THE POTENTIOMETRIC SURFACES OF THE BLACK CREEK AND MIDDENDORF AQUIFERS OF SOUTH CAROLINA: A HISTORICAL PERSPECTIVE

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Abstract. The potentiometric surfaces of the Black Creek and Middendorf aquifers were measured in November 2009 by South Carolina Department of Natural Resources staff and others from a network of nearly 300 wells. Synoptic measurements of the potentiometric surface of Cretaceous aquifers in the South Carolina Coastal Plain have been taken at roughly 5-year intervals for nearly 30 years. The November 2009 potentiometric maps of these aquifers are compared to previous maps, with hydrographs of selected wells noting trends.

The Middendorf and Black Creek aquifers are the source of water for many public, industrial, and agricultural supplies in the Coastal Plain of South Carolina. These important water resources are monitored by regularly measuring the nonpumping water levels in wells. The potentiometric surface of an aquifer is defined by the elevations at which water stands in tightly cased wells completed in the aquifer.

The boundaries of the aquifers used in this investigation are those defined by Aucott, Davis, and Speiran (1987), who delineated the aquifer on the basis of geologic data (primarily geophysical well logs), water-level data, water-chemistry data, and previous investigations. The potentiometric maps presented here were constructed by using water levels measured generally during November when data are likely to be representative of median aquifer conditions, whereas in other periods, such as late winter or mid-summer, measurements represent maximum and minimum levels, respectively. Data were collected by DNR, U.S. Department of Energy, South Carolina Department of Health and Environmental Control, and U.S. Geological Survey, Office of Ground Water, Ground-water Resources (USGS) personnel. Wells measured by previous investigators were used, where possible, to compare with historical potentiometric maps. Hydrographs were constructed from measurements by DNR and USGS. Where continuous records were available, daily mean water levels were plotted.

The Coastal Plain formations of South Carolina compose a wedge of sediment that thickens from about 0 ft (feet) at the Fall Line to more than 4,000 ft at Hilton Head Island. The sediment consists of sand, clay, and limestone of Late Cretaceous and younger ages that were deposited on a pre-Cretaceous basement complex of metamorphic, igneous, and consolidated sedimentary rock. The Middendorf Formation is between the Black Creek Formation and the Cape Fear Formation, the former being the youngest and latter being the oldest of the Cretaceous formations in the region. The Middendorf aquifer crops out along the Fall Line from Chesterfield County to Edgefield County, except for some areas in Aiken County where it is not exposed. Its outcrop is narrowest in southwestern Edgefield County and widest in Chesterfield County. The aquifer dips southeastward near the Fall Line and southward along the coast. The top of the aquifer is at elevation 100, -700, and -1,700 ft msl (feet, referenced to mean sea level) at Aiken, Little River, and Charleston, respectively. Thickness ranges from 0 ft at the Fall Line to more than 300 ft in Dorchester County. The Black Creek aquifer crops out in the eastern Coastal Plain along a narrow band extending from Lexington County to Sumter County and along a wider area from Sumter County to Dillon County. It dips southeastward toward the coast. The top of the aquifer is at elevation 300, -250, and -1,000 ft msl (feet, referenced to mean sea level) at Aiken, Little River, and Charleston, respectively. Thickness ranges from about 100 ft near Aiken to more than 400 ft at the coast.

The potentiometric surface of both aquifers generally slopes toward the coast, and the direction of ground-water flow is southeastward. In areas where the aquifer crops out it is recharged directly by rainfall. In the upper Coastal Plain, stream valleys are incised into the aquifers; where contours are deflected upstream, the aquifers discharge to those rivers. In the lower Coastal Plain the aquifer discharges only into overlying aquifers and through pumping wells.

