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POTENTIOMETRIC SURFACE OF THE MIDDENDORF AQUIFER IN SOUTH CAROLINA NOVEMBER 2001

by
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ABSTRACT

The potentiometric surface of the Middendorf aquifer for November 2001 shows that the generally southeastward ground-water flow is affected by several potentiometric lows. These cones of depression have developed because of ground-water pumping in the Florence-Hemingway area, around Mount Pleasant and around Kiawah Island.

Comparing the November 2001 data with historical data shows that water levels near the outcrop areas of this aquifer have declined as a result of the drought conditions that have persisted in South Carolina since 1998. In areas influenced by pumping, water levels have declined 47 to 267 feet during various periods of record.

INTRODUCTION

The Middendorf aquifer is the source of water for many public, industrial, and agricultural supplies in much of the Coastal Plain of South Carolina. This important water resource is monitored by regularly measuring the static (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. This map of the potentiometric surface of the aquifer was prepared by the Land, Water and Conservation Division of the South Carolina Department of Natural Resources (DNR), using data collected during late 2001. For selected wells (indicated by *), trends in the ground-water levels are shown by hydrographs.

METHOD OF INVESTIGATION

The boundaries of the Middendorf aquifer 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. They acknowledged that the complex deposition of sediments in the Coastal Plain makes aquifer delineation problematic. This aquifer has been studied extensively by Cooke (1936), Siple (1957), Colquhoun and others (1983), Renken (1984), Aucott and Speiran (1985a, and 1985b), Stringfield and Campbell (1993), Aucott (1988 and 1996), and Hockensmith and Waters (1998).

The potentiometric map presented here was constructed by using water levels measured in 130 wells in November and December 2001 (see table). Water-level measurements made during this period are likely to be representative of median aquifer conditions, whereas other periods, such as late winter and midsummer, would represent maximum and minimum levels, respectively. Data were collected by DNR, the Environmental Protection Department of Westinghouse Savannah River Company, South Carolina Department of Health and Environmental Control (DHEC), and U.S. Geological Survey. Wells used by Aucott and Speiran (1985b), Stringfield and Campbell (1993), and Hockensmith and Waters (1998) were used, where possible, to facilitate comparison of the potentiometric maps made in 1982, 1989, 1996, and 2001. Data from additional wells also were used.

The hydrographs were constructed from data collected by DNR and U.S. Geological Survey personnel. Where continuous records were available, daily mean water levels were plotted.

HYDROGEOLOGIC FRAMEWORK

The Coastal Plain formations of South Carolina compose a wedge of sediments that thickens from 0 at the Fall Line to more than 4,000 ft (feet) at Hilton Head Island on the coast. These sediments consist of sand, clay, and limestone of Late Cretaceous and younger ages that were deposited on a pre-Cretaceous basement complex of metamorphic, igneous, and sedimentary rock.

The Middendorf Formation lies between the Black Creek Formation and the Cape Fear Formation, the latter the oldest of the Cretaceous formations in the region. The Middendorf aquifer is composed mostly of permeable sediments of the Middendorf Formation (hence its name), but locally it includes sediments from underlying or overlying formations. In the updip areas, the aquifer is composed of sand interbedded with clay lenses deposited in an upper delta plain environment. Toward the coast, the aquifer is composed of thin- to thick-bedded sand and clay that were deposited in marginal-marine or lower delta plain environments. In general, the Middendorf aquifer has coarser sand and less clay in the western part of the Coastal Plain than in the eastern part.

The Middendorf 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 dip of the aquifer is southeastward in much of the Coastal Plain, becoming southward along the coastline. The top of the aquifer is at elevation 100, -700, and -1,700 ft msl (referenced to mean sea level) at Aiken, Little River, and Charleston, respectively. Thickness ranges from 0 at the Fall Line to more than 300 ft in Dorchester County.

