of the deeper aquifers in this area and more water-level data from wells screened in only the McQueen Branch aquifer would greatly improve confidence in the potentiometric map of this aquifer.

Additional data points and more reliable monitoring in northern Florence County would help define the cone of depression that probably exists near the City of Florence, but does not appear on this 2016 map because of insufficient data. The problems encountered with trying to measure water levels in the production wells in that area highlights the need for dedicated monitoring wells in this area.

Because of the numerous monitoring wells at the Savannah River Site and surrounding area, the northwestern corner of the Coastal Plain (primarily Aiken and Barnwell Counties) is adequately covered by the existing well network. In the southern part of the state (Beaufort, Colleton, Dorchester, Hampton, and Jasper Counties), few McQueen Branch wells were available for measurement, so the addition of even one or two wells in each county might improve confidence in the potentiometric contouring in this region.

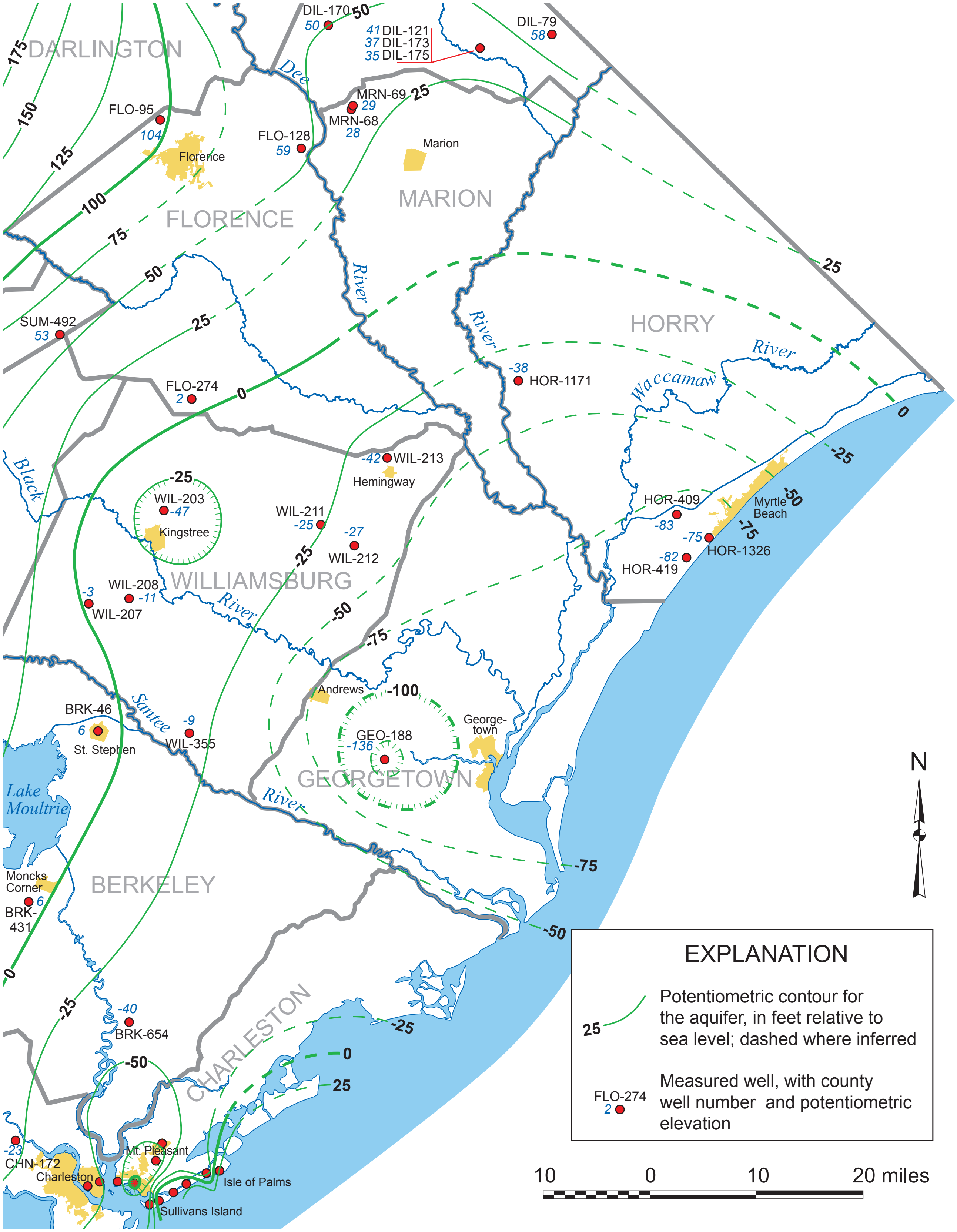


Figure 15. The November–December 2016 potentiometric surface map of the McQueen Branch-Charleston-Gramling aquifer in eastern South Carolina (see Plate 3). This map includes six wells in Horry, Georgetown, and Williamsburg Counties that would be considered Black Creek aquifer wells in the hydrostratigraphic framework of Aucott and others (1987).

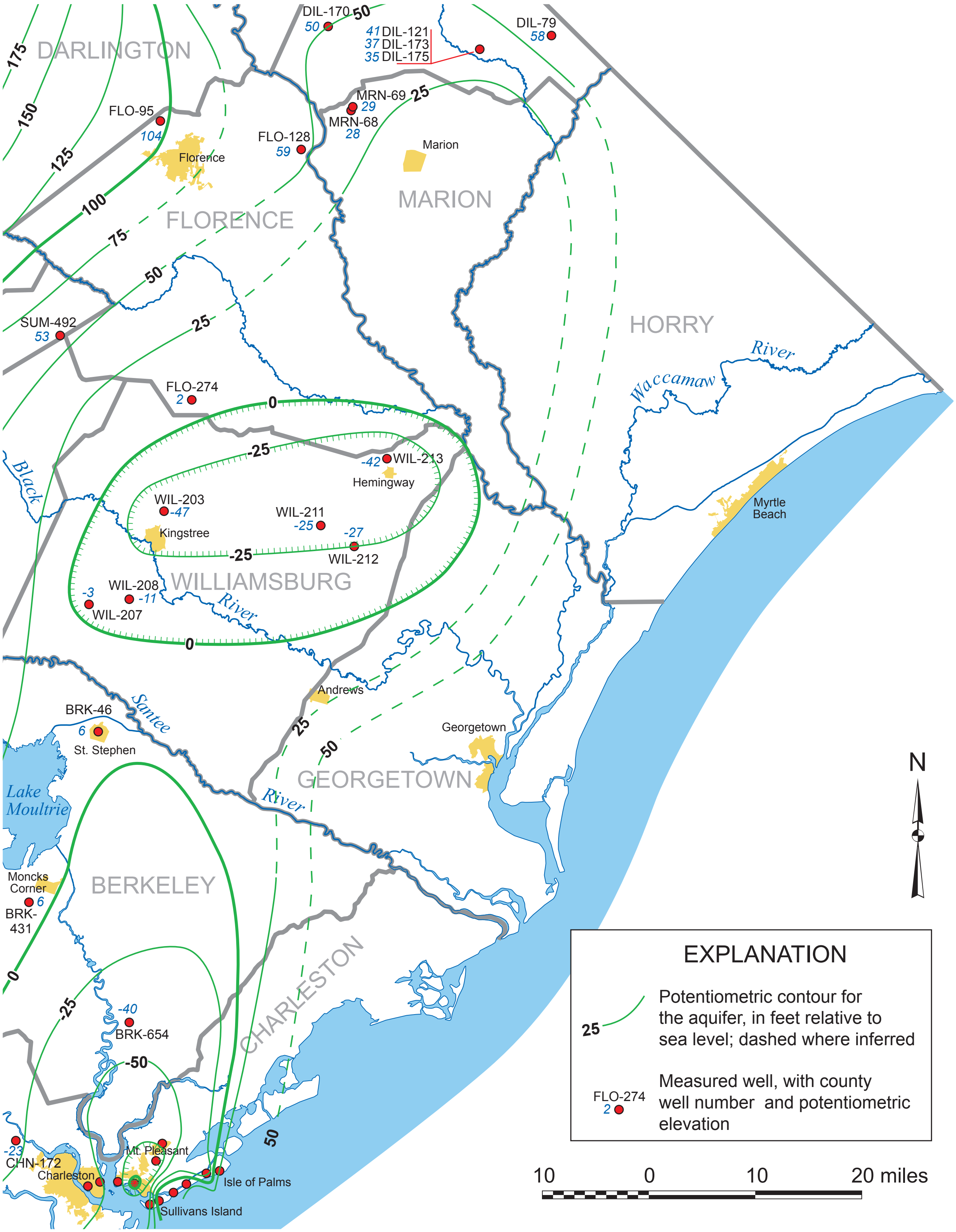


Figure 16. The November–December 2016 potentiometric surface map of the Middendorf aquifer in eastern South Carolina, as it would have been drawn if using the hydrostratigraphic framework of Aucott and others (1987).