Dimpling this surface are cones of depression caused by pumping. In 2009, the Middendorf potentiometric surface was most affected by pumping in Berkeley, Charleston, Colleton, Florence, Lee, Sumter, and Williamsburg Counties. The lowest point on the potentiometric surface, -129 ft msl, was at Kiawah. The Black Creek potentiometric surface was most affected by pumping in Marion, Sumter, southern Georgetown, and northern Florence Counties. The lowest point on the potentiometric map, -133 ft msl, was west of Georgetown.
The potentiometric levels of the Middendorf and Black Creek aquifers have been recorded since 1917 or earlier (Cooke, 1936). Aucott and Speiran (1985a and b) compared estimates of the predevelopment surface with November 1982 water levels and determined that Middendorf aquifer water levels had declined throughout the northeastern two thirds of the Coastal Plain and that Black Creek aquifer water levels had declined in Horry and Georgetown Counties. Stringfield and Campbell (1993) published November 1989 water levels for each aquifer and observed further declines since 1982. Regarding the Middendorf aquifer, Hockensmith and Waters (1998), using November 1996 data, showed additional declines and a generally southeastward ground-water flow influenced by large cones of depression in the Florence-Hemingway area and around Mount Pleasant. Hockensmith (2003) noted that by 2001, the cones of depression in Florence and Charleston Counties had expanded and deepened. Regarding the Black Creek, November 1995 (Hockensmith, 1997) and November 2001 (Hockensmith, 2003) data showed additional declines and a generally southeastward ground-water flow influenced by large cones of depression near Marion, Andrews, Georgetown, and Pawleys Island.

The worst multiyear drought on record, from June 1998 through August 2002, caused significant effects on hydrologic conditions in South Carolina. Historical low flows were recorded in 2001 for numerous regulated and unregulated streams (Kiuchi, 2004). Many of the large lakes, originally built for hydroelectric power or flood control, were at their lowest levels near the end of the drought: some were substantially below desired operating levels (Gellici and Badr, 2004). Water levels in selected Coastal Plain wells averaged declines of 8.7 ft (Gellici and Harwell, 2004) as a direct result of this meteorological event or, indirectly, because of increased ground-water pumping in response to the rainfall and surface-water deficit.

**Middendorf Aquifer:**

The region most affected by ground-water pumping is centered at Mount Pleasant, in Charleston County, where the cone of depression has expanded and deepened from 2001 to 2004. The potentiometric surface declined to -129 and -170 ft msl, in CHN-173 and CHN-163. Predevelopment levels were estimated near 130 ft msl (Aucott, 1988); therefore, a decline of about 300 ft has occurred in this area. Ground-water withdrawals by Mount Pleasant Waterworks (MPW) increased from an average of 6.2 mgd (million gallons per day) in 2001 (Greg Hill, MPW, written communication, 2002) to 7.8 mgd in 2005 (Newcome, 2005). Beginning in 2004, MPW began supplementing its water supply with surface water from the Charleston Water System: about 2 and 4 mgd were purchased in 2004 and 2005 (Jim Ouellet, MPW, oral communication).

By early 2008, water levels were at a low of 2 ft msl but recovered to 7 ft msl by November 2009. Water levels have recovered by between 45 and 70 ft by November 2009, as a result.

Water levels in CHN-14 showed a decline of more than 93 ft -between June 1991 and August 2004, to a low of -95 ft msl in August 2004, and -87 ft msl in November 2004. By November 2009, water levels had recovered to -39 ft msl. Seasonal changes in water level are apparent. The hydrograph for BRK-431 shows the effects of pumping from Summerville prior to November 1994, when water levels declined an average of 5.3 ft per year to a minimum of 38 ft msl. From November 1994 through August 1996, water levels recovered at a rate of 2.5 ft per year to a maximum of 42 ft msl. Since August 1996, water levels have declined at a rate of about 4 ft per year to 9 ft msl in November 2004. By early 2008, water levels were at a low of 2 ft msl but recovered to 7 ft msl by November 2009.

The cone of depression in southern Charleston County, around Kiawah and Seabrook Islands, deepened from 2001 to 2004. These islands are primarily resort communities for which a large portion of the water is used for golf-course and lawn irrigation. Water use by Kiawah Island Utilities increased from 1.9 to 2.4 mgd between 2000 and 2005, part of which was provided by ground water (Newcome, 2000; and Newcome, 2005). Consequently, water levels in CHN-174 and CHN-186 declined 32 and 17 ft, to -69 and -112, ft msl, respectively, from 2001 to 2004. The cone of depression may be deeper than apparent from the 2004 data because the well that indicated a -119 ft msl water level in 2001 was not measured in 2004. Predevelopment water levels for CHN-174 were at least 148 ft msl, thus indicating total declines of 217 to 260 ft. In 2009, the depth of the cone was the same as 2004 data indicated (-129 ft msl), however, the location shifted from Seabrook to Kiawah.