GROUND-WATER FLOW SYSTEM

The potentiometric surface of the Middendorf aquifer generally slopes toward the coast, thus the direction of ground-water flow is southeasterly. In areas where the aquifer crops out, it is recharged directly by precipitation. In the upper part of the Coastal Plain where stream valleys are incised into the aquifer, those streams drain it. The curving of contour lines pointing upstream near the Great Pee Dee, Congaree, Wateree, and Savannah Rivers shows this. In the lower part of the Coastal Plain, the aquifer discharges into overlying aquifers having lower hydrostatic head or through pumping wells.

The potentiometric surface has been affected by ground-water withdrawal in Berkeley, Charleston, Colleton, Florence, Sumter, and Williamsburg Counties, resulting in cones of depression in the potentiometric surface. The two lowest points on the potentiometric map, with water levels below -115 ft msl, are near Kiawah Island and Mount Pleasant.

HISTORICAL TRENDS

The potentiometric levels of the Middendorf aquifer 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. Stringfield and Campbell (1993) published November 1989 water levels and observed that levels in Berkeley, Charleston, Dorchester, Kershaw, and Williamsburg Counties had further declined since 1982. Hockensmith and Waters (1998), using November 1996 data, showed additional declines and a generally southeasterly ground-water flow influenced by large cones of depression in the Florence and Hemingway areas and around Mount Pleasant. Historical water-level trends in eight Middendorf aquifer wells are shown on the hydrographs.

Drought conditions have persisted in South Carolina since mid-1998 and caused water-level declines in this aquifer throughout the State. The diminished recharge from precipitation directly resulted in declines in areas near the outcrop, where the aquifer is sensitive to meteorological events. The drought indirectly caused additional declines where ground-water withdrawals increased to mitigate surface drought conditions.

A comparison of the 2001 surface with the November 1996 surface indicates that water levels have declined in Chesterfield, Kershaw, Lee, and Marlboro Counties. In Chesterfield County (CTF-46), water levels were 115 ft msl in November 2001, 2 ft lower than November 1996 but within the 113 to 117 ft msl range reported between 1972 and 1996. Kershaw County wells (KER-82 and 87) showed a decline of 1 ft since 1996. Water levels in Marlboro County wells (MLB-112* and 110) have declined 4 and 5 ft, respectvely, since 1996. The November 2001 water level at LEE-23 was 189 ft msl, 3 ft lower than November 1996; however it also is within the 188 to 195 ft msl range recorded since 1980.

Water levels in central Dillon County have declined from predevelopment levels. Southeast of Dillon, water levels were at 69 and 48 ft msl in 1996 and 2001, respectively (DIL-121). Predevelopment levels were estimated near 75 ft msl for this well. Water levels at DIL-79, in the eastern part of the county, have declined little since 1982.

Potentiometric contours in Aiken County and western Barnwell County show ground-water flow toward, and discharge into, the Savannah River. This is consistent with previous investigations (Aadland and others, 1995; Aucott and Speiran, 1985a and b; Clarke and West, 1997; Siple, 1967; Stringfield and Campbell, 1993; and Hockensmith and Waters, 1998). An average of 15 mgd (million gallons per day) of ground water was pumped from the Middendorf and overlying aquifers in Aiken and Barnwell Counties during 2000 (J.E. Castro, DNR, written communication, 2002), but the extent to which pumping affects water levels is not discernible from the 2001 data, owing to the high transmissivity of the Middendorf aquifer, the distribution of measurements and the effect of natural discharge to the Savannah River.

Wells in this region are likely to be sensitive to meteorological events, in addition to pumping (Clark and West, 1997). Water levels in AIK-817* and AIK-430* have shown declines of 1.6 feet per year since January 1999. AIK-817 had a water level of 235 ft msl in late August 2001, equal to the minimum for the period of record. The minimum water level of 196 ft msl for AIK-430 occurred in late October 2001. These hydrographs reflect the effects of the drought conditions and related increases in pumping.

In eastern Barnwell County, the direction of ground-water flow is to the south-southeast. In comparison with the western part of the county, water levels are more likely to be affected by ground-water use than by rainfall variations (BRN-349*) (Clark and West, 1997) because the Middendorf is well confined in this area (Aadland and others, 1995). Water levels in BRN-349 have declined nearly 8 ft since November 1996.