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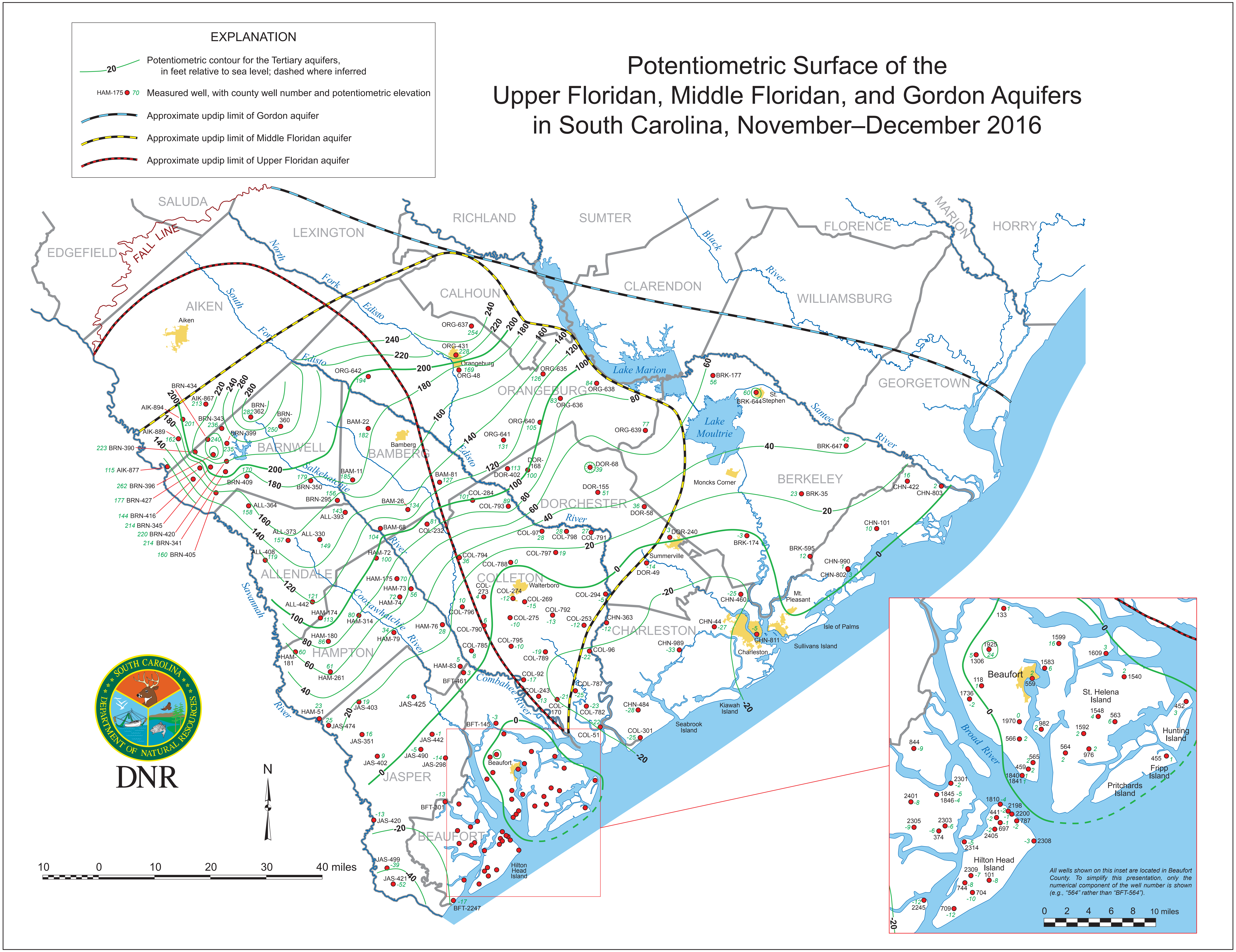
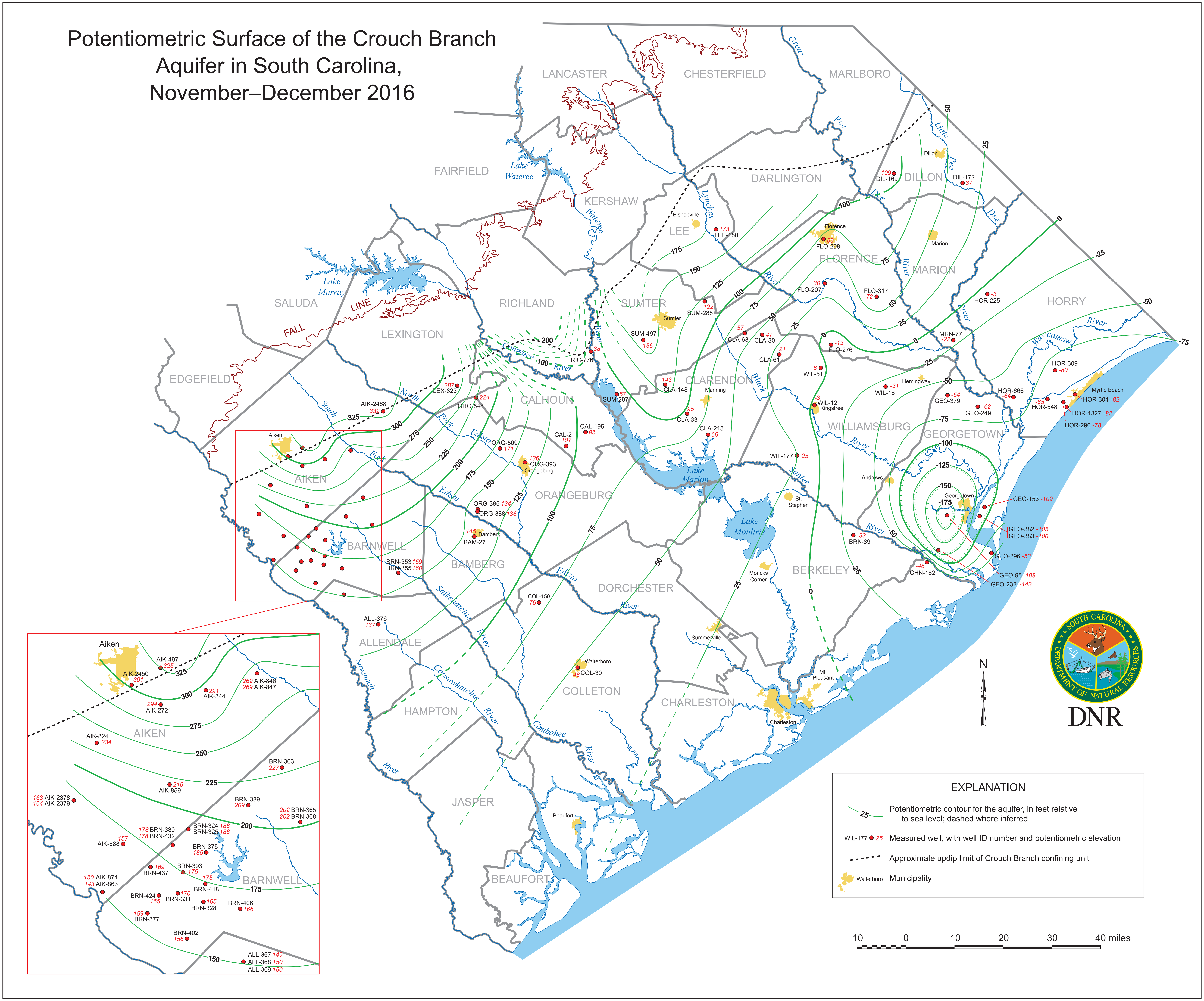
Potentiometric Surface of the Upper Floridan, Middle Floridan, and Gordon Aquifers in South Carolina, November–December 2016



Potentiometric Surface of the Crouch Branch Aquifer in South Carolina, November–December 2016



Potentiometric Surface of the McQueen Branch, Charleston, and Gramling Aquifers in South Carolina, November–December 2016