Water-level declines in Sumter County are a result of pumping in and around the city of Sumter. November 2004 data (SUM-69, SUM -119, SUM -132, SUM -153, and SUM -161) indicate that water levels declined between 6 and 13 ft since 2001. Declines as great as 52 ft have occurred since the predevelopment state of about 125 ft msl (Aucott and Speiran, 1985a). Average ground-water pumping in 2005 exceeded 15 million gallons per day for Sumter (the State’s largest municipal ground-water user) and nearby High Hills Water District (Newcome, 2005), most of which is from the Middendorf aquifer. Because the median transmissivity of the Middendorf aquifer is about 45,000 gpd/ft (gallons per day
per foot) (Newcome, 1993), a shallow cone of depression exists about the city, although it is not apparent from the data distribution.

Water levels in the Middendorf aquifer at Walterboro declined in 2004 from 2001 in COL-50 but likely remained the same in 2009. The water level was 103 ft msl in November 1996 and November 2001 but was 95 ft msl in November 2004. Previous investigations noted water levels between 136 and 126 ft msl in 1982 and 1989, correspondingly. Aucott and Speiran (1985a) reported a water level of 150 ft msl in a well north of Walterboro, which suggests a decline of about 55 ft since 1980. Walterboro pumped an average of 1.9 mgd from 14 Cretaceous wells (Black Creek and Middendorf) in 2005. In light of the pumpage and the documented water-level declines, there is presumed to be a cone of depression about Walterboro; however, it is not evident owing to the paucity of data in this region.

**Black Creek Aquifer:**

The lowest point on the potentiometric surface in 2009 is -133 ft msl (GEO-77), lies within a cone of depression about Andrews and Georgetown, and represents a total decline from estimated predevelopment levels (above 50 ft msl, according to Aucott and Speiran, 1985a) of about 170 ft. Water level in this well declined 8 feet since 2004. The lowest point on the potentiometric surface in 2004 was -145 within the same cone of depression. In the west, near Andrews, water levels recovered 14 ft (GEO-193) from 2001 to 2004 and another 18 ft by 2009. Along the coast, water levels recovered 2 to 34 ft from 2001 to 2004. Public water supplies for the city of Georgetown and the Waccamaw Neck area of Georgetown County are obtained from the Pee Dee and Waccamaw Rivers, and wells serve as backup sources. Ground-water pumpage for Georgetown County declined from 3.48 to 2.85 mgd from 2001 to 2004, according to Bristol (2003) and Childress and Bristol (2005). Lack of data in 2009 precludes determination if water-level recovery continued to 2009.

The region where the potentiometric surface has been most historically affected is Horry and Georgetown Counties. The hydrograph for HOR-290 shows that water levels recovered 103 ft to -49 ft msl since 1988, when most of the public water suppliers in Horry County began a conversion to surface water.

In Florence County the center of a cone of depression about Florence noted in earlier maps, is absent in 2009. It may still be locally present, however, one observation in a well not pumped for a year had a static water level of 61 ft msl, indicating a regional recovery of 60 ft since 2004. Closer monitoring is warranted.

In Williamsburg County, improved data density has allowed the effects of pumping in the southwestern part of the county to be seen. In Kingstree, water levels in wells declined 7 to 14 ft between 2001 and 2004. Water levels in WIL-64, in southwestern Williamsburg County, declined 48 ft between 2004 and 2009. Ground-water pumpage in the county increased by about 0.3 mgd from 2001 to 2004 ((Bristol, 2003; and Childress and Bristol, 2005). A cone of depression about Johnsonville, evident in 1995, is not discernible in 2004 data because of the loss of observation points near Johnsonville.

Near Sumter, water levels have also appeared to recover, based on the data from one well. A recorder had been installed to more closely monitor water levels at this site. A new observation well has been installed to aid in monitoring.

Water levels in southern Marion County (MRN-77) have declined steadily since 1982.

**REFERENCES**


——— 1985a, Potentiometric surfaces of the Coastal Plain aquifers of South Carolina prior to development: U.S. Geological Survey Water-Resources Investigations Report 84-4208, 5 sheets.