Middendorf aquifer water levels in Calhoun and Richland Counties reflect both geologically influenced discharge to streams and pumping-influenced discharge by industry. The upper and middle reaches of the Congaree and Wateree Rivers are incised into the Middendorf aquifer and its overlying confining beds. Potentiometric contours generally parallel these stream sections and indicate areas where the Middendorf discharges to streams and increases surface-water flow. Ground-water withdrawals near the Congaree River (1.6 mgd), in Calhoun County, and the Wateree River (3.4 mgd), in Richland County, intercept some water that otherwise would contribute to surface-water gains. Pumping-induced potentiometric patterns are not obvious, owing to the widely spaced observation points, but are superimposed on the patterns formed by natural discharge.

The cone of depression in northern Florence County was first mapped in 1982 (Aucott and Speiran, 1985b). Florence pumped an average of 12 mgd from 27 wells open to Cretaceous-age sediments in 2000 (Newcome, 2000), a 23.7 percent increase from the 9.7 mgd reported in 1995 (Newcome, 1995). Water levels declined in FLO-209 from -40 ft msl in 1989 to -84 ft msl in 2001 and are estimated to have declined more than 180 ft from predevelopment levels. In FLO-146, water levels were -35, -70, and -62 ft msl in 1982, 1996 and 2001, respectively, and are effected by nearby pumping. Water levels in FLO-128* declined from 61 ft msl in 1959 (Aucott and Speiran, 1984) to 5 ft msl in August 1993 and fluctuated between 34 and 4 ft msl from September 1993 to November 2001. This well is likely to have well-interference effects as a result of the nearby industrial pumpage of 0.13 mgd (J.E. Castro, DNR, written communication, 2002). Until the public utility supplements with surface water in late 2002 (Forest Whitington, City of Florence, oral communication, 2002), the cone of depression about Florence will continue to expand.

The cone of depression centered at Mount Pleasant, Charleston County, has expanded since 1996. Water levels in CHN-14* show a decline of more than 65 ft between June 1991 and August 1995, with some seasonal variations caused by pumping at Summerville, Mount Pleasant, Sullivans Island and Isle of Palms. Several area water utilities began using surface-water sources during the mid-1990's. Summerville and Sullivans Island ceased pumping Middendorf wells in 1994 and early 1996, respectively. Isle of Palms and Mount Pleasant began supplementing public supplies with surface water in December 1996 and August 1997, respectively. By March 1998, water levels in CHN-14 had recovered to -36 ft msl but have since declined at an average rate of 11 ft/yr.

Other wells in this cone of depression also show water-level declines since 1996. The hydrograph for BRK-431* shows the effects of pumping from Summerville prior to November 1994, when water levels declined to a minimum of 38 ft msl at an average rate of 5.5 ft/yr. From November 1994 through August 1996, water levels recovered at a rate of 2.2 ft per year to a maximum of 42 ft msl. Since August 1996, water levels have been declining at a rate of 3.8 ft/yr to a minimum of 22 ft msl. Water levels in BRK-444, which is closer to the major centers of pumping, declined 28 ft between November 1996 and November 2001. In CHN-2, water levels declined from 28 to -43 ft msl between 1989 and 2001.

The center of this cone of depression in Mount Pleasant is likely to be deeper than suggested by the -116 ft msl level measured in CHN-185. CHN-185 was the only Mount Pleasant well available for measurement during the data collection period. Ground-water withdrawals by Mount Pleasant Waterworks (MPW) increased from an average of 3 mgd in 1995 (Newcome, 1995) to 6.2 mgd in 2001 (Greg Hill, MPW, written communication, 2002). Furthermore, industrial pumping in southern Berkeley County began in 1997 (DHEC, 2001) near BRK-654. By 1996, the potentiometric surface in the Mount Pleasant area had declined to -132 ft msl, more than a 257-ft decline from predevelopment levels. CHN-14 and BRK-431 were 13 and 16 ft lower, respectively, in November 2001 than the minimum levels recorded in the mid-1990's. Since water use has more than doubled and water levels in wells on the flanks of the cone of depression have declined by a minimum of 13 ft in the past 6 years, it is likely that the levels in the center of the cone have declined by at least as much, to below -145 ft msl in 2001.

A second cone of depression has appeared in southern Charleston County about Kiawah and Seabrook Islands. These islands are primarily resort communities for which a large portion of the water is used for golf course and lawn irrigation. Water levels in CHN-174 and CHN-186 declined 55 and 89 ft, respectively, from 1996 to 2001. The center of the cone of depression is -119 ft msl. Predevelopment water levels for CHN-174 were at least 148 ft msl and indicate total declines of 185 to 267 feet.

Water levels in northern Berkeley County also have declined significantly since 1996. Water levels in BRK-245, at St. Stephen, were 80 and 31 ft msl in 1996 and 2001, respectively. Water levels are influenced by pumping for public and industrial supplies in the St. Stephen area, in addition to the regional effects of pumping.

The cone of depression in eastern Williamsburg County, previously reported by Hockensmith and Waters (1998), persists with a water level of -25 ft msl. This cone of depression is a result of public-supply withdrawal by the town of Hemingway, which pumped an average of 0.38 mgd during 2000 (J.E. Castro, DNR, written communication, 2002). Predevelopment levels were 54 ft msl for WIL-37 in 1970 (Aucott and Speiran, 1984); therefore, total water-level decline in this area is 79 ft. In western Williamsburg County, public-supply and industrial pumpage exceeds 5.8 mgd, part of which is obtained from the Middendorf aquifer, and it is likely that the potentiometric surface has declined in this area.

Water levels in the Middendorf aquifer at Walterboro are similar to those of 1996, on the basis of data from COL-50. The water level in this well was 103 ft msl in November 1996 and again in November 2001. Previous investigations noted water levels between 136 and 126 ft msl in 1982 and 1989, respectively. Aucott and Speiran (1985a) reported a water level of 150 ft msl in a well north of Walterboro, which suggests that a decline of about 47 ft occurred there between 1980 and 2001.

Water-level declines in Sumter County are a result of pumping in and around the city of Sumter. According to Aucott and Speiran (1985a), predevelopment levels in the area exceeded 125 ft msl. November 2001 data (SUM-161) indicate that water levels have declined more than 37 ft, to 88 ft msl in this area. Average ground-water pumping in 2000 exceeded 15 million gallons per day for the city and nearby Shaw Air Force Base (Newcome, 2000); most of this is from the Middendorf aquifer. Because the median transmissivity of the Middendorf aquifer is two and a half times as great in Sumter County as in Florence County where a large cone of depression has developed, and the pumping near Sumter is greater than at Florence, it would be expected that a broad but shallower cone of depression exists about the city of Sumter, but it is not apparent from the distribution of data.

Ground-water levels have declined in southern South Carolina. Water levels in ALL-347* and JAS-426 have declined 6 and 7 ft, respectively, since 1996. Near Beaufort, BFT-10 and BFT-11 had declines of less than 4 ft since 1996, to water levels of 146 and 132 ft msl, respectively, in 2001. The discrepancy between the two wells may be a result of the difference in well construction (BFT-10 is screened in a deeper zone). Wells BFT-454 (open to both the Middendorf and Cape Fear aquifers) and BFT-2055 (open only to the Cape Fear) on Hilton Head Island had similar water levels, 163 and 162 ft msl, respectively, in 2001 but were several feet lower than 1996 levels. They are probably influenced by the pumping from BFT-2155 on southern Hilton Head Island that began in October 2001 and averaged between 1.5 and 2.0 mgd (Kelley Ferda, South Island Public Service District, oral communication, 2002). Water levels in the Middendorf aquifer are probably lower than those of the Cape Fear aquifer in this area. In view of these data, the 150-ft potentiometric contour is drawn near Beaufort. This would indicate that ground-water flow becomes easterly or northeasterly in Jasper and Beaufort Counties.

SUMMARY AND CONCLUSIONS

The potentiometric map for the Middendorf aquifer, constructed by using water-level data from 130 wells measured during late 2001, shows that the generally southeastward ground-water flow is affected by several potentiometric lows. These potentiometric lows have developed because of ground-water pumping around Florence, Hemingway, Mount Pleasant, and Kiawah Island.

Historical data show that water levels are stable nearest the aquifer's outcrop area and that fluctuations have occurred in areas influenced by pumping. The greatest water-level change has occurred at Kiawah Island, where water levels have declined as much as 267 ft from the estimated predevelopment level. The cone of depression about Mount Pleasant remains a major feature and has expanded and deepened because of continued pumping for public supplies and the recent industrial pumping in Berkeley County. Water-level declines also have continued at Florence. Drought conditions contributed to water-level declines in much of the aquifer.

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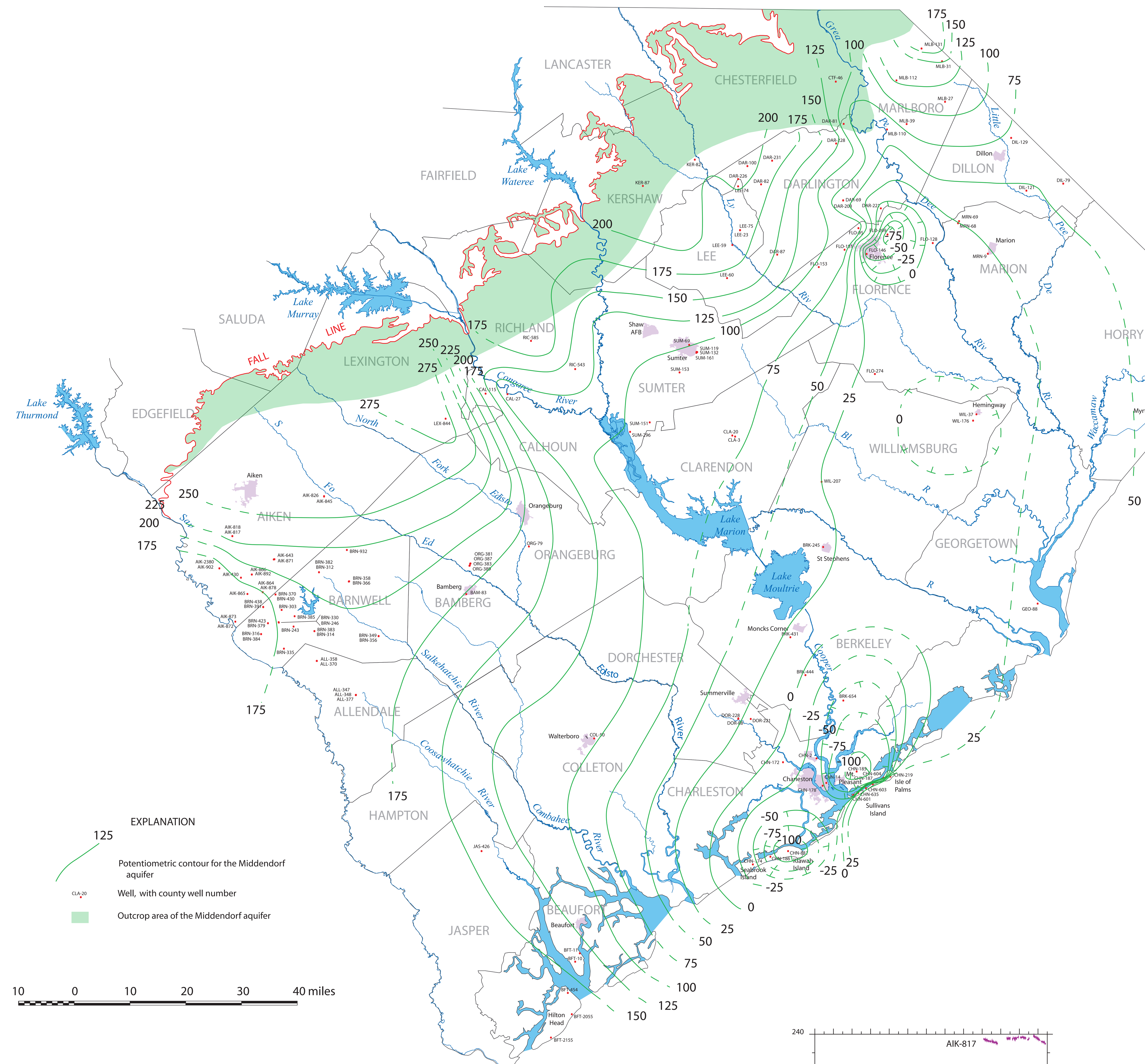

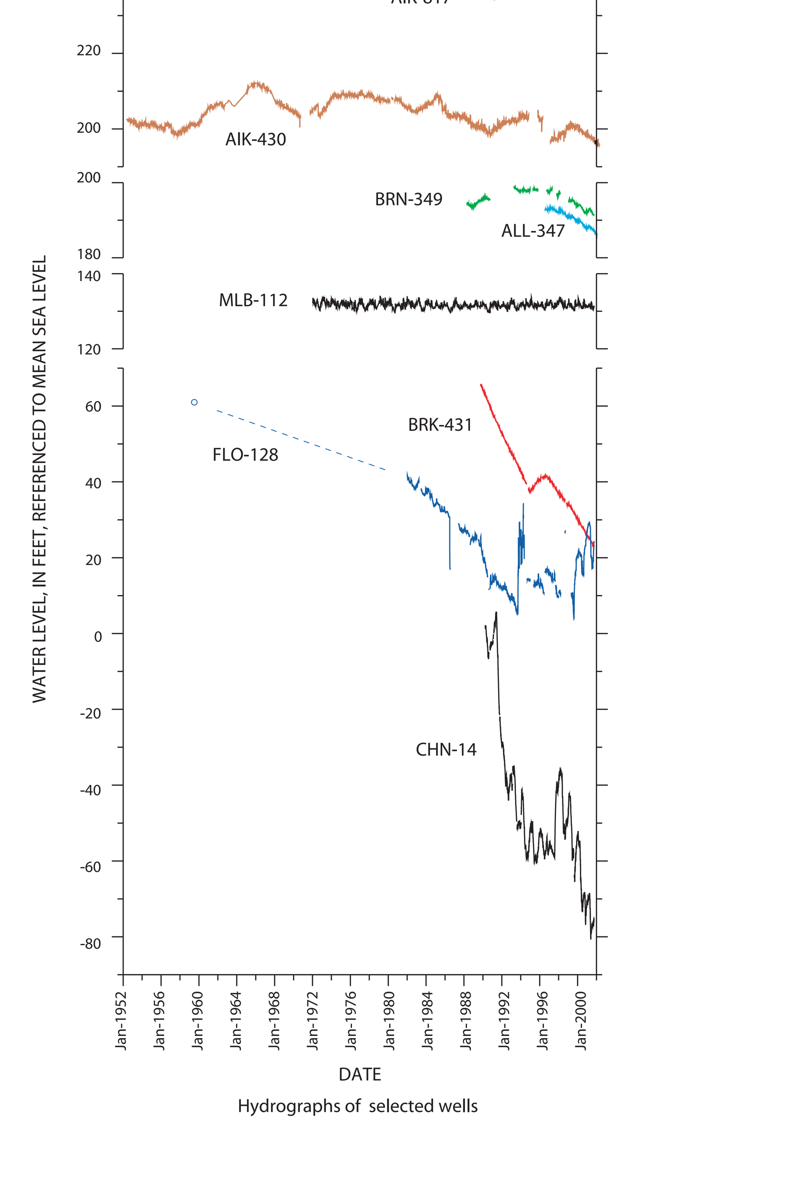

Hydrographs of selected wells

November 2001 water-level elevations in wells completed in the Middendorf aquifer in South Carolina

Well number	Grid number	Latitude, in degrees, minutes and seconds	Longitude, in degrees, minutes and seconds	Water level elevation above or below (-) mean sea level, in feet	Change in water level from 1996 to 2001, rounded to nearest foot (blank where 1996 data are unavailable)
AIK-430	39X-e1	331940	814435	196	
AIK-643	38W-n1	332240	813820	216	- 5
AIK-817	40V-s2	332615	814612	235	- 3
AIK-818	40V-s3	332615	814612	237	- 3
AIK-826	36U-o1	333232	812908	271	- 5
AIK-845	36U-o2	333235	812908	270	
AIK-864	39X-k25	331729	814029	175	- 2
AIK-865	39X-n62	331712	814320	162	- 9
AIK-866	39N-w2	332016	814231	199	- 7
AIK-871	38W-n3	332238	813827	220	
AIK-872	40Y-k7	331251	814532	162	
AIK-873	40Y-k8	331251	814532	161	
AIK-878	39X-k26	331729	814029	175	
AIK-892	39W-w3	332015	814231	190	
AIK-902	40W-q1	332110	814835	166	- 2
AIK-2380	40W-q4	332110	814835	166	- 2
ALL-347	35AA-q2	330130	812303	187	
ALL-348	35AA-q3	330130	812304	199	
ALL-358	37Z-t3	330648	813021	190	
ALL-370	37Z-x11	330648	813020	185	
ALL-377	35AA-q10	330129	812304	187	
BAM-83	31X-m12	331718	810235	173	
BRN-243	37Y-o1	331209	813441	181	
BRN-246	38Y-m1	331246	813727	177	
BRN-303	38Y-b1	331445	813657	179	
BRN-312	37W-u1	332041	813001	213	
BRN-314	37Y-t1	331128	813048	186	
BRN-316	39Y-u1	331057	814043	167	
BRN-330	33Y-m3	331249	813728	177	- 4
BRN-335	38Z-i3	330842	813628	179	- 5
BRN-349	34Y-x1	331042	811852	191	- 8
BRN-356	34Y-x8	331044	811852	192	- 6
BRN-358	35X-e2	331916	812424	209	- 5
BRN-366	35X-e6	331914	812428	210	
BRN-370	38X-n56	331709	813806	179	- 3
BRN-379	38Y-o12	331239	813927	172	
BRN-382	37W-u3	332041	813001	213	- 5
BRN-383	37X-t3	331128	813048	186	- 5
BRN-384	39Y-u3	331057	814043	167	- 4
BRN-385	37Y-f7	331347	813431	183	- 4
BRN-391	39X-u10	331511	814021	172	
BRN-423	38Y-o10	331239	813927	172	- 1
BRN-430	38X-n58	331709	813806	179	
BRN-438	39X-u9	331510	814021	171	- 3
BRN-932	35W-e4	332411	812451	224	
BFT-10	27JJ-c1	321947	804228	146	- 4
BFT-11	27II-s2	322109	804125	132	- 3
BRK-245	18W-b1	332424	795602	31	-49
BRK-431	19Y-w3	331020	800219	22	-17
BRK-444	18AA-e4	330424	795935	- 3	-28
BRK-654#	17AA-w1	330022	795235	- 83	
BRW-1865	2Q-j6	335333	783523	65	
CAL-27	30R-j2	334836	805453	110	- 3
CAL-115	30R-g2	334840	805858	155	- 7
CHN-2	18CC-r1	325121	795741	- 43	-22
CHN-14	18DD-k3	324730	795553	- 74	-30
CHN-172	19CC-x1	325048	800353	- 5	
CHN-174	20GG-e1	323451	800937	- 37	-55
CHN-178	18DD-l3	324703	795635	- 47	
CHN-185	17FDD-a4	324914	795015	-116	
CHN-186	20FF-v1	323602	800623	- 95	-89
CHN-187	16DD-m2	324713	794718	23	
CHN-219	15DD-f1	324822	794402	29	- 1
CHN-601	17DD-u7	324534	795056	- 72	
CHN-603	16DD-q2	324637	794835	3	
CHN-604	16DD-j1	324812	794517	- 79	-61
CHN-635	16DD-y3	324553	795000	5	3
CHN-831	19FF-q2	323653	800306	-119	
CTF-46	17H-m1	343711	795244	115	- 2
CLA-3	21S-r2	334149	801218	87	- 7
CLA-20	21S-m1	334159	801249	88	- 5
COL-50	26CC-d2	325443	803852	102	- 1
DAR-69	17L-i3	341835	795136	58	- 5
DAR-81	17I-v2	343034	795119	82	- 2
DAR-82	20K-s3	342113	800701	185	- 3
DAR-87	19M-y1	341012	800406	148	
DAR-100	20K-e4	342406	800935	209	
DAR-208	17L-i4	341836	795135	69	
DAR-221	15L-o4	341717	794430	- 9	
DAR-226	21K-l1	342204	801121	211	
DAR-228	17J-m1	342730	795248	131	- 4
DAR-231	19K-e1	342455	800455	191	
DIL-79	9K-u4	342042	791006	64	
DIL-121	10L-c1	341943	791702	48	-21
DIL-129	10J-f4	342806	791954	71	
DOR-88	21BB-m3	325739	801207	28	
DOR-221	20BB-o4	325737	800948	19	> -4
DOR-228	21BB-d1	325742	801207	28	
FLO-95	16M-d3	341413	794847	93	
FLO-128	13M-p3	341144	793449	16	3
FLO-146	16M-w1	341011	794718	- 62	7
FLO-153	18N-i2	340813	795619	88	17
FLO-181	17M-v2	341052	795127	90	3
FLO-209	16M-h2	341310	794318	- 84	-10
FLO-274	16Q-s1	335122	794600	13	-11
GEO-88	10X-v1	331506	791615	>10	
JAS-426	30FF-o2	323705	805944	140	- 7
KER-82	22J-y7	342511	801930	205	- 1
KER-87	24K-p1	342107	802918	220	- 1
LEE-23	21M-b1	341405	801103	189	- 3
LEE-59	21M-r3	341146	801232	191	
LEE-60	21N-q1	340636	801334	169	
LEE-74	21K-v1	342045	801136	204	
LEE-75	21M-k1	341406	801104	183	- 2
LEX-844	32S-b4	334446	810627	293	
MRN-68	13M-a1	341447	793001	23	4
MRN-69	12L-y1	341506	792950	27	22
MLB-27	13I-h1	343348	793207	111	- 4
MLB-31	13G-w1	344008	793236	152	- 1
MLB-39	14I-y2	343024	793926	87	- 3
MLB-110	15J-d2	342935	794310	59	- 5
MLB-112	15H-l2	343715	794115	127	- 4
MLB-131	14G-l1	324212	793626	192	- 4
ORG-79	29V-v1	332445	805053	162	- 8
ORG-381	31W-l3	332207	810148	181	
ORG-383	31W-l5	332205	810152	184	
ORG-387	31W-s2	332148	810156	150	-48
ORG-389	31W-s4	332145	810159	171	-24
RIC-543	27Q-m1	335229	804210	137	-19
RIC-585	29P-t4	335656	805027	197	- 5
SUM-69	23P-t1	335611	802047	102	
SUM-119	22P-y2	335504	801917	95	2
SUM-132	22P-y1	335506	801924	81	
SUM-151	24S-d1	334406	802816	97	-17
SUM-153	23Q-r1	335154	802236	81	
SUM-161	22Q-e2	335458	801927	88	- 3
SUM-296	25S-l1	334238	803156	94	
WIL-37	12S-c1	334451	792706	- 23	
WIL-176	12S-h1	334353	792744	- 25	12
WIL-207	18U-b1	333436	795612	25	- 3

\# Water level recovering in well